PHYSIOLOGY AT THE FARM

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IN AID OF

REARING AND FEEDING THE LIVE STOCK

BY

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WILLIAM BLACKWOOD AND SONS
EDINBURGH AND LONDON
MDCCCLXVII

TO

GENERAL

The Marquess of Tweeddale,

K.T. K.C.B.

WHO,

AFTER GAINING, BOTH AT HOME AND ABROAD,

IN A LONG CAREER OF SERVICE FROM AN EARLY PERIOD OF LIFE,

MANY LAURELS AS A SOLDIER,

DEVOTES THE WELL-EARNED LEISURE

OF HIS LATER LIFE TO THE SUCCESSFUL PROMOTION

OF EVERY PURSUIT THAT TENDS

TO THE ADVANCEMENT OF AGRICULTURE,

WHILE HE LEADS THE WAY

IN MANY SIGNAL AND ORIGINAL IMPROVEMENTS,

This Work,

IN TOKEN OF THEIR SINCERE ADMIRATION

OF HIS WHOLE CHARACTER,

IS DEDICATED BY

The Authors.

PREFACE.

Farming, after having been followed for ages as an empirical art, or art resting solely on experience not generalised, now begins to take a place among pursuits that claim to be rational in their character, or, in other words, to have their foundations in principles of science. Nay, in our day it is not enough for the holder of a farm to know the composition of its soils and the kinds of material to be thrown from time to time thereon, to replace what the annual crops never fail to carry off. It is not sufficient for him to have learned how to deal with the laws that govern the vegetation of the seed, the growth of his crops, and their ripening for harvest,—he has also to carry his attention to animal nature. A large amount of his capital is absorbed by horses, cattle, and sheep. The return on his live stock will be, as a rule, in proportion to the skill brought to bear on its management. When diseases assail his animals, the veterinary can be called into counsel; but in relation to their daily treatment, and the keeping of them in ordinary health, he should be able to rely on himself.

To have some acquaintance with the physiology of nutrition, and of the intimate connection between the condition of his stock and the several kinds of food thereby consumed, cannot but materially assist him in his daily tasks, and save him from a multitude of errors.

The work now offered to him is designed to bring such a knowledge within his reach.

It is a concise survey of the actions of nutrition and of the chemistry of food with reference to the animals subservient to agriculture, to which is added a still briefer notice of some other functions concerned in organic life.

It consists of Three Parts: in the First Part, a detailed account of the organs of nutrition and their mode of action in the horse, the ox, the sheep, the pig, the dog, and in the chief kinds of poultry, is exhibited, amply sufficient to enable the agriculturist to judge for himself in many important questions that arise daily in the farm.

The Second Part contains a somewhat minute detail of the chemistry of food in the animals referred to in the First Part, and of the particular nutritive value, as far as that is as yet ascertained, of each article, in order to put into the hands of farmers the means of becoming their own advisers in respect to the choice of food for the several kinds of animals when new circumstances present themselves.

In passing under review the articles derived from the vegetable kingdom that afford nutritive material, it was found impossible to draw any broad line of distinction between those that must remain fit exclusively for human food and those that hereafter may possibly augment the supply of nutriment to the animals of the farm; hence, while the chief attention is paid to articles in daily use, all the plants known to contain esculent matter, as far as space would permit, are cursorily noticed, without any attempt to estimate the probability of this or that being added in future to the list of forage plants.

In the Third Part an attempt has been made to show the theoretical grounds on which the agriculturist must proceed in determining, from his knowledge of preceding facts in physiology and chemistry, the kind and amount of diet that will more or less probably be necessary when special circumstances arise, as well as to satisfy himself how far there is a harmony between established usages of the farm in respect to animals and the precepts of physiological and chemical science. The calculations introduced into this Part are only correct in so far as the chemical analysis of the several articles concerned is already complete. The plan exhibited will suffice, however, to give exact results in proportion as the analyses become more perfect.

With respect to the share which each of the authors has had in this work, it will be sufficient to say that with Mr Stephens, as largely experienced in agriculture and long apprised of the exact kinds of knowledge required by his brethren in that department, originated the plan of the book, and that he has throughout ruled the order, range, and limits of its subjects; that on Dr Seller rests the responsibility of the execution of that plan in all its details, with the exception of such as are purely of a practical nature.

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Articles of Food, arranged as obtained from Natural Families of Plants.

Dicotyledones.

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LIST OF WOODCUTS.

PHYSIOLOGY AT THE FARM.

PART FIRST.

THE ORGANS OF NUTRITION IN THE QUADRUPEDS OF THE FARM IN GENERAL.

In acts of life there is a continual wear and tear of the whole substance of the animal frame, so that, to preserve the same weight from day to day, there must be a supply of food afforded with only short intervals of interruption. When the frame is in a state of growth—that is, when its weight is daily increasing—there must be an amount of food sufficient not merely to cover the loss by wear and tear, but also to supply the material for the increase of weight. The food, as a whole, must represent the substance of the living body which it sustains. There may be in the food elementary particles which do not enter into the substance of the animal that is fed. These are thrown off as useless along with the particles detached in the wear and tear of the body. But within a short period of time, the food taken in must contain all the elementary particles that go to make up the fabric of the animated being and the constitution of its fluids, otherwise the health of the being will not be maintained. There are, at the least, fifteen simple substances—that is, chemical substances that have hitherto resisted decomposition—in the bodies of ordinary quadrupeds; and to insure the thriving condition of health, all these must be supplied more or less constantly in their food. The most important of these simple substances must be contained in the daily food; while it may be sufficient that others of them, which exist in minute quantity in the living system, should be afforded in occasional food. But this question belongs to the consideration of the minute chemical composition of the several articles of food proper for each animal, to be spoken of elsewhere in this treatise. In the mean time, it will be enough to observe that the necessity for the food affording a more or less constant supply of all the elementary constituents of the animal body, arises from the unceasing disintegration of the living substance in almost every part of the frame. The refuse, so uninterruptedly thrown off by a living animal, includes every kind of elementary particles which enter into the composition of the frame, and all those elementary particles contained in the food which are either superfluous at that particular moment, or which do not enter at any time into its chemical constitution. Thus, throughout any given period, not too brief, the particles contained in the food are identical in kind with the particles contained in the whole refuse; and the particles contained either in the food or in the whole refuse, after the deduction of a variable superfluity, are the same in kind as the particles that enter into the constitution of a living body.

By the mouth alone food is supplied to the animal frame. Under some circumstances the skin absorbs, but what it takes up in general is merely water, so that it can hardly give passage to food, but only to drink or medicine. By the fundament an attempt is sometimes made to administer nourishment, but barely with success. It is at times maintained that increase is acquired by the lungs; yet one thing is certain, that the body, unless it be in very brief periods, must always lose more weight by the lungs than it can gain. It is a sure truth, that by the lungs the body can acquire nothing but oxygen, nitrogen, or water.

The name alimentary canal, or *primæ viæ,* is the term somewhat vaguely applied to the long passage—including the gullet, stomach, and intestines—from the mouth to the fundament. This canal has for its lining membrane a part of one of the two great mucous membranes of the body, while another part of the same great membrane descends through the windpipe, lining its ramifications, and reaching to the very minute cavities in which these terminate, called the air-cells of the lungs. Another part of the same great membrane passes from the back part of the throat to the tympanic cavity of the ear on each side, and, rising upwards into the nostrils, extends through the lachrymal passages to the fore part of the eyes and the inner surfaces of the eyelids.* This vast extent of web is accounted all one membrane, because its anatomical structure, though considerably modified in certain parts, is everywhere of the same general character, while it is continuous throughout—that is, through all this prolonged extent it shows no break or interruption. It is called the gastro-pulmonary mucous membrane, with reference to its two chief seats—namely, the gastric or alimentary passages, and the pulmonary or air passages. The only other mucous membrane is quite detached from this, being that which lines the urinary passages and the interior of the genital organs,—this last is named the genito-urinary mucous membrane, while it agrees in its general structure with the gastro-pulmonary mucous membrane.

To exclude for the present the genito-urinary mucous mem-

* An explanation of the technical terms employed here and elsewhere in the volume will be found in the Glossary at the end.

brane, it will be seen that the trunk of the animal body may be likened distantly to a hollow pillar, the external convex surface of which pillar corresponds to that part of the trunk which is covered by the skin, while the interior concavity or pipe of the pillar answers to that part of the trunk of the body which is traversed by the alimentary canal from the mouth to the fundament. Thus the substance of the pillar also corresponds to the fabric of the trunk, composed of flesh, blood, bone, and the other constituents of an animal organism. Thus the alimentary canal, corresponding to the pipe of a hollow pillar, receives the food which enters by the mouth, and prepares it, in several parts of its cavity, to yield up its nutrient material to minute tubes at certain points in the substance of the trunk answering to the solid portion of the pillar; while the refuse, after various changes, is thrown out by the fundament at the opposite end of the canal in the form of excrement. The nutrient part of the food taken up from the alimentary canal, after various important changes, finally passes into the blood; and the blood is the sole source from which the various solids and fluids of the body are actually repaired or augmented. Whatever the body loses in weight—and when it is stationary it loses daily a weight exactly equivalent to the weight of its food—it loses through the blood, with the single exception of the excrement or the refuse thrown out by the fundament. But even the excrement is not made up entirely of the unabsorbed part of the food; for that unabsorbed part, in its passage towards the fundament, is mingled with secreted matters derived from the mucous lining membrane and from the several glandular organs, as the liver and sweetbread, which pour their products into the intestines. Hence, even when an animal is kept fasting, excrement is passed, owing to the large proportion of it supplied by matters secreted from the blood. When a looseness sets in, the quantity of more or less altered excrement thrown off is almost incredible. But this appears less wonderful when the great extent of the lining mucous membrane, from which secretion takes place, owing to the enormous length of the intestinal tube, is taken into account. The resemblance of the hollow trunk of a living animal to a perforated pillar, though striking, is but distant, as before said; for the canal which constitutes the hollow of the trunk is very far from being straight. It is so convoluted as to permit of its being of exceeding length. In all mammals—that is, in all the order of animals to which common quadrupeds belong—the intestines are of considerable extent. In carnivorous quadrupeds they are not so long proportionately as in herbivorous quadrupeds. In omnivorous animals of the mammal class the length is intermediate. In man, as an omnivorous animal, the intestines are six or seven times longer than the body. In the pig, an omnivorous animal, the intestines are thirteen times longer than the body. In the dog, as belonging to the carnivorous tribe, the intestines are of moderate length: thus, in the mastiff the intestines are about five times the length of the body—that is, five times the distance from the muzzle to the root of the tail. The intestines are proportionately longest in ruminant animals, as the sheep and ox. In the sheep the intestines are twenty-eight times longer than the body; in the ox, twenty-two times longer. In the horse and the animals allied to the horse, as the ass and the zebra, the intestines are shorter than in other vegetable-feeding quadrupeds, and even of less proportionate length than that observed in some omnivorous animals. The intestines of the horse, being only ten times longer than the body, do not come up to the standard of the pig, an omnivorous animal, in which, as stated above, the proportion is as one to thirteen. In the wild boar, however, the intestines are no more than nine times longer than the body.

The quantity of secretion—that is, of humid material—derived from the blood, which is poured into the long tube of the intestinal canal, far exceeds the amount of the excrement thrown off at the fundament. How this should happen is easily understood, when it is known that absorption goes on freely from living surfaces, so that the humid material, more or less fluid when secreted, is reabsorbed, sometimes after various changes, within the intestinal canal, and restored to the blood, either separately or along with that part of the food which serves for nutriment to the blood. Owing to this absorption of the fluid previously mixed with it, the excrement is for the most part somewhat consistent or even solid. It amounts in general to near a fifth or a sixth part of the food taken in within an equal period of time. Though somewhat solid, it contains as much as three-fourths of its weight of water ; but this is even less than the proportion of water present throughout the bodily frame, which is commonly estimated at four-fifths of its weight. The solid food of animals, though varying much in this respect, generally contains something approaching to a like proportion of water. The loss which an animal body sustains in a given time, while its weight remains stationary, is compensated for, not only by the food, but also by the drink taken in within that period. The loss of the liquid part of the living system is by other channels than the bowels —namely, by the urine, or the secretion of the kidneys ; by what is carried off from the lungs with the expired air, or the pulmonary exhalation ; by what is thrown off by the skin, or the cutaneous transpiration. To the loss of weight sustained by the living body through the bowels, the kidneys, the lungs, and the skin, must be added the loss, more or less considerable according to circumstances, which the external surface of the body undergoes by friction. The outer surface of the integuments, including the hairs, is covered by a peculiar structure known as the cuticle or epidermis, and also called epithelium.

This continually separates, particularly under friction, in the form of laminated particles like scales, more or less mingled in general with fluid matters. Yet when rubbing, without moisture, is employed, the particles fall off in a dry state. This epithelium is remarkable as having neither nerves nor blood-vessels, and as being wholly destitute of sensibility. It is a secretion from the subjacent blood-vessels—or, to speak more correctly, it continually renews itself by drawing material from the subjacent blood-vessels, as the outer layers of cells are thrown off. The same kind of structure, under the name epithelium alone—that is, not epidermis—also covers the free surfaces of the internal cavities in general; while the outer layer of cells is in like manner continually thrown off in the form of flattened cells like scales, and becomes mingled with the several secretions proper to these internal cavities. For example, an epithelium, variously modified, exists as on the skin, so on the mucous membranes; on the serous membranes, such as those which line the shut cavities of the chest and abdomen; on the synovial membranes, which line the cavities of the joints; and on the lining membrane of the blood-vessels and lymphatics. It is common to the epithelium of all these parts, as well as to that of the outer surface, that it consists of cells united together by a more or less cohesive matter; that the cells make their first appearance at the deepest part of the structure, and after undergoing various changes of form, are finally thrown off, to be succeeded by others from below.

To obtain a just idea of the nature of the changes which the food has to undergo before it is rendered fit to become incorporated with the body, so as to augment and repair its fabric, and perform whatever other uses it may be discovered to possess, it has to be traced through a long series of organs. Of these the mouth stands first. In the mouth the food is masticated by the teeth, and mingled with the saliva derived from the salivary glands. After this first reduction, the mass is transmitted through the gullet into the stomach, to undergo a further process of reduction. In animals having a single stomach, like the horse, the pig, and the dog, the food is subjected at once to the peculiar influence of the secretion termed the gastric juice. There is nothing like mechanical trituration in the stomachs of mammals. The action of the gastric juice is closely allied to that of a mere chemical fluid, and the movements to which the digesting mass is subjected have solely the effect of bringing its several parts more completely within the range of the influence of that fluid, and of transmitting the portions already sufficiently operated on towards the outlet of the stomach, and finally onwards to the upper part of the intestines. In ruminating animals like the ox and sheep, it is the fourth of the four stomachs, termed the "rennet," which corresponds to the one stomach of other mammals—that in which ventricular digestion is finally completed. In these animals the food—unless, being already in a pulpy state, it is fit for the third and fourth stomachs—passes from the mouth partly into the first stomach, called the paunch, partly, yet not in the same large proportion, into the second stomach, called the honeycomb, and after being well moistened it is thrown up from both into the mouth for further mastication and insalivation ; the mass next descends into the third stomach, termed the manyplies, whence, after the requisite changes have been accomplished, it is sent into the fourth or stomach proper, in which the changes made upon it are effected by the agency of a gastric juice, as in the stomachs of other mammals. Of the long tract of the bowels, the duodenum, or uppermost part of the small intestines, and the cæcum, or uppermost part of the great intestines, are almost exclusively the seats of important changes on the alimentary mass. In the duodenum, the bile or secretion of the liver, and the pancreatic juice or secretion of the sweetbread, are mingled with its contents, and produce effects of the most essential kind. The digesting mass, passing onwards from the duodenum, is now ready to afford its nutritive essence for absorption into the real interior of the system, —a process which takes place chiefly in the two succeeding portions of the small intestines, respectively named the jejunum and ilium. The process of absorption in these portions of the intestine is twofold—one, by certain minute, short, thread-like bodies hanging into the intestines, termed *villi*, through which the absorbed matter is conveyed to what is named the lacteal system, and finally into the blood—the other, as it would seem, by a direct entrance of such products as are soluble into the veins of those parts of the intestines, so as to become at once mingled with their venous blood. That which is absorbed through the villi undergoes changes probably of much consequence, and, beginning thenceforth to be called chyle, is transmitted through the minute vessels termed lacteals to certain diminutive organs in the mesentery or double serous membrane which supports the small intestines, named the mesenteric glands—there it goes through further changes—while it finally is conveyed by the trunk in which the lacteal vessels converge, termed the thoracic duct, to veins at the anterior part of the chest, where it is mingled with the venous blood. Thus, by whichever channel the essential nourishment absorbed from the small intestines gets into the real interior of the living system, it is mingled first, not with arterial blood, but with the blood of veins. As the veins of the intestines join in forming a peculiar venous trunk termed the portal vein, which is distributed in the liver, whatever nutriment is taken up directly by the veins of the intestines passes through the liver, and there undergoes important changes; whence the liver must be regarded as having a twofold office in the function of nutrition—first, as affording a secretion, namely, the bile, which, being poured into the duodenum, contributes to the preparation of the true nutriment for absorption; and, secondly, as producing ulterior changes on whatever part of that nutriment afterwards comes to be transmitted through its substance along with the blood of the portal vein. The venous blood of the liver, derived chiefly from the ramifications of the portal vein in the substance of the liver, passes almost immediately to the right side of the heart, and the venous blood of the veins in the fore part of the chest, with which the chyle from the lacteal system is mingled, passes, by a course in no great degree longer, to the same side of the heart. Thus the venous blood, which receives the nutriment by the two channels just indicated, is brought at once to that side of the heart whence the blood is transmitted through the lungs. In the lungs the nutriment, after new changes, is finally incorporated with the blood as it passes from the venous to the arterial state, whence the arterial blood arrives at the left side of the heart, reinforced by supplies of fresh material, to be distributed by the arterial system of vessels all over the body, to renovate the solids and secretions concerned in the never-ceasing offices of life.

Such are the two obvious modes in which the constitution of the blood is maintained. There is, however, another kind of sanguification highly probable, yet still somewhat obscure, and therefore rather conjectural than certain. It seems not unlikely that the blood itself affords germs separated from it within certain organs, called of late vascular or blood glands, and that these germs grow into corpuscles or globular cells, at the cost of the proteine compounds contained in the lymphatics with which such vascular or blood glands are abundantly supplied; and that such corpuscles, being conveyed into the vascular system in part, if not wholly, by the lymphatic trunks, constitute the white corpuscles of the blood, out of which the red corpuscles of the blood are finally developed. Among such vascular or blood glands the mesenteric glands rank, through which the chyle passes in its progress from the small intestines to the thoracic duct that conveys it to the venous blood.

These blood-glands are supposed to be capable of secreting the germs of vesicular organisms, which, coming into contact with proteine compounds in the lymphatic and lacteal vessels, and afterwards in the blood itself, pass into the red corpuscles of the blood.

Thus nutrition in the higher animals would take place exactly on the same type as in the simplest organisms in the scale of being. The *Protococcus nivalis,* or red snow, is a simple cell which becomes developed by drawing nourishment from a surrounding plasma or cytoblastema. The proteine compounds yielded by the digestive organs to the lacteal vessels and blood correspond to the cytoblastema of the red snow; while the germs of the blood corpuscles, and the organic atoms of the solids requiring repair, correspond to the organic cell of the red snow.

ORGANS OF NUTRITION IN THE HORSE.

Mouth and Teeth.—The mouth is the space included between the lips and the throat. In front, the muzzle being supposed to be directed forward, it is bounded by the lips; on the sides by the cheeks; below by the tongue; above, anteriorly, by the bars of the hard palate—posteriorly, by the soft palate; while behind it communicates with the pharynx, the funnel-shaped cavity placed between the mouth and the gullet.

Before describing the uses of these several parts, it will be convenient to speak of the teeth, which occupy both jaws within the lips and cheeks.

In the function of nutrition the teeth are of infinite importance, as the agents in the indispensable office of mastication.

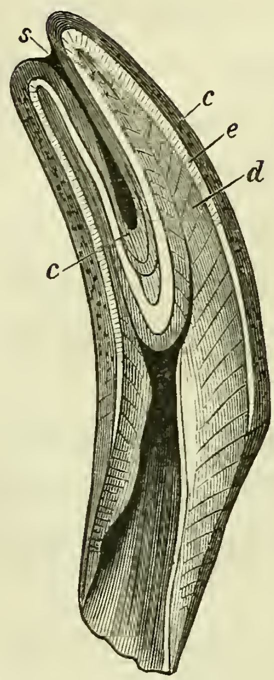
As in the human body, so in the horse, a temporary set of teeth, termed the milk or deciduous teeth, precedes the permanent teeth. Between four and five years old the permanent teeth are completed, and thus the young animal, from being a colt or a filly, becomes a horse or a mare. As in the human body, there are in the horse three kinds of teeth—the incisors or front teeth, called in the horse nippers—canine, in the horse called tushes—and molar or grinding teeth. The teeth are more numerous in the horse than in man, as there are forty teeth in the horse, while in man there are but thirty-two. As in the other mammals belonging to the farm, the teeth do not, like those of man, form two close unbroken lines along the upper and under jaws. There is a space, on each side of each jaw, between the incisors or nippers and the grinding or molar teeth. In this space, though far from large enough to fill it up, there is the canine tooth or tush, on each side above and below. This canine tooth does not, for the most part, appear in the mare, so that the mare has only thirty-six teeth. The tush or canine tooth is described as rudimentary in the mare—that is, all the four canine teeth or tushes are formed within the jaw, but are not cut so as to appear beyond the gums, or, if they appear, it is only in very old mares. The forty teeth in the horse consist of twelve incisors or nippers—six above and six below; and twenty-four grinding or molar teeth—six above and six below, on each side of the mouth; together with four tushes, properly tusks, one above and one below, in each of the interspaces of the jaw between the front row of incisors and the side row of grinding teeth.

In the horse there are twenty-four milk teeth or deciduous teeth—namely, twelve incisors in the front of the mouth—six above and six below; and twelve grinding teeth—three above and three below on each side of the mouth. The four tushes are not shed—that is, these are permanent teeth; no more are shed the three last grinding teeth above and below on each side of the mouth, for they are also permanent teeth. By attention to the varying state of the mouth, owing to the changes on the teeth, much may be learned as to the age of the animal; but to enter into any detail on this point is foreign to the immediate purpose of the present treatise. It should be remarked, however, that during the period between the shedding of the central milk-nippers and the protrusion of the corresponding permanent nippers, between the second and third year, the colt may fall away in condition, owing to the difficulty of grazing, in which case mashes and corn or cut meat should be provided.

The part of a tooth which appears beyond the jaw is named the crown, that part which is sunk in the jaw is called the root or fang, while a narrow space between the crown and the fang is known as the neck of the tooth.

The substance of a tooth is not homogeneous—that is, its substance is not throughout of one character. The textures which enter into the composition of the teeth, in such animals as the horse, are termed respectively enamel, dentine, and cement—the last formerly called the petrous crust. The dentine forms the body of the tooth, and is more or less allied to bony substance. The cement forms the outer crust of the tooth. The enamel is the hardest of the whole, and has its place between the dentine and the cement. Even on what is so well known as the enamel on the crown of the human front teeth, there is, at least originally, a very thin layer of cement. The teeth of mammals in general consist of hard unvascular dentine, defended at the crown by an investment of enamel, and everywhere surrounded by a coat of cement. In man, the monkey tribe, and common carnivorous quadrupeds, the coronal cement is of extreme tenuity. It is thicker in herbivorous quadrupeds, particularly in the grinders of the elephant. In the horse vertical folds of enamel and cement penetrate the crown of the tooth. Even the incisors or nippers of the horse have a single fold, composed of cement and enamel, which dips from the horizontal flat surface of the crown into an excavation of the dentine, as represented in fig. 1. This fold is peculiar to the incisors or nippers of the horse, being found in the incisor teeth of no other animal. This fold, or process as it is called in anatomy, consists, as just said, of cement and enamel, the enamel being interposed between the cement and the dentine, in which exists the excavation wherein the fold is lodged. When the tooth begins to wear, the fold becomes an island of enamel enclosing a cavity partly filled by cement, partly by tartar and substances derived from the food, which cavity constitutes the "mark." In aged horses the incisors are worn down beyond the limits of the fold, whence the "mark" disappears. In the mid-incisors the cavity disappears at the sixth year, in the incisor on each side of these at the seventh year, and in each outer incisor at the eighth year, in the lower jaw. In the incisors of the upper jaw the mark remains somewhat longer.

Fig. 1.



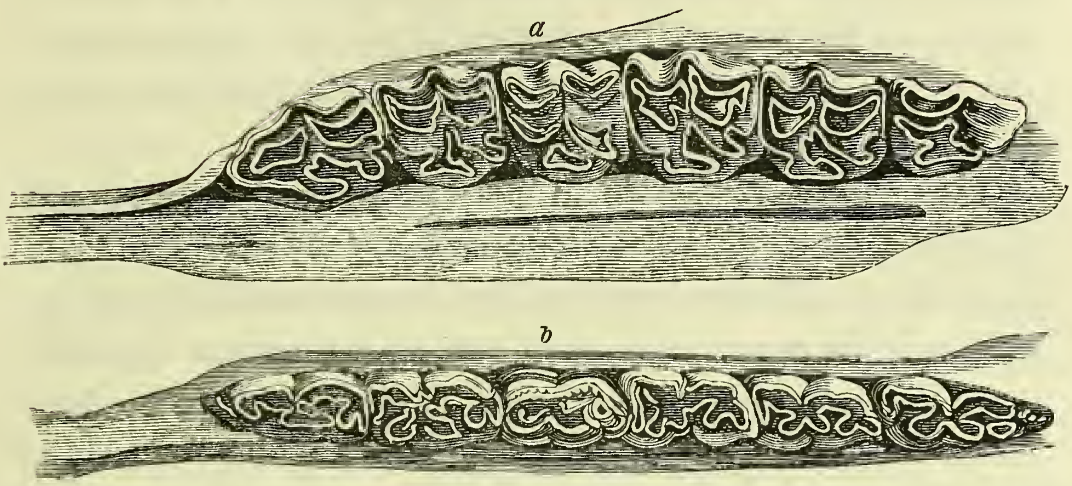
LONGITUDINAL SECTION OF THE INCISOR TOOTH IN THE HORSE.

d, The dentine; *e*, the enamel; *c*, *c*, the cement; *s*, mass of tartar and particles of food.

The folds of cement and enamel, which in like manner penetrate the dentine from the summits of the crowns in the molar teeth, are not single, as in the incisors, but several—the effect of which is that, as the tooth wears, the hard enamel, being most resistant, continues to present a sharp edge, of varied pattern, of signal power in the trituration of the food.

The effect of this triturating edge may be judged of from fig. 2.

Fig. 2.



Grinding Surfaces of the Upper and Lower Molars in the Horse.

The pattern presented in *a* is by the six molars on one side of the upper jaw in the horse, owing to the unequal wearing of the dentine, enamel, and cement. The same in *b* in the six molars on one side of the lower jaw. In both *a* and *b* the front molar is to the left hand.

The mode in which each tooth forms in the gum, illustrates the structure which it is afterwards to exhibit. There is produced, corresponding to each tooth, a pulp contained within a capsule. The pulp is converted subsequently into dentine, the capsule into cement. Thus the original relative position of the pulp contained within the capsule answers to the relative position of the interior dentine and the exterior cement. When the tooth is besides to possess enamel, a peculiar product appears on the inner surface of the capsule, which is finally developed into enamel. When a tooth is to be displaced at a fixed age by a permanent tooth, the original matrix gives origin to a germ, which finally passes into a pulp contained, in like manner, within a capsule. When no germ is detached from the first matrix, no second tooth ever arises. The original pulp of each tooth assumes the figure of the dentine into which it is to be converted, so that the pulp of a grinding or molar tooth resembles a stem with short expanding branches, the interstices between these branches being subsequently filled up with enamel and cement, while the stem consisting of dentine, covered externally with cement, represents the fang. The minute study of the original formation of the teeth is of great physiological interest, but hardly falls within the scope of this treatise.

The pulp, with its encircling membrane, consists originally of cells freely interspersed with capillary blood-vessels; and while these cells are developed into the matured forms of the pulp and the capsule, the hard substances become deposited upon the soft from the adjacent blood-vessels. The hard matter constituting the dentine appears first on the outside of the pulp, and successive shells from within that first produced, so that, finally, a minute cavity remains in the interior of the pulp, to which blood-vessels and nerves have access by a small aperture at the extremity of the fang. This minute cavity is hereafter the only seat of vital activity and sensibility in the system of the teeth.

All the substances composing the teeth consist of earthy matter disposed in a fixed arrangement on an organic matrix. Even in the enamel, the hardest of substances in the living animal, the earthy matter is mainly contained in canals produced from the original cells, which, in animals like the horse, being comparatively large with extremely thin walls, are completely filled therewith.

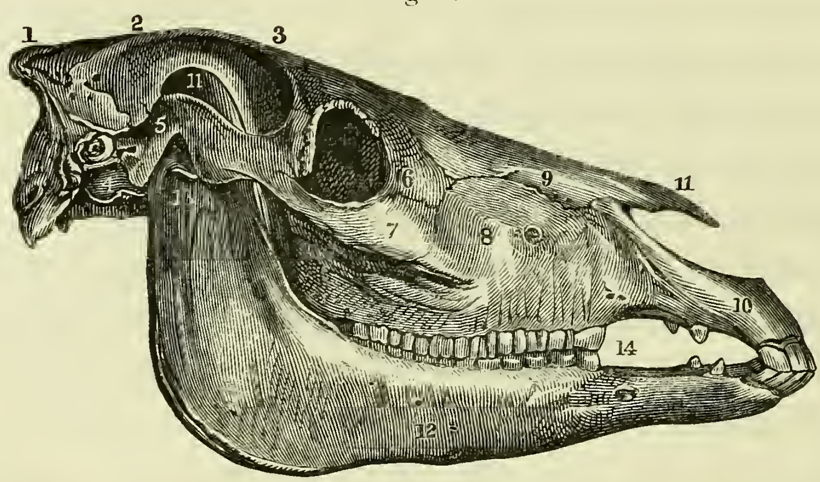
The chemical bodies found in the teeth are not unknown elsewhere in the living system. They are phosphate of lime, with a trace of fluate of lime, carbonate of lime, phosphate of magnesia, some other saline matter, chondrine, and fat.

After these several bodies have once been deposited in the teeth, there is no reason to suppose that any part of them is subsequently removed therefrom, so as to require renewal—the teeth, from their extravascular character, being in this respect unlike the other parts entering into the animal frame. But as dentition goes on in the horse during a period of five years, it should be considered, during that age, whether all the chemical materials entering into the teeth are sufficiently supplied to the growing animal. Of the chemical substances entering into the teeth, the fluate of lime, more properly termed the fluoride of calcium, is the only one not universally found in vegetable bodies. Small as is the proportion of this substance in the teeth, it cannot be doubted that, were it not supplied to the colt during the time of the formation of the teeth, that process would either not take place at all, or be carried on in an imperfect manner.

The teeth are fixed, each in a separate socket of the jaw to which it belongs, not by ossification or anchylosis, but by a peculiar kind of connection likened to that of a nail in a board. The periosteum or membrane of the bone lines the alveolus or socket, and is reflected on the fang of the tooth, which it invests up to the neck. This membrane blends with the tissue of the gum. The gum is composed of a dense fibrous tissue, covered by a red, not very sensitive, mucous membrane, smooth in its general surface, but, where it closely surrounds the teeth, beset with fine papillæ. The action of the teeth in cropping and mastication depends on the movements of the lower jaw, of which hereafter.

The bones which form the roof of the mouth are the intermaxillary bone, the upper jaw-bone, and the palatine plates of the palate-bones. The intermaxillary bone belongs to mammals, with the exception principally of man, in whom the upper jaw-bones of the opposite sides unite in the mesian line —that is, in the middle line—and support all the upper teeth. On the other hand, in the horse and mammals generally, a distinct bone lies behind the upper lip, interposed between the fore parts of the opposite upper jaw-bones, so that these bones meet only behind the central point of the palate. This intermaxillary bone, called also the *"os incisivum,"* supports the incisor teeth and the upper tushes. The intermaxillary bone is sometimes designated as a pair of bones, under the name of the anterior maxillaries. The upper or superior maxillary bone is of great size; it enters into the formation of the orbit of the eye, and into the nose, as well as into the mouth. The extent of its connections is apparent in fig. 3.

Fig. 3.



SKELETON HEAD OF A HORSE.

1, Crest of occipital bone; 2, parietal bones; 3, frontal bone; 4, 5, temporal bone; 6, lachrymal bone; 7, malar bone; 8, superior maxillary bone; 9, nasal bone; 10, intermaxillary bone; 11, nasal spine; 12, condyle of lower jaw; 13, ramus of lower jaw; 14, position of the teeth to the right and left.

The palatine bones form but a small portion of the roof of the mouth. They are placed at the back part of the palate, and surround the edge of the communication between the posterior parts of the mouth and the nose.

The lining of the roof of the mouth is the palate, composed of a dense elastic substance divided into ridges termed bars. The soft palate, or veil of the palate, is further back. It extends from the crescentic margin of the palatine plates of the palate-bones to the fibro-cartilaginous body covering the orifice of the larynx, termed the epiglottis. The veil of the palate forms a curtain interposed between the cavity of the mouth and the cavities of the nose. In short, it is a valve having the effect of cutting off the communication between the posterior nostrils and the cavity of the mouth. This veil or valve gives passage to the masticated food backwards into the pharynx, but at other times lies so close on the back part of the epiglottis or lid of the larynx, that the air from and to the windpipe in respiration does not pass through the mouth, but only through the nostrils. In like manner, when it happens, which is rare, that the horse rejects the contents of the stomach upwards, the rejected matter does not issue through the mouth, as in animals that vomit, but through the nostrils. The veil of the palate is composed of mucous membrane enclosing muscular fibres.

Tongue.—The tongue occupies the floor of the mouth. It lies between the nearly parallel sides of the lower jaw, and thus has the chief share in filling up the void between these. Those portions of the tongue which, in the language of anatomy, are free—that is, unadherent to adjacent parts—are covered by mucous membrane. The whole of the upper surface and its margins, from the epiglottis or lid of the larynx to the tip, are free—also the anterior part of the under surface. The substance of the tongue is muscular—that is, fleshy. A considerable portion of the tongue is made up of muscular fibres, which are confined within the limits of the organ. Other sets of muscular fibres come from adjacent parts, and, running into its substance, increase its bulk. Those muscular fibres which extend from adjacent points necessarily enter the tongue by those parts of its surface which are not free—namely, its base, and the posterior part of its under surface. The muscular fibres which do not extend beyond the limits of the organ, serve principally to alter its form—for example, to curve the tip of the tongue upwards, or to curve its tip downwards.

But those muscular fibres which enter the tongue from adjacent points have a much greater power over its motions. The hyoid bone is termed the bone of the tongue. This name is hardly correct; nevertheless it is a principal point whence muscular fibres proceed into the tongue. The hyoid bone resembles the upsilon or *υ* of the Greeks; by modern veterinary writers it is likened to a spur. Its convex part presents between the larynx and the anterior-inferior point of the lower jaw—its branches proceed backwards in connection with the upper margin of the larynx. These branches constitute the concavity of the spur; while from the middle of its convexity, pointing forwards there is a straight projection (called appendix by some) corresponding to the neck of the spur. The part resembling the spur is small compared to the lesser and greater horns. The lesser horns articulate with the body, and have an upward, forward, and outward direction: the greater horns are long and flat, passing from below backwards and upwards; their inferior extremities articulate each with one of the lesser horns. These few particulars show very considerable differences between the hyoid in man and that bone in the horse.

The hyoid bone is connected by muscular fibres not only with the tongue, but also with the lower jaw, the temporal bone, the larynx, the pharynx, and the breast-bone. When these muscular fibres contract, an approximation takes place between the two points of attachment, so that the point more movable at the moment approaches to the more fixed point. To this rule all the movements of the tongue can be referred. The movements of the tongue dispose the food for being ground between the teeth, and are afterwards concerned in collecting the masticated morsels together and conveying them to the back part of the mouth in order to be swallowed. The tongue is also concerned in deglutition, and forms a canal through which the water passes when the animal drinks.

The upper surface of the tongue is covered all over with numerous projections or eminences termed papillæ. They are distinguished into orders according to their size and form. These different kinds of papillæ are highly vascular and sensitive prolongations of the mucous coat of the tongue. When injected they seem to consist entirely of capillary vessels. Nerve-tubes also seem universally to penetrate into the papillæ. The papillæ are at once the seat of a high degree of tactile sensibility, and are also the parts chiefly concerned in the special sense of taste.

Salivary Glands.—The salivary glands supply the saliva with which the aliment is mingled during mastication. There are three principal glands of this sort on each side, which are respectively named the parotid, the submaxillary, and the sublingual. Of these the parotid—lodged in the space between the angle of the jaw, the zygomatic arch, and the mastoid process—is the largest; the submaxillary gland, on the inside of the jaw near its angle, is next in size; and the sublingual, beneath the tongue, is the smallest of all.

The parotid saliva of the horse is usually perfectly limpid and colourless, devoid of smell and taste, incapable of being drawn out into threads, and of a distinctly alkaline reaction. Its density very little exceeds that of pure water (1.0051 to 1.0074). It contains potash, soda, and lime, combined with an organic matter named ptyalin ; an extractive matter soluble in alcohol and in water, precipitable by tannic acid ; sulphocyanide of potassium ; the potash-salt of an acid belonging to the butyric group ; epithelium and mucous corpuscles ; the chlorides of sodium and potassium ; phosphates ; alkaline sulphates.

The salivary glands are of large proportionate size in the horse, and the secretion of saliva appears to be great in the same proportion. In no mammal but the ruminants does the development of the salivary glands appear to equal that in solidungulous animals, of which order the horse is one.

The saliva has an especial effect on starch. When saliva or a portion of the salivary glands, or even a little dried ptyaline, is added to starch-paste, the starch is very rapidly transformed into dextrine and grape-sugar. One use of the saliva then, may be to assist in the transformation of the starch of the aliment—that being naturally insoluble—into soluble dextrine and grape-sugar, so as to be rendered more fit for absorption.

Lips.—The lips are attached to the respective alveolar projections of the superior and inferior maxilla by the muscles which move them, by the areolar or cellular tissue contained in their substance, and, finally, by the lining membrane. The lips exhibit externally perpendicular lines of division, have little papillary eminences on their surface, and show a soft and short coating of hair, out of which spring several long, straggling, strong hairs or whiskers. The lower lip is smaller and thinner than the upper, and has near its centre a tuft of coarse hairs, commonly called the beard. The orbicular muscle, or muscle which closes the mouth, being free from any direct attachment to bone, is properly regarded as forming the main substance of both lips. The other muscles which enter into the lips are attached to adjacent bones, and determine the other movements of the lips in accordance with the usual rule of muscular action. There are numerous glandular bodies, termed follicular glands, spread over the mucous membrane which invests the lips. The lips are possessed of great sensibility. With his lips the horse, as with a hand, gathers up his corn, and with them collects together the grass before he divides it with his nippers.

Cheeks.—The cheeks constitute the sides of the mouth closing the interval between the two jaws. They consist of a cutaneous, a muscular, and a mucous layer, besides fat, areolar (called also cellular) tissue, and glands. The principal muscle in the cheek is the alveolo-labialis or buccinator. The muscular substance of the cheeks powerfully contracts the cavity of the mouth.

Lower Jaw.—To complete the notice of the parts concerned in the changes of the aliment within the mouth, the lower jaw has still to be spoken of. It is the movement of the lower jaw which gives efficiency to the teeth. The mode of its motion depends on the kind of articulation between it and the temporal bone, into a cavity of which its head, called its condyle, is received. In the horse, however, the temporal bone divides into two separate bones—the squamous bone and the petrous bone. It is with the squamous bone that the lower jaw articulates. The lower jaw itself somewhat resembles the letter V with its two upper extremities bent to an angle with the upper surface of the sides. The part which is bent out of the original direction is known on each side, particularly in human anatomy, as the *ramus*. This ramus ends in two processes—the anterior, the coronoid; the posterior, the condyloid. It is this last which articulates with the squamous bone; the anterior process or coronoid is for the attachment of the powerful muscle named the temporal muscle, which makes the teeth of the under jaw strike against the teeth of the upper jaw. Here, in the language of natural philosophy, the power is between the fulcrum and the resistance. If the coronoid process were behind the condyloid process, while the temporal muscle had its attachment as now, it is plain the contraction of that muscle would separate the jaws by drawing the lower jaw downwards, for then the fulcrum would be between the power and the resistance. The simplest movement of the lower jaw is that which belongs to carnivorous animals, such as the dog: in these the movement is merely up and down, like that of the blades of a pair of scissors. In animals of this description the cavity in the squamous portion of the temporal bone is deep, and is directed forwards, while it is so bounded by an anterior and posterior bony eminence, that the condyle of the jaw received into it can move only in one direction. In herbivorous animals, on the contrary, the glenoid cavity is shallow, permitting a great extent of movement to the condyle; and this is the case in the horse. Thus, besides the hinge movement common to all mammals, there is a power of moving the jaw forwards, backwards, and laterally—movements of essential effect in grinding the food to a proper degree of comminution. The temporal and masseter muscles, which belong to the external aspect of the head, are those concerned in the hinge-like motion of the jaw; while the pterygoid muscles, lying on the inner side of the jaw, on each side, and acting not together on the opposite sides, but alternately, produce the grinding movements.

Pharynx and Gullet.—A short notice of the pharynx and gullet will permit the act of deglutition to be taken along with the changes on the aliment in the mouth.

The pharynx is the muscular pouch behind the veil of the palate, into which the masticated food passes from the mouth to be immediately transmitted to the gullet. It has a conical form, the smaller end being below, where it meets the gullet, and is lined by a mucous membrane. The muscular fibres are attached to the neighbouring bones, and are so disposed as, by their contraction, to narrow the whole cavity of the pouch, by which action the mass is directed downwards.

The gullet is continued down from the pharynx. It is a powerfully muscular tube lined by mucous membrane. As it descends in the neck it inclines a little to the left side, and, finally, is found altogether to the left side of the windpipe. It passes through the chest between the two sacs of the pleura, where these form the superior mediastinum. It passes between the crura of the diaphragm or midriff, and ends in the stomach, at a right angle, about the centre of its upper and anterior part.

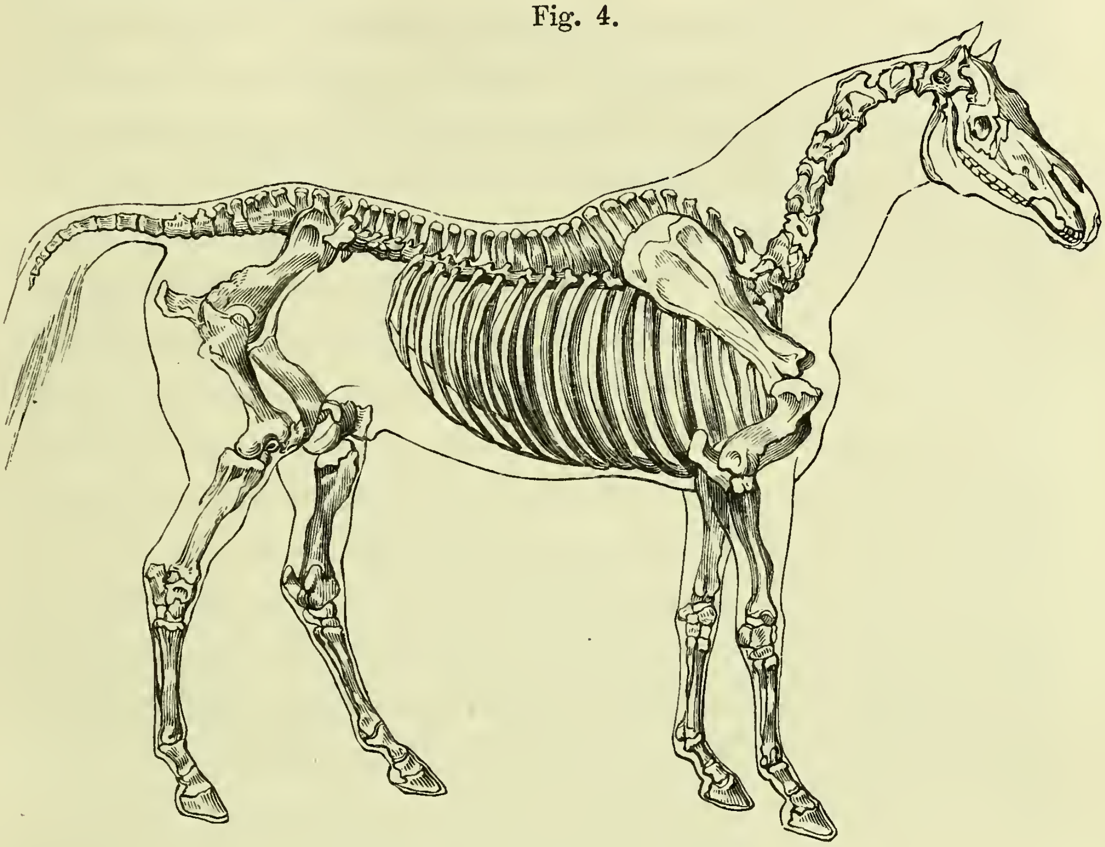
The several parts of the mouth now spoken of are freely supplied with blood by arteries derived on each side from the external carotid artery, which blood is returned by corresponding veins terminating finally in the right and left jugular veins. The pharynx also is supplied with blood from the external carotid, while the gullet receives branches from the posterior aorta. The external carotid artery is itself one of the three branches into which, on each side, the carotid artery splits near the top of the larynx, the other two being the internal carotid and the anastomotic branch. The right and left carotid arteries, which there split, are themselves branches of one common trunk—namely, the common carotid. This common carotid is a large artery, though no more than an inch in length, issuing by the upper part of the anterior aperture of the chest, on the fore part of the windpipe, and there dividing, as just said, into the right and left carotids. This short artery, the common carotid, is itself the continued trunk of the right anonymous artery, which, again, is one of the two branches into which the anterior aorta divides—namely, the right anonymous artery and the left anonymous artery. Of these the right anonymous artery is much the larger, inasmuch as the right affords branches to the right anterior extremity as well as to the head, while the left gives no branches to the head, but only corresponding branches to the left anterior extremity. The anterior aorta is a very short trunk, even less than an inch in length, which comes off from the aorta beneath the fourth dorsal vertebra; or perhaps, more correctly, it is one of the two great divisions into which the aorta, springing from the left ventricle of the heart, breaks, about four inches from its origin — namely, the posterior aorta, the larger, and the anterior aorta, the smaller division.

Jugular Veins.—The right and left jugular veins, which receive the blood from the several veins about the mouth, begin by a communication with the venous system of the brain at the jugular foramen between the petrous portion of the temporal bone and the occipital bone, and finally unite with the axillary vein, coming on each side from the anterior extremity, to form the anterior vena cava, and that conveys the blood into the right auricle of the heart.

Nerves.—While the blood serves for the maintenance and repair of living parts, the nerves are concerned in the sensibility and the movements of the same. When a bit of marble is taken into the mouth it makes an impression on the extremities of the nerves touched, and these convey the impression to the brain—the effect of which is a state of consciousness referred to the parts with which the marble is in contact. This constitutes a sensation. Again, when a bit of sugar is taken into the mouth, it melts and affects the nerves of the tongue; the impression here also is conveyed by these nerves to the brain, the effect of which is also a state of consciousness, referred, as before, to the place over which the melted sugar has become diffused. This is also a sensation; but if the animal had previously been conscious of the peculiar sensation afforded by sugar, it might recognise the sensation as something which had before occurred in its consciousness. This recognition seems to be what constitutes perception. If a dog has been often treated to a bit of sugar, it will get up and run in haste when it sees the door of the cupboard opened where the sugar is kept, in expectation of getting a bit at the moment. Here, then, the remembrance of the sensation prompts to action. The action consists in muscular movement, and that movement is determined by nerves acting through the brain on the muscular system. Thus impressions made on the extremities of nerves end in muscular acts set up through the nerves by certain conditions of the brain. Moreover, physiologists have discovered that there are two kinds of nerves—namely, nerves of sense and nerves of motion; or, as these are sometimes named, afferent nerves and efferent nerves—the nerves of sense being termed afferent, because they carry impressions to the central nervous organs; and the nerves of motion efferent, because they convey from the brain or centre the stimulus by which muscular fibres are called into activity. In all familiar instances in which motion follows impressions, there is interposed a state of consciousness, or rather two states of consciousness—the one constituting a sensation; the other a volition, or that act which precedes muscular action. But there is also a kind of cases in which muscular movement arises without volition, and to this, of late, the name of reflex action has been applied. To illustrate the difference: if a man sitting with his foot on the fender sees the tea-kettle about to boil over, he deliberately withdraws his foot. Here the sensation in the act of sight is followed by a voluntary act; the impression on the eye is followed by one state of consciousness and then a volition—that is, another state of consciousness arises able to determine the contraction of the muscles necessary for the withdrawal of the foot. If, however, the tea-kettle boils over without any previous warning, and some drops of hot water fall suddenly on his foot, the foot is withdrawn instantly, without any intervening volition. This is a case of reflex action. Here, however, there is one state of consciousness—namely, the sensation consequent on the impression made by the hot water on the nerves of the foot; the state of consciousness which is wanting is the consciousness of volition. But there are cases of reflex action known, both in man and in the animals beneath him, in which there is absolutely no state of consciousness interposed between an impression on afferent nerves and the motion produced through efferent nerves. For example, in a man apparently completely insensible from apoplectic seizure, a teaspoonful of some drug being carried towards the back part of the tongue makes an impression, succeeded, without any intervening consciousness, by the contraction of the numerous muscles concerned in deglutition. This is the most striking kind of reflex action.

Of the nerves supplied to the parts about the mouth and to the pharynx and gullet, some are nerves of sense, some nerves of motion; or, according to the other mode of nomenclature, some are afferent nerves, some are efferent nerves. All of them are cranial nerves—that is, are nerves derived from the nervous parts within the head, commonly, yet not accurately, included under the name brain. It is usual to reckon nine pairs of cranial nerves. The second, third, fourth, and sixth pairs belong exclusively to the eye. The fifth pair has an extensive distribution: part of it is spent on the eye and nose, while other parts of it are spread to the jaws, teeth, lips, tongue, and palate. The fifth pair of nerves is the largest of the cranial nerves: its filaments are chiefly nerves of sense, and a portion of it is a nerve of special sense—namely, the gustatory nerve, or nerve of taste in the tongue—while a portion of it includes motor filaments, and these motor filaments are spread upon the muscles of mastication. A portion of the seventh pair belongs to the sense of hearing; while the chief remaining portion comes out upon the face, to become the motor nerve of the face, and therefore is concerned in some of the actions of the mouth. The eighth pair is a widespread nerve: its chief destination is the stomach, but in its progress it supplies the pharynx and gullet; and a special division of it, named the glosso-pharyngeal, is distributed to the tongue and the pharynx. The ninth pair of nerves is a motor nerve, and being chiefly spent on the tongue, bears the name of the lingual nerve.

Fig. 4.



SKELETON AND OUTLINE OF A HORSE.

The figure of the skeleton of the horse, fig. 4, with the soft parts in outline introduced here, will assist the reader in following the descriptions of the parts concerned in nutrition.

Deglutition.—The natural food of the horse, in such countries as are favourable to his existence in the wild state, consists mainly of green herbage, and, at certain seasons, of the same herbage in a more or less dried condition, together with its fruit, also in a dry and hard form. Such herbage is made up principally of various species of grasses, and of plants of the leguminous order; many of the latter of which—as clover, lucern, tare—when cultivated, are known as the artificial grasses. To food of this kind the teeth of the horse are finely adapted. The incisor teeth cut through the stems, whether succulent or dry, like a pair of scissors ; and, while the mouthful is mingled with the saliva, it is reduced gradually to a pulp by the molar teeth. It is manifest, however, that when the herbage is dry and its fruit hard, a much greater amount of mastication will be necessary than when it is soft and succulent, and when the fruit is still unripe and humid. Moreover, it is obvious that when the food is of this dry description, particularly if the season be still warm, a much larger amount of drink will be requisite than when the food abounds in humidity. It should be remarked, also, that when the fruit of grasses or of leguminous plants is eaten as it exists in the wild state, a large proportion of the straw must be consumed at the same time ; so that dry aliment, like plain oats or plain beans by themselves, never becomes the food of the horse in the wild state.

These few facts, bearing reference for the moment not to the intrinsic nutritiousness of the alimentary articles, of which elsewhere, but to their merely greater or less fitness for mastication, should not be lost sight of in adjusting the mixture of his food in the domesticated state. The purpose of the changes in the mouth is to reduce the aliment to a soft pulp preparatory to the further transmutation which is to go on in the stomach. In so far as the food naturally supplied is concerned, the teeth and salivary apparatus are excellently adapted to the end intended ; but it is manifest that such hard articles of food as unmingled oats or unmingled beans never constitute the natural food of the horse. There is danger, then, when the horse is put on either of these two forms of food without admixture with some less hard food, that the process of mastication will be imperfectly performed, and the oats or beans swallowed in a state less fit for digestion in the stomach, and therefore liable to give rise to disorder in the inferior part of the alimentary canal. The appearance of the dung sufficiently proves that oats and beans, when given alone, are imperfectly chewed by all horses, and scarcely at all by hungry and greedy ones.* The knowledge of this fact has led to the rational practice of mixing the chopped dry culms of forage or cereal grasses with the corn and beans. By this addition the animal is compelled to chew his food. What is here called chopped dry culms is very improperly called chaff, thus confounding it with the husks of grain. It is usually a mixture of cut hay and cut straw (both of which are properly termed culms) variously proportioned. For example, it may be composed of equal proportions of clover and meadow hay, and wheaten, oaten, or barley straw, cut into pieces of a quarter or half an inch in length, and mingled well together; to this the proposed allowance of oats or beans is then added and thoroughly mixed therewith. It is also an advantage first to bruise the oats or the beans. The animal is by this contrivance forced to chew the food. The chopped culm is too hard and too sharp to be swallowed without a complete mastication, and while the horse is compelled to employ his molar teeth upon the chopped culm, the oats or beans obtain the requisite amount of grinding, to the great increase of the nourishment supplied.

When the food, whatever be its nature, has become completely masticated by the teeth, and at the same time mingled with the salivary secretion, so as to have become of a pulpy description, it is collected on the tongue preparatory to the act of deglutition—that is, preparatory to the act of swallowing—by which it is conveyed through the pharynx and gullet into the stomach.

The act of deglutition is commonly considered as consisting of three stages:—In the first, the bolus, as it is technically called, is pressed backwards towards the base of the tongue; in the second, it makes a kind of bolt from the base of the tongue over the orifice of the air-passages of the lungs into

* Youatt on the Horse, p. 463.

the pharynx ; in the third stage, it is transmitted through the gullet to the stomach.

The collecting of the masticated food on the tongue is accomplished by the complicated movements of the tongue itself, and by the contraction of the fore part of the cavity of the mouth. In like manner the bolus is driven backwards on the tongue by the contraction of the back part of the cavity of the mouth. In the second stage of deglutition the act is somewhat complex. It begins as soon as the bolus has arrived at the back part of the tongue. It may be remarked that, except in drinking, the mouth during deglutition is always closed. This, then, is a first step in the second stage of deglutition. Then the hyoid bone is drawn upwards and forwards by muscular contractions, and along with the hyoid bone the larynx and pharynx, which are connected with that bone, are made to move upwards and forwards—the epiglottis or lid of the larynx is at the same time depressed so as to close the larynx. Now a kind of convulsive movement occurs, during which the bolus is precipitated across the epiglottis into the pharynx. The pharynx, being a muscular organ, contracts, and transmits the bolus onwards to the gullet, and the gullet being also muscular, propels, by its movements, the bolus into the stomach. The mouth is shut in order to fix the lower jaw, from which the principal muscles concerned in raising the hyoid bone originate.

The whole act of deglutition is an involuntary act, belonging to that description of acts technically known as reflex acts. The second stage of deglutition is indeed a remarkable illustration of acts of that kind. As soon as the bolus arrives at the back part of the tongue, it stimulates the extremities of the afferent nervous filaments distributed there ; this stimulus or impression is, by these nervous filaments, conveyed to the nervous centre within the skull, where an effect is produced destined in the animal economy to originate motor influence, which being conveyed through efferent nervous filaments to the muscles having a share in deglutition, particularly to those concerned in the elevation forwards of the hyoid bone, that act occurs altogether independently of the will, or, to speak technically, of volition.

The act of deglutition in the horse is well illustrated by attending to the corresponding act in man. As soon as a man has collected the bolus on the tongue, and permitted it to pass backwards towards the posterior part of that member, he loses all control over it. If the finger be placed on the larynx, or on the part termed Adam's apple, it is felt to rise forcibly at the moment of swallowing; and should the act fail to take place with its usual regularity, a sense of sinking or of impending death arises, which technically is termed anxiety.

Organs of Digestion in the Abdominal Cavity of the Horse.—The large trunk of the horse is divided, like that of other similar animals, into thorax or chest, abdomen, and pelvis. The chest, which is of great size, is bounded on the lower part and sides by the breast-bone, and eighteen pairs of ribs, while posteriorly it is separated from the abdominal cavity by the great tendino-muscular partition termed the midriff or diaphragm. The abdominal cavity is bounded superiorly by the lumbar vertebræ of the spine, and on the sides and below by the large abdominal muscles extended between the ribs and the margins of the pelvic bones. Owing to the concavity of the posterior surface of the diaphragm, the abdominal cavity extends considerably farther forward than the posterior margins of the ribs. The pelvis is the nearly straight, cylindrical cavity formed at the posterior part of the trunk by the bones of the pelvis.

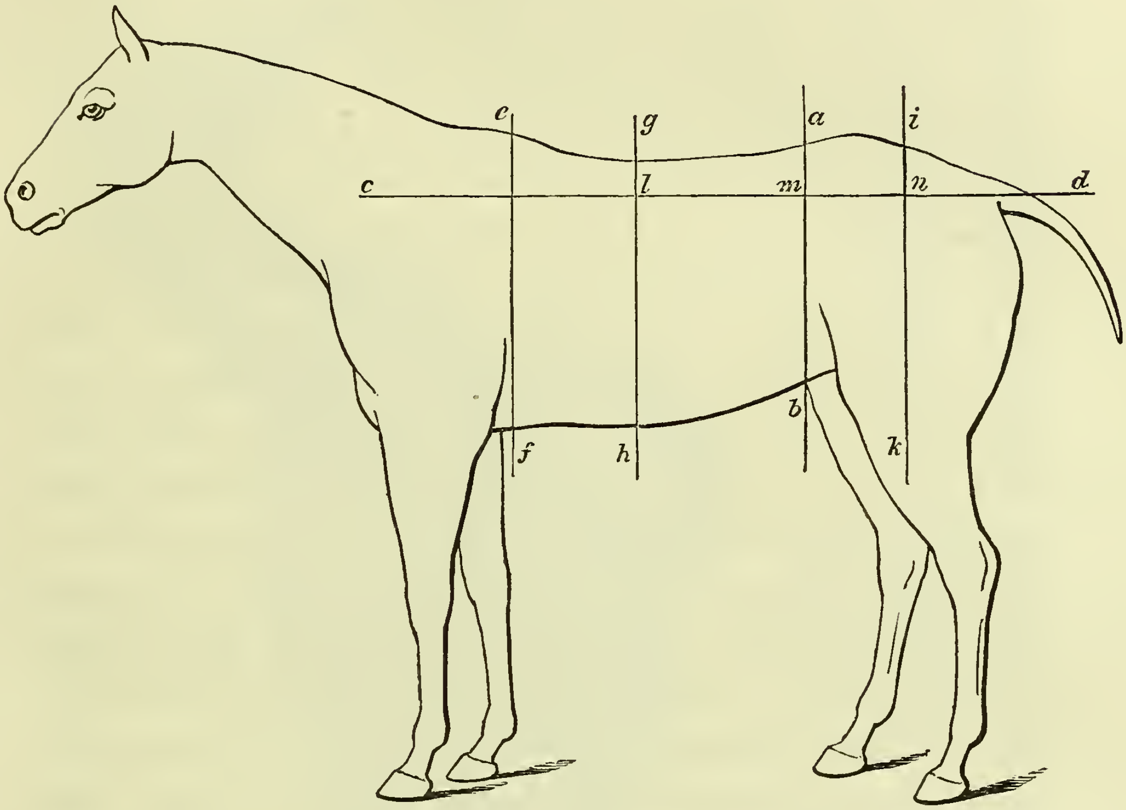
The whole of the alimentary canal is contained in the abdominal cavity, with the exception of the gullet and the rectum. The gullet, as already mentioned, passes through the chest, to terminate in the stomach after piercing the diaphragm. The lowest division of the great intestine, which, owing to its being nearly straight, is called rectum, passes through the pelvis, following the course of the *os sacrum*, or rump-bone, to end in the fundament.

As the inferior and lateral walls of the abdomen are powerful muscles, as well as the anterior wall formed by the diaphragm, the wall constituted by the abdominal muscles, reinforced by a powerful elastic covering, is capable of antagonising that formed by the diaphragm; while if these several muscular boundaries contract simultaneously, the contents of the abdominal cavity may be strongly compressed.

It is useful to mark out, by imaginary lines, certain external regions of the abdomen which correspond more or less exactly to the place of the organs situated within. In the horse, as in mammals generally, the abdomen is marked out by perpendicular lines into three zones—an anterior, a middle, and a posterior, as in fig. 5—and each of these three zones is divided by longitudinal horizontal lines into three subordinate regions. The three regions of the anterior zone are the epigastric in the middle, and the right and left hypochondriac on either side. The three regions of the middle zone are the umbilical in the middle, and the right and left lumbar region on either side. The three regions of the posterior zone are the hypogastric in the middle, and the right and left iliac region on either side.

Part of the epigastric region, and of the left hypochondriac region, are occupied by the stomach; the right hypochondriac region, part of the epigastric region, and even a minute portion of the left hypochondriac region, are occupied by the liver. The spleen lies in the left hypochondriac region. The pancreas, or sweetbread, is situated in the epigastric region, lying across the spine. The duodenum or uppermost portion of the small intestines surrounds the head of the pancreas. The

Fig. 5.



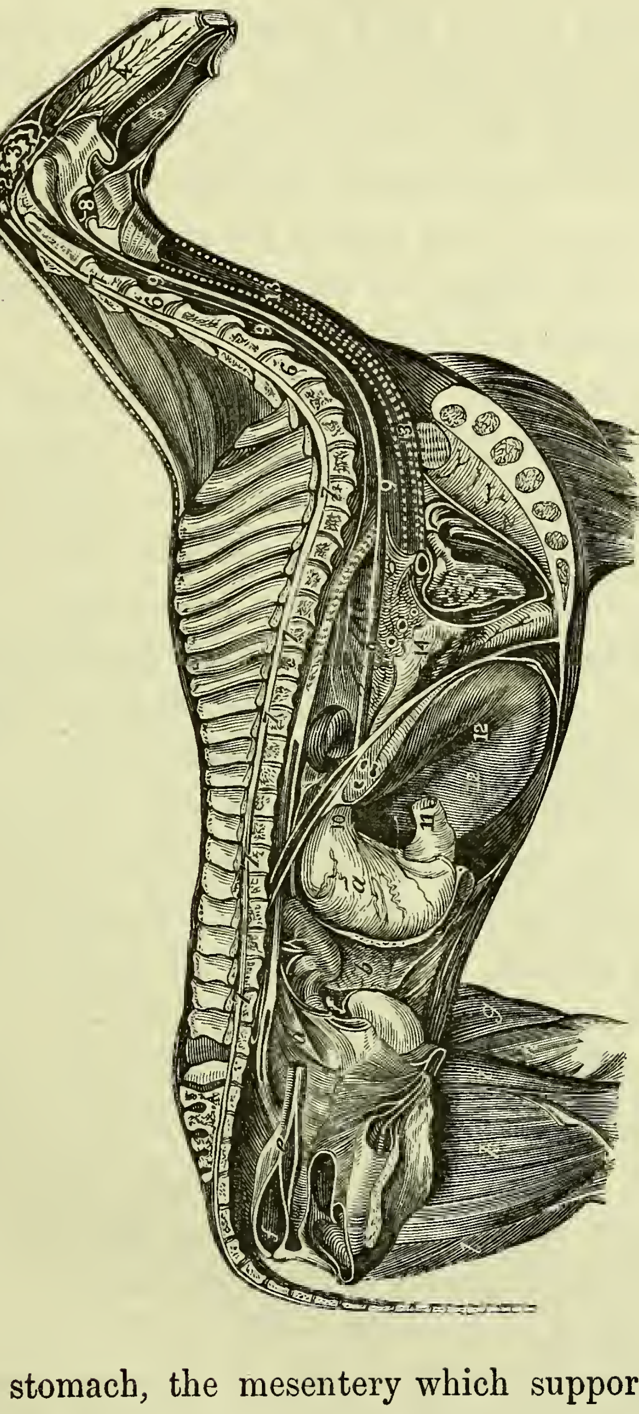
Zones and Regions in the Abdomen of the Horse.

e f, *h g*, Left side of anterior zone; *g h*, *b a*, left side of middle zone; *a b*, *k i*, left side of the posterior zone; *a b*, a vertical line drawn through the anterior superior spinous process of the os ilium; *c d*, a line passing through the same process at right angles to *a b*; *e f*, and *g h*, lines parallel to *a b*; *g h*, passing through the lower extremity of the eighth rib; *f l*, epigastric region of the left side; *e l*, left hypochondriac region; *h m*, umbilical region on left side; *g m*, left lumbar region; *b n*, hypogastric region on left side; *a n*, iliac region of left side.

ilium, the third and longest portion of the small intestines, occupies chiefly the umbilical region.

When the inferior wall of the abdomen is cut open by a crucial incision, the large intestines are first presented to view. About the middle of the cavity, the apex of the cæcum or blind-gut is seen protruding from the colon, and encircled by it as it extends to the right side. The small intestines are not usually seen at first, but come into view when the cæcum is turned to the right side. The glistening appearance of all the parts which are presented to view on opening the abdomen, arises from the general investment of the contained organs with the peritoneum or serous membrane of that cavity. The peritoneum is the largest of the serous membranes in animals resembling the horse; it forms, like other serous membranes, a shut sac, resembling a double night-cap. The interior of the sac throughout is the secreting surface; the exterior of the sac the surface of attachment, the former surface being everywhere free in the anatomical sense of that term, the latter surface being everywhere joined to the face of the adjacent parts by a thin connective layer of substance. The peritoneum is the lining membrane of the abdominal cavity—that is, one part of the exterior surface of the shut sac, which it forms, makes the lining of the cavity, while the remaining part of the exterior surface adheres to and constitutes the outer coat or covering of the several organs within the same cavity. The part of the exterior surface of the peritoneal sac which constitutes the outer covering of the several organs, is very intricate, being thrown into numerous folds and processes, between the laminæ of which blood-vessels, nerves, and lymphatic vessels pass, without, however, ever deviating from the type of a double night-cap, to which it was likened above. The double night-cap is simplicity itself compared to the intricacy of the peritoneum. This point, however, still holds good throughout all its intricacies, that the part of the night-cap which touches the head corresponds to the surface of attachment in the serous membrane, while the free glistening secreting surface answers to the interior shut sac of the night-cap, to which there is no access from without. Among the folds, consisting of two laminæ which the peritoneum forms, are the ligaments of the liver, the lesser and greater omentum connected with

Fig. 6.



Longitudinal Section of the Trunk of the Horse.

1, Occiput; 2, cerebellum; 3, cerebrum; 4, nasal membrane; 5, tongue; 6, 6, cervical vertebræ; 7, 7, 7, 7, spinal cord; 8, pharynx; 9, 9, 9, œsophagus; 10, cardiac orifice of the stomach passing through the diaphragm; 11, pylorus; 12, 12, posterior surface or abdominal aspect of diaphragm; 13, 13, trachea; 14, lungs; 15, heart.

a, Stomach; *b*, spleen; *c*, left kidney; *d*, broad ligament of the uterus with left cornu and ovary displayed; *e*, rectum; *f*, anus; *g*, *h*, *i*, *j*, *k*, *l*, internal muscles of the thigh. The intestines and liver have been removed.

the stomach, the mesentery which supports the small intestines, the meso-colon and meso-rectum which are connected with the great intestines. Again, these double laminæ separate from each other, and expand over the adjacent organs, so as to afford them an outer free-surfaced covering—namely, the liver, the stomach, the small intestines, the great intestines.

A great arterial trunk passes from the chest through the diaphragm backwards in the loins to supply the abdominal viscera with arterial blood, while a great corresponding vein collects the blood, which, after being in part sent through the liver, goes through the diaphragm to the heart. Nerves and lymphatics also abound in every part of the abdominal cavity.

The Stomach.—The stomach of the abdominal organs deserves the first particular notice (fig. 6).

The stomach of the horse, which is small compared with the size of the animal, lies behind the diaphragm, between the gullet and the duodenum. When distended it represents a conical-curved bag with its large end towards the left, its small end towards the right side. It has been likened to the wind-bag of a bagpipe, which is by no means an unapt comparison. The large end of the stomach is termed its fundus, and this name properly applies to that expanded part of the organ which lies to the left of the entrance of the gullet—for the gullet in the horse, and in herbivorous animals in general, does not enter at the extreme left of the organ, as in purely carnivorous animals, but nearly in the middle of its anterior side. In the human stomach the entrance of the gullet holds a middle place between that exhibited in herbivorous animals and that exhibited in carnivorous animals. It results from its bent form that the stomach has two curvatures—the concave or lesser curvature, and the convex or greater curvature. The concavity of the lesser curvature looks upwards and to the right; the convexity of the larger curvature looks downwards and forwards, the stomach turning as it becomes distended on an imaginary axis running through the cardia and pylorus, that is, the upper and under orifices, so that the axis subtends the lesser curvature. The stomach is not in complete apposition with the posterior surface of the diaphragm, and not at all with the upper surface of the abdominal wall, so that it cannot, in the horse, be strongly compressed between these two muscular parts, as happens in the complete vomiting of carnivorous animals. A fold of the small intestines has sometimes been found passing between the posterior surface of the diaphragm and the outer wall of the stomach.

The outer surface of the stomach, being a serous surface—that is, a part of the inner surface of the great peritoneal sac—is everywhere free, in the anatomical sense, except at the cardiac and pyloric orifices, and along the line of the two curvatures. To the line of the lesser curvature a fold of peritoneum, composed of two close laminæ, extends from the liver; along this line the two laminæ open and expand into the peritoneal coat of the stomach, the one lamina passing over its superior aspect, the other over its inferior aspect, to meet at the great curvature, where they reunite to form the two anterior laminæ of the great omentum. Thus the great omentum, which is of no great size in the horse, is projected as a double lamina from the great curvature of the stomach, and is found to become continuous with a double lamina of the same membrane proceeding from the transverse part of the colon, the inferior lamina of the gastric omentum, and the superior lamina of the colic omentum, being a second replication of the serous sac at the foramen of Winslow, close to its original attachment to the liver.

The left lobe of the liver lies anterior to the right extremity of the stomach, and the spleen lies between the stomach and the lower ribs, termed the false ribs; the pancreas or sweetbread is behind and rather above the small curvature of the stomach, lying across the spine. The principal coats of the stomach are the peritoneal or serous, already referred to, the muscular or contractile, and the mucous or villous, as it is sometimes improperly called, which lines the interior of its cavity. As these coats are severally conjoined by a connective substance, a greater number of coats is sometimes described. It is enough, however, to consider the stomach as composed of three essential coats. The muscular coat consists of exterior fibres, which are longitudinal, and interior fibres, and these are circular; and there are, besides, oblique fibres, the most internal of all. Of these three sets of fibres, the circular are the most conspicuous and the most important. Towards the pyloric orifice the circular fibres become blended with those of the duodenum, while the valve of the pylorus is formed by a circular production of muscular fibres enveloped within a fold of the internal coat. The cardiac, or upper orifice of the stomach in the horse, is still more carefully guarded than the pylorus; here the gullet enters the stomach obliquely through its outer coats, and then its muscular fibres arrange themselves into segments of circles interlacing each other, so that by their contraction the orifice is forcibly closed against the regurgitation of the contents of the stomach.

The mucous lining of the stomach in mammals generally is covered with an epithelium; but in the horse it has long been observed that what was termed a cuticular lining is very conspicuous in the left portion of the stomach. It covers nearly one-half of the entire cavity of the organ, and, when inspected in the relaxed state of the organ, it is thrown into wrinkles or rugæ, which sometimes assume the appearance of a sort of network. This aspect is, however, entirely owing to an inferior degree of elasticity in the cuticular expansion, in consequence of which it does not contract evenly along with the other coats of the stomach. The same appearance, though in a less degree, is seen, under the same circumstances, throughout the right half of the stomach, and it belongs indeed to the stomachs of mammals in general, owing to the loose connection between the mucous coat and the immediately subjacent textures, as well as to the smaller elasticity of the internal lining. The mucous coat of the stomach, as seen in the right half of the cavity, is a smooth, soft, rather thick, and pulpy membrane, which has generally a rather pale pink hue, though, when well washed, it is of a greyish-white or pale straw colour. During digestion its vessels become distended, and, when examined in that state, it is always much darker than usual. The mucous coat of the stomach is often described as villous ; but it does not appear that there are any true villi in the stomachs of animals, these minute structures being found only in the small intestines, as in the duodenum and jejunum. What have been mistaken for villi in the stomach are the elevated margins of minute alveoli —that is to say, little depressions or pits—visible with the aid of a lens, especially near the pylorus. The microscope exhibits, in the mucous membrane of the stomach, a number of minute tubules set side by side perpendicularly to the surface of the membrane: some of these have been supposed to possess a glandular structure, and to be specially concerned in the secretion of the gastric juice, whence they have been termed peptic glands.

The stomach is very copiously supplied with blood by its proper arteries. An important blood-vessel, the aorta or great systemic artery, arises from the left ventricle of the heart, and divides opposite the fourth dorsal vertebra into an anterior and posterior aorta—the latter being directed backwards, so that after giving branches to the parts within the chest, it passes between what are called the crura of the diaphragm, and becomes the abdominal aorta, the inferior aspect of which, immediately after it has penetrated the diaphragm, gives origin to a very short stump, which is called the cœliac artery. This short stump or root immediately breaks into three arteries

—namely, the hepatic, the gastric, and splenic. The gastric runs towards the small curvature of the stomach between the layers of the lesser omentum, giving off branches which encircle the stomach by passing before and behind that organ. The splenic artery and the hepatic artery send additional branches, which run along the great curvature of the stomach.

The veins of the stomach do not immediately join the great systemic venous trunk, but first contribute to form the portal vein, by which, as before mentioned (p. 9), the venous blood of all the organs termed by anatomists chylopoetic viscera, is transmitted through the liver before it reaches the systemic venous system.

The lymphatics of the stomach are very numerous. Some are placed beneath the peritoneal coat; others between the muscular and mucous coats. They take a retrograde course in the direction of the several sets of arterial branches, which reach the stomach, and finally terminate in the nearest lymphatic and lacteal trunks.

The nerves of the stomach are large: they consist of the two terminal branches of the pneumo-gastric nerves of the eighth pair of cranial nerves, together with offsets from the solar plexus of the sympathetic system.

Digestion in the Stomach of the Horse.—Animal bodies are produced, without the slightest exception, from the elementary substances existing in the mineral kingdom. It was already mentioned (p. 1) that there are fifteen elementary substances—that is, substances which chemists have not yet been able to decompose—known to exist as the component parts of the bodies of ordinary mammals, like the horse, ox, and sheep. It was also noticed above that the perfect health of such an animal cannot be continued, unless every one of those fifteen elementary substances be supplied in the food, as fast as it is lost or thrown out by excretion from the animal economy. Nevertheless, no substance passes directly from the mineral kingdom to enter into the constitution of any part of the animal body. The vegetable kingdom belongs to organic nature as well as the animal kingdom. The organic substance of the vegetable kingdom is as absolutely of mineral origin as the material of animal bodies. Water, carbonic acid, ammoniacal gas, and a few saline matters existing in the soil of the earth, are converted in vegetation into the organic parts of plants. Thus all the organic material of the vegetable kingdom is derived directly from purely mineral substances. The vegetable kingdom has the prerogative of metamorphosing into its own fabric the constituents of the mineral crust and aërial envelope of the earth. The animal kingdom is, in this special aspect, subordinate to the vegetable kingdom. The vegetative power of the animal kingdom has less of a creative character than what belongs to vegetable nature. The animal kingdom rests exclusively on the vegetable kingdom for its support and maintenance. All the various shapes of the food of animals are ultimately derived from vegetable nature. Were the vegetable kingdom to perish, the animal kingdom would quickly run to ruin. For though many animals are purely carnivorous, their prey could not long survive the extinction of vegetable nature. On the contrary, were the animal kingdom to perish, the vegetable kingdom would not indeed escape damage ; yet, as a whole, it would flourish more prosperously than ever.

Though water is a principal part of the food of plants, it is not enumerated among the aliments of animals. It constitutes the drink of animals. This may seem, at first sight, a distinction without a difference. But it is not really so. It is not customary to speak of the drink of plants ; nevertheless, plants drink very largely, and the drink they take in serves some of the very same uses to which the drink of animals is applied. Plants during the period of vegetation continually take in water from the soil: this is their drink. The water so obtained conveys the nutritive matter throughout the plant, and in particular to and from the leaves, where important vegetative operations are performed, and, moreover, preserves that state of moisture throughout the vegetable tissues without which, manifestly, no living function can be carried on. But the water, which is described as the food of plants, has another and a very different office. Under the agency of solar light, it is decomposed, and supplies its elements, or a part of them, along with the carbonic acid and ammonia of the atmosphere, and the protoplasma already existing in the leaves of a living plant, for the production of starch, sugar, albumen, fibrine, and the other proximate principles necessary for the ulterior operations of vegetation, by which products fit for the food of animals are developed.

Now, it is because there is no evidence of water being decomposed in the animal body for a purpose of the above-described kind that it is refused the name of an aliment in animals, and stationed by itself under the name of drink. And it is to be remembered that many liquids, termed drinks, though they consist of strictly nutritive matter largely diluted with water, are drinks only in so far as they consist of water, the contained organic substance being digested, just as if it had been taken in under a solid form. Thus, physiologically, water is the sole drink of animals.

But the office which this unchanged water serves everywhere in the animal economy is of the most important character. It was already remarked incidentally that the proportion of water in the body of a living mammal is estimated at four-fifths of its entire weight (p. 6). This very large proportion of fluid almost takes the animal solids, with the exception of the bones, cartilages, and hoofs, out of the category of solid parts. In the animal solids, with the exception of those few just enumerated, hardness is unknown. A greater or smaller tenacity is the characteristic which best marks out the textures pre-eminently meriting the name of solids. Nevertheless, it is common to attach much importance to the division of the component parts of the animal body into solids and fluids. When such a solid as bone is contrasted with such a fluid as saliva, the distinction seems broad and palpable. But when brain, which ranks as an animal solid, is put side by side with blood, which ranks as an animal fluid, the distinction appears to be less natural than conventional. Brain has few of the characters of a solid; it has little tenacity, and but a small power—that which is characteristic of a solid—of maintaining figure against the influence of gravity. The blood, on the other hand, though a fluid in the hydraulic sense, as capable of motion under ordinary impulses, is very far from being a fluid in the chemical sense, owing to the large proportion of undissolved solid matter which it contains. The difference in density between the two bodies shows the advantage on the side of the blood—brain having an average density of 1.036, and blood that of 1.052. It has to be remarked, however, that what is here said is true in particular of the grey cerebral matter, as the white cerebral matter owes its similar deficiency in the true characters of a solid not so much to the large proportion of water as to the great amount of fluid fat contained in its structure. The urine is sometimes as dense as healthy blood; yet it does not therefore lose the character of a true chemical fluid, inasmuch as the naturally solid substances which it contains are completely dissolved in the water present.

But to return to the uses of this large proportion of water spread everywhere throughout the animal economy: it is manifest that the organic atoms which compose the solids of the animal body exist in a fluid medium very much of the same kind, though less in degree, as that in which the organic atoms of the blood—for example, the red particles—exist in their proper fluid. In the blood the proportion of this fluid medium—namely, water with a slight saline impregnation—is larger; in the animal solids the proportion is somewhat smaller; nevertheless it is universally diffused, and must surround the several orders of organic atoms, and, perhaps, even enter between their ultimate constituents. The water of the blood constitutes a kind of liquid atmosphere to the vital solid atoms of that fluid, in which they can perform the special acts for which they are fitted in the freest possible manner. So the water spread throughout the interstices of the living particles of the solids constitutes a like fluid atmosphere, in which these living particles act and react on each other with all possible facility. If the supply of water be withheld throughout the animal economy, all the movements of living action are suspended or extinguished. It is, in short, the peculiarity of living molecular action that it takes place between solid organic atoms in a fluid medium or circumambient fluid atmosphere. The fluid is doubtless derived from the blood, but in quantity it far exceeds the amount of the blood. Like the serum, or rather the serosity of the blood, it contains a small impregnation of soluble saline matter. When organic atoms are spoken of, it is to be understood that these are not chemical atoms, but the smallest living molecules—that is, particles endowed with living properties—which cannot be divided without the loss of their living character. Of late such bodies have been regarded in physiology as living cells.

If a horse weigh 1500 lb., the quantity of his blood will probably be about 300 lb.; but the amount of water besides diffused through his frame will not fall short of 900 lb.

If the proportion of water in the blood fall below the just standard, thirst arises, and if drink be supplied the due balance is quickly restored; if more water be afforded to the blood than requisite for the present wants of the blood, and of the living system at large, the kidneys usually take on an increased activity, and soon bring down the dilution of the blood to the proper degree.

That water passes with extreme rapidity from the stomach of the horse, as from that of mammals in general, is apparent from the well-known fact that a horse will drink within a few minutes a much greater quantity than what his stomach can contain. It is commonly supposed that the excess passes at once into the highest part of the small intestines, namely, the duodenum. But this supposition is hardly necessary, for it is proved that absorption of thin fluids takes place from the inner surface of the stomach with an almost incredible rapidity. This fact is established by many experiments; and, moreover, that substances dissolved in the water taken in have been found in the urine within an incredibly brief period. The purer the water, the more rapidly is it absorbed—partly, perhaps, on the principle of endosmose. That principle is briefly this, that when a texture like an animal membrane is interposed between two fluids which differ in density, the less dense fluid passes freely towards the side where the denser is, while but a small proportion of the more dense fluid passes in the mean time to that side on which the less dense fluid is—the latter process being called exosmose.

Mare's Milk.—The horse, as everybody knows, is a purely vegetable feeder; nevertheless, as in mammals universally, the first food of the young animal for some time after it is foaled is an animal fluid, the mare's milk. The average daily increase of a foal during the three months of sucking is upwards of two pounds, being a considerably greater daily increase during this period than after it is weaned. It appears that the average increase of a young horse is 12 per cent in live weight on the amount of food he eats. It may seem at first sight that the aliments supplied by the mare's milk to the foal while sucking are very different from those contained in the grasses and the like, on which the young horse is afterwards reared. It is now ascertained, however, that the proximate principles of the animal kingdom, which serve for the nutrition of animals, are chemically very much the same as those subservient to nutrition afforded by the vegetable kingdom. The mother's milk in every species of mammal is for the present the best standard available to enable us to determine the due constitution of the diet of that species. As a general rule, the proximate principles adapted to animal nutrition are arranged under the three heads, albuminous, oleaginous, and saccharine. Substances coming under each of these descriptions are found in the milk of the mare, while corresponding substances are discoverable in the herbaceous food of the young horse after weaning. The albuminous constituent of milk is caseine, the saccharine constituent sugar of milk, and the oleaginous constituent oil or butter. In the earlier days of animal chemistry, caseine was confounded with albumen. From that principle, however, it differs in several essential respects, particularly in not being coagulable by heat. Caseine is still, however, ranked as an albuminoid principle. There is no albumen in normal milk, though it appears to be present in the colostrum, or the milk first drawn after parturition. Neither is there fibrine in healthy milk. Thus caseine is the only plastic or nitrogenous nutritive principle in milk. It is not present in a very high proportion in mare's milk, notwithstanding that the amount of solid substance in mare's milk is rather above the general average. The proportion of fat, and also that of sugar, is high. The salts usually discoverable in milk are the chlorides of sodium and those of potassium, phosphates of the alkalies, phosphates of lime and magnesia, a small proportion of oxide of iron, together with potash and soda, united with the caseine by which that substance is rendered soluble. To this brief notice of milk it should be added that in herbivorous animals it is slightly acid, that when a thin layer is viewed through the microscope, the fluid appears to be transparent; that it contains a large number of highly refracting transparent oily globules floating in a transparent liquid; that these globules are contained in a very thin investing membrane, which becomes visible on the addition of acetic acid.

Such, then, is the kind of substance that is first received into the stomach of the foal to undergo digestion preparatory to being applied to the maintenance and growth of the young animal.

What we seek to learn from the process of digestion in its largest sense is the series of steps by which aliment is converted into blood, or at least those by which the waste of the blood is supplied by what the aliment affords. When the composition of the blood is compared with the composition of the *milk,* these fluids are found to agree in certain general points of view, while in particular respects they differ in no slight degree.

The blood contains two plastic substances, as they are termed —namely, fibrine and albumen, the former being in much less proportion than the latter. It also exhibits the blood-corpuscles or red particles, which make by far the largest proportion of its contained solid matter. It affords besides some fatty matter, some extractive matters, and a variety of salts. It contains no caseine, and, in the healthy state, no sugar. The small proportion of iron belonging to the blood is believed chiefly to enter into the constitution of the blood-corpuscles or red particles. It may be noticed here that a minute proportion of iron has been detected in the ash of milk.

During the period that the young animal is fed exclusively on milk, the caseine of that fluid is the only azotised principle which can replace such azotised principles of the blood as fibrine, albumen, and the blood-corpuscles. It is certain, then, that during that period caseine is rapidly converted either directly or indirectly at least into albumen and fibrine. The ultimate composition of the three substances—caseine, fibrine, albumen—differs but in a very slight degree. Every one of the three consists of carbon, hydrogen, nitrogen, and oxygen, very nearly in the same absolute proportions, notwithstanding the very decided differences in their sensible properties. It seems established, however, that albumen and fibrine contain besides less than two per cent of sulphur and phosphorus, while caseine contains no phosphorus, but only sulphur. Though chemists are not yet satisfied that caseine can be converted into albumen or fibrine in the laboratory, there is nevertheless no difficulty in conceiving that this transmutation should readily take place in the living system, under the various circumstances operative during the progress of digestion, especially in its ulterior stages. It has often happened that chemists, after long trying in vain to produce certain combinations of elements, at last succeed by employing a more complete apparatus and nicer adjustments ; but what can exceed the perfection of the means provided for the accomplishment of ends in organic nature, even though the final effect be the result of nothing more than the ordinary affinities prevalent among simple substances !

The general plan on which transmutation of one organic principle into another takes place in living nature, is that a portion of the substance to be augmented is mingled with the substance which is to undergo transformation in contact with a living surface. Thus in vegetation the carbonic acid, watery vapour, and ammonia of the atmosphere absorbed into the cells of the leaves of plants are metamorphosed, under the influence of the sun's rays, into the vegetable proximate principles already existing in those cells—viz., albumen, lignine, starch, sugar. Changes of the same character are even observed where no actually living surface is present: thus pure charcoal saturated with strong vinegar, under very free exposure to air, has the effect of changing dilute alcohol into a large quantity of diluted vinegar—the presence of the vinegar, as it would seem, determining the conversion of the alcohol into the same compound. Chemists, it is true, are not agreed in the views taken of changes of this kind. But in the mean time it is satisfactory to find that parallel cases in point of fact can be brought together from different sources. What is undeniable here—that is, in the case of the first digestion in the colt—is, that in the body of the colt at birth there is no caseine; that nothing of the nature of a plastic substance, except caseine, is contained in the mare's milk; and, in particular, that there is no albumen or fibrine present; that nevertheless albumen and fibrine, being the substances out of which the chief organs and parts of the colt are built up, are both present in abundance at the moment of birth, and go on growing in quantity, while no plastic substance but caseine is supplied prior to the time of weaning; thus that this is not improbably one of the cases in which the presence of a proximate principle has a share in determining the conversion of another proximate principle into itself.

As already noticed, caseine contains very nearly the same proportions of carbon, hydrogen, nitrogen, and oxygen, which exist in albumen and fibrine. It contains also, like these two principles, sulphur. It does not show phosphorus in its composition. There are phosphates of potash, soda, lime, and magnesia in mare's milk as in other kinds of milk; and from this source the phosphorus requisite for the conversion of caseine into albumen or fibrine doubtless is derived. For this purpose, however, the deoxidation of the phosphoric acid in some of these phosphates is required. But deoxidation is not a frequent mode of chemical action in the living system. On the contrary, oxidation is everywhere therein in full operation. It is to be remarked, however, that the proportion of oxygen in caseine is somewhat less than what exists in albumen and in fibrine—so that room is left for the supposition, that when caseine in contact with a phosphate passes into albumen or into fibrine, the deficient oxygen is supplied by the deoxidation of phosphoric acid, while the phosphorus set free affords the necessary atoms of phosphorus.

In mares' milk, as in the milk of other similar mammals, oil or butter, and sugar-of-milk, exist in considerable proportion. These two proximate principles, as being destitute of nitrogen, are accounted non-plastic principles—that is, they are incapable of supplying materials for the production or repair of the solid fabric of the body. They have been termed, in contradistinction to such proximate principles as caseine, calorifacient principles—that is, principles capable of supplying animal temperature, either by being themselves slowly converted into water and carbonic acid by the agency of the oxygen received into the living system during respiration, or by being converted into other non-azotised principles which may be similarly acted on by oxygen with the production of heat.

Oily particles plainly exercise an important influence throughout the living system. When the food is destitute of oily material, other non-azotised principles are certainly converted into oil in some part of the process of digestion. The oily principle in food, as the oil of mares' milk, doubtless undergoes considerable changes in the various stages of digestion, without, however, losing the essential characters of oil or of its subordinate constituents. A principal change to which it is uniformly subjected is that of extreme comminution of its particles, as in the form of emulsion, by which change it appears to be able to make its way through the minutest kinds of vessels known in the living economy.

The salts found in mares' milk—namely, chlorides and phosphates of the alkaline and earthy bases—are such as are required for the due maintenance of the blood and the animal solids.

The excrement of the foal appears to contain a good deal of undigested caseine, some fatty matters, doubtless derived from the milk, and substances derived from the biliary secretion of the liver.

The milk in the colt passes into the stomach most probably with but little admixture of the fluids of the mouth and gullet. The first change which it undergoes is that of coagulation, a change which invariably takes place on milk in the healthy stomach of animals throughout life. The coagulation of milk in the stomachs of animals must be regarded as a special effect of the peculiar secretion of the stomach commonly known as the gastric juice. What is commonly called rennet is the fourth stomach of the calf salted and dried. The solution of a small portion of this substance freely coagulates milk. It was taught a few years ago that the sugar of the milk was converted into lactic acid by the rennet, and therefore that the real agent in the coagulation of the milk was the lactic acid. This, however, has been disproved, and no explanation of the effect has as yet been discovered.

Gastric Juice.—The gastric juice, which is the secretion of the inner coat of the stomach after food has been received into its cavity, is an acid fluid, containing a peculiar albuminoid substance, to which the name of pepsine has been applied. An artificial gastric juice may be prepared by heating moderately for some time a portion of the mucous membrane of the stomach with a very dilute solution of hydrochloric acid. Such a solution, if kept at a temperature of 100° F., will in the course of six or eight hours dissolve muscular fibre, boiled eggs, and albuminoid substances generally. The solutions so obtained do not coagulate on the application of heat, so that they cannot be regarded as containing perfect albumen. The substance so obtained has been termed incipient albumen, which may be regarded as identical with what has been named albuminose; that is to say, incipient albumen or albuminose may be set down as the nearest approach to albumen which the stomach-digestion is capable of producing out of such proximate principles as caseine, fibrine, and albumen proper. It is supposed that the complete conversion of these aliments into albumen takes place subsequently under the influence of the biliary and pancreatic secretions.

Under the influence, then, of the gastric juice, the caseine of the mare's milk is changed in the stomach of the colt into this incipient albumen or albuminose. In the ordinary language of physiology, it is common to say that the aliment received into the stomach is changed into chyme. It is to be understood, then, that chyme is the heterogeneous mass into which the aliment is changed in the stomach, composed of incipient albumen or albuminose, together with such substances as fat and sugar, more or less altered, but which are to be further altered in ulterior processes, and substances which, as incapable of alteration, are finally to be expelled with the excrement.

The movements of the stomach are subservient to the due application of the gastric juice to the mass of aliment, and finally to the propulsion of the chyme from the right side of the organ into the duodenum or highest part of the small intestines. The gastric juice, being derived from the inner surface of the stomach, is necessarily applied first and principally to the exterior part of the mass, chiefly in the left or great extremity of the stomach. As the exterior parts of the mass at the left side, by the influence of this secretion, are changed more or less perfectly into chyme, they are moved towards the right extremity by a kind of vermicular movement of the muscular coat of the organ, so as to give place to an inner layer of the mass, and it appears in the mean time to undergo a kind of circulation, so that the interior parts are in succession brought into contact with the secreting surface of the inner coat. In this manner the whole mass is gradually formed into chyme, and then expelled by a more powerful movement into the duodenum, the resistance of the pyloric valve being overcome.

Intestines in the Horse.—It was already said that the intestines of the horse, as being a purely vegetable feeder, are of extreme length (p. 5). The intestines of the horse are about ninety feet long, or between eight and nine times the length of his body. The great intestines make but a small part of this great length. The duodenum, the jejunum, and the ilium are the three divisions of the small intestines; while the cæcum, the colon, and the rectum are the three parts of the great intestines. The coats of the intestines are three, as in the stomach—namely, an exterior serous derived from the peritoneum; a middle muscular, composed of both circular and longitudinal fibres; and the internal mucous. As before noticed (p. 36), while the peritoneum or serous lining membrane of the abdominal cavity affords an outer covering to the intestines, it also forms the remarkable folds between the laminæ of which the vessels and nerves of the intestines are supported, and by which the intestines, some in a much less degree, others in a greater degree, are retained in their place. There are certain parts of the intestines that are less completely covered by the peritoneal coat than the rest—namely, the duodenum, the cæcum, and the rectum; and these several parts have a more fixed position than the other parts in general. This will be easily understood by a familiar comparison. The intestines, generally, are like the arm placed in a sling hung from the neck, the handkerchief enveloping the whole circumference of the arm; but the less covered and more fixed parts of the intestines resemble the arm bound close to the side by a handkerchief passed tightly round the body.

The duodenum is more capacious than the two other divisions of the small intestines, though much shorter, and yet its length is greater than its name denotes. The name signifies 12 inches long, bearing reference to the same gut in man; in the horse the duodenum is about 24 inches long. It begins in the pylorus at the right extremity of the stomach. It makes a turn round the head of the pancreas, having the liver before, and the great arch of the colon behind. At the concave part of the liver it makes a sudden turn upwards and to the right, and obtains an attachment to the right kidney; it then crosses the spine between the roots of the mesentery and the meso-colon to the left side, where it forms the commencement of the jejunum. About six inches from the pyloric orifice it receives at the same point the pancreatic and hepatic ducts. The jejunum is extremely tortuous, and being attached only to the mesentery, is permitted to float loosely within the cavity. There is no distinct line of division between the jejunum and the ilium, the part named the ilium being one-fifth longer than that named the jejunum. From the beginning of the duodenum to the lower end of the ilium, there is a slight but gradual tapering of the canal. The small intestines are estimated to contain about eleven gallons of fluid. The small intestine terminates in the side of the great intestine at a right angle, and the part of the great intestine which forms the spur at the point of entrance is that which is termed cæcum, or the blind gut—that is, because it leads to no other cavity but its own. The spur or projection which forms the cæcum is between two and three feet in length in the horse.

The cæcum of the horse has no appendix vermiformis like what is known in human anatomy. Its capacity is estimated at four gallons. Its contents after death are generally found to be fluid.

At the junction of the ilium with the great intestine there is a valve termed the ilio-colic valve. It appears to be formed by a doubling of the mucous coat, in the fold of which muscular fibres are contained. It has a half-moon shape.

The cæcum occupies the right side of the abdomen, and appears immediately on opening the cavity of the peritoneum. Commencing from the colon and ilium in the right iliac region, it extends forward towards the right side, with its pocket-like part applied towards the diaphragm and liver, near the ensiform cartilage. It is sometimes said that the ilium in the horse enters the cæcum only. This statement refers to what is sometimes regarded as the rudiment of a second cæcum, a kind of elbow of the great intestine, between which and the cæcum proper the ilium is inserted, the colon being represented as arising from this rudimentary cæcum. The colon, then, at its junction with this rudimentary cæcum, is narrowed, but immediately enlarges into a capacious canal. It makes nearly the circuit of the abdomen, and is again contracted in a slighter degree. It then once more enlarges, and again passes round the abdomen, when, lessening a third time, it ends in the rectum. The colon is distinguished from the small intestines not only by its greater size in the chief part of its course, but also by longitudinal bands, namely, three distinct in the first part of its course, two in the latter part. These bands contract the colon into cells which are deep and capacious in the first part of its course, shallower as the rectum is approached.

The rectum is more capacious in its posterior than in its anterior extremity. It exhibits no longitudinal muscular bands like the colon, yet is highly muscular throughout. Its posterior extremity is furnished with a circular muscle or sphincter, which is cushioned in fat so as to give the well-known prominence to the anus in the living animal. The peculiarity of this sphincter muscle, and of other sphincter muscles, is that their fibres are constantly in a state of contraction till overcome by some power occasionally made to antagonise them.

The intestines are freely supplied with blood. From the inferior surface of the posterior aorta, two mesenteric arteries come off, the anterior or great mesenteric, and the posterior or smaller mesenteric artery. From these vessels branches proceed between the laminæ of the mesentery, meso-colon, and meso-rectum, to supply the coats of the intestines. Two corresponding veins, the posterior and anterior mesenteric veins, unite with the other veins coming from the chylopoetic viscera to form the portal vein.

The nerves of the intestines are derived from the anterior mesenteric plexus, the posterior mesenteric plexus, and the hypogastric plexus, all coming from the splanchnic nerves of the sympathetic system. Like the blood-vessels, the nerves reach the coats of the intestines between the folds of the mesentery, the meso-colon, and meso-rectum.

Between the laminæ of the mesentery in particular are lodged the lacteal and lymphatic vessels, and the glands connected with these, which take so remarkable a share in the function of nutrition.

The principal trunk of the absorbent system, termed the thoracic duct, runs forward along the spine to terminate in the left subclavian vein. This trunk, the thoracic duct, is formed by the union of five or six vessels, two or three of which come from and through the pelvis, two or three from the mesentery, and a single one from the environs of the stomach and liver. The vessels which convey the chyle from the small intestines to the mesenteric glands, and thence to the thoracic duct, are regarded as being of exactly the same structure, and even as performing the same function—except soon after food has been taken into the stomach—as the general system of lymphatic vessels spread over the living frame. That is to say, the lacteal vessels, except when chyle is to be conveyed from the intestines, are merely lymphatic-absorbent vessels. Moreover, the mesenteric glands, through which the lacteal vessels pass, appear to be of exactly the same character as what are called the conglobate glands, everywhere connected with the lymphatic system. To this subject, however, reference must be made hereafter.

The liver, and pancreas or sweetbread, produce each a distinct secretion which mingles with the chyme received by the duodenum from the stomach, so that these organs are beyond question chylopoetic viscera. The spleen is, with less certainty, ranked in the same order of organs; nevertheless, as there are many strong reasons why it should be regarded as analogous in its function to that of the mesenteric glands—that is to say, that it is not a conglomerate gland, like the liver, but a conglobate gland—it is in the mean time taken along with the chylopoetic organs.

Liver.—The liver is a large organ placed in the right hypochondrium, whence it extends into the epigastrium, and even into the left hypochondrium. Its right lobe or division is in contact with the diaphragm, the duodenum, and the right kidney, and the middle and left divisions with the stomach. It is irregular in its shape, and composed of a peculiar brown substance: it is confined in its proper situation by means of ligaments, which with one or two exceptions are doublings of the peritoneum, or serous membrane lining the abdominal cavity. The right ligament attaches the right lobe to the diaphragm; the left ligament, the left lobe to the same organ; the suspensory ligament connects the middle lobe with the diaphragm; and the name coronary ligament is given to a ligament lying above the suspensory in the same line of direction. Between the laminæ of the suspensory ligament the remains of the umbilical cord, changed into a ligament, pass from the navel to the right lobe. The liver in the horse has properly but two lobes, or it is less distinctly divided than the liver in man. In the horse there is no gall-bladder, but in lieu of it there is a large dilatation of the hepatic duct at its origin.

The liver is covered, with very slight exceptions, by the peritoneum reflected upon it from the abdominal cavity, under the form of the ligaments just enumerated. Beneath the serous coat there is a fibrous coat which becomes continuous with the capsule, which, under the name of the capsule of Glisson, runs throughout the substance of the liver to connect the several parts of its structure together. The substance is of a brown colour and mottled aspect, compact, but not very firm. When this substance is torn, the broken surface is not smooth, but minutely granular, owing to its being composed of a multitude of small masses termed lobules. These are closely packed, about the size of a pin's head, and held together either by a fine areolar tissue, or merely by the blood-vessels and ducts. The relation of these lobules to the blood-vessels of the liver is very remarkable. There are, it will be remembered, three kinds of blood-vessels in the liver—namely, the ramifications of the portal vein, which is a trunk formed from the veins of the stomach, spleen, pancreas, and intestines; the ramifications of the hepatic artery derived from the cœliac axis of the posterior aorta; and the ramifications of the hepatic vein or veins (for there are usually two or three trunks), which end behind the liver in the great hollow vein (*vena cava*) of the abdomen. The ramifications of the last-mentioned vessels, the hepatic veins, follow a course in the liver different from that taken by the ramifications of the hepatic artery and the ramifications of the portal vein. The trunk of the hepatic artery and the trunk of the portal vein are seen entering the liver on its concave surface at the same point where the trunk of the hepatic duct comes forth. The nerves of the liver enter at the same point, and the lymphatic vessels come out from the organ there. All these several vessels, nerves, and duct, are here surrounded by a sheath of areolar tissue, named the capsule of Glisson, which is continuous with the fibrous covering of the liver, and which proceeds into the interior of the liver, constituting a canal ramified along with the ramifications of the vessels, nerves, and ducts so as to form what are named the portal canals, spread everywhere throughout the liver, coextensively with the vessels and ducts. Thus, of the five kinds of vessels found in the liver—namely, the hepatic artery, the portal vein, the hepatic duct, the lymphatic vessels, and the hepatic veins—the last alone are excluded from the portal canal formed by the capsule of Glisson. These last vessels—namely, the hepatic veins, two or three in number—are very large veins, as their name in human anatomy indicates; for they are called the *venæ cavæ hepaticæ,* not because they end in the vena cava of the abdomen, but because of their great size. Their great size requires explanation; for while it is a rule of the animal system that systemic veins are much larger than the corresponding arteries, it is remarked that this rule is less exemplified in the case of secreting organs than in parts which do not secrete, and therefore that it might be expected that in the instance of a gland supplying so large a secretion as the bile, the veins would little exceed the corresponding artery in size. The great size of the hepatic veins is owing to the peculiarity of the circulation in the liver; for these veins have two distinct supplies of blood, one from the hepatic artery, the other from the portal vein, while the blood from both these sources has no other channel for return to the general vascular system but the hepatic veins. Thus the trunks of the hepatic veins, as they enter the abdominal vena cava, correspond not merely to the hepatic artery, but to all the arterial trunks which supply arterial blood to the chylopoetic viscera, namely, the gastric, the splenic, the anterior mesenteric, the posterior mesenteric. But it is believed now, that within the substance of the liver the blood of the hepatic artery, after nourishing the several component textures of the liver by its minute ramifications, is collected by a small set of veins which pour their blood into the minute divisions of the portal vein as these are about to secrete the bile; so that the blood which nourishes the liver contributes, like the blood of the other chylopoetic viscera, to the secretion of the bile. It may be remarked that while the arteries are commonly given off from the trunks in pairs, there are in the abdominal aorta three remarkable azygous arteries — that is, arteries without corresponding fellows—namely, the cœliac axis, the anterior mesenteric, and the posterior mesenteric; and that these three azygous arteries are wholly spent upon the chylopoetic viscera, including the liver; and further, that the *venœ cavœ hepaticœ*, or great veins of the liver, correspond to these three azygous arteries in the sense that these veins return to the abdominal vena cava the blood which had been carried out from the aorta by these three arteries.

But to return to the mode in which the blood-vessels of the liver are connected with the pin-head lobules of the organ. It is remarked that the base of each lobule rests on a small venous trunk, and that a minute vein descends from the body of the lobule through the middle of its base to join this minute trunk. This minute trunk and its branch are radicles of the hepatic veins. These minute trunks on which the pin-head lobules rest gradually unite into larger veins which pursue an independent course, and finally form the large veins which join the abdominal vena cava just behind the diaphragm. When a portal canal, however minute, is cut across, it is observed to contain a twig of the hepatic artery, a larger twig of the portal vein, and a minute branch of the hepatic duct—the hepatic artery especially ramifies on the ducts—and, finally, from its capillaries arise a minute set of branches corresponding to veins, which communicate with the ramifications of the portal vein. These ramifications of the portal vein proceed between the pin-head lobules, and at last penetrate the lobules, and end in capillaries from which the minute vein already spoken of returns the residue of the blood after secretion to the small trunk of the hepatic vein on which the pin-head lobule rests. Minute branches of the hepatic duct arise from each pin-head lobule, conveying away the secretion. The pin-head lobules are filled with hepatic cells, which are of the kind called nucleated cells, the medium diameter of which does not exceed the thousandth part of an inch. The mode in which these cells are concerned in the production of the secretion is still far from being agreed on.

It does not appear that the bile in the horse has been made a special subject of investigation. Yet it does not seem that there is any very essential difference in the bile of mammals in general. This secretion may be regarded as a species of soap, formed by the combination of two peculiar resinoid acids with soda. Both these acids—namely, the glycocholic and taurocholic—contain nitrogen. The taurocholic also contains sulphur, from which the glycocholic is free. In bile, also, there is a peculiar colouring matter known usually as biliverdine. There are also found cholesterine and a small amount of stearic, oleic, and lactic acids, united with potash and ammonia. There is no saccharine matter in the bile, nevertheless the liver appears to have the power to convert some other proximate principles into sugar. It has long been believed that, besides affording a secretion of paramount importance in digestion, the liver, in some other manner, contributed largely to the maintenance of the animal economy in a healthy state. These views have of late taken a more definite form. Thus it is taught, that substances absorbed from the alimentary canal, and brought with the blood of the portal vein into the liver, there undergo important changes before being thrown into the general course of the circulation. This is held to be particularly the case with incipient albumen or albuminose. The proof of this, with respect to albuminose, is, that if it be injected into the jugular vein, it speedily appears in the urine, whereas, if injected into the portal vein, so as to be allowed to traverse the liver, it is no longer ejected as a foreign substance, but appears to become incorporated with the albuminous part of the blood.

With respect to the formation of sugar in the liver, a great diversity of views prevails. In the mean time, however, the liver may be considered as an organ destined to produce two kinds of secretion—namely, bile and sugar. The bile, being chiefly excrementitious—that is, fitted to separate something from the blood, the retention of which would prove noxious—passes along the bile-ducts into the intestines, where it may be subservient to some purpose connected with digestion, and being afterwards in part absorbed, is finally eliminated during the production of animal heat. The sugar being soluble may be supposed to be taken up by the blood of the hepatic veins and conveyed through the right side of the heart to the lungs, where, being consumed in the respiratory process, it contributes to the generation of animal heat.

The quantity of bile secreted daily by the liver is very great, amounting to several pounds weight; and since but a small proportion of decomposed bile is found in the excrement, it follows that a great part of the bile, or of its chemical constituents, must be re-absorbed after it has been poured into the duodenum.

Pancreas or Sweetbread.—The pancreas lies across the spine in the curvature of the duodenum, and in the epigastric region (fig. 5). In its structure it resembles the salivary glands, and its secretion has a great resemblance to saliva. It consists of a head or right large extremity, a body, and tail. A portion of the gland, sometimes marked off from the rest, is called the lesser pancreas. The peritoneum merely passes over the pancreas without affording it a distinct coat. It is abundantly supplied with blood-vessels, nerves, and lymphatics, from the same sources as the adjacent organs. It consists of numerous lobes and lobules of various sizes, held together by areolar tissue, blood-vessels, and ducts. The principal excretory duct runs through the entire length of the gland from left to right. As the duct advances towards the head of the pancreas, it receives a duct from the lesser pancreas, and finally joins with the hepatic duct to enter the duodenum together.

The pancreatic juice is colourless, transparent, and slightly viscid. When fresh, it is alkaline, and is said to contain a peculiar animal matter, termed *pancreatine*, and salts similar to those found in saliva, except that no trace of sulphocyanogen has been discovered.

Starch appears to be acted on by the pancreatic juice even more powerfully than by the saliva. It appears that the raw starch granules which resist the action of the gastric juice are dissolved in the duodenum; the bile does not appear to be capable of such an effect, so that it must be attributed to the pancreatic juice. This juice also seems to emulsify the fat. Some doubt still exists on the question whether the pancreatic juice can dissolve albuminous substances.

Spleen or Milt.—The spleen is a spongy organ very full of blood, covered with a peritoneal coat, and of a mottled blue or purplish grey colour. It seldom exceeds three pounds in weight. In the horse it has a pyramidal form ending in a point. It has no excretory duct. It is largely provided with blood-vessels, nerves, and lymphatics. The spleen has a proper coat beneath the external peritoneal covering. This internal coat, the proper tunic, is thicker and stronger than the serous coat, and covers the entire surface of the organ. It is of a whitish colour, and consists of interlaced fasciculi of areolar tissue, mixed with a fine elastic substance. In addition to these there are pale soft fibres having the appearance of unstriped muscular fibres. The proper tunic cannot be detached from the spleen, because prolongations pass from it into the substance of the organ. This coat also, at the *hilum* or point where the vessels enter and issue, is reflected inwards, forming elastic sheaths or canals in which the large blood-vessels and nerves, and their chief branches, are supported. A number of small elastic bands stretch across in every direction between these sheaths and through the intermediate substance of the spleen, which are named *trabeculæ,* or little beams. The inner coat is the origin of all that elastic framework running through the spleen. There is contained in this framework, besides the vessels and nerves, a peculiar red pulpy substance with which the tufts or pencils of capillary vessels lie in contact, supported by microscopic trabeculæ running through the pulp in all directions. The pulp itself lies altogether outside the vessels between the branches of the venous plexus. It consists of numerous rounded granular bodies which have a reddish colour, and are about the size of the blood-corpuscles. Their cohesion is very slight, and the terminal tufts of the arterial system spread out amongst them. In the substance of the spleen, elongated caudate corpuscles are seen in considerable numbers. There are also round nucleated cells and free nuclei. Besides which there are large cells, some of which are nucleated and others not, but both of which contain blood-corpuscles in different conditions. The Malpighian corpuscles of the spleen are white vesicular-looking bodies, varying in diameter from 1-35th to 1-60th of an inch, and consisting of two coats, the external continuous, as it would seem, with the trabecular tissue supporting the arteries. A soft white semi-fluid matter fills them ; this contains microscopic globules resembling, with the exception of colour, the corpuscles composing the red pulp of the spleen. Both much resemble chyle-corpuscles.

The lymphatics of the spleen are a superficial and a deep set. The superficial set run under the serous coat towards the hilum. The deep lymphatics accompany the blood-vessels, and proceed from the hilum along the gastro-splenic omentum to the neighbouring lymphatic glands.

Villi of the Intestines.—The villi are confined exclusively to the mucous membrane of the small intestine. They are minute vascular processes less than a line in length, covering the surface of the mucous membrane (in the human body) in the proportion of about twenty-five to every square line, whence they give to the mucous surface a peculiar velvety fleecy appearance. When empty they are flat and pointed at their summits; when full of chyle they are cylindrical. At the base of each villus one or more lacteal vessels enter, which pass up the middle and reach near to the tip, to terminate in a somewhat dilated extremity without any perforation or open extremity. Two or more small arteries are spread within each villus, and from their capillaries proceed, through the base of the villus, one or two minute veins. A thin layer of organic muscular fibres forms a kind of hollow cone around the central lacteal, and is therefore situated beneath the blood-vessels and much of the granular basis of the villus. This muscular cone is continuous with a layer of organic muscular fibres situated within the mucous membrane of the intestine. No nervous twigs have been found within the villi. Each villus, being a process of the mucous membrane, has an investing basement membrane, the outer surface of which is covered with a layer of cylindrical epithelium.

Duodenal Digestion.—The chyme, or partially changed mass which passes by the pyloric orifice from the stomach into the duodenum or highest part of the small intestines, is destined to undergo important changes before it is fit to afford the chyle to the intestinal villi. The bile, the pancreatic juice, and the peculiar secretion of the glands of the duodenal mucous membrane, are the agents by which such changes are to be effected. It was formerly believed that nothing derived from the food capable of nourishing the living frame, found its way into the blood by any other channel than the lacteal vessels. It is now, however, held to be well established, that the blood-vessels, and, in particular, the capillary network of blood-vessels, freely absorb fluid or gaseous bodies, or even solid matter soluble in the blood, when brought into contact with their walls. Hence it follows that all such bodies contained in the food, or formed during the processes of gastric or duodenal digestion, as are soluble in the blood, may be freely absorbed into the blood independently of the lacteal absorption. Even oil, when minutely divided, as in emulsion, will pass slowly into the blood-vessels. The process termed endosmosis before referred to (p. 47) has a large share in such absorption, and hence it is observed that the amount of absorption in this manner is great in proportion as the fluid is of small density.

Absorption of Nutriment.—Though the subject of the absorption of certain soluble substances by the capillary blood-vessels of the mucous membrane of the stomach and small intestines, during the progress of digestion, be as yet far from existing in a state complete for description, yet, even as it stands, it deserves a close attention.

The proximate principles which have chiefly drawn notice under this point of view have been termed carbo-hydrates, such as celluline or cellulose, gum, starch, and the several forms of sugar. Celluline, the principle which, with lignine or woody fibre, constitutes the vegetable cell, has hitherto been considered as capable of resisting the action of all the digestive fluids and other solvents; so that the whole of the vegetable substances which essentially consist of it have been held to reappear unchanged in the excrements of herbivorous and omnivorous animals. There is reason to think that, at least in some animals, as in the beaver, celluline undergoes solution in the lower part of the intestines, where the secretions acquire an alkaline character. The effect of alkaline secretions on celluline is probably to convert it into starch—of which hereafter.

Gum.—Among the older authorities on dietetics and on therapeutics gum was held an important article of food, and also a valuable demulcent, even in those canals of the living body to which fluid has access only by secretion from the blood. Modern chemistry, in the mean time, contradicts this belief, denying that gum can either directly enter the blood from the alimentary canal, or that it is there convertible into any soluble principle, by the change into which it might gain access to the blood. Thus, if the present views of chemists rest on sure grounds, the gum received into the stomach, notwithstanding its great solubility, must almost wholly pass unchanged with the excrement.

Starch.—Starch is by far the most important of the carbohydrates under consideration. As already noticed (p. 65), starch is acted on powerfully by the saliva and by the pancreatic juice. It is now long since Magendie showed that, while neither the parotid nor the submaxillary saliva exerts any action on starch, the common or the mixed saliva of the horse converts both crude and boiled starch into sugar at the temperature of the animal body. And it is now acknowledged by most physiologists that the pancreatic juice possesses this power of transmuting starch into sugar in a far higher degree than the mixed saliva. It seems established that the gastric juice exerts no such effect on starch; and authorities are still divided on the question whether the intestinal juice below the duodenum possesses the property of changing starch into sugar. This change of starch into sugar is believed to take place by the influence of an azotised ferment contained in the fluids just referred to, by which the starch is converted first into dextrine (the substance so long known as British gum) and then into sugar. Thus, as respects starch, digestion goes on in the following manner:—As the food remains but a short time in the mouth, little more can be accomplished there beyond the free admixture of the mixed saliva with the mass of food, whence the greater part of the starch passes unchanged into the stomach. In so far as the gastric juice is applied to the mass of aliment, the process of the conversion of starch is suspended—that is, this process is postponed at the outer surface of the mass which is immediately acted on by the gastric juice; but in the interior parts of the mass, to which the gastric juice does not at once gain access, the starchy parts thereof for a time are left to the undisturbed operation of the saliva imbibed by it in the mouth. Doubtless, however, much of the starch escapes this change in the stomach, as the process is suspended as soon as the gastric juice gains access to its particles. But after the due sojourn in the stomach, what remains of the starch comes into the duodendum, and is there brought into contact with the powerfully acting pancreatic juice, when the metamorphosis commences anew. In the ilium the pancreatic juice disappears, and in its stead the intestinal juice, as alleged by many, continues the same action in a less energetic manner. The starch granules soften on their surface, and, while they dissolve, become changed to dextrine and then into sugar. Lamellæ separate from the granules in a greater or less state of disintegration, isolated shreds being often perceptible by the microscope after the application of iodine. The farther the starch descends in the intestine, the smaller do the granules appear, in consequence of this gradual solution of their surface. The dextrine first formed is so rapidly changed into sugar that it is rarely found in the intestines. Thus the greater part of the starch contained in the food finds its way into the blood, not by the lacteal vessels, but by direct absorption into the capillaries of the intestinal mucous membrane, whence it passes into the radicles of the portal vein to be transmitted through the liver. Some part of the starch contained in the aliment passes, even in the small intestine, into lactic acid, and in the lower portions of the small intestine, and particularly in the great intestine, into butyric acid; and under these forms it is even more rapidly absorbed into the blood than when changed into sugar. It appears that nearly the same rules as to the absorption of saccharine matter prevail, whether it be formed from starch within the alimentary canal, or introduced as an integral part of the aliment under the forms of glucose or grape-sugar, sucrose or cane-sugar, or sugar-of-milk.

Vegetable mucus or bassorine, and vegetable jelly or pectine, are said, like gum, to be totally unaffected by the digestive fluids.

Oil or Fat.—With respect to the digestion of oil or fat, difficulties present themselves. No material changes take place on oil either in the mouth or in the stomach, for both the saliva and the gastric juice are devoid of any effect, either mechanical or chemical, on this principle. It is agreed, then, that the digestion of oil commences in the duodenum. There the oil ceases to appear in large drops or in semi-fluid masses, and takes on the form of minute drops. The farther it descends in the small intestine so much the more minute do these drops become, so that at length the oil becomes finely comminuted, and the chyme presents an emulsive appearance. Since the lacteals are seen to be distended with white oily chyle after the use of oily food, it cannot be doubted that the principal channel by which the oil makes its way into the blood is by lacteal absorbent vessels in the intestinal walls. It has been taught that there are special cells in each of the villi solely charged with the absorption of oil; and while it is certain that oil makes its way to the blood chiefly by the lacteal absorbents, it is undeniable that the capillary blood-vessels of the intestinal mucous membrane also take up oil, though in less considerable quantities. This latter fact is confirmed by the manifest augmentation of oil in the portal blood of animals a few hours after they have been fed—a fact which cannot be explained by the assumption of a conversion of carbo-hydrates into oil during their passage from the intestinal cavity into the portal vein. It is, however, maintained on high authority that there is a direct transmission of oil into the blood of the capillaries from the epithelial cells and the parenchyma of the villi.

Proteine Compounds.—The course of the subject of digestion leads now to the azotised proximate principles or plastic principles. These are the albuminoid group, called also of late the proteine principles, namely, albumen, caseine, fibrine. The name *peptones* has been applied by some authorities to albumen, fibrine, and caseine, after the metamorphosis which they undergo in the stomach under the influence of the gastric juice. These peptones then, it is conceived, undergo absorption, and are in the lacteal system reconverted into the well-known plastic substances, namely, albumen, fibrine, caseine. It is maintained that the gastric juice is not of itself sufficient for the conversion of these proteine bodies into nutritive matter, and that the intestinal juice possesses, in a very high degree, the property of preparing them for absorption. It appears to be only in the upper part of the small intestine in which such changes are effectually produced, or in that tract of the intestinal canal where true villi exist. These several substances, then, undergo such a change as permits them to be absorbed by the intestinal villi, and, as it would appear, they are absorbed by the intestinal villi because they cannot pass through the walls of the capillary blood-vessels of the intestinal mucous membrane.

Chyle.—The fluid contained in the lacteals, during fasting, is clear and transparent, differing in no respect from ordinary lymph; but while absorption is going on by the villi acting on the chyme contained in the intestinal canal, that fluid becomes milky, and acquires the other characters assigned to chyle. The whiteness and opacity of the chyle appears to be dependent on the presence of innumerable particles of oily or fatty matter, of very minute size, and yet nearly uniform in that respect, and said to measure nearly the 30,000th part of an inch in diameter. These constitute what has been called the molecular base of the chyle. Their number, and by consequence the opacity of the chyle, varies with the quantity of oily or fatty matter contained in the food. The fatty nature of these molecules is proved by their solubility in ether, after the evaporation of which various-sized drops of oil are deposited. It has been remarked that these drops do not run together to form large drops, as commonly happens to particles of oil. It has hence been concluded that each molecule is coated over with albumen, as happens when minute drops of oil are set free in an albuminous solution. It is a confirmation of this supposition that when water or acetic acid is added to chyle, a number of the molecules is lost sight of, owing, as it would seem, to the investments of the molecules being dissolved, so that they are permitted to run together.

The chyle taken from the villi, or from the lacteals near them, exhibits no other solid bodies but these fatty molecules. The fluid, indeed, in which they float is albuminous; it does not coagulate spontaneously, yet on the addition of ether a coagulum forms. The chyle, however, which has been collected near the thoracic duct, after it has passed through one or more of the mesenteric glands, is found to be much elaborated. There is now a smaller proportion of oily molecules; cells, to which the name of chyle-corpuscles is given, are observed in it; and apparently, owing to the presence of fibrine, the fluid coagulates spontaneously on being allowed to rest. The higher the point in the thoracic duct from which the chyle is collected, the more developed is this new character—that is to say, the larger is the proportion of chyle-corpuscles, and the firmer the clot which forms when the fluid is left at rest. This clot is not unlike the clot of coagulated blood without the red corpuscles—the chyle-corpuscles are entangled in it, and the fatty particles form a creamy film on the surface of the serum. The chyle clot is, however, soft and moist compared with the blood clot. It resembles the blood in this respect, that, within the lacteal vessels, or the thoracic duct, it may remain a long time uncoagulated, like the blood in the blood-vessels, but that when drawn off it quickly concretes. The presence of fibrine in this elaborated chyle can hardly be doubted, while the increase of this proximate principle appears to take place in the like proportion with the multiplication of the chyle-corpuscles. Like the chyle-corpuscles the fibrine is not absorbed as such from the chyme, there being no fibrine in the chyle of the villi, but it appears to be gradually elaborated out of the albumen or albuminoid matter which chyle in its earliest form contains.

The chyle-corpuscles are conceived to be the early stage of the red corpuscles of the blood. They are circular, and nearly spherical in figure—about 1-250th of an inch in diameter, and with a tuberculated surface. They appear to be nucleated cells, the nuclei of which are soft granular or tuberculated masses filling the cavities of the cells. These chyle-corpuscles do not differ from the lymph-corpuscles and the white corpuscles of the blood. And it begins now to be a prevailing opinion that these corpuscles, the rudiments of the red corpuscles of the blood, are chiefly derived from the conglobate or absorbent glands (the same which are now called lacteal and lymphatic ganglia). Moreover, it seems not unlikely that the spleen joins in this office, and that lymph or chyle corpuscles issue from the spleen, not by the veins, but by the lymphatic vessels of that organ. The fibrine of the chyle, according to some authorities, is also elaborated in the same glands.

Lymph.—It thus appears that the lymph of the lymphatic vessels concurs with the chyle in the renovation of the blood. What, then, is the source of the lymph? The answer to this question is hardly agreed upon among physiologists. The lymph agrees very closely in composition with the blood, with the exception of the red corpuscles. The blood is usually considered at present as consisting of two principal parts, namely, the liquor sanguinis, or blood-plasma, and the red corpuscles. Now the lymph corresponds very closely in composition with the blood-plasma. Both consist of fibrine, albumen, white corpuscles, and saline substances. But in the process of nutrition, the blood-plasma is believed to exude from the capillary network of blood-vessels, while the adjacent tissues standing in need of repair absorb from this liquor sanguinis, or blood-plasma, the materials of which they stand in need.

But it does not follow that the whole of the blood-plasma poured forth in any one region of the living fabric should be exhausted in the process of nutrition or assimilation there carried on. So much fibrine, so much albumen, so much saline matter are withdrawn from a given amount of blood-plasma, but what becomes of the residue? What more likely than that, being absorbed by the radicles of the lymphatic system, it is conveyed back to be again applied to use in reinforcing the circulating blood? The near correspondence between the composition of the lymph and that of the blood-plasma, is a strong evidence in favour of this view.

Do the products of disintegrated solids nourish?—Another idea not so much in opposition to that just explained as accessary to it, is still dwelt on by some physiologists,* namely, that the substances derived from the unceasing decomposition of the solids in the several acts of life are new-modelled by the radicles of the lymphatics, and carried back by them to aid a second time in recruiting the blood. This is a remnant of the Hunterian doctrine of interstitial absorption, which Hunter supposed to be performed solely by the agency of the lymphatic vessels. It is an acknowledged principle in physiology that every living part is continually undergoing disintegration during the acts of life in which it is concerned. But this disintegration appears to be complete. Thus, when a muscle contracts, a certain portion of its tissue loses its vitality. But this loss of vitality is not conceived to be mere physiological death, such as has happened to the parts of animals exposed for sale as food in the shambles. It is chemical or absolute death, produced under the influence of oxygen supplied by the red particles of the blood—a death which implies the conversion of the proximate principles of the part so circumstanced into their

* Bennett, 'Outlines of Physiology,' p. 82.

ultimate elements, or into substances composed of those ultimate elements in their mineral capacity, under new forms of combination, such as water, carbonic acid, cyanate of ammonia or urea. If this be the kind of death which portions of the living solids undergo when called into activity, that death or disintegration cannot be the source of supply to the lymphatics, which, besides water and salts, contain only proximate principles of an organic kind, such as fibrine and albumen. It is to be borne in mind that no organic proximate principle is known to be formed from ultimate elements or their compounds in the mineral state within the animal body—that the source of such proximate principles is the process of vegetation in vegetable nature. The utmost that can be accomplished within the animal organism, is the conversion of one proximate principle into another; for example, the change of starch into sugar, or that of albumen into fibrine. When it is affirmed, then, that the lymph of the lymphatic vessels is derived from the disintegration of the living solids all over the body, under the various living acts in which they are severally concerned, it is assumed that the disintegration referred to is not a disintegration or resolution of proximate organic principles into mineral compounds—such as that of albumen and fibrine into water, carbonic acid, and cyanate of ammonia—but either a mere loss of vitality, such as takes place in all the living solids under somatic death—that is, in the death of the individual—or that such disintegration is merely a conversion of certain organic proximate principles into other organic proximate principles, like the assumed conversion of the albumen of the chyle into fibrine, as that fluid ascends higher in the thoracic duct.

It must be admitted that the ideas here placed in contrast are still of a speculative stamp; but it is nevertheless no waste of time to debate them, for until it is settled on which side the truth lies, there remains a great gap in the description of animal nutrition.

As the food received into the stomach consists of proximate organic principles, quite analogous to or rather identical with the proximate organic principles that constitute the solids of the living animal fabric, it seems, on a superficial consideration, the mere pursuit of a close analogy to assume, that as dead organic substance from without is undeniably a source of nutrition, so disintegrated organic matter from within should be a second source of nutrition. But here the death which indeed inevitably follows on the mere plucking of a flower is not distinguished from the complete chemical death exemplified in its final rotting.

> "When I have plucked the rose;
> I cannot give it vital growth again,
> It needs must wither."

So the grass made into hay withers; but the proximate organic principles of which it consists still retain their composition, until such complete chemical death, resolving them into the pure mineral substances, takes place, as when it rots in the dunghill.

It is not necessary for the present object to determine whether it be impossible for the chemist to succeed hereafter in producing from mineral nature compounds equivalent as food in the animal world to albumen, fibrine, and the like; it is plain that organic compounds do not owe their fitness for the food of animals to any remains of vitality in them, since their nutritive virtue is, for the most part, not impaired, but improved by processes so destructive of vitality as those of cookery. The necessity, then, for organic products to constitute the food of animals may lie merely in the near coincidence between the chemical composition of such products and that of those materials which are in demand for the due maintenance of the constitution of the blood and of the solids, and may not be at all an absolute necessity.

The supposed analogy above referred to between the supply of nourishment from without, and its supply from the disintegration of the living solids, is neither improved nor impaired, whichever necessity is assumed—that is, whether the necessity for organic products as the food of animals be contingent or absolute.

Excretion of Urea.—The quantity of urea excreted in a given time along with the secretion of the kidneys, is the principal criterion of the amount of the living animal solids which in the same period has undergone complete disintegration. Nevertheless, the exact estimate of the quantity of urea thrown off by the kidneys in a given time, does not indicate the absolute amount of disintegration in the solids within that period, because there is reason to think that some part of the nitrogenous principles of the food may undergo decomposition without ever having become a part of the living solids. But the distinction between the blood and the solids may be put aside in the mean time; for it is certain that whatever is taken into the blood from the digestive organs acting normally, is in a certain measure assimilated to the living system for the period under consideration. Thus it is correct to say that the quantity of urea thrown off by the kidneys in a given time indicates the amount of disintegration of the nitrogenous organic principles in the blood and the living solids during that period. Now, it seems certain that this disintegration is uniformly a complete or chemical death —that is, that the products thereof are no longer plastic substances, like fibrine, albumen, and caseine, but either water, carbonic acid, ammonia, or substances capable of being changed into urea. It is commonly assumed that plastic proximate principles or proteine compounds may, by slow combustion in the process of respiration, give rise to animal heat, as in carnivorous animals. If that be the case, it is manifest that the atoms, for example, of albumen cannot, after parting with carbon, remain in any state representative of a proteine compound; or, what is the same thing, that their disintegration must be complete, or such as to deprive them entirely of their organic character. In like manner, if the albumen or fibrine of the muscular tissue be decomposed by the oxygen of the blood into carbonic acid and water, the remainder can no longer represent any form of a plastic or proteine compound; whence it follows that the disintegration of the solids under the action of the oxygen of the blood must be complete or a total death, so that the products of that disintegration can no longer possess nutritive properties.

Thus it appears to be beyond all reasonable doubt that the lymphatic vessels cannot derive nutritive matter from the decomposition of the living solids, and that a proximate principle which has once entered into the composition of a living solid, must pass into the mineral state before its elements can again serve as nourishment to the living body of which it once formed a part.

There is thus a strong probability that the debris of the solids pass into the blood of the veins, and that the lymphatics merely carry back the superfluous blood-plasma after the nutrition of the adjacent solids has been satisfied.

The blood-plasma is free from the vesicular or corpuscular element. In the lymph, however, there are corpuscles. Whence then are these derived? To furnish these appears to be the function of the lymphatic glands or lymphatic ganglia (also called conglobate glands), through one or more of which the lymphatic vessels, with hardly an exception, pass before reaching the great trunks. These corpuscles, derived from the conglobate glands, seem to be the rudiments of the blood-corpuscles, and to be identical with the chyle-corpuscles, and with the white corpuscles of the blood.

The lymphatic vessels arise either by radicles or distinct plexuses; but there is no reason to believe in the existence anywhere of open mouths; thus, whatever passes into the lymphatics must pass by transudation through their coats. It is to be remarked, however, as singular, that the origin-plexuses are everywhere composed of vessels larger than those of the adjacent plexuses of the blood-vessels.

Recapitulation of Nutrition in the Horse.—It becomes now easy to exhibit a condensed view of the process of nutrition. The object is to trace the several steps by which grass, hay, oats, beans, are rendered, in the first place, fit to repair the waste of the blood, and through the blood to supply the place of the continually disintegrated portions of the living solids, particularly the muscular organs of motion during the performance of their functions. The several organs in which the crude aliment, such as grass, hay, oats, beans, successively undergoes important alterations, are the mouth, the stomach, the duodenum, the jejunum, and ilium, with the aid of the bile and pancreatic juice, the villi of the small intestines, the mesenteric glands, after which the elaborated aliment reaches the blood. It reaches the blood partly by mingling with the blood of the capillary blood-vessels in the mucous membrane of the stomach and small intestines, and partly through the thoracic duct, the common trunk of the lacteal and lymphatic system of vessels. A great part of the blood into which the elaborated aliment is poured passes through the liver, and all of it through the lungs, before it is transmitted through the arterial system to repair the loss of the solids. The capillary blood-vessels are the immediate parts of the vascular system concerned in nutrition. The capillary arteries—

that is to say, the minute vessels into which the arterial branches subdivide — most commonly form a network or plexus, while from the same plexus the capillary veins take their origin. The capillary blood-vessels do not undergo any further division. Though not absolutely of the same calibre even in the same part of the body, they are pretty nearly alike. They have no open mouths, as was formerly supposed. Hence whatever fluid escapes from them exudes through their coats, while whatever has not exuded passes on to the venous capillaries, and returns through veins successively joining into larger and larger branches till it reaches the right side of the heart. The exudation from the capillaries for the purpose of nutrition is the blood-plasma, called the liquor sanguinis — namely, the serum of the blood holding fibrine in solution; while the red corpuscles are retained in the capillaries to be sent back by the veins to the heart.

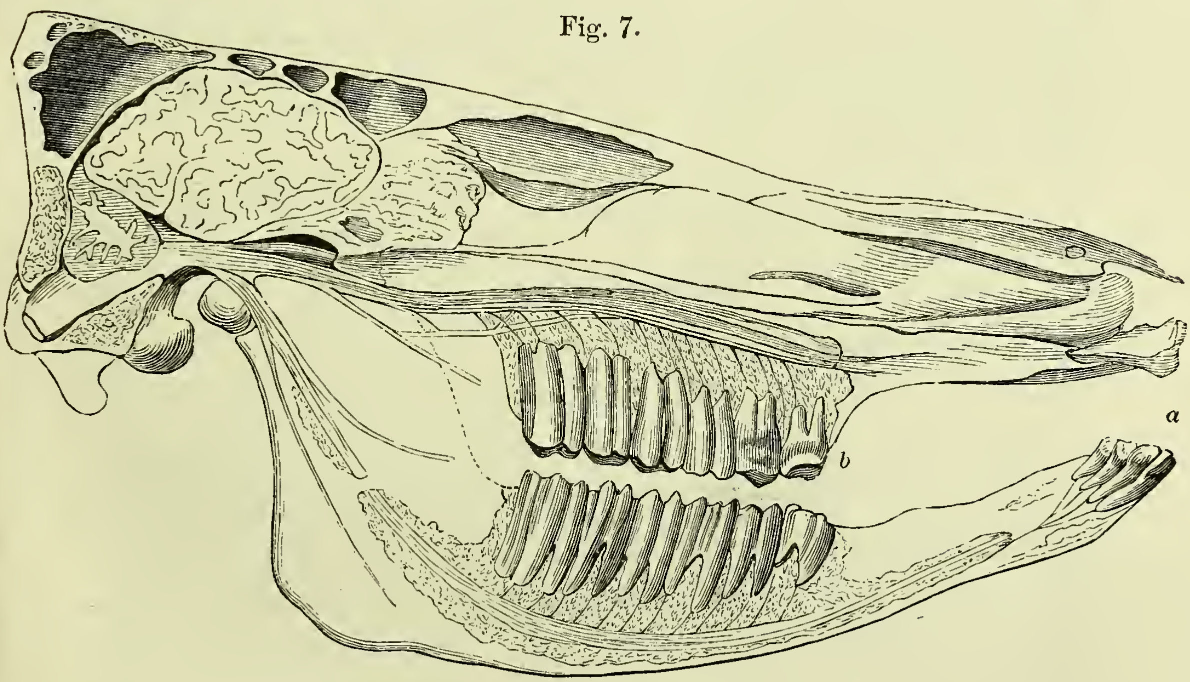
The great law of increment or growth in organic nature is, that assimilable matter being brought into contact with a living texture, that living texture (be it a cell or other form of living tissue) attracts to itself the assimilable material, and undergoes an augmentation. Here the blood-plasma poured forth from the capillary blood-vessels is the assimilable matter. It is in contact with textures of the living frame standing in need of repair. Each living texture attracts to itself from the blood-plasma the materials necessary, in the due proportion and of the due character, to renovate itself after the losses which it has sustained by the disintegration of its own substance in the acts of life assigned to it. A more minute detail of the process of repair is not yet afforded by the progress of animal physiology. It is, nevertheless, strictly in accordance with the law known to pervade all organic nature. Thus the simplest form of nutrition and growth, as in the red snow (an isolated vegetable existence consisting of a single cell), is expressed in the very same terms—there is proto-plasma and a cell. The cell grows by the absorption and elaboration of the proto-plasma. The proto-plasma (called also cytoblastema) corresponds to the blood-plasma (p. 11).

And the same rule applies to sanguification, if the blood-corpuscles are originally vesicular germs secreted by the blood-glands and nourished into maturity by contact with organic proximate principles in the lacteal and lymphatic vessels—subsequently in the blood itself.

ORGANS OF NUTRITION IN THE OX.

The mouth in the ox has the same general character as the mouth in the horse, and includes corresponding parts, as seen in fig. 7.

Fig. 7.



VERTICAL SECTION OF THE HEAD OF AN ADULT OX.

a, Incisor teeth ; *b*, molar teeth. The course of the nerves connected with the teeth is also shown in this figure.

Mouth, Teeth.—Like the horse, the ox has a set of deciduous or milk teeth. This, however, as well as the set of permanent teeth, is less numerous than the corresponding teeth in the horse. For the ox, like all the horned ruminating animals, has no upper incisors to correspond to the upper nippers of the horse. Neither has the ox canine teeth or tushes. In the ox, as in mammals generally, with the exception of man, there is a large space of the jaw destitute of teeth between the incisors or front teeth and the back teeth, called molars or grinding teeth.

The number of teeth in the adult ox is 32—the same as the number of the teeth in man. The teeth of the ox differ in character from the human teeth. The incisors or front teeth, though confined in the ox to the lower jaw, are the same in number as in man. The back teeth or grinding teeth in the ox are more numerous—namely, 24—that is, six on each side of each jaw; while in man there are only 20 molar teeth. The three anterior molar teeth on each side of each jaw in the ox, like the two bicuspid molar teeth in man, are termed the false molar teeth.

The milk or deciduous teeth in the ox are the same in number as the milk-teeth in man—namely, twenty. Of these, eight are incisors, confined to the lower jaw, and twelve are molar—namely, three on each side of each jaw. The permanent dentition in the ox commences considerably before the shedding of the first set begins; thus the first permanent molar comes out in the back part of the mouth from the fourth to the sixth month after birth, while the middle incisors of the first set are only shed from the fourteenth to the twentieth month of the calf's age. The second permanent incisor replaces the corresponding milk incisor from the twenty-eighth to the thirty-second month. In the latter part of the second year the fifth molar, a permanent tooth, appears in the back part of each jaw. In the course of the third year the second molar of the first set gives place to the second permanent molar, which is one of the false molars. In the course of the fourth year the third molar of the first set makes way for the third permanent molar, the farthest back of the false molars; while the third milk incisor gives place, about the same period, to the third permanent incisor. In the latter part of the fourth year, or in the beginning of the fifth year, the sixth molar, on each side of each jaw, makes its appearance—that is, the backmost tooth of all. The teeth which complete the second dentition are the two outer of the eight incisors, which replace the corresponding incisors of the first set before the end of the fifth year.

Each tooth in the ox, as in other common mammals, consists of a crown, a neck, and a fang or fangs.

The substances composing the teeth of the ox are the same as those which enter into the teeth of the horse, and into the teeth of ruminant animals in general—namely, enamel, cement or the petrous crust, and dentine. The arrangement of these several substances in the teeth of the ox so much resembles that already described in the teeth of the horse, that it seems unnecessary to do more here than to refer to what has been said under the head of structure in the teeth of the horse, p. 13. The same may be said of almost all the other important particulars respecting the teeth of the ox.

The bones which form the roof of the mouth are, as in the horse, the intermaxillary bone, the upper jaw-bone, and the palatine plates of the palate-bones. The intermaxillary bone, as in the horse, is behind the upper lip, but does not, as in the horse, exhibit any incisor teeth or any tushes. As in the horse, the intermaxillary is made a pair of bones, under the name of anterior maxillaries. The upper jaw-bone, called also the superior maxillary, is, as in the horse, of great size. It enters into the formation of the orbit of the eye, and into the nose, as well as into the mouth. The extent of its connections is apparent in fig. 7. The palate-bones, as in the horse, form but a small part of the roof of the mouth. These bones are placed at the back part of the palate, and surround the edge of the communication between the back parts of the mouth and the nose.

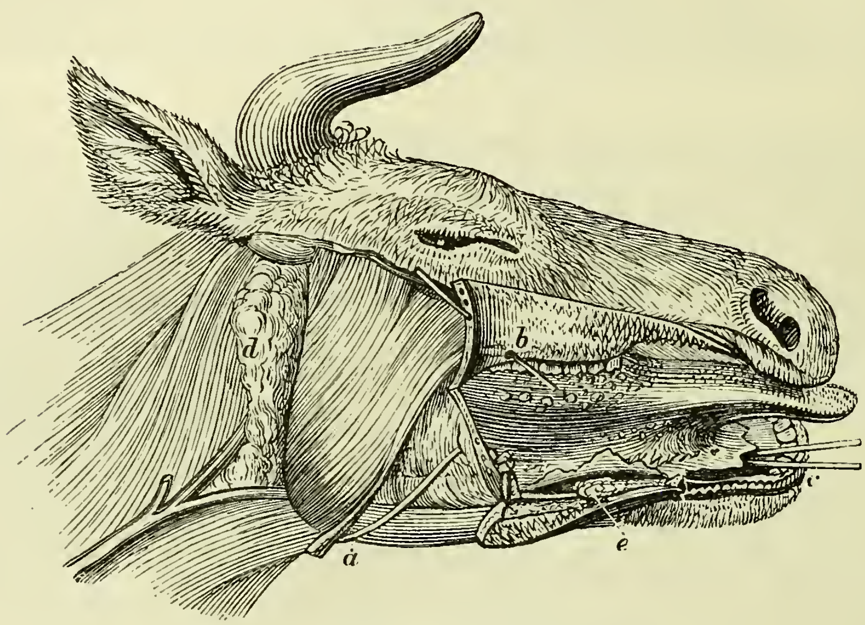
Palate.—The lining of the roof of the mouth is composed of a dense substance, covered with mucous membrane, well known at table as the ox palate. It does not form the prominent ridges termed bars in the horse. The veil of the palate occupies the back part of the mouth. It extends from the crescentic margin of the palatine bones to the fibro-cartilaginous body covering the orifice of the larynx termed epiglottis. This veil of the palate (velum palati) forms a curtain between the cavity of the mouth and the cavities of the nose, by no means so close, however, as in the horse. It differs from the veil of the palate in the human body, chiefly in the absence of the uvula. The veil gives passage to the masticated food backwards to the pharynx, and permits the alimentary mass, after the first steps in digestion, to return to the mouth for rumination. This veil is composed of mucous membrane enclosing muscular fibres.

Tongue.—The tongue occupies the floor of the mouth. It lies between the nearly parallel sides of the lower jaw, and thus has the chief share in filling up the void between these. The surface of the tongue, wherever it is free—that is, not adherent to adjacent parts—is covered by mucous membrane. The substance of the tongue is muscular. Of the muscles which compose the organ, some are confined within its own limits, while others extend to adjacent parts. In the ox, the tongue is covered with a firm membrane, forming innumerable pointed papillæ directed towards the throat. These, like so many tenter-hooks, assist in laying hold of the grass and other kinds of food, and serve, at the same time, to increase the organ of taste. The tongue in the ox is long, and can issue a great way out of the mouth. It can also twist upon itself. It is thus fitted to seize the tuft of grass and bring it between the jaws, in which act the papillæ just mentioned lend important aid.

The hyoid bone has the same general character as in the higher mammals, being shaped like the upsilon (υ) of the Greeks. It was before mentioned that veterinary writers liken it to a spur (p. 20). This form in the horse results from the union of the body and posterior cornua into an arch, from which a long process descends. In the ox, the posterior cornua unite with the body into an arch which, instead of a long process, has a tuberosity in the middle of its inferior part. The anterior cornua have each two pieces of unequal length, the short one being articulated with the styloid process of the temporal bone. The hyoid bone is especially concerned in the act of deglutition. It is connected by muscles with the tongue, the lower jaw, the temporal bone, and the anterior part of the breast-bone. It is a centre of motion, so that when it is drawn upwards and forwards, or in the opposite direction, the adjacent parts are moved. In particular the larynx is drawn towards the jaw, and in the opposite direction, along with the hyoid bone.

Salivary Glands.—The salivary glands, as in the horse, are very large in the ox. These glands have the same names as in the horse—namely, the parotid, the submaxillary, and the sublingual. The parotid is situated in the space between the angle of the lower jaw, the zygomatic arch, and the mastoid process; the submaxillary is placed on the inside of the lower jaw near its angle; and the sublingual is beneath the tongue. The duct of the parotid gland is termed Steno's duct. In man it pierces the buccinator muscle to reach the mouth, while in the ox it passes by the lower edge of the masseter, and then pierces the buccinator to open between the

Fig. 8.



HEAD OF AN OX.

a, Parotid duct; *b*, its opening into the mouth; *c*, entrance of the submaxillary ducts; *d*, parotid gland; *e*, sublingual glands.

second and third upper molar teeth. The duct of the inferior maxillary, which is termed Wharton's duct, opens near the *frenum* of the tongue.

Saliva.—The saliva of the ox does not appear to have been particularly examined; but there is every reason to believe that it conforms to what has been observed in regard to the saliva of the horse. As already noticed, the parotid saliva is limpid and colourless, devoid of smell and taste, incapable of being drawn into threads, and of a distinctly alkaline reaction. The sulphocyanide of potassium appears to be a general constituent in the saliva of the higher animals. The power of converting starch into sugar seems also to be a general property of saliva. In this transmutation ptyalin, the peculiar organic constituent of saliva, is concerned. As before stated, a portion of a salivary gland, or a little dried ptyalin, as well as saliva, rapidly transforms starch into dextrine and grape-sugar (p. 22).

Lips.—The lips in the ox are composed, as in similar animals, of muscular fibres, and areolar tissue, and glandular bodies, covered in part by skin, and more largely by mucous membrane. While the lips are not very prominent in the ox, their distinct muscles are fewer than in the human body. The lips in the ox are not of the same importance as prehensile organs as in the horse. With the tongue the ox seizes the grass, the incisors cut it with an upward motion, and then the lips assist in conveying it to the mouth. The upper lip is short.

Cheeks.—The cheeks are composed of muscular fibres and areolar tissue, enclosed between the internal mucous lining of the mouth and the integuments of the face. The principal muscle, as in other animals, is the alveolo-labialis or buccinator, and this is large. The effect of the muscular contraction of the cheeks is powerfully to diminish the capacity of the cavity of the mouth.

Lower Jaw.—A notice of the action of the lower jaw is required to complete the account of the parts concerned in the changes of the aliment within the mouth. The lower jaw, as compared to that in man, is longer in proportion to the size of the skull, and is destitute of the chin or mental process. The condyles are rounded to permit the free motions of the jaw in the mastication of the food. The lower jaw is comparatively smaller than in the horse. The inferior border is convex; the condyles are double-concave laterally, and convex from before backwards; and the coronoid process turned backwards and outwards. The two lateral branches are never ossified together, even in old animals. The lateral motion of the jaw is very conspicuous in the ox, and may be seen at times to be kept up for long periods without interruption, the mouthful being first masticated on one side and then on the other.

Pharynx and Gullet.—The pharynx and gullet remain for notice, in order to complete the account of the parts concerned in deglutition. The pharynx is the expanded upper part of the alimentary canal, communicating, on the one hand, with the cavity of the mouth; on the other, with the canal formed by the gullet. It has a conical form, the smaller end being directed downwards. In the second stage of deglutition the masticated food passes into the pharynx over the epiglottis, which guards the orifice of the larynx. By the contraction of the pharynx it is transmitted into the gullet. The gullet, termed also the œsophagus, is a very muscular tube, being indeed the most powerfully muscular part of the whole length of the *primæ viæ*. The muscular fibres differ in the ox from those in the human gullet, by decussating each other, and running spirally in opposite directions: these muscular fibres, at the same time, are remarkably strong. The lining mucous membrane of the gullet is plentifully supplied with secreting follicles for the lubrication of the tube. The gullet tapers as it slopes backwards, and, passing between the two sacs of the pleura in the chest—that is, through the mediastinum—it proceeds, between the pillars of the diaphragm, to terminate in the paunch or first stomach.

Arteries.—The arteries which supply blood to the several parts of the mouth and the pharynx are branches of the external carotid, while the gullet receives blood from the posterior aorta. The distribution of these arteries is so similar to what was before stated respecting the corresponding blood-vessels in the horse, that it seems superfluous to repeat the description. The same observation applies to the veins and nerves (pp. 25, 26).

Deglutition.—The changes which take place on the food in the mouth of the ox are chiefly effected after it has been swallowed, and has remained for some time in the paunch or first stomach, and in the honeycomb or second stomach, and is thence returned to the mouth for further mastication. The grass is crushed rapidly, and swallowed by a process quite similar to that by which the horse swallows his food. After remaining in the first and second stomachs until thoroughly impregnated with fluid, the food, in the form of little balls or pellets, is returned at intervals to the mouth to undergo the slow process of mastication and insalivation, which is termed chewing the cud, or rumination. The process of rumination occupies much time. It has even been estimated that a fourth part of the day is spent in this operation. It appears that the saliva is not merely mingled with the food during the first and second periods of mastication; but that, in the interval between feeding and rumination, the saliva is constantly swallowed, by which the contents of the paunch are prevented from becoming so dry as not to be readily transmitted to the mouth. It is further affirmed that experiments show that if the course of the saliva into the paunch be prevented, no amount of water swallowed will suffice to keep the alimentary mass in a state soft enough for regurgitation. To enable the food at its first deglutition to get into the first stomach or paunch, it is necessary that it should be somewhat dry and bulky, otherwise it fails to separate the lips of the groove or demi-canal by which an entrance is gained to the first and second stomachs. In proof of this it has been shown that food reduced artificially to a soft and pulpy condition, when swallowed for the first time, passes along the demi-canal into the third stomach, while only a small portion of the mass makes its way into the first and second stomachs. When the food has been macerated in the fluids of the first two stomachs, with the aid of the saliva continually swallowed after the first deglutition of food has ceased, it is returned by an inverted peristaltic action of the gullet to the mouth. The pellets of food so returned are moulded in the demi-canal, the ends of which are drawn together, so as to give the pellets a globular form. These pellets are conveyed to the mouth at regular intervals, apparently by a rhythmical movement of the œsophagus. After the effect of rumination, the mass, now reduced to a pulpy semi-fluid state, is again swallowed, and now it passes along the groove which forms the continuation of the œsophagus without its lips being opened, and thus is conveyed into the third stomach. Thus it appears that when the mass of food is bulky, dry, and resistant, it is forced into the continuation of the œsophagus, and by its bulk and the force with which it is propelled, it opens the lips of the canal, so that it is straight driven into the first and second stomachs, the structure of which will be explained immediately; but that when the mass of food after the second mastication is soft, pulpy, and yielding, it does not offer sufficient resistance to open the lips of the canal, so that it is propelled onwards to the third stomach.

The mechanism of the act of deglutition has been already explained in the horse, from which the same act in the ox will be sufficiently understood (p. 31).

Organs of Digestion in the Abdominal Cavity of the Ox.— The trunk of the ox, like that of the horse and other mammals, is divided into chest or thorax, abdominal cavity, and pelvis. The chest is very capacious. There are thirteen dorsal vertebræ in the ox: the most forward of these have the spinous processes very much developed, and very long, for the more advantageous attachment of the muscles and of the nuchal ligament which supports the weight of the head and neck. The ribs in the ox, as in other animals, are the same in number as the dorsal vertebræ. Thus in the ox there is one pair of ribs more than in man. The horse has five pairs more than the ox, while the sheep has the same number. The ribs are broad and thick in the ox, as generally in herbivorous mammals. The chest of the ox, as is commonly the case in animals without clavicles, is more compressed on the sides than the chest in man—that is to say, the chest is deeper proportionately from sternum to spine than in man. In the ox there are six lumbar vertebræ, or one more than in man—the same as in the horse and sheep. The sacral and caudal vertebræ in the ox are the same as in the sheep—namely, four of the former and sixteen of the latter; in the horse there are but two sacral, while there are seventeen caudal vertebræ. Of the pelvic bones the iliac bones are developed to a great breadth in the ox.

The midriff or diaphragm, a highly muscular partition, and a principal agent in respiration, divides the chest from the abdominal cavity. The diaphragm is also an important agent in the evacuation of the bowels and bladder; for, though the diaphragm and abdominal muscles commonly act in antagonism to each other — that is to say, in ordinary cases, the contraction of the muscular fibres of the diaphragm causes the abdominal organs to move backwards, and the abdominal muscular parietes to protrude, while, in turn, the contraction of the muscular fibres of the abdominal parietes pushes back the diaphragm, and so diminishes the cavity of the chest—yet, when the diaphragm and the abdominal muscular parietes act simultaneously, the whole contents of the abdominal cavity, and also the contents of the pelvis, are powerfully compressed. Hence this is the state of the parts, not merely in the evacuation of the bowels and bladder, but in violent vomiting and in the expulsion of the birth. To which may be added every great effort of the whole frame; for here the aperture of the larynx being closed, so that air cannot escape as in expiration, the whole chest, abdomen, and pelvis are strongly compressed at once, the effect of which is, that the entire frame becomes one solid unyielding pillar for the muscles of the extremities and neck to pull upon.

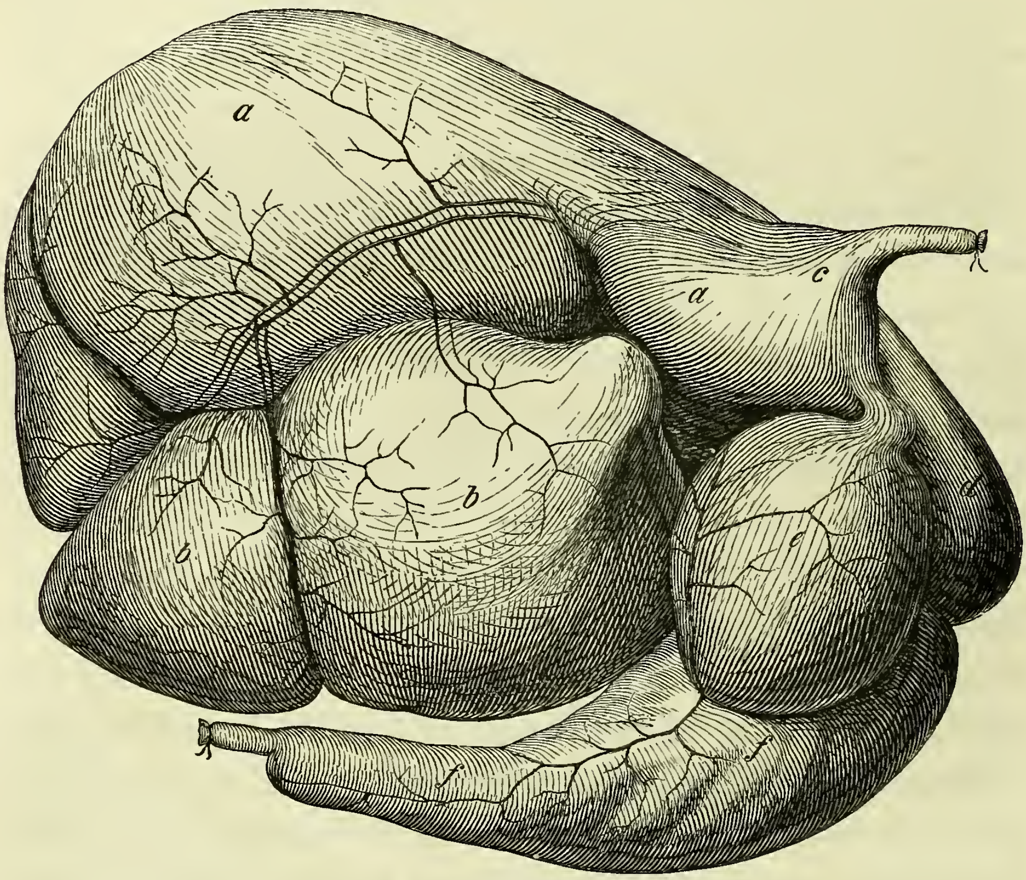
The external wall of the abdominal cavity—that is, its inferior wall—may be marked out into zones and regions, as in the human body; namely, an anterior, middle, and posterior zone; and each of these zones into three regions. Thus the anterior zone consists of the epigastric region, in the middle, flanked on each side by the right and left hypochondriac region; the middle zone has, in the middle, the umbilical region, flanked on each side by the right and left lumbar region; and the posterior zone has the hypogastric region in the middle, flanked right and left by an iliac region. Three regions of the pelvis may be added to these—namely, the pubic region, and on each side a right and left inguinal region (fig. 5).

The lining membrane of the abdominal cavity in the ox has the same general character as in man and the higher animals. It is a serous membrane, known widely throughout the vertebrated orders as the peritoneum. In the ox, as in similar animals, it is a shut sac, so disposed that the surface of attachment by which it adheres to the several organs contained in the abdomen is the outer side of the sac. The inner surface of the sac is absolutely empty, unless that it contains as much moisture as damps the finger when it is touched. During perfect health every part of the inner surface of the peritoneal sac is in close contact with some other part of the same surface. This inner surface is, however, a secreting surface, commonly, as said above, giving forth no more fluid than is sufficient to damp the finger. Yet in morbid states this secretion may increase to an immense extent, so as to constitute dropsy of the abdomen—that is, dropsy in the peritoneal cavity. Thus the sac of the peritoneum is all but empty in health; but, being capable of allowing the accumulation of fluid, when the secretion augments, or the ordinary rate of absorption fails, it is one of those cavities termed by physiologists a potential cavity.

The stomach, the liver, the spleen, the pancreas or sweet-bread, the small and the great intestines, all obtain their outer serous coat from the peritoneum. It covers also the womb, and the large end of the urinary bladder. The outer surface of all these organs, where the peritoneum forms that surface, is, in the language of anatomy, free—that is, unattached, and capable of gliding smoothly over the free surface in contact therewith. As a general rule, the peritoneal sac reaches all these organs to give to them their covering, in the form of a fold, consisting of two plates or laminæ, quite close to each other, being joined by the immediate contact of two parts of the outer surface, or surface of attachment. As the fold approaches the organ to be invested, the two laminæ separate and enclose the organ, meeting again at the opposite side of the organ in some instances, while in other instances the organ is embraced between the laminæ like a stone in a sling, and thus hangs as it were projecting into the interior of the sac. The small intestines afford an example of the latter disposition of the laminæ, as these are suspended by the fold forming the mesentery, like a stone in a sling; while the liver and stomach illustrate the other mode of adjustment—for the peritoneum, passing from the diaphragm in the form of two laminæ united, reaches the liver and encloses it; after which the laminæ close, and, under the form of the omentum gastro-hepaticum, composed of two united layers, reaches the stomach, where, again expanding, these layers cover the stomach, to unite again at the anterior and inferior side, where, by another union, they form part of the great omentum.

Stomachs.—When the inferior wall of the abdomen is cut through in the middle line, and thrown back to each side, in the ox, it is not the colon, as in the horse, which makes the most conspicuous appearance by occupying the chief part of the exposed abdominal surface, but the paunch, or first of the multiple stomachs in the ruminants. This first stomach covers nearly the whole of the left side, concealing many parts from view. These multiple stomachs, in the ox, four in number, but

Fig. 9.



External View of the Paunch in the Ox, as seen on the Right Side.

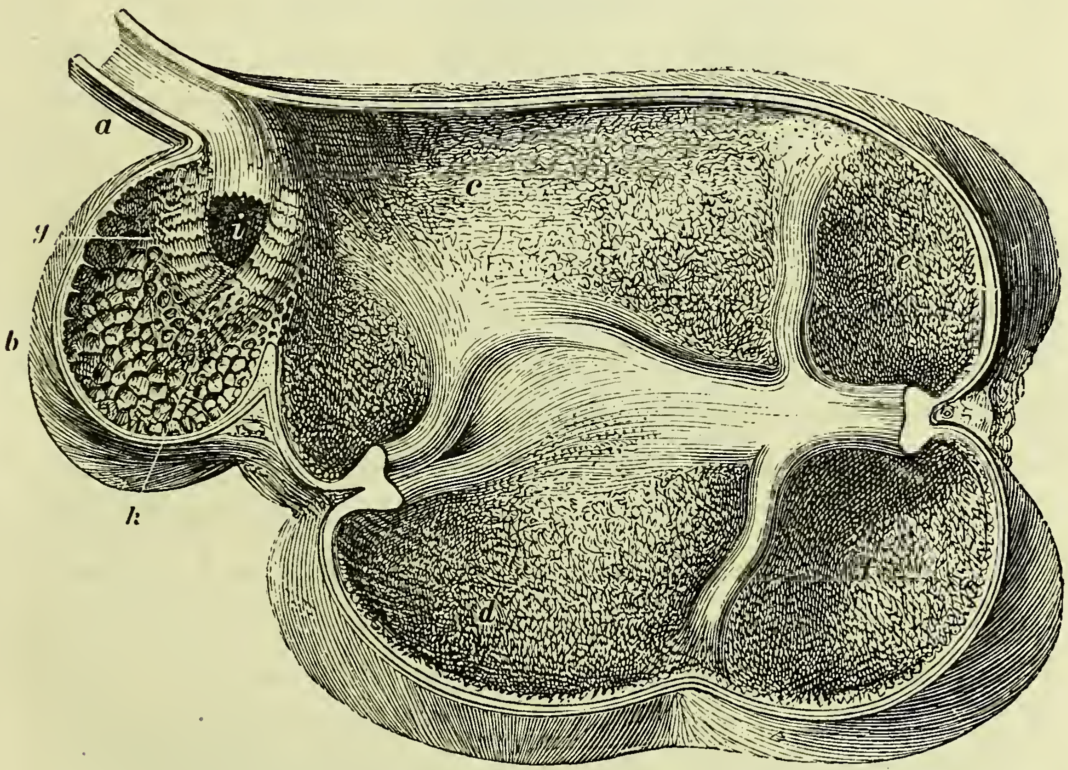
a, *d*, Paunch; *b*, *b*, honeycomb; *c*, gullet; *e*, manyplies; *f*, true stomach, or red.

of very unequal size, form a cluster, with the middle of which the lower end of the gullet is connected. At the point where the gullet ends, the first, second, and third of these stomachs approach each other, so that the gullet communicates more or less directly with each; the fourth, or principal stomach, is more distant from the gullet, and communicates with the gullet only through the third stomach. The fourth stomach is, however, the only one of the four which opens into the duodenum or highest part of the small intestines.

The gullet, as before said, coursing through the neck, more distinctly above the windpipe than in the horse, crossing the two first ribs, then traversing the upper part of the chest, and passing through the midriff, enters the paunch or first stomach at its anterior and superior part.

The paunch is by far the largest of the four stomachs. It has somewhat of a cubical form with the angles rounded off.

Fig. 10.



Paunch and Honeycomb in the Ox, laid open by removing the Left Wall while *in situ*.

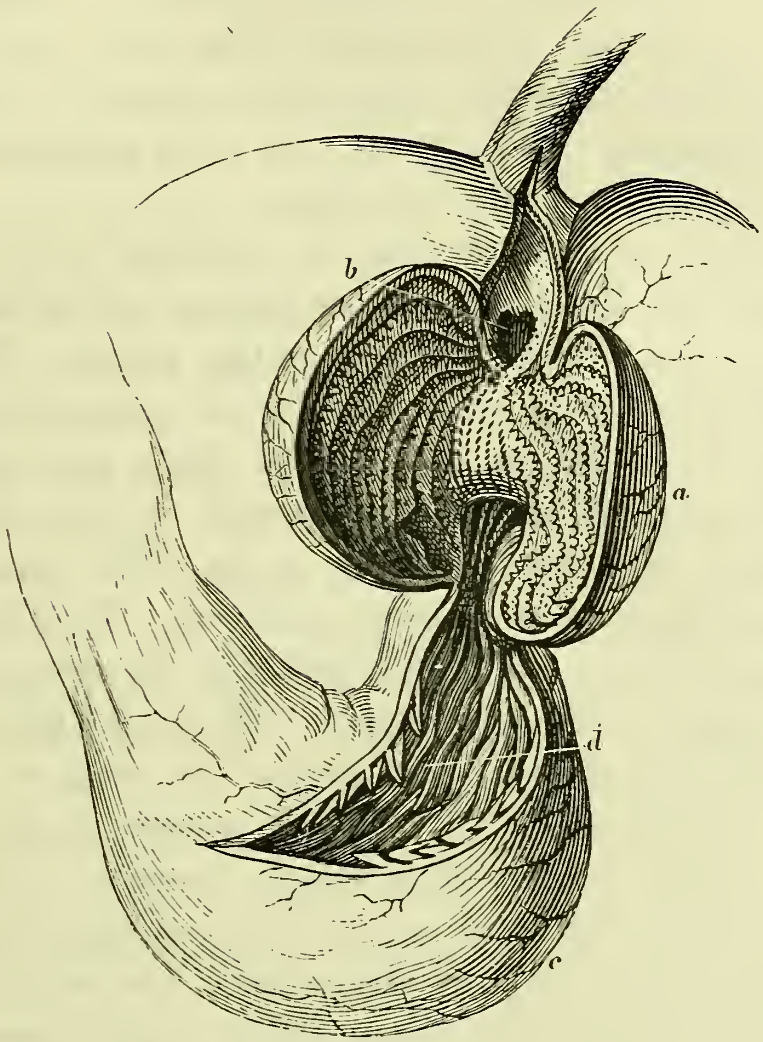
a, Gullet; *b*, honeycomb; *c*, anterior pouch of paunch; *d*, middle pouch; *e*, posterior-superior pouch; *f*, posterior-inferior pouch; *g* and *h*, pillars of the œsophageal canal; *i*, entrance to the manyplies.

It inclines to the left side, and occupies a large portion of the abdominal cavity, extending from the diaphragm in front to the pelvis behind. It consists, like the other parts of the abdominal digestive cavities, of muscular fibres enclosed between a serous external and a mucous internal tunic—the muscular fibres being crossed by strong fleshy bands which divide the organ into four pouches. Externally these divisions are best seen when the right aspect of the paunch is examined. They are, however, more easily understood when seen after the paunch has been laid open, as in fig. 10.

The first stomach is of very great size, and occupies a considerable part of the abdominal cavity. It is lined with a cuticular investment, and presents a shaggy pile, but either does not secrete any fluid, or only in sparing quantity. It is termed the paunch or rumen, and is merely a temporary reservoir for the food. The second stomach is much smaller, and its walls are covered with numerous polygonal cells, which, being like the cells of the honeycomb, have gained for it the name of the honeycomb or the reticulum. The lining membrane of the second stomach, like that of the first, is cuticular. The third stomach is the smallest of all : it has its lining membrane so disposed as to form deep lamellæ arranged longitudinally in alternating large and small layers, so as to present a most extensive surface. It is named popularly manyplies, and is also called psalterium and omasum. Its lining membrane is cuticular, like that of the first and second stomachs. The fourth stomach is the second in point of size : it has an elongated pyriform shape, and its internal membrane has all the prominent characters of the mucous membrane of the stomach in man and other mammals in which the organ is simple. It is commonly called the red or reid, the abomasum, or the rennet. Both third and fourth stomachs are seen cut open in fig. 11.

The first stomach is of small size in the calf, and while the young animal is fed on milk it does not take part in the reception of the food. When it is fully developed it is divided externally, at its extremity, into two saccular appendages; and on the inside it is slightly separated into four divisions. It

Fig. 11.



Manyplies and Red in the Ox, cut open.

a, Omasum or manyplies, cut open to show its folds, &c.; *b*, the opening communicating with the reticulum or honeycomb; *c*, abomasum or red, the true digestive stomach; *d*, the mucous membrane of abomasum, which is also plicated.

lies to the left side of the extremity of the gullet. The second stomach also is small in the calf, and has no concern with the digestion of milk. When fully developed it seems at first sight to be but an appendage of the paunch or large stomach. It lies to the right of the gullet, and of the fore part of the paunch. In front it is near the tendinous centre of the diaphragm. The name bonnet, or king's hood, sometimes heard applied to it, refers to its globular shape. The third stomach, also, is little developed in the calf, as taking no part in the digestion of milk. It is placed on the right side of the paunch, behind the liver. The fourth stomach is well developed in the calf. It lies to the right of the paunch, and, for a short distance, under the manyplies.

Rumination.—Under the head of deglutition (p. 90), something has been already said of rumination, and of the part taken by some of these stomachs in that process. It must be confessed there is some difficulty in understanding the mode in which the several stomachs obtain their contents from the gullet, and as respects the mode in which the two first restore their contents to the gullet. The terms demi-canal and temporary canal create confusion. If the function of this canal in the calf is first looked to, its true character will be more easily apprehended. When the milk is to pass into the third and fourth stomachs at once, how is its passage accomplished? A complete passage at that time extends from the gullet to the third stomach—a continuation, in short, of the gullet to the third stomach, through the upper part of the first and the second. The action of this canal in the more mature animal differs in this respect from its action in the calf—namely, that it is capable of opening up laterally; that is, what is tantamount to a longer or shorter slit lengthwise in the canal may form, so as to allow its contents to pass into that stomach, or those stomachs, into which the slit opens at the time. When a ruminant animal drinks, it was once supposed that the water passes directly into the third and fourth stomachs like the milk in the calf—which supposed fact seemed well to illustrate the nature of the communication of the third stomach with the gullet; but this illustration is not complete, since it seems to be proved that, though the water, on drinking, passes directly into the third and fourth stomachs, it passes also into the first and second stomachs. The aliment, however, after the thorough mastication and insalivation which constitute rumination, being now a soft, somewhat uniform pulp, under the impulse of deglutition, passes through the first part of the canal with much the same facility as the milk in the calf, and, creating no distention such as is sufficient to open the canal freely, reaches the third stomach.

The preliminary stage of the process of stomach-digestion in the ox proceeds nearly in the following manner: the food, unless it be of a pulpy character, passes, after a first imperfect mastication, wholly into the first and second stomachs; if it be of a pulpy character, it goes, after this slight mastication, in part into all the four stomachs. When the coarser food which had passed into the first and second stomachs has become, with the aid of the saliva that is continually swallowed in the interval between eating and ruminating, sufficiently macerated and dissolved, it is thrown by the contraction of these two stomachs, assisted by the action of the abdominal muscles and diaphragm, into the demi-canal; this canal then contracts, and, moulding the pulp that has passed into it to the shape of its narrowed and shortened form, converts it into a pellet; the canal next throws this pellet into the gullet, by the inverted action of which the pellet is transmitted to the mouth for rumination—that is to say, for a second mastication and insalivation. In the second deglutition the ruminated aliment passes by the demi-canal chiefly into the third stomach, but a portion of it passes at the same time into the first and second stomachs. That portion of the ruminated aliment that arrives at the third stomach, after the changes effected on it there, passes into the fourth or proper stomach, where true ventricular digestion takes place. The portion of the ruminated aliment which goes into the first and second stomachs, being mingled with the new aliment, may possibly, in part, be again carried to the mouth.

The coats of these stomachs are much the same as the essential coats of the stomach in the horse—that is, the outer covering is a serous membrane, being a part of the general shut sac of the peritoneum; the middle coat consists of muscular fibres; and the internal coat is a mucous membrane, covered, however, in the three first stomachs, by a cuticular investment corresponding to that investment which lines the cardiac half of the stomach in the horse. The fourth stomach has a mucous lining, soft like that of the human stomach, and thrown into folds, which are transverse at the extremity near the third stomach, and longitudinal in the middle, and becoming by degrees effaced near the intestinal opening. According to Cuvier, there is no valve in the pyloric opening, but one between the third stomach and the fourth.

These stomachs are abundantly supplied with blood by arterial branches derived from the posterior aorta. The arteries of the stomach have a course corresponding to that already described as observed in the horse (p. 41). The veins enter into the formation of the portal vein, or that great peculiar vein which, formed from the veins of the organs in the abdomen concerned in digestion, enters the liver for the purpose, as is believed, of supplying the secretion of the bile. The nerves of the stomach in the ox, like those of the horse, are derived from the terminal branches of the pneumo-gastric nerves of the eighth cranial pair, together with offsets from the solar plexus of the sympathetic nerve.

Process of Digestion in the Stomachs of the Ox.—The general observations made under the head of stomach-digestion in the horse, apply equally to stomach-digestion in the ox (p. 42). The body of the ox consists of the same fifteen simple elements, all drawn from the mineral kingdom, as the body of the horse. As in the case of the horse, all these enter the structure of the ox, not directly from the mineral kingdom, but indirectly, as constituting the elements of the vegetable food on which the animal feeds. It is equally certain that the maintenance of health in the ox depends on the due conservation of its several solid textures and fluids in their exact normal chemical constitution—that is, on the due proportion of each element being present in the several textures and fluids.

Again, it is certain that water holds the same place in the nutrition of the ox as in that of the horse,—namely, that it is not an aliment in the same sense in which albumen or fibrine is an aliment—nevertheless, that it is essential to the living actions, which go forward all-unceasingly in every living animal. About four-fifths of the weight of the ox, as in similar animals, are water; and thus, what are called the animal solids have water for their basis, much in the same manner as fluids, like the blood, only that the solid particles which move in the water are generally at smaller distances apart in the solids than in the fluids.

Cow's Milk.—As in the foal growth takes place to a surprising extent while the materials of that growth are drawn solely from the mother's milk, so in the calf the same fact is observed. The nutritive substances in the milk of the cow are, as in the milk of the mare, albuminous, saccharine, and oleaginous. The only albuminous proximate principle in the milk of the cow, as in the milk of the mare, is caseine; while the saccharine principle is sugar-of-milk, and the oleaginous principle butter. The saline matters contained in milk also act an important part in early nutrition. The specific gravity or density of cow's milk varies from 1.030 to 1.035. In 100 parts 87.4 are water, 4.0 are butter, 5.0 are sugar and soluble salts, and 3.6 are caseine and insoluble salts. The salts contained in milk are chlorides of potassium and of sodium, phosphates of the alkalies, and a certain proportion of soda and potash, which are combined with the caseine and render it soluble—besides phosphate of lime, and, perhaps, phosphate of magnesia ; there is also a notable proportion of oxide of iron.

As the body of the calf undergoes a very considerable increase in bulk and weight when the sole food afforded is the mother's milk, every element which enters into that increase must be derived from the milk consumed in the mean time. The sugar and butter of the milk, besides the uses which they probably serve in the processes of digestion, afford materials for the maintenance of animal temperature in the eremacausis which takes place in connection with the function of respiration. The caseine alone can provide materials for the augmentation of such solids as the muscular frame and the nervous system. As remarked when speaking of the nutrition of the foal (p. 48), the caseine having much the same ultimate constitution in respect to oxygen, nitrogen, carbon, and hydrogen, as albumen and fibrine, it is not difficult to believe that it passes into one or other of these under the operative influence of the living body, and though caseine be deficient in the phosphorus which albumen and fibrine severally contain, yet that the requisite phosphorus may be obtained by the deoxidation of phosphoric acid derived from the phosphates found in milk. The phosphate of lime and the phosphate of magnesia, both of which have been detected in cow's milk, account for the increase of the skeleton while the diet of the young animal is confined to the mother's milk. Among the substances present in living bodies in very minute proportion is the fluoride of calcium. There is little reason to doubt that this substance will be found in cow's milk as well as the other constituents of bone.

It was already noticed that, during the digestion in the calf, the milk is conveyed, after deglutition, straight into the fourth or proper stomach, the other stomachs at that period being in a rudimentary state (p. 98).

Gastric Juice.—The gastric juice in the ox is the secretion from the membrane of the fourth stomach, by which the final effect of stomach-digestion is produced on the aliment. It is the chief agent in the digestion of the albuminoid portions of the food, while it exerts hardly any influence over its starchy and saccharine constituents. When there is no food in the stomach, the fluid present shows quite different qualities from those possessed by the fluid secreted when food has reached the organ. The fluid obtained from the empty stomach has either no effect on litmus-paper or its effect is alkaline; but after food has passed into the stomach, the secreted fluid is uniformly acid. In this state the gastric juice is a clear colourless liquid, with a peculiar odour, and slightly saline and acid taste. It does not become turbid when boiled, and is distinguished by a remarkable antiseptic property. It has no tendency to become putrid, even when kept at the temperature of 100° Fahr. The nature of the acid present in the gastric juice has been much debated. According to some physiologists, it is the hydrochloric acid—and this is the prevailing opinion. The most probable case is, however, that it is a mixture of hydrochloric and lactic acids. Not a few contend that it is lactic acid alone, while others maintain that it is phosphoric acid in the form of superphosphate of lime. Some saline matters have been detected in the gastric juice—such as common salt (chloride of sodium), small quantites of chlorides of calcium and of magnesium, lactate of soda, and traces of phosphate of lime and of iron. The amount of phosphate of lime is very small, and the sulphates and phosphates of the alkalies are hardly discoverable. The gastric juice, however, contains, in small proportion, a peculiar organic compound, which has been termed *pepsine*. To this substance, aided by the free acid present, the remarkable solvent powers of the gastric juice are supposed to be owing. Pepsine belongs to the albuminoid description of bodies: it is soluble in water, insoluble in alcohol. By boiling, its remarkable solvent power is destroyed. An artificial gastric juice is made by digesting the mucous membrane of the stomach with a warm but very dilute solution of hydrochloric acid. Such a liquid, if the temperature be kept at 100° Fahr., will dissolve, in six or eight hours, pieces of hard-boiled egg and of beef. The solutions so procured do not coagulate on the application of heat.

The gastric juice, though doubtless somewhat different in the several quadrupeds of the farm, yet, on the whole, possesses in all the striking qualities above described. This secretion, then, is the chief agent by which, in the fourth stomach of the ox, the aliment is finally changed to chyme, or to that mass which the duodenum—namely, the highest part of the small intestine—receives from the fourth stomach.

The motions of the several stomachs in the ox during digestion have not been very clearly ascertained. These motions manifestly have two effects: the one to propel the food or the chyme from cavity to cavity—as, for example, the chyme when formed from the fourth stomach into the duodenum; the other motion is of a different kind, being a kind of vermicular motion, by which the aliment, now more, now less, changed, is made to pass along the surface of the cavity, so as to be more effectually subjected to the influence of the secretion poured out by that surface. The motions of the fourth stomach in the ox, in these two respects, do not appear to differ much from similar motions in the human stomach (p. 8).

Intestines in the Ox.—As in other mammals, the intestines of the ox, the great length of which has been already referred to (p. 5), consist of the small and the great. The small intestines come under the three heads of duodenum, jejunum, and ilium ; while the great intestines include the cæcum, the colon, and the rectum. The principal coats of the intestinal tube are three—namely, the external serous, derived from the peritoneum ; the middle muscular, in two layers of fibres, the outer longitudinal, the inner circular; and the lining or mucous membrane. The peritoneum, in its passage from the upper part of the abdominal cavity to reach the intestines, forms the fold, consisting of two layers of the serous membrane, termed the mesentery. At the free margin of these layers—that is, where they take the form of a sling—the intestine is contained. Between these layers, the arteries, veins, nerves, absorbent vessels with the conglobate glands, belonging to the intestine, are supported in their course. There is a considerable peculiarity in the mesentery of ruminants as compared with the mesentery in the horse and many other animals. In the horse, as in man, the great intestine is supported by a separate doubling of the peritoneum, termed the meso-colon and meso-rectum; but in the ox a great part of the colon is contained in the same doubling of the peritoneum which forms the mesentery —that is to say, the small intestines hang in the concavity of the sling, while the great intestine lies above the small intestine between the same two layers, in the free margin of which the small intestines are suspended. In the cæcum of the ox the longitudinal muscular fibres are very well developed; in the colon the longitudinal muscular fibres are arranged in broad bands, between which are narrow intervals, and in these the circular fibres of great strength are visible. The lining mucous membrane of the small intestines has no doublings, except in the duodenum, where these are transverse. The villi here resemble fine scales. At the lower part of the small intestines, this membrane shows Peyerian patches to a very considerable extent—that is, a glandular structure named after Peyer, and well known in the human body. The mucous membrane of the cæcum is smooth, except at the place where the gut is contracted, and there longitudinal duplicatures are seen. From that place, also, to its lower extremity, the mucous membrane is thicker and more glandular. In the colon the mucous membrane is smooth and without duplicatures. Towards the lower part of the rectum, the walls of which are altogether thicker than those of the colon, the mucous membrane shows parallel longitudinal duplicatures, and towards the fundament they become circular and concentric.

The small intestines correspond in the ox very closely to their condition in most mammals; as to the great intestines, the cæcum, as in all ruminants, differs from its state in vegetable-feeders in general, by being moderate in size and free from dilatation. There is no vermiform appendix in the ox. The colon is not of great magnitude, though of considerable length.

The cavity of the great omentum is very large in animals resembling the ox. It encloses the four stomachs, the duodenum, and the pancreas. Its two interior laminæ adhere to the whole surface of the first and second stomachs, while the two outer laminæ are detached from the paunch at the middle line between its two faces, and are prolonged behind beyond that stomach without finally becoming contiguous. This omentum, moreover, appears to be suspended from the whole posterior border of the fourth stomach. The latter also gives attachment by its right border to an appendix of the great omentum, forming in its front a triangular *cul-de-sac,* the superior lamina of which passes on the duodenum, and proceeds to become confounded with the corresponding lamina of the omentum. The third stomach is enveloped entirely in the layers of this appendix, which serve for its suspension.

The free part of the great omentum contains in the ox, as in man, for the most part, a pretty large deposit of fat. The ox has likewise around the great intestines the epiploic appendages of the same character as those known in man.

Blood-Vessels.—The arteries which supply the intestines with blood are branches of the posterior aorta—namely, the anterior and posterior mesenteric arteries. The posterior mesenteric artery is small in the ox, owing to the close connection between the small and the great intestines, so that the anterior mesenteric greatly preponderates in size. The branches of the anterior mesenteric which supply the intestines are: first, three considerable branches which give blood to the commencement of the small intestine; then a large branch directed to the colon and cæcum; then a last branch, which furnishes branches to the small intestines as these pass backwards to the remotest part of the mesentery. These branches do not form arches, as in man, nor do they anastomose frequently with each other, but proceed straight to the intestines. The small posterior mesenteric in the ox carries blood principally to the rectum, the few twigs sent to the colon being altogether unimportant.

The veins of the intestines enter into the formation of the portal vein.

Nerves.—The nerves of the intestines are derived from the anterior mesenteric plexus, the posterior mesenteric plexus, and the hypogastric plexus, all which are formed by the splanchnic nerves of the sympathetic system. Like the blood-vessels, the nerves reach the intestines by passing between the folds of the mesentery.

Lacteals.—Between the laminæ of the mesentery also are lodged the lacteal and lymphatic vessels, and the glands connected with these, which bear so important a part in the function of nutrition.

The principal trunk of the absorbent system, termed the thoracic duct, is traced running forward along the spine to end in the left subclavian vein. The thoracic duct is made up by the junction of five or six vessels, two or three of which come out of the pelvis, two or three from the mesentery, and one from the neighbourhood of the stomach and liver. The tubes which conduct the chyle from the small intestines to the mesenteric glands, and thence to the thoracic duct, are viewed as being of precisely the same structure, and even as performing the same office, except after food has been taken, as the common system of lymphatic vessels spread over nearly the whole system. In short, as is commonly taught, the lacteal vessels found between the laminæ of the mesentery are in general merely lymphatic absorbent vessels; but when chyle is formed in the intestines, then their office is to take up that chyle, or, to speak more strictly, that incipient chyle, which the small intestines afford. Again, the mesenteric glands, through which the lacteal vessels are transmitted, are held to possess quite the same structure as what belongs to the conglobate glands, which are almost everywhere found in connection with the lymphatic system. But of these hereafter.

Liver.—The liver, and sweetbread or pancreas, secrete each a fluid which mingles with the digesting mass in the duodenum or highest part of the small intestines, so that these organs are beyond doubt rightly named chylopoetic viscera. It is not so certain that the spleen merits the same name. It is, nevertheless, at present commonly ranked among the chylopoetic organs. The reason now assigned for putting the spleen in this place is, that its function, though not perfectly ascertained, seems to be analogous to that of the mesenteric glands, which unquestionably exert an important effect on the nutritious fluid delivered up to the lacteal vessels by the small intestines. The great glands throughout the body, by an old arrangement, are called conglomerate—such as the liver, the pancreas, the parotid, the kidney—and the spleen, owing to its great size, was commonly ranked with these, notwithstanding that no duct had ever been discovered, or any secretion like the bile, the pancreatic juice, the saliva, or the urine. Contrasted with the conglomerate glands were the conglobate glands—organs with no evident secretion—through which the absorbent vessels, both lacteal and lymphatic, were observed to pass in their progress towards the great trunks and the thoracic duct. Though these do not throw forth any distinct secretion, yet there is reason to believe that the fluid carried into them by the vasa inferentia undergoes important changes before being brought out from them by the vasa efferentia. Thus their similitude to glands is supposed to be established; and as the spleen is believed to produce analogous changes on the fluids conveyed into it, it has been transferred from the order of conglomerate glands, to which its title was very equivocal, and ranked with the conglobate, its old claim to being a chylopoetic organ being recognised under this new view of its functions. The spleen is also ranked under the new order of glands termed blood-glands or vascular glands.

The liver is the largest gland in the body, even of ruminants, in which it is of less size proportionately than in the horse and most mammals. It lies in the right hypochondrium, but does not extend so far across the abdominal cavity as in man or in the horse, as if its development in breadth were restrained by the great space occupied by the four stomachs. It is reduced, in short, to one principal lobe, with one or two tubercles at most adhering to its posterior aspect near its base, and these take the place of lateral lobes and lobules. On the diaphragmatic aspect, the liver of the ox presents one united mass, thicker above and to the right, becoming thinner towards its margin, which presents a sharp edge. A suspensory ligament divides this aspect into two unequal portions, of which that on the right is much the larger. Indeed, as seen on the diaphragmatic or convex side, the liver of the ox has much the appearance of the liver in man. There is a notch, not very deep, at the place where the umbilical ligament reaches the margin of the liver, and passes into its substance. The intestinal aspect of the organ below and to the right shows a lobule of a prismatic shape, corresponding to the right lobe above, the base of which exhibits a prominence like the rudiment of a lobule. There is no left lobe; but the vestige of a lobule may be recognised in a papilla which is above the transverse sulcus, where the principal vessels enter and leave the liver.

With very slight exceptions, the surface of the liver is free—that is, unattached. This large free surface is a serous secreting surface, the outer covering of the liver being a part of the great shut sac formed by the peritoneum. Thus the free secreting surface of the liver is a part of the interior surface of that sac. This free secreting surface is everywhere in contact with a like free secreting serous surface—namely, some other part of the interior of the same great shut sac formed by the peritoneum. The parts adjacent to the liver are the diaphragm, the posterior surface of which is lined by peritoneum—the walls of the abdomen, also lined by peritoneum—the stomachs, and particularly the third or manyplies—and the intestines, the outer coat of which is peritoneum. The liver, though free in so large a portion of its surface, is not loose; it is supported by the parts in contact with it, and is permitted to move only in a very limited degree when the attitude of the whole body is changed. As its covering of peritoneum is not isolated, but a portion of one great sac, it is obvious that that membrane must extend to the liver and pass from it at particular points; moreover, the blood-vessels, nerves, and lymphatic vessels common to it with the rest of the body, and its proper duct, by which its secretion is carried to the gall-bladder and the duodenum, must have an inlet and exit from the liver. At all such points, then, the liver is not free, but attached, in the anatomical sense of the term.

The duplicatures of the peritoneum which pass from adjacent parts to the liver are termed its ligaments. The chief of these is that spoken of above as seen when the diaphragmatic or convex aspect is in view—namely, the broad, suspensory, or falciform ligament. It is a doubling of the peritoneal sac inwards, shooting from a line passing along the nether surface of the diaphragm to the umbilicus, and striking the liver from the shallow notch spoken of above, as seen at its sternal edge along a line on its convex surface to its opposite border. This ligament, arising narrow at the umbilicus, passes broadening and curving to the convex surface of the liver so as to present something of the scythe-like form from which it draws one of its names—the falciform ligament. During intrauterine life, the calf derives nourishment from the placenta or after-birth, while the vascular communication between the placenta of the mother and the body of the calf is by two arteries and a vein passing through the umbilicus to the placenta. This umbilical vein, after entering by the umbilicus, goes straight to the liver, through which the chief part of its blood circulates before being distributed to the body of the fœtal calf. After the birth of the calf the portion of the umbilical vein between the umbilicus and the notch in the edge of the convex surface of the liver becomes a fibrous cord throughout life, and constitutes what is called the round ligament of the liver. It extends between the umbilicus and the edge of the liver, coming originally from without. It does not penetrate the peritoneal shut sac which forms the lining of the abdomen, but runs in the free margin of the duplicature of that sac, which forms the falciform or suspensory ligament. It may be remarked how ill the name suspensory applies to it in the ox, correct enough as it is in man, since, in his erect posture, its chief direction is downwards; but in the ox this falciform ligament has its direction backwards and upwards to reach the organ which it is described as suspending. There is a portion of the liver on its spinal aspect which is not covered by peritoneum, but where an attachment takes place by means of areolar or cellular tissue between the liver and the diaphragm. This cellular portion of the surface of the liver is bounded by peritoneal membrane passing from the diaphragm to the liver, and that doubling of peritoneum is called the coronary ligament. By these two folds or duplicatures of the peritoneum—namely, the falciform ligament and the coronary ligament—the peritoneal shut sac passes upon the liver. The peritoneum again passes from the liver to the stomachs in the form of duplicature, to which the name omentum minus has been given.

Beneath the serous or peritoneal covering of the liver there is a fibrous coat, which is reflected into the substance of the organ so as to connect together the several separate tissues entering into its structure. This fibrous coat, where it is reflected inwards, receives the name of capsule of Glisson, from the anatomist who first made it known. This second coat of the liver, and its reflection inwards into the substance of the organ, is also called the areolar coat.

The proper substance of the liver has a reddish-brown colour and mottled aspect; it is compact, but not very firm. It breaks down under pretty strong pressure with the fingers, particularly when it is somewhat disorganised. Even in severe falls during life the substance of the liver is sometimes rent, though no other great injury has been sustained. When the torn surface of the liver is inspected, it does not present a smooth aspect, but is minutely granular, which granular appearance arises from the minute lobules entering into its structure. Such lobules are from half a line to nearly a line in diameter. Their size is nearly that of a pin-head, polyhedral in figure, and closely packed, held together jointly by a fine areolar tissue, and the blood-vessels and ducts concerned in their peculiar office. These lobules are believed to be isolated—that is, each to be independent of connection with the others. Their union with the minute blood-vessels is very remarkable. The blood-vessels of the liver are the hepatic artery, a branch of the cœliac axis, derived in turn from the posterior aorta; the portal vein, which, formed from the veins of all the organs concerned in digestion, is distributed like an artery within the liver; and the hepatic veins, which, receiving all the blood that enters the liver, return it to the vena cava in the abdomen.

Each lobule of the liver rests with its base on a minute twig of the hepatic venous system; a still more minute twig descends from the centre of the lobule to join the twig at its base; the twig which descends to the base of the lobule is formed by the union of the capillary blood-vessels contained in the lobule. The hepatic venous system, in its course from the liver, does not run side by side with the branches of the hepatic artery, but reaches the hepatic venous trunks by channels peculiar to itself. On the contrary, the hepatic artery, the portal vein, and the hepatic duct, and their subdivisions, enter the liver together, and, having a parallel distribution, pursue their course through ramified common passages termed portal canals. It is these vessels which are accompanied by the capsule of Glisson in their course through the portal canals. The minute branches of the portal vein pass into the substance of each lobule. The minute branches of the hepatic artery also pass into each lobule, supplying the accompanying ducts in particular with blood. It is believed, further, that the capillaries supplied with blood by the hepatic artery throw their blood, now become venous, into the terminal branches of the portal system; and that the secretion of bile in each lobule is the product of the venous blood drawn by the general portal system from the veins of the chylopoetic organs, and of the venous blood formed in the liver itself, and supplied in the lobules by the capillaries of the hepatic artery to the capillaries of the portal vein. Finally, the venous twig first referred to, descending through the lobule to the larger twig on which the lobule rests, receives the residual blood after the secretion of the bile within the lobule, and the twig of the hepatic duct, which passes from the surface to the nearest portal canal, carries away the bile so secreted, to throw it into larger and larger ducts running in the larger portal canals.

Secretion of Bile.—Thus the bile is secreted within these lobules from the venous blood collected from all the chylopoetic organs, not excepting even the liver itself; and after the bile has been separated, the residual large quantity of venous blood is conveyed by the hepatic system of veins to the veins termed venæ cavæ hepaticæ, by which it is poured into the abdominal cava just as it is about to terminate in the heart itself.

Besides the blood-vessels and ducts connected with the lobules, there are hepatic cells. These are nucleated cells—that is to say, minute closed cells, in the walls of which severally there is a corpuscle or nucleus. These cells are of extreme minuteness, their diameter being only two or three times longer than that of the blood-corpuscles. These cells are doubtless concerned in the secretion of the bile; yet there are none found to be contained in the bile when carefully examined. These cells, or hepatic corpuscles, occupy the interstices between the blood-vessels and the commencement of the biliary ducts in each lobule. The matter composed of these corpuscles or cells is sometimes termed the hepatic substance.

The bile of the ox has often been examined with much care by chemists of the greatest eminence. According to the most recent views, it may be considered to be a variety of soap, made by the union of two distinct resinoid acids with the alkali soda. These acids (the glycocholic and taurocholic) both contain nitrogen. One of them, the taurocholic acid, contains sulphur, which element does not exist in the other, or glycocholic. In ox-bile, besides mucus derived from the gall-bladder, there are also contained minute quantities of cholesterine, and a small proportion of stearic, oleic, and lactic acids, combined with potash and ammonia. Besides these constituents, a peculiar colouring matter exists, joined to an alkaline base. There is also a body recently announced, to which the name lecithin has been applied, known by affording oleophosphoric acid when boiled with hydrate of baryta.

The important views recently brought forward as to the power of the liver to convert various proximate principles into sugar have already obtained a sufficient notice when the bile of the horse was spoken of (p. 64).

The quantity of bile secreted in a given time is very large as compared with the average amount of the daily excretion by the rectum. Hence it is obvious that the bile is decomposed within the alimentary canal, and reabsorbed in one form or another, while but a small proportion of the whole product of the liver is mingled with that excretion.

The bile is conveyed from the liver to the duodenum by the great bile-ducts. In the ox, as in man, there is a gall-bladder —a piece of the biliary apparatus which does not exist in the horse. This receptacle of the bile lies on the concave surface of the liver. It is lined by a prolongation of the mucous membrane, which, extending from the intestine through the great duct, reaches the interior of the gall-bladder. External to this is an areolar coat, and over all a peritoneal coat, by which the gall-bladder is made to cling close to the surface of the liver. In rare cases the gall-bladder is entirely covered with peritoneum, the lamina from either side being united into a duplicature between the gall-bladder and liver, by which the organ is suspended from the liver. The veins of the gall-bladder join the portal system of veins. The duct of the gall-bladder is named the cystic duct. It conveys the bile into the gall-bladder from the hepatic duct, and when the bile is required it returns by the same duct to the point at which it had before left the hepatic duct. The hepatic duct is formed by the successive union of all the minute biliary ducts derived from the lobules into larger and larger branches, passing outwards through the portal canals. The hepatic duct, when joined with the cystic duct, becomes the great common bile-duct, known in human anatomy as the *ductus communis choledochus.* This duct does not join the pancreatic duct, as in man, but ends separately in the duodenum.

Pancreas or Sweetbread.—The pancreas or sweetbread has a band-like form. It extends across the spine between the duodenum and the spleen. In the ox it is more complex than in most mammals. It has a duodenal portion besides the principal part of the gland. It appears, from some recent investigations, that several small supplementary glands communicate with the biliary ducts, notwithstanding that the proper pancreatic duct terminates separately from the common bile-duct in the duodenum.

The pancreas is what has been called a conglomerate gland. It resembles the salivary glands in a great many particulars. Its intimate structure is very much the same as that of the parotid gland. Its texture is, however, more loose, and softer. It is composed of many lobes and lobules, very different in size, united into one by blood-vessels and ducts, together with areolar tissue. The areolar tissue penetrates everywhere between the lobes and lobules, so as to unite them into groups and into a whole. The pancreas and its supplementary parts are abundantly furnished with blood—its blood-vessels, nerves, and lymphatics being from the same sources whence the adjacent organs are supplied. The peritoneum merely passes over the pancreas without investing it in the form of a complete tunic.

The pancreatic juice is colourless, transparent, and slightly viscid. It has an alkaline reaction, and putrefies rapidly. It has the property, like saliva, of changing starch to sugar. Thence it appears to be concerned in the assimilation of the starchy portions of the food on which the gastric juice has no effect. Some question has arisen on the point how far it is concerned in the assimilation of oily substances. It is certain that the pancreatic juice forms a very perfect emulsion when agitated with oil, and that this emulsion remains unchanged for many hours. The pancreatic juice contains albumen in the soluble form.

Spleen or Milt.—The spleen is a highly vascular organ, invested with a peritoneal tunic varying somewhat in colour, but commonly of a mottled blue or purplish-grey colour. It has been believed that there is a peculiarity in the structure of the spleen in the ox and sheep, in so far that this organ in each "is distinguished by a peculiar cellular structure from the merely vascular texture which it possesses in other animals of this class."* This observation does not, however, appear to have been followed out by recent anatomists. With respect to the general structure of the spleen, the chief particulars known have been already stated in speaking of the spleen of the horse (p. 65).

Villi of the Intestines.—The prominences on the mucous membrane of the primæ viæ or alimentary passages are, in particular, papillæ and villi. The papillæ are small processes of the corium of the mucous membrane, for the most part of a conical or cylindrical figure, enclosing blood-vessels and

* Blumenbach, by Lawrence, p. 125.

nerves, and covered with epithelium. These vary in size, being either small and simple, or large and compound, or even cleft into secondary papillæ. Such papillæ are designed for various uses: some, as the papillæ in the tongue, have their office in the senses of taste and touch; some act merely in a mechanical manner; others have no other end but to give an extension to the surface of the corium for the development of a thick coating of epithelium. The villi belong in particular to the mucous coat of the small intestines. They spring up so close to one another as to resemble the pile or nap of cloth, whence the parts of the mucous membrane on which they are developed obtain the name "villous,"—a name, however, too often given to the mucous membrane of the alimentary canal indiscriminately—that is, without reference to the presence or absence thereon of such villi. The villi in the mucous membrane of the small intestine are small elevations or processes of the superficial part of the corium or substance of the membrane invested with epithelium, and enclosing blood-vessels and lacteals, which thus exist under the most favourable circumstances for taking up nutrient fluids from the bowel.

These villi are well exhibited by the easy experiment of immersing a piece of well-cleaned intestine in water, and studying its surface with a simple lens. The most usual form of the villi is a minute, flattened, triangular process: again, it is conical or cylindrical, clubbed or filiform—that is, at its free extremity. At times, two or even three villi are united together at their base.

Their length (and here we draw on human anatomy) is from 1-4th to 1-3d of a line, and the broad and flattened form shows a breadth of 1-6th or 1-8th of a line, while they are from 1-24th to 1-20th of a line thick. In the duodenum and the jejunum they are most developed, both in number and size; while in the ilium they become by degrees shorter, smaller, and fewer.

Duodenal Digestion.—The food of the ox, like that of similar animals, contains proximate chemical principles derived from the vegetable kingdom, some of which are capable of augmenting the organism of the animal frame, and repairing the waste which it is unceasingly undergoing during the various acts of life. Others are incapable of repairing this waste, yet serve, by their slow combustion during the act of respiration, to maintain the temperature of the animal in a medium which, being almost always much below the standard animal temperature, is continually abstracting heat therefrom. The proximate principles which can augment and repair the animal organism are albumen, fibrine, and caseine; those which cannot produce this effect, but serve to maintain temperature, are principally starch, sugar, and oil. While, however, it must be acknowledged that such substances as starch, sugar, and oil, do not enter into the composition of the principal solids of the living body as essential constituents, yet, as respects oil in particular, it must be borne in mind that, though in the semi-fluid state during life, it is contained in a sufficiently firm series of membranous cells—so that, in effect, it does act the part of a solid. In such circumstances it obviously belongs, like the bones, to the passive organs of locomotion. In the feeding of cattle for food, fat or oil holds so prominent a place that no circumstance discoverable respecting it, whether hitherto explained or still inexplicable, is to be neglected or left out of view. There is one fact respecting oil or fat as an aliment, which physiology has not yet placed in a sufficiently clear light. The lacteal absorbents arising from the upper part of the small intestines become opaque, owing to the presence of chyle, some time after a meal. This opacity is due, so it is taught, to the presence of fatty corpuscles: here, then, a question naturally arises, if these fat corpuscles exert any special function in the process of nutrition. The case stands thus: the fat element is a universal constituent in mammals of healthful chyle, the essential nutrient of the blood, and yet this fat element is incapable of performing what must be regarded as the most important part in nutrition, namely, the repair of the great living solids. It would certainly be satisfactory if some special use of these never-failing fat-corpuscles in the chyle of mammals were ascertained. It does not diminish the difficulty, but essentially adds thereto, that it is a fact recognised in physiology that the chyle in birds is transparent. Is it that the active respiration of birds, extending all over the bodily frame, burns away the fat which in other animals gives whiteness to the chyle? The progress of physiology, it is to be hoped, will dissipate all such difficulties.

In all considerations respecting animal nutrition, it is to be borne in mind that the blood stands between the food and the organism. The blood is the fountain of nutrition to all the solids and fluids of the living frame. Nutrition is sometimes spoken of as vascular and non-vascular, but there is in reality no such distinction. Every solid of the body, and every fluid except the blood itself, is beyond doubt extravascular. It has been common to represent the epidermis and its appendages as extravascular solids, in contradistinction to the skin, the membranes, and the solids in general. But this obviously is an oversight. The epidermis, as an outspread solid, is correctly described as non-vascular when compared with the outspread solid the skin, in the substance of which vessels everywhere abound. But as the skin is composed of a number of minute organic parts, the aggregation of which constitutes the entire skin, so the epidermis consists also of an aggregation of a number of minute parts—but the minute parts of which the skin is made up are as much extravascular as the minute parts by the cohesion of which the epidermis is constituted. And the same thing may be said of every vital part in contrast with the epidermis ; the minute parts which compose any one living solid are all extravascular ; they are as much a deposit from the blood as the cells of the epidermis. Thus there is nothing in any solid or in any fluid which was not once in the blood—that is to say, the elements of which at least were not once in the blood; and there is nothing in the blood which was not once in the aliment, except such slight material as may be absorbed by the skin or lungs.

To maintain the blood, then, in its normal condition, is the great object of nutrition, and such normal condition is that state in which it is fit to supply every necessary constituent to the solids and fluids as often as a deficiency has arisen. The expenditure of the blood is most manifestly for the augmentation and repair of the solids and fluids. That expenditure is greatly increased under violent or long-continued exertion of the muscular frame. Every contraction of a muscular fibril is accompanied with a partial disorganisation of its living substance—that is, with the conversion of part of its living texture into non-vital chemical compounds, which must be thrown forth as effete, and therefore, if retained, are useless or hurtful to the animal economy. This continual disintegration of the muscular solid, or conversion of it into inert chemical products, would, it is to be supposed, furnish the same variety of substances which are produced when a piece of muscle is subjected to destructive distillation, while the influence of the atmosphere is excluded ; but what really occurs is similar to the effect produced when such an animal solid is subjected to destructive distillation after being mingled with a substance like oxide of copper, capable of supplying oxygen in abundance, because the contraction of a muscular fibril always takes place in the presence of the abundant oxygen contained in the blood thrown upon it at that moment. As the addition of the oxygen afforded by oxide of copper in the destructive distillation of a piece of muscle diminishes the number of products, so that nearly the whole of the carbon of the piece of muscle is converted into carbonic acid, and nearly the whole of its hydrogen into water, with the conversion of its nitrogen into cyanate, or some other compound of ammonia, so in the disintegration of the living muscular fibre under its contraction in the presence of the oxygen of the blood, there are few other products than carbonic acid and water, while its nitrogen passes into cyanate of ammonia or urea.

Thus the arterial blood, in parting with its oxygen during the contraction of a muscular fibril, acquires water and carbonic acid, together with compounds of ammonia. The loss which the blood itself sustains in parting with its oxygen has not yet been fully ascertained. If, however, the general system is not to suffer loss, that disintegration consequent on the contraction even of a single muscular fibril must be ere long compensated for by a new deposition from the blood. Whence some idea may be formed of the extensive disintegration necessarily arising when, under violent muscular exertion, numerous muscular fibrils are undergoing repeated contractions.

It is to be remarked also that the disintegration here spoken of is the disintegration of the solid organism—that which requires for its repair not such proximate principles in organic food as sugar, starch, oil, but such as albumen, fibrine, caseine. It thus also appears why, if the bodily frame is to be maintained without loss of substance, the allowance of food must be proportionate to the amount of muscular exertion which the animal has put forth in a given time. At what a cost of food, then, must long journeys on foot be maintained, if the oxen are not to suffer a loss of weight!

Animal Temperature.—It remains to be noticed how the disintegration of the muscular fibre in particular affects the animal temperature. The temperature of the ox, like that of mammals in general, is about 100° of Fahrenheit's thermometer. As generally at the earth's surface, and particularly in such a climate as that of the British Islands, the temperature of the atmosphere is much below that just indicated, it is obvious that the body of the ox must be continually losing heat, and that unless it contained within itself a constant source thereof, its heat would soon descend to the present temperature of the air.

It is quite correct to say that the temperature of the body is entirely maintained at the cost of the blood. The greater the degree of external cold, the greater is the waste of blood required to maintain the uniform temperature. If an animal be kept at rest in cold air, it will cool down much faster than if it be exercised. But the additional heat produced by exercise is at the cost of the loss of weight by the bodily frame, and in the first instance by the blood.

A great deal has been written of late as to the effect of such aliments as starch, sugar, and oil in the maintenance of animal temperature. And, doubtless, the facts stated are in a general way quite correct. But it should not be forgotten that muscular exertion, even in an animal at rest, never entirely ceases, and therefore that there is always some amount of disintegration of the muscular fibre going on ; and therefore that when the air is not cold, while moderate exertion is maintained, the amount of disintegration so produced may be sufficient to keep up the animal temperature. Thus it is certain that, under all circumstances, animal temperature is maintained at some cost of blood expended in the repair of the organic tissues disintegrated even in a state of rest. Nor does the blood fail to suffer loss even in the preparation of such substances as starch, sugar, and oil, before they become fit to generate animal temperature by being transmitted to the vessels of the lungs. It seems possible that an excess of such kinds of food as are merely fitted to maintain animal temperature might sometimes be afforded, when the temperature derived from the ordinary disintegration might be sufficient, so all the labour of the system in their preparation might be expended in vain. No doubt this can hardly occur when oxen are in the course of being fattened for slaughter, since, if the present amount of muscular disintegration be sufficient for the maintenance of the standard of temperature, any superfluous starch and sugar being changed into fat will be deposited in the tissues, and improve the animal's condition. But in the simple rearing of the young animal, during the period preceding the preparation for the shambles, it seems obvious that attention should be given to adjusting the due proportions of azotised and non-azotised aliment—that is to say, of flesh-forming and heat-giving aliment. There is no doubt an appropriate amount of muscular exercise required for the proper growth and development of the young animal, even when its final destination is merely the shambles; so that it will always be a point for skill to determine when the preponderance should be given to the aliment which repairs the blood for mere heat-giving, when to that which renews the blood after it has been exhausted by the repair of the active organs of locomotion.

Thus the amount of muscular exercise necessary for the perfect growth and development of the young animal is a grave subject for consideration; nor can trustworthy results be expected from any source but observation and experience under a large variation of circumstances. Physiology can only point out the mode in which effects are produced, while the data on which calculations can be founded must be determined by actual experiment.

The amount of carbonic acid thrown off by a living animal in a given time is a just criterion of the proportion of carbon which has united with oxygen in that time, and therefore indicates the quantity of heat produced by their combination within the body. But the knowledge of the amount of carbonic acid formed within the living body—for example, in a day—does not indicate how much organic tissue has been disintegrated in the process, or to what extent the decomposition of non-nitrogenised proximate principles has contributed to the effect. Even the loss of weight does not solve this difficulty; for though an animal deprived of food burns its own substance in the maintenance of its temperature, yet what burns first under such circumstances is the fat which has accumulated in the interstices of the solids, and then, and not till then, the organic tissue shares the same fate. Moreover, it appears probable, from various circumstances, that even when an animal is deprived of food, disintegration of the organism does not take place to any greater extent than corresponds to the amount of muscular exertion that continues to take place—that is, that the decomposition of the animal solids hardly occurs unless when their vitality is first lost by the exertion of living action. Whence it should follow that the more a starving animal can be kept in motion, the longer it will be able to support life by feeding on itself.

When disintegration of the organism of the kind composing the muscular tissue occurs, nitrogenised compounds, such as urea, must be produced within the living system. Whence it appears that an estimate of the nitrogenised products thrown off by the urine in a given time should be an index of the amount of organic tissue disintegrated within that time. Thus, when an animal is very much exercised, a much larger proportion of urea, the most abundant of the nitrogenised principles thrown off by the kidney, is found in the urine. It must be confessed, however, that the proportion of urea in the urine seems to increase by an increase in the quantity of nitrogenised aliment; so that though an increase of muscular exertion causes an increase of urea in the urine, yet that the estimate of that increase will not exhibit the quantity of organic tissue destroyed, unless the nitrogenised food remain unchanged in the mean time.

From these considerations it sufficiently appears that a constant drain exists on the blood, standing, as it does, intermediate between the aliment on the one hand and the organism and secretions on the other.

Chyme.—The blood, then, derives its repair, in some degree it may be, from the stomach, but principally from the duodenum and the upper parts of the jejunum. The partially changed mass descends from the fourth stomach, under the name of chyme, into the duodenum. There the agents by which further important changes are made on the alimentary mass are the peculiar secretions of the intestinal mucous membrane and glands of the duodenum, the secretion of the liver or the bile, and the secretion of the pancreas or sweetbread.

The chyme, as it passes from the fourth stomach into the duodenum, is a greyish, semi-fluid, apparently homogeneous substance, slightly acid in taste, otherwise insipid. Some kinds of food give it a creamy aspect; but when derived from farinaceous food, it has the aspect of gruel. The albuminoid parts of the food, whether in the form of fibrine, albumen, or caseine, principally exist in chyme in the state of albumen; yet some portions of these seem to remain in it still undissolved. Gummy matters, unless in the forms incapable of solution, exist in the chyme dissolved. The starch in the ox, as it would seem, is almost entirely converted into sugar before it reaches the duodenum. Oily matters are reduced to very minute particles, and in that state are dispersed throughout the other constituents of the chyme. But there are still some substances undissolved, the presence of which therefore detracts from the perfect character of chyme as a homogeneous substance: such are the woody fibre from cell-walls, resinous matters, horny and thick epidermic tissue. Some of these, being insoluble in the alimentary canal, necessarily pass out with the alvine excretion.

The changes produced on the chyme in the duodenum by the three agencies already referred to—namely, the duodenal secretion, the bile, and the pancreatic liquor—have been made as yet only in part.

The acid of the chyme is certainly neutralised by the excess of alkali contained probably in all the three just mentioned agents, but certainly in the bile and the pancreatic juice. The starch, if any remain, begins anew to be converted into sugar, that process being suspended in the true stomach. The fatty matters, probably by the joint action of all the three duodenal agencies, is still further comminuted, and brought into that state of fine division known as "emulsion;" by which complete division it seems to become admissible into the absorbent vessels. Lastly, the albuminoid substances are still more completely brought to the state of soluble albumen.

Direct Absorption by the Blood-Vessels of the Mucous Membrane.—The earlier stages of the assimilation of the aliment consist of processes of reduction and solution, so timed as to adapt themselves specially to certain other arrangements of the animal economy. The reduction and solution of the albuminoid portions of the food belongs in particular to the true stomach; and the suspension of the saccharification of the starch there has probably the effect of leaving the stomach undisturbed in its proper function; while the postponement of the complete conversion of the starch into sugar and of the oil into emulsion, till the chyme reaches the duodenum, has the advantage of retarding the too free absorption of sugar and emulsified oil into the general circulation, and confining that absorption to the vessels which are to carry these combustible substances straight to the lungs to be burnt off in the maintenance of animal temperature. In short, had the stomach completed the preparation of sugar and emulsified oil, these substances, being soluble, would have passed too freely into the capillary blood-vessels of that organ, and would have been conveyed to the lungs faster than they could have been burnt up, so that the residue would have deteriorated the general mass of the arterial blood by admixture therewith. As the case is, however, it has been always a cause for surprise that so much sugar and emulsified oil should be absorbed from the alimentary canal in animals like the ox without any evidence of their general presence throughout the mass of the blood. The explanation of this circumstance seems to be afforded jointly by the retardation of their absorption and by their rapid transmission after absorption to the seat of their combustion. While, then, such soluble parts of the contents of the small intestines as the sugar and the emulsified oil, are absorbed by the capillary blood-vessels in the mucous membrane—probably of the stomach itself, and certainly of the upper part of the small intestines—the dissolved albuminoid constituents of the food are taken up by the lacteals in the villi of the same part of the intestines.

It has been supposed, in the ox and other vegetable-feeders, that the contents of the intestinal tube, after yielding the sugar and emulsified oil to the capillary blood-vessels in the higher region and the soluble albumen to the lacteals, undergo a second digestion in the cæcum analogous to the stomach-digestion, and thus that any remaining albuminoid matter is reduced and rendered soluble previous to a new exercise of absorption. What gives countenance to this idea is the acid reaction discoverable in the cæcum. But, as respects the ox at least, this view has not as yet attained any firm ground of belief. The mass, deprived of its nutritive constituents, and mingled with the residue of the bile, of the pancreatic juice, and of the intestinal secretions, is transmitted to the great intestines, and finally thrown forth from the rectum.

Lacteals.—The lacteals commence in the villi of the intestines; they form a close plexus, and proceed to the thoracic duct in which they all terminate. They are derived much more numerously from the small intestines than from the large intestines. Whence their chief seat is the mesentery, and particularly that part of it which upholds the jejunum and the ilium. As the transverse colon in the ox is contained in the upper part of the mesentery, it is less easy in the ox than in many other animals to distinguish between the few lacteals passing from the great intestine and the great number passing from the small intestine. Two sets of absorbent vessels are met with along the intestinal tube, each of which has a different position and direction. The set which lies nearest to the external surface of the gut runs along the canal longitudinally, immediately beneath the peritoneal coat; while the other set, lying deeper between the muscular and mucous coat, turns transversely around the intestine, and thence proceeds, along with the arteries and veins, between the two laminæ of peritoneum which form the mesentery. The distinction formerly made between those two sets of absorbents—namely, that the superficial set were lymphatics, and the deep-seated set alone lacteals—does not hold good. They communicate freely by anastomosis. What was said long ago by a high authority is true—namely, that the lacteals absorb chyle when it is presented to them; at other times they absorb other fluids. These absorbents run through the mesentery, and enter the numerous mesenteric glands placed between that fold of the peritoneum.

Mesenteric Glands.—The mesenteric glands are numerous — probably not much less in number than two hundred — their medium size, that of an almond. They are much more numerous in that part of the mesentery which supports the jejunum. They are, in general, at least two inches distant from the border of the intestine. When the lacteal vessels have passed through one or other of these glands, they, by degrees, unite as they near the attached part of the mesentery—that is to say, two or three join into one larger vessel. Thus they become fewer and fewer in number, until, finally, near the root of the anterior mesenteric artery, they have become reduced to two or three trunks, which end in the thoracic duct. At other times a considerably greater number of trunks open, one by one, into that duct. Such is the course of the lacteals coming from the whole of the small intestine, and from the transverse colon. Those from the inferior parts of the colon join some of the lumbar lymphatics, or turn forwards, and, by a distinct trunk, end in the posterior part of the thoracic duct. To the posterior extremity of the thoracic duct also proceed, from behind forwards, the lymphatic vessels from the lower limbs, so that it is correct to say that the thoracic duct begins at the common union of these lymphatics with the trunks of the lacteal system ; and here there is a dilatation which more truly deserves the name of "receptaculum chyli" than in the human structure.

Thoracic Duct.—The thoracic duct extends from the loins to the neck. At first it lies to the right side, or above the aorta, passes in contact with the right crus of the diaphragm, and gets into the thorax, where it is seen on the inferior surface of the bodies of the dorsal vertebræ, between the aorta and azogous vein—the last being to its right side. By degrees it inclines to the left, at the same time diminishing in size, until it arrives at the third dorsal vertebra, where, passing above the arch of the aorta, it comes into contact with the gullet, between the left side of which and the pleura it lies; it then reaches the level of the point of union between the left subclavian vein and left jugular vein, without any arch such as there is in the human body. There are very few valves in the thoracic duct of the ox. In man the lymphatics and lacteals do not appear to reach the great trunks without passing through conglobate glands. It has been affirmed that in animals like the ox exceptions to this rule are very numerous.

Lymphatic Duct.—The right lymphatic duct is a shorter and smaller vessel than the thoracic duct. It is formed entirely by the successive junction of lymphatic vessels, and does not receive any lacteal vessels. It receives the lymphatics from the right anterior extremity; from the right side of the head and neck; from the right side of the chest; from the right half of the lung and heart; and from the upper surface of the liver. It ends in the angle formed by the right subclavian vein and the right jugular vein, in a manner corresponding to the termination of the thoracic duct. A lacteal vessel, according to the most recent views, arises in a villus of the intestine, by a plexus of minute tubes. Both the lacteals and lymphatics are freely furnished with valves resembling the valves of the veins. The mesenteric glands, through which the lacteal vessels pass before reaching the great trunks, closely resemble the lymphatic or conglobate glands, called also lymphatic ganglia. A lymphatic gland is described as varying from the size of a hemp-seed to that of a kidney bean; and as to shape, these glands are either round or oval.

Absorbent Glands.—An absorbent or conglobate gland has an external coat formed of areolar, that is, of cellular tissue, including, as usual, elastic fibres and their formative cells, and even sometimes muscular fibres of the plain variety. The outer coat is perfect, unless where it gives passage to the absorbents themselves and the larger blood-vessels. This part of the gland, presenting a fissure or depression, is called the hilum. The gland itself is composed of an outer cortical part, and an inner medullary part. The cortical part surrounds the medullary part, except at the hilum, and in large glands attains a considerable thickness. From the outer areolar coat numerous thin partitions run inwards, so as to form many loculaments of a polygonal figure. These loculaments are filled with a whitish pulpy matter made up of cells and nuclei, identical in character with the corpuscles of the lymph and chyle. When this substance is washed out, each loculament is seen to be crossed in all directions by numerous fine columns or trabeculæ, subdividing its interior into a great many smaller intercommunicating cavities, and giving origin to a spongy structure, in the meshes of which the pulpy matter is lodged. Fine capillary blood-vessels are supported within by the larger trabeculæ.

This spongy structure belongs only to the cortical part of the gland. The medullary part in the centre of the gland consists of a plexus of absorbent vessels which directly communicate with the absorbent trunks, which issue from the gland at the hilum. It should be borne in mind that the lacteals which enter a conglobate gland are termed the afferent vessels (*vasa afferentia*), and those which issue efferent vessels (*vasa efferentia*). It appears, then, that the afferent vessels enter the gland at various points of its surface, and open by fine branches into the meshes of the spongy structure of the cortical part; and that other fine vessels take their rise from the cavities of that spongy structure, and pass to the central plexus in the medullary part, whence the efferent vessels originate, and these pass out solely by the hilum by which the blood-vessels enter and issue.

Chyle.—Thus there is reason to think that the chyle is poured by the afferent vessels into the cavities of the spongy structure, from which it passes by minute lymphatic branches into the central lymphatic plexus, to be conveyed thence by the efferent vessels, and out of the gland by the hilum. Thus the pulpy matter in the cavities of the spongy structure is chyle, and as the chyle is richer in corpuscles when it issues from a gland than before it enters, fresh corpuscles must be produced in the glandular cavities from the blood-plasma supplied by the numerous capillaries. Thus the new or crude chyle brought from the intestines is mingled with the perfected matter directly derived from the blood, in accordance with what seems a rule in organic life—namely, that the material of repair newly derived from aliment is mingled with material forming already a part of the organism before it is ready to become itself assimilated, and taken up as an integral part of the living structure.

A recapitulation was already given of the process of nutrition in the horse in terms so general as to apply almost word for word to that process in the ox. Instead of repeating that statement here, we refer our readers to the passage in question at p. 81.

ORGANS OF NUTRITION IN THE SHEEP.

Mouth and Teeth.—The mouth extends from the lips in front to the pharynx or commencement of the alimentary canal behind. Its sides are formed by the cheeks, its base by the tongue, its upper part by the hard palate anteriorly, and posteriorly by the soft palate or veil of the palate.

Like the horse and ox, the sheep has a set of deciduous or milk teeth. The teeth of the sheep, both deciduous and permanent, as in the ox, are fewer than in the horse. This is owing, in particular, to the defect of incisor teeth in the upper jaw—a deficiency which belongs to ruminants in general. Neither has a sheep canine teeth or tushes—a deficiency which also is common to ruminants in general, with the exception of some of the deer tribe, as the stag and the musk-deer. As in mammals generally, with the exception of man, there is a long space in the lower jaw destitute of teeth—namely, between the incisor most distant from the centre, and the most forward of the molar or back teeth.

Like the ox, the sheep has the same number of teeth as man, the number in the adult sheep being thirty-two. The teeth in the sheep conform to very much the same rule as in the ox. There are, in the lower jaw of the sheep, eight incisors. This is the same number of incisors as are in man, the difference being that in man there are four incisors in the under jaw and four in the upper jaw, while in the sheep all the eight incisors are in the under jaw. In the sheep there are twenty-four back teeth or grinding teeth—that is, four more such teeth than man has; but the deficiency in the sheep of canine teeth, of which man has four, reduces the whole number of the teeth to the same number as in man—namely, thirty-two. The three anterior molar teeth on each side in the sheep, like the two anterior molar teeth in man, having only two tubercles, are termed bicuspid teeth or false molars.

The milk teeth in the sheep are, as in man and in the ox, twenty in number—namely, eight incisors in the lower jaw, or the same as the number of the permanent incisors, while the milk molar teeth are only three on each side of each jaw, or twelve in all. The milk molars in the sheep differ from the permanent molars which replace them, by being longer from before backward than in the cross direction. The two central incisors come out before birth, or a few days after birth, and change eighteen months after birth; the incisor on each side of these comes out as early, but does not change till thirty months after birth; the third incisor, on each side, comes out about fourteen days after birth, and changes at forty-two months after birth; the fourth, or corner incisor, on each side, comes out from six to nine months after birth, and changes about fifty-four months after birth. The three milk molars on each side of each jaw come out before or a few days after birth, and are shed, the first at eighteen months after birth, the second at thirty-two months after birth, and the third at forty months after birth. The first permanent molar comes out from six to nine months after birth, the second at thirty-two months after birth, the third does not come out till the fifth year of the sheep's age.

In the teeth of the sheep, enamel, cement or petrous crust, and dentine, occur as in the horse and in the ox, and the arrangement therein of these three substances is so similar to that already fully described under the title "Teeth of the Horse" (p. 13), that it would be a waste of time to go over the subject again. The same remark applies to all the other particulars of interest in regard to the teeth of the sheep.

The roof of the mouth in the sheep, as in man, is formed by the upper jaw-bone and the palate-bone on each side; while, however, it differs from the human structure in having immediately behind the upper lip the intermaxillary bone, made a pair under the name of anterior maxillaries. In the sheep, as in other ruminants, the intermaxillary bone differs from the corresponding bone in the horse by being destitute of upper incisor teeth. The superior maxillary bone in the sheep has extensive connections entering into the nose and the orbit as well as into the mouth. As in the horse, and as in the ruminants in general, it is comparatively short, but very broad and high. The palate-bones form the posterior part of the palate, and assist in forming the communication between the nose and the posterior part of the mouth. At the posterior part of the mouth their palate-plates hardly meet in the mesial line.

The lining of the roof of the mouth is a dense fibrous structure covered with mucous membrane. The veil of the palate is, as in most animals but man, destitute of uvula.

Tongue.—The tongue in the sheep does not offer anything very different from the tongue in the ox. It is similarly composed of muscular parts, some of which terminate within the organ, others extend to adjacent parts. It has similar papillæ on the surface of its investing mucous membrane. The sheep does not use the tongue so much as the ox in seizing the tuft of grass. The hyoid bone, or bone of the tongue, has a like position and a like use as in the ox (p. 87).

Salivary Glands.—The salivary glands are large, as in the ox: they bear the same names, have the like structure, and hold the same anatomical relations. The buccal and labial glands are large in the sheep, as in ruminants generally—in particular the posterior buccal glands, which are situated in the substance of the buccinator muscle, united with each other into several considerable masses, communicate with the mouth by several rather long ducts. The amygdalæ are of considerable size, with ducts putting on the appearance of papillæ at their openings into the mouth.

The secretion of the salivary glands in the sheep is proved to correspond in its general chemical character with the saliva of the ox and the horse. Sulphocyanide of potassium and ptyalin have been detected in the sheep's saliva as in that of other mammals. It must be confessed, however, that the saliva in the sheep has not drawn so much attention as that of the horse and dog.

Lips.—The lips in the sheep are of the same structure as in the horse and in the ox—muscular within, the muscular fibres being enclosed between skin and mucous membrane. In the mucous membrane glandular bodies are imbedded, which pour forth a peculiar secretion to mingle with the saliva. The muscles of the lips and mouth in such animals as the sheep differ considerably from the corresponding muscles in man. The orbicular muscle, or sphincter of the mouth, is very thick, but is small comparatively. The common levator of the ala of the nose and of the upper lip is confounded with the proper levator of the upper lip. The levator of the angle of the mouth, small and elongated, descends almost vertically from above and behind, downwards and forwards. The zygomatic muscle, long and thick, but narrow, arises by a long and narrow tendon. The buccinator, or alveolo-labial, which is of great thickness, is much elongated. The depression of the lower lip is not determined by proper muscles, but is accomplished by a very thin portion of the cutaneous muscle (platysma myoides), which passes over the buccinator, to become confounded with the orbicular muscle of the lips. The temporal muscle, notwithstanding its important use in mastication, though thick, is very small. The masseter is very large and of moderate thickness: it consists of two layers, the external being highly tendinous; the internal small, and of a triangular form. The internal pterygoid is long, broad, and of medium thickness; the external pterygoid is very thick and of moderate length, passing in a transverse direction. The digastric is small: its anterior belly is very much larger than its posterior, and is attached to the posterior third of the lower jaw. In the ox there is a square muscle extended from one digastric to the other. The lips are much used by sheep in grazing the pasture.

Cheek.—The buccinator, or alveolo-labialis, is the muscle of the cheek, and by the simultaneous contraction of these muscles on the opposite sides the cavity of the mouth is diminished.

Lower Jaw.—The lower jaw in the sheep has very much the same characters as in the ox. The proportions between the ascending and the horizontal portions are very much the same. The height of the ascending portion equals nearly half the length of the horizontal portion. The coronoid process, which is long and narrow, and curved upwards and backwards, is situated immediately before the articular surface. The condyloid process is more than twice as broad from without inwards as from before backwards. Its central part is somewhat concave—its lateral parts convex. The horizontal portion of the jaw is slightly contracted in front of the molar teeth, from above downwards and from within outwards; it becomes thicker again more forwards, where it supports the incisor teeth, uniting itself to its fellow of the opposite side at an acute angle.

The motions of the lower jaw in the sheep correspond very closely with those of the same bone in the ox: the lateral motion is very conspicuous, as concerned in the slow grinding process to which the semi-dissolved aliment is subjected in rumination.

Pharynx.—The pharynx—that is, the expanded upper part of the alimentary canal—a funnel-shaped muscular bag, lined with mucous membrane, and attached to many adjacent parts by muscular fibres, has very much the same character in quadrupeds like the sheep as in man. For the most part, however, its muscularity is proportionately greater than in man, owing probably to the superior force required for deglutition in the position of their bodies, in which less aid is derived from mere gravitation. In the first stage of deglutition (p. 31), the masticated food is collected on the tongue and pressed backwards towards its base; in the second stage, it is precipitated from the base of the tongue across the orifice of the windpipe into the pharynx: thus the pharynx is concerned in the third or last stage of deglutition, in which stage the gullet also takes a part.

Gullet.—The gullet or œsophagus is the most muscular part of the whole alimentary canal, or, to use an old expression, of the *primæ viæ.* The gullet is lined with mucous membrane. Its muscular fibres, as in the ox, are arranged spirally in opposite directions, with turns so close that one partially covers another. These fibres in the sheep may be described as forming two layers, each having an opposite direction. Thus the fibres of the internal layer turn from behind forwards, while those of the external layer turn from before backwards. It was for a long time supposed that this double direction of the muscular fibres in the gullet of the sheep and ox had some reference to the act of rumination; but it is now ascertained that a similar double arrangement exists in animals that do not ruminate, as in the horse, the cat, the dog, the bear, the seal.

Blood-Vessels.—The several parts of the mouth and throat obtain their nutrition from the blood supplied by branches of the external carotid artery, and, as far as the gullet is concerned, by branches from the posterior aorta. For some more particular account of these it will be sufficient to refer to what was said of the arteries distributed to the corresponding parts in the horse (p. 25-29). The same observation applies to the veins and nerves.

Organs of Digestion in the Abdominal Cavity of the Sheep.—The changes which take place on the food in the mouth of the sheep, as in the ox, are principally accomplished after it has been swallowed, and has been subjected for some time to certain operations in the first and in the second stomach, when it is again brought back to the mouth for a new mastication and insalivation.

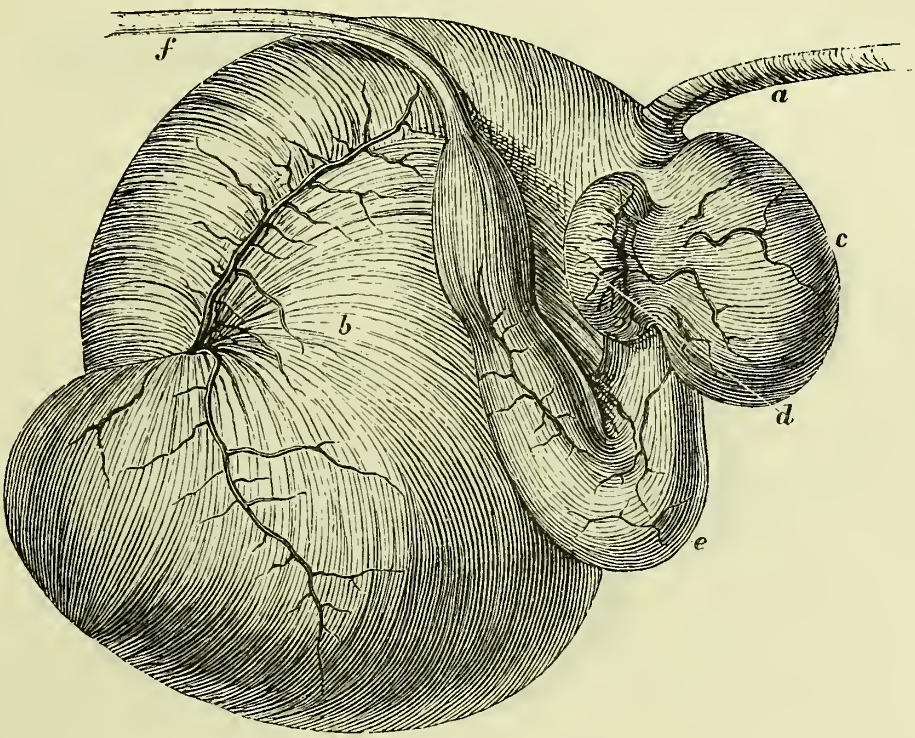
Saliva.—The saliva appears to perform very important offices in ruminating animals in respect to the first changes to which the aliment is subjected. Thus the saliva is not only mingled with the food in the first imperfect mastication, but it is swallowed unceasingly during the period which intervenes between grazing the pasture and the commencement of regurgitation, so as to exert an effect on the aliment in the first and second stomachs; and, finally, during the act of chewing the cud, the new insalivation must be one of the most efficient parts of the process.

Rumination.—Under the head of "Rumination" in the ox, some account has been given of the four stomachs and their function in digestion, all of which is also applicable to the sheep (p. 100). In the following description of rumination in the sheep, a somewhat fuller view has been taken, so that the one account may serve to illustrate the other, and both tend to explain the obscurities that may occur in this somewhat difficult subject.

The ruminating animal swallows at first aliment which it has barely masticated; it brings back this aliment again to the mouth to reduce and masticate the same more completely; and after having thus reduced and masticated the regurgitated aliment, it swallows it for the second and last time. The aspect of the process at once is seen to be complex, and its complexity does not diminish on inspecting the organs concerned. To borrow the sentiments of a distinguished anatomist—"Ruminants have four stomachs, and each of these stomachs has a proper structure, whence one might conclude that each stomach has a separate function. But what is that function? That is what the relative connections of these several stomachs, both with each other and with the gullet, seem designed to conceal."

Stomachs.—The two first stomachs are placed parallel to each other, or on a level the one with the other, and the gullet ends almost equally in each. Then the gullet is prolonged in the form of a gutter or demi-canal; and this demi-canal ends almost equally in two of the stomachs—namely, the second and the third. Lastly, all these parts—the gullet, the demi-canal of the gullet, the first, the second, and the third stomach—not

Fig. 12.

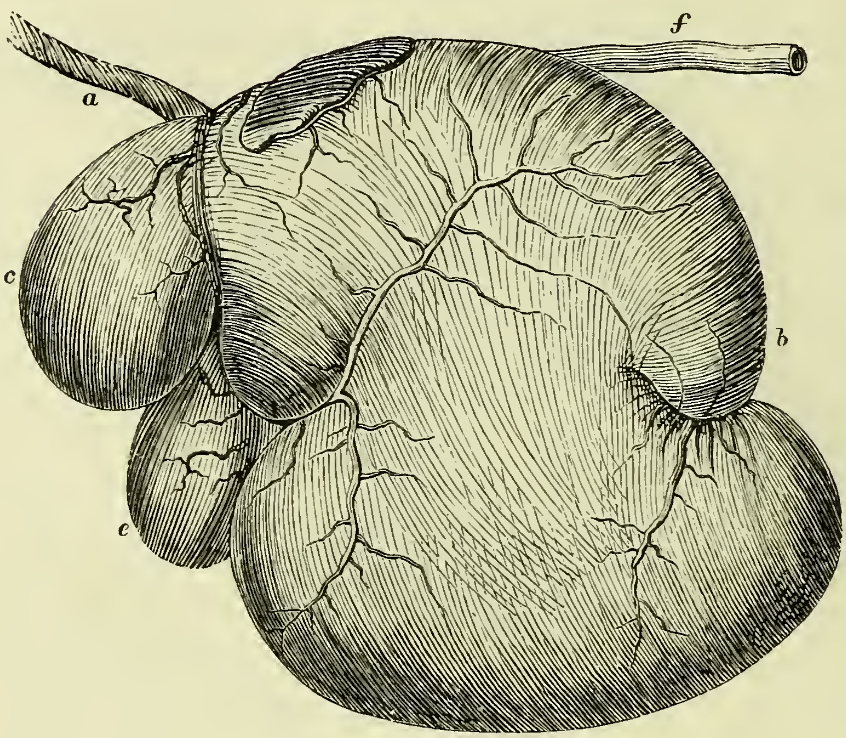


Right View of the Stomachs in the Sheep.

a, Œsophagus; *b*, rumen or paunch; *c*, reticulum or honeycomb; *d*, omasum or manyplies; *e*, abomasum or true stomach; *f*, duodenum.

only communicate with each other, but all communicate at one common point—the point, namely, where the gullet terminates, and where its demi-canal begins, and towards which the three stomachs open or abut. Thus anatomy does not show into which stomach the aliment passes in the first deglutition, for the gullet conducts almost equally into the first stomach and into the second. Neither does anatomy determine what parts are concerned in returning the altered aliment to the mouth; for all the parts which can be conjectured to produce this effect—namely, the gullet, the demi-canal of the gullet, the first stomach and the second stomach—abut on the same point—that point, namely, where the effect, that is, the rejection, occurs. Again, anatomy does not indicate into which of the remoter

Fig. 13.



Left View of the Stomachs in the Sheep.

a, Œsophagus; *b*, rumen; *c*, reticulum; *d*, omasum, not seen; *e*, abomasum *f*, duodenum.

stomachs the ruminated aliment is returned; for the demi-canal of the gullet, which manifestly takes the chief share in this act, abuts almost equally on the second and third stomachs, just as the gullet itself abuts almost equally on the first and second. The anatomical structure thus leaves everything in doubt. It is not surprising, then, that very contradictory views have been entertained by anatomists in past times as to the proper mechanism of rumination.

The four stomachs in the sheep have a similar relative position, and the same names as in the ox. The first is the paunch or rūmen; the second is the honeycomb or kingshood; the third is the manyplies or psalterium; and the fourth is the red or rennet. The paunch, the honeycomb, and the manyplies communicate with the gullet by a common opening.

The muscular tunic is of moderate thickness in all the four stomachs. The mucous membrane in the three first stomachs has a covering of epithelium easily separable, of which there is no vestige in the tender vascular mucous membrane of the fourth stomach.

The paunch is by far the largest of the four stomachs. It is four times larger than all the other three put together. It has somewhat of a cubical form, with the angles rounded off. It has, near the middle of its left aspect, a contraction more or less determinate dividing that aspect into two portions—the one anterior, the other posterior—each being drawn into a short blunt point. A like contraction is observable on the right aspect, which presents the appearance of a furrow directed obliquely from right to left, and from before backwards. It lengthens the greater part of the inferior aspect of this portion, and makes an imperfect separation of the right anterior small part of the paunch—namely, that which receives the gullet—from the left and posterior portion, which is also the largest. The presence of these two contractions gives to this stomach the appearance of being twisted into a spiral form like the italic *S*. The internal surface of the paunch is rough, with a multitude of lamellar pulpy prominences compressed and close together, so that its surface is uneven. The size of these prominences, as well as their form, varies much in different situations. They are much more developed in the right anterior sixth of the paunch than anywhere else. The interspaces of the larger papillæ are filled up by others of less size. They are all elongated, and adhere to the mucous membrane by a narrow base. While these belong to the paunch in ruminants generally, in the sheep they are often six lines long and two lines in breadth. To the right, and posteriorly, they are much less prominent, but proportionately broader. As the eye is carried towards the base of this part of the stomach, it meets some of almost as great a size as at the anterior part. In the anterior portion of the left half these prominences are smaller than anywhere else, their vertical diameter being there no more than a line; those, on the other hand, which occupy the blunted point of this portion have the same, or nearly the same, magnitude as the prominences of the anterior left portion.

The right half of the paunch is divided from the left by a longitudinal ridge, smooth throughout, extending from the contraction that separates the left border into two halves as far as the middle of the length of the paunch.

An analogous ridge of a circular form is seen to the right; it divides the corresponding half of the paunch into two parts, the one anterior and small, the other posterior and much larger. Towards the middle of the length of this last part a third ridge is met with like the preceding, but somewhat less distinct, which divides this portion into two other portions, the one anterior, the other posterior. Nevertheless all these ridges, while not very apparent even in the collapsed and empty state of the paunch, disappear almost entirely when the organ is distended with aliment.

In front and to the right of the paunch the second stomach —the reticulum, the honeycomb, or kingshood—is observed. This second stomach communicates with the gullet by the same orifice as the paunch. This stomach is in effect nothing more than an appendage of the paunch, with which it communicates by a large opening. Placed on the inferior or ventral aspect of the stomachs, this sac is but imperfectly separated from the paunch by an almost imperceptible ridge like those described as being on the first stomach. Beginning at the posterior side of the circumference of the cardiac orifice, this ridge is directed first to the right and backwards, and then passes above the inferior aspect of the paunch to the left and forwards.

Quite close to this ridge, at the circumference of the orifice of this stomach, above all inferiorly and posteriorly, are seen long prominences, quite resembling those which occupy the anterior right portion of the paunch. As to the internal surface of the second stomach, it presents a multitude of cells almost rounded, having every one five or six angles arranged systematically in groups. These cells are surrounded by partitions which are very prominent, narrow, and rough, with close-set papillæ, elongated and of a triangular figure. The bottom of the cells exhibits a great number of analogous papillæ. The cells increase considerably from before backwards in number and size, their size here being eight or ten times that of the commencement of the texture. For this organisation develops itself by degrees in proportion as the distance is greater from the paunch and from the circumference of the second stomach, of which last part this organisation is, in some measure, but a transformation. One may see, in short, the lamellar villosities at first rudely join, then approach each other in a manner to constitute by their union the partitions of the cells; while others, much smaller, remain isolated, and form a prominence in the bottom of the cells. Further, the toothed-like structure of the partitions of the cells should suffice of itself to prove the affinity which exists between these two orders of villosities. It happens often, more particularly behind, that the interior of the cells is traversed by other less-marked prominences, which, in some measure, form rudimentary partitions, so as to divide the cavity into two, three, or four little cells.

To the right, above and before the second stomach, is the manyplies or psalterium, which in the sheep has the smallest capacity of all the four stomachs. It has less than a third part of the capacity of the second stomach. It communicates with the second stomach by a narrow aperture. It communicates with the gullet. It is in connection with the orifice of the gullet by the sixth part of its circumference. It is this insertion into the gullet which constitutes the true origin of the third stomach. At this place are seen to arise two strong ridges, the one in front, the other behind, which are directed from before backwards, and from left to right, passing before the front aperture of the second stomach. The two ridges by their relative position form a species of narrow demi-canal, which proceeds to open into the third stomach, by means of which, when the two borders of the demi-canal cling the one to the other, the aliment, without passing into the second stomach, can directly reach the third stomach.

The internal surface of the third stomach is overspread with a considerable number of very distinct longitudinal folds differing in size, projecting farther in the middle than anywhere else. These encroach a good deal on the capacity of the cavity, yet they very notably enlarge the extent of its surface. The two surfaces of these folds, as well as their free margin, are beset with triangular indentations, which do not differ from those of the second stomach otherwise than by the very much greater width of the spaces which separate them. Such of these indentations as are in front are much larger than the rest. The indentations that are in the demi-canal are widely distant from one another. By reason of these indentations the third stomach resembles the second. As to the longitudinal folds, they may be very well regarded as decomposed cells.

The fourth stomach, the red or rennet, comes immediately after the third, with which it communicates by a pretty large opening situated at the right extremity of the manyplies, and opposite to its œsophageal orifice. The fourth stomach is of the same size as the honeycomb, but it differs from the other stomachs by its oval form, and by a considerable diminution of its diameter as that approaches the right side. The fourth stomach opens straight into the commencement of the small intestine. The internal surface of this stomach has longitudinal folds analogous to those of the manyplies, yet less prominent, and entirely destitute of indentations. These folds communicate together by means of small transverse or oblique processes. Towards the pyloric extremity of the stomach the muscular tunic becomes increased considerably in thickness, so as in no small degree to contract the opening. In the ox, the stag, the camel, the lama, as well as in the sheep, there is besides in the superior and posterior part of the first portion of the duodenum a rounded collar formed by the lining membrane, which occasions a very sensible diminution of width in the pyloric orifice: there is no such collar in the human structure.*

Rumination.—To explain the mechanism of rumination, three questions require an answer: first, What are the stomachs to which the aliment passes during the first digestion? secondly, What are the parts which determine its rejection? thirdly, What are the stomachs to which the aliment is transmitted in the second digestion?

The answers to these three questions are now, owing to the exact experiments of Flourens, very satisfactory. The aliment which is swallowed for the first time goes exclusively into the first and second stomachs. The aliment which has been ruminated—that is to say, the aliment which is swallowed for the

* Meckel, 'Anatomie Comparée,' tom. ix. p. 433-441.

second time, passes, at least in part, into the third and fourth stomachs. And as to the mechanism by which the one or the other of these two effects is produced, it is discovered that there are two distinct modes of deglutition—the one that of the gullet alone, which carries the aliment into the first and second stomachs; and the other that of the demi-canal of the gullet, which conducts the ruminated aliment to the third and fourth stomachs. Thus the non-ruminated aliment by the first mode of deglutition gains access to the first and second stomachs, and the ruminated aliment by the second mode of deglutition arrives in the third and fourth stomachs. In more general terms, it may be stated that non-ruminated aliment, or any aliment which has not undergone sufficient comminution and reduction, so that it still preserves a certain resistant bulk, takes the first mode of deglutition, because by its bulk it dilates the lower aperture of the gullet, and is carried directly into the two first stomachs to which that aperture leads; on the other hand, the ruminated aliment—or aliment, if not ruminated, which is already comminuted and reduced or fluid—takes the second mode of deglutition, because, not being sufficient by its resistant bulk to open the inferior aperture of the gullet, it finds no other passage open but that of the demi-canal of the gullet, by which it is carried straight into the third stomach, and through it into the fourth stomach.

Flourens has given ample proof of the correctness of this statement. For example, if a sheep is opened immediately after eating common food, that food is found partly in the first and partly in the second stomach; but none is found in the third stomach, or in the fourth stomach. In this experiment a larger proportion of the food employed is found in the paunch, a smaller proportion in the honeycomb. When the food is reduced to a pulp before being given to the sheep—for example, carrots reduced to a pulp—a part of the pulp, and the larger part, is found in the first and second stomachs, and another part in the third and in the fourth stomachs.

In making such experiments there was always found in the two first stomachs, besides the food eaten just before the sheep was opened, alimentary matters which had been previously swallowed—some still dry and unreduced, others reduced and fluid, the proportion of the unreduced being always greater in the paunch, and that of the reduced greater in the honeycomb.

Another series of experiments gives further proof of the true mechanism of the stomachs in ruminants like the sheep. It is practicable to make each of the stomachs communicate directly from without while the animal still lives, and freely eats and drinks. When such an aperture has been made in the first stomach, and food is put before the animal, it eats and swallows, and part of the food immediately issues by the aperture. And if the finger is introduced through the aperture into the paunch, the food is felt arriving in the paunch as it is given up by the gullet. If such an aperture has been effected in the second stomach, when the sheep eats a part of the food issues forth by the aperture; and the finger introduced into the honeycomb by the aperture feels the food enter that stomach as it passes from the gullet. These two forms of experiment confirm the belief that the food in the first deglutition passes, though in different proportions, into the first and also into the second stomach. Yet there are experiments which show that the food passes from the paunch into the honeycomb, and from the honeycomb into the paunch. Thus, if an aperture is made into each of these two stomachs—that is, one aperture into the paunch and another aperture into the honeycomb—the finger, introduced alternately into the one and the other aperture while the animal is eating, discovers the aliment coming now into the paunch, now into the honeycomb; but if the finger is thus alternately introduced into the one and the other aperture while the animal is neither eating nor ruminating, at the moment when a slight movement of the abdomen is perceived the finger in the paunch is sensible of a contraction in it also ; and if the finger is quickly transferred to the honeycomb, food is discovered to be passing from the paunch into the honeycomb. Moreover, if a substance be introduced on the left side of the body of the animal into the paunch by the artificial aperture, this substance, after a certain time, more or less altered, issues by the artificial aperture in the honeycomb on the right side of the animal. Thus not only does the aliment swallowed in the first deglutition pass, some part into the paunch, some part into the honeycomb, but the aliment also passes, with the aid of the contraction of the abdominal muscles, at least from the paunch into the honeycomb, if not also from the honeycomb into the paunch, independently either of deglutition or rumination.

But to proceed to what happens during the second deglutition. When the finger is introduced into the paunch through the artificial opening, during rumination, portions of the ruminated aliment are discovered at intervals to enter the paunch ; and the same thing is observed with respect to the honeycomb when the finger is transferred thither by the artificial aperture belonging to it ; and when the margins of the aperture into the honeycomb are held aside, a part of the ruminated aliment is seen to take the course of the demi-canal of the gullet, and to pass at once into the manyplies. Thus, in the second deglutition, while rumination is going on, the first and second stomachs do receive a portion of the ruminated aliment, and the rest of it passes at once by the demi-canal into the third stomach.

It appears to be a mistake to say that, in drinking, the liquid passes at once in totality into the third stomach, and so into the fourth. If there be an artificial aperture in the paunch, the liquid, when the animal drinks, issues copiously from the paunch; if there be an artificial opening in the honeycomb, or in the manyplies, or in the red, the liquid, when the animal drinks, issues copiously by the aperture whatever be the stomach in which it exists. Hence the proper conclusion seems to be that, in drinking, the water passes into all the stomachs.

It is manifest from what has been already stated that the two first stomachs must be the only stomachs concerned in the regurgitation of the macerated aliment for rumination; the only question that remains is whether these act merely by their own contractile force or derive aid from without.

When the stomachs are laid bare in a living sheep, their contractile power, under irritation, is found to be very slight; but when, on the other hand, a finger is introduced through an artificial aperture leading into any one of the four stomachs, the contraction is felt to be very forcible, particularly in the paunch and the honeycomb, during the regurgitation of the aliment for rumination. As to the effect of the parietes of the abdominal cavity in aiding the regurgitation of the aliment for rumination, Flourens draws the following conclusions from his experiments:—1. The section of the diaphragmatic nerves, in the living animal, enfeebles rumination. 2. The section of the spinal marrow, which destroys the contraction of the abdominal muscles, destroys rumination. 3. The section of the nerves of the eighth pair of cerebral nerves not only prevents the animal from ruminating, but even prevents it from eating and drinking. These effects are such as might have been anticipated from the known influence of the abdominal muscles and diaphragm in the rejection of the contents of the stomach in animals in general, as well as from the established facts regarding the uses of that pair of nerves in digestion.

It is to be remarked, however, that the regurgitation of the aliment in rumination is not the rejection *en masse* of the contents of the stomach, like what occurs in ordinary vomiting. It has long been remarked that in rumination a portion of the mass of the aliment is detached, rounded, and moistened by some means before entering the gullet, to return into the mouth. It was formerly believed that the honeycomb is the agent in this process, "that the second stomach detaches a portion of the mass of the aliment received into the paunch, that it rounds that portion, moistens it, compresses it, and forms it into a pellet," before it ascends by the gullet for rumination.

Flourens has proved by his experiments that rounded pellets are detached from the aliment received into the paunch, and that these rounded pellets ascend to the mouth for rumination; but his experiments also demonstrate that these rounded pellets are not formed in the second stomach.

According to Flourens, then, these rounded pellets are formed between the demi-canal and the openings of the gullet into the first and second stomachs. To understand this, it must be remembered that the demi-canal extends from the opening of the gullet to that of the manyplies; that when the canal contracts, it makes the one of these two apertures approach to the other; that of these two apertures, the one, that of the gullet, is commonly closed, and that the other, that of the manyplies, naturally narrow, can become more close and also shut itself by its proper contraction; that when the two first stomachs, compressed by the abdominal muscles and diaphragm, contract, they push all at once the matters which they contain both against the two openings opposed to each other and against the demi-canal which is opposed to these stomachs. Thus the two first stomachs, by contracting, push the aliment contained in them between the lips of the demi-canal; and the demi-canal, contracting in its turn, brings the two openings nearer—namely, the opening into the manyplies and the opening into the gullet; and these two openings being shut and brought together at this instant, a portion of the aliment is seized and detached in the form of a pellet.

On the one hand, this pellet is detached; but it cannot be seized by the two openings jointly without being detached from the mass of aliment. On the other hand, this pellet is round; but this rounded form is exactly that of the apparatus by which it is formed when this apparatus is in action; that is to say, when the demi-canal, by contracting, brings the two apertures nearer the one to the other. Lastly, this pellet is about an inch in diameter; and an inch is also nearly the extent of the demi-canal when it contracts.

To recapitulate the whole process. Unless the food, after a first imperfect mastication, be of a pulpy character, none of it passes into the third and fourth stomachs, it all goes into the first and second stomachs; but if the food, after this first imperfect mastication, be of a pulpy character, it goes in part into all the four stomachs. When the coarser kind of aliment has been sufficiently macerated in the first and second stomachs, with the aid of the saliva continually swallowed during the interval between eating and ruminating, it is thrown into the demi-canal by the contraction of the first and second stomachs, aided by the contraction of the abdominal muscles and diaphragm; then the demi-canal contracts, and, moulding its contents to the shape of its narrowed and shortened form, converts this separated portion of the aliment into a pellet, and at the same time throws the pellet into the gullet, by the inverted action of which it is transmitted to the mouth for rumination—that is, for a second mastication and insalivation. In the second deglutition the ruminated aliment passes partly into the first, partly into the second stomach, and by the demi-canal partly into the third stomach, to be from the third transmitted into the fourth stomach for complete digestion. Such is an abridged view of the elaborate statement of Flourens as to the process of rumination in the sheep.

The end served by all this complex process is doubtless the more complete subjection of the aliment to the effect of mastication and insalivation, and, finally, to the influence of the secretions of the several layers of membranous tissue, the chief of which is the gastric juice finally supplied by the fourth stomach, or red. From the fourth stomach the chyme there formed is transmitted into the upper part of the small intestines or duodenum.

Intestines of the Sheep.—The intestines of the sheep, as already noticed (p. 5), are of extreme length. The duodenum is large, and forms a kind of pouch ; the colon and cæcum are of moderate size ; the colon is uniform on its surface, and has no ligaments tacking it up into cells. A great part of the intestines form concentric turns without showing much difference in respect to size. At the commencement of the colon its diameter is about five times greater than that of the small intestines ; but, finally, its diameter hardly exceeds that of the small intestine. The cæcum is simple, of considerable length, terminating in a blunt point. It has no cells ; it is much greater in diameter than the adjoining part of the small intestine, having a diameter equal to that of the colon. The capacity of the cæcum is very much the same as that of the fourth stomach, which it somewhat exceeds in length.

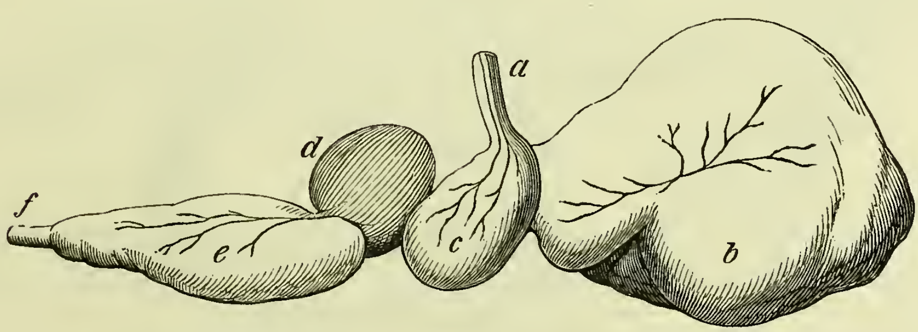
The small intestine undergoes a great number of circumvolutions, and is held in its place by a very short mesentery. It is not of great diameter, and is remarkable for the thinness of its coats. The internal or mucous coat is not so strikingly villous, except in the lower or posterior part of its course.

The great intestine is first directed forwards in the form of a considerable arch, it then passes backwards, where it undergoes the sensible diminution of diameter just referred to, and forms a great number of circumvolutions, narrow, elongated, and concentric, all the while diminishing its diameter, which, however, at length enlarges. At the root of the mesentery it turns again forward, describing a second large arch ; then a second turn to the left and behind, when it terminates in the rectum. The internal surface of the great intestine is remarkably smooth. On the external surface there are no irregularities occasioned by cells.

The coats of the stomach and bowels in the sheep are the same as in the higher mammals generally—namely, an internal mucous, a muscular and an external serous, a part of the general shut sac of the abdominal peritoneum, of which an account has already been given under the horse (p. 55), and the ox (p. 106).

The stomachs of the sheep placed in a straight line are distinctly represented in fig. 14.

Fig. 14.



The Stomachs of the Sheep in a Straight Line.

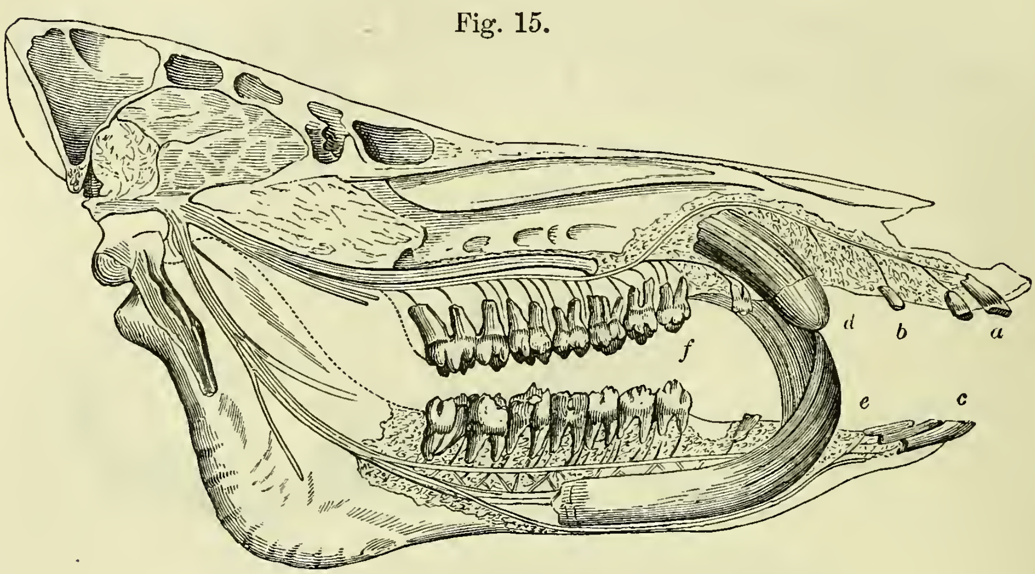
a, Œsophagus; *b*, paunch; *c*, reticulum or honeycomb; *d*, omasum or manyplies; *e*, abomasum or red; *f*, pylorus.

It were needless to speak of the liver, pancreas, spleen, the lacteals, and mesenteric glands in the sheep, after the full account given of these organs under the horse (pp. 59, 65) and the ox (pp. 109, 110, 118, 119, 131, 132.)

ORGANS OF NUTRITION IN THE PIG.

Teeth.—Of the parts composing the mouth the teeth stand first in order. The pig, like other mammals, has a set of milk teeth which precede the permanent teeth. According to the newest views on the subject of the teeth in mammals, those are incisor teeth which are inserted in the intermaxillary or premaxillary bone of the upper jaw, and in the corresponding part of the lower jaw, whatever be their shape or size.* The tooth which is situated in the maxillary bone, at or near the suture with the premaxillary, is the "canine tooth," as is also the tooth in the lower jaw, which, in opposing it, passes in

Fig. 15.



VERTICAL SECTION OF THE HEAD OF THE PIG.

a, Superior incisors; *b*, superior lateral incisor; *c*, inferior incisors; *d*, upper canine or defence tusk; *e*, inferior canine or defence tusk; *f*, superior and inferior molars. The course of the nerves may be distinctly traced in the figure.

front of its crown when the mouth is shut. The other teeth of the first set are "the deciduous molars;" the teeth which displace and succeed them vertically are the premolars. The

* Owen.

posterior teeth, which are not displaced by vertical successors, are the "molars," properly so called.*

"The hog is one of the few existing quadrupeds," says Owen, "which retain the typical number and kinds of teeth. Examples of the typical dentition are exceptions in the actual creation; but it was the rule in the forms of mammalia first introduced into this planet, and that, too, whether the teeth were modified for animal or vegetable food."

In the pig the teeth are numerous—more numerous than in man or in the horse—the permanent teeth amounting to forty-four. These forty-four permanent teeth are equally divided between the upper and the under jaw, so that there are twenty-two teeth in each. The twenty-two teeth in each jaw consist of incisors, canine or tusks, premolar or false molar, and molar or true molar. The number of each kind is the same in both jaws—namely, six incisors; two canine, one on each side; eight premolar, four on each side; and six molar, three on each side; so that there are in all in the pig, of permanent teeth, twelve incisors, four canine, sixteen premolar, and twelve molar.

The incisors in the lower jaw, says Youatt, are long, round, and nearly straight; of those in the upper jaw, four closely resemble the corresponding teeth in the horse; while the outer incisor on each side has some resemblance to the *fleur-de-lis* shape of those of the dog. These last sometimes come so near to the canine as to obstruct their growth.

The seven molars on each side of each jaw—namely, four premolars and three true molars—augment from before backwards so rapidly that the last has at least fifty times the bulk of the first. The anterior teeth of these seven are of a more simple configuration than the posterior, being flattened laterally and pointed in the middle. The posterior present four, and the

* Owen.

last of all, which are so much more voluminous, seven great points, without counting points of smaller size. The farthest back of these points is an odd one, and all are traversed by longitudinal grooves, while the spaces between the great points are occupied by smaller ones.

In the pig there are thirty-two milk-teeth—namely, twelve incisors, four canine, and sixteen false or premolar teeth—equally divided between both jaws. Some division of opinion exists as to the succession in which these appear. According to Simonds, the pig is born with eight teeth—namely, two upper and two under middle incisors, and one canine on each side of each jaw. By the age of one month the incisors have increased to four in each jaw, while twelve premolar teeth have come out—namely, three on each side of each jaw. At three months the outer incisor on each side of each jaw appears. At six months the last premolar comes out, and the teeth of the first set are now complete.

About the age of nine months the outer incisors on each side of each jaw drop, and are replaced by the corresponding permanent incisors—this change being usually somewhat later in the lower jaw than in the upper. Near the same age the milk tusks or canines are exchanged for the corresponding permanent teeth. Between the age of one and that of two years the middle incisors or pincers are shed and replaced. About the same time a black circle appears at the base of each of the canine teeth. Between one and two years of age the deciduous or premolar teeth are shed, and replaced by permanent premolars. The first and second true permanent molar teeth appear before the shedding of the milk teeth is over—the first, namely, at six or seven months of the pig's age ; the second, at about ten months ; but the third does not come forth till three years after birth.

After three years the age of the boar may be computed by the growth of the tusks or canine teeth. At four years, or somewhat earlier, the upper canines begin to lift up the lip; at five they appear through the lips; at six the canines of the lower jaw come to display themselves out of the mouth, while they take on a spiral form. The latter acquire a prodigious size in old animals, particularly in the entire boar, and, as they grow in length, they take on a curved form in an outward and backward direction—becoming often so crooked as to require the file or nippers to restore a free motion to the jaw.

For what relates to the structure of the teeth in the pig, enough may be gathered from what has been already stated under the head of the teeth in the horse (p. 13 *et seq.*)

Snout.—A comparison between the face of the pig and that of other animals shows that the object of the structure is to give firmness and strength to the snout. The snout is the implement with which the pig, in a state of nature, digs in the ground for his food.

In the pig the nasal bones are large and elongated; they extend as far as the anterior extremity of the ascending branch of the intermaxillary or os incisivum; they terminate by a simple spongy point. The superior maxillary bone, properly so called—that is, to the exclusion of the os incisivum or intermaxillary—consists essentially of a superior branch, more or less vertical, and of an internal, horizontal, or palatine branch. In the pig the superior maxillary is high posteriorly, extending vertically downwards. The os incisivum, another name for the intermaxillary, in the pig is long and broad. The facial branches, by their upper and posterior extremity, touch the external border of the nasal bones. The palate bones are formed of a vertical branch and a horizontal branch, united together at a right angle. The bones of opposite sides are joined in the median line, so as to form the posterior part of the roof of the mouth and of the floor of the nostrils, the rest of the roof of the mouth being formed by the intermaxillary or os incisivum, and the palatine plate of the superior maxillary bone. The lower jaw in the pig has its ascending portion low and broad ; the coronoid process very short, and far distant from the condyloid process. The condyloid process is narrower from without inwards, and broader from before backwards, than in ruminant animals. The angle of the jaw also is higher and thicker than in the ox and sheep.

Mouth.—The mucous membrane of the mouth in the pig is smooth, but the surface of the palate is marked by several transverse prominences of considerable size. The lips of the pig resemble those of the ruminants, with this difference, that the upper lip advances somewhat farther forward. Owing to the kind of food, roots in particular, on which the pig naturally feeds, the extremity of the muzzle is transformed into a peculiar digging organ—the jaws are contracted, and the nasal bones, as already said, reach the level of the incisor teeth. The cartilaginous partition of the nostril contains, between the nasal spine and the intermaxillaries, a small bone which is named the spade-bone. The upper lip is confounded with the fleshy prolongation in which the nostrils are pierced, which prolongation is moved by powerful muscular fibres, and terminated by a kind of disc with a well-marked border. The snout seems to be insensible at its extremity, and therefore well adapted for burrowing in the earth. Running down the nose and spread out over the nostril is a large plexus of nerves, which, doubtless, enables the pig to direct its digging operations with the greater certainty. The olfactory nerve, too, is large, holding a middle place between that nerve of sense in the herbivora and in the carnivora. It is larger comparatively than in the ox, and few animals except the dog are gifted with a more acute sense of smell than the pig—witness its power of detecting truffles buried in the earth.

Tongue.—The tongue in the pig is much elongated. It is free in its anterior larger half. Its surface is very smooth—the numerous filiform papillæ which cover it being extremely small. There are, besides, found lenticular papillæ of small size occurring here and there, which posteriorly become larger and more closely set together. Far behind there are two large cup-shaped papillæ which are rough on their surface, with a multitude of extremely small eminences. The middle of the hyoid bone, or bone of the tongue, is of a square form, much broader on one side than on the opposite, united firmly with the cornua. The cornua, of small length but broad, are cartilaginous in a great part of their extent behind. Anteriorly, the hyoid supports two other cornua much smaller, broad, a little raised, and inclined forward. These cornua have a long fibrous ligament which joins them loosely to a second structure—namely, that which is contiguous to the styloid bone, and may well be regarded as an integral part of that bone.

Salivary Glands.—The parotid gland, of a crescentic figure, is very much larger proportionately than in the ox, the sheep, and the horse. It is perhaps even proportionately greater than in any other animal, since in adult pigs it weighs as much as three ounces. The duct of the parotid arises at the inferior extremity of the gland; it is covered in its passage by the masseter muscle and the lower jaw-bone.

The submaxillary gland in the pig is of an elongated triangular form; it is situated immediately below and within the parotid. These two glands differ from each other both in colour and consistence. The lobes of the submaxillary are comparatively much larger. This gland is much firmer and whiter than the parotid, which is of soft consistence and of a reddish colour. Besides these differences the lobes of the parotid are united to each other in a much less intimate manner. The volume of the submaxillary is to that of the parotid as one to nine, its weight in an adult hog being nearly three drachms.

The sublingual gland is somewhat smaller than the submaxillary. It is elongated and much less elevated, and less thick before than behind.

It does not appear that the physiological or the chemical effects of the saliva in the pig have been specially inquired into.

Pharynx.—The pharynx in the pig has the same character as in the horse, ox, and sheep—that is to say, it is a conical muscular bag lined with mucous membrane, the muscular fibres being connected with the several adjacent bones.

Gullet.—The gullet, as in the horse, the ox, and the sheep, is a very strong muscular canal, passing through the chest between the two sacs of the pleura, and penetrating the diaphragm to reach the abdomen, where it terminates in the cardiac extremity of the stomach. The muscular coat of the gullet has a double layer of fibres arranged in a spiral manner as in the ruminants.

Stomach.—The stomach in the pig differs from the stomachs of the other members of the order pachydermata by its rounded form, which is much more decided than in the others; by the dimensions of its great *cul de sac,* as well as by the complexity of that part; and by the division of the stomach into several compartments.

The gullet enters the stomach to the right at a considerable distance from the middle of the length of the organ, without making allowance for the extent to be gained were the curvature of the great *cul de sac* straightened. That *cul de sac* looks upwards and to the right. It is the anterior wall of the stomach which receives the gullet.

The fundus or base of the stomach contracts to an obtuse point, and, turning upwards and backwards, it becomes contiguous to the dorsal aspect of the organ ; it extends sufficiently to the right to pass the middle of the organ, and even to cross the insertion of the gullet. Everywhere in its course this reflected portion of the stomach is tightly fixed against the posterior aspect of the organ. The anterior border of the organ is convex, and divided into two prominences by two grooves, the one on the right, the other on the left, between which the gullet is seen nearly in the middle. Of these two prominences, that which is towards the right is nothing else than the last division of the stomach, or that which ends in the pyloric orifice. In the rest of its extent the stomach is nearly of uniform diameter, yet the pyloric portion is somewhat larger than the cardiac portion. The cowl-like appendix which terminates the cardiac *cul de sac* has its cavity distinct from the rest of the stomach, by a broad circular fold extending over three-fourths of the circumference of its commencement, while its walls are thicker than those of the principal part of the cardiac *cul de sac.* The left prominence receives the gullet, and the epithelium of that tube is continued to the right and to the left throughout a small extent of the cavity, and terminates towards its posterior extremity and on the dorsal aspect of the stomach, by a transverse row of strong nipple-shaped projections, which insensibly diminish from left to right until they entirely disappear. The *cul de sac* is simple, and is invested on its dorsal aspect with a membrane which is whiter and drier than in the rest of the stomach. On the anterior aspect this membrane forms well-marked wrinkles. At the pyloric orifice there is observed a strong prominence, flattened on the sides and elongated, becoming detached at the upper part of the circumference of the pylorus, and stopping up exactly that orifice. The inner membrane of the cowl-like appendix has wrinkles and wave-like folds, and a glandular aspect like the pyloric portion.

Intestines.—The intestines are of a considerable length in the pig, being made, by some authors, even thirteen times longer than the body. They are, probably, at least nine or ten times longer. The colon and rectum together make about a fifth part of the length of the small intestines. The ilium is something near a fiftieth part of the length of the body.

The small intestine is of uniform diameter throughout. It ends in the cæcum, which is of moderate diameter, and puckered by the effect of three tendinous bands. The colon is of the same diameter as the cæcum at its commencement; it makes numerous turns, and in some parts hardly exceeds the small intestine in diameter. It is puckered also, but has only two tendinous bands. In the ilium there is a long glandular patch. It is formed by glands of Peyer, patches of which are also found at the commencement of the colon, particularly near the orifice of the small intestine. The interior of the colon appears everywhere pierced with extremely minute orifices, visible with merely a lens, but innumerable. This apparatus appears to be of the same nature as the patches of Peyer.

The internal membrane of the small intestine has very fine, short, hardly perceptible papillæ.

The intestines in the pig have the same coats as in other mammals—namely, an outer serous membrane derived from the shut sac of the peritoneum, a muscular tunic of longitudinal and circular fibres, and an internal mucous membrane. The blood-vessels, nerves, lymphatics, and lacteals follow the same general plan, to which ample reference has been already made under the horse (pp. 59, 65, 68).

Liver.—In the pig the liver corresponds in situation to its place in other mammals—namely, in the right hypochondrium and the immediately adjacent regions. It has but three lobes, though it has four divisions. The two middle divisions belong to the principal lobe, which is deeply cut to receive the umbilical ligament. The gall-bladder is a little to the right of this division ; it is buried in a depression of the right portion of this lobe. There are besides two lateral lobes, of which the left is greater than the right without the detached lobule. There is no trace of such a lobule at the base of the left lobe. There is a slight division marking the lobule in the right lobe.

Though the gall-bladder is wanting in animals allied to the pig, such as the elephant, the rhinoceros, the peccary, the daman, the tapir, yet here it is of great size, and the common duct is also very large. The latter terminates near the pylorus, at some distance from the entrance of the pancreatic duct into the duodenum.

Pig's bile contains from 10.6 to 11.8 per cent of solid constituents, as compared with rather more than 14 per cent in human bile, and from to 10 to 13 per cent in ox bile. Pig's bile has some peculiarities in its composition, which, however, are of too intricate a nature to be detailed here.

Pancreas.—The pancreas or sweetbread in the pig is no more than six times the size of the parotid gland. It has three lobes in the pig. The pancreatic duct ends in the duodenum, six inches farther from the pylorus than the entrance of the common hepatic duct.

With respect to the chemical constitution of the pancreatic juice in the pig, no particular observations appear to have been made.

Spleen.—The spleen, as in all mammals, is flattened in the pig. It has a much elongated triangular form. Not uncommonly it far exceeds its normal size. It is usually about six times larger than the liver. Its structure may be gathered from what has been already stated under the head of the spleen in the horse (p. 65).

ORGANS OF NUTRITION IN THE DOG.

Teeth.—The teeth in the dog consist of incisors, canine teeth, and molar teeth. A full-grown dog has usually forty-two teeth in all—namely, twenty in the upper jaw, and twenty-two in the lower jaw. Besides these there are sometimes supernumerary teeth. The incisor teeth are six in each jaw; the canine or tusks are four in all—namely, one on each side of each jaw; and the molar on each side are six in the upper jaw and seven in the lower jaw. The incisor teeth are not all of the same size. In the lower jaw the two central incisors or pincers are the largest and strongest; the incisor on each side of these is somewhat less, and the corner incisor on each side is small and weak. In the upper jaw, however, the corner tooth on each side is larger than the adjacent incisor between it and the corresponding pincers; these corner teeth of the upper jaw are somewhat apart from the neighbouring teeth, and terminate in a conical point, curved a little inwards and backwards. The surface of the incisors has an interior cutting edge, and within they exhibit a depression. The terminating edge is divided into three lobes, the middle of which is the largest; but this lobed appearance is at length effaced by the wearing down of the edge. The incisor teeth, when newly cut, are flat on the sides, and bent somewhat backwards, forming a cavity in which a pulpy substance is enclosed.

The cuspidate teeth take their name, "canine," from their conspicuous appearance in the dog. These teeth are conical, and inserted in the jaw close to the suture between the upper jaw and the intermaxillary bone. They are of great strength, the fang thicker and longer than the enamelled crown. The crown is conical, slightly recurved, sharp-pointed, convex in front, almost flat on the inner side, and having a sharp edge behind.

The molar teeth in the dog are on the strict model of the teeth in carnivorous mammals, that is to say, there are false molars next to the canine teeth, which, from their form, have been named conical; next comes the proper carnivorous tooth, a cutting tooth with several external lateral points; and, lastly, a tooth with a triturating surface. With respect to the number of such teeth in the dog, the false molars or conical teeth are three in the upper jaw and four in the lower jaw; the carnivorous is single on each side of each jaw; and the tuberculated or triturating teeth are two on each side of each jaw, the farthest back of all. Hence, when the dog eats grass, he throws it quite to the back part of the mouth, that it may be triturated by these tuberculated teeth. For a better idea of the dog's teeth, see fig. 16. The milk teeth in the dog are twenty-eight; namely, six incisors in each jaw, as in the full-grown dog, four canine teeth or tusks in all, and twelve false molars—that is, three on each side of each jaw. The whole of the milk teeth are cut in no long time after birth. They begin to fall at three or four months after birth, and before the age of eight months the permanent teeth are complete. The structure of the teeth in the dog corresponds with their structure in carnivorous animals in general, and approaches more nearly to the character of the teeth in man than to that belonging to the horse and ox. In such teeth the cement or petrous crust does not appear so conspicuously as in herbivorous mammals. As in man, the teeth of the dog seem, on a superficial inspection, to be composed only of dentine and enamel; but it is found that the crowns originally, and the fangs always, are covered by a thin coat of cement.

Mouth.—The roof of the mouth in the dog is composed, as in the horse and ox, of the intermaxillary bone, the palate plates of the superior maxillary bones, and the inferior portions of the palate bones. The hard palate or roof of the mouth consists of mucous membrane spread over the periosteal covering of the bony plates just mentioned.

The veil of the palate has much the same character as the corresponding part in the horse, with this difference, however, that it does not form at any time so complete a separation between the anterior and posterior cavities of the mouth, but freely permits the contents of the stomach in vomiting to be discharged through the anterior part of the cavity.

Tongue.—The tongue of the dog does not differ much from the tongue in the human body. It is, however, proportionately longer and narrower than in man. Moreover there are upon the root of the tongue in the dog, as well as upon the mouth, many papillæ placed obliquely backwards, which assist in preventing the food from escaping. There is, likewise, in the dog's tongue a tendinous cord, vulgarly called the worm, in the under part of the substance of the organ, which extends as far as the point, and is enclosed in a membranous sheath. Comparative anatomists are not quite agreed as to the character of this cord or ligament. Cuvier describes it as belonging to the cat and the bear, as well as to the dog. Others say it is peculiar to the dog and the opossum, which last animal drinks like the dog. However this may be, there is a general persuasion that this ligament is of service in the process of drinking. In drinking, the horse, the ox, and the sheep bring their lips into contact with the water, and sip it gradually; the dog, with a longer tongue, plunges it a little way into the water, and, curving its tip and edges, laps the water with a quick succession of the same movements. The hyoid bone, or bone of the tongue, conforming in its details of development in the dog to the standard exhibited in carnivorous animals, agrees in its more prominent characters with those belonging to mammals in general. In it, as in man, the resemblance to a spur fails. It is connected, as in these, by muscular fibres with the lower jaw, the temporal bone, the larynx, the pharynx, and the breast bone, and is concerned in particular with the act of deglutition.

The tongue, besides being the organ of taste, to which the papillæ on its surface are subservient, is of important use, as already stated when speaking of the mouth of the horse, in the mastication of the food, and in the act of swallowing (p. 20).

Salivary Glands.—The salivary glands are not so largely developed in the dog as in the horse and in ruminant animals. The glands, however, bear the same names, and occupy corresponding situations. The parotid gland in the dog is of a crescentic form, embraces the concha of the ear, and extends as far as the submaxillary gland, which equals it in size. The sublingual gland seems to be little more than a prolongation of the submaxillary gland, or, according to Cuvier, the sublingual gland is wanting in the dog, and what has been taken for it is a small gland accessory to the submaxillary lying along Wharton's duct. The situation of these glands, as well as their general structure, will be understood by what has been said of the corresponding organs in the horse (p. 21).

Ordinary saliva is a mixture of the secretion of the buccal mucous membrane and of the several glands. The parotid secretion in the dog is limpid and colourless, devoid of smell and taste, incapable of being drawn out into threads, and of a distinctly alkaline reaction. Its specific gravity varies from 1.0040 to 1.0047. The same secretion contains, of inorganic matters, alkaline chlorides, carbonate of lime, carbonate of potassa, phosphate of lime and magnesia, phosphate of soda, and sulphate of soda. Among the organic matters are ptyalin, alcohol extract, and sulphocyanide of potassa.

The secretion of the submaxillary glands of dogs is like that of the parotid, a colourless, limpid, tasteless, and inodorous fluid, devoid of all morphological elements, such as epithelium-plates and mucous corpuscles. Its specific gravity is 1.0041 ; it has less of an alkaline reaction than the secretion of the parotid ; it contains less lime in combination with organic matter, and therefore attracts less carbonic acid from the air than the parotid secretion ; in other respects it contains the same constituents, including the sulphocyanide of potassium. The ratio of the inorganic to the organic matter is 66.2 to 33.8 ; while that ratio in the parotid secretion is as 70.2 to 29.8. The secretion of the submaxillary gland differs from that of the parotid in being viscid, so that it can be drawn out into threads. The effect of the mixed saliva to convert starch into sugar, belongs to that form of saliva in the dog as well as in man and the vegetable-feeders. One point of doubt remains, namely, whether the saliva, as taught by Liebig, conveys oxygen into the stomach to aid in the process of digestion.

Lips.—The lips in the dog offer no striking peculiarities. As in the horse, the lips serve to gather together the food, and to convey it to the mouth. The orbicular muscle which closes the lips forms the main substance of the lips, as in similar animals, being attached to no bone, while the other labial muscles take their attachment from the adjacent bones, and perform various movements by their contraction, in obedience to the ordinary law of muscular action, that the more movable part then approaches to the more fixed. The lips in the dog are covered, as in other such animals, by mucous membrane, and are everywhere freely studded with follicular glands, which secrete abundantly.

Cheeks.—The cheeks in the dog consist, as in other quadrupeds, of a cutaneous, a muscular, and a mucous layer. They form the sides of the mouth, and close the interval between the two jaws. The principal muscle is that termed buccinator, as in other mammals, by which the cavity of the mouth is powerfully contracted into a narrower space.

Lower Jaw.—The lower jaw-bone in the dog closely conforms to the common type of that bone in carnivorous mammals. The general character of the jaw-bone has been already described somewhat particularly under the horse (p. 23). As in other mammals, the jaw-bone in the dog has the V shape, with the upper extremities bent to an angle, and the part directed upwards being known as the ramus. This ramus divides at its upper extremity into the coronoid process, to which the temporal muscle is attached, and the condyloid process, which articulates with the temporal bone. As in carnivorous mammals in general, the ramus, or ascending part of the jaw, in the dog, is much shorter, and particularly the part which bears the condyle, than in the horse, ox, and sheep; the part of the ascending ramus which bears the coronoid process is, however, well developed both in breadth and height. This last process, indeed, in the dog, forms the chief part of the ascending ramus. There is a deep fossa on the external aspect, of which there is hardly a trace in the vegetable-feeders, designed to lodge the muscle which descends from the zygomatic arch to the jaw. The angle itself, by which the ascending branch is joined with the body of the jaw, is more open than in man and the vegetable-feeding mammals; so that the masseter muscle acts perpendicularly on the coronoid process, which occupies the anterior part of the ramus. The angle itself posteriorly presents in the dog a considerable projection, by which the extent of the attachment of the masseter muscle is increased.

The condyle, which is received into the squamous part of the temporal bone, is prolonged transversely, and rounded; while the glenoid cavity into which it is received is deeply hollowed out, and is guarded by a bony process before and behind. It follows from this mode of articulation that the jaw-bone of the dog has little other motion than that of a simple hinge, or even approaches to that of a pair of scissors. The zygomatic arch formed by the junction of the upper jaw-bone and the temporal bones, beneath which the largely-developed temporal muscle descends, and from which the zygomatics take their origin, is very much more expanded in every way than in the horse, ox, and sheep.

Pharynx.—The pharynx in the dog, as in mammals in general, has a sac-like form. It is, in short, the funnel-shaped commencement of the alimentary canal. It is composed of muscular fibres of considerable power, which are fixed to the adjacent bones, and is lined by the mucous membrane in its passage from the mouth to the gullet. Anteriorly it communicates with the mouth across the orifice of the larynx, and its upper part is on the level of the openings into the posterior nostrils and the communications with the ear on each side termed the Eustachian tubes. It may be described as suspended beneath the base of the skull. When the muscular fibres contract, the whole cavity is narrowed.

Gullet.—The œsophagus or gullet is the second part of the alimentary canal, continued backwards from the pharynx in the form of a tube of smaller diameter. It is the narrowest part of the whole alimentary canal or *primæ viæ.* It is also the most powerfully muscular. It passes through the chest united to the vertebral bones of the spine, and gets into the abdomen by going between the pillars of the midriff or diaphragm. It is not so long proportionally in the dog as in the horse, ox, and sheep. It is, however, more extensible in the dog, as in carnivorous animals generally, than in the herbivorous. In the dog the muscular fibres are in two layers, which are spiral, the external fibres being directed from before backwards, while the internal run in an opposite direction from behind forwards—a structure different from that observed in man, and which was once believed to be peculiar to the gullet in ruminating animals. A mucous membrane lines the gullet, which, in the contracted state of the organ, is thrown into folds.

Stomach.—The stomach in the dog is somewhat larger proportionally than in man. It is placed more lengthwise in the animal. It is also thicker and stronger than the human stomach. In the dog the rugæ go lengthwise from the cardia to the pylorus. The cardia or communication with the gullet is constantly closed except when food is passing from the gullet into the stomach, or in the act of vomiting, when the contents of the stomach are rejected upwards. It is almost at the extreme left of the stomach, which manifestly renders vomiting more easy. The stomach has three coats—the internal or mucous, the middle or muscular, and the serous or external, derived, like the corresponding serous coat in other mammals, from the general shut sac of the abdominal peritoneum. The motions imparted to the stomach by the muscular coat serve to move the contents of the stomach along the secreting mucous membrane, so that the digesting aliment is more effectively subjected to the solvent power of the secretion—namely, the gastric juice. As the chyme is formed it is expelled by the pyloric or lower orifice into the duodenum.

Intestines.—The intestines in the dog, as in other mammals, are divided into the small intestines and the great intestines. The small intestines, as in other such animals, have three divisions—the duodenum, the jejunum, and the ilium ; and the great intestines consist of the cæcum, the colon, and the rectum. There is much less difference in dimension between the small and the great intestines in the dog than in the horse. The whole intestinal tube in the dog does not average more than five times the length of the body, and the small intestines average about seven times the length of the great. The intestines consist of three coats, like the stomach—namely, the internal or mucous, the middle or muscular, and the external or serous, which is derived from the shut sac of the abdominal peritoneum.

The duodenum is fixed to the liver near the pylorus, but its lower part hangs free in the abdomen. The valvulæ conniventes of the duodenum, formed by plicæ of the mucous membrane, are placed in a longitudinal direction. The cæcum makes turns upon the ilium. The colon, furnished with a circular valve, is small and short, and, without making any circuitous turn, goes directly across the abdomen to form the rectum. It is nearly uniform throughout, and has no cells.

The internal surface of the small intestine is beset with numerous long, thickset villosities, diminishing considerably in size from before backwards, and disappearing entirely in the great intestine.

The glandular patches of Peyer are very distinct in the dog; they are of great size, numerous, sunk deep, and elongated.

The mesentery, as in other similar animals, is a fold or doubling of the general shut sac of the peritoneum, supporting the small intestines as in a sling; while the blood-vessels, nerves, and absorbents, together with the mesenteric glands, are contained between the two laminæ, at the continuation of which—the one into the other—the intestine hangs. What has been already said under the horse (p. 55) and the ox (p. 106) nearly applies to the organs contained between the laminæ of the mesentery in the dog.

The omentum, also a part of the general shut sac of the peritoneum, exists in the dog as in mammals in general. It is of considerable extent in the dog, and, like the great omentum in man, descends from the stomach to return upon itself and enclose the transverse part of the colon.

Liver.—The liver in the dog is in the right hypochondrium, bounded by the diaphragm, stomach, duodenum, colon, and right kidney. In the dog it appears to have no fewer than eight lobes. More correctly, however, it has a principal lobe, a right lobe, a left lobe, a right lobule, a left lobule, besides some other prominences elevated to the rank of lobules. The fissures in the principal lobes are deep; the right fissure of the middle lobe receives the gall-bladder, the left fissure the umbilical ligament. The liver in the dog is said to have about one twenty-seventh part of the weight of the body.

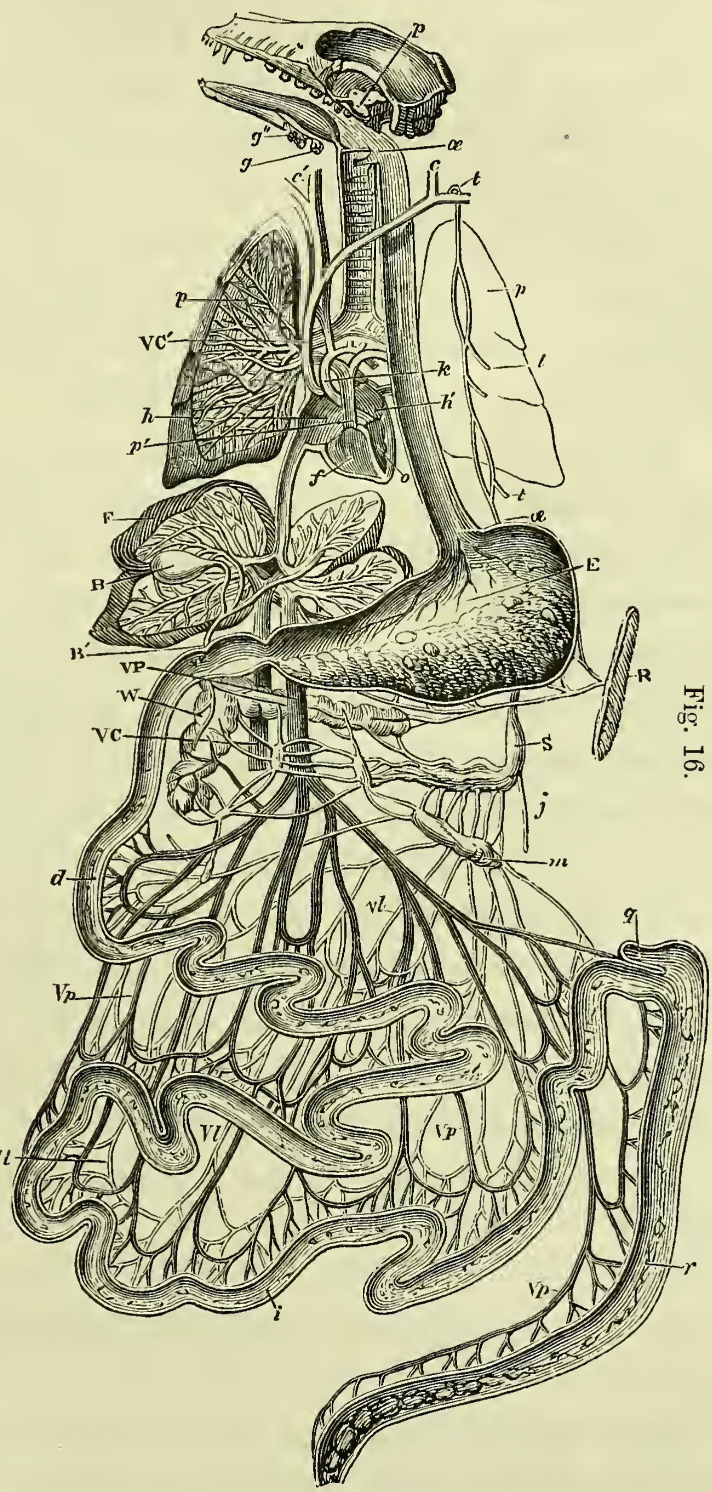
The portal vein is formed in the dog after the same model as in other mammals—namely, by the union of the veins belonging to the several chylopoetic and assistant chylopoetic viscera, or, what is the same thing, from all the veins which bring back the blood carried out from the posterior aorta by the three great azygous trunks—namely, the cæliac axis, the anterior mesenteric, and the posterior mesenteric. It is distributed in the same manner, like an artery, in the substance of the liver; and before its capillaries terminate in the radicles of the hepatic veins, these are joined by the capillaries of the hepatic artery, so as to receive the only part of the venous blood derived from the cæliac axis which is not poured into the portal trunk before it enters the liver. So strict is the rule as to the blood carried out from the aorta by the three great azygous trunks just referred to, that even the veins of the gall-bladder terminate in the trunk of the portal vein. The subdivisions of the portal vein pass throughout the liver in the portal canals formed by the fibrous coat reflected into the interior of the organ, under the name of the capsule of Glisson. The branches of the hepatic artery, the nerves, and lymphatics, follow the same course in their distribution, being contained, like the subdivisions of the portal vein, in the portal canals. The trunks of the hepatic veins, on the contrary, pursue a separate course, and end between the liver and the dorsal spine in the posterior vena cava. Their great size is easily understood when it is considered that they return to the vena cava the whole of the blood carried out from the aorta by the three great azygous trunks before mentioned—namely, the cæliac axis, the anterior mesenteric, the posterior mesenteric, to which these hepatic venous trunks really correspond.

The lobules of the liver in the dog are of the same structure as in other mammals. Each lobule rests on a minute vein; a still more minute vein descends through the base of the lobule to join the first,—these belong to the hepatic system of veins; the latter minute vein receives its blood from a capillary of the portal system after it has secreted bile, and that capillary has derived its blood, in part, from the venous blood of the abdominal chylopoetic organs, partly from the capillaries of the hepatic artery. A minute duct carries away the secretion from the lobule, pursuing the same course by which the corresponding subdivision of the portal vein and of the hepatic artery had reached the lobule.

The hepatic duct unites in the dog with the cystic duct sent out by the gall-bladder to form a common duct like the *ductus communis choledochus* in man. This common bile-duct terminates in the duodenum, having first received one of the ducts of the pancreas. The coats of the gall-bladder are very thick in the dog, and the internal has a villus-like surface. Some ducts termed hepatico-cystic, in the dog as in some other animals, pass straight from the liver to the gall-bladder.

Of the general character of the bile some account has already been given (p. 116). The bile in the dog conforms to that common character of the two resinoid acids combined with soda which seem to constitute the usual composition of bile—namely, the glycocholic and the taurocholic; the latter appears in particular to belong to the bile in the dog. In short, it has been asserted that the bile in the dog contains almost exclusively the taurocholate of soda.

Fig. 16.



DIGESTIVE TRACT IN THE DOG.

p, Parotid gland; g, submaxillary gland; g″, sublingual gland; œ, œsophagus or gullet; c′, right carotid; c, jugular vein; p, p, lungs—that on the left opened to show the bronchial tubes, arteries, and veins; VC′, superior vena cava; k, aorta; h, right auricle of the heart; h′, left auricle; f, right ventricle; o, left ventricle; p′, pulmonary artery; t, t, thoracic duct; F, liver; B, gall-bladder, entering the intestines by the duct B′; E, stomach; R, spleen; S, Pecquet's reservoir; j, lymphatics; m, mesenteric ganglia; VP, trunk of portal vein; Vp, Vp, origins of portal vein; W, pancreas; VC, inferior vena cava; d, duodenum; Vl, lacteals; i, small intestine; q, cæcum; r, colon or large intestine. After Bernard.

Pancreas.—The pancreas or sweetbread is principally placed behind the stomach, between the spleen and the duodenum. It is in the dog, as in other animals, of a structure closely resembling the salivary glands. For the most part the pancreatic ducts and the common bile-duct have a separate insertion into the duodenum, the pancreatic duct being the most distant from the pylorus. There are, however, sometimes two pancreatic ducts, one of which unites with the common bile-duct, while the other is inserted into the intestine at the distance of a few lines. This latter arrangement exists when there is one pancreatic duct for the principal gland, and another separate duct for the accessory or duodenal gland.

Spleen.—The spleen is closely connected with the left side of the stomach. The omentum, between the layers of which the stomach is contained, passes thence to the spleen, which thus receives for its outer covering a part of the shut sac of the abdominal peritoneum. The spleen is of a deeper colour than in man. Its shape is long, flat, and prismatical. It is a very vascular organ. The splenic artery is a branch of the cæliac axis on the inferior aspect of the abdominal aorta. The splenic vein is the most direct part of the portal vein with which the veins of the rest of the chylopoetic and assistant chylopoetic viscera successively unite. The nerves are from the splanchnic nerve of the sympathetic system of nerves. The peculiar structure of the spleen has been already described under the head of the horse (p. 65).

The digestive tract in the dog may be minutely traced in fig. 16.

ORGANS OF NUTRITION IN POULTRY.

Bill, Mouth.—The part which supplies the place of the teeth in birds is the bill. This is formed of a horny substance of the same nature as the claws and spurs, and is moulded upon the osseous part of the jaws. The form and texture of the bill vary with the habits and food of the animal. In rapacious birds the bill is hard and hooked at the end for seizing and tearing the prey. In birds that bruise very hard seeds it is also of firm texture. The bill is of a more delicate structure in birds which use a softer food. Finally, it is found to be soft and remarkably sensitive in birds of the duck kind, which seek their food in water or in mud. In poultry, as well as in the hawk tribe, a soft skin covers the base of the bill. It is named cire, but the use of it is not ascertained.

Bones of the Head.—The bones of the head in birds have created much discussion among comparative anatomists. The plan of this work does not admit of any attempt to exhibit the several views insisted on. It will be sufficient to state a few particulars hardly admitting of doubt. There are no sutures in the skull of adult birds. The false sutures in young birds soon become obliterated. The bones of the cranium, like the rest of the skeleton in birds, admit air to give additional lightness. The crest or horn peculiar to some birds is united with the frontal bone, and may be regarded as an enlargement of its orbitar portions. The interior of the cranium is divided into two principal compartments, the one for the cerebrum, the other for the optic thalami, the cerebellum and medulla oblongata. There are nearly as many bones in the skull of the bird as in the human skull. The orbital cavities are of great extent. In some birds there is only a membrane between the two orbits; in others the partition is more or less osseous. The temporal bones are destitute of a zygomatic process. In the whole order of birds, the head is supported on the neck by a single hemispherical condyle situated at the fore part of the foramen magnum.

Jaws.—The proportion between the cranium and the jaws varies much in different birds. There is also much difference in different birds in the size of the nasal and palatine openings.

In most birds the upper jaw or mandible has a greater or less mobility. In birds in general the upper jaw is united into one piece with the cranium by means of elastic bony plates; but in some, as in the parrot tribe, it constitutes a particular bone articulated with the cranium. In a few the upper jaw is immovable; for example, in the cock of the wood (*Tetrao urogallus*).

There is in birds a bone named os quadratum, by which the lower jaw is articulated with the cranium on both sides. Connected with the os quadratum is another small bone resting, by its opposite end, against the palate in such a manner that it elevates the upper jaw when the os quadratum is carried forward by its muscles. The os quadratum is usually termed the tympanic bone by recent comparative anatomists.

The horny substance investing the two mandibles acts the part of teeth, and it is even sometimes serrated so as to imitate the form of teeth.

According to Cuvier, the muscles concerned in the mastication of birds belong to the lower jaw and to the tympanic bone (os quadratum). For example, in the domestic duck there are six tympanic muscles, three external, one of which represents the masseter, and three internal. Two muscles besides the masseter raise the lower jaw, one of which corresponds to the temporal, the other to the pterygoid; there is besides a large broad muscle which depresses the lower jaw.*

In poultry the upper mandible is vaulted, and the nostrils are pierced in a large membranous space at the base of the beak, and covered by a cartilaginous scale.

Salivary Glands.—There are salivary glands in birds,

* For the muscles of the jaws in birds, see Meckel, 'Anatomie Comparée,' tome viii. p. 188 *et seq.* Paris, 1836.

and in poultry these are well developed. There are four salivary glands. The lingual gland is situated by the side of the tongue, and corresponds by its position, as well as by its structure, with the sublingual in mammals. A pair of glands is found behind the symphysis of the two lateral parts of the lower jaw, the secretion being poured into the mouth in the median line immediately before the tongue. This pair of glands, according to Cuvier, is the sublingual. Another gland is found on each side before the anterior segment of the lateral horn of the hyoid bone, which in the goose opens at once by several orifices. In the cock and some other birds it has a long excretory duct, which opens before the tongue and behind the last mentioned pair of glands. There is a fourth gland found immediately beneath the skin near the commissure of the jaws, which on each side opens by several orifices into the mouth.

Tongue.—The tongue of birds is formed principally by the middle anterior portion of the hyoid bone. It contains, besides some weak muscular fibres, a greater or less proportion of fat and cellular tissue. The tongue, however, varies more in birds than in any other of the divisions of vertebrate animals. In poultry it is triangular, pointed, smooth, cartilaginous, and destitute of papillæ except at its root; while its firmness prevents it from being injured by the hard and pointed substances on which they live. In the duck tribe it is fleshy and large, while the hyoid bone entering into it is of considerable size, and terminates in front by a cartilaginous portion. In all the duck tribe there are rigid hairs on the side of the tongue, while in many there are ranges of osseous laminæ. In the swan the tongue is covered with stiff hairs, osseous plates, and fleshy papillæ. The joint resembling a ginglymus in the hyoid bone is particularly remarkable in poultry. Besides the anterior cartilaginous part of the tongue, there is an osseous part articulated with the hyoid bone. The median line even is osseous from the point of the hyoid bone to the anterior extremity of the tongue, whence their tongues are but little movable; neither are they bifurcated as in some other birds, or apt to change their form.

Pharynx.—The pharynx conforms to the dimensions of the neck, and is for the most part both long and of considerable size; its circumference is generally much the same as that of the stomach. The internal membrane is smooth, with a few doublings; the muscular coat is very thick. In the pharynx of birds there are no special constrictors, the muscular coat being merely continuous with the corresponding coat of the gullet.

Gullet.—In granivorous birds the gullet is a little inclined to the left side of the trachea, and terminates at the bottom of the neck in a large sac, the ingluvies or crop, termed by the French *jabot.* It has the same structure as the gullet, but is thinner.

Crop.—The crop in poultry is of a globular form, and is placed at the fore part of the chest. The gullet terminates at the upper or fore part of this sac, and issues again from its opposite extremity; thus the crop forms a *cul de sac* between these two orifices. The crop belongs to other birds besides the gallinaceæ; for example, to diurnal birds of prey, and parroquets. It has, however, comparatively, a considerable development in gallinaceous birds, and among these particularly in the pigeon. This pouch, however, differs entirely in the pigeon from its character in other birds, both in respect to size and to the peculiar mode in which it is constructed and placed, since in the pigeon it is prolonged into two lateral halves, quite symmetrical, occupying a corresponding place on each side.

Upon the inner side of the crop are numerous glands, with very distinct orifices in the larger birds, which throw out a liquor to assist in the solution of the food. These glands are often in irregular rows. In pigeons, which feed the young from the crop, these glands swell remarkably during the time that this mode of feeding continues. What is singular is, that corresponding changes take place in the crop of the male pigeon during the period of incubation. For the first three days after exclusion from the egg, the young pigeon receives no nourishment but what is derived from the crop.

Stomach.—The second stomach is funnel-shaped, hence called infundibulum. It is also named *ventriculus succenturiatus*, and the glandular stomach ; it is situated in the abdomen, and is commonly smaller than the crop : it is more general in the order of birds than the crop, while in the different species it varies much. It obtains a covering from the peritoneum : it is thicker even than the gullet, but this thickness is due rather to the numerous glands which secrete its peculiar fluid than to greater muscularity. These follicles are placed vertically, forming rows very close to each other, and superimposed one on another with orifices directed downwards : these follicles reach their maximum development in granivorous birds. In these they are besides divided into a great number of denticulated appendages. Their form is without exception that of elongated tubes closed at the inner extremity.

Gizzard.—The infundibulum, or second stomach, ends in the gizzard, or third stomach. So close are these two stomachs that many authors describe them together as the one stomach of birds, divided into two cavities. It is more convenient, however, to speak of them as the second and third stomachs. This third stomach, or gizzard, is often, in works of anatomy, termed the *ventriculus callosus*. In gallinaceous birds it is much larger than the second stomach ; in other birds, for the most part, it is the reverse. It is generally situated in the upper part of the abdomen, close to the spine, and resting on the intestines. In a few birds it is covered by the intestines.

Its form is for the most part globular, somewhat compressed; it consists of four muscles possessed of great strength and thickness. Of these, two occupy the sides, having fibres running around two tendons, also on the sides of the organ. The other two muscles, smaller than the former, are placed at the opposite extremities of the stomach.

The gizzard has among its outer coats a tendinous expansion lined by a thick strong callous coat, regarded by some as a continuation of the cuticle. This inner layer forms irregularities on its inner side, which, on the opposite surfaces, adapt themselves to each other. Compared to its external surface, the inner surface is very small, while its two orifices are singularly near each other.

The great thickness of the gizzard is supposed to compensate for the defect of teeth in birds. Such statements as the following are cited in proof of its great power: that pieces of money, and even pebbles of the hardest sort, swallowed by a fowl, have lost a considerable part of their weight within a few days; that a silver thimble swallowed by a young turkey was taken from its gizzard a few days after with its sides squeezed together. Each of the small muscles at the ends of the gizzard forms a kind of receptacle for the small stones habitually swallowed, in order to separate them from the digested food which passes on to the intestines.

The muscularity of the gizzard is at its maximum in granivorous birds; in carnivorous birds it is at its minimum.

A parroquet and some other birds have been thought to chew the cud like ruminant quadrupeds. The name spurious rumination has been sometimes applied to the effect produced on food by the hard and callous gizzards of poultry and geese.

The swan and the palmipedes for the most part have a gizzard approaching in muscularity to that of the gallinaceous birds.

Intestines.—The pyloric orifice by which the gizzard communicates with the intestines has no sphincter. The intestines are much shorter proportionately in birds than in mammals. The intestinal canal varies in different birds from twice to five times the length of the body. Here, however, considerable anomalies appear, owing to the more varied form of the body, and especially to the great diversities in the length of the neck in birds as compared to mammals. In carnivorous birds the intestines have the smallest proportional length; in gallinaceous birds, and the order passeres, which feed on grains, the intestines are proportionately longest; in birds that live exclusively on fish, the intestines are comparatively nearly as long as in the gallinaceous birds.

In all birds the distinction obtains between small and great intestines, though the difference in the external aspect of the great intestines as compared to the small is very slight. The small intestines, as in mammals, are commonly longer than the great. It is remarked, however, that in the ostrich the great intestines are longer than the small. In the greater number of birds the same description is applicable to the situation, form, and structure of the intestines. The duodenum begins near the termination of the gullet; that is to say, the entrance to the gizzard and the exit from it are close to each other. Between these two openings, in the common fowl, and in some other birds, there is a prominence which may have the effect of preventing the food from escaping into the duodenum before the stomach-digestion is completed. The duodenum hangs loose in the common fowl towards the right side of the abdomen, while the remaining portions of the small intestines make turns and unite themselves to each other. In birds, as a rule, the intestines are destitute of *valvulæ conniventes.*

The gallinaceous birds are distinguished by their very long cæcums, which appear to possess an important share in the functions of chylification. Pigeons alone make an exception; these have either only rudimentary cæcums, or else are altogether destitute of them.

The dimensions of the intestinal canal in gallinaceous birds are great in diameter as well as in length. It is remarkable that the length of the intestinal canal is in an inverse proportion to that of the cæcum. In the grouse tribe the cæcums are of the greatest proportional length. This great length coincides with the existence of intestinal papillæ which extend almost to their termination, while these are not found in other gallinaceous birds, except in a portion always small at their commencement. These papillæ are generally composed of filaments variable in their dimensions. In pheasants the last doubling of the intestine is attached to the duodenum; the cæcums are dilated into a club at their extremity, and give entrance to feculent matters. In the domestic cock the pile of the mucous membrane is formed of innumerable folds like ruffles, without fringed borders but pressed close together. Towards the extremity these folds become detached and form a foliaceous pile, which is observed in the first third of the cæcums, while the remaining portion by degrees loses these irregularities and becomes wholly uniform. As to the rectum, it presents the same foliaceous pile as the cæcums and the end of the small intestine.

In the golden pheasant the duodenum presents a network with very distinct meshes.

In the peacock the internal surface of the duodenum exhibits a fine network with polygonal meshes, the borders of which are fringed: this network is continued throughout the whole extent of the small intestine, but the laminæ of which it is formed become thicker and nearer to each other, losing their regularity, and no longer fringed in the border. The same structure prevails at the commencement of the cæcums, and in a portion of the rectum. In the other portion of the rectum there are only detached foliaceous papillæ, which become rounded quite at the extremity. The same rounded and conical form of the papillæ is all that exists in the cæcums, where there is seen besides a remarkable fatty network.

In the cock of the wood (*Tetrao urogallus*) the duodenal curvature is of moderate extent. The middle intestine is not so long as in the other gallinaceous birds, yet disposed in the same manner. The cæcums are so long that each of them is longer than the whole intestine above the point of insertion. Their rectum is short.

In birds generally there are two cæcums (*intestina cæca*), a few of the aquatic kind excepted. The cæca are inserted at the sides of the termination of the ilium. They are generally smaller at the base, and enlarge towards their shut extremities. They lie parallel to the small intestines, and contain the same kind of aliment with them. In carnivorous and omnivorous birds they are commonly long and of considerable diameter. In nocturnal birds of prey they are in general very large; but in diurnal birds of prey they are absent, or of inconsiderable size. From the end of the ilium, and also from the cæcum, the colon is sent off; it is proportionately short, and differs in this respect from its ordinary condition in mammals, that it is not formed into cells.

The intestines are fixed to the body by the mesentery, which arises from the spine opposite to the anterior mesenteric artery. Where the mesentery supports the small intestine it is pretty broad, but that part which surrounds the colon is narrow, that intestine being more firmly fixed than the rest.

The rectum, before terminating in the anus, undergoes a dilatation termed cloaca, which is suspended under the os coccygis, and receives the terminations of the ureters or ducts from the kidneys, the ends of the vasa deferentia or seminal ducts in the male sex, and also the penis when it exists, the opening of the oviduct in the female, and the orifices of the bag named "bursa Fabricii." The cloaca has a variety of forms in different species, but its appearance nevertheless is more or less of an oval shape. In both sexes it serves as a reservoir of urine and fæces. Its movements are directed by several muscles, which arise from the adjacent bones. At the upper and back part of the opening into it in both sexes is situated the bursa Fabricii. In some large birds, as in the goose, it is more than an inch long, with its cavity lined by mucous glands. It is proportionally of greater size in young birds, while in old birds it is very much contracted. It is uniformly found empty, and its use has not yet been discovered.

In birds in general there is no omentum, unless the lump of fat covering the intestines in some aquatic fowls be regarded as representing that structure. In the ostrich there is an omentum, with a large quantity of fat.

The Liver.—In birds the liver is proportionately larger than in mammals. It has a more uniform figure. It is for the most part divided into two almost equal lobes, and these are rarely very unequal. It occupies both the right and left hypochondriac regions, and even a great part of that portion of the common cavity which corresponds to the chest in mammals. The great size of the liver in birds seems to correspond with what is commonly received respecting the functions of that organ and their relation to the functions of the lungs.

It might seem that such an organ should decline in importance, and consequently in size, in proportion as a tribe of animals has an augmented respiration; but it may be answered that in birds there cannot be too many means of augmenting the proportion of oxygen in the blood, since the great activity of movement in flight requires the greatest possible irritability in the muscular system. The liver is upheld by the adjacent viscera, and is fixed by doublings of the peritoneum. The tint varies in different species, but the essential colour is a reddish brown.

The gall-bladder lies between the two lobes of the liver, sometimes closely clinging to the organ, sometimes loose and pendulous. It is oval in some, in others of round form, and, as in mammals, has its fundus placed undermost. In some birds, as in the pigeon, the parrot, and the ostrich, there is no gall-bladder.

In birds, for the most part, the hepatic duct does not unite with the cystic duct, or duct from the gall-bladder, but opens separately into the duodenum. In short, there is no communication between the two ducts; whence the bile found in the gall-bladder does not reach that receptacle by regurgitation, as is the case in mammals, but gets there directly from the biliary vessels in the liver by means of hepato-cystic ducts, which open either into the fundus or neck of the gall-badder. Such ducts, besides conveying bile into the gall-bladder, serve to connect it more firmly with the liver.

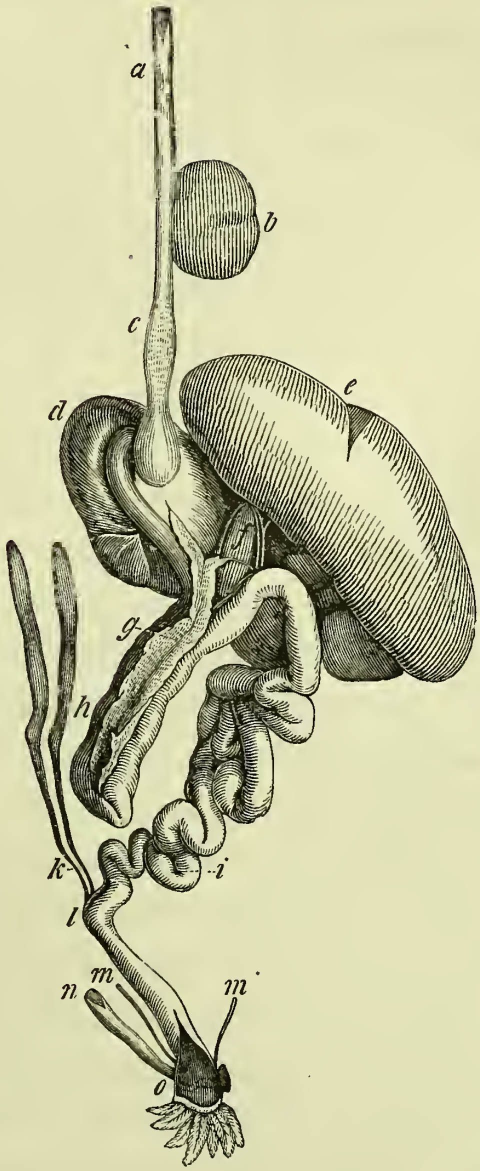
The bile of birds resembles in its sensible characters the bile of mammals. What has been asserted of the bile is probably correct—namely, that the only difference in the composition of the bile of different animals is in the varying proportions in which the taurocholic and the glycocholic acids respectively exist. The bile of birds does not appear to have been extensively examined. The bile of the goose is said to contain almost exclusively taurocholic acid.

Pancreas or Sweetbread.—The pancreas in birds lies between the turns of the duodenum. It is inserted, as it were, between the two portions of the curvature of the duodenum. It has the same direction as that curvature, and when inflexions exist in the curvature it makes corresponding turns. It may be said that the pancreas of birds is a development merely of the duodenal portion of the pancreas in mammals. In birds, in short, the pancreas does not retain its relation with the stomach, except in a slight manner, by its anterior extremity, in its advance towards the spleen, which lies to the right of the crop and the gizzard. The pancreas of birds is retained in its position by the laminæ of the gastro-colic and gastro-hepatic omentum, which glide above and below between the two portions of the curvature of the duodenum. Sometimes this organ is locked between these laminæ in such a manner, however, that it is raised more or less above their level; in other birds these laminæ supply it with a small mesentery which, as in the duck, allows it to float to a moderate extent in the abdomen.

The colour of the pancreas is of a rose hue, somewhat yellow, rarely brown. It is of a firm consistence. Its substance is much more compact than in mammals, nor does it present those distinct and more or less separated lobules which prevail in them. Its figure is very irregular; generally it is long and straight, to adapt it to the situation it has to occupy. It is rarely without some division, and sometimes that is deep. There are even two distinct glands, or three, as it is alleged. Thus the pancreas is double in the bustard, the curassow (*Crax alector*), the swan, the duck—and in the domestic cock it is bifurcated. The right branch in the cock is broad and short; the left is narrow and long, advancing towards the pylorus.

The pancreas commonly sends forth one, two, or three ducts; these are more visible than in other animals. They terminate in the duodenum, with few exceptions, separately from the biliary ducts. There are many varieties in the insertion of the biliary and pancreatic ducts into the duodenum. The rule seems to be that the pancreatic duct opens first into the intestine, that the hepatic duct is inserted a little farther on, and that the cystic duct terminates at the greatest distance from the pylorus.

Fig. 17.



DIGESTIVE APPARATUS OF BIRDS.

a, Œsophagus; *b*, crop; *c*, infundibulum; *d*, gizzard; *e*, liver; *f*, gall-bladder; *g*, pancreas; *h*, duodenum; *i*, small intestines; *k*, cœca; *l*, large intestines; *m*, *m*, ureters; *n*, oviduct; *o*, cloaca.

Few observations have been made on the pancreatic secretion of birds. It appears, as before stated (p. 65), that the pancreatic juice in animals generally has the power of converting starch into sugar, as is the case with the secretion of the salivary glands. And it has been alleged, on the evidence of direct experiment, that the pancreatic juice of fowls and geese possesses this property.

Spleen.—There is generally one spleen only in birds, very variable in figure, being in different species round, oval, or reniform. It lies between the left lobe of the liver and the stomach, and is retained in its place by folds of the peritoneum, as in mammals. It has no excretory duct; its venous blood is sent, as in mammals, to the portal vein.

SUPPLEMENT TO THE ACCOUNT OF THE ACTS SUBSERVIENT TO NUTRITION IN DOMESTICATED ANIMALS.

The prehension of the food exhibits some remarkable differences in different animals. The assistance which man and many other animals derive from the thoracic extremities in the prehension of the food shows how far from absolute is the distinction between the functions of relation and the functions of assimilation. The horse, the ox, and the sheep make no use whatever of the thoracic extremities in the prehension of food. The dog holds his prey with his fore feet while he tears it with his teeth. The pig plants at least one foot on any large piece of aliment while he detaches a portion of it with his teeth. These are but trivial effects compared with the aid obtained from the thoracic extremities in the prehension of food by man, the monkey tribe, the rodent animals, and other animals possessed of a clavicle or collar-bone. When the fore legs no longer supply assistance in this act the lips come to take an important share in this office, as in the horse, the ox, and the sheep. The incisor teeth and the tongue are also so modelled in these animals as to be of essential service in introducing the food into the mouth. The upper lip of the horse, long and flexible, and endowed with great sensibility, gathers together the tuft of grass, then the nippers seize and detach it, when the tongue carries it backwards to fall under the molar teeth. If the lips of a horse are turned inside out, and retained in that position by means of ligatures, he tears wisps of hay from the rack, but drops them on the ground, unable to introduce them into his mouth.

The ox has not the same advantage from the upper lip. It is short, thick, not flexible, and too little distinct from the muzzle. The defect of incisor teeth in the upper jaw still more distinguishes the mode of prehension in the ox from that in the horse. Here the tongue takes on itself a larger share in the office. It is long, susceptible of much protraction, and capable of being twisted on itself while it is covered on its upper surface with papillæ having horny sheaths. When the ox is on pasture the tongue issues from the mouth, is thrown to one side, and, turning upon itself, seizes a tuft of grass and draws it to the entrance of the mouth, where it is held fast between the lower incisors and the rim of the upper jaw, and, being torn away by a slight movement of the head, it is quickly carried between the molar teeth. When the grass or hay lies loose on the ground, it is gathered with the tongue and carried into the mouth. If the fodder is in the rack, the tongue is thrust between the bars to seize it; when the food is in grains, as oats, or in the form of meal, it is still with the tongue that it is taken up.

The sheep makes rather less use of its tongue than the ox: the goat makes an approach to the horse in the use of the upper lip: the same is the case with the mouflon, the gazelle, and the antelopes, when they eat dry comminuted substances; but when they are on pasture they cut it close to the root between the inferior incisor teeth and the fibro-mucous rim of the upper jaw.

The pig, as before stated (p. 161), makes much use of his snout when his food has to be dug from the ground; when he eats from a trough he thrusts his snout to the bottom to seize what lies there. His lower lip is short and pointed, and this he may be seen to use when he gathers grain from the ground —his teeth in this case afford no aid.

The dog in the prehension of his food brings his teeth and jaws into action. He fixes the bone which he gnaws to the ground by means of his fore paws, and uses the incisor teeth of both jaws, like cutting-pliers, while his long and curved canines tear the prey.

The prehension of liquids in these animals takes place in several different ways.

The suction by which the young of mammals obtain their first food is a very peculiar process. It is sometimes ascribed to the suction or enlargement of the chest, but this is an error. It is performed by the suction of the mouth, which is found to be much more powerful than the suction of the chest. An animal which drinks by suction can still drink freely after the windpipe has been opened, and even after the nostrils and the windpipe have been effectually stopped up. In suction the lips and tongue are principally concerned—the lips form a tube which is filled up by the tongue; if, then, a tube, communicating with fluid subject to the pressure of the atmosphere, is introduced into the mouth, like the nipple in sucking, the tongue being drawn backwards, a vacuum is created which is immediately filled by the rush of the fluid through the tube into the mouth. There is no other difference between this suction and the mode of drinking in the horse, the ox, and the sheep, than that, the extremity of the head being plunged into the water, the water rises a little way into the tube formed by the lips before a vacuum is created by the withdrawal of the tongue.

Some animals seem to drink by the suction of the thorax—that is, by the enlargement of the chest—while the extremity of the head is plunged under water. Thus, while the pig at times drinks quietly by the suction of the mouth, at other times he draws the water into his mouth mingled with air by snatches, with much gurgling noise.

The dog, like other carnivorous animals, cannot immerse the extremity of the head so as to cover the corners of the mouth without plunging the nostrils also under water; hence the dog laps the water in drinking. In lapping the tongue is used like a spoon; the tongue is plunged into the water and quickly withdrawn, being at the same moment curved and rendered hollow on its upper surface, and thus a portion of the water is at each such movement thrown into the mouth.*

The organs in which the aliment undergoes important changes before becoming fit for the repair of the blood, or for the maintenance of animal temperature, are—1, the mouth; 2, the stomach or stomachs; 3, the duodenum, subservient to the changes in which are the liver and pancreas; 4, the intestinal villi; 5, the mesenteric glands; and, lastly, the lungs. When the aliment is only to serve for the maintenance of animal temperature, it appears to pass from the stomach and upper part of the intestinal tube into the blood of the portal vein for transmission through the liver, and thence to the right side of the heart, to be conveyed to the lungs, where it undergoes a slow combustion.

The greater or less comminution by the teeth, and mixture with the saliva and the secretion of the mucous membrane, are the operations to which the aliment is subjected in the mouth. The required comminution varies much in different

* See Colin, 'Physiologie des Animaux Domestiques,' tome i. p. 411.

animals, being very much greater in vegetable-feeders. In carnivorous animals, like the dog, the jaw has but two motions—namely, the hinge-like movement by which the mouth is opened and shut; the teeth of the one jaw cannot glide over the teeth of the other. Thus, in the dog and animals of the like character, mastication consists merely in the cutting, tearing, and chopping of the aliment, to which operations the incisor, the canine, and the molar teeth in the dog are severally adapted.

Besides the mere hinge-motion of the jaw, common to herbivorous animals with the carnivorous, the herbivorous can carry the jaw forwards, backwards, and to either side. There is a peculiarity in the jaw of herbivorous animals besides—namely, that the under jaw is narrow from side to side as compared with the upper jaw, the effect of which is that the molar teeth of the lower jaw cannot be made to fit against the corresponding teeth of the upper jaw on the two sides at once. When the teeth of the two jaws are brought into a line on the one side, the teeth of the other side are no longer in a line, whence it follows that in these animals mastication must be unilateral; and it is observed that in such animals the one side of the mouth is used in mastication to the exclusion of the other side for long periods, as for a quarter of an hour, half an hour, or even an hour.

Mastication is a very slow process in the horse and other herbivorous animals that do not ruminate. In those that ruminate, the first mastication is very rapid; the second mastication, however, after rumination, is a slow process.

The following statement is made as the result of observations on the mastication of the horse. A horse of moderate size took an hour and a quarter to masticate 4 pounds and some ounces of dry hay, which he swallowed in from 60 to 65 portions. A large horse took an hour to the same quantity, and swallowed it in 60 portions; a second, an hour and twelve minutes, and swallowed it in 95 portions; a third, an hour and a half, and swallowed it in 120 portions; a fourth, which was very small, took an hour and forty-four minutes to the same quantity, swallowing it in 150 portions. On an average, then, a horse takes 45 seconds to masticate an ounce of hay, at the rate of from sixty to eighty strokes of the teeth per minute. If from any cause there be a deficiency of saliva, the amount of movement in the jaw required is very much increased.*

From the account already given, under the head of the several animals included in this treatise, it sufficiently appears how uniformly important the process of mastication is towards the promotion of digestion. It seems certain that much has yet to be discovered respecting the special uses of the saliva in animals that differ in conformation. If the saliva has no chemical effect but that of transforming starch into sugar, it seems singular that such glands as the salivary should be present so extensively throughout the carnivorous tribes of the animal kingdom.

In the ruminant animals the supernumerary stomachs may be regarded as appendages of the mouth—that is to say, as concurring with the teeth and salivary glands in the preparation of the aliment for the proper ventricular digestion in the fourth stomach.

The act of swallowing has been sufficiently illustrated in the several animals to which reference has been made in the preceding pages.

The effect of the stomach on the prepared aliment consists principally in the application to it of the gastric juice or peculiar secretion of the lining membrane; and even the muscular movement of the organ, besides the transmis-

* Colin, 'Physiologie des Animaux Domestiques.'

sion of the chyme or product of ventricular digestion into the duodenum, is mainly for the purpose of subjecting the alimentary mass in every part to the due influence of that secretion.

As regards the effect of the gastric juice on the aliment, few differences have been remarked between what occurs in the human stomach, which has been chiefly studied, and what takes place in the stomachs of the animals here under particular consideration.

When the mucous membrane of the human stomach, in a distended state, is submitted to examination, it is found to be smooth, level, soft, and velvety. When allowed to contract, numerous folds or rugæ, chiefly longitudinal, are discoverable. Examination of the free surface with a lens brings out a remarkable honeycomb appearance, occasioned by shallow polygonal depressions or cells, varying in diameter from the 200th to the 350th of an inch ; increasing, however, near the pylorus, to the 100th part of an inch. Elevated ridges separate these cells from each other, and these ridges sometimes bear minute narrow, vascular processes, more particularly in some morbid conditions of the organ, which have been mistaken for villi like those by which absorption takes place in the small intestines. The bottom of each cell exhibits minute openings, and these are the orifices of very small tubes or glands placed perpendicularly side by side in sets, so close together as to compose nearly the whole structure of the mucous membrane. The length or depth of these tubes varies from one-fourth of a line to nearly a line. Their length indeed is proportionate to the thickness of the mucous membrane at different parts of the stomach: near to the pylorus they are both more thickly set and longer than elsewhere. The tubes are of greater diameter at their bases, which rest on the submucous tissue, than at their orifices, their diameter at the base being about the 300th of an inch, while that of the orifice is about the 500th. The basement membrane of the mucous coat of the stomach is the essential part of their walls. In the upper third of the tube there is a lining of epithelium in the form of cylindrical cells, continuous with the epithelium of the surface of the stomach; in the lower two-thirds the place of this epithelium is taken by numerous roundish, oval, or polygonal nucleated cells in various stages of development, enclosing much fine granular matter, and engaged in the secretion of the gastric juice, which when fully matured issues from the cells to mingle with the aliment in the stomach. These cells, being supposed to afford the so-called pepsine of the gastric fluid, have been named peptic cells. The tubes or glands in which they are met with have also been called peptic glands. Other glandular structures are detected in the stomach, both near the cardiac and the pyloric orifices; and there are besides small opaque white sacculi, like Peyer's glands in the intestines, which are said to be present only during digestion.

The peculiar fluid to which the name gastric juice is now given does not exist in the empty stomach. When food and certain kinds of foreign substances are introduced into the stomach, the mucous membrane assumes a more vascular appearance, and an acid fluid begins to pour forth in minute drops, which gradually coalesce and run down the walls of the stomach. Even in the human stomach the average daily secretion is believed to range between 10 and 20 pints.

The evidence that the gastric juice is the main agent in digestion was originally supplied by experiments in which perforated metallic or ivory tubes, filled with aliment, were introduced into the stomach and subsequently withdrawn, and found to contain the aliment changed to chyme. Such experiments were originally performed chiefly on dogs. More recently these experiments have been entirely confirmed by experiments performed on persons in whose stomachs a communication existed with the external air. Similar experiments may be made, out of the living body, by means of an artificial gastric juice. This artificial gastric juice is made by macerating in water portions of fresh or recently dried mucous membrane of the pig, or of the fourth stomach of the calf, and adding to the infusion a few drops of hydrochloric acid. Portions of aliment introduced into such a fluid and exposed for some time, as an hour or more, to the temperature of 100° F.—that, namely, of the warm-blooded animal body—become softened and otherwise changed, much in the same manner as in the living stomach.

The mode in which such changes are effected on the aliment in the stomach is hardly understood. It may be supposed that the pepsine of the gastric juice acts a part like that of a ferment in setting up the requisite changes; but the process nevertheless differs essentially from the ordinary forms of fermentation. Whatever alters the composition of the pepsine—for example, excess of heat, strong alcohol, and powerful acids—puts an end to its digestive quality.

The change which the aliment undergoes in the stomach is its conversion into chyme. The signification of chyme, however, is not very well defined. What the stomach gives up to the duodenum is not a homogeneous substance. The signification commonly attached to chyme is probably that it is the portion of the aliment which has undergone complete solution in the stomach; but what the stomach surrenders to the duodenum is composed in part of aliment which has undergone complete solution, together with substances more or less changed, that are to go through further changes in the duodenum under the influence of the bile, the pancreatic juice, and the proper intestinal secretion, and lastly with substances that, being unsusceptible of alteration within the living system, are to be expelled from it, in much the same state as they were received, along with the feculent matter. It is manifest then that the term chyme should in particular denote the aliment that has undergone complete solution in the stomach, mingled, however, with the secretions which it has imbibed in the process. If there be any homogeneous substance which the phrase *perfect chyme* represents, it is, as it would seem, what has been called of late albuminose or peptone—that low form of albumen not precipitable by heat or nitric acid, into which the albumen, fibrine, and caseine in the aliment appear to be first converted, previously to being elevated by further elaboration into that condition in which they become fit to repair the blood. In the farinaceous portion of the food the starch has in part been changed into sugar by the saliva, and that sugar is probably absorbed directly from the mucous coat of the stomach into the blood of the portal vein; but another part most probably still awaits the influence of the digestive agents proper to the duodenum. The oily parts of the aliment undergo little change till transmitted into the duodenum.

The following are extracts from the work of Dr Beaumont, who performed experiments before referred to in page 201, on an individual who suffered from a fistulous opening in the stomach and the wall of the abdomen, so that aliment could be introduced from without, and the interior of his stomach inspected during the progress of digestion; while, moreover, gastric juice could be collected directly from the digestive organ.

"At half-past eleven o'clock, after having kept the lad fasting for seventeen hours, I introduced a gum-elastic tube, and drew off one ounce of pure gastric liquor, unmixed with any other matter except a small proportion of mucus, into a three-ounce vial. I then took a solid piece of boiled, recently salted, beef, weighing three drachms, and put it into the liquor in the vial, corked the vial tight, and placed it in a saucepan filled with water raised to the temperature of 100° F., and kept at that point on a nicely-regulated sand-bath. In *forty* minutes digestion had distinctly commenced over the surface of the meat. In fifty minutes the fluid had become quite opaque and cloudy; the external texture began to separate and become loose. In sixty minutes chyme began to form. At one o'clock P.M. (digestion having progressed with the same regularity as in the last half-hour) the cellular texture seemed to be entirely destroyed, leaving the muscular fibres loose and unconnected, floating about in fine small shreds very tender and soft. At three o'clock the muscular fibres had diminished one-half since the last examination. At five o'clock they were nearly all digested, a few fibres only remaining. At seven o'clock the muscular texture was completely broken down, and only a few of the small fibres could be seen floating on the fluid. At nine o'clock every part of the meat was completely digested. The gastric juice, when taken from the stomach, was as clear and transparent as water. The mixture in the vial was now about the colour of whey. After standing at rest a few minutes a fine sediment of the colour of the meat subsided to the bottom of the vial. A piece of beef exactly similar to that placed in the vial was introduced into the stomach through the aperture at the same time. At twelve o'clock it was withdrawn, and found to be as little affected by digestion as that in the vial. It was returned to the stomach, and on the string being drawn out at one o'clock P.M., the meat was found to be all completely digested and gone. The effect of the gastric juice on the piece of meat suspended in the stomach was exactly similar to that in the vial, only more rapid after the first half-hour and sooner completed. Digestion commenced on, and was confined to, the surface entirely in both situations. Agitation accelerated the solution in the vial by removing the coat that was digested on the surface, enveloping the remainder of the meat in the gastric juice, and giving this fluid access to the undigested portions." *

The following extracts show the effect of the gastric juice on some vegetable substances as well as on animal substances :—

"March 13, 1830. At ten o'clock A.M. stomach empty—introduced tube, but was unable to obtain any gastric juice. On the application of a few crumbs of bread to the inner surface of the stomach the juice began slowly to accumulate and flow through the tube. The crumbs of bread adhered to the mucous coat, soon became soft, and began to dissolve and digest. On viewing the villous membrane before applying the bread crumbs the mucous coat and subjacent follicles only could be observed; but immediately afterwards small sharp papillæ and minute lucid points, situated in the interstices of, and less than, the mucous follicles, became visible, from which exuded a clear transparent liquor. It then began to run through the tube. †

"January 27, 1831. At eight o'clock A.M. stomach empty—introduced elastic tube, and obtained one and a half drachms of gastric juice by very slow distillation. Applied crumbs of bread to the villous coat, and the juice began immediately to flow freely through the tube.‡

"December 6, 1832. At 8.30 A.M. he breakfasted on bread and butter and one pint of coffee; 9.45, examined—stomach full of fluids; 10.30, examined, and took out a portion resembling thin gruel in colour and consistence, with the oil of the butter floating on the top, a few small particles of the bread and some mucus falling to the bottom, about two-thirds digested. It had a sharp taste. Temperature of the stomach, 100°; atmosphere, 38°. 11.30, stomach empty.§

"December 7. At eight o'clock A.M. examined stomach, and

* Beaumont—Experiments 2 and 3 of First Series.

† Ibid.—Experiment 12 of Second Series.

‡ Ibid.—Experiment 15, Second Series.

§ Ibid.—Experiment 4, Third Series.

took out, with considerable difficulty, an ounce only of gastric juice, and that not very pure: some yellow bile came mixed with the latter portions. Temperature of the stomach, 99°; atmosphere, 28°. He breakfasted at nine o'clock on corn and wheat bread, butter, and coffee.

"At 10.45 examined, and took out a portion—food partly digested—a few small particles to be seen—stomach full of fluids, with a thin pellicle of oil on the top. Temperature of stomach, 100°. At twelve o'clock A.M. stomach full of fluids—digestion not complete—particles of bread floating about in a pulpous state—oil floating on the surface. At 12.30 A.M. examined—contents of stomach half diminished—distinct particles of oil on the surface. At 12.45 entire particles of bread yet to be seen—quantity of fluid diminishing. At 1 P.M. distinct particles of bread still floating; fluid less. At 1.15 P.M. stomach empty.

"*Remarks.*—Some indications of gastric derangement this morning—small aphthous patches on the mucous membrane—juice acrid and sharp, with bile mixed with it." *

Subjoined are examples taken from Beaumont's table of the periods of time required respectively for natural digestion in the stomach, and for artificial digestion with gastric juice collected from the stomach, in the case of various vegetable substances. It should be premised, that in artificial digestion one ounce of gastric juice was as near as possible employed for each drachm of aliment. Rice, boiled, required for digestion in the stomach one hour. Apples, sweet, mellow, raw, required for digestion in the stomach an hour and a half; in the artificial process, six hours and forty-five minutes. Sago, boiled, stomach, one hour and forty-five minutes; vial in sand-bath, three hours and fifteen minutes. Tapioca, boiled, stomach, two hours; vial, three hours and twenty minutes.

* Beaumont—Experiment 6, Third Series.

Barley, boiled, stomach, two hours. Apples, sour, mellow, raw, stomach, two hours; masticated, vial, eight hours thirty minutes. Cabbage, with vinegar, raw, stomach, two hours; shaved, vial, ten hours fifteen minutes. Beans, pod, boiled, stomach, two hours thirty minutes. Parsnips, boiled, stomach, two hours thirty minutes; mashed, vial six hours forty-five minutes. Potatoes, Irish, roasted, stomach, two hours thirty minutes; do., baked, stomach, two hours thirty minutes. Cabbage-head, raw, stomach, two hours thirty minutes; masticated, vial, twelve hours thirty minutes. Apples, sour, hard, raw, stomach, two hours fifty minutes; entire pieces, vial, eighteen hours. Bread, corn, baked, stomach, three hours fifteen minutes. Carrot, orange, boiled, stomach, three hours fifteen minutes; mashed, vial, six hours fifteen minutes. Bread, wheaten, fresh, baked, stomach, three hours thirty minutes; masticated, vial, four hours thirty minutes. Turnips, flat, boiled, stomach, three hours thirty minutes. Potatoes, Irish, boiled, stomach, three hours thirty minutes; mashed, vial, eight hours thirty minutes. Green corn and beans, boiled, stomach, three hours forty-five minutes. Beets, boiled, stomach, three hours forty-five minutes. Parsnips, boiled, entire piece, vial, thirteen hours; parsnips, raw, vial, entire piece, eighteen hours. Carrot, orange, raw, vial, entire piece, seventeen hours fifteen minutes.

Supposed Influence of Nerves on Digestion.—An idea has often prevailed in past times that the digestion of the aliment in the stomach is much under the influence of nervous power communicated by the nerves of the stomach. It is certain that secretion in the stomach is to a certain extent influenced by the gastric nerves, and not less certain that the movements of the organ are at least modified by the like agency.

Many experiments have been made with a view to clear up these points. It is very certain that division of the nerves of the stomach suspends the secretion of the gastric juice, and thus arrests digestion. Yet, under favourable circumstances, it is found that after such an operation the digestive action of the stomach may be entirely recovered, so that chyme is perfectly formed, and the nutrition of the animal proceeds in a manner little different from its effects in health. As to the influence of the gastric nerves on the movements of the stomach, it appears that irritation of these nerves during digestion produces active movements of the muscular fibres of the stomach, but that when the stomach is empty the same kind of stimulus occasions no such effect. Correspondent with this is the fact, that during digestion the pyloric orifice is irritable so as to close against everything but chyme; but when digestion is completed, undigested food, and even non-esculent substances, such as small metallic bodies, may pass without opposition.

Hunger and Thirst.—To the influence of the nerves of the stomach, also, the sensations of hunger and thirst appear at first sight exclusively to belong. The division, however, of the nerves of the stomach does not allay the sensations of hunger, and the repair of the blood through other channels than the stomach allays hunger; thus, while the nerves of the stomach are in part concerned in hunger, it seems, nevertheless, to be manifested in consequence of a deficiency of recruiting supplies in the system at large. That the nerves of the stomach are in part concerned appears from the fact, that the introduction of non-alimentary substances appeases for a time the sensation. In short, while the whole system suffers from an exhausted state of the blood, the stomach is made to suffer more immediately and largely from the prevailing deficiency.

With respect to thirst, it depends not merely on the dryness of the fauces, or throat, but on a deficiency of fluid in the blood. It is relieved by an increase in the watery part of the blood, in whatever way that is effected. It may be regarded as a state of the general system in which the nerves of the fauces and mouth are more sensitive to the condition of the blood than the sensitive nerves elsewhere.

Under the duodenal digestion in the horse a full account was given of the ulterior processes to which the aliment is subjected previously to its incorporation with the blood (see p. 68). Nothing, then, seems to remain untouched on in this respect, unless that the peculiar glandular structure of the mucous membrane of the intestines has been rather cursorily treated of.

Additional particulars as to Mucous Membrane of Alimentary Canal.—The first point which attracts attention in the intestinal mucous membrane is what relates to the *valvulæ conniventes.* These, indeed, are by no means universal in the animals of the farm; nevertheless, their character in a treatise on animal nutrition requires to be made known. These so-called valves, as seen in the human intestines, are transverse folds of the lining mucous membrane in the higher parts of the small intestine, by the presence of which the extent of surface in that membrane is very much augmented. The *valvulæ conniventes* are found from the point of the duodenum at which the bile-duct enters to near the middle of the ilium—that is, in the human body, through an extent of nearly twenty feet of the small intestine. These folds are large in the duodenum and placed closely together, and this character they retain throughout the jejunum, while in the ilium they gradually diminish in size and in proximity until they finally disappear. No similar folds exist in any part of the great intestines. The *valvulæ conniventes* are always much less distinct in other mammals than in the human intestines. They belong to herbivorous animals rather than to the carnivorous—yet even in many of the herbivorous they are hardly perceptible.

In the substance of the mucous lining of the intestines numerous glands exist; it is covered throughout with cylindrical epithelium—that is to say, from the cardiac orifice of the stomach to the fundament—while the more common pavement, that is, tesselated epithelium, covers the mucous membrane from the mouth to the cardiac extremity of the gullet. The cylindrical epithelium of the intestinal canal dips into the various ducts which open upon the lining membrane. The glands of the small intestines are of three principal kinds, named respectively, after anatomists, the glands of Lieberkühn, the glands of Peyer, and the glands of Brunn or Brunner.

The glands, or follicles, or crypts of Lieberkühn are the smallest of the whole. They are simple tubular recesses of the intestinal mucous membrane, thickly distributed over the whole surface of the large intestines, as well as of the small intestines. They cannot be seen in the small intestines without the aid of a lens; in the great intestines they are of greater size, and the lower they are the larger, so that near the fundament their orifices may be visible to the naked eye. Their special use has not yet been discovered.

The glands of Peyer are peculiar to the small intestines. They are found in greater numbers the nearer to the ilio-cæcal valve or the junction of the small intestines with the great intestines. Peyer's glands are either solitary or aggregated in groups of several sizes, these groups being termed Peyer's patches. The surface of the solitary glands are beset with villi, which makes the chief difference between them and the individual glands of the agminate patches. Each gland is a closed sac from half a line to a line in diameter, either sunk beneath or somewhat prominently raised on the surface of a depression in the mucous membrane. The sac has no outlet. The openings which surround it appear to be the openings of follicles of Lieberkühn. It seems probable that these shut glands are engaged in some office bearing on the preparation of the chyle in connection with lacteal absorption. If this conjecture be well-founded, they belong to the same order of organs with the mesenteric glands and the spleen.

Brunner's glands are found solely in the duodenum. They lie beneath the mucous membrane in the submucous tissue. They are lobulated bodies, like detached pieces of the pancreas. They are visible in the human intestine to the naked eye. They have permanent ducts which pierce the mucous membrane and open on its surface. If they have not the same function as the pancreas, they may be regarded as bearing the same relation to the pancreas which the labial and buccal glands bear to the parotid and submaxillary salivary glands.

TEXTURES AND FLUIDS, OR THE COMPONENT PARTS COMMON TO THE BODIES OF THE HIGHER ANIMALS.

The animal body, particularly in the higher orders of the animal kingdom, is of a very composite but yet similar character. It consists, according to the received view in physiology, of solids and fluids. The firmest and most compact of the solids is bone, the softest or most watery of the solids is the brain. The chief of the fluids is the blood, which, however, is hardly a fluid in the physical sense, being water crowded with solid particles; the nearest approach to a chemical fluid is the urine, which is water containing a large proportion of saline matter in a state of solution.

The living body is also represented as composed of several connected systems, such as the vascular or circulatory system, the respiratory system, the nervous system, the digestive system, the urinary system, the reproductive system, the locomotive system. These several systems are made up of organs, and organs in turn are composed of textures or tissues, some more, some less simple. The simplest textures or tissues cannot be decomposed farther, unless into the proximate chemical principles of organic nature ; and the resolution of these, when in their normal state of simplicity, yields the ultimate elements—that is to say, such simple substances as oxygen, nitrogen, hydrogen, carbon, sulphur, and the like.

The organised constituents of the animal frame—that is, the textures and the fluids containing organic particles—are as follows :—

1. The blood, chyle, and lymph.
2. Epidermic tissue, including epithelium, cuticle, nails or hoof, and hairs.
3. Pigment.
4. Adipose tissue.
5. Areolar, cellular, or connective tissue.
6. Fibrous tissue.
7. Elastic tissue.
8. Cartilage and its varieties.
9. Bone or osseous tissue.
10. Muscular tissue.
11. Nervous tissue.
12. Blood-vessels.
13. Absorbent vessels and glands.
14. Serous and synovial membranes.
15. Mucous membranes.
16. Skin.
17. Secreting glands.
18. Vascular or ductless glands.

The textures here enumerated are not simple tissues, but are more or less compounded; while several textures which are very local in their character are omitted, as better spoken of along with the organs in which they occur. Of this description are the crystalline lens of the eye and the enamel of the teeth.

It should be remarked further that some of the textures above enumerated are spread throughout nearly the whole frame, while others are confined to certain parts. Thus the blood-vessels and the nerves extend to almost every part of the body, the only certain exceptions being such parts as the cuticle and the enamel of the teeth. Again, what is now called the areolar or connective tissue—known, however, in past times by a multitude of names, such as cellular membrane, cellular substance, cellular tissue, reticular tissue—spreads throughout every organ and corner of the body, so as to connect together the several simpler parts of which each organ is made up. In contrast with these, there are textures proper, named particular textures, confined to one part, such as the osseous tissue and the cartilaginous tissue.

When the microscope is used for the unravelling of the textures a still greater degree of simplicity is attainable, so that the constructive elements, when regard is had to form only, and not to chemical constitution, may be reduced to the following—viz., 1, simple fibre; 2, homogeneous membrane, either spread out or forming the walls of tubes or cells; and, 3, globules or granules, varying in diameter from the 12,000th to the 6000th of an inch. These, with a proportion of amorphous matter, may be regarded as making up the several kinds of structure recognisable in the textures.

Dr Bennett prefers placing the ultimate microscopic textures under the following four heads—viz., 1, molecule-tissues; 2, cell-tissues; 3, fibre-tissues; and, 4, tube-tissues.

A molecule is a minute body presenting optically the appearance of a point or minute dot. When such a minute dot, by being magnified, presents the appearance of an external ring or margin, which ring or margin is alternately dark or light according to the focus under which it is examined, it is termed a granule. Hence molecules and granules are structurally the same. In composition the molecules and granules may be various—albuminous, fatty, pigmentary, or mineral matter. When of still larger size, as in the milk, they are termed globules.* Molecular fluids are fluids in which organisation is proceeding, or the fluids within cells containing the commencement of new germs, or the deposits of secreted or effete matter. Molecular fibres are fibrous arrangements of molecules or organic fluids. Molecular membrane, the chief example of which is the substance of cell-walls, is composed of molecules closely aggregated together. Molecular movements are the movements of molecules floating in a fluid, the laws governing which have not yet been clearly ascertained; these may be vibratile, circular, spiral, serpentine, or wholly irregular.

"When we know," says Dr Bennett, "that essentially different fluids, as oil and albumen, when brought into contact, immediately precipitate molecules that assume a globular, fibrinous, or membranous form, and that such a process is facilitated by numerous chemical reagents, acids or alkalies acting on albuminous, fibrinous, or mineral solutions, we readily observe one way in which histological elements may be produced within the body. Such elements, subject to the laws of vitality, may be formative elements (histogenetic), whilst others may be retrograde, and give evidence of vital cessation (histolytic). Hence the first and the last element is, as regards the form, the molecular. Organic formative fluids deposit molecules, which arrange themselves, subject to vital laws, into nuclei, cell-walls, and higher textures. These, once produced, subsequently decay in an inverse order, breaking down into individual fragments, and ultimately into minute molecules. During the whole life of an individual organism, we observe in it a constant series of these formations and disintegrations, of these histogenetic and histolytic actions."†

* Bennett, 'Outlines of Physiology,' pp. 14, 15. † Ibid., p. 17.

The animal textures, like the vegetable, originate to a great extent from cells. Such cells, remaining as distinct corpuscles in the fluids, and grouped together in the solids, continuing in some with little change, in others undergoing a more or less complete transformation, give rise to the varieties of form and structure met with in the animal tissues. Even the germ from which an animal originally proceeds is a distinct cell, and the embryo in its earliest stages is but a cluster of cells originating from that primordial cell ; while no distinction of texture is discovered, till a process of transformation of the cells has entered on its progress. In short, reproduction is in the strictest analogy with nutrition, so as to be really but a special form of the great office of assimilation.

Cells are divided into proper cells and cells of transition; the first being those which do not proceed beyond the cell form in their development; the second, those which become transformed into more permanent textures.

1. *Chyle and Lymph Cells.*—These are believed to be blood-corpuscles in an early stage of development. They are for the most part free nuclei, but a small number having cell-walls around them.

2. *Blood-Cells.*—The blood-cells are either coloured or colourless. The coloured cells are the ordinary blood-corpuscles of the blood. These cells have a character different in fishes, reptiles, and birds from that which they exhibit in mammals. In the three first-mentioned orders of vertebrated animals, they are for the most part oval, being largest in reptiles and smallest in birds. An oval vesicle or nucleus occupies about a third of their area. Dilute acetic acid partially dissolves the cell-wall and destroys the colour, while its action is resisted by the nucleus. There is a fluid of a yellowish tint between the nucleus and the cell-wall. In mammals (except in the camelidæ, in which they are oval), the

coloured blood-cells (blood-corpuscles) are round and flat like a piece of money, or they are described technically as biconcave circular discs, smallest in the Napu musk-deer, and largest in the elephant. These coloured blood-cells or blood-corpuscles in mammals have no included body or nucleus. They consist of a vesicle containing a coloured fluid. When put into water they swell out and become globular, losing their colour, and sometimes bursting. Acetic acid renders them transparent and almost invisible. They tend to run together, so as to form cylindrical columns, like piles or rouleaus of pieces of money, the nature of the attraction to which this tendency is due being still unknown. Moreover, these cylinders are apt to join together in the form of an irregular network.

The colourless blood-cells are globular, or only slightly flattened. They have a distinct nucleus, which, on the addition of acetic acid, shows two or three granules. In mammals they are somewhat larger; in the other vertebrated orders they are smaller than the coloured blood-corpuscles. They are fewer in number than the coloured blood corpuscles. According to some physiologists, the blood-cells nourish the *liquor sanguinis* in which they ultimately become dissolved.*

3. *Nerve-Cells or Ganglionic Cells.*—The nerve or ganglionic cells, called also ganglionic corpuscles, ganglion globules, and nerve vesicles, constitute one of the two structural elements of the nervous system. The fibres are found universally in the nervous cords, and constitute the greater part of the nervous centres; the cells or vesicles are confined to the grey matter of the cerebro-spinal centre and the ganglia, and do not exist in the nerves properly so called, unless at the peripheral expansions in some of the organs of special sense. They are very various in figure. For the most part each con-

* Bennett's 'Outlines of Physiology,' p. 20.

sists of a vesicle constructed of a fine simple transparent cell-membrane filled with granular matter, and containing a vesicular nucleus with one or more nucleoli. Their diameter varies from the 300th of an inch to less than 1-10th of that measure, so that some hardly equal the size of an ordinary red globule of the blood. Their function is of the most important character—they plainly constitute the means of communication between the several nerve-filaments or nerves, and originate that signal force by which the sensitive and motor processes of the nervous system are carried on.

4. *Adipose-Cells.*—The adipose-cells, into which the oily and adipose matter is secreted, are the largest cells in the body. Owing to the pressure to which they are often subjected, they are apt to assume a polygonal form.

5. *Pigment-Cells.*—Pigment-cells, within which are produced in a fluid or granular form the various coloured substances that colour different textures of organic bodies, present, as might be anticipated, remarkable variations of size and shape.

6. *Glandular or Secreting Cells.*—In the function of secretion, taken in its largest sense, cells very various in character perform an important part. Such cells draw from the blood, some bile, some urea, some saliva, some milk, and some even the germs of new blood-corpuscles, and no explanation can be given of this surprising result. The process of secretion, in which the cell-structure uniformly takes part, is an ultimate fact in physiology—that is, one of which no explanation has been as yet discovered.

7. *Cells of Transition.*—This name is given to such cells as are destined to undergo development into other forms of tissue of a more or less permanent character. 1. Cells observed in the development of the ovum of plants and animals. 2. Fibre cells. 3. Epithelial cells. 4. Cartilage cells. Such cells are in the end to be transformed into various organs,

as blood-vessels, nerve, tubes, fibres, membranes, bone, and cartilage.

Laws which regulate the Origin and Development of Cells.—The laws which regulate the origin and development of cells afford some insight into the plan on which organic bodies grow and are sustained. The fluid in which cells originate is termed blastema or germ-substance. At first this fluid is clear, and after a time it becomes opaque by the formation in it of numerous molecules or granules. Such a fluid in every known instance owes its origin to a previously existing living organism. The molecules and granules coalesce and give rise to a larger body, on which a delicate membrane is produced and gradually detached therefrom by the accumulation of fluid. The cell so developed, on attaining perfection, consists of an external envelope or vesicle, termed the cell-wall; the body within which the cell-wall was produced, now termed the nucleus; and a fluid interposed between the inner surface of the cell-wall and the outer surface of the nucleus. In the nucleus may often be remarked one or two included granules; granules of this character are named nucleoli.

Cells exhibit varied phenomena: they may gradually dissolve and perish, or, the cell-wall bursting, the fluid contents may be set free, *constituting a secretion*—various matters may be deposited in the interior of the cell, such as pigmentary substance, a mineral matter, bone, and the like—the cells may unite with contiguous cells to form complex tissues, as fibres, tubes, networks. Cells, again, often show a reproductive property: thus, the cell-wall may burst and set free included germs, each of which shall give origin to a new cell; a nucleus may enlarge and divide into two, and these, again, into other two, the multiplication here being within the original cell-wall; the cells may resolve themselves into two or more divisions; or the cells may throw out processes or buds at one part of the circumference that subsequently separate.

Epidermic, Epithelial, or Cuticular Tissue.—The type of an epidermic or cuticular tissue is that thin membrane raised by the application of a blister to the skin of an animal. It is certain that a cuticular covering of this character, variously modified, exists—1, on the surface of the skin ; 2, on mucous membranes ; 3, on the inner or free surfaces of serous membranes which line the walls of the closed cavities in the head, chest, abdomen, and other parts ; 4, on the membranes termed synovial, within the joints; 5, on the inner surface of the blood-vessels and lymphatics.

This texture has neither vessels nor nerves, and is wholly destitute of sensibility. It has, however, an undoubted organic structure. It is made up essentially of nucleated cells joined together by a more or less cohesive intercellular matter. The cells are formed from a blastema or germ-fluid derived from the blood-vessels of the subjacent tissue. Appearing first in the deepest part of the structure, they gradually rise, while they undergo various changes, to the surface, where they are given off to be succeeded by others. During all the changes the original nucleus remains little altered. Its diameter is from the 6000th to the 4000th part of an inch.

Epithelium takes on several forms in different situations, which have been distinguished by separate names—namely, the scaly, columnar, spheroidal, and ciliated.

The scaly is what is called by some pavement or tesselated epithelium. As a simple layer the scaly occurs on serous membranes ; in stratified layers it covers the skin, forming the scarf-skin or epidermis. In the columnar variety of epithelium, the cells are elongated in a direction perpendicular to the surface of the membrane, so as to form short upright columns. The columnar variety of epithelium is found only in the mucous membranes. In the spheroidal epithelium the cells retain nearly their primitive form, or so changed that they have a polyhedral aspect. The chief seat of this description of epithelium is in the urinary passages, with the exception of the urethra, in which the epithelium is columnar.

In ciliated epithelium, the particles, which are generally columnar, bear at their free extremities little hair-like processes, which are agitated incessantly during life, and for some time after death, with a lashing or vibrating motion. These minute and delicate moving organs are named cilia, from the Latin word signifying eyelashes. In the human body and mammiferous animals in general, ciliated epithelium occurs in the following parts : on the mucous membrane of the air-passages and its prolongations ; on the mucous lining of the uterus ; on the parietes of the ventricles of the brain.

The nature of ciliary movement is still involved in much obscurity.

The chemical composition of epithelium is still somewhat uncertain.

The epidermis of the integuments appears to be similar to horny matter in composition—the chief constituent being a substance intermediate between the albuminoid and gelatigenous components of the body, joined to a considerable proportion of sulphur.

Pigment.—See Pigment-Cells, p. 217.

Adipose Tissue or Fat.—In the most healthy state of the body there is present a considerable amount of fat. It is found in the blood and in the chyle, and, though in much more sparing quantity, in the lymph. It exists also in the products of secretion, as in the milk, the sebaceous matter of the skin, the cerumen of the ears, the bile, and, moreover, in the formation of the *corpus luteum* in the ovaries. But the greater part of the fat is contained in small cells or vesicles spread over the body, and known as the adipose tissue. It forms a considerable layer under the skin, constituting, along with the subcutaneous areolar tissue in which it is lodged, what has been called the *panniculus adiposus.* Around some internal parts it accumulates —for example, around the kidneys. It fills up the furrows on the surface of the heart, and imbeds the nutritive blood-vessels of that organ underneath its serous membrane. In several situations it lies beneath serous membranes, or is deposited between folds of that tissue, as in the mesentery and omentum, there affecting, at least in its first depositions, the course of the blood-vessels. Fat also is observed around the joints lying on the outer surface of the synovial membrane, or lodged, as it is in the omentum, in folds of that membrane, which project into the cavity of the joint. It exists, moreover, in the bones, in the interior of which it forms the marrow. As examples of situations in which fat is not found during health, may be mentioned the subcutaneous areolar tissue of the eyelids, the lungs, and the cavity of the skull.

Under the microscope the adipose tissue is found to be made up of minute vesicles filled with an oily matter, and lodged, for the most part, in the meshes of the areolar tissue. The vesicles commonly cluster into little lobes, and these again collect into the lumps of fat which become apparent to the naked eye. At other times, as when they collect alongside the minute blood-vessels of the membranous structures, the clustered arrangement does not exist. The average size of the fat-cells is from the 300th to the 600th of an inch in diameter. Each consists of a very delicate envelope, transparent and homogeneous, enclosing what appears to be a single drop of oily matter.

It is the undue accumulation of the adipose tissue which gives rise to obesity and polysarcia, from continually-increasing quantities of connective tissue (areolar tissue) becoming involved in this accumulation of fat. What is often called the fatty degeneration of muscles is nothing but a more or less predominant development of adipose cellular tissue between the primitive muscular fasciculi. It is a like effect which is met with in the fattening of animals—that is, like the simply fattened muscles in the human body. Fat-cells insinuate themselves in the primitive muscular fasciculi, and therefore lie in stripes in the direction of the muscular fibres, which may remain unchanged. The development in such a case has its commencement in the interstitial tissue of the muscle. At its first origin, and when it proceeds with very great regularity, it may be that single rows of fat-cells, lying one behind the other, alternate with the rows of muscular elements. Here, when the primitive fasciculi are forced asunder, and the circulation in the muscle is generally disturbed in consequence of the abundant development of fat, so that the flesh becomes pale, it looks to the naked eye as if there no longer existed any muscular tissue whatever.

In the fat-cells of the embryo a nucleus has been discovered, and, more recently, even in the fat-cells during after-life. The nucleus contains one or two nucleoli, and is attached to the inside of the cell-wall or imbedded in its substance.

The ordinary fat in human bodies is regarded as a mixture of the solid fatty substance named "margarine," and the liquid oily substance, "oleine;" on the other hand, the suet or fat of oxen and sheep consists chiefly of a second solid principle, "stearine," associated with oleine. These three substances—margarine, stearine, and oleine—are compounds of the base named glycerine with three fatty acids—namely, the margaric, the stearic, and the oleic; while glycerine is supposed to be the oxide or hydrated oxide of a hypothetical radical glyceryl.

The fat in the cells during life is liquid, but after death crystalline spots sometimes appear, indicating the solidification of one of its constituents. This solid crystalline substance is most probably margaric acid.

It was a part of the old physiology, that the fat must be contained, not in the common cells of the cellular tissue, but in proper cells, because, though fluid, it did not gravitate to the lower parts of the body, like the water in dropsy. The difference between the old view and the new lies merely in the circumstance, that the proper cell of the fat, which was formerly a conjecture, is now a recognised fact.

There is another series of tissues which do not form permanent reservoirs for fat, in which it appears only at certain times and transitorily—that is to say, it disappears after a while, and leaves behind no trace of change in the part. This is the case in the ordinary absorption of fat from the alimentary canal. In the passage of digested matters from the intestines into the lacteals they pass through the epithelium and the villi, and some hours after a meal the epithelium and the villi concerned are full of fat. When a fatty substance has been eaten and has been converted into an emulsion, and in that state has reached the duodenum, but, more particularly, the jejunum, the villi of the mucous membrane become whitish, clouded, and thick, and on minute examination they are found to contain extremely minute granules, much more minute than can be produced by any artificial emulsion. These granules—and they occur even in the chyme—come in the first place into contact with the cylindrical epithelium, with which every one of these intestinal villi is invested. On the surface of every epithelial cell we find a peculiar border, which, when the cell is seen in profile, exhibits minute and fine striæ; when seen from above and upon the surface, the cell seems to be hexagonal, and, as it were, dotted over with a number of minute points. It has been conjectured that these fine striæ and dots correspond to minute pore-canals, and that the absorption of fat is accomplished by its minute particles being taken up through these minute pores upon the surface of the epithelial cells. Another conjecture is, that the upper border of the cell is composed of little rods or pillars resembling cilia. However this may be, the fat passes through the cells, so that at first only their outer end is filled with it, then after a time the outer end becomes entirely free from it, the inner still containing a little, and at last the fat entirely vanishes from the cells. After the fat has proceeded as far as the inner extremity of the cells, it begins to pass into the parenchyma of the villus. In the interior of the villi there is found a network of blood-vessels somewhat below the surface, and in the axis a tolerably wide canalicular cavity with a blunt extremity, which appears to be the commencement of the lacteal vessel. At the periphery of the villus a layer of muscular fibres has been recently announced, which must be of great importance in digestion, as by their contraction the apex of the villus is made to approach to its base. When the villi are cut off from the intestine of an animal just killed, they may be seen under the microscope to contract, become wrinkled, thicker, and shorter—thereby a pressure from without inwards is manifestly produced, which promotes the onward movement of the juices.*

Something analogous to what has just been described takes place in the liver with respect to the transitory presence of fat in the hepatic cells. A sucking animal, a few hours after digestion has taken place, shows the presence of a fatty liver, not as a morbid condition, but as a physiological occurrence. When of the same litter of animals some are allowed to suck, while the rest are made to fast, those only which have sucked

* Abridged from 'Cellular Pathology,' by Virchow, translated by Chance.

show a fatty liver after a few hours. A short time after the hepatic cells exhibit this repletion with fat, a similar condition is found in the course of the biliary ducts, while both in them and the gall-bladder the epithelium presents the same appearances which are witnessed in the intestinal epithelium during the absorption of fat. The fat, as it would seem, is secreted from the blood into the hepatic cells, passes thence with the bile into the biliary ducts, and from the biliary ducts is reabsorbed into the blood.

Another type of the production of fat is found in the secretion of the milk, of the sebaceous matter of the skin, and the cerumen of the ears. The characteristic difference here is, that the cells are thrown off with the fat, and so being lost to the body are continually replaced by new cells. That the secretion of milk and that of sebaceous matter in the skin should be analogous to each other is nothing surprising, if what is now affirmed be admitted—namely, that the mammary gland is but an enormously developed and peculiarly formed accumulation of cutaneous sebaceous glands, both being produced by a progressive proliferation from the internal layers of the epidermis. Of the same description are the ceruminous glands of the ear and the large glands of the armpit.

Besides serving the mere mechanical purpose of a light, soft, and elastic packing, filling the vacuities of the body, affording support, facilitating motion, and protecting from the injurious effects of pressure, the fat, being a bad conductor of heat, serves as a means of retaining the warmth of the body, especially in warm-blooded animals exposed to great natural cold—for example, in the whale tribe.

But the subserviency of fat to the function of nutrition is its most important use. It is ready at all times to maintain the temperature of the body by supplying material for eremacausis in the lungs. Thence, when the digestive process introduces more compounds of hydrogen and carbon than are required for immediate use, the excess of these elements is stored up within the body in the form of fat, to be ready for use when the expenditure exceeds the supply at the moment. When the body is subjected to active muscular exertion, under which respiration is always augmented, the accumulation of fat is prevented by the increase in the consumption of the fuel employed. But when the supply of calorific matter for respiration is lessened by a deficiency of food, or by failure in the digestive process, there is a reserve within the body in the fat which has become accumulated; and in starvation, the fat is the first solid which disappears.

In hybernating animals, such as the hedgehog, the fat accumulated before winter sets in, both maintains the temperature during the suspension of nutrition, while their winter sleep lasts, and affords a temporary supply of material for eremacausis in spring, when the respiration first recovers its activity.

It has been calculated that the mean proportion of fat in the human body is about one-twentieth of its weight. Here, however, the greatest differences must prevail. The proportion for the most part is greatest in the middle period of life, while it declines as old age advances. In man, rich food, tranquillity of mind and body, and an excess of sleep, favour the growth of fat. In females and in eunuchs the tendency to the production of fat appears to be in higher measure. In domesticated animals a corresponding state of the fact is observed.

Areolar, Cellular, or Connective Tissue.—The cellular tissue, known by a multitude of names, is the soft filamentous substance, often of a white fleecy aspect, by which the various other textures of the living body are connected together. The mode of representing the extent of this tissue common with the old authorities was to say that if all the other tissues were annihilated, this would still preserve the form of the body.

When examined under the microscope, the areolar tissue is seen to be principally made up of exceedingly fine transparent and apparently homogeneous filaments, from about 1-15,000th to 1-25,000th part of an inch in thickness. These are for the most part united by means of a small quantity of clear homogeneous connecting substance into bundles and filamentous laminæ of various sizes, which, to the naked eye, appear as simple threads and films. The bundles intersect in every direction, yet the filaments of the same bundle run nearly parallel to each other, and no filament is seen to divide into branches, or to become continuous with another. The united filaments take an alternate or waving course without losing their parallelism. Such filaments not only belong to the areolar tissue strictly so called, but form the chief part of the tendons, ligaments, and other white fibrous tissues.

Intermixed with these filaments of the areolar tissue are yellow elastic fibres which seem to be identical with the fibres of the proper yellow elastic tissue.

The areolar tissue contains a large proportion of fluid, so as to lose much weight by drying. By boiling it is resolved almost entirely into gelatine.

Fibrous Tissue.—The fibrous tissue forms the ligaments of the joints, the tendons of the muscles, and, assuming the membranous character, it constitutes the fibrous membranes. Of these the chief are the periosteum, the perichondrium, which cover the bones and cartilages, the layer of the dura mater next the skull, and the fibrous layer which strengthens the pericardium. To these may be added the albugineous coat of the testicle and that of the ovary, and the sclerotic coat of the eye. Fibrous expansions under the name of aponeuroses or fasciæ bind down the muscles—for example, the great fascia enclosing the muscles of the thigh and leg. The tendons of muscles, as those of the broad muscles of the abdomen, may present the expanded aspect of aponeuroses. Thus the fibrous tissue is seen under two principal forms—viz., the fascicular and the membranous.

The fibrous tissue is very strong and tough, of a white or yellowish-white colour: it is perfectly pliant, yet devoid of extensibility.

The fibrous tissue is made up of filaments agreeing in all respects with the white filaments of the areolar tissue. The fibrous tissue, like the areolar, is resolved into gelatine by boiling in water.

Yellow or Elastic Tissue.—As the fibrous tissue is characterised by its want of extensibility, so the yellow tissue is remarkable for possessing that property in a high degree—it is, in short, an extensile and highly elastic material.

Examples of this texture on the great scale are seen in the horse, ox, elephant, and other large quadrupeds, in which it forms what is called the *ligamentum nuchæ,* an elastic ligament that extends from the spines of the vertebræ to the occiput (hind head), so as to aid in the support of the head. In the same animals it constitutes an elastic subcutaneous fascia, spread over the muscles of the abdomen, so as to support the contents of that cavity.

In the human body this tissue forms—1, the *ligamenta subflava,* extending between the arches of adjacent vertebræ; 2, The chief part of the stylohyoid, thyrohoid, and cricothyroid ligaments, the vocal cords, and the suspensory ligament of the penis—also the longitudinal bands beneath the mucous membrane of the windpipe and its ramifications; 3, The elastic material in the coats of the blood-vessels, particularly of the arteries; 4, The submucous coat of the gullet and of the lower part of the rectum and part of the tissue which surrounds the muscular coat of the gullet on its external aspect; 5, The tissue underlying the serous membrane in many parts; 6, Part of certain fasciæ; 7, Part of the tissue of the skin.

By long boiling in water the elastic tissue affords a substance somewhat resembling gelatine; more than a half, however, remains undissolved.

Cartilage.—Gristle is known to anatomists by the name of cartilage. This texture is distinguished by its great elasticity. It readily yields to pressure or torsion, but immediately recovers its original shape when the force applied is withdrawn. Along with bone and the substances of the teeth, it constitutes the hard solids. It is somewhat less than twice the density of water.

In the early embryo, the skeleton is in great part cartilaginous, which texture in due time gives place to bone. The chief of the permanent cartilages are the articular and the costal cartilages. Others again enter into the external ear, the nose, the eyelids, the Eustachian tube, the larynx, and the windpipe. Cartilages, except those of the joints, are covered by fibrous membrane termed perichondrium.

When a thin slice of cartilage is examined with the microscope, it is found to consist of nucleated cells disseminated in a solid mass or matrix.

Ordinary permanent cartilage is resolved by long boiling into chondrine.

Of the ashes of cartilage 100 parts consist of—

Carbonate of soda, ...	35.07
Sulphate of soda, ...	24.24
Chloride of sodium, ...	8.23
Phosphate of soda, ...	0.92
Sulphate of potash, ...	1.20
Carbonate of lime, ...	18.37
Phosphate of lime, ...	4.06
Phosphate of magnesia, . . .	6.91
Oxide of iron and loss, ...	1.00
	100.00

Fibro-Cartilage.—Fibro-cartilage is a compound of cartilage and the fibrous tissue, so as to partake of the qualities of both. The examples are—1, Interarticular fibro-cartilages, as in the joint of the lower jaw, in that of the clavicle in man, in the knee-joint; 2, The articular cavities of bones are often deepened by a rim or border of fibro-cartilage, as in the hip-joint; 3, The connecting substance in the symphysis pubis and between the bodies of the vertebræ; 4, The lining of the bony grooves in which the tendons of muscles glide; 5, Nodules of fibro-cartilage in the substance of tendons, as in the tendon of the tibialis posticus; 6, The fibro-cartilage in the orifices of the heart giving attachment to muscular fibres.

Like fibrous tissue, fibro-cartilage yields gelatine by boiling in water.

Bone or Osseous Tissue.—Bones are covered with a fibrous membrane, termed periosteum, and contain marrow within, which, particularly in the long bones, fills their cavity and renders them lighter. Bones consist of animal and earthy matters; the earthy constituent amounting to about two-thirds of the weight of the bone. When bones are subjected to a destructive heat, the animal matter is dissipated and the earthy matter remains. If a bone be steeped in dilute nitric or hydrochloric acid, the earthy matters are removed, and a tough flexible substance remains, preserving in every part the exact shape of the original bone. This tough residue is, by boiling in water, resolved almost wholly into gelatine. It is therefore improperly called the cartilage of bone. The earthy constituents of bone consist principally of phosphate of lime, with about a fifth part of carbonate of lime, and much smaller proportions of fluoride of calcium, chloride of sodium, and salts of magnesia.

The following is the analysis of Berzelius, placed side by side with a recent analysis by Mr Middleton of University College, London. In 100 parts are—

	Berzelius.	Middleton.
Animal matter, . . .	33.30	33.43
Phosphate of lime, . . .	51.04	51.11
Carbonate of lime, . . .	11.30	10.31
Fluoride of calcium, . .	2.00	1.99
Magnesia wholly or partially in the state of phosphates, . .	1.16	1.67
Soda and chloride of sodium, .	1.20	1.68
	100.00	100.00

When a bone is sawn through, it presents in some places a dense and close texture like ivory, in others an open and reticular texture; hence the distinction of osseous tissue into the compact and the spongy or cancellated. Both, however, have the same structure, the difference being in the larger interstices between the plates of bone in the cancellated form—in short, bony substance is everywhere porous in a greater or less degree. The outer surface of a bone is always compact, while the texture within is more or less spongy.

The cancellated texture is seen on exact inspection to be made up of slender bars or spiculæ of bone and their lamellæ meeting together to form a reticular structure. The open spaces or areolæ of the bony network communicate together freely. In the fresh state they contain marrow or blood-vessels. When a long bone is broken across and its compact part is examined with a magnifying-glass, numerous little round apertures are seen on the broken surface, which are the orifices of short longitudinal passages running in the compact substance, named Haversian canals. Blood-vessels run in these canals, and the widest of them also contain marrow. They are from the 1000th to the 200th part of an inch in diameter. They form an irregular network of tubes freely communicating through the compact tissue. When a thin section of compact tissue is viewed under the microscope, the opening of each Haversian canal is seen surrounded by concentric lamellæ.

Other lamellæ in the long bones are concentric with the medullary canal, and again other lamellæ are discovered in different parts of the section.

What were formerly termed bony corpuscles are now found to be lacunæ, or minute cavities, which communicate by transverse minute passages termed "canaliculi."

The bones are plentifully supplied with blood, and even nerves and lymphatics have been described.

Muscular Fibre.—The muscular tissue is the great agent in the locomotions of the living body. It constitutes the flesh of animals, in the large sense in which that word includes the moving substance of birds, fishes, and other animals. The muscular tissue is composed of fine fibres collected into distinct organs termed muscles. Such fibres are also arranged round the sides of cavities and between the tunics of hollow viscera, where these fibres form strata of greater or less thickness. The property which distinguishes muscular fibres is named contractility. The property bearing this name is that by which a muscular fibre, under several known conditions, shortens itself, and again becomes elongated when the condition just before applied ceases. The ordinary conditions under which a muscular fibre contracts are grouped together under the name of *stimuli.* Even when a muscular fibre contracts or shortens itself in obedience to the will, the will is said to act as a stimulus to its contraction. When the will acts, however, it is through a nerve, the filaments of which reach the group of muscular fibres constituting a muscle. The muscular fibres which contract in obedience to the will, contract also under other stimuli, whether applied directly to the nerve or to the muscular fibre. Nevertheless, owing to their property of obeying the will, they are called voluntary muscular fibres. The muscular fibres that cannot become obedient to the will constitute a distinct class of muscles, different even to some extent in their anatomical structure.

The involuntary muscular fibres are named the unstriated, in contrast with the voluntary muscular fibres, which are known as the striated muscular fibres. This distinction is microscopic; nor is there a complete agreement as to the cause of the difference of aspect. The fibres of the heart, which undoubtedly are involuntary, present a similar aspect in respect to the transverse markings, though not quite so distinct as the voluntary fibres.

This appearance in the voluntary fibres is thus described:—"When viewed by transmitted light with a sufficiently high power of the microscope, the fibres, which are then clear and pellucid in their aspect, appear marked with very fine dark parallel lines passing across them directly or somewhat obliquely at exceedingly short but regular intervals. The lines as first mentioned are dark, and the intervals between them light; their distance apart is about 1-9400th of an inch, and they are even closer together in parts of a muscle which happen to be contracted." *

Each fibre is composed of a great number of extremely fine filaments or fibrils enclosed in a tubular sheath. This sheath is named sarcolemma. It seems to consist of homogeneous membrane with some degree of toughness. When a fibril is completely insulated it seems to consist of a single row of minute particles connected together like a string of beads—these are the particles termed sarcous elements. These elementary particles are remarkably uniform in size in mammals, birds, reptiles, fishes, and insects.

The muscular tissue is abundantly supplied with blood. The nerves too are of considerable size, particularly in the voluntary muscles. Their branches pass between the fasciculi, and re-

* Sharpey in 'Quain's Anatomy,' vol. i. p. 145.

peatedly unite with each other in the form of a plexus, and that is most commonly confined to a small part of the length or muscular division to which it belongs. It is doubtful if the nerve-fibres penetrate the sarcolemma.

The solution obtained from lean beef by means of cold water gives the soluble substances present in muscle. These consist of albumen, the soluble salts of the blood, of the crystallisable animal principles named kreatine and inosine, of phosphoric acid, and at least three organic acids—viz., the lactic, the inosinic, and the butyric. Possibly also acetic and formic acids are present in small quantity. The colour of the solution is due to the red colouring matter of the blood. The salts consist chiefly of phosphate of potassa, phosphate of magnesia, and a small quantity of chloride of sodium and of phosphate of lime.*

A muscle when in action is shortened; at the same time it swells in the middle, and becomes firm and rigid to the feel. This state after a short time is succeeded by relaxation. No change of volume occurs during the action of a muscle. The stimuli to action are mechanical irritation, chemical stimuli, electrical stimuli, sudden heat or cold; lastly, mental stimuli and organic stimuli.

A muscle does not contract throughout at once: it appears that numerous contractions and relaxations take place successively in different parts during what seems to be its contraction. A considerable waste of organic substance is sustained during the action of a muscle.

Nervous Texture.—The nerve or ganglionic cells were already referred to (p. 216). The nervous system consists of a central part, or rather of a series of connected central organs, called the cerebro-spinal axis or cerebro-spinal centre, and of the nerves in the form of cords connected by one extremity with the cerebro-

* Miller, 'Elements of Chemistry,' part iii. p. 782.

spinal centre, and extended thence through the body to the muscles, sensible parts, and other organs laid under their control. The nerves constitute the medium of communication between these distant parts and the nervous centre. One order of nervous filaments, named afferent or centripetal, carry impressions towards the nervous centre; another, the efferent or centrifugal, convey motorial stimuli from the centre to the moving organs. The nerves are therefore described as internuncial in their function; the cerebro-spinal centre receives the impressions conducted to it by the one order of nerves, and imparts stimuli to the other, while it renders certain of these impressions cognisable in consciousness, and combines in due association, and towards a definite end, movements, whether voluntary or involuntary, of different and often distant parts.*

Besides the cerebro-spinal centre, the term centre is sometimes applied to certain bodies named ganglia, connected with nerves in many situations. Ganglia are of small size, yet possess the same elementary structure as the brain, and seem to have the same relation as the cerebro-spinal centre to the nervous filaments with which they are connected. Hence it is believed, though grounds of doubt exist, that the ganglia are nervous centres to which impressions may be referred, and from which motorial stimuli may be emitted in a reflex manner, and such operate independently of consciousness and of the intervention of the will.

The nerves fall under two heads, the cerebro-spinal and the ganglionic nerves. The cerebro-spinal nerves are transmitted in particular to the skin, the organs of the senses, and such parts as are endowed with manifest sensibility, and to muscles placed more or less under the dominion of the will. They are connected in pairs to the axis of the cerebro-

* Sharpey in 'Quain's Anatomy,' vol. i. p. 169.

spinal centre, and, like the parts on which they are distributed, present a remarkable symmetry on the two sides of the body. The ganglionic nerves, called also sympathetic, are distributed chiefly on the viscera and blood-vessels, in which the natural sensibility is obscure and the movements involuntary. They are distinguished also from the cerebro-spinal nerves by their colour, which is greyish or reddish, by a much less degree of symmetry in their arrangement, and in particular by their connection with very numerous ganglia. Branches of communication pass from the spinal nerves of the cerebro-spinal, and from several of the cerebro-spinal nerves originating within the skull at a short distance from their roots to join the ganglionic system of nerves, so that the two systems mutually give and receive nervous filaments.

In the nervous system there are contained, besides its proper substance, enclosing membranes, areolar tissue, and blood-vessels. The nervous substance is distinguished into a white substance and a grey substance, called also cineritious substance.

The chemical constitution of the cerebral substance is still far from being perfectly known. The brain plainly contains a large proportion of albumen in the uncoagulated form; its peculiar composition, however, appears to be due to the presence of a solid fatty acid named cerebric acid, in which phosphorus exists, and to a liquid oily acid called oleo-phosphoric acid, in which also phosphorus is detected. Besides these two acids and albumen, there are found cholesterine, and the ordinary fats named stearine and oleine.

In 100 parts of human brain there are about 7 parts of albumen, 5 parts of the several kinds of fatty substances, and 80 of water.

Under the microscope the nervous substance is found to consist of two distinct structural elements—namely, fibres and cells or vesicles. The fibres exist everywhere in the nervous cords, and also make up the greater share of the nervous centres, that is, of the cerebro-spinal centres ; the cells or vesicles, on the contrary, are met with in the cerebro-spinal centre and in the ganglia, and do not exist in the nerves properly so called, unless it be at their peripheral expansions in some of the organs of special sense. It is in the grey matter of the brain, spinal cord, and ganglia, that the vesicular structure is found, the grey matter being made up of vesicles intermixed in many parts with fibres and with a variable proportion of granular or amorphous material.

The fibres are of two kinds, the tubular or white and the gelatinous or grey, the former being by far the most abundant. The gelatinous or grey fibres are found principally in the sympathetic nerve, yet exist also in many of the cerebro-spinal nerves.

The white fibres consist of a fine membranous tube, enclosing a peculiar soft substance, while this contained substance is distinguishable into a central part placed like a sort of axis in the middle of the tube, and a peripheral portion surrounding the axis, so as to occupy the space between the axis and the tubular enclosing membrane. Many of the tubular nerve-fibres, under the microscope, exhibit a varicose appearance—that is, they seem to be dilated or swollen out at short distances along their length, and contracted in the intervals between the dilated parts. Such appearances occur in the brain and spinal cord, and in the intracranial portions of the olfactory, the ophthalmic, and acoustic nerves. It appears, however, that these fibres are cylindrical like the other nerve-fibres, and that they only take on this appearance when handled, and thereby subjected to pressure. This effect is most apt to occur in fibres of small size, as in those ranging from the 1200th to the 3600th of an inch in diameter.

The gelatinous fibres are also termed organic or grey nerve-fibres; they exist in great numbers in the sympathetic nerve and in small proportion in many of the cerebro-spinal nerves. They are found associated with tubular or white fibres, giving a grey colour to the nervous cords in which they predominate. A doubt, however, has arisen if these be true fibres, it being maintained that they belong to the class of enveloping structures, and that in reality they are allied to the areolar tissue.

The following quotation from Professor Bennett's 'Outlines of Physiology' points to the modern use of several terms liable to be misunderstood :—

"1. The brain proper is that portion of the encephalon situated above the *corpus callosum.*

"2. The spinal cord is divided into a cranial and a vertebral portion.

"3. The grey matter evolves, and the white conducts, nervous power.

"4. Contractility is the property peculiar to fibrous texture, whereby it is capable of shortening its fibres. Motion is of three kinds—contractile, dependent on muscle; diastatic, dependent on muscle and spinal cord; voluntary, dependent on muscle, spinal cord, and brain.

"5. Sensibility is the property peculiar to nervous texture, whereby it is capable of receiving impressions. Sensation is the consciousness of receiving impressions."

Blood-Vessels.—The blood-vessels consist of arteries and veins and capillaries—of pulmonary arteries and pulmonary veins and pulmonary capillaries.

Arteries are endowed with considerable strength and with a very high degree of elasticity, being extensible and retractile both in their length and width. When cut across they exhibit, even when empty, an open orifice; the veins, on the contrary, collapse when cut across, unless that effect is prevented by connections with surrounding parts.

The arteries are composed of coats. In most parts of the body they are enclosed in a sheath formed of dense areolar tissue, their proper outer coat being connected to the sheath by filaments of the same tissue—so loosely, however, that when the artery is cut across its ends readily shrink, each in an opposite direction, some way within the sheath. Sometimes other parts besides an artery are enclosed in one common sheath: for example, the common carotid artery, the internal jugular vein, and pneumogastric nerve are contained within one common sheath. The arteries within the cranium are destitute of sheaths. Arteries in general have three coats besides the sheath; and this, by common consent, is now received as the proper statement, when microscopic observation is not referred to. The inner coat of the arteries is formed of epithelium and elastic layers—the latter consisting of elastic tissue, under the two forms of fenestrated membrane and longitudinal elastic network; while these may either coexist in equal proportion, or the one or the other may largely predominate. The middle coat consists of distinct fibres arranged circularly around the vessel, yet not so as to form complete rings. A great part of the thickness of the larger arteries is made up of this coat, which may include many layers. In the smaller arteries this coat is said to be thicker in proportion to the calibre of the vessel. Between the layers are found shreds of elastic membrane, either finely reticular or wholly similar to the fenestrated membrane of the inner coat. It does not appear that any part of the middle coat of the arteries is identical with the yellow elastic tissue, as was believed for a time by anatomists. It contains two kinds of fibres: the one corresponding to the plain variety of muscular fibres, and the other fine elastic fibres joined together in a reticular manner. The muscular tissue of the middle coat is more pure in the smaller arteries.

The external coat has two layers of different texture—namely, an internal stratum of genuine elastic tissue, most obvious in arteries of large size, and at length disappearing in small arteries; and an outer layer, consisting of ordinary areolar tissue, in which the filaments are closely interwoven, and in large and middle-sized arteries, run diagonally or obliquely round the vessel. The areolar layer is commonly of great proportionate thickness in the smaller arteries.

The vital contractility of the arteries is a subject which has often engrossed the attention of physiologists. It has been frequently confounded with their elasticity. The contraction of the artery that immediately follows its distension by the wave of blood received from the heart, appears to be due solely to the elasticity of the artery. The vital contractility, on the other hand, produces its effect by a slow contraction of such a kind as may accommodate the artery to a larger or smaller volume of the contained blood. It is identical with what was formerly described as tonicity. The importance of such a property in the arteries can be readily conceived. If this property should by any cause be diminished in any part of the arterial system, that part will immediately appropriate to itself more than its former share of blood; if, on the other hand, the contractile property become more energetic, then the part of the arterial system so affected will contain less than its usual share of blood. To this property is due the emptiness of the arteries after death, for as soon as the heart's action ceases, or even as soon as it becomes much weakened, the force which before tended to keep open the arteries fails, and therefore the tonicity or slow contractile property begins to expel the blood into the veins; but as vital contractility begins to fail soon after death, the elasticity of the arterial tissue restores the artery nearly to its former dimensions, so that, though empty, the arteries are not found actually closed some time after death.

This vital contractility in the arteries seems to have its seat in the soft pale fibres of the middle coat. This property is readily demonstrated in the small-sized arteries of the transparent parts in cold-blooded animals. Some physiologists deny the existence of this property in the large arteries, but, as it would seem, without sufficient reason.

The veins in most regions of the body are larger and more numerous than the arteries. The capacity of the venous system thus much exceeds that of the arterial system. The capacity of the venous system of the lungs does not come under this rule; that is, the capacity of the venous system of the lungs—which, however, contains arterial blood—does not exceed that of the system of the pulmonary artery.

There are two sets of veins—the *venæ comites*, which generally take a course corresponding to that of the arteries; and the superficial or subcutaneous veins, so conspicuous in the skin of the horse when heated with exercise. The anastomoses between the veins are more numerous than between the arteries. The veins have thinner coats than the arteries, and collapse when cut across. The veins, nevertheless, are possessed of considerable strength, being, according to some authorities, stronger than arteries of the same calibre. As to the number of their coats there is little agreement; three coats are, however, commonly admitted.

Some traces of a vital contractility analogous to that of the arteries have been detected, particularly in the great veins near the auricles of the heart; but little has been ascertained of certain on this point.

The most remarkable peculiarity in the veins is the presence of valves adapted to prevent the reflux of the blood. The veins of muscular parts—that is, of parts in which the veins are subjected to irregular pressure—are those provided in particular with valves.

Capillaries.—When the web of a frog's foot is inspected through a microscope, the blood is seen passing rapidly along the small arteries, and thence more slowly through a network of finer channels by which it is conducted into the veins. These small vessels, interposed between the finest branches of the arteries and the commencing veins, are the capillary vessels. The capillary vessels of a part most commonly assume the form of a network, the branches of which, though not all absolutely equal, are of tolerably uniform size, and do not divide into smaller branches like arteries, or unite into larger ones like the veins ; but the diameter of the tubes, as well as the shape and size of the reticular meshes which they form, differ in different textures. Their prevalent size in the human body may, speaking generally, be stated at from 1-3500th to 1-2000th of an inch, as measured when naturally filled with blood.*

The capillaries have real coats, and are not mere channels drilled in the tissue which they pervade. The number as well as the structure of their coats differs according to the size of the vessels. Capillaries of a diameter less than 1-2400th of an inch have but a single coat formed of simple homogeneous transparent membrane, with nucleiform corpuscles attached at intervals on the outer surface, or enclosed, as it were, in the substance of their long diameters parallel to the axis of the vessel.† In vessels one or two degrees larger the structure is more complex. "The corpuscles of the primitive simple membrane are more numerous and more lengthened. An epithelium exists on the inside of the primitive membrane, and on its outside is added a layer containing nucleiform corpuscles elongated in a direction across the diameter of the vessel. This layer corre-

* Sharpey in 'Quain's Anatomy,' vol. i. p. 227. † Idem.

sponds with the middle or muscular coat of the arteries; and accordingly, in vessels of somewhat greater size, the characteristic circular fibres of that tunic appear in the layer in question as well as the nuclei. Outside of all is the areolar coat, marked by longitudinal nuclei. In vessels of 1-60th of an inch in diameter, or even less, the elastic layers of the inner coat may be discovered, in form generally of fenestrated membrane, more rarely of longitudinal reticulating elastic fibres; while the primitive membrane, with its longitudinal corpuscles, disappears."*

The vital properties of the capillaries form a subject of the greatest importance, but too little settled to be given within a short compass.

The lymphatics and lymphatic glands have been already noticed in some detail at p. 133.

The serous membranes have also been reviewed at p. 94.

The mucous membranes have also engaged a large share of attention at p. 108.

OUTLINE OF ASSIMILATIVE FUNCTIONS LESS DIRECTLY NUTRITIVE, AS EXERCISED IN THE HIGHER ANIMALS.

As it is hardly possible to obtain an intimate acquaintance with the physiology of any system of living parts without a general acquaintance with the whole animal economy, it seems proper to exhibit a brief outline of the other principal functions in the higher animals, by way of supplement to the special subject of this treatise.

Arrangement of the Functions as a whole.—The functions exercised by the higher animals are commonly arranged into (1) functions of assimilation, (2) functions of reproduction, and

* Sharpey in 'Quain's Anatomy,' vol. i. p. 231.

(3) functions of relation. No such method can be rigidly perfect; nevertheless this arrangement is very useful. The circulation of the blood, respiration, digestion, secretion, excretion, are examples of the functions of assimilation, as all these and some others are directly or indirectly concerned in the development, growth, and maintenance of the living system. The functions of reproduction are those concerned in the continuance of the species. The functions of relation are those which connect the animal with the world without—the functions of knowledge and power; that is, the functions by which the animal becomes acquainted with external things, and acquires power over the same. Such functions are manifestly the senses and the muscular actions on which bodily activity depends.

Circulation of the Blood.—The parts concerned in the circulation of the blood are the heart, the arteries, and the veins. The heart consists of two sides, between which there is no direct communication—namely, the left side and the right side; and each side contains two cavities—namely, an auricle and a ventricle; and between each auricle and the corresponding ventricle there is a free communication. As to the arteries, there are two great arterial systems, between which there is no immediate communication or connection; namely, the aorta and its extensive ramifications, and the pulmonary artery with similar ramifications. As to veins, there are also two great venous systems, between which there is no immediate communication or connection; namely, the system of the *venæ cavæ* and their numerous ramifications, and the system of the pulmonary veins with like ramifications.

There are two kinds of blood, the red and the black; that is, the bright red and the dark red. The red is called the arterial blood, but it exists only in one of the arterial systems—namely, in that of the aorta; the black is called venous blood, but it exists only in one of the venous systems—namely, that of the *venæ cavæ.* The system of the pulmonary artery is filled with black blood, the system of the pulmonary veins is filled with red blood. The cavities of the right side of the heart—namely, the right auricle and the right ventricle—are filled with black blood; the cavities of the left side of the heart—namely, the left auricle and left ventricle—are filled with red blood. Thus of the sanguiferous organs, the system of the pulmonic veins, the left cavities of the heart, and the aortic system, transmit red blood; the system of the *venæ cavæ*, the right cavities of the heart, and the system of pulmonic arteries, transmit black blood. Between the ramifications of the aortic arterial system and the radicles of the venous system of the *venæ cavæ* are interposed capillary blood-vessels. These capillary blood-vessels are situated between the finest ramifications of the aortic system and the finest twigs of the system of the *venæ cavæ.* They are not all of one uniform size; yet they do not differ much from each other in calibre, the largest of them not exceeding the 2000th part of an inch in diameter, while they inosculate with each other, so as to form a general network. In these capillary vessels there are no apertures or open mouths, so that the interior of the aortic system and the interior of the system of the *venæ cavæ* are one continuous cavity, the communication between the two divisions being established by the uninterrupted cavity of the capillary blood-vessels. In its passage from the fine ramifications of the aortic system to the fine radicles of the system of the *venæ cavæ,* through the capillary blood-vessels, the red blood changes to black. In like manner between the ramifications of the pulmonary artery and the extreme radicles of the system of the pulmonary veins, there is interposed a system of capillary vessels of equal or even greater fineness, giving the same continuity between the interior of the system of the pulmonary artery and the interior of the system of pulmonary veins.

Also the black blood of the system of the pulmonary artery, in its passage through the capillaries to reach the radicles of the system of the pulmonary veins, changes to red blood.

Thus the vascular organs—that is, the cavities of the heart and the blood-vessels—are conveniently arranged into those which convey black blood; namely, the system of the *venæ cavæ,* the right cavities of the heart, and the system of the pulmonary artery and those which convey red blood—namely, the system of the pulmonary veins, the left cavities of the heart, and the system of the aorta. Each of these divisions has its moving force—namely, its own portion of the contractile heart placed in the middle; that is to say, the right auricle and the right ventricle, propelling the black blood by their contraction, stand in the middle between the system of the *venæ cavæ* and the system of the pulmonary artery; while the left auricle and the left ventricle, propelling the red blood, stand in the middle between the system of the pulmonary veins and the system of the aorta. Moreover, the points of demarcation between these two divisions of the vascular apparatus are, on the one hand, in the capillaries in which the red blood, during the operations of assimilation, becomes black; and, on the other, in the capillaries in which the black blood, by the agency of the atmosphere in respiration, becomes red.

There are in the heart two chambers on the right side and two chambers on the left side. The chamber which receives blood coming from a distance is on each side termed an auricle; the chamber which sends forth blood to a distance is on each side termed a ventricle. The vessels which bring the blood to the heart on each side are named veins, those which carry the blood out from the heart are known as arteries.

When a particle of blood has found its way, for example, into the left ventricle, there is only one course by which, after leaving that ventricle, it can return to it again. In so returning it performs what is known as a circulation, the great fact discovered by Harvey. Such a particle of blood passes from the left ventricle into the aorta, and being propelled into some branch of the aorta it reaches a corresponding radicle of the system of the *venæ cavæ* through the capillary system interposed between the system of the aorta and the system of the *venæ cavæ.* By the system of the *venæ cavæ* it reaches the right auricle of the heart, and from that auricle passes into the right ventricle, whence it is propelled into the pulmonary artery, and being conveyed from some fine branch of the pulmonary artery to the pulmonic capillary system, it reaches a corresponding radicle of the pulmonary system of veins, and thereby is carried back to the left ventricle, from which it was supposed to set out. Such is the circulation of the blood. Every particle of blood which sets out from the left ventricle, provided it escapes disintegration, performs a similar course; yet in some instances its progress is more complicated.

By the contraction of the cavities of the heart, say of the left ventricle, is signified a sudden and powerful diminution of its cavity, by the action of the muscular fibres which form its walls. The effect of this contraction is to expel the blood. But this ventricle has two apertures, one communicating with the left auricle, the other leading into the aorta. If both apertures were equally open at the moment of the contraction of the ventricle, the blood would be driven out in two directions; but while there is a valve commanding each aperture, that which is in the mouth of the aorta, named the sigmoid or semilunar valve, is so constructed as to yield readily when the ventricle contracts; on the other hand, the valve in two divisions connected with the orifice leading from the auricle extends into the ventricle, and is attached by numerous tendinous threads to two short blunt muscular pillars (the *musculi papillares*), which, contracting at the same moment as the ventricle itself, tighten the membranous segments of the valve and close the orifice. As soon as the contraction of the ventricle is finished, it immediately expands, and the valve commanding the orifice leading from the auricle being relaxed, the blood enters from that auricle to fill, without fully distending, the ventricle ; at the same time the blood is prevented from regurgitating into the ventricle from the aorta by the semilunar segments of the valve in the orifice of the aorta, which are expanded so as to close the orifice under the pressure of the column of blood in the direction of the heart, produced by the slight contraction of the aorta due to the elasticity of its coats, and consequent on a corresponding expansion propagated along the aortic system when the blood is forced into it by the contraction of the ventricle. That is to say, the portion of blood thrown into the aorta by the contraction of the left ventricle creates a wave in the blood of the aortic system with a corresponding undulatory distention of the coats of that system of vessels. But the elasticity of their coats produces an immediate contraction, and this contraction of the aorta, near its junction with the ventricle, would cause a regurgitation of the blood into the ventricle at the moment of its expansion, did not the semilunar segments expand under the pressure of the returning column of blood, and intercept its progress. The undulatory movement of the aortic system is the pulse, which is felt when the finger is applied to an artery ; that is to say, to any ramification of that system. The pulse in an artery distant from the heart is in a slight degree later than in one close to the heart. This difference is not, however, unequivocally perceived, unless when the pulse is slower than usual. As was stated above, the ventricle expands immediately after its contraction, and becomes filled with blood without being distended, under the influx of blood from the auricle through the auriculo-ventricular orifice. Now with very little delay the auricle itself becomes distended by the continued influx of the blood pressing onwards from the pulmonary veins, and this distention is the cause of its contraction ; but this contraction throws a new quantity of blood into the ventricle by which it is distended to such a degree as to cause its contraction ; by which contraction, as above stated, the blood is thrown into the aorta. The auricle and ventricle of the right side act exactly in the same manner as the auricle and ventricle on the left side. The two auricles contract together, and the two ventricles together.

The great cause of the movement of the blood in its circulation is the muscular contraction of the heart, by which the capacity of its cavities is suddenly diminished, and the blood more or less completely expelled in a determinate direction. Some other causes concur, and the investigation of these has much engaged the attention of physiologists. The most striking of these is the effect of muscular exertion throughout the body. The veins in all the muscular parts of the body concerned in ordinary locomotion are provided with valves, which permit the blood to pass in one direction only. Hence when any one of these veins is momentarily compressed, the blood in it is sent more swiftly towards the heart. But in active muscular exertion such veins are subjected to repeated strokes of pressure, so that the ordinary motion of the blood in them towards the heart is very much quickened. When a man climbs a high hill his pulse may rise from 70 in a minute to 150. Then the first effect is probably that just referred to. By the contraction of the muscles affecting the adjacent veins, the blood consequently in a given time reaches the right side of the heart in larger quantity ; these cavities, being more rapidly filled, contract more frequently, so that the blood is sent through the system of the pulmonary artery and that of the pulmonary veins, and carried onward to the left cavities of the heart in much less time than usual; hence the left cavities of the heart contract more frequently, and send the blood all over the body at a far more rapid rate than in ordinary circumstances. To this view other effects might be added; for example, that when the blood is made to move more rapidly in the veins, the resistance to the passage of the blood from the aortic system into the system of the *venæ cavæ* is very much diminished, so that, under this violent exercise, the moving power, or the heart's contraction, acts more efficiently at the same time that the resistance to be overcome undergoes a great diminution.

The circulation of the blood, even when the body is at rest, takes place in a wonderfully short time. Many experiments concur in proof of this fact. An easy mode of conceiving this effect is the following:—In the human body the left ventricle is assumed to throw two ounces of blood into the aorta at each stroke of the heart; the average number of strokes in the minute may be taken at 70, whence the ventricle throws into the aorta 140 ounces of blood per minute, or nearly 9 imperial pounds in that space of time; but the calculated amount of blood in the whole body does not exceed from 18 to 27 pounds, so that the left ventricle pours out a quantity of blood equal to the whole blood in the body in from two minutes to two minutes and a half. Now this period is plainly the average time which the particle of blood which performs the circulation a number of times takes to complete one circuit.

Plethora.—When an animal is in the highest degree robust and vigorous, there is a certain harmonic balance between the proportion of blood contained in the arteries and that contained in the veins. Naturally the venous system is much more capacious than the arterial system. A common estimate is, that the capacity of the system of the *venæ cavæ* is about three times greater than that of the aortic system; in correspondence with which proportions it is believed that the average velocity of the blood's motion in the aortic system is three times greater than in the system of the *venæ cavæ.* The same rule does not apply to the pulmonary system of arteries and that of the pulmonary veins, since it seems certain that the capacity of the system of the pulmonary veins does not exceed, if it even equals, the capacity of the system of the pulmonary artery.

When nutrition goes on vigorously, and an animal is freely exercised within the limits of its strength, amidst circumstances conducive to health and activity, the lines of the body are sharp and angular without disposition to rotundity of parts, the pulse of any considerable artery is full, strong, and swelling, the contraction of the muscles of locomotion is steadily energetic, the veins are full and tense, the secretions are everywhere abundant, and there is a boundless tendency to active movement. Here the due balance is preserved between the proportions of blood which belong respectively to the aortic system and to the system of the *venæ cavæ.* When, however, circumstances arise, the tendency of which is to weaken the force of the circulation of the blood, a change appears to take place in the distribution of the blood, the veins appropriating to themselves a larger proportion than naturally belongs to them. Nutrition may still go on freely, and the mass of blood be even greater than under the state first described. Excretion becomes diminished, and the solids become relaxed by the presence everywhere of a larger proportion of fluid parts; and in particular, a larger amount of oil or fat accumulates in the tissue appropriated to that secretion, whence the former sharpness and angularity of the contour of the body gives place to a more or less complete smoothness and rotundity.

Thus the kind of management as to diet and regimen which fits an animal like a horse for powerful and continued muscular exertion, is very different from that which prepares an animal like the ox for slaughter, by rendering the solids soft, tender, and free from toughness. The essential difference appears to be that an arterial plethora or fulness of blood is to be cultivated in the case of the horse, while a venous plethora is to be promoted in that of the ox.

Respiration.—When an animal solid, consisting of oxygen, hydrogen, carbon, and nitrogen, is decomposed in the presence of oxygen, it can readily be understood to afford carbonic acid, water, and some compounds of an ammoniacal nature, or allied in composition to ammonia; as urea, the essential saline principle of the urine. When, on the other hand, an organic product, free from nitrogen—such as sugar derived directly from the aliment, or obtained by the transmutation of starch or oily matter, such as fat derived from the food or absorbed into the blood from the adipose tissue—is decomposed in the presence of oxygen, it affords carbonic acid and water. These two decompositions—namely, the decomposition of non-azotised matter and the decomposition of azotised matter—are unceasingly taking place within the living body, and are indeed essential to its continued existence. If these two decompositions did not go on at all times, the blood would become loaded with the debris of the solids, so as to be no longer fit to maintain the vital properties of the component tissues of the organs essential to life, and the body would begin to cool down to the temperature of the surrounding medium.

It belongs to the function of respiration to supply the oxygen required in these two indispensable decompositions. Of these decompositions, that of azotised matter is doubtless altogether the most important; for in countries where the heat of the climate at times equals the natural temperature of the animal body, the decomposition of non-azotised matter, on which chiefly the production of temperature depends, becomes superfluous; but that by which the purification of the blood from the debris of the solids results, must at all times be indispensable.

The mechanism of respiration in the higher animals is so contrived as alternately to draw into the body and expel from it a certain amount of atmospheric air, nearly a fourth part of which is the oxygen required. The respirations in a minute amount to about a fourth part of the number of pulsations of the heart. Care must be taken not to misunderstand "draw in" as used above. The air is not drawn in by what is sometimes called a *vis a fronte,* as we draw in water from a well with a bucket, but is drawn in as the water is drawn into the common pump when the handle is depressed. In short, the atmospheric pressure, being about fifteen pounds to the square inch on objects at the earth's surface, whenever the slightest rarification takes place in a cavity communicating with the atmosphere, the atmospheric air must instantly begin to enter that cavity, and go on entering it so long as the rarification, however minute, is continued.

The lung is, in fact, a bag divided into many millions of small sacs or vesicles, to which there is but one narrow entrance —namely, the orifice of the larynx; but every one of these little sacs comports itself in respiration exactly as if it were one large sac of the same magnitude as the lung itself, and like it at all times during health, filling exactly the cavity of the chest in which it is lodged, and communicating with the atmosphere, like the lung, only by the narrow aperture of the larynx. The cavity of the thorax in which this sac is lodged, and which it entirely fills, is capable of undergoing alternately a very considerable enlargement, and a like contraction, in its dimensions, owing to the mobility of the walls which bound the cavity. Thus, when the walls of the thorax (the ribs and midriff) are at rest, the sac within contains air having exactly the same density as the air of the surrounding atmosphere, the elasticity of the walls of the sac being sufficiently overcome by the pressure of the atmosphere acting through the aperture of the larynx, so as to reach into every corner of the cavity of the thorax in which the sac is lodged. It is easy to conceive a sac with walls so highly elastic that the ordinary atmospheric pressure should not be sufficient so completely to overcome that high elasticity as to permit the sac to protrude exactly into every corner of the cavity of the thorax. In such a case there would be a vacuum between the inner surface of the cavity of the thorax and the outer surface of the sac. Such a state of things would render the effort of inspiration much more difficult; that is, there would be required for it a much greater mechanical force. But such is not the case in any known animal. In the ordinary case the elasticity of the air-bag or air-bags of the lungs is never so great as to permit any approach to a vacuum between the inner surface of the walls of the chest and the outer surface of the wall of the lungs. Whenever, then, the cavity of the chest by the movement of its walls becomes in the slightest degree enlarged, the air-bag within becomes proportionately enlarged, so as always to fill the cavity of the chest, even when brought to its largest capacity. Whenever the chest enlarges in a given time by an increment greater than corresponds to the bulk of air that can pass through the larynx into the lung in the same time, then it is manifest the air in the lung or air-bag must be rarefied before the entrance of new air into the lung. And in proportion as the enlargement of the chest in a given time exceeds the measure of air which can enter the lung in that time, is the amount of rarefaction on the body of air already in the lung before inspiration begins, or previous to the addition of new air from without. Such rarefaction of the air in the lung when inspiration begins is retarded by the degree in which the lung or air-bag is elastic; and in proportion as such resistance is offered, is the amount of mechanical effort required to enlarge the chest.

Such is the mechanism of respiration: the diaphragm descends in man, or, to include animals that are prone, is thrown towards the abdominal cavity, and the ribs are drawn nearer to a right angle with the spine, by which changes the thorax is enlarged and the air enters the lung—this is inspiration : by an opposite movement, which to a certain extent is spontaneous, the chest is contracted in its dimensions, and the air in the lung, being condensed, issues forth.

The air which enters is the air of the surrounding atmosphere, consisting of one volume of oxygen, nearly four volumes of nitrogen, and variable proportions of carbonic acid gas and watery vapour. The air which issues from the lung has lost a large proportion of its oxygen, has acquired a considerable proportion of carbonic acid, and is charged with watery vapour. It has often been contended that the proportion of carbonic acid gas given off in expiration corresponds exactly in volume with that of the oxygen consumed ; but subsequent inquiries show a great variety in this respect under different circumstances, and that as a rule much more oxygen is consumed than is required to produce the carbonic acid gas thrown off. In short, the oxygen consumed in respiration must suffice not only for the oxidation of the carbon to be eliminated, but also for the oxidation of the hydrogen, and of every other oxidisable substance that is to be thrown off from the system, the only probable deduction required being the amount of oxygen that may be swallowed in the air mingled with the food after mastication.

Excretion of Urine.—The purification of the blood is in particular ascribed to the agency of three important organs—namely, the lung, the liver, and the kidney. The lung separates carbon in the shape of carbonic acid, the liver compounds abounding in hydrogen, and the kidney urea, which is especially made up of nitrogen. The structure of the kidney is somewhat complex. In mammals generally the kidneys are two in number, one on each side of the vertebral column. The surface of the kidney is smooth, and the colour is deep-red. The kidneys are imbedded in fat. They are covered by a proper fibrous coat; the same coat passes into the interior of the kidney by the fissure named the *hilum*, and lines the sides of what is called the *sinus*, then surrounds the blood-vessels, giving sheaths to the chief of these, and accompanying them into the substance of the gland. The solid part of the kidney consists of two substances, the cortical and the medullary. The cortical is exterior, immediately beneath the fibrous capsule, and forms the superficial part of the organ to the depth in the human kidney of about two lines. The cortical substance also sends prolongations inwards towards the sinus, between which prolongations the medullary substance is found. The medullary substance is collected into a series of conical masses, the bases of which are directed towards the surface of the kidney, whilst their apices are turned towards the sinus. Their number varies from eight to eighteen. The greater part of each pyramid is imbedded in the cortical substance, but each apex is free, and projects into the sinus under the name of mammillary process. The cortical portion forms about two-thirds of the substance of the kidney, while the medullary portion makes up the remaining fourth part of the organ. Each medullary cone is originally a separate lobe, and this lobular structure remains throughout life in many animals. The entire substance of the kidney, whether cortical or medullary, consists of uriniferous tubes, blood-vessels, lymphatics, and nerves connected in some parts with a fine areolar tissue.

The excretory duct of the kidney is the ureter, which extends from the inner concave surface of the kidney to reach the side and base of the bladder in the pelvic cavity. At its connection with the kidney the ureter dilates—that is, as it approaches the *hilum*, or aperture at the inner concave part of the kidney; the funnel-shaped cavity which it forms being termed the pelvis of the kidney. The pelvis of the kidney is a cavity lined with mucous membrane, which, on the side of the kidney, divides first into two or three principal short branches that again divide into a larger number of smaller tubes, and these communicate with the apices of the mammillary cones converging towards this part of the kidney. Into the interior extremities of these smaller subdivisions of the pelvis of the kidney the apices of the mammillary cones enter, two or three sometimes projecting into one, so that the number of the subdivisions of the pelvic cavity is less than that of the mammillary cones.

Each mammillary cone is found to be occupied by a system of tubes, the tubuli uriniferi dividing and subdividing in a divaricate manner from the small number of trunks that open at the apex into the corresponding subdivision of the pelvic cavity. From the base and sides of the mammillary cones the minute tubuli uriniferi pass into the cortical substance, where, from being before straight and radiating in their course without anastomosing, they at once become convoluted in a very intricate manner, with very free anastomoses. The blood-vessels ramify on the walls of these minute tubuli. The sanguiferous system of the kidney is somewhat intricate. The renal artery dividing at the *hilum* into four or five branches, the vessels proceed between the medullary cones towards the cortical substance, and at the bases of the pyramids form a number of anastomotic arches, the numerous branches derived from which ramify through the cortical substance, and end in a system of capillary vessels that form a network on the uriniferous tubes throughout the whole substance of the kidney. In the medullary portion, where the uriniferous tubes are straight, the capillaries form oblong meshes; but in the cortical substance the minute vessels enter the Malpighian corpuscles, or little red bodies imbedded in the cortical substance. Their ordinary diameter is 1-120th of an inch. They are vascular tufts formed by an afferent and an efferent vessel. The afferent vessel divides into from five to eight branches which cover the surface of the corpuscle, and end into a finer set of central vessels. From these last the efferent vessel arises, and, passing out of the tuft, divides into capillaries which form a plexus around the adjacent tubuli.

The connection between the Malpighian body and the uriniferous system of tubes is, that the Malpighian body projects into a blind dilated portion of a tubule, and so obtains a capsule which is pierced both by the afferent and the efferent blood-vessel; which last, after ramifying on the tubule, terminates in a radicle of the renal vein.

The following short passage from Professor Bennett's work probably indicates the mode in which the urine is formed:—"The two kidneys contain in their cortical substance globular convolutions of capillary vessels which hang in the blind extremities of the tubular glands. This arrangement permits the ready passage of a large amount of water from the blood, which, as it flows out through the duct, receives the secretion formed by the cells which line them."

The urine of man and that of mammals in general is characterised by the large proportion of water which, as compared with its solid constituents, it presents. The solid constituents seldom amount to so much as five parts in a hundred parts of fluid urine. There is, however, no constant relation between the amount of watery fluid and the proportion of solid constituents. The kidney, in short, may be described as having two separate functions—one being to throw off water when that accumulates in undue proportion in the blood; the other being to eliminate the saline matters and the peculiar organic products that result from the waste of the tissues. Water accumulates in undue proportion in the blood under various circumstances of no uncommon occurrence, such as by the effect of a cold or damp atmosphere diminishing the natural amount of the cutaneous perspiration, or by abstinence from the accustomed amount of exercise, or by the use of an unusual quantity of drink. To draw off this excess of water from the blood the Malpighian bodies are supposed to be especially adapted, the thin-walled capillaries of which "allow the transudation of water to take place under a certain pressure into the tubuli uriniferi, and thus act the part of regulating valves, permitting the passage of whatever is superfluous, while they retain the liquid that is needed in the system." * The same rule, however, does not hold in birds. They drink very little; so that the proportion of water in their urine is only sufficient to give it a semi-fluid consistence. The urinary secretion of reptiles is still more solid; and the same seems to be the case in fishes. The solid matter of the urine consists, as just hinted at, of organic compounds originating within the body under the disintegration of the tissues, or the decomposition of the aliments taken into the stomach, or of organic salts, which, under any special circumstances, may have exceeded their due proportion in the blood.

Though the organic compounds in the urine are not the same in all animals, yet they bear a close relation to each other, and in particular agree as to the large proportion of nitrogen that they respectively contain. For the most part they assume a crystalline form, which marks their affinity with inorganic substances, inasmuch as that form appears to be wholly incompatible with the possession of plastic or organisable properties.

In the urine of man the characteristic substance is urea, a crystalline body; neutral—that is, neither acid nor alkaline; very soluble in water, somewhat less soluble in spirit; isomeric—that is, containing the same simple elements in the

* Carpenter, 'Comparative Physiology,' p. 434.

same proportions with cyanate of ammonia. When pure, it shows little tendency to decomposition, but brought into contact with substances that act as ferments, it assumes the oxygen and hydrogen of two equivalents of water, and becomes resolved into carbonate of ammonia; and as all urine, after it is discharged from the body, undergoes this change, owing to the mucus of the bladder acting as a ferment, the carbonic acid and ammonia which have been decomposed in the production of the organic compounds of plants are restored to the inorganic world.* The urine of man contains also in small proportion uric acid, called also lithic acid, but which has no further connection with urea than that it exists along with it in the secretion of the kidneys. Uric acid is hardly soluble in cold water, but is more soluble in warm water holding phosphate of soda in solution, which is probably its state in natural urine. When combined with ammonia, uric acid is more soluble. In the semi-solid urine of serpents, uric acid is partly conjoined with ammonia, while a portion of it exists, as in the urine of birds, undissolved. The guano found in the islands of the Pacific Ocean, where no rain falls, consists chiefly of urate of ammonia, formed of the excrements of birds (urine and fæces) accumulated through countless generations, and more or less extensively decomposed. When purified, uric acid is a glistening snow-white powder, to appearance amorphous, but when subjected to the microscope it exhibits very minute regular crystals. It has neither taste nor smell, and its acid reaction is very feeble.

In the urine of herbivorous animals uric acid is replaced by hippuric acid, which is also present in the human urine in very small quantities, but more easily detected after using vegetable food, and particularly after taking benzoic acid into the system. Hippuric acid is most readily obtained from the

* Carpenter, 'Comparative Physiology,' p. 435.

urine of the cow, which, according to Boussingault, contains to the extent of about 1.30 per cent. Hippuric acid is also contained in the urine of the horse, at least when the animal is kept at rest; but if he be made to work actively, the greater part of the hippuric acid disappears, and benzoic acid is found in its stead. Hippuric acid, when pure, crystallises in long transparent four-sided prisms, and has a strong acid reaction, with a bitterish taste; it is much more soluble in cold water than uric acid, and it is freely soluble in hot water. When dissolved in a liquid containing putrescent albuminous compounds, hippuric acid is converted into benzoic acid, ammonia being at the same time given off.

In the fluid of the allantois of the fœtal calf (and probably also of other animals), which may be regarded as a temporary urinary bladder receiving the product of the *corpora Wolffiana*, or temporary kidneys, a substance termed allantoine is found, which may be artificially formed from uric acid by boiling it with peroxide of lead. It is a neutral substance, in brilliant prismatic crystals, free from taste, somewhat soluble in cold water. Allantoine is decomposed by strong acids; being resolved into ammonia, carbonic acid, and carbonic oxide; and when decomposed by alkalies, being resolved into ammonia and oxalic acid.

Creatine and creatinine are two new substances which have been discovered in the urine of man and the mammalia; they seem to be intermediate in character between the albuminous compounds and the compounds characteristic of the urine. Creatine, which exists in the juice of raw flesh, is neutral, colourless, crystalline, sparingly soluble in cold water, freely soluble in hot water. By strong acids creatine is converted into creatinine, which differs in composition by containing two proportionals less of the elements of water, yet is of an opposite chemical character, being possessed of a strong alkaline reaction, and serving as a powerful organic base to acids.

Creatinine also to a small extent exists in the juice of flesh, and along with creatine is found in the urine.

The following table from Carpenter gives the composition of these substances in relation to each other and to that of albuminous compounds; for each is given the number of combining equivalents of its individual components, and the percentage proportion which the nitrogen bears to the whole.

	Carbon.	Hydrogen.	Nitrogen.	Oxygen.	Percentage of Nitrogen.
Albumen { Liebig	49	36	6	14	15.67
Albumen { Mülder	40	31	5	12	
Urea	2	4	2	2	46.67
Uric acid	5	2	2	3	33.33
Hippuric acid, hydrated	18	9	1	6	7.82
Allantoine, hydrated	8	5	4	6	35.44
Creatine	8	9	3	4	32.06
Creatinine	8	7	3	2	37.17

"Hence," says Dr Carpenter, "the proportion of nitrogen in the components of urine ranges from double to triple that which exists in the albuminous constituents of the living fabric, the only exception being in the case of hippuric acid, whose proportion of nitrogen is only one-half of that which exists in albumen, whilst its percentage of carbon is triple that which is contained in urea." *

There are besides in the urine other substances, the nature of which has not been as yet clearly determined. These are commonly grouped together under the name of extractive matters, and probably are in part at least non-azotised matters in a state of change.

There are also numerous inorganic or saline matters in the urine, partly salts which are taken in as such in the food, partly salts formed in the animal economy, the required acid being supplied by the oxygenation of bases contained in the aliment or derived from the disintegration of the animal solids,

* Carpenter, 'Comparative Physiology,' p. 436.

and an ammoniacal base being afforded by the like disintegration of albuminous compounds, whether of the food or of the same solids. Chloride of sodium (common salt) holds a principal place among the saline constituents of the urine, and manifestly comes directly from the serum of the blood. The phosphate of lime and the phosphate of magnesia are also derived directly from the serum of the blood, yet it does not follow, as is sometimes concluded, that they are derived immediately from the food. These phosphates exist throughout the solids, and in proportion as the solids undergo disintegration in a given time, these salts will in the mean time come by absorption into the blood. Thus even when the weight of the body is stationary, and when it is certain that the food contains more earthy phosphates than the system requires, it is impossible to pronounce that the earthy phosphates of the urine are the identical earthy phosphates of the food; all that can be pronounced with certainty is, that as much of these phosphates, from whatever source derived (wholly or in part), is thrown off as has been, during a specified time, received in the food. Neither is it true, as sometimes affirmed, that "the proportion of these earthy phosphates in the urine appears entirely to depend upon the amount ingested in the food;" for if there has been great muscular exertion prolonged for many hours, no food being taken in the mean time, there is usually a large proportion of these phosphates in the urine, plainly coming solely from extensive disintegration of the living solids—a fact which has been long familiar to medical men.

Of the alkaline phosphates and sulphates in the urine there may be the same double source; the one or the other source, according to the circumstances of the case, being predominant. Thus the phosphoric and sulphuric acid in these salts may be formed by the oxygenation of phosphorus or sulphur contained free either in the albuminous compounds used as food or in the products of the living solids by disintegration, and the base of such salts may be either ammonia originating in that disintegration, or potash and soda taken in with the food, combined with citric, tartaric, oxalic, or other organic acids, these acids in the living system being changed into carbonic acid to be eliminated for the most part in respiration. Potash and soda, particularly potash, abound in the food of herbivorous animals, and therefore the alkaline sulphates and phosphates abound especially in their urine; but being deficient, for the most part, in the food of carnivorous animals, they are replaced in the urine of such animals by a larger proportion of ammonia.

The following passage from Dr Carpenter's work on Comparative Physiology affords a good summary of what is known further of the urinary function:—"Although the relations of the amount of the organic compounds in the urine to food, exercise, &c., have been as yet studied almost entirely in the human subject, there can be no reasonable doubt that the same general rules will be found to hold good elsewhere. The proportion of urea which is voided in a given time is proportional, *cæteris paribus,* to the amount of muscular exertion that has been put forth, showing that its presence depends in part upon disintegration of the muscular tissue. But this is not its sole source, for it is greatly augmented also by an excess of azotised compounds in the food—these compounds, as already shown, not being applied to the nutrition of the muscular substance, unless a demand for augmented formation has been created by previous functional activity. Thus the average proportion of urea in the human urine, under ordinary circumstances as to food and exercise, appears to be from about 20 to 35 parts in 1000, but may be raised to 45 parts by violent exercise, and to 53 parts by an exclusively animal diet; whilst it may fall as low as 15 or even 12 parts when the diet is deficient in azotised matter. The average daily amount excreted by adult *males* is about 430 grains—by adult females, about 300 grains; in children of eight years old it is nearly half what it is in adults, whilst in very old persons the quantity sinks to one third or even less, showing that the proportion is greatly influenced by the rapidity of interstitial change at different periods of life. There can be no doubt that creatine and creatinine have the same origin and character, since they are actually found in the juice of flesh as well as in the urine. So the proportion of alkaline phosphates in the urine is found to bear such a close relation to the previous energy of the *nervous system* that there can be little doubt that, *cæteris paribus*, their amount may be taken as a measure of its disintegration by functional activity. It has been pointed out that for the maintenance of this activity a constant supply of arterialised blood is a necessary condition; and whilst the other elements of the nervous tissue (whose composition is almost entirely adipose) will be carried off by oxygenation in the form of carbonic acid and water, the phosphorus which largely enters into it will be oxygenated and taken back into the blood in the form of phosphoric acid, uniting there with alkaline bases, as already explained. The portion of *extractive matters* appears chiefly to depend upon the nature of the food; being greatly augmented by an exclusively vegetable regimen, and greatly diminished by an exclusively animal diet. The importance of the urinary secretion in removing superfluous or injurious saline compounds from the system (the introduction of which into it has taken place by endosmotic action) is further shown by the increase in the secretion which most of these substances produce; this increase being the result of an augmented determination of blood to the kidneys, and a consequently increased transudation of its watery portion carrying these substances with it." *

* Carpenter, 'Comparative Physiology,' pp. 436, 437.

The urine of the horse has a peculiar unpleasant odour, a bitter saline taste with a sweetish after-flavour. Being allowed to rest, it deposits a mixture of carbonate of lime and carbonate of magnesia, which blackens on being burnt. Its specific gravity varies between 1.030 and 1.050. It has an alkaline reaction, and effervesces with acids. When left in contact with atmospheric air it acquires a deeper colour, and by evaporation deposits a fresh quantity of earthy carbonates combined with an animal matter. After evaporation it leaves about 0.05 of residue, 4-5ths of which is soluble in alcohol; the undissolved portion is principally carbonate of soda. The alcoholic solution affords crystals—first of chloride of sodium, then of hippurate of soda in brown plates. When the residue, after the evaporation of the alcohol, is dissolved in water, hydrochloric acid throws down hippuric acid from the solution. After having evaporated the urine of the horse, and thrown down urea by nitric acid, and saturated the mother liquor with an alkali, according to Fourcroy and Vauquelin, a small quantity of solid reddish fat is obtained. This substance has an acrid taste, is volatile along with the vapour of water, is very soluble in alcohol, and combines with acids. The same fatty substance, according to these chemists, is to be obtained from the urine of herbivorous animals in general, and is the cause of its smell and colour. Their analysis of the urine of the horse is as follows:—

Urea, ...	0.7
Hippurate of soda (*urobenzoate*), . .	2.4
Carbonate of soda, ...	0.9
Chloride of potassium, . . .	0.9
Carbonate of lime, ...	1.1
Water, with a little mucus and acid fat, .	94.0 *
	100.0

The absence of uric acid and of the phosphates is common

* Berzelius: 'Traité de Chimie,' traduit par Esslinger, tome vii. p. 396.

to the urine of the horse and to that of other herbivorous animals.

On examining the urine of cattle soon after its discharge, it is found to be clear, of a bitter taste, a pale-yellow colour, and with a strong alkaline reaction. It contains much sulphate and bicarbonate of potash and magnesia, but very little lime. According to Boussingault, it contains no phosphates, very little chloride of sodium; but, on the other hand, a large amount of lactate of potash. According to Von Bibra, the quantities of urea and hippurate of potash are liable to great variations, even when the feeding and external conditions remain unchanged. Lehmann says, "I have always found oxalate of lime in the sediment; but, like Boussingault, I have never been able to detect ammoniacal salts in the fresh urine of oxen."* The urine of the ox contains from 8 to 9 per cent of solid constituents, of which from 1.8 to 1.9 per cent are urea. The hippuric acid varies, according to Von Bibra, from 0.55 to 1.20 per cent. Boussingault found free carbonic acid in it besides the alkaline carbonates.

The following table of two analyses of the urine of the ox is from Von Bibra:—

Water,	914.01	923.10
Extractive matters soluble in water,	22.48	16.43
Insoluble matters,	14.21	10.20
Salts soluble in water,	24.42	25.77
Insoluble salts,	1.50	2.22
Urea,	19.76	10.22
Hippuric acid,	3.55	12.00
Mucus,	0.07	0.06
	1000.00	1000.00

The urine of calves differs very much from that of cattle, approximating in its composition to the allantoic fluid of the

* Lehmann: 'Physiological Chemistry,' translated by Day, vol. ii. p. 456.

fœtus. According to Branconnot and Wöhler, the urine of calves, as long as they are sucking or are fed on milk, is almost colourless, clear, devoid of colour, of very little taste, and with a strong acid reaction, which it does not lose even on evaporation. Allantoine is the principal organic constituent of this urine. "It contains urea and likewise uric acid in the same proportions as they occur in normal human urine; hippuric acid, on the other hand, cannot be discovered in it. It contains a very considerable amount of phosphate of magnesia and of the potash salts, but only very small quantities of the phosphates, sulphates, and soda salts." The solid constituents altogether amount to no more than 0.62 per cent. The allantoic fluid of the fœtal calf appears to have precisely the same properties and the same composition as the urine of the calf while still living on milk.*

In the urine of sheep no peculiarity has been remarked different from its character in oxen.

The urine of the pig is of a pale yellow, clear and transparent. It contains urea, the sulphates of potash and of soda, the chlorides of potassium, of sodium, and ammonium, and traces of the carbonate of lime and the sulphate of lime.

The urine of the dog takes its character from that of the carnivorous group of animals to which it belongs.

The following table affords the type of the urine in carnivorous animals :—

Urea and free lactic acid, ...	13.220
Uric acid, ...	0.022
Mucus, ...	0.510
Sulphate of potash, ...	0.122
Chloride of ammonium and trace of chloride of sodium,	0.116
Carry forward, ...	13.990

* Lehmann, 'Physiological Chemistry,' translated by Day, vol. ii. pp. 456, 457.

Brought forward,	13.990
Phosphate of lime and phosphate of magnesia—trace of carbonate of lime,	0.176
Phosphate of potash and of soda,	0.802
Phosphate of ammonia,	0.102
Lactate of potash,	0.330
Water,	84.600
	100.000

Defæcation.—The feculent mass which animals pass by the fundament, so important in an agricultural point of view, consists—1. Of the parts of the aliment which have been subjected to all the agencies concerned in digestion, without being thereby reduced to solubility ; 2. The part of the bile which combines with the refuse of the alimentary mass ; 3. Actual bile, which has been neither decomposed nor absorbed; 4. Intestinal mucus ; 5. Saline matters, such as are incapable of being absorbed.

The quantity of the daily fæces is very variable. On this point the observations have been made chiefly in the human body. The mean quantity amounts to between four and five ounces in man. The irregularity does not seem to be connected with an excess of undigested matter. When the alimentary mass passes rapidly through the intestines, the daily quantity of fæces, due allowance being made, is greater than when the mass descends more slowly. The fæces, when formed or half formed, contain near 74 per cent of water—or at least of water and matters volatile at a temperature a little above the boiling point of water—and 26 per cent of solid constituents ; in regard to the latter, however, there are very considerable variations.

The amount of undigested matters varies very much in different cases, equalling, on an average, from 10 to 12 per cent of the solid matters. A microscopic examination always exhibits remains of the food that has been recently taken; vegetable cells, hairs, and spiral vessels are seen in abundance. In the human fæces, muscular fibres coloured yellow and corroded by the bile, yet still retaining distinct striation, are constantly found. A peculiar comminuted fæcal matter, containing partially-destroyed epithelium, is described. Starch is often found. Crystals of ammonio-phosphate of magnesia, when the evacuation is neutral or alkaline, are always present. Berzelius remarked on the large proportion of phosphate of magnesia very constant in the human fæces. "This salt," he says, "is traced to bread, in which it exists in considerable proportion." "As," he continues, "the bones and solid parts of man contain in general less of this salt than the corresponding textures in herbivorous animals in general, it would seem that the absorbent vessels of the intestinal canal in man are much less disposed to take up this salt than those of such herbivorous animals."

Amorphous fat is a constituent of the human fæces, yet it is doubtful if crystals of cholesterine occur. Connective tissue is found only after a very abundant flesh-diet. The ether extract of fæces varies much according to the nature of the food; after a very fatty diet it rises very much above the average proportion. It consists, for the most part, of a waxy fat. The alcohol extract is also rather variable—it hardly ever affords indications of bile; hence it appears that, as a general rule, no bile occurs in an unchanged state in the fæces. The water extract is a brownish-black mass, which uniformly undergoes decomposition in drying. Its average quantity is about 20 per cent of the dried fæces. The quantity of salts contained in the human fæces, as compared with the quantity of salts found in the urine, is very small. Indications of chlorine are more frequently discovered than those of sulphuric acid. The salts precipitable by ammonia vary in different individuals. After a dose of sulphate of magnesia the proportion of such salts may rise to 20 per cent, the great mass being phosphate of magnesia, associated with a small quantity of phosphate of lime and a little iron. From Marcet's experiments, a new organic substance, possessing an alkaline reaction, appears to exist in the human fæces, to which the name "excretine" has been given. It is crystalline, insoluble in water, sparingly soluble in cold alcohol, but freely soluble in ether. It contains nitrogen and sulphur in small proportions. Marcet regards excretine as one of the immediate principles of the fæces—existing in them, for the most part, in a free state. The excrement of a healthy man was found by Berzelius to consist of—

Water,	733
Albumen,	9
Bile,	9
Mucilage, fat, and other animal matters,	167
Saline matter,	12
Undecomposed food,	70
	1000

Such excrement, when freed from water, left 132 of ash in 1000 parts; the ash consisted of—

Carbonate of soda,	8
Sulphate of soda, with a little sulphate of potash and phosphate of soda,	8
Phosphate of lime and of magnesia, and a trace of gypsum,	100
Silica,	16
	132

Considered as a manure, man's excrement, or nightsoil, contains about three-fourths of its weight of water; when exposed to the air it undergoes very rapid decomposition, and gives off much volatile matter, consisting of ammonia, carbonic acid gas, and of sulphuretted and phosphoretted hydrogen gases, and at last loses its smell. By this fermentation a large proportion of valuable matter is allowed to escape into the air. The most economical method of obviating this loss is to mix it with earth rich in vegetable matter, with partially-dried peat, with sawdust, or with some other readily accessible absorbent substance.*

The excrements of carnivorous animals, as of the dog fed on flesh, contain a substance allied to excretine, but not identical with it; they contain no excretine, but they contain butyric acid, which is not found in the excrement of man.

The excrements of herbivorous animals, as the horse, ox, sheep, and those of the dog fed on bread, contain no excretine, no butyric acid, and no cholesterine.

The following table, after Boussingault, shows the comparative ultimate composition of horse-dung and cow-dung:—

	Horse.	Cow.
Carbon,	38.7	42.8
Hydrogen,	5.1	5.2
Oxygen,	37.7	37.7
Nitrogen,	2.2	2.3
Ash,	16.3	12.0
	100.0	100.0
Water,	300.0	566.0
	400.0	666.0

Analysis of ash of horse-dung from Hemming's tables. Dung dried at 212° Fahr.:—

Organic matter,	86.4
Ash,	13.6
	100.0
Sand and silica,	62.4
Potash,	11.3
Soda,	2.0

* Johnston, 'Agricultural Chemistry,' pp. 682, 683.

Lime,	4.6
Magnesia,	3.8
Oxide of iron,	1.2
Oxide of manganese,	2.1
Alkaline chlorides,	0.3
Phosphoric acid,	10.5
Sulphuric acid,	1.9

Ash of cow-dung from the same :—

Organic matter,	90.2
Ash,	9.8
	100.0

Sand and silica,	63.7
Lime,	7.6
Magnesia,	3.6
Oxide of iron,	8.5
Phosphoric acid,	12.5
Sulphuric acid,	1.8

Horse-dung in the short period of twenty-four hours heats and begins to suffer loss by fermentation. If left in a heap for two or three weeks, hardly seven-tenths of its original weight will remain. Hence, when to be used for manure, it should be removed early from the stable, and mixed as soon as possible with some other material, such as those just mentioned in the case of nightsoil.

Cow-dung ferments more slowly than that of the horse and the sheep. In fermenting it does not heat much, and gives off little if any unpleasant odour. It thence acts more slowly, though for a longer period, when applied to the soil. The slower fermentation of cow-dung arises partly from the less proportion of substances containing nitrogen, partly from the less perfect mastication of the food than in man, the horse, or the sheep. Cow-dung, nevertheless, undergoes a sensible loss if exposed uncovered to the open air.

The sheep's dung contains—

Water, ...	68.0
Animal and vegetable matter, . . .	19.3
Saline matter or ash, ...	12.7
	100.0

Pigs' dung is less fermentable than that of the cow. It has a very unpleasant odour, so that when used alone as a manure it communicates to the crop, and especially to the root crops, the same offensive smell. It is said that when tobacco is raised on soil manured with pigs' dung its leaves are unfit for smoking; but for crops not designed for food, such as hemp and flax, it is an excellent manure. It is best employed, however, when mixed with the other manures of the farmyard.*

Pigeons' dung, being much prized wherever it can be obtained in quantity, has been repeatedly analysed. Its effect as a manure depends on the proportion of soluble material therein present.

Davy found 23 per cent of soluble matter, and after fermentation only 8 per cent. Sprengel found 16 per cent in pigeons' dung six months old. The soluble matter consists of uric acid in small proportion, of urate, sulphate, and especially of carbonate, of ammonia, common salt, and sulphate of potash; the insoluble matter chiefly of phosphate of lime, with a little phosphate of magnesia, and a variable admixture of sand and other earthy matters.† When exposed to moisture, recent pigeons' dung undergoes fermentation, and thereby losing a portion of its ammoniacal salts, becomes less valuable.

Hens' dung runs to waste in poultry-yards, when by a little care it might supply some of the uses of pigeons' dung.

Goose-dung is less rich than hens' or pigeons' dung. The injurious effects of goose-dung on grass is but temporary—it arises from its being too concentrated when applied. When the weather is humid, or rain succeeds, it is innocuous; and

* Johnston, 'Agricultural Chemistry,' pp. 682, 683. † Ibid., p. 668.

even when it destroys the green blades it brings on new shoots with fresh luxuriance.*

It belongs to physiology to explain why vegetable matter is more sensibly active as a manure after it has passed through the body of an animal, than if applied to the land in an unmasticated and undigested state. Of this no more concise explanation can be afforded than that given in the following quotation from the late Professor Johnston's work :—"Everything which enters the body in the form of food must escape from the body in one or other of three different channels. It must be breathed out from the lungs, perspired by the skin, or rejected in the solid or liquid excretions. We have already seen that the function of the lungs is to give off carbon in the form of carbonic acid, while they drink in oxygen from the air; and that the quantity of carbon thus given off by a healthy man varies from five to thirteen or more ounces in the twenty-four hours. From the skin also carbon escapes along with a small and variable proportion of saline matter. The weight of carbon given off by the skin has not been accurately ascertained. Let us leave it out of view for a moment, and consider solely the effect of respiration upon the nature of the solid and liquid excretions.

"Suppose a healthy man, taking a moderate degree of exercise, to give off from his lungs six ounces of carbon in twenty-four hours, and to eat during the same time two pounds of potatoes, half a pound of beef, and half a pound of bread, then he has taken in his food—

	Carbon. Grains.	Nitrogen. Grains.	Saline matter. Grains.
In the potatoes, .	1716	47	196
In the bread, . .	1004	34	22
In the beef, . .	790	120	35
	3510	201	253

* Johnston, 'Agricultural Chemistry,' p. 669.

	Carbon. Grains.	Nitrogen. Grains.	Saline matter. Grains.
And he has given off in respiration, . .	2625	—	—
Leaving, to be rejected sooner or later by the excretions,	885	201	253

"In this supposed case, therefore, the carbon, nitrogen, and saline matter were to each other nearly as the numbers

	Carbon.	Nitrogen.	Saline matter.
	35	2	$2\frac{1}{2}$ in the food ;
and as			
	9	2	$2\frac{1}{2}$ in the excretions ;

or, in other words, the carbon being in great part sifted out of the food by the lungs, the excretions are necessarily much richer in nitrogen and saline matter, weight for weight, than the mixed vegetable and animal matters on which the man has lived.

"But the immediate and most sensible action of animal and vegetable substances as manures depends upon the proportion of nitrogen and saline matters they contain. This proportion, then, being greater in the excretions than in the crude vegetables, the cause of the higher estimation in which the former are held by the practical farmer is sufficiently clear."*

Reproduction.—The ovaries in the female, the testes in the male, are the essential organs of reproduction throughout the greater part of the animal kingdom. Even in plants analogous organs are concerned in the same great function. In phanerogamous plants the pollen derived from the anther or male organ is conveyed to the ovule at the base of the pistil or female organ. It is well ascertained that no ovule becomes a productive seed unless the pollen has had access thereto. The same is the type of the reproductive process in animals. In but few species are there not both male and female organs. In some

* Johnston, 'Agricultural Chemistry,' pp. 692, 693.

molluscous animals the male and female organs exist in the same individual, so that such individual impregnates itself; which is, in fact, what happens in the major part of phanerogamous plants. In all vertebrate animals the male organs exist in one individual, the female organs in another individual. The germ-cells produced in the ovaries are discharged from these organs at intervals (in the human female at the menstrual periods), and would be always thrown off from the system without further development, did they not upon occasion meet with vibratile particles formed in the male organs. These vibratile particles are the spermatozoa. Thus, germ-cells derived from the ovary, and spermatozoa or spermatozoids derived from the testes, are essential to reproduction. For a long time it was the general persuasion that the mere contact of the vibratile spermatozoid with the ovule was all that is essential to impregnation; but it is now proved by abundance of evidence that the spermatozoid actually makes its way through a minute aperture into the ovule, or that the elements of male origin are actually blended with the elements of female origin. It is supposed that this blending of elements derived from each parent in the very outset of reproduction, affords an explanation of the resemblances that exist between parents and their offspring in feature as well as in bodily and mental qualities. According to popular belief, the child, in what relates to outward form, gait, and manners, takes after the father, while it draws upon the mother in regard to size and internal qualities and dispositions. There can be no doubt that any such rule is liable to large exceptions. As a general law, however, it is said to hold very extensively among cattle. "Such facts seem in their turn to be accounted for by the circumstance that the spermatozoid enters and melts down in the external parts of the yolk of the egg—that is, in connection with those layers of the germinal membrane which form the nervous system and muscles; whereas the glands and internal organs are formed from the mucous layer, which is that part of the membrane farthest removed from the action of the male element."*

The function of reproduction in birds and other vertebrated animals which are viviparous, is not so different from that in mammals as may at first sight appear. In all birds the male organs have their place in one individual, the female organs in another individual. The testes, or spermatic organs of the male, are compact bodies situated close to the kidneys, composed, as in mammals, of long convoluted tubules, and made capable of great development at the season of sexual activity. The seminal ducts derived from the testes terminate by two distinct orifices in the cloaca, and a pair of papillary elevations in which these terminate constitute in most birds the sole rudiment of a penis. The ovary is, like the testes in the male, situated close to the kidney, and is composed of a "stroma," or bed of compact fibrous tissue, in the midst of which the ova are developed. As the ovisacs enlarge, they gradually project, carrying before them their envelopes, and at last the ovary presents almost the appearance of a bunch of grapes. At last the ovum escapes by the rupture of its coverings, and these remain in a sort of cup, which finally disappears by absorption. The oviduct commences by a wide slit, into which the ovum, at its escape from the ovary, is received; at the lower part the oviduct dilates into a thick glandular sac, which secretes the shell. It terminates in the cloaca, the common outlet of the rectum, and of the genito-urinary apparatus. What is singular is, that in most birds only one ovary is developed, though in the embryo two are present; the right ovary and oviduct remain unchanged for the rest of life. Hence, while there are two Fallopian tubes in mammals,

* Bennett, 'Outlines,' p. 164.

the corresponding part in birds—namely, the oviduct—is single.

The ovum, by the addition of a thick layer of albumen within the oviduct, becomes capable, after its exit from the mother, of supplying such an amount of material for the development of the chick, as is supplied to the embryo of mammals by the blood of the parent.

The periodical excitement of the organs of reproduction is a striking peculiarity observed throughout the higher orders of the animal kingdom. It is observed in both sexes, but in the female sex possesses more of a spontaneous character—that is, it takes place in the female of each species at a definite period of the year, and consists in a general increased development of activity throughout the parts subservient to reproduction. This state of increased activity is doubtless connected with the arrival of ovules in the ovary at their state of maturity, by which the female is rendered fit for producing offspring, provided impregnation by the male is permitted. If such impregnation does not take place, then the ovule or ovules brought to maturity are thrown off as useless. The state of heat, as it is termed, that accompanies these changes in the female, ceases as soon as impregnation takes place, and does not return, for the most part, during the period of gestation. If impregnation is not permitted, it ceases in one or two days in the cow and the ewe, and in three days in the goat, but in the bitch it may last ten or twelve days. In this case—that is, when impregnation is prevented—it returns in the cow every three weeks or every month; and the oftener it has returned without being followed by impregnation, the shorter is its period of duration. In the females of many animals the heat does not recur after bringing forth till the period of lactation is over; but the cow, the mare, and the she-ass are ready for the male a few days after they have brought forth their young.

There appears at first sight to be a great difference between the economy of the females of the human race and that of other mammals in respect to the function of the ovaries; but that difference becomes less striking when the subject is more attentively considered. In the ovary of the females of the human race during reproductive life, at every monthly period an ovule is matured and thrown off, and that uselessly, unless impregnation simultaneously takes place. If impregnation has taken place, then the function of the ovary is suspended till after delivery. But what occurs in common mammals is a close approximation to this course. For example, in the cow, soon after the calf is produced, heat arises; which indicates that a mature ovule is passing from the ovary towards the womb by the Fallopian tube, and if the approach of the male is permitted impregnation takes place; but if the cow is kept apart from the male, the ovule is thrown off uselessly, and the heat after one or two days ceases. In three weeks or a month heat again arises, denoting that another ovule is matured, and has escaped from the ovary; and so in succession for a number of times, so long as the sexes are kept apart.

In the males of such animals the heat recurs spontaneously and with force at a certain season, even when they are kept out of sight or hearing of the females; but yet at other seasons the presence of a female in heat is sufficient to throw a male into that state.

Lactation.—Accessory to the organs of reproduction are the glands concerned in lactation. The presence of these glands is the distinguishing mark of the highest order of animals in the animal kingdom. In the female of the human race these glands occupy a place different from their position in the bodies of most mammals; for in mammals generally the mammæ, with the exception of the monkey tribe and the bat tribe, in which, as in the female of the human race, they are situated on the breast, are close to the pelvis—that is, to the cavity with which the special organs of reproduction are connected. This is their situation in the mare, the cow, the ewe, the sow, and the bitch. In what may be regarded as the lower tribes of mammals, as in the duck-billed animals, and even in the whale tribe, the structure of these glands has a much more simple conformation than in such mammals as specially belong to this treatise. There is, however, a similarity of structure throughout the entire order of mammalians. Each gland consists of innumerable minute secreting cells grouped together in lobules and lobes. Delicate excretory ducts, taking their rise from the ultimate cells, join again and again together, until capacious ducts or rather reservoirs for the milk are produced. In the female of the human race the lactiferous canals open by numerous orifices upon the extremity of the nipple; but in animals in which the nipples or teats are of large size, as in the cow, there is generally a wide cavity where the milk accumulates in considerable quantity, and is discharged through one or two orifices only. In the cow the reservoirs are so capacious as to be capable of containing at least a quart of the secretion. In the cow a large reservoir is situated just above each teat. The teats are four in number, or occasionally even six, by the superaddition of extra mammary glands in some cows; these, however, for the most part, are imperfectly developed, and therefore hardly yield any supply of milk.* Each teat is perforated by a duct which, communicating with the milk reservoir above, affords a copious stream of the secretion. This duct is lined by a mucous membrane, with a thin covering of tesselated epithelium for defence. The same membrane is prolonged into the reservoirs and lactiferous tubes, so as to line them throughout; but in the smallest ramifications, and

* Professor Simmonds "On the Mammary Gland of the Cow," 'Agricultural Journal of England,' vol. xix. p. 81.

also in their extremities, where the milk is secreted, the epithelium presents the form of cells. The duct is strengthened and rendered elastic by fibrous and elastic yellow tissue placed externally to the mucous membrane. Near the external terminal portion the same tissue becomes more and more developed, restricting the opening, so that no milk can escape from the teat unless by suction, or by pressure from above. It is owing apparently to a defect in the development of the fibrous tissue at the end of the teat that some cows lose the milk as soon as the reservoirs and ducts become full. The popular idea that the udder of a cow consists of four quarters, each of which is independent of the others, is correct, as representing what was stated above—namely, that there are usually four glands in the mamma of the cow, to each of which corresponds a teat, and also a reservoir for the milk immediately above its upper extremity.

Woman's milk is generally of a more bluish-white colour than that of the cow or other animal, and is likewise sweeter in flavour. Its reaction is strongly alkaline, and it has less tendency to become acid than other kinds of milk. Its specific gravity ranges between 1.030 and 1.034, and the proportion of solid constituents varies from 11 to 13 per cent, while among these there are on an average 3.5 per cent of caseine and 4 to 6 of sugar. The caseine in woman's milk is not so completely precipitated by acids and by rennet as in the case of cows' milk; the coagulum, moreover, is somewhat gelatinous, and not so dense and solid, and is therefore more easily dissolved in the child's stomach. The butter of woman's milk is supposed to have a larger proportion of oleine than that of cows' milk.

Cows' milk is nearly pure white, or verging somewhat to a yellowish-white colour. Its specific gravity ranges between 1.026 and 1.035. The proportion of solid constituents varies between 12.9 and 16 per cent. The caseine is in larger proportion than in woman's milk; besides, while it has less sugar it has more butter. The proportion of salts is greater, but the excess chiefly affects the insoluble salts belonging to the caseine, and therefore is the consequence of the presence of a larger proportion of that proximate principle.

Mares' milk is white, somewhat thick, and has a specific gravity of 1.034 to 1.045. It contains 16 per cent of solid residue; it has a small proportion of caseine, a large amount of fat, and a considerable proportion of sugar.

Sheep's milk is thickish, white, and of an agreeable odour and taste. Its specific gravity varies between 1.035 and 1.041. The solid constituents amount to 14.38 per cent, and of these there are 4.02 of caseine, 4.20 of butter, 5.0 of sugar, and 0.68 of salts. Compared with cows' milk, it appears to contain less caseine and less butter, but more sugar of milk.

Of the milk of the sow no account is to be met with.

The milk of the bitch is somewhat thick, and on being heated it becomes much thicker even without coagulation. When the animal has been fed only on vegetable food the milk is neutral, or has a faintly-alkaline reaction. When animal food has been allowed, the milk has an acid reaction, while the specific gravity varies from 1.033 to 1.036. It contains, then, from 17.46 to 22.48 per cent of solid constituents, of which from 8 to 11 per cent are caseine, and from 6.84 to 10.95 butter, besides which there is a small quantity of sugar of milk. When the food is mixed, there is more butter and also more sugar. The ash sometimes contains as much as 3 per cent of insoluble salts.

According to Boussingault, a cow yields on an average, for every thousand parts of her weight, 10.4 parts by weight of milk.

Table of the proportions of the several proximate principles and salts in the milk of the cow:—

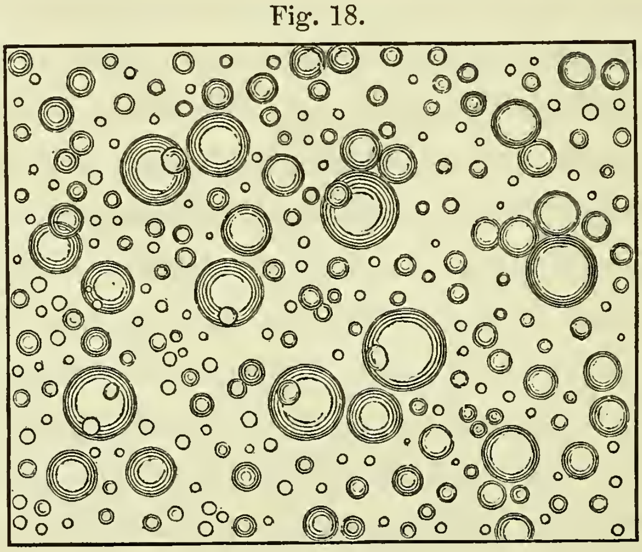
Caseine (cheese),	4.48
Butter,	3.13
Milk-sugar,	4.77
Saline matter,	0.60
Water,	87.02
	100.00

Table of the composition of the ash in two specimens of milk from different cows. In 1000 pounds of milk there were—

	I.	II.
Phosphate of lime,	2.31 lb.	3.44 lb.
Phosphate of magnesia,	0.42	0.64
Phosphate of peroxide of iron,	0.07	0.07
Chloride of potassium,	1.44	1.83
Chloride of sodium,	0.24	0.34
Free soda,	0.42	0.45

The milk-globules vary considerably in size, as is shown by fig. 18 — some being mere points, others measuring about

Fig. 18.



Globules in Cows' Milk.

1-2000th of an inch in diameter. Their number diminishes as the poverty of the milk increases.

Here ends our notice of the Functions of Assimilation and of Reproduction. The Functions of Relation do not fall within our plan.

PART SECOND.

THE CHEMISTRY OF THE FOOD OF THE ANIMALS AT THE FARM, WITH RELATION TO THE COMPOSITION OF THEIR BODIES.

ORGANIC nature is entirely built up of materials derived from the mineral kingdom. Under the head of mineral kingdom falls everything at the earth's surface which is not organic—that is, everything which is not at present an organic body, or which does not bear indications of having once been endowed with life. Some substances, such as coal, shells, marl, and the like, which manifestly once belonged to organic nature, are more conveniently spoken of as the remains of organic nature now mineralised. The mineral kingdom, with this reservation, includes not only the solid parts of the crust of the earth, but also the liquid parts—as water; and the elastic parts—as the air of the atmosphere, and all gaseous bodies. Organic nature consists of the vegetable kingdom and the animal kingdom, and all the members of each of those kingdoms are regarded as being endowed with life. The functions or great offices fulfilled by the members of the vegetable kingdom are almost solely those of vegetation and reproduction ; the members of the animal kingdom, besides the functions of vegetation, or nutrition, and the functions of reproduction, almost uniformly possess what are termed relative functions—namely, those of sensibility and locomotion. The latter, or the relative functions, being almost exclusively the property of animals, are therefore often termed the "animal functions."

With respect to the chemical constitution of organic nature, it is to be remarked that there is no simple substance in the vegetable kingdom which is not to be found in the mineral kingdom, and that in the animal kingdom there is no simple substance which does not exist in the vegetable kingdom. It is a nearly absolute rule that the members of the animal kingdom obtain all the materials of their structure, not from the mineral kingdom, but from the vegetable kingdom. And there is this grand difference between these two kingdoms of organic nature—that the vegetable kingdom draws its food, in the mineral state, solely from the mineral kingdom, while the animal kingdom feeds on mineral matter hardly at all, but, with the very slightest exceptions, on substances which have been first converted by the vegetable kingdom into organic matter. In short, the food of the vegetable kingdom is mineral—the food of the animal kingdom is organic. To this rule, absolute as it seems and really is, a slight qualification may be sought to satisfy some minds. Thus water, which is so imperatively required at all times by the members of the animal kingdom, is taken into that kingdom in the purely mineral state. It is hardly a sufficient answer to say that water is not an aliment, but a drink; the better mode of removing the objection is to insist that water is not an aliment in the same sense as the ordinary organic aliments—for it is not decomposed or chemically altered within the living system, but is uniformly diffused as the medium in which the animal organism is sustained. A like objection might be raised in respect to common salt, which is essential to the health of many animals, and is by man uniformly taken in the purely mineral state. So fond are some animals of salt, that in the vast prairies of America the herds are prevented from straying by establishing salt-washes, or saline drinking-places, within certain bounds. It must be confessed, then, that salt is a real exception to the absoluteness of the rule referred to—that it is essentially an aliment—that it is decomposed or chemically altered within the body—and that it is, almost always in man, derived directly from the mineral kingdom. It may be worth while to notice that iron is sometimes required by the human body to a greater extent than the diet at the time can afford, and that the direct use of iron in the mineral state contributes to the restoration of health. Here, doubtless, it is a medicine — yet it is a medicine which operates its effect by acting as an aliment. The disease in which this exception is most remarkably observed is chlorosis —one of those maladies in which, in ruder times, the patient was often detected eating earth, ashes, and the like, as if a natural instinct suggested a search after the mineral food required at the time by the system. It would be curious to inquire if animals in the state of freedom ever frequent chalybeate springs.

But it is almost trifling to dwell on such exceptions as these. A more important, though almost purely speculative difficulty, is involved in one of the statements made above; namely, that the food of plants is exclusively mineral. This, however, seems to be the view which now stands nearly established. The food of plants consists of water, carbonic acid, ammonia, and certain earthy and saline matters. A great part of the carbonic acid which serves for food to plants is derived from the atmosphere, and this portion of their food is beyond doubt in the mineral state. But plants also take in carbonic acid from the soil, set free during the decomposition of organic matters therein contained; and the question which has been so much debated is, Whether these organic matters in the soil, which manifestly are the source of food to plants, undergo complete decomposition before being absorbed, so as to supply mere mineral carbonic acid to the radicles; or whether they are taken into the plant while still possessed of an organic character, and are decomposed to supply food actually within the plant? The determination of the question in this particular form does not, perhaps, possess the importance usually attached to it; for if the carbonic acid derived from the organic matters of the soil, whether set free in the soil before the absorption, or set free after the absorption of these organic matters within the structure of the plant, be decomposed solely in the leaves by the influence of light, so that its carbon is then only fixed in the plant, the question is virtually settled; that is to say, the carbonic acid, whatever be its source, contributes to the process of vegetation only under the influence of light, and while it has been reduced to a purely mineral state. To be set free in the plant from organic matters previously received by the radicles is not to nourish; to nourish, it must be carried to the leaves, and there, being decomposed by light, and its oxygen set free, its carbon is ready, like that immediately derived from the carbonic acid of the atmosphere, to become incorporated with the plant.

If in the process of vegetation all the carbon incorporated with the structure of plants be derived from mineral carbonic acid, it is easy to understand that the whole soil of the earth, in so far as it contains carbon, has been in process of time accumulated from the carbonic acid of the atmosphere—that is to say, that the first beginnings of soil were from the decay of such vegetables as mosses and lichens growing on moist rocks, and that by the successive creation of plants, as the soil increased under the decay of the previous vegetation, the soil and vegetation together have expanded to their present extent at the expense of the carbonic acid of the atmosphere.

The carbonic acid of the atmosphere is but limited in quantity; nevertheless, so vast is the atmosphere, that the withdrawal therefrom of so large a quantity as to supply all the carbon at present contained in the soil of the earth and in the whole animal and vegetable kingdoms, makes but a small difference on that proportion. The other simple bodies which enter into the food of plants—oxygen, hydrogen, nitrogen, and the rest—are inexhaustible in nature, so that there is no limit to the increase of the organic world but the amount of carbonic acid in the atmosphere. The animal kingdom is continually engaged, by the function of respiration, in restoring to mineral nature the carbon, in the shape of carbonic acid, which the vegetable kingdom has worked up into the organic form. Thus a single horse gives to the atmosphere in a year about a ton of carbon combined with oxygen.

Writers on the functions of plants and animals have speculated on the period during which organic life can maintain itself on the surface of the earth. To this there is no limit but the will of the Author of Nature. Since there is manifest proof that from time to time the land is elevated above the present level of the ocean, there is no reason to predict that the dry land will be gradually, in the long course of time, washed down into the ocean. Neither is there any ground for the belief, which some distinguished philosophers have entertained, that the respiration of animals will at length so poison the air as to render it impossible for animals to live therein. Those who reason thus forget that animal life, being exclusively supported by the vegetable kingdom, cannot outstep it; and that the vegetable kingdom continually destroys the poisonous carbonic acid produced by the animal kingdom.

Whence it follows that the vegetable kingdom must keep pace with the most rapid increase of the animal kingdom; and therefore that the antidote to the poison in the atmosphere will be active in proportion to the growth of the poison itself. Animals cannot multiply except by the multiplication of plants, and plants cannot multiply without purifying the atmosphere.

When we come to the analysis of the individual members of the organic world, whether vegetable or animal, we find each individual first of all reducible into fluid parts and solid parts. Again, each of these two forms of constituents are reducible into proximate elements, or more properly proximate principles. And finally, each proximate principle is reducible into ultimate elements.

The ultimate elements of organic matter are simple chemical bodies; that is, bodies found in organic nature, which chemists have not yet been able to separate into any ulterior elements. Of these oxygen, carbon, and potassium are examples.

The proximate elements or proximate principles are bodies entering into the constitution of the solids or the fluids of organic nature, which consist of more or fewer of the ultimate elements once compounded. Of these gum, starch, sugar, albumen, fibrine, and caseine are examples.

The ultimate elements of organic nature admit of being arranged under two heads; namely, those which are almost universally present in the several proximate principles, and those which exist less constantly, and when found, then in smaller proportion.

The ultimate elements of the first order are oxygen, hydrogen, carbon, and nitrogen. It is to be remarked, however, that though nitrogen holds the same place as the three other elements just enumerated in the principal nutritive proximate principles derived from the vegetable kingdom, yet in the proximate principles of the vegetable kingdom in general it is absent. Whence it is common to say that animal matter differs from vegetable matter in this respect, that animal matter consists of oxygen, hydrogen, carbon, and nitrogen; whereas vegetable matter is made up of oxygen, hydrogen, and carbon. It is, in short, true that an immense proportion of the substance of the vegetable kingdom cannot supply effective nourishment to the higher animals; yet that apparently non-esculent substance yields food to such lower animals as are provided with organs fit to separate the nutritive from the non-nutritive matter.

The ultimate analysis of organic matter, both qualitative or that which determines the kinds of elements, and quantitative or that which settles the proportion of each element present, has now been carried to great exactness; but it would be foreign to our present purpose to explain the methods resorted to for this end. A few words respecting the older or first methods will afford an easier explanation of the kind of operation required to accomplish such an analysis.

It was at an early period observed that vegetable matter, when subjected to a destructive heat while the atmospheric air was excluded, gave off much carbonic acid gas and watery vapour, along with carbonic oxide, carburetted hydrogen, acetic acid, and empyreumatic oil; while the ashes contained principally carbonate of potassa—that is to say, the vegetable body was reduced to ashes consisting of carbon and carbonate of potassa, with some less abundant saline matters, while nothing was volatilised but bodies known to consist of oxygen, hydrogen, and carbon. It occurred to chemists that if a body capable of affording oxygen freely were mingled with the vegetable substance before the destructive heat was applied, the new supply of oxygen, together with that already existing in the body under analysis, might be sufficient to convert the whole of its carbon into carbonic acid, and the whole of its hydrogen into water: in which case the simple determination of the amount of carbonic acid and the amount of watery vapour collected, together with the amount of oxygen afforded, would suffice to show how much carbon, how much hydrogen, and how much oxygen, were in the weight of the substance submitted to analysis. The plan was found to give very satisfactory results. The substance finally chosen was the black oxide of copper ($CuO = 39.7$), which may be exposed to a very high temperature by itself without undergoing any change, but which, when heated with combustible substances, parts readily with oxygen. Thus, by weighing a quantity of this oxide before and after the experiment above described, the quantity of oxygen which had united with the elements of the organic body under examination was at once ascertained. The analysis of the ashes gave the ultimate elements present belonging to the second head above indicated.

Nearly the same observations apply to an organic substance from the animal kingdom, with this exception, that, owing to the general presence of nitrogen, it affords by destructive heat, besides such products as are so obtained from a vegetable substance, ammonia, cyanogen, and free nitrogen. The exact analysis by black oxide of copper is conducted on a like plan.

Ultimate Elements of the First Order.

Oxygen.—Oxygen is the most abundant substance in nature. It exists everywhere—so that the difficulty is rather to discover natural bodies in which there is no oxygen than to enumerate those of which it is a constituent. It makes nearly a fourth part by weight of the atmosphere, it constitutes eight-ninths of the whole weight of the waters of the globe, and nearly a half of the weight of the general crust of the earth. To come to organic nature, it forms half the weight of lignine, which is nearly identical with wood, and nearly a fourth part in the weight of dried muscular flesh. The only simple bodies which approach to the same abundance with oxygen in nature are silicon, the inflammable basis of flint; and the metal aluminum, the basis of our clays. The bodies found in nature destitute of oxygen are the few simple bodies found in the uncombined state, such as carbon in the form of diamond, sulphur, and those metals which exist in the virgin state; also, several compound bodies, such as the native compounds of chlorine, iodine, and sulphur, and therefore the natural beds of rock-salt and the native sulphurets or sulphides of iron, copper, and zinc.

Oxygen in the uncombined state is known only in the form of gas; all attempts to condense it into a liquid have heretofore failed. It combines with every simple substance hitherto discovered, with the exception of fluorine, which, however, is still a simple body only by hypothesis. It appears to be owing to its energetic affinity for bodies that it supports combustion in so high a degree. Oxygen gas, however, hardly sets bodies on fire at ordinary temperatures, as chlorine does. But many bodies which burn tranquilly in atmospheric air—that is, in oxygen diluted with about four parts of nitrogen—burn vividly when put, in a state of combustion, into oxygen gas. A splinter of wood, with a glowing spark upon it, soon exhausts itself and goes out in atmospheric air; but if put into oxygen gas, the spark bursts into flame and burns brilliantly. In this case combustion is going on in the air, but the evolution of heat is so slow that less heat is extricated from the spark than is sufficient to compensate for the amount lost from the burning spot by the conduction and radiation of heat therefrom; whence the heat required for the continuance of the combustion fails. In oxygen gas the combustion goes on so rapidly as far more than to compensate for what is lost by radiation and conduction. Phosphorus and potassium, if previously heated, burst into flame when put into oxygen gas. According to recent views, the rapid motion between the atoms of the two bodies, determined by their great affinity, when stopped by their near approach, becomes changed into heat. Combustion, then, is a mere accident of chemical combination between two bodies ; that is, such combination is called combustion, when the heat extricated is sufficient to give rise to light. If it be asked why there are cases of chemical combination in which cold is produced ? the answer is that such cases are uniformly accompanied with liquefaction, as when snow and salt, or snow and chloride of calcium, are mingled. There is undoubtedly in both examples an exercise of affinity, but in the transition from the solid to the fluid form of the solution there is heat changed into motion—whence the heat disappears to a certain extent.

When charcoal or carbon burns in oxygen gas, great heat is produced, notwithstanding that the product, carbonic acid, is gaseous. But the heat here produced would be greater if the product were solid and of considerable density ; for the actual heat, as measured, must be the heat extricated on the interruption of the motion given to the atoms by the affinity, diminished by the amount of heat converted into motion during the expansion of the carbonic acid or the product.

It is an important fact in physiology, that the heat produced by the combination of a given quantity of oxygen with carbon, to afford carbonic acid, is always the same under the most different circumstances ; for example, the same whether the combination takes place at a high temperature of the atmosphere, or slowly within the bodies of animals.

To the slow combustion not merely of carbon but of other combustible bodies, as hydrogen, sulphur, and phosphorus, such as takes place within the animal body, the name eremacausis (slow combustion) has been lately given; and the same term is applied to the decay of organic bodies under the influence of oxygen.

Under this slow combustion within the living body, free sulphur becomes sulphuric acid, free phosphorus becomes phosphoric acid; and all salts consisting of an oxidised base, with such vegetable acids as the tartaric, the citric, the acetic, pass into carbonates of the same base; and this last statement indicates an analogy between such slow combustion and the long-known fact that the tartar of wine, or the impure bitartrate of potassa, is by destructive heat changed into the pure carbonate of potassa, so long known from this circumstance as the "salt of tartar."

The process of respiration in animals, in so far as it is a chemical operation, is an eremacausis. The energy of a living animal is in proportion to the activity of its respiration. Birds which perform the extraordinary exertion of carrying themselves by the power of their wings through the atmosphere, have of all animals the most powerful respiration. It is ascertained that in every kind of animal activity, and particularly in the contraction of muscles, the solids concerned lose a portion of their vitality, that portion becoming reduced to inert matter. According to the views recently advocated, the force of muscular action is due to the combustion of a portion of the muscle at each contraction; that is, to the combination of its carbon with the oxygen of the blood, by which carbonic acid is formed. That is to say, the heat so produced is changed into motion, while the animal heat, in so far as muscular motion is its source, is merely that portion of heat which remains over, or is not changed into motion.

The carbonic acid formed in such animal acts passes into the venous blood, and being conveyed to the lungs, is there discharged along with what may be formed in the vessels of the lung itself during the reception of new oxygen from the inspired air.

Hydrogen.—Hydrogen is the lightest known substance. It is sixteen times lighter than oxygen, fourteen times lighter than nitrogen, and twenty-two times lighter than carbonic-acid gas. It was once thought that owing to its great levity it might form the highest layer of the atmosphere, and this idea is not wholly incompatible with the view adopted at present as to the mode in which the constituent gases of the atmosphere exist diffused through one another. For if hydrogen exist in the atmosphere—and some facts seem to show that it does—then it must extend from the surface of the earth gradually diminishing in density, according to the law affecting the whole atmosphere, till it reach its utmost limit. But as the relative heights of the several columns of the atmospheric gases must be in the inverse proportion of the density of each—that is, in the direct proportion of the levity of each—the idea referred to is so far correct that the column of carbonic-acid gas, the most dense of the whole, must be the shortest; so that the hydrogen must be highest as the lightest, and therefore it will in fact be the sole gas which crowns the summit of the atmosphere. The great source of hydrogen is the waters of the globe, of which it forms one ninth part by weight. It does not exist in the rocks of the crust of the earth, unless in so far as they contain water. Combined with nitrogen, it is present in ammonia. It constitutes about one sixteenth of the whole weight of the tissue in wood, and nearly the same in starch and sugar. Of dried muscular flesh it makes up about one thirteenth by weight. Such, then, are the proportions in which the hydrogen of water contributes to the substance of vegetable and animal tissues. The hydrogen derived from water is an essential part of the nutrition of plants. It is in this way that hydrogen comes to enter into organic structure. Neither water nor hydrogen is accounted an aliment of animals, because, as already said (p. 286), though water is essential to the life of animals, it is in order to furnish in its entire state a basis for the tissues, and not that it may be decomposed to supply hydrogen to the organic structure. The hydrogen which so universally is present in the organic structure of animals is derived from their organic food, into the composition of which the hydrogen enters by the decomposition of water in the vegetable kingdom.

Carbon.—Carbon, the most familiar form of which is charcoal of wood, exists only in the solid state. It cannot be volatilised by any intensity of heat. Hence it is to be remarked that smoke, which essentially, or at least most commonly, is carbon, is really in the solid form, however much it may be comminuted, and that it ascends merely because the heated air in which it is suspended rises upwards. Carbon uncombined exists but sparingly in the mineral kingdom, but combined with oxygen it abounds in the form of carbonic acid gas. Besides what exists in the atmosphere, it is a component in the numerous varieties of carbonate of lime, as chalk, marble, limestone, marl, of which it forms nearly an eighth part, and of the carbonate of magnesia, of which it constitutes more than a seventh part. It is the characteristic constituent of all substances termed organic. The solid parts of plants, shrubs, and trees owe their form and solidity to this element. In the tissue of wood the proportion of carbon is nearly three-sevenths, while in dried muscular flesh the proportion of carbon by weight is not far from one-half.

Nitrogen.—Nitrogen is also called azote, and this last name is so frequently used, both in the simple form and in compound words, that the knowledge of it cannot be dispensed with. The name azote is derived from Greek words signifying privation of life ; that is, nitrogen, though abundant in the atmosphere, is not the element which supports life. It serves merely to dilute the oxygen, which, when pure, so powerfully stimulates that it at length extinguishes life. Neither does nitrogen support combustion. Nitrogen is a most important constituent of the organic structure, inasmuch as no organic products destitute of nitrogen can augment or repair the animal frame. Aliments destitute of nitrogen, usually called non-azotised, are fit to support animal heat and to accumulate fat, but not to nourish the solid frame of a living animal. The nitrogen of the atmosphere, which constitutes nearly four-fifths of its weight, does not directly act as nourishment to either vegetable or animal bodies. The nitrogen of organic nature is chiefly derived from the ammonia of the atmosphere, which is constantly present, though in small quantity. Nitrogen forms nearly five-sixths of ammoniacal gas. A question has arisen whether the generation of ammoniacal gas can go on without limit in nature. If this question were answered in the negative — namely, that ammoniacal gas cannot arise except from the decomposition of organic tissues containing nitrogen—then there would be a limit to the increase of organic nature ; thus, that it could not increase beyond what the ammonia actually in the atmosphere and that derived from the decomposition of the azotised organic products in actual existence at present could afford, unless, indeed, a continued supply could be counted on from volcanic sources. It seems, however, certain that ammonia is actually formed on many occasions in nature altogether independently of the decomposition of organic matter, or of the presence of volcanic influence. When oxidation takes place in the presence of moisture, it is attended with the formation of ammonia. Thus moistened iron filings, if exposed to the air, become rusty, and the oxidised compound retains a small quantity of ammonia. This subject bears with momentous importance on the production of artificial manures. Besides being of volcanic origin, ammonia exists in nature in the salts having ammonia for their base. These of course should be mentioned as a source of nitrogen in mineral nature, to which the natural nitrates are to be added. Nitrogen exists also in the compound mineral inflammables, which, however, have a vegetable origin, common pit-coal being a principal example. Nitrogen does not exist as a common element of the rocks of the crust of the earth.

Ultimate Elements in Organic Nature of the Second Order.

Chlorine.—Chlorine is known in organic nature merely as combined with sodium, forming sea-salt. In this form it is very essential. In mineral nature it exists only in the form of chlorides.

Sulphur.—Sulphur abounds in mineral nature, particularly in combination with metallic bodies and in volcanic formations. It appears to be an essential constituent of many organic bodies ; and in particular, it exists, though in minute proportion, in the principles termed the proteine compounds, which constitute the chief forms of azotised animal aliment. Its presence in the soil, then, where crops are reared for food, must be of the last importance, a point not to be neglected in the contrivance of artificial manures. It has long been remarked that the presence of sulphur is always distinguishable in the order of cruciferous plants to which the turnip and the coleworts belong. Minute as is the proportion of sulphur in those organic bodies in which it has been observed to exist, there can be no doubt that any deficiency even of that small proportion must necessarily be attended with a failure of vegetative energy. Sulphur is thrown off from the animal body after oxidation in the form of sulphuric acid combined with the common bases, as potassa, soda, ammonia.

Phosphorus.—Phosphorus does not manifestly exist free in organic nature. It can be detected, however, in the nervous substance of the animal kingdom, and in the proteine compounds, fibrine and albumen. It exists abundantly, combined with oxygen, in all the three kingdoms of nature. It exists in the form of phosphates in small proportion, but widely diffused throughout the rocks of the crust of the earth. From the disintegration of such rocks it gets into the soil of the earth, to supply the two organic kingdoms with their proportion of phosphates. Phosphate of lime is known under two mineral forms—namely, apatite and phosphorite; which, though in some districts they constitute mountain-masses, are not widespread over the earth. Phosphorus is a far more abundant element in organic nature than sulphur, and therefore deserves a proportionately greater attention in the consideration of artificial manures and in the feeding of animals. It has been said, though some doubt is cast on the statement, that even sea-water contains phosphates. The ashes of red wheat contain, according to Liebig, 94.44 per cent of phosphates; the ashes of white wheat, 91.47 per cent; the ashes of pease, 85.46 per cent; the ashes of beans, 97.05 per cent of the same salts—whence it follows that the ashes of these several substances have phosphorus present in them to the extent of from 15 to 20 per cent.

Phosphorus is contained, probably free, in albumen and fibrine. In the animal kingdom the phosphates hold a prominent place among its saline constituents. If the phosphates in the living body amount to about one-fifth part of its weight, as some calculations would intimate, then every human body must contain several pounds of phosphorus. The phosphates, and particularly the phosphate of lime, are the chief hard materials of the bones in vertebrated animals, the carbonate of lime being in very inferior proportion. In the higher animals phosphates are found generally throughout the fluids and soft parts as well as in the skeleton.

The acknowledged value of the soluble phosphate of lime, and even of bone-dust, as a manure, has turned the attention of chemists of late to the localities in which phosphate of lime exists mineralised in a more concentrated state than in the common rocks of the earth's crust. Many such localities have been determined, and these promise to become most valuable sources of phosphatic manure. A few of these minerals deserve notice: Norwegian apatite, which is imported into Britain in shiploads, contains from 77 to nearly 90 per cent of tribasic phosphate of lime or bone-earth. Spanish or Estremadura phosphorite, which occurs in immense quantities near Truxillo, in Estremadura, contains nearly 80 per cent of bone-earth. It does not appear to have been yet profitably used as a manure. Bavarian phosphorite, found at Amberg in Bavaria, and containing a small proportion of iodine, is of much the same composition as the Estremadura phosphorite. It has been used in Germany for agricultural purposes, but has hardly yet found its way in quantity to Britain. Osteolith, discovered near Hanau, is very rich in phosphate of lime; but it cannot be excavated so as to defray the cost. Phosphatic nodules from the lower chalk are known in commerce under the name of Cambridgeshire coprolites. These contain from 54 to 58 per cent of bone-earth. Under the name of Suffolk coprolites, pseudo or false coprolites, or crag-coprolites, are known in commerce, the mixed fossil bones, fish-teeth, and phosphatic pebbles, which occur in the tertiary deposit termed Suffolk crag, varying from three to eighteen inches in thickness between the coralline crag and London clay.

The average proportion of bone-earth in this substance is from 52 to 61 per cent. Maracaibo, or Monk's Island guano, is American phosphate. The phosphoric acid, amounting to 41.34 per cent in this substance, appears to form a mixture of pyro-phosphate and of tribasic-phosphate of lime, or bone-earth; whence it is rich above the average of such minerals in phosphoric acid. Sombrero rock, or crust-guano, has been brought of late years in quantity to Britain from the West Indies. It is not a guano, but the rock itself, of which the islet Sombrero is almost entirely composed. It appears to be a rock breccia. It averages as much as 75 per cent of bone-earth. Kooria Mooria (Curia Muria) guano is imported into Britain in considerable quantities from the group of islands of that name on the south-east of Arabia. It contains organic matter and from 45 to 60 per cent of phosphates of lime and magnesia. It occurs in a fine powder, and is accounted a valuable manure. It thus appears that commercial speculation has been by no means idle in ransacking the earth to obtain a supply of phosphates for the uses of agriculture.*

Silicium or Silicon.—Silicon, one of the most abundant substances in nature, is found in small proportion throughout the organised kingdoms. In the animal kingdom a minute proportion can commonly be detected in the bones and in the urine. As respects its presence in the urine, probably much depends on the kind of food employed. In the vegetable kingdom it gives strength to the stem, as in grasses, so as to enable it to support the weight of the grain. In the bamboos of the East Indies a deposit of pure silica occurs in considerable masses, which has been named "tabasheer." In the stem of the equisetaceæ or horse-tails, which some animals will eat, the silica is seen deposited in a crystalline arrangement.

* On this subject see Voelcker, 'Agricultural Journal of England,' vol. xxi. p. 350.

Potassium.—Potassium, the oxide of which is potassa, or the true vegetable alkali, is spread throughout the mineral kingdom. The ashes of all plants growing elsewhere than on the sea-shore afford by lixiviation an impure carbonate of potassa. The proportion, however, varies much ; but those plants which are rich in this alkali refuse to grow if the soil is not rich in potassa salts. All fertile soils contain a smaller or larger proportion of potassium in the form of potassa. It passes into these soils from the several sorts of clay in which it exists to the extent of three or four per cent. The clays, again, derive the potassa from the disintegration of felspar, or from some kinds of mica. In felspar potassa is present in the proportion of ten or twelve per cent, and in the micas referred to in the proportion of five or six per cent. In the animal kingdom it is not in general so abundant as in the vegetable kingdom : it exists, however, in the form of salts of several acids, in the milk, the blood, and the urine. In the urine of herbivorous animals it is particularly plentiful, since the excess of potass contained in their food is thrown off by the kidney.

Sodium.—In the ashes of seaweeds, and of plants growing on the sea-shore within reach of sea-water, the carbonate of soda exists. Kelp is the name applied to the impure carbonate of soda, which is obtained by the incineration of algæ or seaweeds. Barilla is the name of the substance, richer in soda than kelp, which is extracted from the ashes of plants growing on the turfy beach of seas where the tides are not strong. Soda was formerly called the mineral alkali, owing probably to the mineral-like character both of kelp and barilla. But as certain salts of soda, particularly the chloride of sodium or common salt and the nitrate of soda, exist in immense masses in the mineral kingdom, it turns out that soda is really entitled to the name of mineral alkali. Sodium is also found, like potassium, in moderate proportion, in certain rocks; thus albite or natron felspar is a rock in which soda supplies the place of the potass in common felspar. Moreover, the vast store of soda, under the form of chloride of sodium, in sea-water, clearly gives it a good title to the name of mineral alkali. Soda is more particularly the alkali of the animal kingdom. It is soda which gives the alkaline character to the blood. The chloride of sodium, the sulphate of soda, the phosphate of soda, and various combinations of soda with the organic acids, are met with in the animal fluids.

Calcium.—Lime, or the oxide of calcium, is spread abundantly throughout organic nature. In the vegetable kingdom the salts of lime exist everywhere in minute proportion. In the animal kingdom lime is collected into masses in combination, in particular, with phosphoric acid.

Magnesium.—Magnesia, or the oxide of magnesium, is far more sparingly found than lime in the vegetable and animal kingdoms. Phosphate of magnesia is often met with in the analysis of vegetable products. Thus in the ashes of wheat, rye, beans, and pease, the phosphate of magnesia exists in considerable proportion. The same salt occurs in the blood and in human bones.

Iron.—Iron is possessed of important offices in organic nature. Combined with phosphoric acid in the fruit of wheat, rye, and pease, the oxide exists. The oxide is met with in the ashes of various kinds of wood. In the ashes of fir-wood the oxide has been found to the extent of 22.3 per cent. In the animal kingdom iron is a universal constituent of the blood.

Manganese.—Manganese appears in the analysis of some woods, and it has been found also in the animal kingdom, as in the human hair.

Proximate Principles of Organic Nature.

Albumen.—Under the name of albumen has been long known a substance of which the type is the white of eggs. The albumen of the white of eggs differs somewhat from the albumen obtained from the serum of the blood. Albumen is distinguished from other proximate principles by its coagulability. In begins to coagulate at 140° of Fahrenheit's thermometer ; and if the solution is concentrated, it sets into a firm mass such as a hard-boiled egg exhibits. Strong alcohol precipitates albumen from its solution ; but if the alcohol be rendered slightly alkaline by potassa, no coagulation takes place. Sulphuric ether, if free from alcohol, does not coagulate albumen, yet it renders a concentrated solution of albumen viscid. Creosote instantly coagulates albumen. The concentrated mineral acids precipitate albumen in a coagulated form, but gradually decompose it. Metaphosphoric acid coagulates albumen ; the other varieties of phosphoric acid have no effect. Acetic acid and the organic acids in general do not cause a precipitate in solutions of albumen. The tannic acid in an infusion of galls has, however, a coagulating effect. Solutions of alum and salts of copper, lead, mercury, and silver, precipitate solutions of albumen. Albumen forms definite compounds with the alkalies and other metallic oxides. Coagulated albumen is dissolved freely by solutions of the alkalies.

The albumen from a hen's egg in 100 parts exhibits 53.5 of carbon, 7.0 of hydrogen, 15.5 of nitrogen, 22.6 of oxygen, 1.6 of sulphur, and 0.4 of phosphorus. This ultimate constitution differs very little from the ultimate constitution of fibrine, and also very little from the ultimate constitution of caseine, except that in caseine no phosphorus has been detected.

Of late it has been taught that the vegetable kingdom contains substances identical with the albumen, the fibrine, and the caseine of the animal kingdom. The juice of many plants, such as that of carrots, turnips, and cabbages, when heated, becomes turbid from the coagulation of a substance which is proved by analysis to be of the same composition as albumen. Wheat flour also contains an azotised substance which is soluble in cold water; and this solution, on evaporation, yields greyish flocculi of albumen.

Fibrine.—The substance which for a long time has been known as fibrine is the concrete body obtained from the coagulum of the blood by the separation of the red particles. The same substance has long been regarded as the chief constituent of the muscular fibre. Some differences, however, have been of late pointed out between the fibrine of the blood and the fibrine of the muscles.

The proportion of fibrine in the blood does not exceed 2.5 parts in the 1000, but in inflammatory diseases it sometimes rises as high as 11.8 in 1000. In anæmic diseases, it is often, yet not uniformly, diminished below its usual proportion. Yet by long fasting it is somewhat increased in quantity. Lymph commonly contains no more than 0.4 or 0.5 parts per 1000. In the chyle of animals it has been found to vary from 0.7 to 7.0 per 1000.

The fibrine of muscle, after it has been well washed and pressed, is dissolved more or less completely in dilute hydrochloric acid. By the addition of ammonia the fibrine is precipitated, and may be purified by successive washings in water, alcohol, and ether. The muscle of different animals varies as to solubility in dilute hydrochloric acid; that of fowl and that of beef was found to be almost wholly soluble; that of mutton was less so; whilst in that of veal the insoluble portion amounted to nearly one-half. This residue, besides other matters, contained a quantity of fibrine which resembled blood fibrine.

Fibrine in its uncoagulated state is found in fresh-drawn vegetable juices, from which, on standing, it is spontaneously deposited. In its coagulated state, it is met with in the gluten of wheat flour and in the seeds of the other grasses.

Caseine.—In milk, caseine exists to the extent of about three per cent. The solutions of caseine do not coagulate by boiling, but the hot liquid, by absorbing oxygen, forms on the surface a pellicle which is insoluble in water. In solution, caseine is at once coagulated by acids. With strong sulphuric, nitric, and hydrochloric acids caseine produces the same reactions as albumen; and its solution in acetic acid gives a similar precipitate with ferrocyanide of potassium. Soluble caseine is sparingly soluble in cold alcohol, but more freely in hot alcohol. Coagulated caseine is readily dissolved by solutions of the alkalies and of the alkaline carbonates. Solutions of common salt, of nitrate of potassa, and of hydrochlorate of ammonia, readily dissolve caseine. Caseine forms insoluble compounds with the alkaline earths. If a piece of poor cheese, which is principally caseine, be reduced to a paste with water and mixed with slaked lime, it forms a tenacious lute, which sets very hard, and may be used for cementing pieces of broken earthenware. The most remarkable property of caseine is its coagulability by rennet, the dried and salted inner membrane of the fourth stomach of the calf.

According to some chemists caseine has not been detected with certainty anywhere but in the milk of mammiferous animals. Liebig, however, regards what has been called legumine, a substance found in the seeds of leguminous plants and in almonds both sweet and bitter, as identical with caseine. Legumine at least so strongly resembles caseine that, after coagulating it, like caseine, the Chinese make it into a kind of cheese. Dried pease contain about a fourth part of their weight of this caseine or legumine.

Proteine.—Though Liebig refuses to adopt the ideas of Mülder on the subject of proteine—namely, that albumen, fibrine, and caseine are derivations of one fundamental azotised principle, and that this substance, by its union with different proportions of sulphur and of phosphorus, gives rise to these three modifications of the albuminoid group—yet the following passage will show how closely, in his opinion, these three nutritive principles are allied: "These nitrogenised forms of nutriment in the vegetable kingdom may be reduced to three substances, which are easily distinguished by their external characters.

"When the newly-expressed juices of vegetables are allowed to stand, a separation takes place in a few minutes. A gelatinous precipitate, commonly of a green tinge, is deposited, and this, when acted on by liquids which remove the colouring matter, leaves a greyish-white substance, well known to druggists as the deposit from vegetable juices. The juice of grasses is especially rich in this constituent, but it is most abundant in the seeds of wheat and of the cerealia generally. It may be obtained from wheat-flour by a mechanical operation and in a state of tolerable purity; it is then called *gluten*, but the glutinous property belongs in part to an oily substance present in small quantity.

"The second nitrogenised compound remains dissolved in the juice after the separation of the fibrine. It does not separate from the juice at the ordinary temperature, but is instantly coagulated when the liquid containing it is heated to the boiling point.

"When the clarified juice of nutritious vegetables, such as cauliflower, asparagus, mangel-wurzel, or turnips, is made to boil, a coagulum is formed, which it is absolutely impossible to distinguish from the substance which separates as a coagulum when the serum of blood, or the white of an egg diluted with water, is heated to the boiling point.

"The third of these important vegetable principles is chiefly found in the seeds of peas, beans, lentils, and similar leguminous seeds. It may be extracted from their meal by cold water and kept in solution. In this solution it resembles the others, but is distinguished from them in this, that its solution is not coagulated by heat. When the solution is heated or evaporated a skin forms on its surface, and the addition of an acid causes a coagulum just as in animal milk.

"The analysis of these three vegetable principles has led to the interesting result that they all three contain sulphur and nitrogen and the other constituents in the same proportion, and, what is still more remarkable, that they are identical in composition with albumen, containing the same elements in the same proportion as that chief constituent of the blood." *

Gelatine and Chondrine.—The proximate azotised principles hitherto spoken of are known as the albuminoid group. Gelatine and chondrine are obtained from substances existing only in the animal kingdom, known as the gelatigenous group of bodies. Neither gelatine nor chondrine appear to exist under the soluble form in the animal body. In short, the principles termed gelatine and chondrine are in all cases the result of the prolonged action of boiling water on the gelatigenous or chondrine-producing tissues. Nevertheless, the composition of gelatine is identical with that of the tissue which yields it by boiling. Thus, a given quantity of tendinous matter, when converted into gelatine by boiling it with water, is not altered in weight. Gelatine and chondrine contain a smaller amount of carbon, and a larger quantity of nitrogen, than the principles of the albuminoid group. The proportion of sulphur is considerably less. Chondrine contains more oxygen and less nitrogen than gelatine, while the percentage of carbon and hydrogen is the same in both substances. In 100 parts of gelatine there are, according to Mülder, carbon, 50.40; hydrogen, 6.64; nitrogen, 18.34; oxygen and sulphur, 24.62.

* Liebig, 'Familiar Letters on Chemistry,' 1851, p. 349.

Isinglass obtained from the inner membrane of the swimming bladder of the sturgeon is a good type of gelatine; glue is an impure form of gelatine; size prepared from parchment is another commercial form of gelatine. Patent gelatine is prepared with more care than glue from the ligamentous parts of animals.

Chondrine is prepared by boiling the cornea of the eye or any of the permanent cartilages; it is obtained also from the primary cartilages before ossification takes place. When a permanent cartilage becomes ossified, it affords by boiling not chondrine but gelatine.

As chondrine exists in cartilage, so gelatine is contained in the bones, tendons, ligaments, the cellular or filamentous tissue, membranes in general, and the skin. It has been affirmed, on grounds that cannot easily be refuted, that gelatine has no nutritive properties—in short, that the use of it as a dietetic substance is rather injurious. It appears that within the living body it cannot be transformed into fibrine, albumen, or caseine, and it is certain that animals fed exclusively on gelatine die with symptoms of starvation.

Crystallisable Azotised Proximate Principles.

Urea, Creatine and Creatinine, Uric Acid, Hippuric Acid.—Urea, creatine, and creatinine are crystallisable principles derived from the disintegration of the muscular tissue destined to be rejected from the living system as excrementitious.

Urea is the chief peculiar constituent of the urine. It is made up of oxygen, hydrogen, carbon, and nitrogen, the last being the predominant element. The constituents of urea are the same as those of albumen, fibrine, and caseine, yet their proportions are very different. In that albuminoid group the proportion of nitrogen is only about 15 per cent, while in urea it is 47 per cent. In the albuminoid group the carbon amounts to 52 or 53 per cent; in urea the carbon is no more than 20 per cent. The hydrogen is very much the same in both; but the oxygen in the albuminoid group is about 22 per cent, while in urea it is 27 per cent.

Creatine consists of oxygen, hydrogen, carbon, and nitrogen. It has neither acid nor basic properties. It is very soluble in hot water, and cold water retains a minute proportion of it in solution. By the action of strong acids it is resolved into creatinine. Creatine is found in minute quantity in the muscular flesh of the common domestic quadrupeds, and also in that of birds and fishes. Creatine and creatinine are found in minute quantity, along with urea, in the urine.

Uric Acid.—Uric acid consists of oxygen, hydrogen, carbon, and nitrogen. Both the nitrogen and the carbon are in considerable proportion. Nitrogen is present to the extent of 32 per cent, while the carbon amounts to 37 per cent. Uric acid is secreted not only by mammals and birds, but also by serpents and many insects. Guano consists chiefly of uric acid combined with ammonia, altered by the greater or less exposure to the elements to which it may have been subjected.

Hippuric Acid.—The urine of the horse yields hippuric acid if the animal be kept at rest; but if he be employed actively at work the greater part of the hippuric acid disappears, and benzoic acid is found in its stead. This acid is readily obtained from the urine of the cow. The acid consists of oxygen, hydrogen, carbon, and nitrogen, but contains no more than 8 per cent of nitrogen.

Saccharine or Amylaceous Group of Proximate Principles.

The types of the saccharine or amylaceous group of proximate principles in organic nature are chiefly from the vegetable kingdom, and constitute important constituents of food, —namely, cane-sugar, the starch of wheat, gum, pectine or vegetable jelly, and celluline. The whole group, with very few exceptions, have this peculiarity of constitution in common, that the proportion of the two elements, oxygen and hydrogen, exists exactly in that necessary to produce water. This peculiarity is the origin of the name sometimes applied to them—viz., hydrates of carbon. It is not to be understood, however, that they are merely compounds of carbon with water, but rather that each of them contains as much oxygen as is requisite to convert the whole of its hydrogen into water. The difference between them in ultimate composition is most commonly to be expressed by a larger or smaller amount of the elements of water, and one of them is often capable of being converted into another by the addition or subtraction of so many atoms of water. Thus, if the carbon in each be represented by 12 atoms, cane-sugar contains 11 atoms of water, starch 10 atoms of water, starch-sugar or glucose 14 atoms of water. Hence also the conversion, for example, of starch into glucose or starch-sugar may be described as the combination of starch with four atoms of water. It is, as it would seem, owing to this peculiarity of constitution that so many members of this group are so prone to the changes produced by fermentation. Most of the members of this group afford oxalic acid under the action of nitric acid.

Sugar.—Of the varieties of sugar known to chemists the most important are the cane-sugar or sucrose, grape-sugar or glucose, called also starch-sugar, fruit-sugar or fructose, and milk-sugar or lactose. It will be sufficient for our present purpose to take notice of these chief varieties.

Cane-Sugar.—The sugar of which cane-sugar is the type abounds throughout the vegetable kingdom. The sugar-cane, beetroot, and the sugar-maple are perhaps the only sources from which cane-sugar is obtained at present for the market; but it is the same variety of sugar which exists in carrots, turnips, parsnips, the pumpkin, the chestnut, the young shoots of the maize or Indian-corn, the ripe sorgho-grass, and numerous common fruits.

Cane-sugar has a density little more than one-half greater than the density of water. It is soluble in one-third of its weight of cold water; and when water is saturated with it to this extent, it obtains the name of syrup. Sugar is very sparingly soluble in spirit. By the spontaneous evaporation of syrup, sugar-candy is produced. Loaf-sugar consists of a crowd of minute transparent crystals.

Cane-sugar readily undergoes fermentation. The yeast of beer causes it to take on the vinous or alcoholic fermentation; it first assimilates the elements of water, and is then decomposed into carbonic acid and alcohol. The lactic fermentation is determined in cane-sugar when put in contact with putrefying caseine and chalk, the product being lactic acid.

Sugar has, to a certain extent, an antiseptic property. If dusted abundantly over meat, fruit, or fermentable substances, it prevents their decay, provided there is not too free an access of air.

As a nutritive substance sugar is not a flesh-former, but when mixed with other suitable food it has a fattening tendency. To say that it is merely an element of respiration, is to give too limited a view of its effects in the nutrition of animal bodies. It must be admitted, however, that alone it is insufficient for the support of life. Its fattening tendency is undeniable. Nevertheless, the proofs of its high nutritive character do not always refer to absolutely pure sugar. Many insects, as butterflies, bees, ants, feed on sugar and saccharine liquids; but this is by no means tantamount to the affirmation that any animal can support life on pure sugar. If saccharine juices are the sole support of such animals, then, doubtless, a sufficient proportion of proteine compounds or flesh-formers are present along with the sugar in such juices. It has long been a received belief, nor is there any reason to doubt its authenticity, that during the sugar season of the West India Islands "every negro on the plantations, and every animal, even the dogs, grow fat." Fat is a non-azotised substance, so that there is no difficulty in believing that the use of sugar, along with other suitable substances, may fatten animals; and as pure sugar is not referred to in the statement made, but the juice of the sugar-cane, in which, doubtless, there is flesh-forming material, it is possible that the fattening spoken of may take place for a time, even when nothing but cane-juice is supplied as nourishment. It is alleged that the fattening tendency of sugar is not greater than that of a corresponding weight of starch. Hence if it be the fact that both sugar and starch have a manifest fattening tendency, the name respiratory aliments does not so strictly apply to them as the mere negative term non-azotised aliments.

By long boiling, a solution of sugar acquires an acid reaction, while it irrecoverably loses the property of crystallising. During this change an additional quantity of the elements of water is assimilated, so that the composition of the substance no longer bears to be 12 atoms carbon and 11 atoms water, but 12 atoms carbon and 12 atoms water. This substance is named inverted sugar, for a reason to be afterwards mentioned, and is the same as what has been called fructose, or the sugar of fruit. If the boiling is carried still farther, particularly after the addition of an acid, such as the oxalic, citric, malic, or any of the stronger acids, another proportion of water is assimilated, and the inverted sugar is transformed into grape-sugar, which consists of 12 atoms carbon and 14 atoms water. In this last case there is produced at the same time a certain proportion of formic acid, and a brown sparingly soluble substance termed ulmine. To prevent such changes in the cane-juice it is usual to add to it a small proportion of lime before it is subjected to heat.

Sugar has some remarkable effects on oxides of metallic bodies, the most important of which is the property of syrup to dissolve lime in large proportion.

The effect of heat on sugar deserves attention. Cane-sugar, when exposed to a considerable heat, undergoes fusion, and when cooled forms the article well known as barley-sugar. When long kept in this form it loses its transparency and becomes crystallised. When cane-sugar is still more heated, it undergoes a change in its ultimate constitution, and passes into a brown, deliquescent, nearly tasteless mass known as caromel. The change that takes place on the ultimate constitution of the sugar is the loss of two atoms of water, so that caromel consists of 12 atoms carbon and 9 atoms of water. Caromel is used by cooks and confectioners as a colouring matter. When sugar is still more heated it gives off inflammable gases, and is converted into a brilliant porous mass of charcoal.

Brown sugar is an impure variety of cane-sugar. There are two varieties—namely, muscovado, called raw sugar; and also foot-sugar and bastard, which last is a finer kind. The colour of raw sugar is owing to the presence of uncrystallisable sugar or treacle. Lime may be detected in it by oxalic acid. Subphosphate of lime, glutinous and gummy matters, and traces of tannic acid, are also present in brown sugar. Brown sugar is said to be extensively adulterated with sugars prepared from potato-starch and from sago-flour. The purest form of coloured sugar is the crystal sugar (brought chiefly from Demerara) employed for sweetening coffee.

Molasses — Treacle.—The brown saccharine viscid fluid which drains from raw sugar, when placed in hogsheads, is properly molasses, and it is used in the preparation of the finer kind of brown sugar termed bastard. Treacle is the viscid dark brown uncrystallisable syrup which drains from the moulds in which refined sugar concretes. Both result from an alteration on the crystallisable sugar, and do not exist in the sugar-cane. Each contains free acid.

Maple Sugar.—The sugar obtained from the sugar-maple (*Acer saccharinum*) and that from the beet (*Beta vulgaris alba*) have the same chemical constitution as the cane-sugar. The maple-sugar is collected by some tribes of American Indians. Perforations are made which penetrate the bark, and extend from a quarter to half an inch into the wood. Two perforations are commonly made in each tree on the side facing the south, and at a height from sixteen to twenty inches above the surface of the ground. The juice is conveyed from these apertures into appropriate vessels. The season for tapping is in March, April, and May, or preferably from the vernal equinox to the middle of April. Sometimes a second tapping is made in the same tree in autumn, but this tapping is more injurious to the tree than the spring tapping. The juice which flows in autumn is twice as strong as that of spring, but the running does not continue so long. The average quantity of sugar from each tree is about three pounds. If properly treated, the same tree may be tapped annually for twenty or thirty years. The maple-sugar is simply this juice concentrated into blocks.

Beet Sugar.—Beetroot-sugar is extracted from the roots of the white beet gathered in October. The expressed juice contains about ten per cent of sugar. This juice is first mingled with a small proportion of lime and boiled; a large portion of albumen and azotised matters rises to the top in the form of a scum, which is to be carefully removed. The remaining stages of the process are chiefly filtrations with the aid of animal charcoal, and finally concentration to the crystallising point. The crystals of beetroot-sugar are longer and flatter than those of cane-sugar, but cannot otherwise be distinguished from cane-sugar.

Grape or Starch Sugar.—Starch-sugar or grape-sugar is prepared by heating starch in a very dilute solution of sulphuric acid, the acid being afterwards separated by means of chalk. The sugar of starch is also called glucose. It is the same kind of sugar which is formed abundantly in the human body in the disease termed diabetes. It is less soluble in water than cane-sugar, yet is more readily taken up by alcohol. It has less than half the sweetening effect of cane-sugar.

Sugar of Milk.—Sugar of milk is an animal product. It is obtained in largest proportion from the milk of herbivorous animals, yet is contained in the milk of animals which are purely carnivorous. It has a less sweetening effect than the sugar of starch. It is less soluble than the cane-sugar or than the sugar of starch. When pure the sugar of milk is not susceptible of fermentation; milk, however, is capable of fermentation, and therefore of affording alcohol.

Fructose, or Sugar of Fruits.—It was once supposed that there is a peculiar sugar in fruits different from the cane and the grape sugar. It appears now that in many fruits the cane-sugar is mingled with a proportion of inverted sugar—that is, the sugar into which a solution of cane-sugar first passes when boiled for some time (p. 314). It is called inverted sugar because while a solution of cane-sugar exerts a right-handed rotation upon a ray of polarised light, this sugar has the effect of causing a left-handed rotation on a polarised ray.

Inverted Sugar.—Inverted sugar is not crystallisable. It can be procured only from cane-sugar by boiling, by the action of acids, or by a peculiar albuminous ferment present in the juice of many ripening fruits. Thus there is no variety of sugar to which the name fruit-sugar is properly applicable, and the name "fructose" may be dispensed with.

Substances allied to Sugar.—There are several soluble substances allied to sugar, of which mannite and glycyrrhizine merit a short notice.

Mannite.—Mannite differs from sugar in chemical constitution by the presence of more hydrogen than is sufficient to convert the whole of its oxygen into water. It forms the largest proportion of the laxative medicine known as manna. This drug is the inspissated juice exuded from the true mountain ash (*Fraxinus ornus*) which grows abundantly in Calabria and Sicily. When the drug manna is digested in hot alcohol, mannite is deposited in tufts of silky quadrangular prisms as the solution cools. By heat mannite fuses into a colourless liquid, which on cooling solidifies into a mass of radiated crystals. Mannite is very soluble in water; it has an agreeable taste.

Besides being contained in manna, mannite has also been found in considerable quantity in celery, onions, asparagus shoots, and in certain kinds of fungi. It is also contained in some descriptions of seaweeds, as in the *Laminaria saccharina*, the saccharine tangle, a white exudation from which is eaten by the inhabitants of Iceland. This tangle, when dried, is said to contain as much as 12 or 13 per cent of mannite. Mannite is also a constituent of the juice which exudes from many varieties of apple and pear trees, and it is formed in what is termed the viscous fermentation of sugar, to which the beet-sugar is particularly liable.

Glycyrrhizine. — Glycyrrhizine is the essential principle of liquorice, or the extract of the root of the *Glycyrrhiza glabra*. The Italian liquorice is obtained from the *Glycyrrhiza echinata*. Glycyrrhizine is not susceptible of fermentation. When boiled for some hours with hydrochloric acid, it separates into a brownish resin and glucose. In the East and West Indies the root of the *Abrus precatorius,* the wild liquorice or rosary pea, is used as a substitute for the liquorice root. The roots of many leguminous and other plants, as the several species of astragulus, contain a sweetish principle which is probably the same as glycyrrhizine.

The following table exhibits the proportion of sugar or saccharine principles in several important articles of food; viz., the proportion in 100 parts :—

	Sugar.
Barley-meal, ...	5.21
Oatmeal (including bitter matter), . .	8.25
Wheat-flour, ...	4.2 to 8.48
Wheat-bread, ...	3.60
Ryemeal, ...	3.28
Maize, ...	1.45
Rice, ...	0.05 to 0.29
Pease, ...	2.00
Sweet almonds, ...	6.00
Figs, ...	62.50
Greengage plum (ripe), ...	11.61
Tamarinds, ...	12.50
Pears (ripe), ...	6.45
Ditto (kept for a time), . . .	11.52
Gooseberries (ripe), ...	6.24
Cherries (ripe), ...	18.12
Apricot (ripe), ...	11.61
Peach (ripe), ...	16.48
Melon, ...	1.50
Expressed carrot-juice evaporated to dryness, .	93.71
Beetroot, ...	5 to 9.00
Ditto, ...	5.8 to 10.00
Cow's milk, ...	4.77
Ass's milk, ...	6.08
Woman's milk, ...	6.50
Goat's milk, ...	5.28
Ewe's milk,*	5.00

* Pereira 'On Food and Diet,' p. 112.

Starch.—Starch is known by the several names, amylum, fecula, and farinaceous matter. It is largely distributed throughout the vegetable kingdom, or throughout the crypto-gamic, the endogenous, and the exogenous subdivisions of that kingdom—viz., in the thallus or cellular expansion in lichens and other cryptogams bearing the fructification, and of the rest in the roots, stems, tubercles, fruits, and seeds.

The starch in the vegetable kingdom is organised. Minute microscopic particles, rounded or elliptical, flask-shaped or mullar-shaped, or polyhedral. These grains have a laminated texture, exhibiting a series of concentric layers or membranes, the outermost of which is the thickest or the firmest. Owing to the pressure of these layers starch grains show rings or rugæ on their surface, as is evident in the grains of "tous les mois" and of potato-starch. When examined with a microscope magnifying to the extent of three hundred or four hundred diameters, the grains are seen to consist of flattened ovate granules of very uniform size in the same plant, but of varying magnitude in different plants. The concentric rings observable have led some to conjecture that there is a deposition of successive layers of starchy matter within an external envelope; but the latest evidence seems to show that the rings are occasioned by a plication of the envelope itself. What is called the hilum in the starch grains is a circular spot, and sometimes two or three such spots, believed to mark the point of attachment of the grain to the cellular tissue of the plant from which it was developed. To show the structure of starch grains, some are placed in contact with a drop of concentrated solution of chloride of zinc (tinged with a little free iodine) in the field of the microscope. Till a little water is added no change takes place; then they become of a deep-blue colour, gradually expanding; around the globule a frill-like plicated margin is developed, opening out by degrees. The plications upon the globule are then seen slowly to unfold, and may at times be traced into the rugæ of the frill. Finally, the granules swell up to twenty or thirty times their original bulk, presenting the appearance of a flaccid sac.*

Grains of potato-starch, when illuminated by polarised light, a Nicol's prism being interposed between the object and the eye, show a well-marked black cross, the centre of which corresponds with the hilum. There being no such appearance in the grains of wheat-starch, a means is thus afforded of detecting the fraudulent addition of potato starch or flour to wheat-flour.

Starch, as found in commerce, is a white glistening powder, which, when pressed between the fingers, produces a peculiar sound, while a feeling of elasticity is discerned. It is insoluble in cold water, alcohol, and ether. In hot water it undergoes a peculiar change: the exterior layer of the granules absorbs water, they swell up, and the mixture takes that viscid character which fits it for stiffening linens. The starch cannot be recovered in its first state from this solution. When dry starch is considerably heated it passes into British gum, which is identical with dextrine.

Starch appears to retain a small proportion of saline matter, which in part consists of potash; and it even contains, in the integument of the grains, a minute quantity of azotised matter.

The deep-blue colour which starch gives with free iodine is the means of detecting its presence even in the most minute quantity. When the solution of starch and free iodine is boiled, the colour disappears, but returns again when cooling takes place. Starch does not ferment with yeast, but when mixed with chalk and cheese, and kept at the temperature of 100° F., it is said that alcohol is developed after several weeks.

The most abundant sources of starch in the vegetable king-

* Busk, 'Quart. Journ. Micros. Society,' vol. i.

dom are the tuberous roots and the seeds of grasses and of leguminous plants. The stem also of certain palms and palm-like plants, as the cycadaceæ, abounds in starch.

It was, not many years ago, believed that the absence of starch was characteristic of the animal kingdom, or that no animal product contained starch. On this point new views have now arisen, though the subject is still involved in much obscurity. Certain it is that the corpuscular variety of the *Corpora amylacea,* known as a morbid deposit in various parts of the animal body, as in the brain and prostate, shows a reaction almost identical with starch, giving a blue colour with iodine.

Among nutritive substances starch holds a prominent place. In many respects, however, further investigation as to the place it holds as a nutriment is imperatively required. Like sugar, as before remarked (p. 313), it is held by Liebig to be merely a respiratory food. By others, again, it is believed to be one of the sources of the fat which becomes deposited in the tissues of healthy animals.

Again, Dumas denies that animals have the power of forming fat, contending that all the fat that manifests itself in the animal body is derived from oily particles in the food. To add to the difficulty, Jacquelain insists that both starch and its granules contain from 0.24 to 0.31 per cent of nitrogen.

In the mean time the most probable state of the case seems to be, that starch, while it is chiefly a respiratory food, is a source of the fat which becomes deposited to serve as fuel against emergencies; and, moreover, that it is not unlikely a minute portion of some nitrogenous or proteine compound is contained in starch granules.

There is some ground for believing that starch is not effectually digested unless previously boiled. According to Raspail, starch is not actually nutritive to man until it has been boiled or otherwise cooked. The heat of the stomach is not sufficient to burst all the grains of the amylaceous mass which is subjected to the rapid action of this organ. The stomach of graminivorous animals and birds seems to possess, in this respect, a particular power, for they use amylaceous substances in a raw state. Nevertheless, recent experiments prove the advantage that results from boiling the potatoes, and partially fermenting the farina, given to them for food. At all events, it is certain that bruised grain is much more nutritive for them than that which is entire; for a large proportion of the latter passes through the intestines perfectly unaffected as when it was swallowed. Branconnot found unbroken starch grains in the excrement of a slug, and also in the excrements of warm-blooded animals fed on raw potatoes.

In short, the exterior laminæ of the starch granules are thicker and more cohesive than the inner ones, and therefore present greater resistance to the digestive power of the stomach.

Potato-Starch.—Potatoes contain about 20 per cent of amylaceous matter. The cellular tissue of the tuber does not exceed 2 per cent; of the remainder, 76 per cent consists of water, with very small quantities of citric acid, sugar, salts, and azotised matters. The potatoes are reduced to a pulp, which is washed on a sieve, so long as the water runs off turbid. The milky liquid is received in vats, where the amylaceous matter is allowed to subside.

It is imported from France and from Guernsey, and is also manufactured in this country. It bears the name in the market of potato-flour, and is also called English arrowroot. Its grains are less than those of *tous-les-mois.* In France it is made to resemble sago, and is sold as potato-sago. It is often substituted in commerce for arrowroot. It is made into potato-sugar, which is used to adulterate brown sugar. In nutritive properties it agrees with the other varieties of starch. It is made use of as a substitute for wheat-flour, as being both cheap and tasteless, for thickening gravies, sauces, and the like.

Wheat-Starch.—Wheat-flour contains near 60 per cent of starch, accompanied by from 14 to 19 per cent of the azotised substance termed gluten, a little cellular tissue, and sugar.

In the ordinary method of procuring the starch of wheat by fermentation much of the amylaceous matter is wasted, and the whole of the gluten is lost, while the gases evolved are of a very offensive nature. By means, however, of a weak solution of alkali, which dissolves the gluten, the starch particles are left unaltered. This method has been chiefly applied, however, to the extraction of starch from rice. Caustic soda is the alkali used to the extent of 1-350th of the weight of water employed. The rice is first digested in one portion of such an alkaline ley for 24 hours, and, that being drained off, in a second portion of the same ley for the same period of time, while frequent agitation is employed. The liquid being then allowed to rest for a short time, the milky fluid is allowed to run off, from which the starch is deposited. The liquid which floats above the starch contains the gluten, which may be obtained by the saturation of the alkali by means of sulphuric acid.

Sago.—The name sago is given to the dietetic starch obtained from the interior tissue of various species of palms. It is manufactured in the Moluccas, and is imported into this country from Singapore. Three varieties of it are met with—namely, sago-meal, pearl sago, and common sago. Sago-meal, called also sago-flour or sago-powder, is a whitish powder, which has been largely employed in the production of a saccharine substance called sago-sugar, made use of, like potato-sugar, to adulterate brown sugar. Pearl sago is in small grains of a pinkish or yellowish colour, the size of a pin's head. It is the sort in most common use. Common or brown sago consists of grains that vary in size from that of pearl barley to that of peas. It is of a whitish-brown colour, or rather each grain is white on one side and brown on the opposite side. The sago-meal and the brown sago, when infused in water, do not swell up and afford a blue colour on the addition of iodine, as is the case with the pearl sago. This difference depends on the mode of the preparation of each, the pearl sago being alone subjected in the process to so much heat as to rupture its grains. The colouring matter contained in all kinds of sago renders them less prized than the white arrowroot and tapioca. Pearl sago may, however, be bleached and rendered quite white. Bleached pearl sago is, however, very like an imitation sago manufactured from potato-starch. The black cross, the centre of which corresponds to the hilum of the granule of the potato-starch, when illuminated by polarised light, and a Nicol's prism interposed between the object and the eye, serves sufficiently to detect such frauds.

Great efforts were made some years back to introduce sago largely as food for domestic animals, and especially for horses; but experience seems to have given unfavourable results—or perhaps the subsequent diffusion of Liebig's views as to the insufficiency of non-nitrogenised food to repair the blood and the muscular flesh prevented the proposal from receiving any extensive trial.

Tapioca.—Among the well-known forms of amylaceous nutriment is that known as tapioca, derived from the *Jatropha manihot.* It is brought to this country from the Brazils. It is sometimes imported in the form of a white powder, in which case it is named Brazilian arrowroot, tapioca meal, mandiocca, moussache, or cipipa. Its most common form, however, is that of small irregular lumps, and it is to this form that the name tapioca is commonly applied. It obtains this form by being dried on hot plates. The heat thus applied breaks the starch globules and renders them partially soluble in cold water; whence an infusion of tapioca in cold water after filtration gives a blue colour with iodine. Boiling water renders tapioca gelatiniform, tremulous, viscous, and transparent. It is purer than sago, owing to the absence of colouring matter. It affords a more consistent jelly than most other kinds of starch.

Cassava.—Cassava is derived from the same plant, and is extensively used for bread in Brazil, Guiana, and Jamaica. The roots of the *Jatropha manihot* are washed and scraped clean, they are then grated into a trough and afterwards subjected to pressure in a hair bag. The expressed juice of the roots of the *Jatropha manihot* are believed to be dangerously poisonous, but the treatment to which they are subjected affords a starch which, whether in the form of cassava or tapioca, is perfectly innocuous.

The name applied to the plant which furnishes tapioca and cassava by Linnæus is *Jatropha manihot,* and this is still its most common name in works on dietetics; but it has also been called *Manihot utilissima,* and from a native American word *Janipha manihot.*

Arrowroot.—The name arrowroot is given to a very pure white amylaceous powder imported from most of the West India Islands, but particularly from Bermuda, that from the latter place being most esteemed. It makes a rather stiff jelly, and has the advantage of being entirely free from colour and from any disagreeable flavour. It is obtained from the roots of the *Maranta arundinacea.* It was called arrowroot because its fleshy root was believed to possess the property of extracting the poison from wounds inflicted with the poisoned arrows of the Indian tribes.

Tous-les-Mois.—An amylaceous food, under the name of *tous-les-mois,* has of late years been imported from St Kitt's. It is the starch of the *Canna coccinea.* This starch has larger grains than any other form of this principle. It is prized as being more soluble than the starches in general. It produces a fine jelly.

Tahiti Arrowroot.—Under the name of Tahiti arrowroot, or Otaheite salep, a white amylaceous powder, obtained from the *Tacca pinnatifida,* has been imported from Tahiti. It is prepared by the native converts at the missionary stations in the South Sea Islands. It is proposed as a substitute for West India arrowroot on the ground of its purity, superior quality, and lower price.

East India Arrowroot.—Two sorts of amylaceous powder are imported from Calcutta under the name of East India arrowroot: the one is white, the other is buff-coloured. It is probable that both are derived from the same genus, as from species of curcuma. The starch known in the East Indies to be got from species of curcuma is called Tickor or Tikur. It forms a large part of the diet of the inhabitants in Travancore.

Portland Arrowroot or Portland Sago.—In the island of Portland a large quantity of starch is obtained from the roots or underground tubers of the *Arum maculatum,* or Wake Robin. This starch is employed as a substitute for the West India arrowroot.

Salep.—The starchy substance obtained from the tubers of the orchis tribe is regarded by some chemists as a variety of Bassorine, but it seems more allied to starch. It is obtained from the tubers of many of our indigenous orchidaceæ; but the most famous and long-known salep is of Oriental origin. It comes from the East in the form of ovate tubers.

Lichinine or Feculoid.—The starchy substance found in the thallus of the foliaceous lichens is not sold in the separate state, but enters largely into the composition of such substances as Iceland moss (the *Lichen Icelandicus* or *Cetraria Icelandica*).

The following table affords a view of the proportion of starch in 100 parts of a variety of substances:—

		Starch.
THALLUS,	Iceland moss,	44.6
ROOTS,	*Janipha manihot* or tapioca plant (var. red),	13.5
	Do. (var. green),	11.5
	Ipomœa batatas (sweet potato),	7.5
	Do. (var. red),	13.3
TUBERS,	Potato (var. kidney),	9.1
	Do. (var. red),	15.0
	Do. (var. shaw),	18.8
	Do. (var. champion),	15.9
	Do. (var. chair rouge),	12.2
	Do. (orpheline),	24.4
	Do. (var. Captain Hart),	15.0
RHIZOMES,	Arrowroot,	12.5
	Do.	26.0
	Canna coccinea,	12.5
	Canna Indica,	3.3
	Ginger,	13.0
	Do.	19.75
	Turmeric,	26.0
	Yam (*Dioscorea sativa*),	12.5
	Do.	22.66
PERICARPS,	*Artocarpus incisa*, or bread-fruit,	3.2
	Artocarpus integrifolia, or jak-fruit,	6.2
SEEDS OR FRUITS,	Barley-meal,	67.18
	Oatmeal,	59.0
	Wheat-flour,	56.5 to 72.0
	Wheat-bread,	53.5
	Ryemeal,	61.07
	Maize,	80.92
	Rice (Piedmont),	82.8
	Do. (Carolina),	85.07
	Pease,	32.48
	Garden-bean (*Vicia faba*),	34.17
	Kidney-bean (*Phaseolus vulgaris*),	35.94*

* Pereira on 'Food and Diet,' p. 122.

Dextrine.—Intimately connected with starch is the substance to which of late years the name dextrine has been applied. Its ultimate constitution is represented by 12 atoms carbon and 10 atoms water, or it is isomeric with starch. Dextrine is derived from starch by heating it to 400° Fahr.; that is, by converting starch by such a temperature into British gum, a substance long known, which is found to be identical with dextrine. This soluble torrified starch or British gum, known among French manufacturers as lerogomme, is largely employed by calico-printers for mixing with their colours in order to give them the requisite consistence.

Dextrine is soluble in water and in dilute alcohol: it is insoluble in anhydrous alcohol; it is insoluble in ether; it dissolves freely in wood-spirit. It differs from starch by not yielding a blue colour with iodine; it differs from gum in its effect on potash and sulphate of copper, for when mixed with potash it forms a beautiful blue colour with sulphate of copper, suboxide of copper being deposited on boiling the solution, while gum yields no such result. Dextrine ranks among the nutritive vegetable principles. It is contained in malt liquor. It owes its name to the effects of its solution in producing right-handed rotation on a ray of polarised light.

Diastase.—The connection which diastase has with starch does not at all depend on its composition. Diastase is, in truth, a nitrogenised body existing in germinating seeds, and is probably albumen or gluten in a particular state of decomposition. Diastase is placed beside starch because the conversion of starch into sugar and dextrine during the germination of seeds appears to be due to the presence of diastase. Malt, which is barley allowed to germinate up to a certain point, and then checked in this process by a high temperature, contains no more than the 500th part of its weight of diastase. One part of malt has the power to change into dextrine and sugar four or five parts of barley. Thus the distillers, by mixing a portion of unmalted barley with their malt, obtain a wort equally sweet with that furnished by an equal weight of malt.

The mode of action of diastase in changing starch into dextrine, as well as the mode of action of yeast in changing sugar into carbonic acid and alcohol, is still involved in obscurity. The two actions, nevertheless, are in some sort analogous. Both are ferments, and their effect in a measure depends on their decomposition. Moist yeast and moist diastase both very rapidly undergo decomposition. The opinion which has arisen of late as to fermentation is, that the formation of each of the compounds concerned depends on a particular stage of decay in the ferment, attended "with the development of fungi or organisms of a kind varying in each particular stage with the products obtained." In appears that the process of fermentation may be prevented in any organic liquid by such isolation from the atmosphere as shall prevent organic germs thence obtaining access to the substance under experiment.

Inulin.—In the roots of many plants, such as those of dahlia (*Dahlia frustranea, Dahlia superflua*), of elecampane (*Inula helenium*), meadow saffron (*Colchicum autumnale*), of dandelion (*Taraxacum dens leonis*), and of chicory (*Chicorium intybus*), there is a variety of starch known by the name of inulin. It is a white, pulverulent, inodorous, tasteless substance, insoluble in alcohol, sparingly soluble in cold water, but readily soluble in hot water, from which it is deposited again on cooling in a pulverulent form. Its solution produces left-handed rotation upon a ray of polarised light. By long boiling it acquires the characters of a gum; with iodine it gives a yellow colour; dilute acids, with the aid of heat, change it first into dextrine and then into grape-sugar.

Gum, or Arabine.—Gum-arabic is the type of gum. The name arabine is sometimes given to this principle. Its ultimate constitution is the same as that of cane-sugar—namely, 12 atoms carbon and 11 atoms water. Gummy matter is found in the juices of almost all plants, yet hardly possessed of the properties observed in typical gum or arabine. Typical gum or arabine is soluble in cold water, which it converts into a tasteless ropy mucilaginous liquid, which by drying acts like a paste or glue. When mixed with sugar and allowed to dry it forms a convenient cement by being simply moistened. A solution of arabine determines a left-handed rotation in a polarised ray of light. Arabine does not undergo fermentation under the agency of yeast, but when digested with cheese and chalk it may be made to furnish alcohol.

Among the reactions characteristic of arabine is, that its solution, when mixed with ammoniacal acetate of lead, gives a curdy precipitate consisting of arabine and protoxide of lead.

Arabine is commonly regarded as a nutritive substance, yet somewhat difficult of digestion. By Liebig it is ranked among the merely respiratory kinds of food. Some gummy substances yield nitrogen, but it is doubtful whether this element belongs to the gummy principle or to some impurity.

Bassorine.—Among the names given to modifications of arabine one deserves notice; namely, bassorine. This derives its name from the gum bassora. This modification of arabine consists of 12 atoms carbon and 10 atoms water. It is insoluble in water, but when moistened swells up into a gelatinous mass. It constitutes a part of gum-tragacanth, and of the gum which exudes from the cherry-tree. Many seeds, such as linseed, quince seeds, and many roots, such as that of marshmallow (*Althæa officinalis*), furnish it abundantly. By the action of alkalies bassorine becomes soluble, and is converted into true gum. Bassorine, however, derived from different sources, presents different modes of reaction.

The following table exhibits the proportion of gummy substance contained in one hundred parts of several important articles of food :—

Barley-meal,	4.62
Oatmeal,	2.5
Wheat-flour,	2.8 to 5.8
Wheat-bread,	18.0
Ryemeal,	11.09
Maize,	2.283
Rice,	0.1 to 0.071
Pease,	6.37
Garden-bean (*Vicia faba*),	4.61
Kidney-bean (*Phaseolus vulgaris*),	19.37
Potatoes,	3.3 to 4.1
Cabbage,	2.89
Sweet almonds,	3.0
Greengage plum (ripe),	4.85
Pears (ripe and fresh),	3.17
Gooseberries (ripe),	0.78
Cherries (ripe),	3.23
Apricot (ripe,)	4.85
Peach (ripe),	5.12
Linseed,	5.2
Marshmallow root,	35.64*

Vegetable Jelly.—The principle obtained from many vegetables which gelatinises spontaneously is essentially an acid; namely, the pectic acid. Pectic acid owes its name to its gelatinous nature, being derived from πηκτις, a jelly. All the modifications of what was formerly termed pectine are quickly converted by a caustic alkali or alkaline carbonate into pectic acid. Vegetable jelly is contained in most pulpy fruits, as in currants, red, white, and black ; apples, both sweet and sour; pears, quinces, plums, apricots; peaches, the cucurbitaceous fruits, as melon ; also in gooseberries, bramble-berries, raspberries, strawberries, bilberries, mulberries, cherries, love-apples (*tomatoes*), oranges, lemons, guava, and tamarinds. It is contained

* Pereira on 'Food and Diet,' p. 108.

also in Jerusalem artichokes (*Helianthus tuberosus*), the onion, the carrot, the parsnip, the turnip, celery, beet, and in many other roots.

The formula given for what was formerly described as pectine is $C^{24}H^{17}O^{22}$.

Sugar promotes the solidification of vegetable jelly. Vegetable jelly is believed to be nutritive and very digestible. The preparation of a singular jelly is described by the French chemist Braconnot. "I dissolved," he says, "in warm water one part of pectate of potass prepared from turnips, and then added sugar to the solution. On the addition of an infinitely small quantity of acid, the whole became in a few minutes a mass of trembling jelly weighing 300 parts." *

Carrageenine.—In the Irish moss, called also carrageen, and pearl moss, which is the *Chondrus crispus*, and also in other seaweeds, a mucilaginous or vegeto-gelatinous principle is contained, which is allied both in properties and ultimate constitution to vegetable jelly.

Celluline and Lignine.—The substance commonly called lignine is now described as made up of two organic principles. One is the basement tissue found in all vegetables. This principle, named cellulose, but more conveniently celluline, is nearly pure in cotton, linen, elder pith, and in the pith of the *Aralia papyrifera,* from which rice-paper is prepared. The other principle, entering into what was formerly called lignine, is the crust lining the cells formed by the celluline, while its title to the name of a proximate principle is doubtful, being perhaps a mixture of several proximate principles. It does not appear to have a uniform composition in all woods. It is characterised, however, by being insoluble in water and soluble in alkaline liquids. It is charred by sulphuric acid, and dissolved by an aqueous solution of chlorine. It appears to be this principle

* 'Ann. Chem. et Phys.,' t. 28 and 30.

or mixture of principles which affords acetic acid when wood is subjected to destructive distillation, since the larger the proportion of the encrusting matter of the cells in any wood, the more acid is obtained from an equal weight. This ligneous matter contains a variable proportion of resinous matter, by which the wood is coloured and its inflammability increased. It also contains a proportion of saline matter and minute quantities of compounds containing nitrogen.

Cellular tissue is the fundamental tissue of every plant, and when procured in an unmixed state its chemical composition is the same, whatever the plant by which it is furnished. It is loose and spongy; nevertheless in the succulent shoots of germinating seeds, and in the roots of plants such as the turnip and potato, in the pith of the rush and of the elder, it is porous and elastic; in the fibres of hemp and flax it is flexible and tenacious; in the wood and branches of growing trees it is compact, while it becomes dense and hard in the shells of the filbert, the peach, the cocoa-nut, and the phytelephas or vegetable ivory.

Vegetable cellular tissue in its succulent forms is digestible and nutritive, but when it has become compact and incrusted with the ligneous deposit, as in the husks of seeds, in the hard portions of stems, and in tenacious fibres like those of hemp and flax, it is no longer fit to serve as nourishment to the higher orders of animals. Nevertheless, it has been well remarked that even in this compact state, or in that formerly termed lignine, it is an alimentary principle, and constitutes the appropriate food of numerous insects and other of the lower tribes of animals, such as are furnished with organs capable of comminuting and reducing it to an appropriate degree of softness.

This is a subject of considerable interest, and deserving of more attention than it has yet received.

Antenrieth, a German professor, stated some time ago that when wood is deprived of everything soluble, reduced to powder, repeatedly subjected to the heat of an oven, and then ground in the manner of corn, it yields, boiled with water, a flour which forms a jelly like that of wheat-starch, and when fermented with leaven makes a perfectly uniform and spongy bread. Moreover, it is stated on the authority of Linnæus that the Laplanders eat bark-bread, prepared from the bark of *Pinus sylvestris*, during a great part of the winter, and sometimes during the whole year.

Of these facts an explanation has been offered, which may or may not be sufficient to account for the whole matter. It is supposed that in the autumn, after the formation of wood has ceased in the vegetable kingdom, starch is formed and diffused through every part of a plant by the autumnal sap. It is asserted that the starch thus deposited in the body of a tree can be recognised by the microscope in its well-known form : again, that the barks of several aspens and pine-trees contain so much of this substance that it can be extracted from them, as from potatoes, by trituration with water. Thus it remains to be proved whether the nutritive principle exists in the wood and bark, or be the starch thus supplied by the autumnal sap.

Fungine.—Closely allied to vegetable celluline is the substance of mushrooms. Fungine, then, is what remains after mushrooms have been deprived of everything soluble in water, alcohol, and a weak alkaline solution. It has been believed to contain nitrogen, but some doubts have arisen on that point.

Table of the quantity of lignine — that is, of celluline incrusted with ligneous substance—in 100 parts of the following alimentary matters:—

	Lignine.
Rice,	4.80
Barley,	18.75 (husk)
Oats,	34.00 (bran)
Rye,	24.20 (husk)
Apricots (ripe),	1.86
Greengage plum (ripe),	1.11
Peaches (ripe),	1.21
Gooseberries (ripe),	8.01
Cherries (ripe),	1.12
Pears (ripe),	2.19
Sweet almonds,	9.00 (and seed-coats)
Pease,	21.88 (amylaceous fibre)
Garden-bean,	25.94 (do. and membrane)
Kidney-bean,	18.57 (do.)
Potatoes,	4.30 to 10.50 (amylaceous fibre)
Cocoa-nut kernel,	14.95

COMPOSITION OF LIGNINE.

	Carbon.	Water.
Lignine from Box,	42.70	57.30
Ditto ditto dried,	50.00	50.00
Ditto from Willow,	42.60	57.40
Ditto ditto dried,	49.80	50.20
Or,	C^{12}	Water 8.00*

Acids contained in Alimentary Substances, or Acid Proximate Principles of a Dietetic Character.

The acids found in the vegetable kingdom, which either are dietetic or connect themselves with dietetic substances, are the acetic acid, the citric acid, the tartaric acid, the malic acid, the oxalic acid, the tannic acid, and the lactic acid.

When such vegetable acids are taken free into the system—for example, united with water as acidulous drink—they appear to undergo no change, except that they combine with a base, since these acids are found in the urine of those who have

* Pereira on 'Food and Diet,' p. 136.

drunk water so acidulated and united with some base. From the fact that the blood and the chyle are always alkaline, it has been concluded that these acids must have united with such base before being received into the blood, while it has been conjectured that the bile is the source of the basic matter by which they are thus neutralised. This statement, which does not appear to have been controverted, is in singular opposition to a belief universally entertained—namely, that when such acids as the acetic, the citric, the tartaric, the malic, the oxalic, are taken into the stomach already combined with such bases as potassa and soda, they uniformly undergo decomposition, so that the acid is changed to a carbonate of the corresponding base. In short, the belief of chemists of high authority at present is, that if the acetate of potassa, for example, be taken into the stomach, it will appear in the urine in the form of carbonate of potassa; but that if water acidulated with acetic acid be drunk freely it will appear in the urine in the form of acetate of potassa, or acetate of soda. These statements, though not absolutely contradictory, are so anomalous as to demand a new investigation before we can rest on them with satisfaction.

Acetic Acid, or the Acid of Vinegar.—To acetic acid, vinegar, pyroligneous acid, sour beer, and sour wine, owe their acid properties. Anhydrous or real acetic acid cannot be procured wholly free from water. The formula of real acetic acid as it exists in some acetates is $C^4H^3O^3$, or four equivalents of carbon to three equivalents of water. Glacial or crystallisable acetic acid, the strongest that can be procured, contains one equivalent of water, or is represented by C^4 with the addition of four water.

Wood Vinegar.—Pyroligneous acid, or wood vinegar, called also white vinegar, is obtained by the distillation of wood. When pure it consists of acetic acid and water, but is by no means so suitable for a condiment as the vinegar obtained by fermentation.

Vinegar.—Common vinegar is malt vinegar, made by subjecting an infusion of malt, or a mixture of malt and raw barley, to the acetous fermentation. It contains a minute quantity of sulphuric acid. It owes part of its peculiar taste and odour to the presence of acetic ether.

Four malt vinegars are known in commerce, of different degrees of strength. They are numbered 18, 20, 22, and 24. The vinegar marked as 24 is called proof vinegar, and is the strongest that is made. It is rather too strong for use at the table, but serves for pickling and preserving meat, fish, and game ; it is therefore known as the strongest pickling vinegar. The vinegar marked 22 is often called best pickling vinegar, being adapted for pickling most vegetables. It is that best suited for the table.

Composition of malt vinegar :—

Acetic acid.
Acetic ether.
Colouring matter.
Peculiar mucilaginous matter.
Alcohol (a small portion).
Sulphuric acid (1-1000th part).
Water.

Vinegar-makers are permitted by the excise laws to add the above proportion of sulphuric acid to malt vinegar.

French vinegar, called also wine vinegar, is made in France from wines of inferior quality. It is either white-wine vinegar or red-wine vinegar. The white-wine vinegar is commonly preferred, as it keeps better. The composition of wine vinegar differs but little from that of malt vinegar. Bitartrate and sulphate of potassa are present in it in small proportion. The wine vinegar is distinguished from malt vinegar by the purplish precipitate given by ammonia added to wine vinegar.

Diluted pyroligneous acid is often sold for distilled vinegar; but distilled vinegar should have a fragrant odour, of which the pyroligneous acid is destitute.

Vinegar when taken in small quantities is beneficial, but in larger proportion, taken habitually, is injurious. It produces leanness, apparently by interfering with the healthy action of the stomach.

Citric Acid.—The citric acid, as is well known, is a principal constituent of the juice of the lemon, the orange (bitter and sweet), the lime, the citron, the shaddock, and other fruits of the genus *Citrus*, which, with little or no mixture of malic acid, owe their sourness to the citric acid. It is contained also in the cranberry (*Vaccinium oxycoccos*), and in the fruit of the dog-rose (*Rosa canina*). Along with an equal proportion of malic acid, it exists in the gooseberry, the red currant, the strawberry, raspberry, the cherry, and bilberry. Mixed with tartaric and malic acids, it is found in the pulp of the tamarind.

The formula of citric acid, as it exists in some citrates, is $C^{12}H^{5}O^{11}$; that of crystallised citric acid, $C^{12}H^{5}O^{11}$ + water; that of commercial crystals, $C^{12}H^{5}O^{11}$ + water^{5}.

The beneficial effects of lemon-juice in the cure and prevention of scurvy in the human body are beyond dispute. But a wide field is open for inquiry as to the utility of the other fruits containing the same acid on the health of man and animals. There is, moreover, reason to believe that the apparent medicinal effects of citric acid in such diseases as rhumatic affections depend on its power of improving the general health where a latent scurvy is present.

Tartaric Acid.—Tartaric acid exists free in tamarinds, grapes, and the pine-apple. In mulberries it is present, combined with potassa in the salt, well known as cream of tartar. The same salt exists, besides the free acid, in tamarinds and grapes. During the fermentation of the juice of the grape, the bitartrate of potassa, combined with colouring and extractive matters, becomes deposited on the sides of the cask, whence it is collected under the name of crude tartar, argol, or wine-stone.

When wine is kept long in bottle a farther deposition of the same material occurs, known then as the crust.

The formula for tartaric acid in the anhydrous state is $C^4H^2O^5$.

Malic Acid, or the Acid of Apples.—The malic acid exists largely throughout the vegetable kingdom. It exists free in apples, pears, quinces, plums, apricots, peaches, cherries, gooseberries, currants, strawberries, raspberries, brambleberries, pine-apples, barberries, elderberries, grapes, love-apples (tomatoes), tamarinds, and some other fruits. Most commonly citric acid accompanies malic acid. Malic acid is contained in wine, cider, and perry. Its formula is $C^8H^4O^8 + \text{water}^2$. In its effects on the living body it appears to be analogous to citric acid ; but it is not employed in the separate state.

Oxalic Acid.—Oxalic acid is found in a considerable number of plants. It exists in the garden rhubarbs, the leaf-stalks of which have been of late years so much employed in tarts and puddings. In these plants, besides the free oxalic acid, there is oxalate of lime, which probably renders the over free use of the leaf-stalks of rhubarb unsafe in constitutions in which there is a tendency to the deposition of mulberry calculus in the urinary passages. In short, the very free use of rhubarbs in diet is not of long enough standing to enable a cautious reasoner to determine its true value as an article of food. The leaf-stalks of rhubarbs were used occasionally in the last century, both in France and in this country, in marmalades and tarts ; but it is not more than thirty or forty years since the use of them became general throughout the United Kingdom.

Oxalic acid is also found free in several species of *Rumex*, as in the common sorrel (*Rumex acetosa*), the sheep's sorrel (*Rumex acetosella*), the French sorrel (*Rumex scutatus*); and all of these, particularly the cultivated common sorrel, have for ages been employed in dietetics, and no harm seems to have resulted from their use. The wood sorrel (*Oxalis acetosella*) also contains oxalic acid, and is eaten in salads; it is used sometimes also as an antiscorbutic. The very poisonous effects of the pure oxalic acid have driven its preparations very much out of use in medicine.

Tannic Acid.—The term tannine was originally employed to denote the several varieties of astringent principle which were employed in the tanning of hides. As most of these possess an acid reaction, the name tannic acid has come to be applied to them. The tannic acid of the British Pharmacopœia is $C^{54}H^{22}O^{34}$, the same to which the name gallotannic acid is still sometimes applied. It is obtained from gall-nuts. These nuts, excrescences formed on the *Quercus infectoria*, contain two-thirds of their weight of tannic acid, and only two per cent of gallic acid. Gallotannic acid is freely soluble in water; also soluble in dilute alcohol, and sparingly in sulphuric ether. Its diluted aqueous solution absorbs oxygen from the air, and is converted into gallic acid. All the forms of tannic acid, indeed, when moist freely absorb oxygen. A particular ferment in gall-nuts favours the conversion of its gallotannic acid into gallic acid. Hence when powdered gall-nuts, moistened freely with water, are allowed to stand in a warm place exposed to the air, they absorb oxygen, and become mouldy, while abundance of gallic acid in crystals is formed.

The most remarkable property of tannic acid is its power of precipitating animal gelatine from its solution—an effect on which the tanning of leather depends. On the contrary, the salts of gallic acid do not cause a precipitate in solutions of gelatine.

A solution of gallotannic acid occasions a violet black precipitate in solutions of the persalts of iron. Hence the basis of ordinary writing-ink is gallotannate of iron. To be distinguished from the effect of gallotannic acid on the persalts of iron, is that of gallic acid on a mixture of the protosalts and persalts of the same metal. When gallic acid is added to a mixture of the protosalts and persalts of iron, a deep bluish-black solution is formed; if the solutions be free from acid, and particularly if a solution of bicarbonate of lime be added, the reaction is found to be one of extreme delicacy.

Most astringent vegetable substances, such as the bark and leaves of the oak, the elm, the willow, the horse-chestnut, the pine, the pear, the plum, the wood and bark of the sumach and whortle-berry, the roots of tormentilla and bistort, precipitate the persalts of iron of a bluish-black colour, and if a free acid be present the solution assumes a dark-green colour. Tea and Paraguay tea give the same colour, but coffee has no such effect. There are astringent vegetable bodies which precipitate the persalts of iron of a dark-green instead of a blue colour, of which catechu and kino are good examples. Again, some astringent plants, of which so powerful an astringent as rhatany (*Krameria triandra*) is an instance, precipitate persalts of iron of a grey colour. The variety of tannin exhibited in catechu and kino is termed mimotannic acid, as derived chiefly from plants belonging to the section *Mimosæ* of the leguminous family.

Lactic Acid.—Lactic acid is the acid of sour milk, yet it is formed by various vegetable substances. For example, when oatmeal diffused in a large quantity of water becomes sour, it is found that lactic acid has been produced. It is commonly procured from cane-sugar. When eight parts of cane-sugar are dissolved in fifty parts of water, and this solution, after the addition of one part of poor cheese and three parts of chalk, is kept at a temperature of 80° F. for two or three weeks, it gradually becomes filled with crystals of lactate of lime. After purification by recrystallisation, these crystals are treated with one-third of their weight of sulphuric acid. The residue being then digested in alcohol, the lactic acid is dissolved, and sulphate of lime left. On the evaporation of the alcohol, pure lactic acid remains.

Lactic acid exists, ready formed, in some plants; thus it may be obtained from nux vomica in the state of lactate of lime. It exists in the animal body, as in the fluids of the muscular tissue.

PLANTS EMPLOYED TO FURNISH ARTICLES OF FOOD, ARRANGED IN A BOTANICAL ORDER.

DICOTYLEDONOUS PLANTS. — Sub-class *Thalamifloræ* — *Ranunculaceæ*, Buttercup order.—Though numerous species of the genus ranunculus, from which the *Ranunculaceæ* derive their name, abound in the pastures of Europe and North America, there is hardly one of this family that can be said to afford nourishment to domestic animals. On the contrary, there prevails generally throughout this family a remarkable acrimony, and not a few narcotico-acrid poisons figure amongst them. Of these it is sufficient to mention the aconite (*Aconitum napellus*), the stavesacre (*Delphinium staphisagria*), the Christmas rose (*Helleborus niger*). It appears, however, that the acrimony of the common buttercups, or crowfoots of our pastures, is much diminished or destroyed by heat. It is not impossible, then, that such plants may be rendered innocuous, if not useful, by a proper preparation. There are two plants in this natural order which may be mentioned under the head of nutritive substances—namely, the *Ranunculus ficaria*, or *Ficaria ranunculoides*, figwort, or lesser celandine; and *Nigella sativa*, small fennel flower—since figwort has roots abounding in starch, and the young leaves in Sweden are eaten as greens, while the seeds of nigella are used in cookery.

Nymphæaceæ, Water-lily order.—The *Nymphæa alba*, the white water-lily, has roots which swine eat, but which are refused by horses and kine. Of the seeds of the *Nymphæa lotus*, the Egyptian lotus, the ancient Egyptians made bread.

Nuphar Lutea.—The common yellow nuphar is to a small extent nutritious. Of the leaves and root swine are fond, but both are rejected by horses, kine, and sheep.

Victoria Regia.—The Victoria water-lily is found in still waters over the whole of eastern South America. The seeds are used for food. They are roasted with Indian-corn, and hence the plant is called water-maize.

Nelumbiaceæ, Water-bean order.—*Nelumbium luteum*, yellow water-bean, has an edible root. The rhizomes, with tubers like those of the sweet potato, are starchy, and are used for food. *Nelumbium speciosum*, the sacred water-bean, the Egyptian lotus, is edible. It is supposed to have been the Pythagorean bean. The rhizome of this plant is used for food in China.

Papaveraceæ, Poppy order.—*Papaver somniferum*, the Oriental poppy, whence opium is produced, belongs to dietetics, inasmuch as the seeds yield a bland oil much used at table on the continent of Europe, while the poppy-oil cake furnishes food for cattle.

Cruciferæ or *Brassicaceæ*, Cabbage order.—*Brassica rapa*, the common turnip; *Brassica campestris*, the origin of the Swedish turnip; *Brassica napus*, rape or colewort; *Brassica oleracea*, the type whence the varieties of cabbage, broccoli, cauliflower, and greens are derived by cultivation; *Crambe maritima*, sea-kale; *Cochlearia officinalis*, scurvy grass; *Lepi-*

dium sativum, garden-cress; *Nasturtium officinale,* water-cress; *Raphanus sativus,* garden radish; *Sinapis alba* and *nigra; Sisymbrium sophia,* flix weed.

Brassica rapa, the common turnip, and *Brassica campestris,* the Swedish turnip or rutabaga, have become the care of the husbandman more than of the gardener. The most esteemed garden sorts are the following:—

Early Dutch.	Yellow Maltese.
Early stone.	Dutch yellow.
Green-topped white.	Aberdeen yellow.
Long white.	Teltow.

"Besides these, the navet of the French (*Brassica napus v. esculenta*) is occasionally cultivated, and more frequently the Swedish turnip or rutabaga (*Brassica campestris v. Napo brassica*), which is a most excellent winter sort, though it belongs more properly to the farm. For early crops the white Dutch is the principal variety; the other white sorts, and the beautiful yellow Maltese, are useful in summer and in the beginning of autumn. The yellow Dutch being capable of enduring a considerable degree of frost, affords the most appropriate winter supply. The teltow, or French turnip, is remarkable for being high-flavoured, and is used only for seasoning to soups or stews." *

For the varieties, and other interesting particulars of the field-turnip, reference must be made to works on agriculture.† It will be sufficient here to give some information respecting the chemical analysis of this important vegetable.

Owing to the large proportion of water present in the turnip, its nutritive value, to judge by weight, does not rank high. By drying *in vacuo* at 230° Fahrenheit, the relative proportion of solid and liquid matter is estimated as follows:—

* Neill, 'The Fruit, Flower, and Kitchen Garden,' p. 224.

† See Stephens's 'Book of the Farm,' vol. i. p. 189 *et seq.*

Water,	92.5
Solid matter,	7.5
	100.0

ULTIMATE COMPOSITION OF THE DRIED TURNIP.

Carbon,	42.9
Hydrogen,	5.5
Oxygen,	42.3
Nitrogen,	1.7
Ashes,	7.6
	100.0

The juice of the turnip contains two nitrogenous constituents—viz., vegetable fibrine and vegetable albumen; the vegetable fibrine coagulates spontaneously on standing; the vegetable albumen is afterwards coagulated by heat.

The following analysis of turnips is given in Hemming's tables:—

TURNIP DRIED AT 212° FAHRENHEIT. COMPOSITION IN 100 PARTS.

Bulbs	Organic matter,	92.4
	Ash,	7.6
		100.0

ULTIMATE ANALYSIS OF ORGANIC MATTER.

Carbon,	46.50
Hydrogen,	5.90
Oxygen,	45.80
Nitrogen,	1.84
	100.04
Ammonia,	2.23

No analysis of proximate principles.

ASH OF BULBS.

Sand and silica,	8.0
Potass,	42.0
Soda,	5.1
Carry forward,	55 1

Brought forward,	55.1
Lime,	13.5
Magnesia,	5.3
Oxide of iron,	1.5
Chloride of potassium, Chloride of sodium,	5.6
Phosphoric acid,	7.5
Sulphuric acid,	13.5
	102.0

ANALYSIS OF TURNIP-TOPS, FROM HEMMING'S TABLES.

Organic matter,	81.8
Ash,	18.2
	100.0

ULTIMATE ELEMENTS.

Carbon,	48.5
Hydrogen,	6.3
Oxygen,	42.2
Nitrogen,	3.0
	100.0
Ammonia,	3.63

No analysis of proximate principles.

ASH OF TURNIP-TOPS.

Total sulphur,	2.0	
Sand and silica,		17.4
Potash,		15.7
Soda,		6.3
Lime,		25.6
Magnesia,		3.2
Oxide of iron, with phosphoric acid,		3.4
Chloride of potassium, Chloride of sodium,		8.8
Phosphoric acid,		3.9
Sulphuric acid,		9.9
Carbonic acid,		5.8
		100.0

The following table, from Professor Thomas Anderson's elaborate paper on the composition of turnips at different stages of growth, is of much interest.* The examination was made at four periods—namely, 32 days after sowing; then after another interval of 35 days; then after a third interval of 20 days; and lastly after a fourth interval of 35 days, bringing the date of the last examination to so late a period in the season as the 5th of the month of October.

PERCENTAGE COMPOSITION.

Period.	No. of days.	Water.	Albuminous compounds.	Other organic matters.	Ash.
Leaves.					
1	32	92.08	2.51	4.79	0.62
2	35	90.90	1.84	5.38	1.88
3	20	89.10	0.76	8.19	1.95
4	35	88.45	2.40	7.27	1.88
Bulbs.					
1	32	81.13	6.31	9.22	3.34
2	35	89.90	1.06	8.16	0.88
3	20	90.02	1.40	7.55	1.02
4	35	90.50	1.18	6.33	1.99

The particular organic substances contained in turnips are not well agreed on. In the mean time it is useful to know, from experiments by Boussingault, that in flesh-forming effect about sixty pounds of turnips correspond to twelve pounds of wheat-flour. Thus, in a cow, the quantity of flesh-forming substances required to counterbalance the daily loss of such substances was nearly eighteen ounces, which quantity is equivalent to what twelve pounds of wheat-flour, or sixty pounds of turnips, can supply. In the same animal, from four to five pounds of carbon are necessary to furnish the carbon contained in the carbonic acid thrown off by respiration; and to yield this amount of carbon daily, about 100 pounds of turnips are no more than sufficient.

* 'Transactions of the Highland and Agricultural Society.'

Brassica napus; Brassica campestris; Brassica campestris Oleifera, Rape.—The seeds of several species or varieties of Brassica are imported into this country for the purpose of making "rapeseed oil," known also by the name of coleseed oil, or colza oil. An oilcake is left after the expression of this oil.

Rape-cake, or rapeseed-cake, is imported into Britain both for use as a manure, and also for the purpose of feeding stock. It is, moreover, used to adulterate linseed-cake, as bearing a lower price in the market.

The following is the chemical analysis of rape-cake in 100 parts:—

Organic matter,	91.40
Ash,	8.60
	100.00

Nitrogen,	6.14
Ammonia,	7.43
Oil,	13.00

Sand and silica,	13.1
Potash,	21.9
Lime,	8.6
Magnesia,	14.7
Oxide of iron,	4.5
Chloride of potassium,	0.2
Chloride of sodium,	0.5
Phosphoric acid,	32.7
Sulphuric acid,	1.6
Carbonic acid,	2.2
	100.0

The rape plant itself, *Brassica napus*, is raised in this country for food to stock; it is particularly serviceable for sheep. It is useful at two seasons, spring and autumn. Sheep are very fond of the rape-plant, and thrive remarkably upon it.*

* For additional particulars of the rape plant, see Stephens's 'Book of the Farm,' vol. ii. p. 101-103.

Brassica Oleracea, Source of the Common Varieties of Cabbage.—The numerous varieties of *Brassica oleracea* are undoubtedly the source of excellent nourishment. The common field cabbage in particular is much relished by lambs.

The turnip-stemmed cabbage, or kohl-rabi, has lately been introduced from Germany with a high character. It is named by Decandolle, *Brassica oleracea caulo-rapa alba.* The varieties are numerous, but the large red and green sorts are the most suitable.

The following analyses by Professor Voelcker deserve attention :—

COMPOSITION OF GREEN-TOP AND PURPLE-TOP KOHL-RABI.

General Composition.

	Green-Top.		Purple-Top.	
Water, . . .	86.020		89.002	
Substances soluble in water,	9.260	Dry 13.98	7.588	Dry 10.998
Substances insoluble in water,	4.720		3.410	
	100.000		100.000	

Detailed Composition.

	Green-Top.	Purple-Top.
Water, ...	86.020	89.002
Oil, ...	0.217	0.177
Soluble proteine compounds,* .	2.056	2.006
Sugar, gum, and pectine, .	6.007	4.486
Salts, soluble in water, . .	0.970	0.919
Insoluble proteine compound,†	0.300	0.269
Digestible fibre and insoluble pectinous compounds, . .	2.993	1.896
Woody fibre (celluline), . .	1.230	1.106
Insoluble mineral matters, .	0.197	0.139
* Containing nitrogen, . .	0.329	0.321
† Containing nitrogen, . .	0.048	0.043
Total nitrogen, .	0.377	0.364
Percentage of ash, . .	1.167	1.058

THE SAME IN A PERFECTLY DRY STATE.

Composition of Kohl-rabi dried at 212° Fahr.

	Green-Top.	Purple-Top.
Oil,	1.623	1.609
Soluble proteine compounds,*	14.706	18.239
Sugar, gum, and pectine,	42.968	40.789
Salts, soluble in water,	6.938	8.356
Insoluble proteine compound,†	2.145	2.445
Digestible fibre and insoluble pectinous compounds,	21.409	17.239
Woody fibre (celluline),	8.798	10.056
Insoluble mineral matters,	1.409	1.263
	99.996	99.969

* Containing nitrogen,	2.353	2.918
† Containing nitrogen,	0.343	0.390
	26.96	3.309
Percentage of ash,	8.347	9.619

On these results Voelcker makes the following remarks :—"A comparison of the preceding results with the analysis of swedes, mangolds, and turnips, shows that, theoretically, kohl-rabi is much more nutritious than white turnips, and fully equal, if not superior, to swedes and mangolds. These remarks, however, I would remind the reader to apply only to the specimens which I had an opportunity of examining. Future examinations, and above all practical feeding experiments, are required to establish fully the comparative feeding value of kohl-rabi.

"I may remark with respect to the kohl-rabi, that it is an excellent food for milch cows, inasmuch as it produces much and good milk. The butter made of such milk has a pleasant taste, altogether unlike the disagreeable flavour that characterises butter made from the milk of cows fed on turnips." *

* 'Journal of Agricultural Society of England,' vol. xxi. p. 95.

COMPOSITION OF FIELD, CATTLE, OR DRUMHEAD CABBAGE, BY DR VOELCKER.

Composition of Outside Green Leaves.

Water,	83.72
Dry matter,	16.28
	100.00

The Dry Matter consisted of—

		Dry matter per cent.
Proteine compounds,*	1.65	10.19
Non-nitrogenous matter,	13.38	82.10
Mineral matter,	1.25	7.71
	16.28	100.00

* Containing nitrogen,	0.26	1.63

GENERAL COMPOSITION OF HEART AND INNER LEAVES.

	Nat. state.	Dry.
Water,	80.42	—
Soluble organic matter,	6.20	18.60
Soluble mineral matter,	0.73	6.89
Insoluble organic matter,	3.53	33.36
Insoluble mineral matter,	0.12	1.15

The outer green leaves contain nearly 6 per cent less water than the heart and inner leaves.

DETAILED COMPOSITION OF HEART AND INNER LEAVES OF CABBAGE.

	Nat. state.	Dry.
Water,	89.42	—
Oil,	0.08	0.75
Soluble proteine compounds,*	1.19	11.24
Sugar, digestible fibre, &c.,	7.01	66.25
Soluble mineral matter,	0.73	6.89
Insoluble proteine compound,†	0.31	2.93
Woody fibre,	1.14	10.77
Insoluble mineral matter,	0.12	1.17
	100.00	100.00

* Containing nitrogen,	0.19	1.79
† Containing nitrogen,	0.05	0.47

"Cabbages contain about the same proportions of water, sugar, and proteine compounds as are found in good swedes. On the whole, I am inclined to think, weight for weight, cabbages and swedes possess nearly the same nutritive value."*

Very little progress has been made in ascertaining how far substances belonging to the order of condiments are of service in the feeding of domesticated animals; nevertheless many circumstances connected with the effect of acids and other such articles on the health of men suggest the importance of examining into the natural instincts particularly of horses, oxen, and sheep in the fields, as respects their occasional use of plants not strictly nutritive.

Under this view of our subject it seems not improper to give here the process by which sourkrout is prepared from cabbage in Germany. The plants are collected from the fields in autumn, divided, the stalks separated, and the leaves cut by machine or hand into slices; a layer of which is placed in a vat, alternating with a layer of salt, until the vat is full, when it is exposed to the pressure of heavy weights placed on the top. After six weeks, more or less, according to the temperature of the place, the acetous fermentation being completed, the preparation is fit for use. When used, it is simply stewed in its own liquor along with the meat with which it is to be eaten. It has a slightly relaxing effect on the bowels. It has a high reputation as an antiscorbutic.

Brassica oleracea acephala arborescens, Cow-Cabbage or Cæsarian Kale.—This cabbage is not sufficiently hardy to stand the climate of Britain unless reared in a very sheltered situation. It is cultivated in many parts of France, and in the island of Jersey. It there lasts four years without fresh planting. In La Vendée it is said to attain the height of from 12

* Voelcker, ibid.

to 16 feet. The farmers there feed their cows with the leaves, plucking them from the stem as they grow, while they leave the crown at the top. At the end of the season, when the leaves are no longer produced, the crown is boiled, and is said to be particularly sweet.

The other varieties of the *Brassica oleracea* belong to the kitchen-garden rather than to the farm.

Crambe maritima, Sea-kale.—*Crambe maritima* grows on the sandy shores in the west of England and elsewhere on the English coast, and the common people have from time immemorial been in the practice of watching when the shoots and leaf-stalks begin to push up the sand and gravel in March and April, and then they cut them off under ground, as is done in gathering asparagus, and boil them as greens. The plant was not introduced into our gardens till about the middle of the last century. Miller says all kinds of cattle eat it.

Crambe tataria has a great fleshy root, known in Hungary as tartar bread. It is peeled and sliced, then eaten with oil, vinegar, and salt. The boiled root is sweet, and is eaten by children. The young shoots also are boiled like those of sea-kale, and have an excellent taste ; but are stringy, which they would not be were the plant well cultivated, as it deserves to be.*

Cochlearia officinalis, Common Scurvy-grass—*Cochlearia armoracia*, Horse-radish.—The common scurvy-grass and some of the allied annual species were formerly much used in salads, with the reputation of being antiscorbutic. The horse-radish keeps its ground as a condiment to roast-beef.

Lepidium sativum, Garden-cress—*Nasturtium officinale*, Water-cress—*Raphanus sativus*, Common Radish.—These well-known relishes are not without their good effect on the

* See Lindley's 'Vegetable Kingdom,' p. 354, and Loudon, 'Encyclopedia of Plants,' p. 557.

health, though less requisite now than in former times, when culinary vegetables were scarce. The extreme prevalence of severe scurvy during the potato-rot, some seventeen or eighteen years ago, demonstrates how largely our ancestors must have been dependent on the plants of the cruciferous family for their freedom from that disease, when neither the potato nor any of our ordinary green vegetables were yet in common cultivation. Even mustard was in much greater request then than it is now.

The garden-cress has been in use in salads from time immemorial, so that its native country is lost. The *Sisymbrium nasturtium*, or *Nasturtium officinale*, the common water-cress, is in great request among the inhabitants of London and other large cities, apparently for its supposed antiscorbutic properties. It is said by Müller to contain iodine. One common plant, a species of the genus *Sisymbrium*—the flix-weed, or *Sisymbrium sophia*—is said to be eaten by kine and sheep, less eagerly by horses and goats, but refused by swine.

The under leaves of the *Sinapis arvensis*, the common charlock, and those of the *Sinapis alba*, the white mustard, are commonly eaten in salads; while the same, as well as the leaves of the *Sinapis nigra*, or black mustard, are boiled for greens. It is recommended in old books of agriculture to eat down the charlocks in early spring by putting sheep on the corn-fields when such weeds are abundant.

The *Raphanus sativus*, or common radish, is a native of Eastern countries, as China and Japan; but was at an early period introduced into English gardens. Long after the beginning of the present century, among such Edinburgh summer-cries as "Neeps like succre," was often heard "Reeforts, bonny reeforts," meaning radishes, though the French word "raifort," from which doubtless it was borrowed, seems to refer only to the horse-radish.

Whether the property of purifying the blood belonging to such cruciferous plants—that is, of proving antiscorbutic—in the human body, extends in any measure to cattle and sheep, is still an unsolved problem ; but it is one, in this age of epidemics in our herds, which well deserves attention.

Resedaceæ, Reseda order.—*Reseda phyteuma* is eaten as a kitchen esculent in the Greek Archipelago.

Capparidaceæ, Caper order.—*Capparis spinosa,* the caper tree or caper bush, a shrub with the habit of a bramble, affords the well-known capers. The capers are the pickled flower-buds of the plant grown in France and Italy. They belong to the order of condiments. *Cratæva nurvala* has berries agreeable to the taste.

Bixaceæ or *Flacourtiaceæ,* Arnotta order.—The *Bixa orellana* is the plant which affords arnotta, so well known formerly in dyeing, and still in great request to colour cheese and butter. The arnotta is the pulp which covers the seeds. It is a native of the West Indies. The pulp of oncoba is sweet, and eaten in Nubia. The fruits of some of the flacourtias are eatable and wholesome.

Malvaceæ, Mallow order.—Some of the malvæ or mallows were in former times used as food. Miller remarks of the common mallow, *Malva sylvestris,* that cattle are not fond of it ; but the important question for solution is, Do cattle ever spontaneously eat the mallow leaves ?

Hibiscus esculentus.—There is a well-known substance "ochro, okra, or gombo, used in the West Indies in soups, which is the fruit of a plant of this order," the *Abelmoschus esculentus,* formerly called the *Hibiscus esculentus.*

The flowers of the *Abutilon esculentum* are used in the Brazils as a vegetable. It belongs also to the *Malvaceæ.* *Gossypium herbaceum,* the cotton plant, affords seeds which in the Levant are esteemed salubrious food. The seeds of all the species of *Gossypium* afford, by expression, an oil, employed in lamps and for many other purposes. Cotton-cake, the residue after the expression of the oil, has of late come into the market as fit for the feeding of cattle. Dr Voelcker has published an analysis of some of the varieties met with in the market. This cotton-cake is the residue after the expression of the oil from the seeds of the *Gossypium barbadense.* Many inferior sorts of cotton-cake have been imported into this country, against which purchasers should be on their guard.

The following varieties of this article appear to be now on sale in this country for the use of agriculturists :—

1. Thin decorticated cotton-cake.
2. Thick decorticated cake.
3. Ordinary cake made of whole seed.
4. Oil meal, or the thick cake reduced to a coarse powder.

Dr Voelcker remarks—"Those who have been fortunate enough to secure the best decorticated cake, I doubt not, will be led by their experience to consider it a most valuable feeding substance; whilst the experience of buyers of inferior cake, made from the whole seed, must lead to a much less favourable practical opinion." *

Cotton-cake does not contain any large amount of mucilage, or anything that produces on mixing with water a volatile pungent or injurious essential oil. Cattle often take it at once, and, even when they have been previously fed on linseed-cake, soon get accustomed to the taste of cotton-cake, and eat it apparently with as much avidity as linseed-cake.

After giving the analysis of seven samples of thin decorticated cotton-cake, Voelcker makes the following among other observations : — "The proportion of oil in all the samples analysed is higher than in the best linseed-cake. As a direct supplier of fat, cotton-cake is therefore superior to linseed-

* 'English Journal of Agriculture,' vol. xix. p. 425.

cake. Decorticated cotton-cake contains a very high and much larger percentage of flesh-forming matters than linseed-cake. This circumstance suggests that cotton-cake may probably be given with great advantage to young stock and to dairy cows. Again, as by far the largest proportion of the nitrogen of food is not assimilated in the system, but passes away with the excrements of animals, the dung produced by stock fed upon cotton-cake will be found particularly valuable. The ash of cotton-cake is rich in bone materials, and amounts to about the same quantity as that contained in other oilcakes. On the whole," he says, "I am inclined to think, as far as I am able to judge on the strength of the preceding analytical indications, that the best decorticated cotton-cake possesses theoretically about the same nutritive value as linseed-cake. Cotton-cake of average quality is probably somewhat inferior to linseed-cake of average composition."

The following is the average drawn from the analysis of the seven samples above referred to:—

Water,	9.28
Oil,	16.05
Albuminous compounds or flesh-forming matters,*	41.25
Gum, mucilage, and digestible fibre (heat-producing substances),	16.45
Celluline (indigestible fibre),	8.92
Mineral matters (ash),	8.05
	100.00

* Containing nitrogen, ... 6.58

Average composition of the ash of decorticated cotton-cake:—

Potash,	37.045
Soda,	*none.*
Chloride of sodium,	*none.*
Lime,	3.750
Carry forward,	40.795

Brought forward,	40.795
Magnesia,	13.500
Oxide of iron,	1.530
Phosphoric acid,	39.649
Sulphuric acid,	0.930
Carbonic acid,	0.362
Soluble silica,	2.528
Insoluble silicious matter (sand),	.706
	100.000

Oil meal, if genuine, is identical in composition with the best decorticated cotton-cake.

In the common cotton-cake made of the entire seeds, which, in other respects, is very inferior in nutritive matters, there is reason to suspect that an adulteration is practised by adding to it some of the seed-shells obtained in the decortication of the decorticated seeds of the superior variety. It appears that such an adulteration is highly dangerous, and one ox is even reported to have died in consequence of the abundance of cotton-seed husks contained in the common cotton-cake with which it had been fed.

Thick cotton-cake hardly differs in composition from the thin, but owing to its hardness it with difficulty yields to the ordinary oilcake-crusher.

Decorticated cotton-cake and cotton-oil meal, in comparison with other kinds of artificial food, appear to be decidedly cheap feeding materials.

Sterculiaceæ, Silk-cotton order.—*Adansonia digitata,* monkey-bread, the largest, or at least the broadest, tree known, called also sour gourd, is produced in Senegal. It is called also boabob or monkey-bread. The small leaves of the tree are eaten, at least in time of scarcity. The acid pulp of the fruit diffused in water is used for drink.

Byttneriaceæ, Chocolate order.—*Theobroma cacao,* the cacao tree, is a native of Demerara. From the seeds called cacao beans, cocoa and chocolate are prepared. Cocoa consists of the roasted seeds or their outer coverings reduced to powder; while chocolate is prepared from the same, with a mixture of sugar, vanilla, cinnamon, and arnotta. The seeds contain a tonic principle called theobromine, allied to theine, and a fatty oil is expressed from them, called the butter of cacao. The pulp of the fruit, which is sweet, with a mixture of acidity, is sucked and eaten raw by the natives of the countries in which the tree is indigenous. This pulp also affords by distillation a kind of spirit. The Brazilians suck the sweet mucilage in the fruit of *Guazuma ulmifolia.*

Tiliaceœ, Linden order.—*Aristotelia maqui* is a native of Chili, producing edible berries of a black or purple colour, which the inhabitants make into wine.

Grewia sapida, a native of the East Indies, producing acid berries, which are used for sherbet.

Corchorus olitorius has leaves used in Egypt as a pot-herb.

Ternstromeaceœ, Tea order.—*Thea bohea, Thea viridis.* The leaves of these plants constitute our Chinese tea. The Assam tea is from a different species, the *Thea Assamica;* but the Himalayan tea is obtained from the same species which affords the Chinese tea.

Tea contains oily matter, tannin, and a bitter principle called theine, which is identical with caffeine, the peculiar principle of coffee.

Camellia oleifera affords an excellent table oil.

Aurantiaceœ, Orange order, or citron-worts.—The *Aegle marmelos,* the Indian bael or bela, yields a delicious fruit. The decoction and jelly of the fruit are used in looseness of the bowels.

Citrus aurantium, the orange; *Citrus vulgaris,* the bitter or Seville orange; *Citrus limonum,* the lemon; *Citrus limetta,* the lime; *Citrus decumana,* the shaddock.

Cookea puncta, the edible wampee-fruit of China.

Glycosmis citrifolia has delicious berries.

Guttiferæ, or *Clusiaceæ,* Gamboge order.—*Garcinia mangostana,* a native of Malacca, produces the delicious fruit " mangosteen." The rind is an astringent.

Mammea Americana affords the mammee apple or wild apricot of South America.

Pentadesma butyracea is the butter and tallow tree of Sierra Leone.

Hippocrateaceæ, Hippocratea order.—*Hippocratea comosa* of South America yields nuts, which are oily and sweet.

Tontelea pyriformis yields a fruit eaten at Sierra Leone. Several species of *Tontelea* in Brazil have a sweet mucilaginous fruit, which is eaten.

Malpighiaceæ, Malpighia order.—The *Malpighia glabra* and the *Malpighia punicifolia* afford the Barbadoes cherry, used in Jamaica as a dessert. The fruit of some Byrsonimas is also eaten there.

Aceraceæ, Maple order.—*Acer saccharinum,* the sugar-maple of North America. *Acer dasycarpum* and other species likewise yield sugar. The juices of the *Aceraceæ* are said to become acrid as the season advances.

Sapindaceæ, Soapwort order.—*Æsculus hippocastanum,* the horse-chestnut, has seeds containing saponaceous matter. The seeds are used as food for sheep. The seeds have been recommended as a substitute for coffee. Sheep eat them greedily. In moderate quantity they are said to give an excellent flavour to mutton.

Cardiospermum halicacabum has esculent leaves.

Cupania (Blighia) sapida furnishes the akee fruit, remarkable for its edible succulent arillus.

Nephelium litchi affords the li-chi fruit of China. *Nephelium longan* gives the Chinese longan fruit, and another species the rambutan fruit.

Paullinia sorbilis is the guarana plant. The seeds of this plant, after being dried and deprived of their white aril, are pounded and kneaded into a dough, which is then made up into balls. This substance supplies an important beverage, and even bread, to the inhabitants of large districts of country in South America. Its principle, guaranine, appears to be identical with theine.

Sapindus senegalensis has much-prized berries. *Sapindus esculentus* has a fleshy fruit in great esteem.

Schmidelia edulis has fruit eaten in Brazil.

Rhizobolaceæ, Suwarrow Nut order.—*Caryocar butyrosum,* or *Pekea tuberculosa,* is a gigantic tree of Demerara, producing the souari, suwarrow, or surahwa nuts, the kernels of which are esteemed the most agreeable of all the nut kind.* An oil is extracted from them not inferior to that of the olive.

Vitaceæ or *Ampelidcæ,* Vine order.—*Vitis vinifera,* the grape-vine. Raisins; currants. The finest raisins are the muscatel. The sultana raisin is seedless. Currant is a corruption of Corinthian grape. Their dietetic use is apparently connected with their acid character.

Geraniaceæ, Cranesbill order.—*Pelargonium triste* has tubers which are eaten at the Cape of Good Hope.

Linaceæ, Flax order.—*Linum usitatissimum* is the cultivated flax. The cake left after the expression of linseed-oil from the seeds is the oilcake of agriculture.

The seeds of the flax have long been known to be highly nutritious. The whole seed boiled soft, together with the water in which it has been boiled, is given in many districts as a cordial drink to cows after calving, and as a tonic to promote recovery after an illness. But even after boiling, owing to the strength of its envelope, the seed is apt to pass through the digestive organs of ruminating animals unaltered. To

* Balfour, 'Class-Book of Botany,' p. 781.

derive the whole benefit from this article, it should be used only after being bruised or converted into meal. Boiled into a porridge or jelly, the meal has long been used to assist the milk in the feeding of the older calves till the time for weaning arrives.

The following is the composition of linseed:—

Oil,	11.3
Husk,	44.4
Woody fibre and starch,	1.5
Sugar, &c.,	10.6
Mucilage,	7.1
Soluble albumen (caseine),	15.1
Insoluble ditto,	3.7
Fatty matter,	3.1
Loss,	3.2
	100.0

The composition of the ash is as follows:—

Potash,	25.85
Soda,	0.71
Lime,	25.27
Magnesia,	0.22
Oxide of iron,	3.67
Phosphoric acid,	40.11
Sulphuric acid,	—
Sulphate of lime,	1.79
Chlorine,	*trace.*
Chloride of sodium,	1.55
Silica,	0.92
	100.00

Percentage of ash, . 4.63

The oilcake has of late come much into use for the feeding of cattle. Oilcake is not used as the sole food, but is conjoined with other substances, as turnips, potatoes, cut hay, or cut straw. When given with cut hay or cut straw, an ox will eat from 7 to 9 lb. of it in a day, and the hay or straw induces rumination, which the cake itself would not do. When given with turnips or potatoes, 3 or 4 lb. a-day of the cake will suffice.

The following is Professor Johnston's analysis of the oilcake of commerce :—

	English.	American.
Water, ...	10.05	10.07
Mucilage, ...	39.10	36.25
Albumen and gluten, . .	22.14	22.26
Oil, ...	11.93	12.38
Husk, ...	9.53	12.69
Ash and sand, . . .	7.25	6.35
	100.00	100.00

The large percentage of proteine compounds is nearly equal to that of pease and beans, a result very unexpected, since the utility of oilcake in feeding has been usually believed to arise from its laying on fat. The proportion of oil is greater than in any of the cereals, since the oat has no more than 7 per cent of oil, while oilcake has as much as 12 per cent.

Oilcake leaves 6 per cent of ash, the composition of which is as follows :—

	English.	American.
Alkaline salts, . . .	31.55	38.20
Phosphate of lime and magnesia, .	47.67	56.26
Lime, ...	4.88	1.24
Magnesia, ...	1.51	*trace.*
Silica, ...	10.81	4.30
Sand, ...	3.58	—
	100.00	100.00

The American cake appears to be a cake of pure quality. The phosphates are in large proportion, even twice as available for making bone as oats or barley. The dung derived from oilcake is more enriching to the soil than that even from grain, inasmuch as it contains more phosphates than the animals can take up, so that the excess must pass into the dunghill.

Moreover, as full-grown animals hardly appropriate any of the phosphates, these, when oilcake is given merely to fatten, will all pass out with the excrement.

Professor Johnston, founding on theoretical considerations derived from the abundance of phosphates in flax seeds, has proposed the following feeding-substitute for linseed oilcake :—

Bruised linseed, ...	40 lb.
Bran meal, ...	60 „
Bone meal (ground bones), . . .	4 „
	104 lb.

The constituents of which, in every 100 lb., are—

Starch, ...	40 lb.
Proteine compounds, ...	27 „
Fat, ...	11 „
Saline matter, ...	7 „
Water and husk, ...	15 „
	100 lb.*

Oxalidaceæ, Wood-sorrel order.—The *Oxalis acetosella,* or wood-sorrel, was formerly officinal, being esteemed refrigerant and antiscorbutic. It was also used in salads. It was called cuckoo's bread, and in France "pain à coucou," because it flowers about the time when the cuckoo is heard. It has not been observed whether any animal naturally at times eats this plant.

The *Oxalis crenata* bears tubers, which are used as potatoes, but insipid. *Oxalis deppei* has fleshy roots, which are used as culinary vegetables, and are deservedly growing in esteem.

Oxalis crassicaulis, O. tetraphylla, and *O. esculenta,* are said to possess similar good qualities.

Tropæolaceæ, Indian Cress order.—*Tropæolum majus,* the Indian cress, improperly called *Nasturtium,* has the peculiar

* For further particulars respecting oilcake, see Stephens's 'Book of the Farm,' vol. i. p. 275-278.

taste of the *Cruciferæ.* Its leaves may be put into salads; the fruit pickled is used as a substitute for capers. The caterpillar of the cabbage butterfly feeds exclusively on the *Cruciferæ* and *Tropæolums.*

Tropæolum tuberosum has tubers, which are eaten in Peru.

T. chymocarpus is used in Peru as an antiscorbutic.

Pittosporaceæ, Pittosporum order.—The genus *Billardiera,* which belongs to New Holland, produces berries, which in some species are eatable. *Pittosporum mutabile* has a very pleasant green subacid fruit.

Zugophyllaceæ, Bean Caper and Guaiacum order.—*Zugophyllum fabago,* the bean caper, so called on account of its flower-buds being used as a substitute for capers, grows in Syria. *Tribulus terrestris,* small caltrops, a native of the south of Europe, is famed for fattening fowls and heightening their flavour; the same is well known in Jamaica as Turkey blossom. *Melanthus major* has flowers full of honey, fit for food.

Rutaceæ, Rue order.—*Correa alba* has leaves which afford a kind of tea in Australia. Some other species of *Correa* are also in use for tea.

Sub-class *Calycifloræ.* 1. *Polypetalæ : Rhamnaceæ,* Buckthorn order.—The genus *Zizyphus* has in general edible fruit.

From *Z. jujuba* and *Z. vulgaris* the jujube paste is prepared. *Z. lotus* affords an edible fruit in use in Arabia. *Z. maimunna* is a fruit the size of a currant, of much request in Afghanistan.

Anacardiaceæ, Cashew order.—*Anacardium occidentale,* the cashew nut, has a fleshy edible peduncle supporting a nut, the kernel of which can be eaten, while the pericarp is acrid.

Mangifera indica affords the mango, a highly-prized tropical drupaceous fruit.

Of the genus *Spondias,* several species, as *S. purpurea* and *S. mombin,* afford edible fruit, called hog plums in the West

Indies. The *S. dulcis,* the Otaheite apple, is cultivated and much prized in the Society Islands and in the Friendly Islands.

Leguminosæ or *Fabaceæ,* Leguminous orders. Sub-orders : 1. Papilionaceous section.—*Faba vulgaris* or *Vicia faba,* the common bean, many varieties of which are cultivated in our gardens, and even several varieties for the food of animals in the fields. Beans are given to the horse whole, boiled, raw, or bruised. They are given to cattle in the form of meal — that is, the husk and grain ground together to a not over-fine powder. Beans may be ground to a fine flour, in which state they are used to adulterate the flour of wheat. Beans are very serviceable to horses employed in fatiguing work. As Stewart observes in his 'Stable Economy' —"If beans do not afford more nutriment, weight for weight, than oats, they at least produce more lasting vigour. To use a common expression, they keep the stomach longer. The horse can travel farther ; he is not so soon exhausted. . . . In the coaching-stables beans are almost indispensable to horses that have to run long stages."

Beans are also of much service in feeding pigs.

The following is the composition of the bean-grain, as given in Hemming's tables :—

COMPOSITION IN 100 PARTS. DRIED AT 212° FAHRENHEIT.

Organic matter,	96.90
Ash,	3.10
	100.00

ULTIMATE ELEMENTS.

Carbon,	46.50
Hydrogen,	7.10
Oxygen,	40.30
Nitrogen,	6.10
	100.00

Ammonia, . . 7.38

PROXIMATE PRINCIPLES.

Albumen, Gluten, Caseine,		32.5
Fat, oil,		2.4
Starch,		45.5
Gum, dextrine, pectine,		5.2
Sugar,		2.4
Fibre and husk,		12.0
		100.0

ASH.

Total sulphur,	0.29	
Sand and silica,		0.9
Potash,		42.1
Soda,		0.9
Lime,		8.7
Magnesia,		6.6
Oxide of iron,		0.4
Chloride of potassium,		0.3
Chloride of sodium,		1.9
Phosphoric acid,		31.9
Sulphuric acid,		4.5
Carbonic acid,		1.8
		100.0

STRAW AND PODS.

Organic matter,	94.44
Ash,	5.56

ASH.

Total sulphur,	0.148	
Sand and silica,		8.0
Potash,		10.9
Soda,		9.3
Lime,		24.9
Magnesia,		4.3
Oxide of iron,		1.5
Chloride of sodium,		0.3
Phosphoric acid,		9.8
Sulphuric acid,		1.5
Carbonic acid,		29.5
		100.0

Pisum sativum, the Common Pea.—Many varieties of the pea are cultivated, both in the garden and in the field. For human food the pea is chiefly used in the green state, and in the form of split-pea for soup in winter. Pease-meal bread is less used now than formerly, and pease-brose is very much confined to invalids. As food for horses and cattle, the use of the pea seems to be on the decline. It may be that the bean supplies this generic sort of food to greater advantage. Nevertheless, as mere fashion (so to speak) has often all the influence in such cases, it may be worth while, before allowing the pea to become wholly obsolete for feeding, to consider how great benefit invalids of the human race often obtain by exchanging their farinaceous food from the cereals to that derived from leguminous plants, as in pease-brose and in the preparations of lentil-meal. It may be the same in horses and cattle; and when they fall out of condition without evident cause, it may be worth while to try the effect of the old pea-food. At any rate, it is quite certain, the best way to finish fattening hogs for ham is to give them whole peas for a fortnight at least before they are slaughtered, with any nourishing slop for a drink.

Analysis of the pea from Hemming's tables:—

GRAIN DRIED AT 212° FAHRENHEIT.

Organic matter, ...		97.25
Ash, ...		2.75
ULTIMATE COMPOSITION.		
Carbon, ...		47.7
Hydrogen, ...		6.2
Oxygen, ...		41.8
Nitrogen, ...		4.3
		100.0
Ammonia, . . .	5.20	
PROXIMATE PRINCIPLES.		
Albumen, Gluten, Caseine, ...		23.3
Carry forward, .		23.3

Brought forward,	23.3
Fat, oil,	2.3
Starch,	53.8
Gum, dextrine, pectine,	5.7
Sugar,	2.3
Fibre and husk,	12.6
	100.0

ASH.

Total sulphur,	0.27	
Sand and silica,		1.2
Potash,		40.2
Soda,		0.7
Lime,		6.3
Magnesia,		6.6
Oxide of iron,		0.6
Chloride of potassium,		1.4
Chloride of sodium,		0.7
Phosphoric acid,		34.8
Sulphuric acid,		5.7
Carbonic acid,		1.8
		100.0

COMPOSITION OF STRAW AND PODS.

Organic matter,	88.7
Ash,	11.3
	100.0

ASH.

Total sulphur,	0.214	
Sand and silica,		7.1
Potash,		8.8
Soda,		4.9
Lime,		31.0
Magnesia,		5.6
Alumina,		0.3
Oxide of iron,		0.5
Chloride of sodium,		4.6
Phosphoric acid,		6.6
Sulphuric acid,		4.9
Carbonic acid,		25.7
		100.0

Vicia sativa.—The cultivated tare or vetch thrives admirably on all kinds of soil. It grows native in Britain. If sown early it affords a forage crop ready for cutting in time of corn-harvest as food for the horses. Tares are also sown for seed, in which case it is recommended to sow beans along with them for the purpose of support. Poultry are fond of the seed of the tare. There are two varieties of the tare, that of winter and of spring.

COMPOSITION OF TARE (GRAIN).

Organic matter,		97.0
Ash,		3.0
Nitrogen,	4.25	
Ammonia,	5.14	

ASH.

Sand and silica,	0.9
Potash,	34.6
Soda,	9.5
Lime,	8.3
Magnesia,	4.5
Oxide of iron,	1.4
Chloride of sodium,	2.0
Phosphoric acid,	36.2
Sulphuric acid,	2.6
	100.0

COMPOSITION OF STRAW AND PODS.

Organic matter,		93.5
Ash,		6.5
Nitrogen,	1.93	
Ammonia,	2.24	

ASH.

Sand and silica,	17.6
Potash,	18.6
Soda,	1.1
Carry forward,	37.3

Brought forward,	37.3
Lime,	43.3
Magnesia,	3.1
Oxide of iron,	0.9
Chloride of sodium,	2.1
Phosphoric acid,	12.3
Sulphuric acid,	1.0
	100.0

Ervum lens, Lentil, is a native of France and the southern countries of Europe. It is a legume of the greatest antiquity, and is much prized in the countries in which it grows freely. In Egypt and Syria the grains are parched in a frying-pan and sold in the shops, being considered by the natives as the best food for those who undertake long journeys. There are three varieties of lentil cultivated in France and Germany—the small brown, which is the lightest-flavoured, and the best for haricots and soups; the yellowish, which is a little larger and the next best; and the lentil of Provence, which is almost as large as a pea, with luxuriant straw, and more fit to be cultivated as a tare than for the grain as human food. The straw is very delicate and nourishing, though scanty as compared with that of the tare, and is preferred for lambs and calves. The grain on the Continent sells at nearly double the price of pease.

COMPOSITION OF LENTILS (GRAIN).

Organic matter,	97.9
Ash,	2.1

ASH.

Sand and silica,	2.0
Potash,	37.8
Soda,	6.6
Lime,	5.0
Magnesia,	2.0
Carry forward,	53.4

Brought forward,	53.4
Oxide of iron,	1.6
Chloride of sodium,	6.0
Phosphoric acid,	39.0
	100.0

Straw not analysed.

Cicer arietinum, Common Chick Pea.—It grows naturally in the south of Europe, and is cultivated there for the same purposes as the lentil. It is called *arietinum* because the young seed bears a very curious resemblance to a ram's head. It contains oxalic acid.

Phaseolus vulgaris, Common Kidney-bean. — Under the name of kidney-bean are included not only the numerous varieties of the *Phaseolus vulgaris,* but also those of the scarlet-runner, *Phaseolus multiflorus.* As our climate is hardly sufficient for the extensive production of the ripe beans for which such plants are cultivated in France and Italy, it is the immature legumes that are gathered for use in this country.

Lupinus luteus, Yellow Lupine.—*Lupinus albus* is supposed to be the species which was cultivated as a forage plant by the Romans. It is the *Lupinus luteus* that is grown at present for this purpose, and in the south of Italy even for human food. In the south of France the same species is grown in poor dry extensive plains as a meliorating crop, to be ploughed in where no manure is to be had, and the ground is too sterile for clover or other better plants.

The yellow lupine is now extensively cultivated as a field crop in several parts of Germany, France, and Belgium, more especially in the sandy districts of northern Germany and Prussia, where it is held to be a most valuable crop to the farmer, because it thrives freely on poor blowing sands, on which no other leguminous crop can be grown. In some districts the blue lupine is grown for the same uses, but the yellow is generally preferred when grown not for seed but for green food, owing to its more numerous large and succulent leaves. Nevertheless it is for the seeds that the lupine is commonly grown, as these afford a nutritious food not much different from pease and lentils. Professor Voelcker says, " If I am not mistaken, the field culture of lupines will, if at all practicable in this country, be found chiefly valuable as a source of green nutritious food for sheep and cattle, on soils upon which clover and the finer and more nutritious kinds of grasses either refuse to grow altogether, or only furnish a scanty supply of inferior green food." *

ANALYSIS.

	Parts.
Woody stems, ...	29.5
Leaves and soft tops, ...	70.5

COMPOSITION OF LEAVES AND SOFT TOPS—*i.e.*, EXCLUSIVE OF WOODY STEMS—CUT DOWN IN A GREEN STATE.

	Fresh.	Dry.
Water, ...	89.20	—
Oil, ...	0.37	3.42
Soluble albuminous compounds, .	1.37	12.68
Soluble mineral (saline substances),	0.61	5.64
Insoluble albuminous compounds, .	1.01	9.35
Sugar, gum, bitter extractive matter, and digestible fibre, . .	3.96	36.68
Indigestible woody fibre, cellulose,	3.29	30.48
Insoluble mineral matters, . .	0.19	1.75
	100.0	100.0

It appears that sheep and cattle soon get accustomed to lupine, and even like it much after some time, notwithstanding the absence of saccharine matter, and even a certain bitterness of taste, but that it is refused by pigs. It is not pretended by the patrons of this kind of food that it is more

* 'English Journal of Agriculture,' vol. xxi. p. 389.

nutritious than the kinds of green food usually grown in this country, but that it has a greater value in this respect than the green food that can be grown on land of the same inferior quality.

Glycyrrhiza glabra, Liquorice.—The liquorice plant, sometimes named *Liquoritia officinalis,* is a native of Spain, and other countries bordering on the Mediterranean and Black Seas. For many years it has been cultivated in several parts of England. The roots are extensively used in porter-brewing as well as in medicine.

Abrus precatorius, Wild Liquorice.—This plant grows in the West Indies. The roots have the same properties as our liquorice. The seeds are used for rosaries. They are frequently thrown, along with other West Indian seeds, on the north-west coast of Scotland. Linnæus affirms that the seeds are deleterious, yet they are eaten in Egypt, though the hardest and most indigestible of the pulse tribe.

Arachis hypogœa, Earth-nut.—The pods of the *Arachis hypogœa,* as they ripen, force themselves under ground—hence the name, earth-nut. In South Carolina the seeds are used for chocolate, and instead of almonds. An oil is obtained from them, which is employed in lamps, and also as a substitute in dietetics for the oil of olives. The plant has been raised in the neighbourhood of Paris, and the fruit employed like other legumes. The oilcake left after the expression is sometimes met with in commerce. The oil is now sold in this country for dietetic purposes.

Geoffroya superba affords a drupaceous fruit, which is used as food in some parts of Brazil.

Alhazi maurorum, Camel's Thorn.—This plant yields a kind of manna.

Ulex Europœus, Furze or Whin.—As an agricultural plant the furze has been sown in several parts of Britain to form hedges ;

but as a hedge it does not answer well unless of great breadth, being apt to get naked below. Sown on a mound, however, the sides may be cut and the prunings used as green food, while the fence is thus rendered close at bottom and durable. The most profitable use of furze, whether sown or grown wild, is that of using it as green food for horses. It must be bruised, for which purpose machines have been invented.* Dry furze bruised is sometimes used to feed asses, and even horses, at least in times of great scarcity. Green, it is used in all seasons. Furze is sometimes killed by severe winters.

Artificial Grasses.—The clovers, the chief of what have been called the artificial grasses, belong in botany to the *Leguminosæ,* and to the genus *Trifolium,* so named from the three leaves or leaflets common to the genus.

Trifolium minus vel filiforme, Lesser Yellow Trefoil or Suckling Clover.—This is a fibrous-rooted perennial, which flowers in May, June, and July. It grows on very dry pastures and poor sandy downs. It is too small to be of much value in pastures, but it affords an agreeable mixture in lawns, particularly useful where the soil is too dry for white clover. It is one of the plants recommended to be sown, to the extent of from 1 to 2 lb. per imperial acre, for fine lawns, bowling-greens, and the like, kept constantly under the scythe, and for warrens or light sandy downs. The average weight of a bushel of the seeds is 64½ lb., and the number of seeds in an ounce rises to 54,000.†

Trifolium pratense, Common Red Clover or Purple Trefoil. —This well-known plant, common in meadows and pastures, flowers during the summer months. Its root is fibrous, hardly creeping, perennial. It is popularly known as honeysuckle clover, and when cultivated is known as broad clover, owing

* See Stephens's 'Book of the Farm,' vol. i. p. 318.

† See Lawson on 'Herbage and Forage Plants.'

to its larger size and greater luxuriance. It is one of the plants recommended to be sown to the extent of from 1 to 3½ lb. per imperial acre, for permanent pastures, for permanent lawn pastures; for marshy grounds; and to the extent of from 3 to 8 lb. in the same measure of ground for alternate husbandry. A bushel of the seeds averages 64 lb. and the number of seeds in an ounce reaches 16,000.

Trifolium pratense perenne, Cow-grass or Perennial Red Clover.—Cow-grass is a more permanent variety than the common red clover. It grows naturally in dry pastures, and answers well when sown with the permanent grasses, and for alternate husbandry when two crops of pasture are taken. It is one of the plants recommended to be sown, to the extent of from 1 lb. to 3 lb. per imperial acre, for alternate husbandry, for permanent pasture, for permanent lawn pastures, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for improved deep mossy ground intended to be kept in grass. A bushel of the seeds averages 64 lb., and the number of seeds in an ounce comes up to 16,000.

Trifolium repens, White or Dutch Clover.—The white or Dutch clover is a fibrous-rooted and creeping-stemmed perennial. It flowers throughout the summer. Each flower is on a footstalk, which becomes recurved after flowering, and then all the legumes are drooping and covered with the withered brown corollas. This trefoil is in great request for pastures. It grows naturally in dry pastures and moors. When too abundant in a pasture it has a tendency to scour cattle. Such a superabundance should be guarded against for this reason, as well as because it occupies the ground that might be more advantageously filled with better pasture-grasses. It does not, however, affect the bowels of sheep. It is one of the plants recommended to be sown, to the extent of from 2 lb. to 7 lb. per imperial acre, for alternate husbandry, for permanent pasture, for permanent lawn pasture, for fine lawns and bowling-greens kept constantly under the scythe, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for heathy and moory lands which have been improved with a view to their producing better pasturage, for improved deep mossy ground intended to be kept in grass, and for warrens or light sandy downs. A bushel of the seeds averages 65 lb., and the number of seeds in an ounce comes up to 32,000.

Lotus corniculatus, Common Bird's-foot Trefoil.—Common bird's-foot trefoil is a deep-rooting perennial. It flowers in June and July. It grows on sandy downs, dry pastures, and moors. It is eaten with avidity by horses, cattle, and sheep. By writers on agriculture it has often been confounded with other plants, which explains some of the contradictory statements respecting its nutrient qualities. It is one of the plants recommended to be sown, to the extent of from ¼ lb. to ½ lb. per imperial acre, for permanent pastures and for permanent lawn pastures. A bushel of the seeds averages 62 lb., and the number of seeds in an ounce reaches 28,000.

Lotus major, Greater Bird's-foot Trefoil.—The greater bird's-foot trefoil is a spreading or creeping-rooted perennial. It flowers in July and August. It grows in moist meadows, banks of streams, and shady places. It is possessed of the same nutritive qualities as the *Lotus corniculatus;* it yields, however, a much greater bulk of herbage, and is suited for a more moist or marshy description of soils. It is doubtful if it be specifically distinct from the *Lotus corniculatus,* there being nothing improbable in the differences between them being due merely to the difference in the kind of soil in which each plant naturally grows.

It is one of the plants recommended to be sown, to the extent of from $\frac{1}{4}$ lb. to 2 lb. per imperial acre, for permanent pasture, for permanent lawn pasture, for lands in preparation for irrigation, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for pasturage and cover in thick shady woods, for improved deep mossy ground intended to be kept in grass, for marshy grounds and such as are occasionally overflowed by fresh-water tides. A bushel of the seeds averages 64 lb., and the number of seeds in an ounce rises to 51,000.

Medicago lupulina, Common Yellow Clover Trefoil, Black Medick, or Nonesuch.—Black medick is a fibrous-rooted biennial or triennial. It flowers from May to August. It grows in dry pastures and cultivated grounds. The species of *Medicago* are readily distinguished by their legume, which in some is bent into an arch, like a sickle, and in others is spirally twisted. The black medick is extensively cultivated, but is hardly equal in nutritive properties to the red and white clover. Some confusion occasionally arises from the black medick being called the hop trefoil, which name at present is confined to the *Trifolium procumbens*, a much less useful plant. The *Medicago lupulina* is one of the plants recommended to be sown, to the extent of from 1 lb. to 3 lb. per imperial acre, for alternate husbandry, for permanent pasture, for permanent lawn pasture, for heathy and moory lands which have been improved with a view to their producing better pasturage, for improved deep mossy ground intended to be kept in grass, and for warrens or light sandy downs. A bushel of the seeds averages 63$\frac{3}{4}$ lb., and the number of seeds in an ounce amounts to 16,000.

Medicago sativa, Lucern.—Lucern is a deep-rooting perennial. It flowers in June and July. It is a native of the south of Europe, but has become naturalised on the chalky, calcareous, and gravelly soils in the south of England. It is for the most part cultivated by itself; but in very dry limestone districts, and in dry sandy downs, particularly where the sand contains fragments of sea-shells or other calcareous matter, it may be introduced into pastures. A bushel of the seed averages 60 lb., and the number of seeds in an ounce rises to 12,600.

Onobrychis sativa, Common Saint-foin.—This plant, saint-foin, was formerly known as the *Hedysarum onobrychis*, the latter name being compounded of two Greek words, the one signifying an ass, and the other to bray—the smell of the plant being supposed to make an ass bray. Saint-foin, or cinquefoil, is a deep-rooting perennial. It flowers in July and August. It grows on dry chalky hills and open downs in various parts of England. It is cultivated to considerable advantage in dry and especially chalky soils. There is a variety known in France under the name of *Onobrychis sativa bifera*, which is of more rapid growth, and attains a larger size than the common plant. It is one of the plants recommended to be sown for warrens or light sandy downs, to the extent of 3 lb. per imperial acre. A bushel of the seeds averages 26 lb., and the number of seeds in an ounce is 11,280.*

Melilotus leucantha major, Bokhara Clover.—Authorities differ in regard to the value of this plant. As one of us has reared it in several successive seasons as an ornamental plant, and has found that it stands our winters and sends up shoots early in April, he has thought it not unlikely to prove a useful forage plant. If this idea turns out to be well founded, it might be sown early in autumn and cut early in spring; or, being sown in April or May, it might be ready for cutting in August. When sown in August, it has been sufficiently

* For further details on artificial grasses, see Lawson on 'Herbage and Forage Plants.'

advanced to stand the winter—its herbage is indeed cut down by the frost, but its roots escape and send up shoots in April. It must be cut when young and succulent; for when it rises above 2 feet in height, its stems become fibrous and harsh to the taste. The objection, indeed, made to it by some agriculturists is, that it is too watery when young, and too stringy when old. It does bear much moisture when young, and is therefore, then, all the more succulent.

Being a biennial, in the second year it throws up six or eight stems, which attain a height from seven to ten feet, throwing out side branches. It thus becomes covered with a profusion of small white flowers with an odour not unlike that of the sweet-scented vernal grass, the *Anthoxanthum odoratum*.

Of the flowers of this plant, as of those of the kindred plants in this family, the honey-bee is very fond. It deserves therefore to be cultivated in the farmer's garden, both for this purpose and as highly ornamental. Nor is this remark so much out of place as it may seem at first sight, since the honey-bee is in reality one of the farm animals from which the diligent agriculturist may derive both comfort and profit.

ANALYSIS OF ARTIFICIAL GRASSES

(as taken from the field).

	Water.	Albuminous or flesh-forming principles.	Fatty matters.	Heat-producing principles—Starch, Gum, Sugar.	Woody fibre.	Mineral matter or ash.	Date of collection.
Trifolium pratense, .	81.01	4.27	0.69	8.45	3.76	1.82	June 7
Trifolium pratense perenne, . . .	81.05	3.64	0.78	8.04	4.91	1.38	4
Trifolium repens, . .	79.71	3.80	0.89	8.14	5.38	2.08	18
Medicago lupulina, .	76.80	5.70	0.94	7.73	6.32	2.51	6
Medicago sativa, . .	69.95	3.83	0.82	13.62	8.74	3.04	16
Onobrychis sativa, .	76.64	4.32	0.70	10.73	5.77	1.84	8

ANALYSIS OF ARTIFICIAL GRASSES

(dried at 212° Fahrenheit).

	Albuminous or flesh-forming principles.	Fatty matters.	Heat-producing principles—Starch, Gum, Sugar, &c.	Woody fibre.	Mineral matter or ash.
Trifolium pratense, .	22.55	3.67	44.47	19.75	9.56
Trifolium pratense perenne, . . .	19.18	4.09	42.42	25.96	8.35
Trifolium repens, . .	18.76	4.38	40.04	26.53	10.29
Medicago lupulina, .	24.60	4.06	33.31	27.19	10.84
Medicago sativa, . .	12.76	2.76	40.16	34.21	10.11
Onobrychis sativa, .	18.45	3.03	45.96	24.70	7.86

COMPOSITION OF RED AND WHITE CLOVER.

	Red.	White.
Organic matter, . . .	92.0	91.3
Ash, ...	8.0	8.7

ASH.

	Red.	White.
Total sulphur, . . .	0.47	0.38
Sand and silica, . . .	3.3	3.7
Potash, ...	14.9	14.3
Soda, ...	1.4	3.7
Lime, ...	35.4	26.4
Magnesia, ...	11.2	8.2
Oxide of iron, . . .	1.0	2.0
Chloride of potassium, . .	3.0	0.0
Chloride of sodium, . .	2.4	5.0
Phosphoric acid, . . .	6.3	11.5
Sulphuric acid, . . .	4.2	7.2
Carbonic acid, . . .	16.9	18.0
	100.0	100.0

2. *Caesalpiniæ,* Senna section.—*Ceratonia siliqua,* Algaroba bean, or carob-tree. This is supposed to be the locust-tree of Scripture. It has also obtained the name of St John's bread.

It is very common in the south of Spain, and the seeds, or beans as they were there called, often formed the principal food of the British cavalry horses during the Peninsular war. It has been used as a manure.

The tree sometimes attains a considerable size. It is very common throughout the southern countries of Europe, and the adjacent regions of Asia and Africa. It has been grown in the open air in this country, but hardly flowers, much less ripens its fruit. It is, however, an ornament of the conservatory, as its leaves remain always green, and their roundness and pinnate character make them remarkable.

Tamarindus indica, Tamarind-tree.—The simple infusion of the pulp of the fruit in warm water, or a whey made by boiling it in milk, is a grateful refrigerant beverage. *Dialium indicum,* called the tamarind plum, has an agreeable pulp. Two *codariums,* called brown and velvet tamarinds, are eaten in Sierra Leone.

3. *Mimoseæ,* Gum-arabic section.—*Acacia Arabica.* Several species of the genus *acacia* afford gum, the type of which is gum-arabic. The gum of a species of *acacia* at Swan river serves for food. *Acacia sophera* in Tasmania affords seeds which are used for food.

Mimosa fagifolia.—This mimosa grows in Martinique. The pods contain a whitish, sweet pulp, which the natives suck; hence the tree and its fruit are known as the *pois doux* or sweet pea. *Parkea Africana* has seeds from which an imitation of chocolate is made.

Moringaceæ, Moringa order.—*Moringa pterygosperma,* the horse-radish tree, East Indies. The seeds of this plant are called ben-nuts, and supply ben-oil, used by perfumers and watchmakers. The root has the taste of horse-radish; the bark yields gum.

Rosaceæ, Rose order. Sub-orders:—

1. *Crysobalaneæ.* — *Crysobalanus Icaco,* the cocoa-plum, West Indies. *Crysobalanus luteus,* a similar fruit, Sierra Leone.

2. *Amygdaleæ* or *Drupaceæ.*—*Amygdalus communis,* the sweet and bitter almond, south of Europe. *Amygdalus Persica,* the peach. *Cerasus serotina,* black cherry, improperly called *Prunus Virginiana.* *Prunus Virginiana,* choke-cherry. The kernels of species of *cerasus* impart flavour to kirschenwasser, noyau, ratafia, cherry-brandy, and maraschino. *Prunus communis,* the common plum. *P. Armeniaca,* the apricot.

3. *Roseæ.*—Under *Roseæ* come the strawberry, the raspberry, the black bramble.

4. *Pomeæ.*—The apple, the pear, the medlar, the quince, the hawthorn, the service-tree, the quicken or rowan-tree, improperly called mountain-ash, the loquat (*Eriobotrya Japonica*), with fruit the size of a gooseberry.

Calycanthaceæ.—*Calycanthus floridus,* Carolina allspice; the bark a substitute for cinnamon.

Rhizophoraceæ, Mangrove order. — *Rhizophora mangle,* mangrove-tree. It covers immense tracts of coast within the tropics, rooting and vegetating even as far as low-water mark. The fruit of the plant is edible.

Combretaceæ, Myrobalan order.—*Terminalia belerica* yields the edible fruit myrobalan. *T. chebula,* a like fruit. *T. catappa* has edible seeds, East India species.

Melastomaceæ, Melastoma order.—*Melastoma:* several species produce edible fruits, which dye the mouth black. *Mouriria puse,* an edible fruit, the size of a plum.

Myrtaceæ, Myrtle order.—*Caryophyllus aromaticus,* the clove. *Eugenia pimenta,* allspice, or Jamaica pepper. *Eugenia cauliflora,* the edible fruit termed in Brazil jaboticaba. *Punica granatum,* the pomegranate. *Psidium,* of which the species *P. pyriferum, P. pomiferum,* and *P. cattleyanum,* afford the fruit called guava. This fruit is in much favour in the West Indies. The purple *P. cattleyanum* is the best. The fruit is of a fine deep claret colour, and the pulp, in consistence and flavour, bears a considerable resemblance to the strawberry.

Lecythidaceæ, Monkey-pot order.—*Bertholletia excelsa* yields the Brazil, Castanha, or Para nuts of the shops. *Lecythis ollaria* affords the monkey-pot, the seeds contained in which are the Sapucaya nuts. A smaller-fruited *Lecythis* yields what is called the monkey's drinking-cup.

Onagraceæ, Evening Primrose order.—*Œnothera biennis,* the evening primrose, and other species, are cultivated for their edible roots.

Halorageaceæ, Mare's-tail order.—*Trapa natans,* the water-chestnut, a European plant, yields edible seeds. *T. bicornis* is the ling of the Chinese, used for food. The seeds of *T. bispinosa* are eaten in India.

Cucurbitaceæ, Gourd order.—*Bryonia alba,* a European plant, and *B. dioica,* a British plant, afford pot-herbs in their young shoots. *Cucumis sativa,* the common cucumber; *C. melo,* the melon—both of uncertain origin. *Cucurbita citrullus* the water-melon of the south of Europe. *C. maxima,* the red gourd. *C. pepo* or *Benincasa cerifera,* the white gourd. *C. ovifera,* the vegetable marrow, from Astracan. *C. pepo,* the pumpkin of the Levant. *Lagenaria vulgaris,* bottle-gourd of the East Indies, the interior of which is eaten. *Sechium edule* yields the fruit called chocho, given to pigs. *Telfairia pedata* has edible seeds the size of chestnuts, with the flavour of almonds.

Papayaceæ, Papaw order.—*Carica papaya,* the papaw tree; the fruit is edible.

Belvisiaceæ, Belvisia order.—The pulp of the fruit in this order is edible.

Passifloraceæ, Passion-flower order.—*Paropsea edulis* is of Madagascar. *Passiflora quadrangularis,* the West Indian granadilla. *P. maliformis, P. edulis, P. laurifolia,* yield fruit for the dessert. *Tacsonia mollissima* and *T. tripartita* have edible fruits.

Portulacaceæ, Purslane order. — *Claytonea tuberosa* has a tuberous root eaten in Siberia. *C. perfoliata* is a pot-herb in North America. *Portulaca oleracea,* purslane, a long-known esculent vegetable, antiscorbutic.

Mesembryanthemaceæ or *Ficoideæ,* Fig-marigold order.—*Lewisia rediviva;* the farinaceous root is eaten in Oregon. *Mesembryanthemum edule,* the Hottentots' fig, has esculent leaves; other species are pot-herbs.

Tetragoniaceæ, Tetragonia order.—*Tetragonia expansa* is used as spinage in New Zealand.

Cactaceæ, Cactus order.—*C. melocactus* quenches thirst. *Opuntia vulgaris,* prickly pear. *Pereskia aculeata,* the Barbadoes gooseberry.

Grossulariaceæ, Gooseberry order.—*Ribes grossularia,* the gooseberry; *Ribes nigrum,* the black currant; *Ribes rubrum,* the red currant.

Hydrangeaceæ, Hydrangea order. — Of hydrangea some species are used as tea.

Hamamelidaceæ, Witch-elm order.—*Hamamelis Virginica* furnishes oily edible seeds.

Umbelliferæ, or *Apiaceæ,* Umbelliferous order.—Umbelliferous plants used as esculents: *Anesorhiza capensis* is a Cape esculent; *Anthriscus cerefolium* (formerly *Chærophyllum sativum*), garden chervil, is cultivated in gardens for the leaves, which are used in soups and salads. The *Anthriscus sylvestris* (formerly *Chærophyllum sylvestre*), wild-beaked parsley, called also smooth cow-parsley, a very abundant wild plant, has poisonous roots, yet the leaves are occasionally used as a pot-herb, and are much liked by cows. On this latter point, however, there are some contradictions among authorities, even among such as cannot be suspected of having confounded this plant with some other umbelliferous plant. Linnæus says that horses, sheep, and goats are not fond of it, and that cows and swine refuse it. Villars says horses will not eat it even in the stable ; and Miller says that few animals care to eat it except the ass. On the contrary, Ray says that it got the name cow-weed (it is called also wild cicely) because it is a grateful food to cows in spring before it runs up to stalk ; and Wainwright says that about Dudley, when a pasture is overrun with this plant, as is often the case there, cows are known to like it so well that they are turned into the field to eat it up. As the plant is very abundant in most districts of this island, it were well that these contradictions were cleared up. Rabbits are known to be very fond of the leaves of this plant. *Apium graveolens,* a plant which grows wild in this country, and is called smallage or wild celery. It is the origin of the garden celery, but the garden celery must be produced from this wild plant in warm climates, and then brought to the gardens of this country. *Arracachia esculenta* (Santa Fe) has esculent roots, superior to parsnips. *Bunium flexuosum* (formerly *B. bulbocastanum*), earth-nut. The roots are farinaceous and sweet, and said to be very nourishing. They are said to be excellent when boiled or roasted. Pigs are said to grow fat upon them. *B. ferulaceum* has tubers eaten in Greece. *Carum bulbocastanum,* pig-nut, is quite wholesome. *Crithmum maritimum,* samphire, a native of our sea-shores. Its seeds resemble grains of barley. It is used in salads as a pickle, and even as a pot-herb. *Daucus carota,* carrot. The carrot grows wild abundantly in this country. The best varieties of the garden carrot are the early Horne or Dutch, the orange-red carrot, and the Altringham, or large orange carrot. The long white carrot is of delicate flavour, but does not keep well. Carrot-seeds do not retain their vegetative power more than a year. The carrot is an aliment of the greatest value in the feeding of horses, oxen, sheep, swine, and deer. One of the difficulties in raising a field-crop of carrots is to fence the land properly against the depredations of hares and rabbits. The carrot, besides, requires a deep and mellow soil. When boiled with milk and barley-meal, carrots are said to form excellent food for packs of hunting-dogs. The white Belgian carrot is now established as the best for field-crops.

COMPOSITION OF WHITE BELGIAN CARROT, BY PROFESSOR VOELCKER.

DRY.

Organic matters containing nitrogen (flesh-forming principles), ...	5.081
Substances free from nitrogen (heat and fat producing substances), ...	88.629
Inorganic matters, ash, ...	6.290
	100.000

PROXIMATE PRINCIPLES.

	Fresh.	At 212° Far. Dry.
Water, ...	87.338	—
Cellular fibre, . . .	3.471	27.412
Inorganic matters attached to the fibre, ...	0.145	1.145
Sugar, ...	6.544	51.628
Salts soluble in alcohol, . .	0.409	3.230
Gum and pectine, . .	0.885	6.989
Inorganic salts insoluble in alcohol,	0.293	2.314
Soluble caseine, . . .	0.498	3.934
Insoluble proteine compounds, .	0.169	1.334
Oil, ...	0.203	1.604
Nitrogen in the state of ammoniacal salts, ...	0.008	0.063
	99.959	99.653

ASH, BY PROFESSOR WAY.

Organic matter,	93.820
Ash,	6.180

Silica,	1.19
Phosphoric acid,	8.55
Sulphuric acid,	6.55
Carbonic acid,	17.35
Lime,	8.83
Magnesia,	3.96
Peroxide of iron,	1.10
Potash,	32.44
Soda,	13.52
Chloride of sodium,	6.51
	100.00

Eryngium campestre, field-eryngo ; *Eryngium maritimum,* sea-holly. The leaves of the *E. campestre* are eaten like asparagus in Sweden. The roots of both are mixed with the corn given to stallions as a restorative.

Fœniculum vulgare, fennel. The buds and leaves of fennel are used in salads and sauces. *F. inochio,* or Florence fennel, has more succulent stems, and answers well in soups, and with macaroni and parmesan. *F. capense* is a Cape esculent.

Haloscias (*Ligusticum*) *Scotticum,* Scottish lovage. *H. Scotticum* and *H. levisticum* are sometimes used as pot-herbs or as ingredients in salads.

Œnanthe pimpinelloides has wholesome tubers.

Pastinaca sativa, parsnip. The parsnip is now less cultivated in this country than it seems to have been before the Reformation, when it was an agreeable accompaniment to dried fish in Lent. Parsnips with salt cod are still universal throughout England on Ash Wednesday ; and it is reported that parsnips begin to be commonly eaten with the winter store of dried fish in the western and northern islands of Scotland. It is certain that parsnips are among the oldest inmates of the kitchen garden in England. Miller, gardener to the Apothecaries' Company at their Chelsea garden in the last century, says: "These roots are sweeter than carrots, and are much eaten by those who abstain from animal food in Lent, or eat salt fish on fast-days. They are highly nutritious. In the north of Ireland they are brewed instead of malt with hops, and fermented with yeast. The liquor thus obtained is agreeable. Hogs are fond of these roots, and quickly grow fat with them." Old Gerarde, the author of the 'Herbal,' who died at the end of Queen Elizabeth's reign, says, "There is a good and pleasant food or bread made of the roots of parsnips, as my friend Master Plat hath set forth in his book of experiments." Miller says, besides, "With attention to the soil, the season for sowing, cleaning, and earthing the plants, and raising the seed from the largest and best parsnips, there is no doubt but the crop would answer much better than a crop of carrots. They are equal to them, if not superior, in fattening pigs; for they make the flesh whiter, and the animals eat them with more satisfaction. Clean washed and sliced among bran, horses eat them greedily, and thrive with them; nor do they heat horses, or, like corn, fill them with disorders."

"In France and our islands adjoining to it parsnips are held in high esteem both for cattle and swine. In Brittany this crop is said to be little inferior in value to wheat. Milch cows fed with it in winter give as much and as good milk, and yield butter as well-flavoured, with parsnips as with grass in May and June."

It is doubtful, however, if the climate of Scotland be well suited for parsnips as a crop; and it is alleged that though parsnips have the property of making horses sleek and fat, they are observed when under parsnips to sweat profusely. It is further affirmed that, under both parsnips and carrots, horses are subject to inflammation of the eye, and to the complaint termed a watery eye.

COMPOSITION OF PARSNIPS, BY PROFESSOR VOELCKER.

Dried in the water-bath, the fresh root lost 31.78 per cent of water. The average proportion of water seems to be 82.05 per cent.

In the dried state 5.16 per cent of ash was left.

Fresh parsnips contain 0.21 of nitrogen, or 1.31 per cent of proteine compounds.

COMPOSITION OF FRESH PARSNIP.

Water, ...	82.050
Inorganic matter (ash), ...	0.932
Nitrogenised organic substances capable of producing flesh, ...	1.280
Substances free from nitrogen, and fitted for the support of animal heat and the formation of fat, ...	15.738
	100.000

PARSNIPS, DRIED AT 212° FAHRENHEIT.

Nitrogenised substances capable of producing flesh, ...	7.27
Substances not containing nitrogen, fitted for the support of animal heat and the formation of fat, ...	87.54
Inorganic matters (ash), ...	5.19
	100.00

Thus parsnips contain 6 to 8 per cent less water than turnips, and 5 to 6 per cent less than mangolds. The quantity of flesh-forming substances in fresh parsnips is about the same as that contained in turnips. In a dried state, however, turnips are richer in proteine compounds than parsnips.

PROXIMATE PRINCIPLES.

	Fresh.	Dry.
Water, ...	82.045	—
Cellular fibre, . . .	8.022	44.671
Ash united with the fibre, .	.208	1.159
Insoluble proteine compounds, .	.550	3.060
Soluble caseine, . . .	.665	3.704
Gum and pectine, . .	.748	4.166
Salts insoluble in alcohol, .	.455	2.535
Sugar, ...	2.882	16.055
Salts soluble in alcohol, . .	.339	1.888
Ammonia in the state of ammoniacal salts, . . .	.033	.184
Starch, ...	3.507	19.537
Oil, ...	.546	3.041
	100.000	100.000

ASH, BY DR RICHARDSON.

Potash, ...	56.12
Soda, ...	3.11
Magnesia, ...	9.94
Lime, ...	11.43
Phosphoric acid, . . .	18.66
Sulphuric acid, . . .	6.50
Silica, ...	4.10
Phosphate of iron, . . .	3.71
Chloride of sodium, . . .	5.54
	119.11

Professor Voelcker remarks further: "By moistening a transverse section of the root of parsnip with tincture of iodine, the external layers are coloured deep violet-blue, whilst the remaining portion of the root is not discoloured. By this means three distinct circles can be distinguished on a transverse section of parsnip—one interior, formed by the heart of the root; an exterior, coloured deep violet-blue by the production of iodide of starch; and an intermediate circle between the heart and the exterior blue-coloured zone. This shows distinctly that starch does not exist in the heart nor in the layers next to it, but that it is all deposited in the external layers of the root."

"On further examination of these three sections of the root, I have also found that the intermediate layers contain much more proteine compounds than either the heart or the outer layer where the starch is deposited. The intermediate portions between the heart and the outer layers, indeed, contained, in this instance, one-half more flesh-forming constituents than the other portions of the root, as will be seen from the following determinations :—

	Outer layers.	Heart.	Intermediate layers.
Percentage of nitrogen, .	1.039	1.067	1.500
Equal to—			
Proteine compounds, .	6.493	6.668	9.375"

The parsnips employed in the foregoing analyses by Voelcker were grown on the farm attached to the Royal Agricultural College, Cirencester, the soil being calcareous, rather strong, but by no means deep.

Prangos pabularia, a herbaceous plant inhabiting the arid plains of southern Tartary, has a great reputation as a sheep-food, which Dr Lindley says it appears not to deserve.

Petroselinum sativum (formerly *Apium petroselinum*), parsley. Parsley is a biennial plant, said to be a native of Sardinia. The varieties are the common, the curled-leaved, and the Hamburg, the last of which is cultivated for the sake of its tuberous roots. The curled-leaved is the most ornamental, and it possesses the advantage of being readily distinguished from the poisonous *Æthusa cynapium*, fool's-parsley, which does considerably resemble the common parsley. The tuberous roots of the Hamburg parsley are to be taken up in the beginning of November, and stored in sand.

Parsley, by distillation, affords a small portion of essential oil.

Both herb and root give an agreeable flavour to soups and stews. The roots, after July, may be boiled and eaten like young carrots, and are found by some very palatable. The chemical composition of parsley has not hitherto attracted much attention. It is recommended to be sown in sheep pastures as a means of preventing red water and rot.

Parsley is so great a favourite with hares and rabbits that they come long distances in quest of it, and if the ground is not guarded where these animals abound the crop will soon be destroyed.

Sium sisarum, skirret. Skirret is a native of China, now seldom seen in our gardens. Its tubers are used like parsnips. When boiled and eaten with butter, or boiled and then fried with butter, they are sweet and agreeable. It is a perennial, and may be propagated by separating the roots in spring, but it succeeds best by annual sowings, which may be made in April. The skirret was formerly in greater request than at present. It was cultivated in Gerarde's time. The roots were eaten boiled and stewed with pepper and salt, or rolled in flour and fried, or else cold after being boiled along with oil and vinegar.

Smyrnium olusatrum, alexanders. This plant was formerly eaten in this country and other parts of Europe, both as a salad and as a pot-herb. Alexanders is corrupted from *Olusatrum*, and *Olusatrum* is *Olus nigrum*, the black pot-herb, owing to the dark colour of its foliage. It is indigenous.

Araliaceæ or *Hederaceæ*, Ivy order.—*Casimiroa edulis*, Zapote blanco, an edible Mexican fruit.

Dimorphanthus edulis affords the Chinese edible young shoots of much delicacy.

Cornaceæ, Cornel order.—*Cornus*, dogwood, several species of which produce fruit which is eaten. *Cornus mascula*, the Cornelian cherry, was formerly much used to make tarts and a *rob de cornis* which was kept in the shops. It is frequent in shrubberies. *Cornus suecica*, the dwarf cornel, produces berries with a sweet watery taste acceptable to children; they are supposed to be tonic, and to cause appetite, hence their name in the Highlands, *lus-a-chrasis*, plant of gluttony. It is often called the dwarf honeysuckle. The wood of *Cornus sanguinea*, the green-barked variety of the common dogwood, is much sought after, owing to the freedom of its charcoal from ash, for the manufacture of gunpowder.

2. *Monopetalæ* or *Gamopetalæ*: *Caprifoliaceæ*, Honeysuckle order.—*Sambucus nigra*, common elder. The berries are used to make a kind of wine. It is said that in Portugal, colour is sometimes given to port wine with its berries. The bark has been prohibited from being used in the vineyards. Blackbirds are very fond of the berries.

Cinchonaceæ, Cinchona order.—*Coffea Arabica*, coffee-tree. The hard albumen of the seeds furnishes the well-known beverage. The endocarp, which encloses two seeds, is called the parchment of the coffee. Coffee contains a bitter principle, caffeine, which is identical with theine.

Coprosma microphylla yields the fruit called native currants in Australia.

Genipa.—Species of this genus yield edible fruits.

Galinaceæ or *Stellatæ*, Madder order.—*Galium aparine*, goose-grass, or cleavers, which grows in every hedge, has an albumen in the seed, employed as a substitute for coffee.

Valerianaceæ, Valerian order.—*Valerianella olitoria*, called also *Fedia olitoria*, lamb's-lettuce, and corn-salad. It was formerly cultivated in this country as well as in France and the adjacent countries, being prized for its early appearance, so as to afford a supply of fresh vegetable in Lent. It was called lamb's-lettuce apparently because it flowers in the lambing season. It is only when young that its flavour is tolerable to most people.

Compositæ, Composite order. Sub-orders: 1. *Cichoraceæ*, Chicory or Lettuce order.—*Cichorium intybus*, chicory or wild succory, is the plant the roots of which are so much employed as a substitute for coffee. It is a deep-rooting perennial. It flowers in July. It grows in rich soils, and yields a great bulk, both of root and stem foliage, of which cattle are exceedingly fond. It is much grown in England for the sake of the roots.

Cichorium endivia is the endive, or garden succory, the leaves of which when etiolated are used in salads.

Lactuca sativa is the garden lettuce.

Leontodon taraxacum, common dandelion. It has been recommended as a winter salad, blanched like endive; but it possesses too much bitter principle to render it fit for table under any management. The tender leaves in spring, used in compound salads, are equal to those of endive or succory. The roots, which are fusiforum, abound in a milky juice, and are eaten raw as a salad by the French, and boiled by the Germans like salsify and scorzonera. Dried and ground to powder, they afford a substitute for coffee, in all respects equal to that of chicory roots. Swine are fond of it, and goats will eat it; but sheep and cows dislike it, and by horses it is refused.*

Scorzonera Hispanica, garden scorzonera or viper's grass. The root is carrot-shaped, about the thickness of one's finger, tapering gradually to a fine point, and thus it bears some resemblance to the body of a viper, against the bite of which the plant has a reputation in Spain. The outer rind being scraped off, the root is steeped in water, in order to abstract a part of

* Loudon, 'Encyclopædia of Plants,' p. 671.

its bitter flavour. It is then boiled or stewed in the manner of carrots or parsnips. The roots are fit for use in August, and continue good till the following spring. Its culture is the same as that of carrot or salsify. This plant was cultivated by Gerarde.

Tragopogon porrifolius, salsify. This plant has a long, tapering, fleshy, white root, which is used like carrots or parsnips, and cultivated in gardens for that purpose. The flavour of the root is mild and sweetish. Dressed like asparagus, there is some resemblance in taste. It is less frequently grown in British gardens than formerly; it still is popular in France and Germany. It is raised and treated in all respects similarly to the carrot. The *Tragopogon pratensis,* which is a common wild plant throughout Britain, is said to answer equally well, and to have been formerly preferred. Gerarde and Parkinson cultivated the salsify, but most probably only for the flowers; but they recommend the common yellow goat's-beard for food. Miller says the common yellow sort, whose shoots are sold in the market, will be fit for use in April or May, according to the forwardness of the season. The best time to cut them is when their stems are about 4 inches long; for if they stand too long, they are never so tender as those which are cut while young. These stems are designed to be dressed for the table like asparagus.

This common goat's-beard is not uncommon in Britain among grass. As the flower closes some hours after sunrise, it is apt to escape attention after 10 or 11 o'clock of the day. It has had many popular names; among others buck's-beard, go to bed at noon, &c.

The roots of such a plant can hardly have remained unknown to some of the inferior animal creation.

Sonchus oleraceus, sow-thistle. The *Sonchus oleraceus* is a favourite food with hares and rabbits, and is said to be eaten by goats, sheep, and swine, but not to be relished by horses. The young tender leaves are in some countries boiled and eaten as greens, and it is even asserted that the tender shoots of the smooth variety, boiled in the manner of spinage, are superior to any greens not in common use. Nearly the same thing may be said of *S. arvensis, S. palustris,* and other species.* *S. tenerrimus,* a native of the south of Europe, is eaten by the common people in Italy as a salad.

Hypochæris radicata is a very common plant in Britain. *H. glabra and H. hispida* are less common. *H. radicata,* or long-rooted cat's-ear, has long roots, which, like the roots of the other species, are eaten by pigs with avidity. The name *Hypochæris* indeed signifies for pigs.

2. *Cynarocephalæ,* Artichoke or Thistle order.—*Arctium lappa,* the burdock. The burdock is common over the whole of the Old World. Few quadrupeds, except the ass, will eat the plant, but birds feed on the seeds, and snails and caterpillars on the leaves. The stems, stripped of their rinds before the flowers appear, may be eaten, either boiled or raw, with oil and vinegar. *Carduus marianus,* the milk-thistle ; *C. nutans,* the musk-thistle ; *C. acanthoides,* welted thistle ; *C. tenuifolius,* the slender-flowered thistle, are natives of Britain.

The foot-stalks of the leaves of most or all of the species of this and the allied genera might be eaten in the manner of cardoons if similarly blanched. The dried flowers of *C. arabicus* and *C. nutans* will curdle milk. The seeds of all the species of *Serratula, Cnicus, Onopordum,* and similar genera, are greedily eaten by small birds, especially the finches.

Cynara scolymus, the common artichoke, is a native of the south of Europe. Owing to the moisture of our climate, it thrives with us better than in its native country. It bears

* Loudon, 'Encyclopædia of Plants,' pp. 668, 669.

drought well. In the very dry summer of 1826, it is said to have been the only vegetable procurable in the neighbourhood of Paris for several weeks. Once in the seventeenth century, and again in 1739, nearly all the artichokes in Britain were destroyed by frost, and had to be replaced from France. Several varieties are in cultivation. The parts used are the lower portion of the leaves of the calyx, the fleshy receptacle of the florets, freed from bristles and seed-down, vulgarly called the choke, and sometimes the tender central leaf-stalk, in a blanched state like the cardoon. *Cynara carduncuIus,* the cardoon. It also is a native of the south of Europe. The edible part or chard is composed of the blanched and crisp stalks of the inner leaves. Besides the common sort, there is the Spanish cardoon and the cardoon of Tours, a prickly variety, much used on the Continent. *Cnicus* is termed generally the horse - thistle. *Cnicus arvensis* is the chief of the troublesome weeds known as thistles. *C. palustris* is a native species, the tender stalks of which, as of most species, being peeled, are eatable either raw or boiled. *C. oleraceus,* which is not a native of this country, is not eaten by cattle, but the Russians are said to boil the leaves in spring, and eat them as coleworts. The tender stalks of *C. cernuus* are used in Siberia. The *C. canus,* a native of Austria, has fleshy white roots like the skirret, and may be dressed and eaten in the same manner. The following passage occurs in Loudon : " Some English botanists seem doubtful if horses and cows will eat the common corn or way horse-thistle (*Cnicus arvensis*) ; but those who know anything of the history of agriculture in Scotland will recollect that, before the introduction of naked fallows and turnips, it formed the suppering of housed cattle during five or six weeks of every summer." The ass, as every one is aware, knows no better food than thistles. To the genera *Onopordum* and *Carlina* similar observations apply.

3. *Corymbiferæ*, Chamomile order.—*Achillæa millefolium*, common milfoil or yarrow, is a fibrous-rooted perennial. It flowers in June and July, and at times in the later months. It grows in sandy downs, by waysides, and in waste places. It is an astringent, and is greedily sought after by sheep. It is recommended to be sown for warrens or light sandy downs to the extent of ½ lb. per imperial acre. A bushel of the seed averages 29¼ lb., and the number of seeds in an ounce reaches 200,000.

The following analysis of yarrow is given by Mr Way:—

Albuminous or flesh-forming principles, .	10.34
Fatty matters, ...	2.51
Heat-producing principles, starch, gum, sugar, &c.,	45.46
Woody fibre, ...	32.69
Mineral matter or ash, ...	9.00
	100.00

An essential oil can be obtained from the flowers.

Miller says this plant is commonly execrated as a troublesome weed, yet sheep are evidently fond of it; and he goes on to make the sensible remark, that in the case of this and many other plants sheep may be led to seek after them not as food but as medicine. *A. moschata* or *Ptarmica moschata,* a native of the southern parts of Europe, the genipi of the Swiss, is a grateful food to cattle. In Savoy it is called *Genipi batard,* the true name, genipi, according to the Savoyards, being applicable to the *Artemisia rupestris,* and even to the *A. spicata* and *A. anethifolia,* all of which are in esteem as medicines. The *Achillæa moschata* or *Ptarmica moschata* is the basis of the aromatic liquor called "Esprit d'Iva."

Artemisia absinthium, wormwood, a native plant hardly nutritive. *A. vulgaris,* common mug-wort, is used in some parts of Sweden instead of hops in malt-liquor. This last plant is readily eaten by cattle and sheep, yet its nutritive property is not established; and other species serve as nourishment to the herds of the Kirghese and Calmucks. *Dahlia variabilis,* a tuberous rooted plant.

Helianthus annuus, common sunflower, affords from 30 to 40 bushels of seeds per acre. These will yield 50 gallons of oil, the refuse will make 1500 lb. of oilcake, and the stalks burnt into ash will afford half a ton of potash.* This crop, however, impoverishes the soil. Some French authorities assert that the leaves, either in a green or dried state, form excellent food for cows, and that they are greedily eaten by them. Poultry are very fond of, and will fatten rapidly on, the seeds.

Helianthus tuberosus (Girasole), the well-known Jerusalem artichoke. This plant is a native of Brazil. The tubers were in use in this country before the potato became common, and that use which had declined has now grown greater perhaps than ever. The plant was introduced into England in the reign of James I., in the year 1621, and so early as 1629 they had become so common that "even the most vulgar began to despise them;" "whereas," as Parkinson says, "when first introduced they were looked on as a dainty for a queen."

COMPOSITION OF JERUSALEM ARTICHOKE, FROM HEMMING'S TABLES.

TUBERS, DRIED AT 212° FAHRENHEIT.

Organic matter,	88.8
Ash,	11.2

ULTIMATE ELEMENTS.

Carbon,	46.0
Hydrogen,	6.2
Oxygen,	46.1
Nitrogen,	1.7
	100.0
Ammonia,	2.06

* Stephens's 'Book of the Farm,' vol. ii. p. 375.

PROXIMATE PRINCIPLES.

Albumen,	4.6
Fat, oil,	0.4
Starch,	14.1
Gum, dextrine, pectine,	5.7
Sugar,	69.5
Fibre and husk,	5.7
	100.0

ASH.

Sand and silica,	1.5
Potash,	55.9
Lime,	3.3
Magnesia,	1.3
Oxide of iron,	0.5
Chloride of potassium,	4.9
Phosphoric acid,	17.0
Sulphuric acid,	3.8
Carbonic acid,	11.8
	100.0

COMPOSITION OF TOPS.

Organic matter,	97.2
Ash,	2.8

ULTIMATE ELEMENTS.

Carbon,	47.0
Hydrogen,	5.6
Oxygen,	47.0
Nitrogen,	0.4
	100.0

Ammonia,	0.48

ASH.

Sand and silica,	17.3
Potash,	6.8
Soda,	3.7
Lime,	40.2
Carry forward,	68.0

	Brought forward,	68.0
Magnesia,		1.9
Oxide of iron,		1.1
Chloride of sodium,		1.8
Phosphoric acid,		0.6
Sulphuric acid,		2.2
Carbonic acid,		24.4
		100.0

Inula helenium, elecampane. It contains the starchy matter called inulin.

Goodeniaceæ, Goodenia order.—Some plants of this order are used as esculent vegetables.

Scævola taccada affords the rice-paper of the Malay Archipelago. Its leaves when young are eaten as pot-herbs.

Madia sativa, a plant recently introduced from Chili into Europe, is allied to the sunflower. Mr Lawson says, "In its native country it has long been cultivated for its oleaginous seeds, the produce of which is deemed by many superior to that of the olive and poppy. Owing to the valuable property belonging to the plant of enduring winter and spring frosts, it may be sown either in autumn or in spring. The crop should be reaped as soon as the earliest seeds acquire a grey colour, and disposed in handfuls to facilitate drying, after which it should be immediately threshed out, as, if stacked in the haulm, the viscid matter which adheres to the foliage would cause fermentation. The seeds should be afterwards washed in warm water, to cleanse them from the same viscid, strong-smelling substance." Professor Lindley says, "*Madia sativa* is a Chilian plant lately introduced with success into the agriculture of the drier parts of Europe. Madia oil, expressed without heat, is described as transparent, yellow, scentless, &c., and fit for salads. Its cake is said to be good for cattle." Mr Lawson concludes some observations on madia thus: "There seems every probability that in ordinarily favourable seasons the madia might be grown very successfully in Scotland."* The culture adapted to the turnip would probably in every respect suit this plant, and the richness of its seed could not fail to prove nourishing food to poultry and pigs.

Campanulaceæ, Harebell order.—*Campanula rapunculus*, the rampion, is used as an esculent vegetable. It is indigenous. The roots are called ramps, and are used now as a salad, or boiled like asparagus, being sometimes eaten hot with sauce, or cold with vinegar and pepper. It is almost out of use in this country, but is much prized in France and Italy. Probably the roots of all the species of *Campanula* which have long, thick, white roots might be used with safety. *Cyphia glandulifera* has farinaceous tubers, which are eaten in Abyssinia. The tubers of the *C. digitata* are used by the Hottentots.

Styracaceæ or *Symplocaceæ*, Storax order. — *Symplocas Alstonia* is sometimes used as tea.

Vacciniaceæ, Cranberry order. — *Oxycoccus palustris* (*Vaccinium oxycoccus*) yields the cranberry, a native. *Thibaudia*, a genus in the shrubby region of the Andes, some species of which are used as food and to make wine. *Vaccinium myrtillus* is the bilberry or blaeberry. *V. Vitis Idæa*, the red whortle-berry or cow-berry, a substitute for the cranberry. *V. uliginosum*, the black whortle-berry of the Highlands of Scotland.

Sub-class *Corollifloræ*. — *Hypostamineæ*. *Epacridaceæ*, Epacris order.—*Astroloma humifusum* is called the Tasmanian cranberry. *Leucopogon Richei* is one of the plants called in Australia native currants.

Epicorollæ or *Epipetalæ*. *Ebenaceæ*, Ebony order.—*Dyo-*

* Lindley, 'Vegetable Kingdom,' p. 707. Lawson's 'Agriculturalist's Manual,' Supplement, p. 383. See also Stephens's 'Book of the Farm,' vol. ii. pp. 105, 106.

spyros kaki affords an edible plum-like fruit, called in Japan keg-fig. *D. Virginiana,* the persemmon, has an austere fruit, becoming sweet as it ripens, and more especially after frost.

Sapotaceæ, Sapodilla order. — *Achras sapota* gives the edible sapodilla-plum; *A. mammosa,* the fruit called marmalade. *Bassia butyracea* has an oily fruit, affording a kind of butter in Nepal. Another species affords the Shea or Galam butter of Mungo Park. *Bassia latifolia,* the mahoua, yields flowers used as food and for the distillation of spirits. From a single tree 200 lb. to 400 lb. of flowers are collected. *B. longifolia* affords an oil fit for lamps. *Chrysophyllum cainito* is the star-apple of intertropical climates; other species supply fruit for dessert. *Mimusops elengi* affords an excellent edible fruit; other species have edible fruit.

Myrsinaceæ, Myrsine order.—*Theophrasta Jussiæi* supplies flour for bread in St Domingo. The fruit of *Myrsine Africana* is mixed with barley for the food of asses in Abyssinia.

Oleaceæ, Olive order.—*Olea Europæa,* from the drupaceous fruit of which is expressed olive-oil. The fruit of the olive belongs to the dessert. A sweet variety is known in some southern countries. The marc, or residue after the expression of oils of various degrees of purity, seems finally to become valueless. *Olea fragrans* in China is said to be employed both to flavour and adulterate tea.

Salvadoraceæ, Salvadora order.—The *Salvadora Persica* seems to be the mustard-tree of Scripture. Its fruit tastes like garden-cress. *S. Indica* has edible fruit.

Asclepiadaceæ, Milk-weed order. — *Gymnema lactiferum* is the milk-yielding tree called cow-plant in Ceylon.

Apocynaceæ, Dogbane order. — *Roupellia grata* produces what is called cream-fruit in Sierra Leone. *Tabernæmontana utilis* is the cow-tree of Demerara, the milky juice of which is nutritious.

Gesneraceæ, Gesnera order.—Natives chiefly of the warm regions of America. The succulent fruits are occasionally edible.

Cordiaceæ, Sebesten order.—The drupes of *Cordia Myxa* and *C. latifolia* are called sebesten plums, and are used as food.

Boraginaceæ, Borage order.—The leaves of borage were formerly employed in cookery or as salads, the flowers in cup and cool tankards. *Mertensia maritima,* a sea-shore plant, has leaves which taste like oysters. *Symphytum asperrimum,* a native of the Caucasus, has been cultivated in Britain as forage. It is particularly nourishing to pigs.

Solanaceæ, Potato order.—*Capsicum,* the genus from which the red peppers come. *Lycopersicum esculentum* affords the tomato or love-apple for sauces. *Physalis Peruviana* yields the edible Peruvian winter cherry. *Puneeria coagulans,* the Puneer plant of Khorassan, to coagulate milk and make cheese.

Solanum tuberosum, potato. The agriculture of the potato does not fall within our plan. It will be enough to indicate its fitness for the food of man and the farm animals by reference to its chemical composition.

COMPOSITION, TAKEN FROM HEMMING'S TABLES.

TUBER, DRIED AT 212° FAHRENHEIT.

Organic matter,	96.0
Ash,	4.0

ULTIMATE ELEMENTS.

Carbon,	45.9
Hydrogen,	6.1
Oxygen,	46.4
Nitrogen,	1.6
	100.0

Ammonia,	1.94

PROXIMATE PRINCIPLES.

Albumen, gluten, caseine,	5.8
Fat, oil,	1.0
Starch,	64.2
Gum, dextrine, pectine,	2.2
Sugar,	13.5
Fibre and husk,	13.3
	100.0

ASH.

Total sulphur,	0.094	
Sand and silica,		1.7
Potash,		43.1
Soda,		3.2
Lime,		1.7
Magnesia,		3.2
Oxide of iron,		0.4
Chlorides of potassium and sodium,		4.7
Phosphoric acid,		8.5
Sulphuric acid,		15.2
Carbonic acid,		18.3
		100.0

COMPOSITION OF POTATO HAULM.

Organic matter,	85.0
Ash,	15.0

ULTIMATE ELEMENTS, DRIED AT 212° FAHRENHEIT.

Carbon,		54.5
Hydrogen,		6.2
Oxygen,		36.6
Nitrogen,		2.7
		100.0
Ammonia,	3.27	

PROXIMATE PRINCIPLES NOT GIVEN.

ASH.

Sand and silica,	37.4
Potash,	2.5
Soda,	1.3
Lime,	36.1
Magnesia,	6.0
Oxide of iron,	1.4
Chlorides of potassium and sodium,	2.8
Phosphoric acid,	7.2
Sulphuric acid,	5.3
	100.0

Solanum melongena and *S. ovigerum* produce edible fruits known as egg-apples. The berries of *S. nigrum* are edible; those of *S. Quitöense* are eaten under the name Quito oranges. The fruit of *S. laciniatum* is eaten in Australia under the name of kangaroo-apple.

Labiatæ or *Lamiaceæ*, Dead-nettle order.—*Salvia officinalis*, sage, and many other plants of this order, are used in cookery, owing to their flavour.

Mentha, Mint.—The common mint, *Mentha arvensis*, is used with vinegar and sugar as an acceptable sauce with lamb. Hogs greedily seek for and devour the roots of all the mint tribe.

Primulaceæ, Primrose order.—*Cyclamen Europæum*, and other species, are called sow-bread, on account of their tubers being eaten by swine.

Plantaginaceæ, Plantain or Rib-grass order.—*Plantago lanceolata*, common plantain or rib-grass, a fibrous-rooted perennial; it flowers in May and June. It grows in dry pastures and cultivated ground; formerly much, and still occasionally, sown in upland pastures, although with questionable propriety, or only admissible to a very limited extent on improved moorlands.* Sheep are fond of its leaves in pasture.

* Lawson on 'Cultivated Grasses,' &c.

COMPOSITION OF RIB-GRASS PLANTAIN (*Plantago lanceolata*), GATHERED MAY 28.

Water,	84.78
Albuminous or flesh-forming principles,	2.18
Fatty matters,	0.56
Heat-producing principles, starch, gum, sugar, &c.,	6.06
Woody fibre,	5.10
Mineral matter or ash,	1.32
	100.00

A great contrariety of opinion exists among authorities as to the utility of rib-wort plantain as a forage plant.

Sub-class *Monochlamydeæ* or *Apetalæ*. *Amaranthaceæ*, Amaranthus order.—*Amaranthus oleraceus*, and some other species, are cultivated as pot-herbs.

Chenopodiaceæ, Goose-foot order.—*Beta vulgaris*, the beet. *Beta vulgaris* (*campestris*), mangold-wurzel.

COMPOSITION OF MANGOLD-WURZEL.

BULBS, DRIED AT 212° FAHR.

Organic matter,	93.7
Ash,	6.3

ULTIMATE ELEMENTS.

Carbon,		45.7
Hydrogen,		6.2
Oxygen,		46.3
Nitrogen,		1.8
		100.0
Ammonia,	2.18	

PROXIMATE PRINCIPLES.

Albumen,	0.7
Caseine,	2.3
Gum, dextrine, pectine,	3.0
Sugar,	73.0
Fibre and husk,	21.0
	100.0

ASH.

Total sulphur,	0.058	
Sand and silica,		2.6
Potash,		24.8
Soda,		13.8
Lime,		2.0
Magnesia,		2.1
Oxide of iron,		0.6
Chloride of sodium,		29.4
Phosphoric acid,		3.1
Sulphuric acid,		3.3
Carbonic acid,		18.3
		100.0

COMPOSITION OF MANGOLD TOPS.

Organic matter,	80.2
Ash,	19.8

ULTIMATE ELEMENTS.

Carbon,		48.6
Hydrogen,		6.5
Oxygen,		39.2
Nitrogen,		5.7
		100.0
Ammonia,	6.90	

NO PROXIMATE PRINCIPLES GIVEN.

ASH.

Total sulphur,	0.502	
Sand and silica,		2.0
Potash,		21.3
Soda,		7.0
Lime,		8.6
Magnesia,		8.7
Oxide of iron,		1.0
Chloride of sodium,		34.0
Phosphoric acid,		5.1
Sulphuric acid,		5.8
Carbonic acid,		6.5
		100.0*

* For further information on mangold-wurzel, see Stephens's 'Book of the Farm,' vol. ii. p. 90-94.

Chenopodium quinoa is a Peruvian plant, the seeds of which are used as food. The meal prepared from them is said to be very nutritious.

C. bonus Henricus, English mercury, mercury goose-foot, or Good King Henry, all-good and wild spinage. This plant was formerly cultivated, as it still is in some gardens, as a perennial spinage, since it is hardy and of early growth. *C. album* is the most common of the species in this island, and used to be boiled and eaten as greens. *C. maritimum*, also native, is by many held to be the most suitable for food. Probably nearly all the species are edible. Pigs are very fond of *C. album*, yet Linnæus says, what is very improbable, that *C. murale* and *C. hybridum* are fatal to that animal.

Atriplex portulacoides, shrubby orache or sea-purslane, and *A. hortensis*, have been used as food. *A. portulacoides* requires a poor, gravelly soil, though it thrives best on the sea-shore and in salt marshes. *A. hortensis* is sometimes called mountain-spinage, and was formerly cultivated as a culinary herb. It is still grown to a considerable extent in the neighbourhood of Paris, and the leaves gathered as spinage. It is believed that all the species might be used as pot-herbs.

Basellaceæ, Basella order. — Some species of basella are used as spinage. *Melloca tuberosa* has a tuberous root, which in Peru is used as a substitute for the potato.

Phytoloccaceæ, Poke-weed order. — The young shoots of *Phytolocca decandra*, poke or pocan, are eaten as asparagus.

Polygonaceæ, Buckwheat order.—*Polygonum bistorta*, bistort or snake-weed, is a strong astringent, yet the young shoots were formerly eaten in herb-puddings in the north of England, where the plant is known by the name of Easter giant; and about Manchester they are substituted for greens under the name of Patience Dock.* *P. aviculare*, knot-grass or hog-weed, affords seeds in much request among small birds.

* Loudon, 'Encyclopædia of Plants,' p. 326.

The name grass refers to its being eaten by cattle, and hog-weed comes from its being sought after with great avidity by swine. It is said that all domestic quadrupeds eat the knot-grass. In short, the seeds, though very small comparatively, are said to possess all the valuable properties of buckwheat.

Polygonum fagopyrum, or *Fagopyrum esculentum*, yields buckwheat. The name is thought to be properly beechwheat, as the old specific name indicates, its grain being like the mast of beech. Buckwheat is supposed to be a native of Asia; and in China and other countries of the East it is cultivated as a bread-corn. It does not suit well with the severity of our winter or the frosts of spring. It was at one time largely imported into this country. The plant is an annual, and flowers very soon after it is out of the ground. The flowers continue to blow and bear seed in succession till the frost destroys the plant. The flour is used in cookery and bread-making in various parts of Europe, and to make cakes and crumpets in England, and as rice or groats in Germany and Poland. The seed is considered to be excellent for horses and poultry and pheasants, the flowers for bees, and the green plant for soiling cattle, sheep, or swine. As an agricultural plant it is valuable, as standing only a short time on the ground; but it produces little straw for manure.*

The composition of the green stems is given as follows:—

Water,	82.5
Starch,	4.7
Woody fibre,	10.0
Sugar,	0.0
Albumen,	0.2
Extractive matter and gum,	2.6
Fatty matters,	0.0
Phosphate of lime,	0.0
	100.0

* Loudon, ibid., p. 327.

COMPOSITION OF THE SEED.

Husk,	26.9
Gluten,	10.7
Starch,	52.3
Sugar and gum,	8.3
Fatty matter,	0.4
	98.6

ASH OF THE SEED.

	Bichau.	Liebig.
Silica,	0.69	0.7
Potash,	8.74	8.7
Soda,	20.15	20.1
Lime,	6.66	6.7
Magnesia,	10.38	10.4
Oxide of iron,	1.05	1.1
Phosphoric acid,	50.17	50.1
Sulphuric acid,	2.16	2.2
	100.00	100.0

P. viviparum, viviparous Alpine bistort. The roots of this species, which is abundant in the Highlands of Scotland, are used by the Esquimaux for food. *Rheum undulatum* and *Rheum hybridum,* and their varieties, are those chiefly cultivated for the sake of the petioles of the leaves, which are used for jams and tarts.. *Rumex patientia* and *R. sanguineus* were formerly used as spinage plants. The former is still eaten on the Continent, and, mashed with a small proportion of *R. acetosa* or *R. scutatus,* it makes a very good spinage. *R. obtusifolius* is the common well-known dock. It is refused by cattle. *R. acetosa,* common sorrel, has been long cultivated in gardens for its leaves as spinage and salad. *R. scutatus,* called French sorrel, is much more delicate. In Ireland sorrel is eaten with fish and other alkalescent food. All domestic cattle eat this and most other species (the common dock excepted) of the genus.

Lauraceæ, Laurel order.—Besides cinnamon and other aromatic plants, this order contains the *Persea gratissima,* the avocado or alligator pear of the West Indies. The fruit is the size of a large pear, and is in universal esteem. When plentiful, even the domestic animals share in this delicacy. It seems to be equally agreeable to the horse, the cow, the dog, and the cat, as well as to all sorts of birds.

Santalaceæ, Sandal-wood order. — *Fusanus acuminatus* yields the quandang nut, which is edible. *Pyrularia oleifera* has a nut, from which a fixed oil is extracted.

Empetraceæ, Crowberry order. — *Empetrum nigrum,* the crowberry, affords a refreshing fruit.

Euphorbiaceæ, Spurge-wort order.—*Janipha manihot,* or *Manihot utilissima,* is the cassava or manioc plant. Its root contains much starchy matter (see p. 326). Tapioca is from the same origin.

Urticaceæ, Nettle order.—Of *Urtica* some species produce esculent tubers. The tops of the tender shoots of *Urtica dioica* are occasionally put into soup. The leaves are the only food of the caterpillars of three of our most beautiful butterflies—*Atalanta, Paphia,* and *Urticæ*—the principal food of the *Io,* and the occasional food of the *Comma album.* The caterpillars also of the *urticata* and *verticalis* moths feed on it. A great number of other indiscriminate feeders devour its foliage, and the bases of the leaves in autumn are frequently disfigured by tubercles which contain small maggots, probably producing *Musca urticæ.**

Humulus lupulus, the hop, belongs to this order, as well as the *Cannabis Indica,* which affords the Indian bang.

Artocarpaceæ, Bread-fruit order.—(1.) *Artocarpeæ,* edible fruits and virulent poisons. *Artocarpus incisa,* the bread-fruit tree. *A. integrifolia,* the jak or jack-fruit tree, less esteemed than the bread-fruit. *Cecropia peltata,* trumpet-wood. The

* Loudon, ibid., p. 783.

leaves are said to be the favourite food of the sloth. *Galactodendron utile,* the cow-tree of South America, the emulsive juice of which is nutritive. (2.) *Moreæ,* mulberries and figs; edible fruits, and caoutchouc the produce. *Ficus carica,* the fruit of which, the common fig, is highly nutritive. *Morus nigra* and several other species afford edible berries. The leaves of the *M. alba* chiefly are used to feed silkworms.

Stilaginaceæ, Stilago order.—*Antidesma pubescens* and *Stilago bunias,* the drupes of which are subacid and edible—natives of the West Indies.

Podostemonaceæ, River-weed order.—Plants having the aspect of mosses or liverworts, chiefly natives of South America. Some of the species are used as food.

Piperaceæ, Pepper order.—Pepper, betel-leaves, cubebs.

Myricaceæ, Gale order.—*Myrica sapida* has a slightly acid fruit, which is edible.

Betulaceæ, Birch order.—From the saccharine sap of the *Betula alba* a species of wine is made.

Corylaceæ or *Cupuliferæ,* Hazel order.—*Castanea vulgaris,* Spanish chestnut; the fruit, the common chestnut. *C. Americana* yields a small sweet chestnut. In Germany and Switzerland swine are fed in large numbers in the chestnut forests. *Corylus avellana,* the common hazel. There are many varieties of hazel nut, such as the white and red filbert, the great and clustering cob, and the Barcelona nut. Hazel nuts yield an oil used by watchmakers.

Fagus sylvatica, Common Beech.—Its fruit, called beech-mast, is eaten by pigs. *F. ferruginea,* of North America, has edible fruit.

Quercus robur, English oak.—When England abounded everywhere with oaks, the swine luxuriated in acorns. The *Q. castanea* of North America produces large edible acorns.

Juglandaceæ, Walnut order.—*Carya alba,* the common hickory-tree of America, produces an eatable nut. *C. olivæformis* yields the peccan-nut, which in America is used like the walnut.

Juglans regia, the well-known walnut-tree. *J. cinerea* gives the butter-nut of Canada.

Coniferæ or *Pinaceæ,* Coniferous or Pine order.—*Araucaria imbricata,* from Chili, and *A. Bidwillii,* from Moreton Bay, have edible seeds. *Juniperus communis* yields the well-known succulent cone as fruit called the juniper-berry, which gives flavour to Hollands. *Pinus sylvestris,* the Scotch fir, the inner bark of which yields the bark-bread of Norway. *P. pinea,* the stone-pine, affords edible seeds.

Taxaceæ, Yew order.—*Salisburia adiantifolia,* the yinko, has a resinous fruit, which is used by the Chinese under the name of pa-kwo. The common yew, *Taxus baccata,* is poisonous to cattle, horses, sheep, and deer; as also to the perch.

Gnetaceæ, Jointed Fir order.—The seeds of several of the species are eaten.

Cycadaceæ, Cycas order.—*Cycas revoluta* of Japan has starchy matter in the stem, which is collected and eaten like sago. *C. circinalis,* in the Moluccas, affords a like kind of sago, as well as a gummy exudation resembling tragacanth. *Dion edule,* in Mexico, has starchy seeds, yielding a kind of arrowroot.

Encephalartos is a starch-producing genus. Many of the species afford what is termed Caffre-bread. *E. pungens* has ripened its fruit in England. *Zamia* is also an amylaceous genus. Some of the West India species afford a kind of arrowroot.

Monocotyledonous Plants.—Sub-class *Dictogenæ. Dioscoreaceæ,* Yam order.—The plants of this order, though amylaceous, are apt to be acrid. *Dioscorea sativa, D. alata, D. aculeata,* produce edible tubers, which in the West Indies are known as yams, and used like potatoes. The acrid principle in the yam probably disappears under boiling. *Tamus communis,* black bryony, is an indigenous plant. Its young shoots are occasionally used in the manner of asparagus, but Professor Balfour says they are not safe. *Testudinaria elephantipes* is the elephant's-foot or tortoise plant of the Cape. The Hottentots eat the interior cellular part of its enormous tuberculated stem.

Smilaceæ, Sarsaparilla order.—*Smilax China,* a native of China, but grown in the West Indies, has large roots, which are employed in China both as food and medicine. In the West Indies it is used to feed hogs.

Sub-class *Petaloideæ* or *Floridæ. Hydrocharidaceæ,* Frog-bit order.—Some of the species of *Boottia, Enhalus,* and *Ottilia,* are esculent. *Anacharis alsinastrum* threatens to fill up the streams of this country by its rapid growth.

Orchidaceæ, Orchis order.—*Eulophia vera* and *E. campestris* are Indian orchids, the tubers of which furnish salep. *Orchis mascula, O. morio,* and *O. papilionacea,* also afford salep. The two first are indigenous, the last is of the south of Europe. *Vanilla planifolia* and *V. aromatica* yield vanilla, used in confectionery and in the preparation of chocolate. *Gastrodia sesamoides* has an edible root used by the native tribes in Tasmania.

Zingiberaceæ or *Scitamineæ,* Ginger order. — Aromatic condiments. *Curcuma longa* affords turmeric, which enters into the composition of curry powder. *C. angustifolia* yields a kind of arrowroot in the East Indies. Other species of *Curcuma* afford starch. *Zingiber officinale* is the common ginger. The young rhizome is used as a preserve.

Marantaceæ, Arrowroot order.—Starch prevails throughout the roots of this order. The corms or rhizomes of *Canna coccinea, C. edulis,* and *C. Achiras* all yield starch, some of which is known as "*tous les mois.*" *Maranta arundinacea* affords arrowroot. *M. nobilis, M. Indica, M. allouyia,* and *M. ramosissima* yield the same starchy matter, the last belonging to the East Indies.

Musaceæ, Banana order.—Natives of the intertropical parts of both the Old and the New World, the produce of the genus *Musa* being one of the most useful kinds of fruit in the world. *Musa paradisiaca* is a native of India; *M. sapientum,* of the West Indies. Three dozen plantains in the West Indies are sufficient to serve one man for a week instead of bread, and will support him much better. The fruit has been ripened in this country—for example, in the palm-house of the Edinburgh Botanical Garden annually for more than twenty years. The young shoots of the species of *Musa* are used like cabbage. *Heliconia psittacorum* has edible roots. *Urania* or *Ravenala speciosa* yields an edible seed.

Iridaceæ, Iris order.—*Iris pseudacorus,* the common yellow flag of our ponds, has seeds which have been recommended as a substitute for coffee. *I. florentina* gives the well-known orris-root. *Trichonema edule* has roots eaten in Socotra. The tubers or corms of various species are eaten by Hottentots.

Amaryllidaceæ, Amaryllis order.—In the genus *Agave* the flowers of some species in Mexico are boiled and used as food. *Alstroemeria pallida* affords a kind of arrowroot. The *Agave Americana* affords a fermentable juice largely used under the name of pulque as a spirit.

Hæmadoraceæ, Blood-root order.—*Hæmadorum:* the roots of some of the Swan River species are roasted and used as food—viz., *H. paniculatum, H. spicatum,* and *Anigozanthus floridus.*

Taccaceæ, Tacca order.—*Tacca pinatifida* has tubers yielding starch used as food, the acrid matter being first removed by washing. It is sometimes called Otaheite salep, or Tahiti arrowroot. Other species of Tacca are equally useful—viz., *T. dubia* and *T. montana*, in the Moluccas.

Bromeliaceæ, Pine-apple order.—*Ananassa sativa*, the pine-apple (formerly *Bromelia ananas*), affords the well-known aromatic fruit. The pine-apple, however sweet and aromatic when cultivated and ripe, in the wild state, and especially when unripe, is excessively acid, so as to hurt the gums.

Liliaceæ, Lily order. — *Allium porrum*, the leek, is a favourite esculent. *A. cepa*, the onion ; *A. ascalonicum*, the shallot ; *A. schœnoprasum*, the chive ; *A. scorodoprasum*, the recambole, are in daily use in the kitchen. Most of these plants have sulphuretted oil in their composition, as well as free phosphoric acid. In warm countries some of these bulbous plants grow to a large size, and instead of being acrid and pungent, are bland articles of food. This is the case in the Portugal, Spanish, and Egyptian onions. They owe their peculiar odour and flavour to the acrid volatile oil combined with sulphur which they contain. This oil becomes absorbed in the living body, quickens the circulation, and occasions thirst. Passing out of the system by the different excreting organs, it communicates its peculiar smell to the secretions. Hence the well-known odour of the breath after eating onions or garlic. If the volatile oil be dissipated by boiling, these bulbs no longer possess any acrid or stimulating qualities. As a wit of the last century sang—

> "This is every cook's opinion,
> No savoury dish without an onion ;
> But lest your kissing should be spoiled,
> Your onions must be throughly boiled."

The following are the constituents of onions, according to Fourcroy and Vauquelin :—

Acrid volatile oil.
Uncrystallisable sugar.

Gum.
Vegetable albumen.
Woody fibre.
Acetic and phosphoric acid.
Phosphate and carbonate of lime.
Water.

Allium leptophyllum has bulbs eaten by the hill people in India. *A. biberosum* is also used in India. *Camassia esculenta* is the quamash of the North American Indians. Their edible bulbs are among the articles of diet called biscuit roots.

Dracæna terminalis, called Ki, supplies food and an intoxicating beverage in the Sandwich Islands. Cattle, sheep, and goats are fond of its leaves.

Of *Lilium tenuifolium, L. Kamtschaticum,* and *L. spectabile,* the bulbs are used as food in Siberia. *L. pomponium* is as much prized in Kamtschatka for its roots, as the potato with us.

Xanthorrhœa, the Grass-tree genus, of different species, afford in their tender tops valuable fodder for all kinds of cattle in the Swan River colony. The tender base of the inner leaves of some of the grass-trees is used as food in Tasmania, either raw or roasted. *Asparagus officinalis* has been from ancient times a favourite esculent. *Polygonatum multiflorum,* Solomon's seal, in its young shoots, affords a substitute for asparagus.

Commelynaceæ, Spider-wort order.—*Commelyna,* in some of its species, has rhizomes, amylaceous and edible—viz., *cœlistis, tuberosa, angustifolia,* and *striata.*

Juncaceæ, Rush order.—The cellular tissue at the base of the leaves in some species of Juncus is eaten ; also the corresponding part in *Astelia alpina,* a sedgy plant of Tasmania.

Palmæ, Palm order.—Palms, among other numerous uses in human life, supply starch, sugar, oil, wax ; their fruits are often edible; their buds are eaten like garden vegetables, and their saccharine juices are often fermented, so as to form a spirit called arrack, or palm-wine called toddy.

Areca catechu furnishes the pinang or betel-nut used all over the East as a masticatory, the nut being wrapt in the leaf of a plant of the pepper tribe, *Chavica betle. A. oleracea,* West India cabbage-palm, is boiled as an esculent vegetable. *Astrocaryum murumuru* has fruit which is edible. *Caryota urens* is one of the palms that furnish sugar as well as the fermentable fluid called toddy. *Cocos nucifera,* the cocoa-nut palm. The sugar it supplies is called jaggery. Toddy is obtained by slicing its spadix. *Euterpe montana,* the mountain cabbage-palm, affords young leaf-buds in use as an esculent vegetable. *E. edulis,* assai, or assai zeiro, yields a pulpy fruit, from which a grateful beverage is prepared. *Hyphæne thebaica,* the doom palm of Egypt, has a fruit, the pericarp of which has the taste of gingerbread, and is edible. *Lodoicea Seychellarum,* a palm of the Seychelles Islands, produces the fruit called the double cocoa-nut. *Mauritia vinifera,* the Muriti palm, and *M. flexuosa,* yield a kind of palm-wine. *Metroxylon læve,* a native of Borneo and Sumatra, is one of the sources of sago. *Phœnix dactylifera,* the date-palm, is a native of the northern parts of Africa, Arabia, and the adjacent regions of Turkey in Asia. The fruit of this tree, the common date, is imported into Britain from Barbary and Egypt, being usually of the variety called *Tafilat.* It is said there are forty-six varieties of dates cultivated in the oasis of Fezzan. Richardson says that 19-20ths of the population of Fezzan in Africa live on dates during nine months in the year, and that many of the animals are also fed on them. The fruit of this tree makes a great part of the diet of the inhabitants of Arabia, part of Persia and Upper Egypt, and many families subsist almost entirely on it. They make a conserve of it with sugar, and for their camels grind even its hard stones in their hand-mills. The juice of the date-tree is procured by cutting off the head or crown of the more vigorous plants, and scooping the top of the trunk into the shape of a basin, where the sap in ascending lodges itself at the rate of 3 or 4 quarts during the first week or fortnight, after which the quantity daily diminishes, and at the end of six weeks or two months the tree becomes dry, and serves for timber or firewood. This liquor, which has a more luscious sweetness than honey, is of the consistence of thin syrup, but quickly becomes tart and ropy, acquiring an intoxicating quality, and giving upon distillation an agreeable spirit, or araky, which is the general name in the East for all hot liquors extracted by the alembic.* *P. farinifera* affords a starchy substance extracted from the interior of the stem. It is called congee in India. It is only used in times of scarcity. It is less nutritive than sago, and less palatable. *P. sylvestris,* the wild date of Bengal, yields sugar. *Saguerus saccharifer* is a valuable sago-palm, from which a large quantity of saccharine juice is obtained when the spadix is wounded, and from this juice sugar is obtained. *Sagus ;* of this genus several species supply the kind of starch named sago. *S. Rumphii* is the sago-palm of Malacca.

Alismaceæ, Water-plantain order. — The fleshy rhizomes in the genera *Alisma* and *Sagittaria* are edible. The native species of *Alisma* are *A. plantago,* the greater water-plantain, *A. natans,* the floating water-plantain, and *A. ranunculoides,* the lesser water-plantain. *Sagittaria sagittifolia* is a native of England and Ireland, and is common in many parts of the world—in Siberia, Japan, China, and Virginia. The bulb, which fixes itself in the solid earth below the mud of the water in which it grows, constitutes an article of food among the Chinese, and upon that account they cultivate it extensively.

* Balfour, 'Class-Book of Botany,' p. 937 ; and Loudon, 'Encyclopædia of Plants,' p. 829.

The roots are larger in those countries than with us. Lindley says it is the *S. sinensis* that is cultivated in China.

Pandanaceæ, Screw-pine order.—*Pandanus odoratissimus,* the screw-pine. The seeds of the screw-pines are edible. The flower of *P. odoratissimus* is fragrant and eatable.

Typhaceæ, Bulrush order.—*Typha,* the young shoots of *Typha latifolia* and *T. angustifolia,* both native, are sometimes used like asparagus. Their large amylaceous tubers are also used for food. The pollen of *Typha elephantina,* or elephant-grass, is made into a kind of bread in Scinde and Western Australia, called boor or booree. The pollen of *T. utilis,* in New Zealand, is used to make a kind of bread called hunga-hunga. Such pollen contains both azotised and starchy matter.

Araceæ, Arum order. — *Arum maculatum,* cuckoo-pint, or wake-robin, has an amylaceous corm. The starch used to be separated in large quantities at Weymouth, and in the island of Portland, and sold under the name of Portland sago. *A. campanulatum* is cultivated in some parts of India on account of its edible corms. *Caladium bicolor,* and other species, have corms which, when roasted or boiled, are used as food. *Colocasia esculenta,* and other species, have edible corms, which, in the West Indies, are called cocoes and eddoes. *C. macrorhiza* has a corm which is the edible tara of the South Sea Islanders. *C. Himalensis* has corms that afford food in the Himalayas.

Orontiaceæ, or *Acoraceæ,* Orontium or Sweet-flag order.—*Calla palustris* has acrid amylaceous rhizomes which, after washing, are used as food. This *Calla* extends to Lapland.

Pisteaceæ or *Lemnaceæ,* Duck-weed order.—Such plants are not only the food of ducks, but of the fresh-water polype, &c.

Sub-class, *Glumiferæ. Cyperaceæ,* Sedge order.—*Cyperus* *esculentus* has corms used for food, and made a substitute for coffee. *C. bulbosus* has also corms fit for food.

Gramineæ, Grass order.—*Andropogon saccharatum,* shaloo, is cultivated in India as a nutritious grain. *A. sorghum,* see p. 476.

Bambusa arundinacea, Bamboo.—The young shoots are used for pickles, and even boiled and eaten for table vegetables, or made into sweetmeats. The seeds of some species are fermented for a drink.

Dactylis cæspitosa, the Tussac grass of the Falkland Islands, has been cultivated with some success in the Shetland Islands, and in the island of Lewis.

Gynerium saccharoides yields sugar in Brazil. *Gynerium argenteum* is the pampas grass of the Cordillera.

Paspalus virgatus, Lamaha grass, in Demerara, is excellent fodder.

Phalaris canariensis produces the grain called canary-seed for birds.

Saccharum officinarum, the sugar-cane.

Zizania aquatica supplies the swamp-rice of Canada.

Forage and Natural Pasture Grasses. Agrostis.—Of the genera of grasses in which lie those which have any claim to culture as forage plants, *Agrostis* is first in alphabetic order. The species of this genus are popularly termed bent grasses. The *Agrostis alba* and the *Agrostis vulgaris* are the only species of this genus which deserve notice. The *Agrostis alba* is plainly the same as what has been called *Agrostis stolonifera,* marsh creeping bent-grass, or fiorin-grass.

The *Agrostis alba* is considered by farmers a troublesome weed, as impoverishing the soil by its long creeping roots. It is a creeping-stemmed perennial, flowering in July and August, and at the end of the latter month its seeds usually ripen. It varies somewhat according to the situation in which it grows.

Its typical form is found in meadows, pastures, and dry sandy ground, and it is even met with 2000 feet above the sea-level. It grows also in peaty and other moist soils, by the sides of streams, wet pastures, and adjacent to rivers overflowed by fresh-water tides ; the variety met with in these humid situations is known as the *Agrostis palustris.*

It cannot be described as a useful grass except in soils and situations where more valuable grasses do not succeed, such as on the margins of bogs. It is eaten by cattle, and they are fond of it as forage or hay on account of its joints being sweet to the taste. It is recommended as one of the plants to be sown in lands in preparation for irrigation, and in improved deep mossy ground intended to be kept in grass, the proportion of seed by weight for an imperial acre being from $1\frac{1}{2}$ lb. to $2\frac{3}{4}$ lb. The seeds are minute ; a bushel has an average weight of 13 lb.; and the average number of seeds in an ounce is 500,000.

No exact chemical analysis of this grass appears to be recorded. From the deficiency of succulence in the stem and leaves, and the minuteness of the seeds, it is manifest that the whole plant must contain an unusual proportion of ligneous deposit in the cellular structure, so as to leave but a small residue fit for nourishment. At the bog of Allen in Ireland it yields 600 stones of hay per imperial acre. A plant of this grass has been measured in Ireland to the length of 10 feet.

The *Agrostis vulgaris,* or common fine bent-grass or black switch, is a creeping-rooted perennial, which flowers in the first week of July and ripens its seed in the second week of August. It grows on dry pastures, moors, waste grounds, woods, and hilly situations, sometimes reaching an elevation of near 2000 feet above the level of the sea. It is often a troublesome weed on elevated light lands. In hand-gathering it from the soil, if the smallest piece of the root is left in the soil, it will soon produce a formidable plant. It is only useful where more nutritious grasses will not thrive, to cover poor gravelly or sandy soils and dry banks with verdure. It is said to be disliked by cattle generally. It is one of the plants recommended to be sown for pasturage and cover in thick shady woods, and for warrens, or for light sandy downs, to the extent of from 1 to 2 lb. of the seeds per imperial acre. The average weight of a bushel of the seeds is 12 lb., and the average number of seeds in an ounce is 425,000. Nearly the same observations apply to this species as to the former in respect to its want of succulence, and the consequent large proportion of ligneous deposit impairing its nutritive properties.

Aira.—The genus *Aira,* or hair-grass, is of as little utility in husbandry as the genus *Agrostis.*

The *Aira cæspitosa* is indeed sometimes sown, but as it grows naturally in moist rich soils, it is commonly esteemed a troublesome weed. It is disliked by cattle. It is a tall elegant grass in shrubberies, but gives an unsightly appearance in meadows, pastures, and parks, owing to its growing into large tufts, termed rough caps or hassacks, very difficult to be got rid of. It appears to grow in every kind of soil and situation, from the marsh to the dry sandy heath, but prefers moist clayey soils where the water stagnates. It owes its English name, tufted hair-grass, to the hassacks which it forms in meadow land. It makes a good under cover for game and shelter for wild-fowl. It is one of the grasses recommended to be sown, to the extent of from 1 to 2 lb. per imperial acre, for pasturage and cover in thick shady woods. A bushel of the seed averages 14 lb., and the number of seeds in an ounce may reach 32,000.

Alopecurus.—Of the genus *Alopecurus,* or fox-tail grass, only one species—namely, the *Alopecurus pratensis,* the meadow fox-tail grass—is of agricultural importance. It is a fibrous or slightly creeping-rooted perennial. It flowers in April, May, and June, and ripens its seed in June and July. It is a common grass throughout the whole of Britain. In most of the rich natural pastures of this island it is the principal grass. It thrives best on rich land of an intermediate quality as to moisture and dryness, such as in low meadow ground, or in boggy places that have been drained. It is hardly found beyond 1500 feet above the level of the sea. It is of great value to the agriculturist, as one of the earliest and best grasses for permanent pastures, and supplying a grateful forage to every kind of stock. It is less adapted for hay, owing to the stems being few and but sparingly furnished with leaves. According to Mr Sinclair, its produce on a clayey loam is nearly three-fourths greater than on a sandy soil, the amount of nutritive matter being also greater in the former case in the proportion of three to two. The value of the aftermath, as compared with that of the flowering crop, is, according to the same authority, as four to three. As this difference of value is not usual in grasses at these respective periods, it must arise from the loss occasioned by the peculiarity of the flower in the fox-tail grass. As this grass does not arrive at maturity until the fourth year after the seeds are sown, it is inferior to many grasses for the purposes of alternate cropping. It is not found, therefore, among the plants recommended to be sown in alternate husbandry; but for permanent pastures, and for permanent lawn pastures, it is one of the plants recommended to be sown, in the proportion of from 1 lb. to $1\frac{3}{4}$ lb. of the seeds to the imperial acre; also in the same proportions for lands in preparation for irrigation, and for improved deep mossy ground, intended to be kept in grass. A bushel of the seeds averages $5\frac{1}{4}$ lb., and the number of seeds in an ounce comes up to 76,000.

Ammophila.—*Ammophila* is the genus to which the sea-reed is now referred, placed formerly under *Arundo*. *Ammophila arundinacea,* formerly called *Arundo maritima*—known also as *Psamma,* the common sea-reed, marum, mat-weed, or mat-grass—is a creeping-rooted perennial, abundantly met with on our sandy shores. It flowers early in July. It grows naturally among shifting sea-sands, for the consolidation of which it is especially adapted by its strong creeping roots and hard elastic foliage. So useful is it found in retaining the drifting sand, and thereby forming an embankment for preventing the encroachments of the sea, that an Act of Parliament exists for its preservation. Mats and ropes are sometimes made of this grass. It is not eaten by any kind of cattle. It grows from eighteen inches to two feet in height. It might be worth while to ascertain if any nutritive quality belongs to the root. It grows only on the driest sandy shores. A bushel of the seeds averages 15 lb., and the number of seeds in an ounce rises to 100,000.

Anthoxanthum.—*Anthoxanthum* is the genus to which the sweet-scented vernal grass belongs, that species being named *Anthoxanthum odoratum.* It is the only native species of this genus, and is distinguished from our other native grasses by having only two stamens or chives in the flower. It is a fibrous-rooted perennial. It grows from twelve to eighteen inches high. It flowers about the middle of April, and the seeds are ripe in the second or third week of June. It grows in dry meadows, pastures, woods, and moors. It makes a part of the herbage on almost every kind of soil, but it attains its perfection only in those that are deep and moist. It does not appear to be a particular favourite with cattle, though eaten in pasture along with other grasses. One of its chief merits is its early growth. It thrives best when grown along with several different grasses, and therefore is truly a permanent pasture-grass. The value of the aftermath is to that of the seed crop nearly as 13 to 9, and the nutritive property of the autumn grass is to that of the first grass of spring as 9 to 7. This superiority of the aftermath is a great recommendation for the purpose of grazing. Altogether, its early growth, its continued vegetation till autumn, and its hardy and permanent nature, give it a high place among the grasses entering into permanent pastures. It is the grass which chiefly gives the peculiar sweet smell to permanent grass-hay. It is believed that pastures in which this grass abounds give an improved flavour to the mutton obtained from the flocks fed on them. It is recommended as one of the plants to be sown, for permanent lawn pastures, to the extent of ½ lb. of seed to the imperial acre; and for permanent pasture and hay in orchards and other grounds overshadowed by trees, to the extent of 1 lb. of seed to the same measure of ground. A bushel of the seeds averages 6 lb., and the number of seeds in an ounce has an average of 71,000.

Arrhenatherum.—The genus *Arrhenatherum* is a comparatively new genus, in which there is the one species, *Arrhenatherum avenaceum*, tall, oat-like, soft grass, or French rye-grass, formerly named *Holcus avenaceus.* It is a fibrous-rooted perennial. It grows from two to three feet high. It is found in dry pastures, rocky and stony places, woods, and is frequently a troublesome weed in corn-fields. It is in particular the variety of this plant, distinguished by having bulbous or knotted roots, that infests corn-fields, especially in high districts. This variety is known as knot-grass, while it is sometimes made a distinct species under the name of *Arrhenatherum bulbosum.* There are some conflicting statements in respect to the agricultural merits of the *Arrhenatherum avenaceum.* There is no doubt that it affords a considerable bulk early in the season of a somewhat bitter-tasted herbage, of which, according to some, cattle are rather unfond; but, according to others, its agricultural merits are as yet but little known in this country —that on the Continent it is highly prized, being eaten with avidity by all kinds of cattle, though it is not so palatable to horses. Its produce on a clayey soil is reported to exceed that on a heathy soil in the proportion of 25 to 8. It flowers in the third week of June, and ripens its seeds about the end of July. It is found as high as 1500 feet above the sea-level. It is a troublesome weed on cultivated soils, as every bulb forms a distinct plant when separated from its neighbour. It is one of the plants recommended to be sown, in the proportion of from 3 to 5 lb. of the seeds to the imperial acre, for pasturage and cover in thick shady woods ; and in the proportion of from 3 to 4 lb. for heathy and moory lands, which have been improved with a view to their producing better pasturage ; and in the same proportion for warrens or light sandy downs. A bushel of the seeds averages 7 lb., and the number of seeds in an ounce stands at 21,000.

Avena.—Among the many species of *Avena* there is one, besides the cereal species, which deserves attention as an agricultural grass—namely, the *Avena flavescens*, or yellow oat-grass. It has been sometimes called of late the *Trisetum flavescens.* It is a fibrous-rooted perennial. It grows from one to two feet high. It flowers in the second week of July, and ripens its seed about the middle of August. It grows in rich dry pastures. It is an early and sweet grass, well suited for light dry soils, but inferior to many grasses in bulk of produce. It grows in almost every kind of soil, from that of the limestone rock to the irrigated meadow, and is always present in the richest natural pastures. It is most luxuriant in a dry calcareous soil, but does not thrive unless grown along with other grasses. Few grasses are more grateful to sheep. It is hardly found more than 1000 feet above the sea-level. It is among the plants recommended to be sown for permanent pasture, for permanent lawn pastures, and for fine lawns, bowling-greens, and the like, kept constantly under the scythe, in the proportion of from $\frac{1}{2}$ lb. to 1 lb. for the imperial acre. A bushel of the seeds averages 5 lb., and the number of seeds in an ounce stands at 118,000.

Brachypodium.—The genus *Brachypodium* is that to which the grass commonly called wood fescue-grass is now referred, under the name of *Brachypodium sylvaticum.* This grass was once called *Festuca sylvatica,* and again *Triticum sylvaticum.* It is a fibrous-rooted perennial. It grows from one to two feet high. It flowers in the first week of July, and ripens its seed near the end of the same month. It is produced naturally in damp woods and moist shady places, but thrives well in open cultivated ground. It is a coarse grass not liked by cattle. Oxen, horses, and sheep refuse it, except when there is no choice. Hares and rabbits are said to crop the ends of the leaves during deep snow or severe frost. It is met with to the height of 1000 feet above the sea-level. It is useful to form an under-covering of verdure in thick woods. It is one of the plants recommended to be sown, to the extent of from $1\frac{1}{2}$ lb. to 2 lb. per imperial acre, for pasturage and cover in thick shady woods. A bushel of the seeds averages $10\frac{1}{4}$ lb., and the number of seeds in an ounce amounts to 15,500.

Bromus.—To the genus Bromus is referred the grass otherwise known as *Bucetum giganteum, Festuca gigantea,* tall fescue-grass, or giant-wood brome grass, under the name of *Bromus giganteus.* It is a fibrous-rooted perennial. It grows from three to four feet high. It is produced in woods and damp shady places, yet when cultivated it thrives in open situations. It is in greater favour with cattle than the *Brachypodium sylvaticum.* Horses and cows eat it, but plainly do not prefer it to most grasses. The leaves, though produced in great abundance, afford but little nourishment to cattle, and as such is really worthless. The seeds are in great request among small birds. It flowers in the third week of July, while the seeds ripen near the end of August. Its limit of altitude does not exceed 500 feet above the level of the sea. It is recommended as one of the plants to be sown for pasturage and cover in thick shady woods, to the extent of 3 lb. per imperial acre. A bushel of the seeds averages 15 lb., and the number of seeds in an ounce is about 8600.

Cynosurus.—Cynosurus is the genus to which is referred the well-known grass, the crested dog's-tail grass, under the name of *Cynosurus cristatus.* It is a fibrous-rooted perennial, and reaches from 12 to 18 inches in height. It flowers in the first week of July, and ripens its seeds in the second week of August. It is produced naturally in old pastures, on moist and dry, as well as heavy and light soils, but is most abundant in pastures at low and medium altitudes. Its limit of altitude is not, however, low, since it reaches the height of 2000 feet. It thrives better in tenacious soils than in those of a drier or sandy nature, and in irrigated meadows it reaches an uncommon size. In general it yields but a scanty crop of herbage, but forms a smooth turf, and is one of the best grasses for fine lawns. For permanent pastures it is a most valuable grass, but is not well adapted for hay, as the stems when dry are hard and tough, while at the time the seeds are ripe they contain but little nutritive matter; when in flower, however, the grass is succulent and tender, affording twice as much nourishment as at a later period, so as to be the favourite food of deer and sheep. The stems are valuable for the manufacture of straw bonnets, and are said to be even preferable to the Italian straw. It is, as might be supposed, one of the plants recommended to be sown for fine lawns, bowling-greens, &c., kept constantly under the scythe, in the proportion of from 5 lb. to 7 lb. per imperial acre. A bushel of the seeds averages 26 lb., and the number of seeds in an ounce is about 28,000.

Dactylis.—Dactylis is the genus to which the well-known grass, common rough cock's-foot, or orchard grass, is referred under the long-established name *Dactylis glomerata.* It is a fibrous-rooted perennial. It grows to the height of two feet or more. It flowers from June to August. Its limit of altitude does not exceed 1000 feet above the level of the sea.

It is one of the commonest grasses in this country. It is found in orchards, woods, hedges, and waste places. It grows most luxuriantly in damp and shady situations. It is one of the best and most productive pasture grasses. To follow Mr Sinclair on this grass, it deserves particular attention that the herbage, when suffered to grow rank or old for want of sufficient stocking, contains nearly one-half less nourishment than that which is of recent growth.

This grass, therefore, he says, is of more value for pasture than for hay, yet even for the latter purpose it will be found superior to rye-grass (*Lolium perenne*) and many other grasses. To obtain the full benefit of this plant as a pasture-grass, it should be kept closely cropped either by cattle or the scythe. Oxen, sheep, and horses eat this grass with avidity, but show a distaste for it when it is allowed to grow rank. It thrives best where the subsoil is porous and not stagnant, so that the fibrous root may extend to a considerable depth, by which extraordinary productiveness and permanence is given to the grass. But when the surface soil is thin, incumbent on tenacious clay, or when the subsoil is retentive of superfluous moisture, this grass succeeds imperfectly, and the slender hold such soil affords to the roots renders the plant liable to be drawn out of the ground by the cattle when grazing. The pastures most celebrated for fattening stock in Devonshire, Lincolnshire, and in the vale of Aylesbury, are partly formed of this grass. It is less impoverishing to the soil than the rye-grass. A combination of three parts cock's-foot, and one part composed of *Festuca duriuscula, Bucetum pratense, Poa trivialis, Phleum pratense,* and *Lolium perenne,* will secure the most productive and nutritive pasture in alternation with grain crops.*

A strong growing variety has lately been brought into notice under the name of giant cock's-foot.

The cock's-foot is one of the plants recommended to be sown for permanent pasture, in the proportion of from 3 lb. to 5 lb. of the seeds per imperial acre; for permanent lawn-pastures, in the proportion of from 1½ lb. to 2 lb.; for permanent pasture and hay in orchards and other grounds much overshadowed with trees, in the proportion of from 5 lb. to 7 lb. of the seeds; for pasturage and cover in thick shady woods, in the proportion of from 4 lb. to 6 lb. in the same measure of ground. A bushel of the seeds averages 11½ lb., while the number of seeds in an ounce amounts to 40,000.

Elymus.—To the genus *Elymus* is referred the sea-sand lyme-grass, under the name *Elymus arenarius.* It is a creeping-rooted perennial. It grows from two to five feet high. It flowers in the second week of July, and ripens its seed about the end of August. It grows among shifting sea-sand, for fixing which, along with the sand-reed (*Ammophila arundinacea*), its numerous strong spreading roots and coarse elastic foliage render it most suitable. According to Mr Sinclair, it may be regarded as the sugar-cane of Britain, owing to the large amount of saccharine matter which it contains. The hay made from it must be very nutritious. It is particularly useful when cut into short pieces to be mixed with corn or common hay.

Many sands on the sea-shore are so liable to be shifted at

* Sinclair; see Parnell's 'Grasses of Scotland,' p. 68.

all times, and particularly when high winds prevail, that it is impossible to produce a permanent effect by merely scattering seeds in the place. The most approved method is to deposit turf at regular short intervals over the surface, and afterwards to sow the seeds of *Elymus arenarius* and of *Ammophila arundinacea* in the interstices, by mixing them with clay attached to small pieces of straw ropes, and dibbling these into the sand; for which purpose 15 lb. to 20 lb. per acre will be sufficient.

To prevent the encroachments of shifting sands, the plan which succeeds best is to sow the seeds of the above-mentioned grasses over a breadth of 20 to 50 yards, and even, in some situations, over as much as 100 yards or more, immediately in advance of such sands, the breadth, as well as the quantity of seeds per acre, to depend on the obstacles to be overcome; but from 20 lb. to 30 lb. of these will generally suffice.* A bushel of the seeds of the *Elymus arenarius* averages 10 lb., and the number of seeds in an ounce is about 2320.

To the same genus, *Elymus*, is referred the jointed sand lyme-grass, under the name *Elymus geniculatus*. It resembles the *Elymus arenarius* in character and habit, except that its roots are less spreading. It is more prolific of seeds, which are large and oat-like, so as to afford agreeable food to wild-fowl. It is sowed in dry and gravelly inland warrens and game preserves. It flowers in the second week of July, and ripens its seed in the end of the first week of August. It is very rarely met with wild in Britain. A bushel of the seeds averages 12 lb., and the number of the seeds in an ounce is near 2300.

Festuca.—To the genus *Festuca* several species of fescue-grass are referred.

The *Festuca duriuscula*, known as hard fescue-grass, is a

* See Lawson 'On the Cultivated Grasses.'

fibrous-rooted perennial, yet somewhat creeping, occasionally throwing out lateral shoots. It grows from one to two feet high. It flowers in the second week of June, and ripens its seed in the middle of July. Its limit of altitude is about 3000 feet above the sea-level.

This grass is of high value among agricultural products. It is of early growth, thrives well on a great variety of soils and situations, and, for its size, is very productive. It resists the effects of severe dry weather better than many other grasses, and retains its verdure during winter in a striking degree. It is, on account of its fine foliage and perpetual verdure, well adapted for sowing in ornamental lawns. Sheep and hares are particularly fond of this grass. When cultivated for hay, it should be mown at the time of flowering, as it then contains more nutritive matter than at the time the seed is ripe.

Several varieties of the wild grass have been noticed under such names as *hirsuta, filiformis, arenaria, humilis,* and *rubra,* and several agricultural varieties have been raised, especially by Mr T. Bishop at Methven Castle.

It is one of the plants recommended to be sown for permanent pastures and permanent lawn-pastures, in the proportion of from 2 lb. to 3 lb. per imperial acre ; and for fine lawns, bowling-greens, &c., kept constantly under the scythe, in the proportion of from 3 lb. to 4 lb. ; for improved deep mossy ground intended to be kept in grass, in the proportion of from 3 lb. to 3½ lb. ; and for permanent pasture and hay in orchards and other grounds much overshadowed by trees, in the proportion of 1 lb. to the imperial acre. A bushel of the seeds averages 9½ lb., while the number of seeds in the ounce amounts to 39,000.

The species of *Festuca* known as tall fescue-grass is recognised in botany as the *Festuca elatior.* Of late years it has also been called the *Bucetum elatius* and the *Schenodorus ela-*

tior. It is a fibrous-rooted perennial, somewhat creeping, forming large tufts. It grows from three to five feet high. It flowers in the first week of July, and ripens its seed about the middle of August. It grows on strong, rich, and rather moist soils, by the banks of rivers, in moist shady woods, and near the sea-coast. It is a very coarse, reedy-like grass, but much relished by domestic herbivorous animals, especially by cows. It might prove a useful grass for such damp soils as cannot be made sufficiently dry for the growth of more valuable grasses. Its limit of altitude is about 500 feet above the sea-level.

A taller and stronger variety than the common is cultivated under the name of giant fescue-grass. There is also a variety with large spikelets, variegated with purple and white, frequent along the sea-shore and on the banks of rivers.

Festuca elatior is one of the plants recommended to be sown for permanent pastures in medium and heavy soils, to the extent of from 1 lb. to 2½ lb. per imperial acre; also for lands in preparation for irrigation, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for pasturage and cover in thick shady woods, and for marshy grounds and such as are occasionally overflowed by fresh-water tides, in the same proportion. A bushel of the seeds averages 14 lb., and an ounce of the seeds numbers about 20,500.

The *Festuca heterophylla*, various leaved fescue-grass, is an exotic species. It is a fibrous-rooted perennial, which flowers in June and July. It is met with in the central and southern countries of Europe. Its uses are similar to those of the *Festuca duriuscula,* being adapted for rich, dry, permanent grass-lands, especially such as are to be at times used for hay. It yields a greater weight of stems than any of the other fine-leaved fescues.

It is one of the plants recommended for permanent pastures, and for permanent lawn-pastures in medium and heavy soils, to the extent of from 1 lb. to $1\frac{1}{2}$ lb. per imperial acre. A bushel of the seeds weighs $12\frac{1}{2}$ lb., while the number of seeds in an ounce is about 33,000.

The *Festuca loliacea*, called also *Bucetum loliaceum*, has several English names. It is called spiked fescue-grass, slender fescue-grass, rye-grass fescue-grass, and darnel-spiked fescue-grass. It is a fibrous-rooted perennial. It grows from one to two feet high. It flowers in the second week of July, but the seeds seldom attain to perfection. It grows naturally in moist and rich meadows, affords a good permanent pasture-grass. It is well suited to moist or marshy alluvial soils and irrigated meadows. The cultivation of this grass by seed is difficult, owing to the small quantity of perfect seed produced, while to transplant the roots is a greater expense than the value of the grass would bear.

It is one of the plants recommended to be sown in lands in preparation for irrigation and in marshy grounds, and such as are occasionally overflowed by fresh-water tides, in the proportion of from 1 to 3 lb. per imperial acre. A bushel of the seeds weighs 15 lb., and the number of the seeds in an ounce is about 24,700.

The grass known as sheep's fescue-grass is named in botany *Festuca ovina*. It is a fibrous-rooted perennial. It grows from three to nine inches high. It flowers in the second week of June, and ripens its seed about the middle of July. It is found at the height of 4000 feet above the sea-level, forming the greater part of the sheep pasture-grounds in the Highlands of Scotland. It is the favourite food of the sheep—they prefer it to all other grasses ; and, though small, it is very nutritious. The smallness of its produce renders it quite unfit for hay. According to Linnæus, sheep show no liking for hills or heaths destitute of this grass. It retains its verdure throughout the winter.

It is one of the grasses recommended to be sown in permanent lawn-pastures, to the extent of 1 lb. per imperial acre. A bushel of the seeds averages 13¼ lb., and the number of seeds in an ounce is about 64,000.

Several natural varieties of *Festuca ovina* are pointed out, the chief of which have been named *Festuca hirsuta, Festuca vivipara, Festuca angustifolia,* and *Festuca cæsia.*

The plant called meadow fescue-grass has several names among botanists. Some unite it with *Festuca elatior,* others with *Festuca loliacea.* Parnell makes it *Bucetum pratense.* In Lawson's Catalogue it is the *Festuca pratensis.* It is a fibrous-rooted perennial. It grows from fifteen inches to two feet high. It flowers in the last week of June, and ripens its seed about the beginning of August. Its limit of altitude is about 500 feet above the sea-level. It grows in rich meadows and pastures. It combines many of the valuable properties without the defects of the rye-grass (*Lolium perenne*). It will thrive well on most soils, and is much relished by all descriptions of cattle. According to Mr Sinclair, "the meadow fescue-grass constitutes a very considerable portion of the herbage of all rich natural pastures and irrigated meadows; it makes excellent hay, and though a large plant, the leaves of the herbage are succulent and tender, and apparently much liked by cattle, as they never form rank tufts, which is the case with the larger grasses. It does not appear to arrive at its full productive powers from seed so soon as either the cock's-foot or fox-tail grass; and though essential for permanent pasture, it is not by itself very well adapted for alternate husbandry, but should be combined with cock's-foot, rye-grass, and rough-stalked meadow-grass. It is of greater value at the time of flowering than at the time the seeds are ripe—as three to one. In the deep alluvial soils in Lincolnshire, this grass is not so prevalent as in the clay districts. In the vale of Aylesbury it constitutes a considerable portion of the most valuable and fattening pastures of that rich grazing district."

It is one of the plants recommended to be sown for permanent pastures, for permanent lawn-pastures, in lands in preparation for irrigation, and for improved deep mossy ground intended to be kept in grass, in the proportion of from 1 lb. to 3 lb. per imperial acre. A bushel of the seeds averages 13 lb., and the number of the seeds in an ounce is about 26,000.

The creeping-rooted fescue-grass is regarded by some as a distinct species under the name of *Festuca rubra,* while by others it is placed (as already done, p. 436), under *Festuca duriuscula* as a variety. Hooper remarks that the only distinction is the creeping root. It is large, if regarded as a variety of *Festuca duriuscula.* It grows to the height of two feet or more. It is found in sandy places along the sea-shore.

It is one of the plants recommended to be sown in light soils for permanent pastures and for permanent lawn-pastures, to the extent of 1 lb. per imperial acre; and for warrens and light sandy downs, and for dry gravelly situations which resist a sward from all ordinary means, to the extent of 4 lb. in the same measure of ground. A bushel of the seeds averages 10 lb., and the number of seeds in an ounce is about 39,000.

Fine-leaved fescue-grass is referred by some botanists to the distinct species *Festuca tenuifolia,* by others it is made a variety of *Festuca ovina,* as *Festuca ovina angustifolia.* It is a fibrous-rooted perennial, which flowers in June and July. It is a delicate and slender variety, with long narrow leaves. It is very common in the Highlands of Scotland, where it forms a great part of the herbage. "It has a less tufted habit of growth than *Festuca ovina,* which, with its fine evergreen leaves and hard elastic foliage, renders it very desirable for fine lawns, especially where these are cut by a machine."

It is one of the plants recommended to be sown in fine lawns, bowling-greens, &c., kept constantly under the scythe, in the proportion of from 1 lb. to 2 lb. per imperial acre. A bushel of the seeds averages 12 lb., and the number of seeds in the ounce is about 88,000.

Glyceria, water sweet meadow-grass, or reed meadow-grass, the *Poa aquatica* of Hooper and the older botanists, is now often called the *Glyceria aquatica.* It is a creeping-rooted perennial. It flowers in the second week of July, and ripens its seed in the middle of August. It grows in alluvial marshy soils, in slow-running streams, margins of fresh-water lakes. "On the banks and little islands of the Thames, where this grass is generally mown twice a-year for hay, it affords abundant crops of valuable winter fodder, which cows and horses are fond of. It yields an immense bulk of coarse and by no means innutritious herbage, but is apt, by its rapid growth and extensively creeping roots, to choke up ditches and small streams."

It is one of the plants recommended to be sown in marshy grounds, and such as are occasionally overflowed by fresh-water tides, &c., to the extent of from 2 lb. to 5 lb. per imperial acre. A bushel of the seeds averages 13¼ lb., while the number of seeds in an ounce is about 58,000.

The floating meadow-grass, floating sweet-grass, manna-grass, or float-fescue, formerly named *Poa fluitans,* is now often called *Glyceria fluitans.* It is a fibrous-rooted perennial. It grows from 15 inches to 2 feet high. It flowers in the third week of June, and ripens its seed about the end of July. It grows in alluvial marshes, also in and by the margins of shallow pools, slow-running streams, and lakes. "It is an early, very sweet, and nutritious grass, well suited for irrigated meadows; its seeds form an agreeable food for waterfowl and fresh-water fish." It bears cultivation on moderately dry grounds as a permanent pasture grass, and yields a considerable produce. When properly cultivated, the bread made of it is said to be little inferior to bread made from wheat.

It is one of the plants recommended to be sown in lands in preparation for irrigation, in the proportion of from 2 lb. to $2\frac{3}{4}$ lb.; and in marshy grounds, and such as are occasionally overflowed by fresh-water tides, in the proportion of 5 lb. per imperial acre. A bushel of the seeds averages $14\frac{1}{2}$ lb., while the number of seeds in an ounce is about 33,000.

Holcus.—Under the genus *Holcus* fall the grasses known as woolly soft-grass and creeping soft-grass.

The *Holcus lanatus* is the woolly soft-grass, called also white grass and Yorkshire fog. It is a fibrous-rooted perennial. It flowers in the first week of July, and ripens its seeds about the end of the same month. It grows in almost all soils and situations, but is regarded as a weed on the better class of pasture lands. Cattle of all kinds seem to dislike it, and horses in particular have an aversion to it. Its limit of altitude is about 1500 feet above the sea-level.

It is one of the plants recommended to be sown in heathy and moory land, which have been improved with a view to their producing better pasturage, in the proportion of from 2 lb. to $2\frac{1}{2}$ lb. of seed per imperial acre. A bushel of the seed averages 7 lb., while the number of seeds in an ounce is about 95,000.

The *Holcus mollis* is the creeping soft-grass. It is, as its name denotes, a creeping-rooted perennial. It grows from one to three feet high. It flowers in the second week of July, and ripens its seed in August. Its limit of altitude is about 1500 feet above the sea-level. It is not so common in Britain as the *Holcus lanatus*. It grows generally on light, barren, sandy soil, either in woods or open pastures. Neither horses, oxen, nor sheep eat it; pigs are said to like the roots, which contain a considerable proportion of nutritive substance, having much the flavour of new meal.

It is one of the plants recommended to be sown for pasturage and cover in thick shady woods, and for warrens or light sandy downs, in the proportion of from 1 lb. to 2 lb. of the seed per imperial acre. A bushel of the seeds averages 6 lb., while the number of seeds in an ounce is about 85,000.

Lolium.—Under the genus *Lolium* are two important grasses—namely, the Italian rye-grass and the common rye-grass.

The *Lolium Italicum,* as the Italian rye-grass is called when it is regarded as a species distinct from the common rye-grass, or the *Lolium perenne Italicum* when it is held to be merely a variety of the *Lolium perenne,* is a native of the southern countries of Europe. It is a fibrous-rooted grass of biennial or triennial duration. It is suited to a great variety of soils and situations. It was introduced into this country, now nearly thirty years ago, by Mr Lawson. It is a most valuable grass; it produces a large quantity of herbage early in spring, of which horses, oxen, and sheep are particularly fond; moreover, it bears cutting three times during the season, when cultivated in moist rich soils or irrigated land. It is a valuable grass for alternate husbandry, yet its limited duration fits it for sowing mixed with the seeds of grasses intended for permanent pasture, since it dies out, giving place to the slow-maturing perennials which are designed ultimately to occupy the ground.

It is one of the plants recommended to be sown, in the proportion of from 3 lb. to 6 lb. per imperial acre, in alternate husbandry, for permanent pastures, for permanent lawn-pastures, for lands in preparation for irrigation, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for heathy and moory lands which have been improved with a view to their producing a better pasturage, for improved deep mossy ground intended to be kept in grass, and for warrens or light sandy downs. A bushel of the seeds averages 15 lb., and the number of seeds in an ounce is about 27,000.

The common rye-grass is the *Lolium perenne.* It is a fibrous-rooted grass of biennial, triennial, or quadriennial duration. It grows from 15 inches to 2 feet high. When not more than three years old, it flowers in the second week of June, and ripens its seed in about twenty-five days after. As the plants become older they flower later, sometimes so late as the beginning of August. It grows naturally in meadows and rich pastures. There are very many varieties of this grass, differing in bulk of herbage and durability in the pasture ; the more permanent being termed perennial, and the less permanent annual. None, however, are strictly perennial, while the term annual is equally inapplicable. One of the most permanent varieties is called, owing to the fineness of its foliage, *Lolium perenne tenue,* and it is much recommended to be sown in lawns. Other varieties are the broad-spiked rye-grass, Pacey's rye-grass, Russel's grass, Whitworth's grass, Stickney's grass, panicled rye-grass, double-flowered rye-grass, viviparous rye-grass, and many more, to the number of seventy. Mr Sinclair says there has been much difference of opinion respecting the merits and comparative value of rye-grass. It produces an abundance of seed, which is easily collected, and readily vegetates on most kinds of soil, under circumstances of different management. It soon arrives at perfection, and produces in its first years of growth a good supply of early herbage, which is much liked by cattle ; but the after-crop of rye-grass is very inconsiderable, and the plant impoverishes the soil in a high degree, if the culms, which are invariably left untouched by cattle, are not cut before the seed advances towards perfection. When this is neglected, the field after midsummer exhibits only a brown surface of withered straws.

For permanent pasture the produce and nutritive powers of the rye-grass, compared with those of the cock's-foot grass (*Dactylis glomerata*), are inferior nearly in the proportion of five to eighteen; and inferior to the meadow fox-tail (*Alopecurus pratensis*) in the proportion of five to twelve; and inferior to the meadow fescue (*Festuca pratensis*) as five to fifteen. The rye-grass is but a short-lived plant, seldom continuing more than six years in possession of the soil, but is continued by its property of ripening an abundance of seed, which is but little molested by birds, and suffered to fall and vegetate among the root-leaves of the permanent pasture grasses. It is only within these last forty or fifty years that other species of grasses have been tried as a substitute for the rye-grass in forming artificial pastures, it having been the favourite grass with most farmers from the time of its first cultivation in 1674 to the present period.

It is a very common grass throughout the whole of Britain. Its limit of altitude seems to be about 1000 feet above the level of the sea.

It is recommended as one of the plants to be sown in alternate husbandry for permanent pasture, for permanent lawn-pastures, for fine lawn-pastures (the *Lolium perenne tenue*), bowling-greens and the like kept constantly under the scythe, for lands in preparation for irrigation, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for improved deep mossy ground intended to be kept in grass, and for warrens or light sandy downs, to the extent of from 5 or 6 to 18 or 20 lb. of seed per imperial acre. A bushel of the seeds of the light-seeded varieties averages 18 lb., a bushel of the seeds of the heavy-seeded varieties averages 30 lb.; and the number of seeds of the former variety in an ounce is about 16,000—of the latter variety, 13,000.

Milium.—The wood or spreading millet-grass is known to botanists as the *Milium effusum.* It is a fibrous-rooted perennial, with several creeping shoots. It grows from 3 to 4 feet high. It flowers in the second and third weeks of June, and ripens its seed in the second week of August. It thrives in rich soils and moist shady woods, but will grow freely when transplanted to open shady situations. It yields an early and bulky crop of herbage, and produces a profusion of small millet-like seeds, which form an agreeable food for young pheasants and other granivorous birds. Where game is preserved, the cultivation of this grass is advised to save the corn.

It is one of the plants recommended to be sown for permanent pasture and hay in orchards and other grounds much overshadowed by trees, and for pasturage and cover in thick shady woods, to the extent of 1 lb. of the seeds per imperial acre. A bushel of the seeds averages 25 lb., while the number of seeds in an ounce is about 95,000.

Phalaris.—The reed canary-grass is the *Phalaris arundinacea* of botanists. It is a creeping-rooted perennial, with long horizontal shoots. It grows from 2 to 5 feet high. It flowers in the second week of July, and ripens its seeds near the middle of August. Its limit of altitude is about 1000 feet above the sea-level. It grows in alluvial marshy grounds, by the sides of rivers, lakes, ditches, and rivulets. It is a very strong-growing and coarse-like grass, but eaten with apparent relish by cattle and horses, especially when cut prior to flowering.

The well-known painted lady-grass, ribbon-grass, or gardener's-garters, is a variegated variety of this grass.

It is one of the plants recommended to be sown in lands in preparation for irrigation and in marshy grounds, and such as are occasionally overflowed by fresh-water tides, in the proportion of from 1 to 2 lb. per imperial acre. A bushel of the seed averages 48 lb., and the number of seeds in an ounce is about 42,000.

Phleum.—The Timothy-grass, cat's-tail, or herd-grass is known to botanists under the name *Phleum pratense.* To the same genus *Phleum* belong several other species of grasses found native; but none of these have been found to possess any agricultural value.

The *Phleum pratense* is a perennial grass, which is knotty or bulbous, and somewhat creeping. It grows from 18 inches to 2 feet high. It flowers in the third week of June, and ripens its seed in the end of July. Its limit of altitude is about 1500 feet above the sea-level. It grows in meadows and rich pastures. Some difference of opinion exists as to its agricultural value. According to Mr Sinclair, it is unfit for cultivation by itself as an alternate husbandry grass, but of great value as a constituent of any mixture of grasses for permanent pasture, or the alternate husbandry, where it should always form a part of the crop. It grows best in tenacious soils, and is especially suited for improved peaty and moist grounds.

It is one of the plants recommended in alternate husbandry, to the extent of from 1 to 2 lb. of seed per imperial acre; also for permanent pasture, for permanent lawn-pasture, for lands in preparation for irrigation, for pasturage and cover in thick shady woods, for heathy and moory lands which have been improved with a view to their producing better pasturage, for improved deep mossy ground intended to be kept in grass, and for marshy grounds and such as are occasionally overflowed by fresh-water tides. A bushel of the seeds averages 44 lb., and the number of seeds in an ounce is about 74,000.

Poa.—The wood meadow-grass is known to botanists as the *Poa nemoralis.* To the same genus *Poa* belong many native grasses, several of which are of agricultural value.

The *Poa nemoralis* has a perennial root, which is fibrous or slightly creeping. It grows from 18 inches to 2 feet high. It flowers in the third week of June, and ripens its seed in the last week of July. Its limit of altitude appears to be about 1500 feet above the sea-level. It grows naturally in woods, thickets, shady banks, and Alpine rocks. It is an excellent grass for permanent pasture and lawns; it affords, too, a fine sward under trees. It can be made to grow freely in exposed situations. Horses, oxen, and sheep are remarkably fond of its fine, succulent, and nutritive herbage.

Several varieties of the *Poa nemoralis* are in cultivation, the chief of which is the *Poa nemoralis sempervirens*, or Hudson Bay hay-grass, also known by the name of *Poa nervosa*. This variety is remarkable for the rapidity with which it grows after being eaten or cut down, as well as by its perpetual verdure.

It is one of the plants recommended to be sown for permanent pasture, for permanent lawn-pasture, for fine lawns, bowling-greens, &c., kept constantly under the scythe, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, and for pasturage and cover in thick shady woods, in the proportion of from 1 to 2 lb. of the seeds per imperial acre. A bushel of the seeds averages 15 lb., and the number of seeds in an ounce comes near to 173,000.

Poa pratensis.—The smooth-stalked meadow-grass obtains from botanists the name *Poa pratensis.* It is a creeping-rooted perennial, the root being extensively creeping in loose sandy soil. It grows from 1 foot to 15 inches high. It flowers in the first week of June, and ripens its seed in the first week of July. It grows naturally in dry and gravelly soils, rocky places, tops of walls, &c. It is sometimes found at the height of 3000 feet above the sea-level. It is a nutritious and very early grass; but its creeping roots render it only admissible in dry light soils, where others are liable to suffer from drought.

It is one of the plants recommended to be sown for permanent pasture in light soils, for warrens or light sandy downs, and for dry gravelly situations which resist a sward from all other means, in the proportion of from 1 lb. to 4 lb. of the seeds per imperial acre. A bushel of the seeds has an average weight of 13¼ lb., and the number of seeds in an ounce amounts to 243,000.

Poa trivialis.—The rough-stalked or stoloniferous meadow-grass is named by botanists *Poa trivialis.* It is a creeping-stemmed perennial. It grows from 12 to 18 inches high. It flowers in the third week of June, and its seeds ripen in the middle of July. It grows naturally in moist pastures, meadows, waste grounds, shady places. It is not cultivated profitably in dry, exposed situations. It is, however, a highly nutritious and useful grass, which should have a place generally in permanent pastures, and is especially suited, along with *Agrostis stolonifera,* the marsh creeping bent-grass, and *Glyceria fluitans* (*Poa fluitans*), the floating sweet-grass, for irrigated meadows.

It is one of the plants recommended to be sown for permanent pasture in medium and heavy soils, for permanent lawn-pastures, for fine lawns, bowling-greens, &c., kept constantly under the scythe, in lands in preparation for irrigation, for permanent pasture and hay in orchards and other grounds much overshadowed by trees, for pasturage and cover in thick shady woods, for improved deep mossy ground intended to be kept in grass, for marshy grounds and such as are occasionally overflowed by fresh-water tides. A bushel of the seeds has an average weight of 15¼ lb., and the number of seeds in an ounce rises to 217,000.

Poa annua, annual meadow-grass, is one of the commonest of the grasses. It affords an early herbage, of which cattle, especially cows, are fond ; but being an annual, and often destroyed by a continuance of dry weather, it is rarely used in cultivation. Nevertheless, as it sheds its seed twice or thrice a-year, it is a valuable grass for giving a close and early herbage in permanent pasture.

Chemical Composition of the chief of the Forage Grasses.—Some progress has been made towards the chemical composition of a few of the forage grasses. The principal point in which the analysis is still defective relates to the separate materials of which the ash of each is made up. The investigation of this part of their composition must be completed before the analysis can be described as satisfactory. In the mean time, as much is here stated as has been determined on good evidence.

Mr Sinclair was the first to attempt a chemical examination of the forage grasses. His method, very imperfect as it is, was a considerable step in advance. The plan was suggested to him by no less an authority than Sir Humphry Davy. A given weight of the grass to be examined was subjected to hot water till all the soluble parts were taken up. The liquid was then separated from the undissolved woody matter by filtration, and carefully evaporated to dryness. The dry product thus obtained was concluded to be the measure of the nutritive matter of the plant under examination.

By a more exact scrutiny, such as the chemistry of the present day permits, the following points are sought to be determined:—

1*st*, The proportion of water in each grass as taken from the field.

2*d*, The proportion of albuminous or flesh-forming principles —that is, of all the nitrogenous principles present.

3*d*, The proportion of oily or fatty matters, such as are regarded as fat-producing principles.

4th, The proportion of elements of respiration or heat-producing principles, under which head come starch, gum, sugar, pectine, &c., or all the non-nitrogenous principles, with the exception of fatty matters and the ligneous crust of celluline.

5th, Celluline and woody fibre.

6th, Mineral matter, or ash.*

The subjoined table is drawn from the tables contained in Mr Way's paper, in as far as relates to the grasses spoken of above, with the exception of a few not noticed by him. It should be mentioned that the grasses analysed by Mr Way were procured, not from cultivated fields, but from their natural habitats.

ANALYSIS OF NATURAL GRASSES, AS REMOVED FROM THE FIELD.

	Water.	Albuminous or flesh-forming principles.	Fatty matters.	Heat-producing principles—starch, gum, sugar, &c.	Woody fibre.	Mineral matter or ash.	Date of collection.
Alopecurus pratensis,	80.20	2.44	0.52	8.59	6.70	1.55	June 1
Anthoxanthum odoratum, . .	80.35	2.05	0.67	8.54	7.15	1.24	May 25
Arrhenatherum avenaceum, .	72.65	3.54	0.87	11.21	9.37	2.36	July 17
Avena flavescens, .	60.40	2.96	1.04	18.66	14.22	2.72	June 29
Cynosurus cristatus,	62.13	4.13	1.32	19.64	9.80	2.98	June 21
Dactylis glomerata,	70.00	4.06	0.94	13.30	10.11	1.59	June 13
Ditto, seeds ripe, .	52.57	10.93	0.74	12.61	20.54	2.61	July 19
Festuca duriuscula, .	69.13	3.70	1.02	12.46	11.83	1.66	June 13
Holcus lanatus, . .	69.70	3.49	1.02	11.92	11.94	1.93	June 29
Lolium Italicum, .	75.61	2.45	0.80	14.11	4.82	2.21	June 13
Lolium perenne, . .	71.43	3.37	0.91	12.08	10.06	2.15	June 8
Lolium annuum, . .	69.00	2.96	0.69	12.89	12.47	1.99	June 8
Phleum pratense, .	57.21	4.86	1.50	22.85	11.32	2.26	June 13
Poa pratensis, . .	57.14	3.41	0.86	14.15	12.49	1.95	June 11
Poa trivialis, . . .	73.60	2.58	0.97	10.54	10.11	2.20	June 18

* See 'On the relative Nutritive and Fattening Properties of different Natural and Artificial Grasses,' by J. T. Way, 'English Journal of Agriculture,' vol. xiv. p. 174.

ANALYSIS OF NATURAL GRASSES, DRIED AT 212° FAHRENHEIT.

	Albuminous or flesh-forming principles.	Fatty matters.	Heat-producing principles—starch, gum, sugar, &c.	Woody fibre.	Mineral matter or ash.
Anthoxanthum odoratum,	10.43	3.41	43.48	36.36	6.32
Alopecurus pratensis, . .	12.32	2.92	43.12	33.83	7.81
Arrhenatherum avenaceum, ...	12.95	3.19	38.03	34.24	11.59
Avena flavescens, . . .	7.48	2.61	47.08	35.95	6.88
Cynosurus cristatus, . .	11.08	3.54	52.64	26.36	6.38
Dactylis glomerata, . .	13.53	3.14	44.32	33.70	5.31
Ditto, seeds ripe, . . .	23.08	1.56	26.53	43.32	5.51
Festuca duriuscula, . .	12.10	3.34	40.43	38.71	5.42
Holcus lanatus, . . .	11.52	3.56	39.25	39.30	6.37
Lolium Italicum, . .	10.10	3.27	57.82	19.76	9.05
Lolium perenne, . . .	11.85	3.17	42.24	35.20	7.54
Phleum pratense, . . .	11.36	3.55	53.35	26.46	5.28
Poa pratensis, ...	10.35	2.63	43.06	38.02	5.94
Poa trivialis, ...	9.80	3.67	40.17	38.03	8.33

Cereals.—The cereal grains, all of which rank botanically as grasses, are wheat, oats, barley, rye, rice, maize or Indian corn, millet, and the less known *sorghum*, *durra*, or negro Guinea corn.

The fruit of the grasses is one-seeded, known to botanists as a caryopsis. Its endocarpium, or inner membrane of the seed-vessel, adheres inseparably to the integuments of the seed. The seed, exclusive of its coats, consists of a farinaceous albumen (in the botanical sense) on the outer side, and at the base lies the embryo. In a nutritive point of view, the albumen is the most important part of the seed.

The cereal grains contain the following proximate principles :—

Starch.
Vegetable albumen,
Vegetable fibrine, } Crude gluten.
Gluten-caseine,
Oily matter.
Sugar.
Gum.
Earthy phosphates.
Ligneous matter (bran, husk, &c.)
Water.

A bitter principle, and resin, have been found in some kinds of corn.

The ultimate elements of the following cereals is thus stated on the authority of Boussingault:—

ULTIMATE ELEMENTS OF CORN, DRIED AT 230° FAHRENHEIT.

	Wheat.	Rye.	Oats.
Carbon,	46.1	46.2	50.7
Hydrogen,	5.8	5.6	6.4
Oxygen,	43.4	44.2	36.7
Nitrogen,	2.3	1.7	2.2
Ashes,	2.4	2.3	4.0
	100.0	100.0	100.0

The nitrogenised constituents of the cereal grains—or, in the language of Liebig, their plastic elements of nutrition—are vegetable albumen, gluten-fibrine, gluten-caseine, and gluten (Dumas and Cahours); while their non-nitrogenised constituents, or the elements of respiration, are starch, sugar, gum, and oily matter.

Triticum vulgare.—The varieties of wheat are too numerous to be noticed here; we must refer the reader for information on this point to some work on agriculture. It is the most valuable of the cereal grains. The grain of wheat consists of two portions, the husk or bran, and the grain proper. The proportion of bran to flour varies in different specimens, but the bran usually forms not less than 15 per cent of the whole weight.

The following analyses are taken from tables by Mr Edward T. Hemming: *—

GRAIN OF WHEAT, DRIED AT 212° FAHRENHEIT.

Organic matter,	97.0
Ash,	3.0

ULTIMATE ELEMENTS.

Carbon,	47.2
Hydrogen,	6.0
Oxygen,	44.4
Nitrogen,	2.4
	100.0

PROXIMATE PRINCIPLES.

Albumen,	3.5
Gluten, Caseine, Fat, oil,	11.6
Starch,	65.5
Gum, dextrine, pectine, Sugar,	5.4
Fibre and husk,	14.0
	100.0

STRAW OF WHEAT, DRIED AT 212° FAHRENHEIT.

Organic matter,	94.9
Ash,	5.1

ULTIMATE ELEMENTS.

Carbon,	52.1
Hydrogen,	5.7
Oxygen,	41.8
Nitrogen,	0.4
	100.0

* 'English Journal of Agriculture,' vol. xiii. p. 450.

PROXIMATE PRINCIPLES.

Albumen,	—
Gluten,	1.6
Caseine,	—
Fat, oil,	0.6
Starch,	—
Gum, dextrine, pectine, Sugar,	36.7
Fibre and husk,	61.1
	100.0

CHAFF OF WHEAT, DRIED AT 212° FAHRENHEIT.

Organic matter,	86.0
Ash,	14.0

Nitrogen, 1 per cent.

No analysis of the organic matter in the chaff.

The following analysis of the bran of wheat is from Johnston :—

Water,	13.1
Albumen,	19.3
Oil,	4.7
Husk (woody fibre and a little starch),	55.6
Salts,	7.3
	100.0

ASH IN THE GRAIN OF WHEAT, DRIED AT 212° FAHRENHEIT.

Sulphur,	0.058
Sand and silica,	1.200
Potash,	22.400
Soda,	10.900
Lime,	2.700
Magnesia,	11.200
Alumina,	—
Oxide of iron,	0.800
Oxide of manganese,	—
Chloride of potassium,	—
Carry forward,	49.258

Brought forward,	49.258
Chloride of sodium,	—
Phosphoric acid,	50.100
Sulphuric acid,	0.100
Carbonic acid,	—
	99.458

ASH IN THE STRAW OF WHEAT, DRIED AT 212° FAHRENHEIT.

Sulphur,	0.238
Sand and silica,	67.600
Potash,	9.200
Soda,	0.300
Lime,	8.500
Magnesia,	5.000
Alumina,	—
Oxide of iron,	1.000
Oxide of manganese,	—
Chloride of potassium, } Chloride of sodium, }	0.600
Phosphoric acid,	3.100
Sulphuric acid,	1.000
Carbonic acid,	—
	96.538

ASH IN THE CHAFF OF WHEAT, DRIED AT 212° FAHRENHEIT.

Sulphur,	0.091
Sand and silica,	81.200
Potash,	9.100
Soda,	1.800
Lime,	1.900
Magnesia,	1.300
Alumina,	—
Oxide of iron,	0.400
Oxide of manganese,	—
Chloride of potassium,	—
Chloride of sodium,	—
Phosphoric acid,	4.300
Sulphuric acid,	—
Carbonic acid,	—
	100.091

Sir H. Davy long ago remarked that the wheat of warm climates abounds more in gluten (gluten-fibrine, gluten-caseine, and gluten) and in insoluble parts than that of colder climates, and therefore that it is of greater specific gravity, harder, and more difficult to grind. "The wheat of the south of Europe, in consequence of the larger proportion of gluten which it contains," he says, "is peculiarly fitted for making macaroni and other preparations of flour in which a glutinous quality is considered an excellence." He adds, that the hard or thin-skinned wheat is in much higher estimation in the south of Europe than the soft or thick-skinned wheat, owing to the same greater abundance of nutritive matter in the former. In connection with this difference it may be useful to refer to an elaborate analysis of growing wheat at different stages, by Professor Thomas Anderson, in a season in which the ripening was very much retarded.*

The grains, after being kept till they had become dry, afforded the following constituents :—

	Grain.	Chaff.
Water,	15.16	10.56
Albuminous compounds,	12.47	2.03
Starch, &c.,	66.00	41.27
Fibre,	4.25	27.22
Ash,	2.12	18.92
	100.00	100.00
Nitrogen,	2.12	0.32

ASH.

	Grain.	Chaff.
Peroxide of iron,	1.07	0.87
Lime,	2.14	2.56
Magnesia,	9.98	1.10
Potash,	30.55	4.81
Carry forward,	43.74	9.34

* See 'Transactions of the Highland and Agricultural Society,' vol. from July 1861 to March 1863, p. 383 *et seq.*

	Grain.	Chaff.
Brought forward,	43.74	9.34
Soda,	2.18	0.48
Chloride of sodium,	1.02	1.22
Phosphoric acid,	46.38	4.09
Sulphuric acid,	1.20	1.02
Silicic acid,	5.48	83.85
	100.00	100.00

In the dry ears the proportion of grain and chaff was as follows:—

		Containing ash.
Grain,	78.57	1.96
Chaff,	21.43	4.53

From which data the ash of the entire ears is calculated.

Peroxide of iron,	0.93
Lime,	2.44
Magnesia,	3.51
Potash,	12.57
Soda,	0.99
Chloride of sodium,	1.16
Phosphoric acid,	17.16
Sulphuric acid,	1.08
Silicic acid,	60.16
	100.00

ANALYSIS OF THE STRAW.

	Upper portion.	Lower portion.
Water,	44.04	50.11
Albuminous compounds,	1.50	0.88
Other organic matters,	48.55	46.51
Ash,	5.91	2.50
	100.00	100.00
Nitrogen,	0.24	0.14

ASH.

	Upper portion.	Lower portion.
Peroxide of iron,	0.12	0.23
Alumina,	—	0.92
Carry forward,	0.12	1.15

	Upper portion.	Lower portion.
Brought forward, .	0.12	1.15
Lime, ...	2.78	2.17
Magnesia, . . .	3.54	3.69
Potash, ...	13.21	13.88
Soda, ...	0.60	0.81
Chloride of sodium, . .	2.77	2.82
Phosphoric acid, . . .	1.60	1.33
Sulphuric acid, . . .	2.50	2.44
Silicic acid, . . .	72.88	71.71
	100.00	100.00

ANALYSIS OF THE LEAVES.

Water, ...	12.83
Albuminous compounds, . . .	2.68
Other organic matters, . . .	67.74
Ash, ...	16.75
	100.00

Nitrogen, . . . 0.43

ASH.

Peroxide of iron, ...	2.71
Lime, ...	3.71
Magnesia, ...	2.09
Potash, ...	6.74
Chloride of sodium, ...	2.27
Phosphoric acid, ...	35.2
Sulphuric acid, ...	1.11
Silicic acid, ...	77.85
	100.00

It appears, on a comparison between the analysis of the grain of wheat quoted by Mr Hemming and that given by Professor Anderson, that the proportion of organic matter is greater while that of the ash is less in that analysed by Professor Anderson, notwithstanding that the specimens used by him were retarded in their ripening by a backward season, and that after due allowance has been made for the water retained in the specimens last referred to.

We learn from Mr Pereira, on the authority of Mr Hards, miller of Dartford, that the following are the products obtained by grinding 1 quarter or 8 bushels of wheat:—

PRODUCE OF 1 QR. OF WHEAT, WEIGHING 504 LB.

	lb.
Flour,	392
Biscuit or fine middlings,	10
Toppings or specks,	8
Best pollard, Turkey pollard, or twenty-penny,	15
Fine pollard,	18
Bran and coarse pollard,	50
Loss sustained by evaporation, and waste in grinding, dressing, &c.,	11
	504

Wheat, owing to the large proportion of gluten which it contains, is commonly regarded as the most nutritive of the cereal grains. Some doubts, however, have been of late cast on this point. It yields the finest, whitest, lightest, and most digestible kind of bread. Its lightness appears to depend on the toughness of its dough, owing to which quality it better retains the carbonic acid evolved in the fermentation, and thus acquires a vesicular or cellular character. Owing to this lightness or sponginess, wheaten bread is more digestible, as the gastric juice more easily permeates the loose texture.

Semolina, soujee, and manna-croup are granular preparations of wheat deprived of bran. They are manufactured in this country from the best Kentish wheat. Macaroni, vermicelli, and Cagliari paste are also prepared from wheat, being most commonly imported from Genoa and Naples. They are also made in this country; in which case they are manufactured from semolina.

Vogel's analysis of wheaten bread, made with wheat-flour, distilled water, and yeast, but without salt, is as follows:—

Starch,	53.50
Torrefied or gummy starch,	18.00
Sugar,	3.60
Gluten, combined with a little starch,	20.75
	95.85

Exclusive of carbonic acid, chloride of calcium, and chloride of magnesium.

This analysis shows that a portion of the starch is gummified or converted into dextrine by the process of panification. A portion of the sugar requires to be accounted for: it is probably formed at the expense of the starch. The gluten does not appear to be changed in quantity, but it is changed in its tenacity and elasticity. If a piece of bread be "placed in a lukewarm decoction of malt, the starch and the substance called dextrine are seen to dissolve like sugar in water, and at last nothing remains except the gluten, in the form of a spongy mass, the minute pores of which can be seen only by the microscope." *

Though bread is named "the staff of life," it does not appear alone to be capable of supporting human life for any considerable period. How far the same observation applies to the animals of the farm in general merits particular attention. It cannot indeed be affirmed that the whole wheat plant, including chaff, straw, and leaves, has been proved to be insufficient for the maintenance of a horse, ox, or sheep. Still, observations on a point so important should not be neglected. In the fermentation of leavened bread, a small quantity of alcohol is produced, the chief part of which is dissipated in the oven. One of the most familiar examples of unleavened bread made from wheat is the article sold in the shops under the name of cabin

* Liebig, 'Chemistry in its Application to Agriculture and Physiology,' pp. 38, 39.

biscuits or captain's biscuits. What is called patent unfermented bread is made as follows :—

Wheaten flour, 7 lb.
Carbonate of soda, 350 to 500 grs.
Water, $2\frac{1}{2}$ pints.
Hydrochloric acid, from 420 to 560 grs., or as much as may be sufficient.

The carbonic acid set free here acts the part of the carbonic acid produced by the fermentation in the ordinary process.

The starch of wheat has been already spoken of (p. 324).*

Avena sativa, common oat.—As an article of nutrition, the oat stands above wheat in the economy of the farm. The oat cultivated in this country is the *Avena sativa*. When the grains are stripped of their integuments, they are called groats or grits ; and these, when crushed, are known by the name of Embden groats, and, when ground into flour, their name is prepared groats. Oatmeal is made by grinding the kiln-dried seeds deprived of their husk and outer skin.

For many particulars of the oat, which would be out of place here, we refer to the 'Book of the Farm.'

The chemical analysis given of the oat by different authorities varies considerably, as in the case of other cereal grains.

The following is the analysis of oats by Vogel :—

THE ENTIRE SEEDS.	
Meal, ...	66
Husk, ...	34
	100

DRIED OATMEAL.	
Starch, ...	59.00
Bitter matter and sugar,	8.25
Grey albuminous matter,	4.30
Fatty oil, . . .	2.00
Gum, ...	2.50
Husk, mixture, and loss,	23.95
	100.00

* For further information on wheat, see Stephens's 'Book of the Farm,' vol. i. pp. 433, 445.

The following is the composition of oatmeal according to Professor Christison :—

Starch,	72.8
Saccharo-mucilaginous extract,	5.8
Albumen,	3.2
Oleo-resinous matter,	0.3
Lignine (bran),	11.3
Moisture,	6.6
	100.0

ANALYSIS OF OATS QUOTED BY MR HEMMING.*

GRAIN, DRIED AT 212° FAHRENHEIT.

COMPOSITION OF GRAIN WITH HUSK.

Organic matter,		97.50
Ash,		2.50
ULTIMATE ELEMENTS.		
Carbon,		52.60
Hydrogen,		6.60
Oxygen,		37.90
Nitrogen,		2.90
		100.00
Ammonia,	3.55	

PROXIMATE PRINCIPLES.

Albumen, Gluten, Caseine,	17.0
Fat, oil,	6.5
Starch, Gum, dextrine, pectine, Sugar,	53.0
Fibre and husk,	23.5
	100.0

* 'English Journal of Agriculture,' vol. xiii. p. 482.

ASH.

Total sulphur,	0.0
Sand and silica,	38.6
Potash,	17.8
Soda,	3.8
Lime,	3.5
Magnesia,	7.3
Alumina,	—
Oxide of iron,	0.5
Oxide of manganese,	—
Chloride of potassium,	—
Chloride of sodium,	0.9
Phosphoric acid,	26.5
Sulphuric acid,	1.1
Carbonic acid,	—
	100.0

COMPOSITION OF OAT-STRAW.

Organic matter,	92.10
Ash,	7.92

ULTIMATE ELEMENTS.

Carbon,	52.6
Hydrogen,	5.6
Oxygen,	41.4
Nitrogen,	0.4
	100.0
Ammonia, 0.48	

PROXIMATE PRINCIPLES.

Albumen, Gluten, Caseine,	1.6
Fat, oil,	0.8
Starch, Gum, dextrine, pectine, Sugar,	42.7
Fibre and husk,	54.9
	100.0

ASH.

Total sulphur,	0.289	
Sand and silica,		35.4
Potash, } Soda, }		29.0
Lime,		6.8
Magnesia,		2.6
Alumina,		—
Oxide of iron,		0.8
Oxide of manganese,		—
Chloride of potassium,		—
Chloride of sodium,		9.2
Phosphoric acid,		—
Sulphuric acid,		16.2
Carbonic acid,		—
		100.0

CHAFF OF OATS.

Organic matter,	83.1
Ash,	16.9

ASH OF CHAFF.

Sand and silica,	59.9
Potash,	13.1
Soda,	4.1
Lime,	8.7
Magnesia,	2.6
Oxide of iron,	1.4
Chloride of sodium,	1.2
Phosphoric acid,	6.3
Sulphuric acid,	2.5
Carbonic acid,	0.2
	100.0

Besides porridge and brose, gruel and sowans are made with oatmeal. Oatmeal in water is a safe drink for horses on a journey, and amongst milk, makes a nourishing diet to calves. Gruel may be made either from groats or from oatmeal. Oat-flour was first introduced to public notice some years ago by the late Mr John Smith, Harecraigs, near Dundee, as a pleasant and nourishing ingredient of puddings and of diet for children. Excellent as it is for these purposes, its costly price has much restrained its use. Sowans are made in Scotland from what are called "seeds"—namely, the husk and some adhering starch separated from oats in the manufacture of oatmeal. These are infused in hot water, and then, by standing, allowed to become sourish, when by expression a mucilaginous liquid is obtained, which, on being sufficiently concentrated, forms a firm jelly—and this is sowans.

Flummery is very similar. Dr Antony Tod Thomson gives the following directions for making flummery:—"Take a quart or any quantity of groats or oatmeal; rub the groats or the meal for a considerable time with two quarts of hot water, and leave the mixture for several days at rest, until it becomes sour; then add another quart of hot water, and strain through a hair sieve. Leave the strained fluid at rest until it deposits a white sediment, which is the starch of the oats; lastly, pour off the supernatant water, and wash the sediment with cold water. The washed sediment may be either boiled with fresh water, stirring the whole time it is boiling, until it form a mucilage or jelly, or it may be dried and afterwards prepared in the same manner as arrowroot mucilage. Flummery should not be made in a metallic vessel." There appear to be no observations recorded as to the use of sowans or flummery in the food of the animals of the farm.

Hordeum distichon, common long-eared barley.—The common barley of this country is the *Hordeum distichon;* but several other species and their varieties are also cultivated, as *Hordeum vulgare,* spring barley, *Hordeum hexastichon,* winter barley, *Hordeum zeocriton,* sprat or battledore barley. The grains, when deprived of their husk by a mill, become Scotch, hulled, or pot barley. When all the coverings of the grains are removed, and the seeds rounded and polished, they form pearl barley. When pearl barley is ground to powder, it is called patent barley, or barley meal.

The husk of barley is slightly acrid. When deprived of the husk, as in Scotch and pearl barley, the seeds are very nutritious. Barley is more laxative than the other cereal grains; it also often increases the urinary discharge. It is regarded as less nutritive than wheat. Barley bread is thought to be more difficult of digestion than wheaten bread. Barley water forms an excellent demulcent.

The following analysis of barley is taken from Hemming's tables:—

BARLEY, DRIED AT 212° FAHRENHEIT.

Grain—organic matter,	96.90
Ash,	3.10

ULTIMATE ELEMENTS.

Carbon,		47.53
Hydrogen,		6.90
Oxygen,		43.60
Nitrogen,		1.97
		100.00
Ammonia,	2.38	

PROXIMATE PRINCIPLES.

Albumen, Gluten, Caseine,	6.0
Fat, oil,	0.3
Starch,	68.7
Gum, dextrine, pectine,	5.0
Sugar,	5.3
Fibre and husk,	14.7
	100.0

ASH.

Total sulphur, . . .	0.53	
Sand and silica, ...		26.5
Potash, ...		12.4
Soda, ...		8.4
Lime, ...		2.5
Magnesia, ...		8.5
Oxide of iron, ...		2.0
Phosphoric acid, ...		39.6
Sulphuric acid, ...		0.1
		100.0

COMPOSITION OF BARLEY STRAW, DRIED AT 212° F.

Organic matter, ...	93.50
Ash, ...	6.56

ULTIMATE ELEMENT.

Nitrogen, ...		0.26
Ammonia, . . .	0.31	

PROXIMATE PRINCIPLES.

Total sulphur, . . .	0.29	
Sand and silica, ...		73.1
Potash, ...		3.4
Soda, ...		1.0
Lime, ...		10.5
Magnesia, ...		1.5
Alumina, ...		2.9
Oxide of iron, ...		0.2
Oxide of manganese, ...		0.4
Chloride of potassium, Chloride of sodium, }		1.3
Phosphoric acid, ...		3.4
Sulphuric acid, ...		2.3
		100.0

AWN.

Organic matter, ...	85.9
Ash, ...	14.1

ASH OF AWN.

Sand and silica,	70.7
Potash,	7.7
Soda,	0.4
Lime,	10.4
Magnesia,	1.3
Oxide of iron,	1.4
Chloride of sodium,	1.1
Phosphoric acid,	2.0
Sulphuric acid,	3.0
Carbonic acid,	2.0
	100.0

Barley is the grain commonly made into malt. This is accomplished by promoting germination by means of moisture and warmth, and then checking the process by a high temperature. In this process the peculiar nitrogenous principle diastase is produced. This principle does not constitute more than the 1-500th part of the malt, yet serves to convert the starch of the seed into dextrine and grape-sugar preliminary to the operation of brewing. Experiments have recently been made on the nutritive properties of malted grain as compared with the same grain unmalted. It does not yet appear that the process of malting materially improves the nutritive properties. The infusion or decoction of malt called sweet-wort contains saccharine matter, starch, glutinous matter, and mucilage. It is nutritious and laxative, and has been employed as an antiscorbutic and tonic. The decoction is made by boiling three ounces of malt in a quart of water, and this quantity is the daily dose for a man.

Barley Sprouts or Comins.—In the germination of barley, which constitutes the first step in the process of malting, the radicles are protruded at one end of the seeds, and when the drying process commences, by which germination is checked, the radicles drop off, and are collected for use under the name of barley sprouts or comins. They are of service both for feeding cattle and also as a manure.

A complete chemical analysis of these barley-sprouts has not yet been made. The ash has, however, been analysed, and some remarkable results obtained. Moreover, it has been discovered that a large proportion of nitrogen is carried off by the sprout from the malt, while diastase is generated, not in the neighbourhood of the radicle or sprout, but in that of the germ. One hundred parts of dry barley yield 90.22 of malt, and 3.99 of malt and kiln dust, which is chiefly made up of the barley-sprouts. In this small proportion of the original 100 parts of barley there is contained 1-9th of the whole nitrogen in the 100 parts of barley; that is, 100 parts of barley lose 13.5 per cent of nitrogen by passing into 90.22 parts of malt.

When dry barley-sprouts are burnt, there is left 7.25 per cent of ash, which has the following composition:—

Potash and soda,	36.78
Lime,	3.09
Magnesia,	5.46
Oxide of iron,	1.09
Phosphoric acid,	24.87
Sulphuric acid,	4.84
Chlorine,	7.95
Silica soluble in water,	1.80
Insoluble silica,	14.12
	100.00

In this table the large figures stand opposite to the alkalies potash and soda, the phosphoric acid, and silica. As silica does not exist in grains of barley freed from husk, therefore the large proportion of silica that exists in the radicle must be derived from the husk during germination. This is thought to explain why the husk of barley clings to the seed till germination is far advanced ; whereas the husk of the oat may be separated at an early stage without detriment to the process.

Draff and Dreg.—Draff consists of the exhausted husks of malted barley after the process of fermentation, whether employed for malt liquor, or for the low wines, as they are called, from which spirit is distilled. Brewer's draff is said to contain less nutritive matter than distiller's draff.

The following is given as the composition of 100 lb. of brewer's draff :—

Water,	75.85
Gummy matter,	1.06
Other organic matter, chiefly husk,	21.28
Proteine compounds,	0.62
Ash,	1.19
	100.00

Professor Johnston estimates the ash of exhausted brewer's malt at 4.93 per cent, and gives its composition as follows :—

Alkaline salts (chlorides, with a small quantity of sulphates) and alkali,		7.60
Phosphoric acid in combination with alkali,		2.11
Lime,	13.00	
Magnesia,	8.21	
Oxide of iron,	1.13	48.90
Phosphoric acid in combination with lime, &c.,	26.56	
Silica,		41.39
		100.00

This draff has lost nearly all the soluble alkaline salts, while it retains a great proportion of the alkaline phosphates, of the phosphate of lime, and of the silica.

Dreg is the residue after the distillation of spirit from the fermented liquid termed low wines. Dreg consists of a thin and a thick liquid. Five gallons of thin and two gallons of thick dreg yield 3 lb. of dry food. One gallon of thin dreg, on evaporation, leaves 4235 grains of solid matter, while 1 gallon of thick dreg leaves 10,884 grains of solid matter. Of the 4235 grains left in the first case, 3871 are organic matter, and 364 inorganic matter. Of the 10,884 grains in the second case, 10,290 are organic matter, and 594 grains are inorganic matter.

Dreg is given by dairymen living near distilleries in large quantities to their cows in the form of drink.*

Secale cereale, common rye.—The *Secale cereale*, or common rye, though largely employed in the diet of the inhabitants of several parts of Europe, particularly in the northern regions, is seldom used as food in the United Kingdom.

ANALYSIS OF RYE AS QUOTED BY HEMMING.
DRIED AT 212° FAHR.

Grain—organic matter,		98.4
Ash,		1.6

ULTIMATE ELEMENTS.

Carbon,		47.5
Hydrogen,		5.5
Oxygen,		45.3
Nitrogen,		1.7
		100.0
Ammonia,	2.09	

PROXIMATE PRINCIPLES.

Albumen, Gluten, Caseine,	10.5
Fat, oil,	3.5
Starch,	64.0
Gum, dextrine, pectine,	11.0
Sugar,	3.0
Fibre and husk,	8.0
	100.0

* See Stephens's 'Book of the Farm,' vol. i. p. 278.

ASH.

Sand and silica,	9.3
Potash,	33.8
Soda,	0.4
Lime,	2.6
Magnesia,	12.8
Oxide of iron,	1.0
Phosphoric acid,	39.9
Sulphuric acid,	0.2
	100.0

COMPOSITION OF STRAW OF RYE.

Organic matter,	96.5
Ash,	3.5

ULTIMATE ELEMENTS.

Carbon,	51.6
Hydrogen,	5.7
Oxygen,	42.3
Nitrogen,	0.4
	100.0

Ammonia, ... 0.48

ASH.

Sand and silica,	64.4
Potash,	17.2
Lime,	9.1
Magnesia,	2.4
Oxide of iron,	1.4
Chloride of potassium,	0.3
Chloride of sodium,	0.6
Phosphoric acid,	3.8
Sulphuric acid,	0.8
	100.0

Rye bread is baked on the Continent in both sweet and sour state. To those unaccustomed to it, it is apt to cause looseness. It is little used in this country, yet, long after the beginning of this century, it was sold at stalls in Edinburgh, near the Cross. It was called anchor-stock, from the shape of the loaves.

Rye is very liable to the attack of ergot, a species of fungus; and to the use of ergotised rye a diseased state of the human body, termed ergotism, is ascribed. This diseased condition assumes two distinct forms, one convulsive, the other gangrenous ergotism. In the convulsive form, spasms of the extremities are present; in the gangrenous, gangrene of the same parts occurs.

Oryza sativa, rice.—Rice in the husk is called paddey in the East. The kinds of rice most esteemed in this country are the Carolina and the Patna rice. Rice is grown not only in India, China, the West Indies, and various parts of America, but also in some of the southern countries of Europe.

The following table, after Branconnot, exhibits the comparative composition of Carolina rice and Piedmont rice :—

	Carolina.	Piedmont.
Starch, ...	85.07	83.80
Parenchyma (woody fibre), .	4.80	4.80
Glutinous matter, . .	3.60	3.60
Rancid, colourless, tallowy oil, .	0.13	0.25
Uncrystallisable sugar, . .	0.29	0.05
Gum, ...	0.71	0.10
Phosphate of lime, . .	0.40	0.40
Water, ...	5.00	7.00
Acetic acid, phosphate of potash, chloride of potassium, and vegetable salts of potash and lime, .	*traces.*	*traces.*
	100.00	100.00

Rice, though nutritious, is less so than wheat, as might be anticipated from the less proportion of nitrogenous matter which rice contains. It is less laxative than the other cereal grains ;

it is even believed to possess a binding quality, so as to be often prescribed against looseness of the bowels.

Zea Mays, maize or Indian corn.—*Zea Mays* is the name given by botanists to the monœcious grass which yields the Indian corn.

ANALYSIS OF INDIAN CORN BY BIZIO.

Starch,		80.920
Zeïne,	Fatty oil,	1.152
	Gliadine,	2.499
	Zimome,	2.107
Zimome,		0.945
Fatty oil,		0.323
Extractive matter and sugar,		1.987
Gum,		2.283
Hordeine,		7.710
Acetic acid, salts, and loss,		0.074
		100.000

In this analysis several names occur not at present in current use — namely, zimome, gliadine, zeïne, and hordeine. Zimome and gliadine were described by Taddei, an Italian chemist, as the constituents of gluten, the zimome being distinguished by striking a blue colour with the powder of guaiacum, the resinous principle got from lignum vitæ, while the gliadine is to be known by being soluble in alcohol. These views, however, have not been adopted, though the names still occasionally turn up in analyses. The term zeïne (from ζεια, a kind of grain) is plainly employed to signify the same principle as gluten under the Italian view—namely, zimome, gliadine, and fatty oil. Hordeine was described by Prout as a principle peculiar to barley, and seems, in fact, to be diastase.

Indian corn is a wholesome and nutritious aliment, yet apt to produce looseness in persons unaccustomed to its use. The young grains in the green state make an excellent vegetable for the table, and are used as a substitute for green pease.

Indian corn meal mixed with cheese and baked into a kind of pudding, forms the dish called by the Italians "polenta." The substance sold in the London shops under the name of polenta is the meal of Indian corn. Poultry are very fond of, and thrive well on, Indian corn; and in Austria horses are fed on it, after it has been steeped for a time in water.

Panicum miliaceum, millet. — The *Milium effusum,* or millet-grass, has been already spoken of among the forage-grasses (p. 445). Its seeds, which are produced in great abundance, form an agreeable food for young pheasants and other granivorous fowls. But the millet-grass (*Milium effusum*) is to be distinguished from the cereals which pass under the name of millet. These are the *Panicum miliaceum,* the *Sorghum vulgare* (*Holcus sorghum*), the *Sorghum saccharatum, Sorghum spicatum,* the *Sorghum halepense.* These several kinds of millet are usually confounded together. Of the *Panicum miliaccum* there are two varieties, the brown and the yellow. They are sometimes cultivated in this country for feeding poultry, or, after the husk has been removed, to be used as a substitute for rice. But for either purpose they are more profitably imported from the shores of the Mediterranean, where they are grown in great abundance. The *Sorghum vulgare* (formerly *Holcus sorghum*) is much cultivated in Arabia and most parts of Asia Minor. It has been introduced into Italy, Spain, Switzerland, and some parts of Germany; also into China, Cochin-China, and the West Indies, where it grows five or six feet high or more, and being esteemed a good food for labourers, it is called negro guinea-corn. In Britain the seeds seldom ripen well in the fields, unless the autumn be particularly dry and warm. In Arabia it is called dora, or durra. The flour is very white, and it makes good bread. In Italy the millet bread is generally dark and coarse. In Tuscany it is used chiefly for feeding poultry and pigeons;

sometimes for kine, swine, and horses. Brooms are made of the spikes, which are sometimes imported into this country.

The *Sorghum saccharatum* abounds in sugar; it is called the millet of Caffraria. The millet of the *Sorghum spicatum* is known in America as couscou.

Acotyledonous Plants.—Sub-class *Acrogenæ*. *Filices*, Fern order.—Of some species the rhizomes are esculent and used as food, as *Cyathea medullaris, Diplazium esculentum, Pteris esculenta, Marattia alata, Nephrodium esculentum, Gleichenia Hermanni*, which are used as food in Australia, the Sandwich Islands, and India.

The *Pteris esculenta* is the Tasmanian fern root. It is reported that pigs feed upon this root when it is turned up by the plough, and in sandy soils that they will themselves turn up the earth in search of it; and that the aborigines roast it in ashes, peel off its black skin with their teeth, and eat it with their roast kangaroo, in the same manner as Europeans eat bread. The root of the Tara fern contains much nutritive matter.

The herbage of the *Ophioglossaceæ* has been used in broths. The young shoots of *Helminthostachys dulcis* have been used as asparagus.

Equisetaceæ, Horsetail order.—*Equisetum fluviatile*, according to Haller, was eaten by the common people among the ancient Romans. Linnæus affirms that the reindeer that refuse hay eat this species; also that it is cut as fodder for kine, but that it is not acceptable to horses. The rhizomes generally of the *Equisetaceæ* contain starch. The species known in this country are *E. fluviatile*, great water horsetail; *E. Drummondii*, blunt-topped horsetail; *E. arvense*, corn horsetail; *E. limosum*, smooth naked horsetail; *E. palustre*, marsh horsetail; *E. elongatum*, long-stemmed horsetail; *E. hyemale*, rough horsetail; *E. sylvaticum*, wood horsetail; *E. variega-*

tum, variegated rough horsetail. The large proportion of finely-divided silica in horsetails may render them useful in manures.

Sub-class *Thallogenæ.* *Musci,* Moss order.—*Spaghnum* forms part of the food of the reindeer, and in the polar regions the inhabitants dry it and make it into a sort of bread.

Lichenes, Lichen order.—*Cetraria Islandica,* Iceland moss, contains starch along with a bitter principle. In Iceland and Lapland it is used as an article of diet, being boiled in broth or milk after being freed from its bitter by repeated macerations in water: it is also dried and made into bread. *C. nivalis* is also nutritive. *Cladonia* or *Cenomyce rangiferina,* reindeer moss, the name being appropriate as the vast herds of reindeer in Lapland are supported by it for a great part of the year, and especially in winter.

Gyrophora includes many species of dark lichens, which have a certain amount of nutritious quality. These are the lichens on which, under the name of *tripe de roche,* Franklin and his companions lived for many weeks.

Sticta pulmonacea, lungs of the oak, is used in the diet of invalids.

Lecanora esculenta and *L. affinis* sometimes appear in Persia, Armenia, and Tartary, suddenly in immense quantities, and are eaten eagerly by the inhabitants as food from heaven.

Fungi, Mushroom order.—A comparatively small number of mushrooms are accounted edible and safe in this country. *Agaricus campestris,* with pink gills, is the common edible mushroom of Britain. *A. Georgii* is another edible British species. *A. prunulus* is a delicious mushroom, neglected in this country.

Boletus esculentus, and some other species of boletus, are edible. *Cyttaria Darwinii* grows on species of beech, and is used as food in Tierra del Fuego. *C. Berteroi* is a Chilian species, growing on *Fagus obliqua,* which is also edible.

Exidea auricula Judæ is used in China as an article of food in soups and stews. *Morchella esculenta,* morel, an edible fungus imported from Italy in a dry state. *Tuber,* the genus under which the several sorts of underground fungi termed *Truffles* are placed. These are scented out by dogs and pigs. *T. æstivum* is that chiefly used in France, and found in the English market. *T. melanosporum* is a richly-scented truffle, to be obtained in the Paris markets. *T. cibarium, brumale, griseum, moschatum,* and *rufum* are also enumerated as in use. In Britain truffles are commonly of small weight. In Van Diemen's Land there is a species called native bread, which weighs from 1 to 2 lb. It has been called *Mylitta Australis,* but is probably a tuber. Their production may be artificially promoted.*

Algæ, Seaweed order. — *Alaria esculenta* is nutritive. *Chondrus crispus* and *C. mammillosus* are called carageen or Irish moss. They contain a substance somewhat allied to starch, which is extracted by boiling water. On cooling it forms a jelly of much use in the sick-room. *Plocaria compressa* also affords this substance. *Diatomaceæ* are ranked under the *Algæ.* Fossil remains, in the shape of siliceous exuviæ, abound in many places. The berg-mehl in Sweden, used as food, is composed of fossil *Diatomaceæ.*

D'Urvillæa utilis is used for food on the coast of Chili.

Fucus vesiculosus forms a principal part of the winter food for horses, cattle, and sheep in some of the Scottish islands, and in Gothland it is commonly given to pigs. *F. serratus* is given to cattle in Norway.

Gigartina speciosa is used to make a jelly at Swan river. *Gracilaria lichenoides* is the Ceylon moss used in soups and jellies. *G. spinosa* is the agar-agar of the Chinese, also an article of diet.

* Balfour, 'Class-Book of Botany,' pp. 963, 964.

Gelidium, one species of which is supposed to be the species used in constructing the famous Chinese condiments. *Iridea edulis* is used as food in Scotland and in the south-west of England. *Laurencia pinnatifida,* pepper dulse, is eaten in Scotland.

Laminaria saccharina yields upwards of 12 per cent of mannite. *L. digitata* also contains mannite. *L. potatorum* is used as food in Australia. *L. bracteata* in Asia is used as food. *Nostoc edule* is used as food in China. Other species of nostoc are edible—one in the arctic regions, another in Central Asia.

Plocaria tenax and *P. candida* are eaten among Indian nations. *P. compressa* affords carageen.

Porphyra vulgaris and *P. laciniata* are eaten after being dressed, under the name of marine sauce or slouk or slowcan.

Rhodymenia palmata, the dulse of the Scotch, the dillesk of the Irish, is edible.

Cattle readily eat these and other sorts of seaweeds.

Sargassum acanthocarpum and *S. pyriforme* belong to Asia, and are used as food. *S. cuneifolium* is also so used in the Sandwich Islands. *Scytosiphon filum* is part of the fodder for cattle in Norway.

Such is a brief account of the vegetable productions that have been ascertained to afford nourishment in any degree to animal nature. To draw a line between those that are suitable for the farm animals and those fit only for man is not easy. No one can predict how soon any of the rarest substances spoken of above may become in the highest degree available for the uses of feeding on the farm.

PART THIRD.

APPLICATION OF THE THEORY OF NUTRITION TO PRACTICAL USE IN THE FARM.

In every case in which life is concerned, it is not at once to be concluded that, so much material being consumed, there will be uniformly and necessarily so much product. This kind of conclusion is not indeed absolutely permitted even in those departments of production in which the materials and the results are wholly inert. In the case of manufactures, wherein the raw materials and the results are alike destitute of physiological character or of a living agency, the failure of perfect uniformity in successive effects is readily understood, when the attention turns to the well-known varieties in the purity of raw materials met with in the market respectively under one name, and again to the more or less perfect adjustment, under different circumstances, of the manipulations prescribed in the processes concerned. But it is not at first easy to realise the idea that the nutrition of animals presents a manifest parallelism to the manufacture of complex chemical substances out of materials existing in nature. And when the idea is once thoroughly apprehended, it is somewhat difficult to avoid running into the opposite extreme, and picturing that in the mind as an identity of things which is really only a parallelism. It is doubtless true that the results, whether of an inert chemical process or of a course of nutrition in a living animal, may be rendered more and more uniform, in every respective case, by more and more pains being bestowed to bring all the circumstances concerned therein to a degree of perfection. But the occasion wherein inert matter alone is under trial will much more certainly repay the pains expended by affording a corresponding uniformity of result, than that in which living action is the subject of experiment. The reason whereof is, that it is commonly easy to bring any given number of inert machines or of manipulations on inert matter to an almost perfect similarity; whereas no pains can bring two individuals endowed with life to act exactly in the same manner, even under an identity of circumstances. Every animal has an individual character, involving peculiarities which affect all its actions, nutritive as well as relative. Whence an approximation only can be made to certainty in the results expected from any rule of treatment, however well established, even in animals not merely of the same species, but of the same variety in that species, and bred as nearly as possible in the same manner.

This tendency to peculiarities of character in individual animals enables us to understand why, in trying any new plan of management, however well it may promise, there is not certainty of success, if no more than one or two animals are subjected to it, and in particular, before any such plan can be pronounced a failure, that the result must be ascertained in respect to a considerable number of the animals concerned; again, why there is room for pretty large variations, even in plans of management proved to be of good general effect in their application to individual animals, such as what is rightly called skill alone can devise and put in practice.

In the earlier parts of this treatise it has been pointed out, as far as the present state of knowledge therein permits, how exact the agreement is between the constituent elements of such and such animal bodies and the constituent elements of the kinds of food on which they thrive. But if any one thinks it certain that he has found out a new kind of food for the perfect nourishment of a horse, an ox, or a sheep, merely because he has become acquainted with an article which contains all the elements known to exist in the chemical constitution of any one of these animals, he has failed to catch up the true spirit of physiology, and runs to a far too hasty conclusion. He has reached a strong probability, but nothing more. He must be content to try his conclusion by successive cautious experiments on sufficient numbers of the animals to which it is applicable. It may be that the article in question, besides the requisite elements, contains some element that proves injurious, or in some way or other interferes with the due nutrition of the animal. The necessary elements, again, may be mingled with nothing hurtful, but may be put together in too coarse a manner to permit the organs of assimilation to appropriate them for the required reparation of the exhausted tissues. It is, in short, to be remembered that the nutrition of an animal is not a simple chemical operation, but one of particular complexity; and that, in proportion to the complexity of any such operation, the sources of failure are more and more increased in number, so as to afford, in the like degree, a widened scope for the exercise of sagacity in the several steps required to be taken.

Besides knowing what kinds of food suffice to nourish the horse, the ox, the sheep, the consideration is required of the particular circumstances under which the animal to be nourished is placed at the time. The race-horse, the hunter, the roadster, the coach-horse, the dray-horse, the farm-horse, demand each a special mode of feeding and management; and to carry such management to its utmost degree of perfection, the knowledge becomes necessary, not only of the kind of horse, of the breed to which he belongs, and of the mode and degree of exertion to which he is at any time to be subjected, but also of his own special temperament and constitution ; and the same things are true of all the other animals of the farm.

Among the circumstances which require special attention in regard to varying the kind of food and method of treatment, in respect to all the animals of the farm, one of the most familiar is the period of breeding. The consideration of this subject, indeed, in some degree of detail would afford the means of illustrating the importance and utility of the whole range of our treatise. But our plan claims precedence for another subject.

Theory of the conservation of energy applicable to show the difference between the diet of an animal at rest and an animal under exertion.—A brief view of a subject, which is most appropriately taken in connection with the horse, will give a wider illustration of the kind of circumstances under which variations should be made on the mode of feeding animals, namely, the different proportions respectively of flesh-forming, and of calorific and fat-giving proximate principles, required to maintain health in an animal at rest or only moderately exercised, and in the same animal fully or excessively worked. Allied inseparably with this question is the new field of inquiry opened up by the discoveries falling under the head of what is termed the "conservation of energy," respecting which it will be enough for our purpose, in the first instance, to remark the principle of the alternate convertibility of heat into mechanical force, and of mechanical force into heat, so that numerical equivalents have come to be employed, significant of each reciprocal effect.

First, then, of animal heat in its relation to the "conservation of energy." It is known that the higher temperature of the animal body, as compared with that of the surrounding medium, depends on a slow combustion, now often termed eremacausis, chiefly between the oxygen admitted in respiration, and the carbon in the blood, as well as the carbon of such solids as are continually decomposed in the actions, whether assimilative or relative, of the living frame. The quantity of carbonic acid thrown off in a given time is the index of the amount of this slow combustion in the same period. And since it has been ascertained that the amount of heat produced by the combustion of fixed quantities of carbon and oxygen is the same whether the combustion be rapid or slow, the sum of the heat generated in a given time in a living body, whether sensible or metamorphosed, is determined when the quantity of carbonic acid thrown off in that period is ascertained. The effect of the combustion of hydrogen, sulphur, phosphorus, is often omitted in such calculations in the mean time, partly for the sake of simplicity, partly because the oxygen of the solids decomposed supplies nearly what is required for their combustion. It is a part, however, of the "doctrine of the conservation of energy" that all the heat that is produced in a living body by the slow combustion in question does not become sensible, but that a part of it passes into, or at least represents, the motive forces continually exercised in a greater or less degree in an animal body. And there are even other actions besides mere motive operations, particularly in the human body, that cause the disappearance of a portion of the heat generated. Thus Dr Lyon Playfair, in one of his excellent memoirs on this subject, says: "In the functions of bodily activity there are four kinds of work which a man has to perform: (1) Vital work, (2) Heat work, (3) Mechanical work, (4) Mental work. The 'vital work' refers to that proceeding in the body, in the direction of which man is more or less an unconscious agent. The heart beats, the blood circulates, the lungs play—digestion, assimilation, and secretion go on by an inner directive movement, independent of the man's will. On these operations a large amount of work is expended. We can calculate it with accuracy in the case of the human heart. This important organ is continually propelling blood with force through the arteries, never ceasing day or night in its labours. If we suppose that the efforts used by it in propelling blood were all concentrated in raising its own weight, then its daily work is represented by the astonishing number that it might raise its own weight about ninety miles high."* Thus the heart's action constitutes a principal part of what in the above quotation is called vital work: it is of the same character in common quadrupeds, and also in other parts of the animal kingdom as in man. What is specially termed "heat work," is that part of the eremacausis or slow combustion which supplies the heat that replaces the temperature lost by the living body, owing to the medium in which it lives being colder than itself. "Mechanical work" is the power with which living bodies operate on things without, as when a labourer is engaged in digging a drain, or a horse is employed in dragging a stage-coach. "Mental work" is the exercise of thought, said to be the source of a high expenditure in man, however limited in common quadrupeds and the like.

It cannot be repeated too often that while an animal is stationary in point of weight, the ingested matter, in a given time, must be equal to the egested matter; that is, that the food must be of the same absolute quantity as the excretions in the period referred to. The excretions which require to be taken into account in making this comparison are essentially the carbonic acid gas thrown off in respiration, the urea as a type of the urinary excretion, and the feculent discharge from the bowels. There is, then, as just stated, during the actions of life, and

* 'Good Words,' February 1865.

great in proportion to their activity at the time, a continual disintegration of the living solids, which, in so far as it is a chemical operation, takes place under the animal temperature in the presence of the oxygen freely supplied in respiration, and conveyed from the lungs by the arterial blood to the capillary vessels of every part of the living system.* This dis-

* What is here stated, as well as the subsequent observations relative thereto, is left as written in the earlier part of the year, before a kind of crusade arose in the course of the summer, directed, as it would seem, against some of the views on the disintegration of the solids for a long time received almost as axioms in Physiology. This crusade took its rise from memoirs in the scientific journals, by Frankland, by Fick and Wislicenus, and by Lawes and Gilbert. It is, however, chiefly in some semi-scientific publications that it has been carried to an unwarrantable extent. To do Fick and Wislicenus justice, they could not cast any doubt on the proposition contained in the sentence to which this note is appended, since their memoir opens with the statement that "it is now a universally acknowledged fact that muscular action is brought about by chemical changes alone;" and again, "that all are not agreed what the substance is which by oxidation furnishes the store of actual energy which is capable of being in part transmuted into mechanical work." Neither can Frankland nor Lawes and Gilbert be charged with denying the general proposition that the disintegration of component parts of the living body is the source of its energy in mechanical effects; yet in the papers of Lawes and Gilbert, as well as in that of Frankland, undue countenance is given to the idea that the chief materials for the production of muscular power are non-nitrogenous, and that the necessity for nutrition in the muscles is not greater after severe exertions than after periods of quiescence. To maintain, as Frankland does, that the blood supplies the material by the transmutation of which mechanical effects in the body, whether internal or external, are brought about, is hardly to deny that the disintegration of living parts is their source—for the blood does not contain crude aliment, but aliment already elaborated in the processes

integration more particularly occurs in the muscular fibres so largely concerned in the operations of the animal economy. It is continually going on in the acts concerned in what was termed above, vital work—that is, in the contraction of the heart and blood-vessels, and in the processes of respiration and assimilation ; and even when the body is at rest, not a few of

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subservient to assimilation. Starch, sugar, oil, albumen, do not escape digestion in the stomach, duodenum, and the organs interposed between the alimentary canal and the system of the venous blood. And even were it allowed that sugar and oil, existing in the venous blood in no closer approach to vitality than as being products of lifeless organic matter, are the source of animal heat, when burnt with the oxygen of respiration, it is plain that the supply of such materials would be but occasional, that is, for a period after each meal, and not constant, like the unceasing competency of a living body to afford animal heat and muscular energy, not always slackening even at the moment when death is at hand. If, then, the blood be largely and constantly concerned in the production of animal heat and muscular energy, it must be by the disintegration of its organic constituents in the presence of the oxygen received in respiration; in which case a long-debated question must recur—namely, whether the carbonic acid expelled in expiration be formed exclusively in the lungs, or partly in the lungs and partly in the capillaries throughout the body. If the animal heat and the heat to be metamorphosed into muscular energy be the result of the combustion of semi-assimilated aliment newly brought from the digestive organs, aided by the disintegration of the organic constituents of the blood itself, then all that heat must be produced within the chest—for the portion to be metamorphosed must in that case be sensible heat till it is conveyed to the muscular organs: surely, then, so large an amount of heat developed in the chest would realise the idea so often put forward of old, and burn up the lungs.

That the blood supplies material for animal heat, in so far as it contains at any time either non-azotised combustible matter, or proteine compounds beyond what the present wants of the living the voluntary muscles are unceasingly in action; but it is in the exercise of greater or less bodily activity that the disintegration of the voluntary muscles principally occurs. To confine our attention, then, to the muscular system, this disintegration, which is continually going on, is manifested principally in the production of carbonic acid—the effect being, that

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system require, is undeniable; yet it seems, *prima facie*, so probable that the muscular system itself affords the material by the oxidation of which mechanical energy is generated, that the impossibility of such being the case almost requires proof before Frankland's idea of the blood being its source finds any room to be entertained.

But to clear the way towards the exact point under dispute, it should be premised that there is a general agreement among the partisans of the doctrine of the "conservation of energy" that the amount of carbonic acid produced in a living body within a given period is an index of the whole energy expended in that interval on the several kinds of work performed therein—namely, heat work, vital work, nerve work, and external mechanical work. And now to come to the point in dispute; what is affirmed by one party—namely, that muscular energy is the effect of disintegration of the muscular substance by its conversion into carbonic acid and azotised compounds, commonly thrown off by the kidney — is denied by the other party, on the ground of the urea and allied compounds in the urine not being uniformly in corresponding measure with the muscular exertion performed in the period of which note has been taken.

Such statements as the following are strongly in favour of the belief in respect to muscular disintegration being the source of mechanical energy in living bodies. Non-nitrogenised alimentary substances, such as starch, sugar, oil, hardly maintain life beyond the period to which it is prolonged under complete abstinence, while, on inspection after death, all the usual marks of death by starvation are met with. On the other hand, when death occurs in an animal confined to one azotised nutritive principle, life is prolonged beyond the period required for death by starvation, and the appear-the oxygen supplied by the blood seizes the carbon which, to the extent of about one-half its weight, is a constituent of the muscular tissue, so as respects some part of it entirely to disorganise its living character. It is well known, however, that when oxygen and carbon combine, whether slowly or rapidly, the case is one of combustion, and that heat is the

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ances belonging to starvation, as seen after death, are not manifest.* But were non-azotised aliment capable of sustaining muscular movements, of which such as take place within constitute so nearly the whole phenomena of a living body, why should not the state of starvation under such a diet be at least somewhat postponed? Urea continues to be secreted when nothing but non-azotised aliment is taken, and even when no food whatever is used, so that the connection, in a certain measure, between its formation and the disintegration of the azotised issues is indisputable. The very number of such observers as maintain that an increase of muscular exertion is attended with an augmentation of urea in the urine is an important circumstance in the controversy; nor is it to be forgotten that the urea formed may be sometimes retained for longer or shorter periods either in the muscles or in the blood; and further, that even a deficiency of the watery part of the urine gives rise to a longer retention of the urea as well as of other constituents of the urine; again, that many circumstances render it probable that other azotic compounds besides urea are sometimes formed at its expense within the body, and of these that some are not thrown off with the urine; in short, that variable conditions may prevent the urine from receiving the whole of the nitrogenous compounds resulting from the disintegration of the azotised tissues, and that it may even happen that when rapid supplies of oxygen are afforded, the nitrogen may escape uncombined, as when albumen out of the body is burnt in pure oxygen gas. Lastly, there is the well-established fact, that dietaries for such animals as the horse and ox, drawn from extensive experience of the admixture of food required by these animals for the maintenance of health and strength, respectively show, under repose and labour, that, in

* See 'Lancet,' April 1863.

primary result. Moreover, if it can be discovered how much carbonic acid has been produced in a given time, we can pronounce how much heat has been extricated, because we know, when a certain quantity of carbon has burned in oxygen, how many times a corresponding weight of water will be thereby raised in temperature one degree of Fahrenheit or one degree

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proportion as the labour is increased, there must be a corresponding increase in the proportion of nitrogenised aliment, otherwise the animal falls out of condition.

But to come to Professor Frankland's memoir, published while this work was already going through the press, there is no reason to doubt the accuracy of his experiments in the total combustion of muscle, albumen, and urea in pure oxygen gas out of the body, and of the numbers he has assigned to the corresponding units of heat in these several substances. But his conclusions involve two disputed questions, and yet settle neither, unless with assumptions that cannot be admitted without new proofs. The first question is, Whether or not the mechanical energy of the muscular system is dependent on the disintegration of the tissue of the muscles concerned, and is altogether independent of the mode in which the nitrogen of the fibres, assumed to be decomposed, escapes from the body? The second question is, Whether the proportion of nitrogen found in the azotised urinary compounds corresponds, under such limitations as extraordinary conditions must produce, with the supposition that there is in operation so constant a source of the extrication of nitrogen as ordinary muscular exertion in the exercise of the assimilative and relative functions? Professor Frankland denies the possibility of muscular energy being dependent on disintegration of the contractile tissue—and why? Because he thinks he knows the narrow limits within which nitrogen must be thrown off by the living system. Yet such narrow limits he does not learn from his own experiments, but from the experiment of Fick and Wislicenus, the fidelity of which his experiments were designed to confirm. Is this not the same as reasoning in a circle? The fidelity of the experiment made by the two Swiss physiologists is assumed in the premises from which Frankland infers that centigrade. The portion of muscular tissue thus disintegrated by the withdrawal of nearly the whole of its carbon, passes with an additional supply of oxygen into urea, which is at least the chief result, and nearly monopolises the nitrogen of the muscular substance decomposed. A portion of nitrogen issues with the feculent discharge, which appears to be the residue of the

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fidelity. It would have been of no use to either of the questions at issue to prove the units of heat corresponding to a gram of purified muscle or of purified albumen, if the nitrogenous compounds in the urine, after the ascent of the Faulhorn, had been considerably greater than what the estimate of Fick and Wislicenus makes them.

Surely, then, Professor Frankland is not entitled to use his conclusions to correct the experiments and estimates made by Smith, Haughton, and Playfair, so long as a doubt exists either as to the amount of nitrogenous aliment required under active muscular exertion, or as to the usual proportion of nitrogen thrown off either by the urine or by any other channel subsequent to such active exertion.

It does not appear from what part of Dr Playfair's lecture Professor Frankland took the statement as to 5.5 ounces of flesh-formers being the average in the diet of the hard-worked labourer, on the result of which his correction is made; but at page 19 of Playfair's lecture there is a table in which the flesh-formers, in the diet of the hard-worked labourer, are stated at 6.5 ounces, from which a mechanical energy equal to 2,329,510 foot-pounds is deducible, the percentage of carbon being taken at 53, while in the heat-givers of the same diet there is a residue of carbon answering to an additional energy for heat work of 7,481,838 foot-pounds.

It would be better to deal with a chemical compound like muscle by equivalents than by grams and the equivalent of proteine, 395 may be taken as its representative; but the equivalent of urea is 60; therefore, with an unlimited supply of oxygen, such as is brought from the lungs by the arterial blood to the muscles, one atom proteine may readily afford two atoms urea, since the nitrogen in one atom proteine is identical in amount with that in two albuminous ferments secreted for the purposes of digestion into the alimentary canal, such as ptyaline, pepsine, pancreatine, and the intestinal ferment.* A certain amount of water is formed by the oxygen afforded by the blood, as there is more hydrogen in the proteine decomposed than in the urea formed. There is but a small proportion of carbon in urea, and a small propor-

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atoms urea, without reference in the mean time to the nitrogen thrown off as a constituent of other substances.

As to the experiment made so recently by Fick and Wislicenus, it is impossible not to compliment them on the spirit that led them to undertake the ascent of a lofty mountain for a scientific purpose. Nevertheless they have laid themselves open to criticism on one or two points, that render their conclusions less trustworthy; first, they have overrated the work done, and next they neglected the precaution so strongly urged by so high an authority as Smith when he showed that the period of the production of urea is not necessarily its period of elimination. To find the work done in terms of the mechanical equivalent of heat, they multiply the weight of each of their bodies, with the addition of the load carried, by the height of the mountain. But the mechanical equivalent of heat founds itself on the lifting of a weight vertically, as water is lifted by a bucket and a hand-rope from a draw-well.

It is at once seen how much greater the task would be to lift the weight of either of these two gentlemen, the one weighing 148 lb., and the other 171 lb., through a height of between six and seven thousand feet, the height of the Faulhorn, than to climb that mountain by a frequented path. Their ascent was necessarily on the hypothenuse of a right-angled triangle, the perpendicular being the vertical height of the mountain. If the general inclination of their ascent was an angle of 45°, then the triangle was a right-angled isosceles triangle, so that the perpendicular as well as the base would be more than a third less than the hypothenuse. But the force which raises a body along an inclined plane is to the force necessary to raise the same body vertically, in the inverse ratio of

* Playfair, 'The Food of Man, in Relation to his Useful Work,' p. 56.

tion of carbon in the constituents of the feculent matters, so that the carbon contained in the carbonic acid given off in respiration, is an index of nearly the whole carbon required in a given time to preserve the body in a stationary state. It is only in carnivorous animals, however, that the whole, or nearly the whole, carbon thrown forth from the lungs in the shape of

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the length of the inclined plane to the vertical height. Thus a third part must be taken from the work claimed by Fick and the same proportion from that claimed by Wislicenus, so that the numbers will stand 129,096 – 43,032 = 86,064 metrekilograms; and 148,656 – 49,552 = 99,104 metrekilograms.

With respect to the neglect of attention in this experiment to the time required after exertion for the elimination of urea, it is to be remarked that the ascent lasted six hours, and that, these six hours included, the urine kept for examination was all collected within twenty-four hours. Here they forgot the remarkable fact so fully established, that urea becomes more abundant on the day of rest after labour, the increase continuing usually for thirty-six hours,* of which a protracted elimination is the only rational explanation. They must have overlooked the effect of their great bodily exertion in diminishing the amount of the watery secretion of the kidney by which the elimination of urea is so sensibly affected. The quantity of urine passed by Fick in the twenty-four hours after the ascent began, but little exceeded the quantity passed in the ten hours before it was entered on; and that passed by Wislicenus in that ten hours before the experiment, considerably exceeded what was passed in the twenty-four hours that followed the ascent.

When all these doubts and difficulties are considered—and doubts and difficulties as respects either side of the controversy it must be confessed they really are—to sing pæans over the demolition of the belief that the nitrogen of the urine is derived from the disintegration of the muscular tissue under the mechanical movements of the body seems at the least to be premature.—(31st October 1866).

* Smith, 'Health and Disease,' p. 124.

carbonic acid, is derived from the disintegration of the solids, as the great difference in the daily excretion of urea between that of carnivorous and omnivorous, and that of herbivorous animals shows. On the contrary, in herbivorous and omnivorous animals there is the distinct kind of food termed calorifacient or non-nitrogenised food, the carbon of which, after various changes within the body, by combining with the oxygen received in respiration, maintains the animal temperature, or, being converted into fat, becomes deposited in the adipose tissue. The case of an animal receiving an excess of food is in the mean time excluded, it being assumed that all the food is put to its proper uses.

Thus, if it be ascertained how much heat has disappeared in the production of a mechanical effect, then it can be pronounced what that mechanical effort is equal to—for example, under the denomination of pounds raised to the height of one foot; or if it be ascertained how much mechanical effort has been expended under a similar denomination, then it can be pronounced how much heat has been produced.

Dr Playfair's views coincide with those of Liebig, and though in a few points we may find it necessary to differ from him, we have judged it preferable to retain his leading principles on this subject, notwithstanding some recent experiments that, in a certain degree, seem to contradict them; because we are satisfied that further inquiry will show his conclusions to be more consonant than the opposite to the established laws of physiology.

Whenever oxygen unites with carbon in the living body, heat is produced; but it is an axiom in physiology that as often as a living act takes place, the organic agents concerned become disintegrated; and as all organic agents contain carbon, and such disintegration always happens in the presence of oxygen supplied by the blood, carbonic acid, and therefore heat, are uniformly produced in all living acts, whether falling under the head of vital work, heat work, mechanical work, or mental work. The heat, however, so produced, in the case of vital work, mechanical work, and mental work, is severally metamorphosed so as not to become sensible—that heat only becoming sensible which falls under the head of heat work.

There is a general agreement among authorities as to the relation between the production of carbonic acid in the living body, and the joint amount of heat work and of the other kinds of work therein developed; but in regard to several ulterior points, as will be seen hereafter, controversies exist of a very perplexing description.

Effect of falling from a height on the temperature of a body.—The relation, however, between the generation of temperature and the production of mechanical force is the point towards which our attention in the first instance is to be specially directed.

When a body falls from a height to the ground, the temperature of that body is increased—it does not matter whether the body be solid or liquid. Thus it has been discovered that when any quantity of water is let fall from a height of 772 feet, the temperature of that water rises one degree of Fahrenheit's thermometer. But it is readily ascertained that the mechanical effect which the impact of such a body falling through that height is capable of producing is equal to what is required to raise 772 times the same mass through the height of one foot. Whence the fact that one lb. of water falling through 772 feet obtains a rise of temperature equal to one degree of Fahrenheit, and the correlative fact that that rise of temperature in one lb. of water is sufficient to raise 772 lb. weight of matter through a height of one foot, constitute the standard of measurement relative thereto in what is called the "conservation of energy."

The production of carbonic acid the measure of the total *force exerted in a living body.*—If, then, it could be easily ascertained how much carbonic acid is thrown off by an animal in 24 hours in the process of respiration, the other channels by which carbon or carbonic acid is eliminated being barely material, a numerical index would be afforded of the sum of all the several kinds of work (before enumerated) performed by the animal in that time. This, doubtless, can be accomplished, yet not so easily as to afford a practical method. Nevertheless it is not without its use in theory. Again, if it could be easily ascertained how much heat is dissipated by an animal to the surrounding medium in 24 hours, that quantity would indicate the proportion of the whole carbonic acid formed in that time which had become subservient to the mere preservation of the temperature of the body. And if the quantity of carbonic acid so indicated were deducted from the whole quantity of carbonic acid produced in 24 hours, the remainder would represent the sum of the vital, the mechanical, and the mental work performed by the frame of such animal in the period referred to. The proportion of vital and mental work cannot as yet be exactly estimated; yet if it were ascertained how much external mechanical work the animal in question had performed in the given time—as by raising a known weight of matter to a certain height—then the quantity of carbonic acid corresponding to the whole work, vital, mechanical, and mental, being diminished by the quantity corresponding to the ascertained amount of carbonic acid derived from the mechanical work, would represent the carbonic acid generated during the vital and mental work. Thus the whole amount of carbonic acid produced by the animal in 24 hours might be divided duly into three portions, representing (1) the vital and mental work, (2) the mechanical, and (3) the heat work. This, then, can in truth be done, but by methods that do not deserve the name of practical.

A few words will suffice to indicate how far such an operation is within our reach. It is believed that one ounce of pure carbon, yielding, with oxygen, 3.66 oz. carbonic acid, evolves, during combustion, heat enough to raise the temperature of 14,200 times its weight of water through 1° of Fahrenheit—that is, of 14,200 oz., or 887.5 lb. of water.* As every pound of water raised through 1° of Fahrenheit's thermometer indicates the exertion of force equal to that produced by the fall of a pound weight through 772 feet—or, what is the same thing, by the fall of 772 lb. of matter through the height of one foot—the consumption of an ounce of carbon in the formation of carbonic acid in the living system shows an amount of work performed such as is equivalent to the effect of 887.5 lb. falling through 772 feet, or to that of 685,150 lb. falling through one foot. If there be 7 oz. of carbon consumed daily in the formation of carbonic acid in the living body, the total corresponding work—vital, heat, mechanical, and mental—will be represented by a force equal to that obtainable by the fall of 4,796,050 lb. through one foot. If, as some think, there be 10 oz., or even more, so consumed, then the total work will be represented by the fall of 6,851,500 lb. through one foot—or, friction apart, to the raising of that number of pounds through the height of one foot. According to some authorities, as much as one-third of the daily force of the frame is absorbed in the action of the heart alone ; so that, when that and the other parts of vital work, the mental work, and the heat work are deducted from the above largest number, 6,851,500, there may not be a much greater estimate of the external mechanical work of which a man is capable than what is brought out by a wholly practical mode of investigation, for $\frac{6,851,500}{4} = 1,712,875$.

Total carbon in the food nearly a measure of the total energy.—According to Professor Playfair, the number of foot-pounds,

* Miller, 'Elements of Chemistry,' part iii. p. 854.

as is the phrase—that is, effect equal to the raising of so many pounds' weight one foot—in a man's full day's mechanical work is 792,000; while he states that this work may reach 1,500,000 foot-pounds when the labour is pushing or driving horizontally—that is, near a fourth part of the whole work at the highest estimate above stated. A medium number would have better suited our purpose—viz., the inferring what belongs to a horse in this respect, from what is ascertained as to a man.

We have chosen the above mode of giving an outline of this very important speculation, as sufficient to make the subject intelligible, in preference to attempting to follow out Professor Playfair's method of proceeding, for which we must refer to the three memoirs indicated below.* Professor Playfair examines dietaries of known authority adapted to men under very opposite circumstances—as for convalescents in hospitals after acute diseases, that of the inmates of prisons, that of soldiers during peace, that of soldiers during war, that of the Royal Engineers, and that of labourers under severe exertions; and from these he deduces not only how much carbon each diet contains, but also what are the relative proportions in each of flesh-giving material and calorific material. Then, choosing out several standard dietaries, one for each class of persons, he tries other dietaries by the standards corresponding to these other dietaries. In this way he produces information of the most important kind, particularly as respects the necessary proportion between the flesh-giving materials and the calorific materials under different circumstances of life.

The proportion of carbon in his several dietaries bears a material reference to the view exhibited above as to the amount of carbonic acid thrown off daily in respiration. In some of

* Playfair, Lecture at the Royal Society, Edinburgh, and at the Royal Institution, London; Memoir 1, 'Good Words,' January 1853; Memoir 2, 'Good Words,' February 1865.

these dietaries the amount of carbon is remarkably high. In the diet of convalescents, or that which is sufficient to support the life of a man without exercise, the proportion of carbon is no more than 6.5 oz.; in the mean subsistence diet, or that of prisoners and the like, the proportion of carbon is estimated at 7.469 oz.; in the mean of soldiers' diet during peace, the proportion of carbon is made 11.642 oz.; in the mean soldiers' diet during war, the proportion of carbon is held to be 12.71 oz.; in the mean diet of the Royal Engineers (the sappers and miners), engaged even during peace in laborious work, the proportion of carbon is stated at 14.844 oz. Thus, to found on this highest proportion assigned to the carbon of the daily food—viz., 14.844 oz.—the total work performed by the animal frame will be represented by the lifting of 10,170,328 lb. through one foot, a number very considerably exceeding that brought out a few pages back. This last high number is obtained on the assumption that one oz. of carbon, in combining with oxygen, yields as much heat as is sufficient to raise 14,200 oz. of water to one degree of higher temperature according to Fahrenheit's scale.

Thus: if 1 oz. of carbon in burning elevate 14,200 oz. of water one degree, then 14.844 oz. of carbon will elevate 210,784 oz. of water one degree, as follows:—

$$1 : 14{,}200 :: 14.844 : 210{,}784.8$$

$$\text{but } \frac{210{,}784}{16} = 13{,}174 \text{ lb.}$$

Again, the heat required to raise every one of 13,174 lb. of water one degree, suffices for the mechanical effect of raising 772 lb. to the height of one foot; therefore, $13{,}174 \times 772 = 10{,}170{,}328$, the number of pounds' weight raised to the height of one foot by the combustion with oxygen of 14.844 oz. of carbon.

Grounds of doubt on the foregoing statements.—A doubt may readily arise as to the accuracy of these modes of estimating the total work done in the animal frame, under the conversion of heat into mechanical force, when it is remembered that till lately it was the universal belief that the production of carbonic acid in the animal body had no other effect than to create a temperature sufficient to maintain that of the system at the standard height above the surrounding medium. For, according to the views which have been engaging our attention, not even a third part of the total heat generated by the daily combustion of carbon is devoted to that purpose, two-thirds being converted into the forces expended in particular by the heart and the muscular system.

The points that require revision to satisfy such doubts as may arise on this subject are—first, the amount of carbon thrown forth daily by the lungs under the variation of circumstances involved in the case; second, the precise amount of heat generated during the combustion of given quantities of carbon and oxygen; and, third, the quantity of heat required under the ordinary range of atmospheric temperature to keep up the standard animal heat in the case of man and the animals included in our inquiry.

As to the amount of carbon thrown out daily, the latest observations, for example those of Dr Edward Smith, entirely confirm the high estimate above stated. Dr Smith* says, —" My own experiments on the amount of carbon which is thrown out of the body are by far the most extended on record, and I have used them in the various Government reports on the foods of the labouring classes;" and he thus concludes the passage: "It may be stated that the adult body requires an average minimum daily amount of carbon of 9½ to 10½ oz. in the middle and light-labouring classes, and of 12½ to 14 oz. in the ordinary hard-labouring classes." His further

* 'Practical Dietary,' p. 20. 1864.

statement is, that about 25 grains per pound weight of the human body, under moderate exertion, is the average daily quantity thrown out by the lungs, and "if 3 grains be added to this for the waste-matter of the bowel, the total will be about 28 grains for each pound of the body's weight daily." He takes the weight of a man at 150 pounds, and states that the actual quantity of carbon contained in the food of English workpeople, according to the severity of the exertion, is from 30 to 38 grains per pound of body-weight.

Thus, according to Dr Smith's observations, the amount of carbon available for the evolution of carbonic acid gas by the lungs in working people is nearly from 10.25 oz. to 13 oz. Liebig's estimate makes the average quantity of carbon even higher, namely $13\frac{7}{10}$ oz., "which pass off through the skin and lungs as carbonic acid gas."* His observations were made on soldiers. He adds, on the authority of Boussingault, that a horse consumes $79\frac{1}{10}$ oz. of carbon in 24 hours; a milch cow, $70\frac{3}{4}$ oz.; a pig fed with potatoes, $21\frac{1}{2}$ oz. Were such a quantity of carbon, to take the nearest round number at 80 oz., daily changed to carbonic acid in the horse, for the purpose of animal temperature, it would suffice to raise 634 lb. of water—a weight equal to that of a small horse—from 100° Fahrenheit to the boiling-point.

With regard to the second point above referred to—namely, the amount of heat yielded during the combustion of given quantities of carbon and oxygen—there appears to be at present little difference of opinion among chemists. The statement cited before, and used in the calculations made—namely, that the combustion of one oz. of pure carbon evolves heat enough to raise the temperature of 14,200 times its weight of water through one degree of Fahrenheit's thermometer—accords very well with the researches of Andrews, which Liebig adopts,

* 'Familiar Letters on Chemistry,' p. 313, third edition.

and differs but immaterially from the results obtained by Favre and Silbermann. Thus, according to Andrews, the combustion of pure carbon with oxygen produces 7881 units of heat—a unit of heat being, as Liebig says, "not an ordinary degree, but the amount of heat which a weight of water equal to that of the burnt body receives when its temperature is raised one degree of the centigrade scale."* Wherefore, an ounce of pure carbon, by combustion in oxygen, yields as much heat as raises an ounce of water one degree centigrade 7881 times—or, what is the same thing, raises 7881 ounces of water one degree centigrade. But the degree centigrade is to the degree Fahrenheit in extent as 1.8 to 1; whence, by inversion, 1 : 1.8 : : 7881 : 14,185—that is, the amount of heat represented by one degree of the centigrade is to the amount of heat represented by one of Fahrenheit's thermometer in units as 7881 to 14,185; or, if a certain quantity of heat be expressed by 7881 oz. raised to one degree centigrade, the same quantity will be expressed by 14,185 oz. raised one degree Fahrenheit. Thus the estimate of Andrews differs but by 15 from that before cited, as the one yields 14,185 oz., while the other makes the round number 14,200. Moreover, according to Favre and Silbermann, the grams of water raised one degree centigrade by the combustion in oxygen of one gram of carbon are 8080 in number. Whence it may be seen that the estimate here made differs from that of Andrews only by the difference between 7881 and 8080.

Thus there is not even ground to suppose that the idea so prevalent of the quantity of carbonic acid produced in the respiration of animals being inadequate to account for the usual amount of animal heat rested at any recent period on a too limited estimate of the number of degrees of heat evolved during the combustion of carbon and oxygen.

* 'Familiar Letters on Chemistry,' p 343.

There still remains, however, the third point for consideration—namely, how far a correct estimate has yet been made as to the amount of heat required daily to keep up the animal temperature in the various circumstances of climate, and particularly in the common range of our own climate. If it cannot be made probable that an over-estimate of the amount of heat required to keep up the animal temperature has hitherto been made, then the prevailing doctrine of animal heat cannot be made to accord with the view belonging to the "conservation of energy"—namely, that a considerable part of the carbonic acid thrown off by the lungs is the result of the decomposition of contractile fibres; for example, in the unceasing action of the heart, and in the contraction of the locomotive muscles by which bodily exertions are accomplished. It is manifestly quite immaterial whether we suppose heat to be first formed and then converted into vital force and into mechanical force, or whether we suppose the vital and the mechanical force exerted at any one period to be the direct result of the combination of carbon and oxygen; in either case the quantity of carbonic acid thrown off in respiration is not, according to the doctrine of the conservation of energy, the mere measure of the heat rendered manifest, but the measure of the heat rendered manifest jointly with the corresponding amount of vital force and of mechanical force put forth in the mean time.

But to come to the point to be considered. It would far exceed our limits to enter upon an examination of the various experiments on living animals—for example, the making them breathe in receivers containing air and surrounded by water, by the rise in the temperature of which the amount of animal temperature produced in a given time has been judged of. The only kind of test for the trial of the point in question of which we can venture to avail ourselves, admits but of an approximative determination. The animal body consists of a large proportion of water, in which is diffused a much smaller proportion of solid materials. Water, however, has a far higher capacity for heat (still, so to speak) than the solid materials diffused through the water in the animal frame. If, then, a body of water is taken to represent the animal body in the process of cooling under exposure to the varying temperature of the atmosphere, it is manifest that the result will not be less in respect to the rapidity of cooling than when a body of flesh and blood is concerned, and therefore that if, *ceteris paribus*, a given quantity of carbon under combustion in oxygen be found to keep up the temperature of a mass equal in bulk, for example, to a human body at 100° Fahrenheit, that quantity of carbon in combustion will be sufficient to keep up the temperature of such a human body; it being certain, the outward protection being the same, that a human body will cool faster than its own bulk of water in proportion to the amount of substances it contains having a less capacity for heat than water. The two cases are only approximative, yet nevertheless the result of the comparison must limit the question at issue within narrow bounds.

Human bodies, or even the bodies of mammals in general, have very much the same density as water—that is to say, the weight of one is pretty much the same as that of an equal bulk of water. The average bulk of an adult male of 150 lb. weight is somewhat short of 2½ cubic feet. As in one cubic foot of water there are 1000 oz., the weight of water corresponding to a human body is about 2500 oz. It has to be determined, then, in what space of time a mass of water 2½ cubic feet in bulk, at a temperature of 100° Fahrenheit, will lose a few degrees of its temperature throughout its mass, when the day is of an ordinary warmth; or, to save figures, let us assume that 14,200 oz. of water, at 100° Fahrenheit, lose 1° per hour, this loss requires one oz. of carbon in combustion for its repair, and this repair requires to be repeated to keep up the temperature at 100° Fahrenheit twenty-four times in the 24 hours. From this, by the rule of three, we come easily at the amount of carbon required in the human body for a like effect. Suppose the weight of a man's body is 150 lb., then the number of ounces is 2400, or 100 less than in $2\frac{1}{2}$ cubic feet of water—and his temperature falls at the rate of 1° Fahrenheit for his whole mass every hour, then, as 14,200 : 2400 : : 24 : 4.05, the last number being the quantity of carbon required for such an effect in the human body. This is indeed a large quantity of carbon to be required under so low an estimate of the heat lost in 24 hours. But it belongs to the advocates for the doctrine of the "conservation of energy" to settle a point so important to the establishment of their views. The non-conducting property of the dress in man, and of the coats of animals, and also of the internal solids, is to be taken into account in any nice calculation under this head.

Application of foregoing views to the choice of food for the Horse.—In the mean time, however, taking it for granted that they can settle this point satisfactorily, we proceed to consider the division of the total carbonic acid produced by an adult animal in 24 hours into the portions respectively belonging to vital force, heat force, and mechanical force; and the application of that division, always with reference to the same doctrine of the "conservation of energy," to the determination of the proportion between the non-nitrogenous food and the nitrogenous food that may be considered compatible with the good condition of animals under the several different circumstances of their existence.

When a living body remains stationary in point of weight, the quantity of carbon consumed daily in the production of carbonic acid must be equal to the carbon contained in the food—that is, in the daily sum of flesh-formers and heat-givers. The carbon available for the support of the standard animal temperature is derived either solely from the heat-givers or jointly from the heat-givers and the flesh-formers, but the carbon applied to the production of other kinds of work, vital, mental, and mechanical, we regard as obtained from the flesh-formers alone; because, by an axiom in physiology, no vital act can take place without a decomposition of tissue having the same chemical composition as the flesh-forming nutrient proximate principles.

In applying this view to the choice of food for the horse, it will be enough to recall the following particulars as to the proportion of carbon in a few of the principal articles of his food:—

	Carbon per cent.
Flesh-formers, such as albumen, fibrine, caseine, legumine, contain . .	53.80
Heat-givers, Starch, ...	44.44
Heat-givers, Sugar, ...	42.10

COMPOUND KINDS OF FOOD.

	Per cent. Flesh-formers.	Per cent. Heat-givers.	Per cent. Total carbon.
Rye grass (dry), .	11.85	45.41	49.2
White clover (dry), .	18.76	44.42	43.7
Red clover (dry), .	22.55	48.14	51.3
Oats, . . .	15.40	58.50	52.6
Beans, . . .	32.50	55.50	46.5
Pease, . . .	23.30	67.10	47.7
Turnips (bulbs dried),	3.50	75.80	46.5
Potatoes (dried), .	5.80	80.90	45.9

Professor Playfair's plan, which deserves to be first considered, consists in making choice of an undoubted diet for the horse—one while at rest, another while under exertion—and then comparing these by means of the standard supplied in the doctrine of the "conservation of energy" with each other, and the amount of labour that the horse is known to accomplish.

On the authority of the late Professor Dick, Professor Playfair makes the following statement:—"A horse may be kept without work, but taking a little exercise, in fair condition, on 12 lb. of hay and 5 lb. of oats; but if a good amount of work is to be got out of it, the horse should get 14 lb. of hay, 12 lb. oats, and 2 lb. beans." Professor Playfair goes on to say these diets, reduced as regards their flesh-formers, are as follows:—

Horse at rest,	. . .	29.2 oz. of flesh-formers.
Horse at work,	. . .	56.2 oz. ,, ,,
Difference for work,	.	27.0 oz. ,, ,,

"The labour of a horse," he says, "is commonly reckoned equal to that of between 7 and 8 men," and as the working-food of a labourer is $5.5 - 2.0 = 3.5$, the proportion $3.5 : 27 :: 1 : x$, in which $x = 7.7$ leads to the same result;" that is to say, the difference between the amount of flesh-formers in the food of a labourer at rest, and the flesh-formers in the food of a labourer at work, $= 3.5$ oz., has the same relation to the difference between the flesh-formers in the food of the horse at rest and the flesh-formers in the food of the horse at work, $= 27$ oz., as the labour of a man has to the labour of a horse, or $1 : 7.7$—that of a horse being taken as between 7 and 8 times greater than that of a man.

The daily labour of which a horse is capable is certainly much more than seven times that amount of energy which Professor Playfair adopts as what a man may continue to exert every day throughout the year—viz., the elevation of 792,000 lb. to the height of one foot. And this is true notwithstanding that we cannot but think the Professor has adopted too high a standard of the daily effort of which a horse is capable. But not to dwell on this matter, we think it will be useful to state here an estimate of the whole energy which a horse can put forth under the two dietaries given by Professor Dick, as drawn from the entire quantity of carbon contained in each respectively in contrast with corresponding estimates. In reference to these dietaries, we assume, for greater simplicity, the average amount of carbon in the flesh-formers and heat-givers concerned to be 47 per cent; and cut off minuter fractional parts.

In the diet of the horse at rest now referred to, there are 29.2 oz. of flesh-formers, and 150 oz. of heat-givers and fat-makers, the sum being in round numbers 179 oz. The amount of carbon is thus found,—100 : 47 :: 179 : 84.

In the work-diet there are 251 oz. of heat and fat-givers, and 59.1 oz., from our tables, of flesh-formers, the sum of both being 310 oz. The amount of carbon is thus found,—

100 : 47 :: 310 : 145.

To find the number of foot-pounds corresponding to the carbon in the diet of rest:—

$14{,}200 \times 84 = 1{,}192{,}800$, number of ounces of water raised one degree of Fahr. by the combustion of 84 oz. of carbon.

$\frac{1{,}192{,}800}{16} = 74{,}550$, number of pounds in 1,192,800 oz.

$74{,}550 \times 772 = 57{,}552{,}600$, the number of pounds raised to the height of one foot by the combustion of 84 oz. carbon.

To find the number of foot-pounds corresponding to the carbon in the work-diet:—

$14{,}200 \times 145 = 2{,}059{,}000$, number of ounces of water raised one degree of Fahr. by the combustion of 145 oz. of carbon.

$\frac{2{,}059{,}000}{16} = 1{,}286{,}875$, number of pounds in 2,059,000 oz.

$1{,}286{,}875 \times 772 = 99{,}336{,}749$, the number of pounds raised to the height of one foot by the combustion of 145 oz. of carbon.

Thus, the difference between the whole energy when the animal is at rest and the whole energy when under labour, amounts in round numbers to 41 millions of foot-pounds. This far exceeds the daily labour of which a horse is capable under any possible data; but it seems certain that outward muscular exertion cannot be carried to any considerable extent without a great increase in all the other kinds of work—namely, vital work, heat work, and mental work, better named, in such a case as that before us, nerve work. Thus, if the outward muscular exertion of which a horse is capable in a day as labour be rated at so high a figure as 12 millions of foot-pounds, there remains a very large share of contemporaneous exertion for each of the other three kinds of work, or nearly 10 millions of foot-pounds each for the vital work, for the heat work, and for the nerve work.

But on the assumption, which is that adopted by Professor Playfair, of the muscular work, whether vital or external, being sustained only by the carbon derived from the flesh-formers—that is, from the disintegration of muscular substance—then the energy attributable to the flesh-formers in the diet of rest amounts to 10,132,500 foot-pounds; while that attributable to the flesh-formers in the work-diet rises to 21,239,264 foot-pounds, the difference being 11,106,764 foot-pounds,—these numbers being brought out thus, fractions apart, and the percentage of carbon taken at 52 oz.:—

$$100 : 52 :: 29 : 15$$
$$15 \times 14{,}200 = 213{,}000$$
$$\frac{213{,}000}{16} = 13{,}125$$
$$13{,}125 \times 772 = 10{,}132{,}500 \text{ foot-pounds.}$$
$$100 : 52 :: 60 : 31$$
$$31 \times 14{,}200 = 440{,}200$$
$$\frac{440{,}200}{16} = 27{,}512$$
$$27{,}512 \times 772 = 21{,}239{,}264 \text{ foot-pounds.}$$
$$21{,}239{,}264 - 10{,}132{,}500 = 11{,}106{,}764.$$

Thus, as the raising of 12 millions of pounds to the height of one foot is the utmost estimate of the muscular ability of a horse in a day, it appears that the difference between the energy corresponding to the combustion of the carbon in the flesh-formers of the diet of rest and that of the carbon in the flesh-formers of the work-diet, approximates to that number. On the assumption, then, that our typical diet of the horse at rest and that of the horse under work is correct, we have the means of determining the fitness of other dietaries for the horse without reference to the nitrogen separated from the system along with the urinary products.

A greater degree of accuracy will be obtained if one-seventh part of the whole carbon in the flesh-formers be deducted, as corresponding to the proportion of the carbon of the solids carried off in urea and the other urinary compounds.

When the estimate of the ordinary severe labour of man made by Professor Playfair, 792,000 foot-pounds in a day, is tried by its correspondence with the amount of carbon burnt with oxygen, it is found to answer to no more than 1.15 oz. of carbon. This quantity answers to 2.21 oz. of flesh-formers, which, being joined to the amount of flesh-formers (2.06 oz.) required simply to sustain life, gives no more than 4.27 oz. of flesh-formers. These numbers are brought out thus:—

792,000 foot-pounds.

$\frac{792,000}{772}$ = 1026 lb. of water raised one degree Fahrenheit.

$1026 \times 16 = 16,416$ oz. do.

$\frac{16,416}{14,200}$ = 1.15 oz. of carbon burnt in raising 16,416 oz. of water one degree Fahrenheit.

The total amount of carbon in this subsistence-diet of man is, in round numbers, 7.5 oz., while it may be called 15 oz. in his full-labour diet. The first quantity yields a total daily energy in the system equal to 5,138,432 foot-pounds — the second, 9,795,136 foot-pounds ; or reference may be made to these as respectively 5 millions and 10 millions of foot-pounds, —brought out thus :—

$7.5 \times 14{,}200 = 106{,}500$ oz. of water raised to one degree Fahrenheit.

$\frac{106{,}500}{16} = 6656$ lb. do.

6656×772 5,138,432 foot-pounds.

$15 \times 14{,}200 = 213{,}000$ oz. of water raised to one degree Fahrenheit.

$\frac{213{,}000}{16} = 13{,}312$ lb. of water do.

$13{,}312 \times 772 = 10{,}276{,}864$ foot-pounds.

Thus the difference between the total energy in a horse under work-diet and the total energy in a man under work-diet is 110,309,536—9,795,136 ; one hundred and ten millions of foot-pounds to ten millions of foot-pounds ; so that probably the available energy of a horse is eleven times greater than that of a man.

" If, again," Professor Playfair resumes, "we take two labouring animals of the same herbivorous nature—the ox and the horse—we can compare their labour and food without complicating the question by deducting the quantity required for the *opus vitale.* Experience shows," he continues, " that an ox is well fed on 50 lb. of mangold-wurzel, 3 lb. of beans, and 17 lb. wheaten straw, the flesh-formers in this food being 38.6 oz. Muschek has given us the labour of an ox, from which we obtain the following ratios :—

Work of horse in foot-pounds, / Work of ox in do., } $\frac{12{,}400{,}000}{8{,}640{,}000} = 1.43$

Plastic food of horse, / Plastic food of ox, } $\frac{56.5}{38.6} = 1.46$ "*

* Lecture, pp. 20, 21.

Explanation of some difficulties in the foregoing views.—Several difficulties, apt to startle the uninitiated reader, occur in Professor Playfair's memoir. To make his observations available in a work of a popular character like ours, it may be worth while to attempt to remove some of these. Professor Playfair's plan is excellent, nor is its excellence affected by any objections that may be started to some of its details.

To go back to the case of the food required respectively by the horse at rest and the horse under labour (p. 508). He says, in 12 lb. of hay and 5 lb. of oats there are 29.2 oz. of flesh-formers. As the composition of hay does not occur in Professor Playfair's table, it must be sought out in some other table. In one of Johnston's tables the amount of flesh-formers per cent in hay is given at 9.3. We have thus the numbers 100, 9.3 per cent, and the quantity of hay concerned, 12 lb. or 192 oz.; from which, by the rule of three, we find the proportion of flesh-formers in the latter in ounces: as 100 is to 9.3, so is 192 to 17.85 oz.

Again, we find the proportion of albuminoid principles or flesh-formers in oats to be 15.4 per cent. Whence, in like manner, the proportion in 5 lb. or 80 oz. is found,—100 : 15.4 :: 80 : 12 oz.

Thus, to omit the fraction, the 17 oz. of flesh-formers in the 192 oz. of hay, and the 12 oz. of flesh-formers in 80 oz. of oats, make the quantity of flesh-formers in the food of the horse at rest. Again, in the estimate of the flesh-formers in the food of the horse under labour, the quantity of hay being now 14 lb. or 224 oz., the proportionals are 100 : 9.3 : : 224 : 20.8 oz.; and the oats being 12 lb. or 192 oz., the proportionals are 100 : 15.4 : : 192 : 28 oz. In beans the percentage of flesh-formers is given in Playfair's own table at 27; hence 100 : 27 : : (2 lb.) 32 oz. : 8 oz.; the sum of which number of flesh-formers in the working diet of the horse, 20 + 28 + 8 = 56—the number of ounces which Dr Playfair gives, the fractions omitted. In his comparison between the food and labour of the ox and horse, the flesh-formers of the food of the ox — namely, mangold-wurzel, beans, and wheaten straw—are found thus, though the total of flesh-formers is larger in our calculation, owing to some slight difference in the estimate given of these in the tables made use of in this work. The proportion of flesh-formers in mangold-wurzel is, according to Cameron, 3 per cent; hence 100 : 3 : : (50 lb.) 800 oz. : 24 oz. The proportion of flesh-formers in beans, according to Playfair, is, as above, 27 per cent; hence 100 : 27 : : (3 lb.) 48 oz. : 12.96 oz. The proportion of flesh-formers in wheat-straw is, according to Johnston, 1.6 per cent; hence 100 : 1.6 : : (17 lb.) 272 oz : 4; whence the sum of these three results is 24 + 12 + 4 = 40 oz.

With respect to the estimate made of the work of the horse in foot-pounds, and the like estimate of the food of the ox, a few words are required. A foot-pound is by no means a happy expression. It belongs altogether to the new doctrine of the "conservation of energy." A foot-pound is the energy required to raise a pound weight one foot. The fall of a pound weight through the space of one foot, friction apart, is sufficient to raise the same weight one foot. This fact is exemplified in the pendulum, in which a ball of a pound weight, by the impulse it receives in descending, is thrown upwards on the opposite side of the line of gravitation. As mentioned before (p. 496), a pound weight of water, in falling through 772 feet, acquires an additional temperature of one degree Fahrenheit. This number, then, 772, is accounted the mechanical equivalent of heat—that is, the heat required to raise a pound of water one degree Fahrenheit is sufficient to raise a pound weight of matter 772 feet, or, what is the same thing, 772 pounds of matter through one foot; and this last fact is expressed by saying that the heat that raises a pound of water through one degree of Fahrenheit has an energy of 772 foot-pounds. Whence, when it is said, as at page 512, that the work of a horse in foot-pounds is 12,400,000, it is signified that a horse in a day can raise that number of pounds to the height of one foot, or half that number of pounds to the height of two feet, the quarter of that number of pounds to four feet. If a horse can raise, as his day's work, 12,400,000 foot-pounds, and a man no more than 792,000 foot-pounds, it is plain that a horse is not merely eight times more powerful than a man, but more than fifteen times more powerful; but this discrepancy does not touch our conclusions.

Observations on Horse-power.—To obtain a correct standard of the average daily working power of a horse is of much moment. What is called horse-power in estimating the effect of a steam-engine is above the average power of a horse for a whole day of eight or ten hours. It is the ability to raise 33,000 lb. per minute to the height of one foot. It was calculated with care, at the instance of Messrs Bolton and Watt, from the performance of the great dray-horses of the London breweries. There can be no doubt that such horses, though by no means the best fitted for continued great labour, are quite equal to this exertion for a short time, but not for what can be called a day's work. Such an exertion, continued for no more than six hours, gives nearly 12,000,000 of pounds raised to the height of one foot (11,880,000); and this is certainly within the working capacity of a horse. In comparison with this may be taken the labour of a man in driving piles, in which the ram, a load of 42 lb., is drawn up 3½ feet twenty times in a minute, so that if this exertion can be continued six hours, the number of pounds raised in that time one foot is more than a million (1,058,436). This, however, is said to be over-severe labour for a man; yet it is only a tenth or eleventh part of what the horse accomplishes. By means of a double bucket a man may draw up from a well 120 feet deep 36 lb. of water 120 times in a day—the whole effect being equal to raising to the height of one foot 518,400 lb. Again, by means of a winch, a man easily raises in a short day 845,000 lb. through the height of one foot.

Several difficulties, however, present themselves in the attempt to estimate the exact ratio between the daily labour of a man and that of a horse. Thus, if the above estimate of the daily labour of a horse be taken as the standard—namely, 12,000,000 lb. to the height of one foot in a day of six hours —and the labour of man in a like length of day be assumed as even so high as the raising of 1,000,000 lb. to the height of one foot, then the labour-power of a horse must be allowed to be twelve times greater than that of a man. But a common statement on this point is, that the labour-power of a horse is five or six times greater than that of a man;* and Professor Playfair, in his recent lecture on the food of man, makes the daily labour of a horse something short of eight times that of a man. For this statement he cites Morin † and Rankin,‡ but they make the daily labour of a man in round numbers equivalent to the effort of raising 1,500,000 lb. to the height of a foot, while that of a horse is rated at 12,000,000 lb. to the same height, the daily labour of the horse being thus regarded as eight times that of a man. But Professor Playfair takes for his ordinary standard of a man's daily labour the exertion of raising no more than 792,000 lb. to the height of one foot, in which case, as just noticed, the daily labour of a horse is nearly fifteen times greater. Professor Playfair's standard of the daily work of a man is taken from the distance performed

* Young, 'Natural Philosophy,' by Kelland, vol. i. p. 102.
† Morin, translated by Bennet, p. 20.
‡ Rankin's 'Applied Mechanics,' p. 397.

on foot by postmen—namely, twenty miles a-day throughout the year, with rest on Sundays. In this standard chosen by Professor Playfair, it is difficult to make a comparison between the weight of the body carried along horizontally by the locomotive organs for a given distance, and the mechanical effort of raising a pound weight to a foot high. It is commonly allowed that five or six times as great a weight can be carried horizontally as can be drawn along the ground with a like effort. Again, the body is moved along a level surface by the motions of the limbs with a facility like that given by wheels to a burden. It is apparently from such data as these that Professor Playfair assumes the resistance of a man 150 lb. weight in walking to be no more than $\frac{150}{20}$ or 7.5 lb., so that the number 15,840,000, or that brought out by multiplying the number of feet in twenty miles by the number of pounds in the body, being divided by 20, affords his number of foot-pounds, 792,000. There is no other fault to be found with this number as the standard of a man's daily moderate work, than the difficulty of finding out how it is arrived at. Even if this relation be correct, as respects the two cases of a man walking unloaded and a man raising a load equal to his own weight, it seems at first sight wholly inapplicable to the comparison between the effort of a man walking with a load, and one raising perpendicularly a load equal to that load and his own weight. And yet the rule is probably quite correct in every case in which the load is not greater than can be carried for the period of five or six hours. Thus, to take one of Dr Young's examples, "a strong porter," he says, "can carry 200 lb. at the rate of three miles an hour, and for a short distance even 300 lb." In the first case, if the effort can be continued for six hours a-day, as is not unlikely, with interposed periods of rest, then the sum of the successive efforts will afford one equal to the carrying one lb. horizontally forward through 33,000,000 of feet (33,264,000); but that number divided by 20 will give a product approaching to the ordinary effort of a man in a day, or the raising one lb. vertically through little short of two millions of feet (1,663,200); or, what is plainly the same thing in respect to dividend and the product, the raising of one lb. vertically through 33,000,000 feet—and, when one-twentieth is taken, the raising of one lb. through nearly 1,600,000 feet.* In the second case, in which the load is supposed to be 300 lb., that and the weight of the body, 150 lb., make together 450 lb.; that weight carried horizontally through one mile, or 5280 feet, equals one lb. carried similarly through $450 \times 5280 = 2,376,000$; so that, to equal the performance in the first, the 300 lb. load would require to be carried just fourteen miles,† an effort probably beyond the limit of human strength—so that this case indicates the kind of limits within which the rule adopted by Professor Playfair is applicable.

In taking as a standard of animal power the number of pounds weight that can be raised to the height of one foot in a day, it would be very desirable that the standard should require no qualification as to the mode in which the animal power is exerted; but that in an absolute manner is impossible, chiefly because velocity, or the rapidity with which the task is to be accomplished, makes so great a difference on the requisite muscular exertion. When the velocity does not make a material element of the case, a near approximation to an absolute standard seems attainable. Taking the mechanical effect of walking on a level as equal to 1-20th of the effort made in raising the same weight vertically, the following statements

* Weight of body, 150 lb., load, 200 lb. = 350; 350×5280 feet in a mile $\times$ 3 miles an hour $\times$ 6 hours = 33,264,000; $\frac{33,264,000}{20} = 1,663,200$.

† $\frac{33,264,000}{2,376,000} = 14$.

serve to illustrate this point:—As just mentioned, a man of 150 lb. weight, walking 20 miles a-day, makes an effort equal to raising 792,000 lb. to the height of one foot; a man of the same weight carrying a load of 60 lb. makes an effort equal to raising, in walking 20 miles, 1,103,800 lb. to the height of one foot—an effort, however, greater than could be continued for several successive days without injury to health. A horse weighing 900 lb., led without any load over 20 miles of road, on the same assumption as to the difference between horizontal carrying and vertical elevation, performs a task equal to the raising of 4,797,000 lb. to the height of one foot, or more than six times the effort made by a man of 150 lb. weight in walking 20 miles. If, again, a horse weighing 900 lb. for 20 miles carry a weight proportionate to the weight of 60 lb. carried by a man of 150 lb., or 360 lb., then the effort made equals the elevation of 6,652,800 lb. to the height of one foot. Lastly, to illustrate what is commonly said as to a man out-journeying a horse in a few days—if a horse do 20 miles a-day with a rider weighing 150 lb., his daily effort should not be too much for him, since it is no more than equal to the exertion of raising 5,016,000 lb. to the height of one foot. If however, this exertion were made, not at the rate at which a horse walks, or short of 5 miles an hour, but at the rate of 8 or 10 miles an hour, the exertion would be very different. Lastly, when a man climbs by the inclined side of a mountain to the top, it is a mistake to regard his effort as equal to that of raising his own weight through as many feet as denote the height of the mountain; for if the inclined side of the mountain be twice as long as the mountain is high, then the effort is only one-half that of raising a load equal to the man's own weight that height.

The whole of this subject thus requires careful revision.

Proposed Dietaries for the Horse tried by the foregoing Principles.—That we may not overrate what we have learned by this somewhat lengthened exposition, for a moment let us recapitulate. The fundamental facts made use of were all ascertained to our hand more or less exactly—the quantity of food required by a man at rest, the quantity required by a man under active exertion; the quantity of food required by a horse at rest, the quantity required by a horse under severe labour; the quantity of food required by an ox. Moreover, it was possible to discover what proportion of flesh-former proximate principles existed in different kinds of food, and to exhibit the proportion of flesh-former proximate principles necessary in the several different circumstances under which a man, a horse, or an ox has been considered.

It must be remembered, however, that the conclusions given as to the respective quantities of flesh-formers required by a horse at rest and by a horse under continued exertion stand solely on the two diets communicated to Dr Playfair by Professor Dick. These diets are determined by experience, but they furnish a standard in the amount of flesh-formers and heat-givers contained, by which to try other diets not equally confirmed by experience. Before going farther, then, let us examine some of the other published formulas for the diet of horses by these standards. The following formula, described as economical, is, according to the standard deduced by Dr Playfair from Professor Dick's diet, sufficient only for a horse at rest:—

10 lb. of chopped straw.
10 lb. of oats.
16 lb. of turnips.

Flesh-formers	in chopped straw,	1.6	per cent.
do.	in oats,	17.0	do.
do.	in turnips,	0.3	do.

Whence

						Flesh-formers.
				oz.		oz.
100	:	1.6	: : (10 lb. straw)	160	:	2.50
100	:	17.0	: : (10 lb. oats)	160	:	27.00
100	:	0.3	: : (16 lb. turnips)	256	:	0.76
						30.26

Here is another formula for the daily food of a horse described as economical,—one, however, which called forth Mr Stewart's remark, "that every one who has a horse has it in his power to starve the animal:"—

Turnips, 16 lb.; straw, 16 lb.

The flesh-formers in this formula are as follows:—

						Flesh-formers. oz.
Turnips,	100	: 0.3	: : (16 lb.)	256 oz.	:	0.76
Straw,	100	: 1.6	: : (16 lb.)	256 oz.	:	4.00
						4.76

The following formula is given by Professor Low for the feeding of horses—viz., chopped straw, chopped hay, bruised or coarsely-ground grain, and steamed potatoes, equal parts by weight, with 2 oz. of salt; of this mixture from 30 to 35 lb. are to be given daily. The following is the amount of flesh-formers therein contained:—

	lb.			Rate per cent.		oz.		Flesh-formers. oz.
Chopped straw,	8½	—	100 :	1.6	: :	136	:	2.17
Chopped hay,	8½	—	100 :	9.3	: :	136	:	12.64
Oats, bruised,	8½	—	100 :	17.0	: :	136	:	23.00
Potatoes, steamed,	8½	—	100 :	1.4	: :	136	:	1.90
	34							39.71

In this formula the proportion of flesh-formers exceeds that of Professor Dick, for a horse at rest, by only 9.45 oz.

In the 'Book of the Farm' it is stated that Mr John Croall, the enterprising coach-proprietor of Edinburgh, supports his coach-horses on 8 lb. of chopped hay and 16 lb. of bruised oats. The flesh-formers in this allowance are brought out as follows:—

	lb.				oz.	Flesh-formers. oz.
Chopped hay,	8 —	100 :	9.3	: :	128 :	11.92
Bruised oats,	16 —	100 :	17.0	: :	256 :	43.52
						55.44

This result nearly coincides with that obtained from Professor Dick's formula for a horse under labour, namely 56.2 oz. (see p. 508). From these examples it may be concluded that Dr Playfair has gone on safe ground when he adopted Professor Dick's two formulas (p. 508) as the ground of his calculations in respect to the amount of flesh-formers in the food of the horse in the two states respectively of rest and labour.

Urea as an index of Muscular Effort.—All the flesh-former proximate principles—viz., the albuminoid group, albumen, fibrine, caseine, legumine—contain nitrogen; but, as has been long known, the nitrogen given off in the waste of the solids is carried off by the urine chiefly in the form of urea. The amount of urea secreted in twenty-four hours being, even in man, more than an ounce for its average, and the means of discovering it in the urine quantitively being now very perfect, there is room to expect that the estimate of the amount of urea in the urine, under different circumstances in animal existence, may throw much light on the varying necessities for food. The importance of the analysis of the urine in the theory of feeding animals will hardly be doubted if this undeniable proposition be kept steadily before the mind,—"The bodies contained in the urine are mainly the products of oxidation occasioned by the action of respired air upon the nitrogenised tissues, and the sulphur and phosphorus which they contain."* Thus the oxygen taken into the lungs in respiration has not only to convert carbon into carbonic acid, but also to oxidise such elements as sulphur and phosphorus, which appear in the urine in the state of sulphates and phosphates; whence is explained, in part, why there is uniformly more oxygen consumed in respiration than is contained in the amount of carbonic acid thrown off in that function. It may be asked whether the hydrogen contained in the proximate constituent principles of the solids and of the blood does not also require oxygen when these proximate principles are decomposed. It is often said at present that part of the oxygen taken in during respiration must form water with the hydrogen of the substances decomposed during the actions of the body. In so far as any of these are pure hydrocarburets, or components merely of carbon and hydrogen, this must be the case; but there are, strictly speaking, no hydrocarburets in the living body. Even fat itself contains about 5 per cent of oxygen to 46 per cent of hydrogen, and nearly 50 per cent of carbon. If, then, as is taught, fat, sugar, and starch, or something equivalent to starch, are the proximate elements in venous blood, which, principally by slow combustion with the oxygen received in respiration, maintain animal heat, the process must be as follows: the oxygen takes the carbon from the starch, or its equivalent, and from the sugar, and in both cases there remains water—the hydrogen and oxygen left being just sufficient for that purpose; but in the case of fat, when the oxygen of respiration takes its carbon, the oxygen left is not sufficient to convert the hydrogen left into water, so that an additional portion of the oxygen received during respiration is required to convert the whole residue into water.

When, however, we compare the chemical constitution of the solids, such as the muscular tissue, with the chemical constitu-

* Miller, 'Elements of Chemistry,' vol. ii. p. 812.

tion of urea, we find the large percentage of carbon in the albuminoid proximate principles reduced to a minimum in urea, there being 54 per cent of carbon in proteine, their representative, and only 20 per cent in urea. The hydrogen is, indeed, in larger proportion than can be changed to water by the oxygen, the hydrogen being 6.8 per cent to 24.3 per cent of oxygen ; but if we suppose urea, or some representative of urea, to be formed immediately on the decomposition of the muscular tissue, then nearly the whole of the hydrogen of that tissue, and but a little more oxygen, is required for urea—for there are in proteine 6.8 per cent of hydrogen and 24.3 per cent of oxygen, and in urea 6 per cent of hydrogen and 27 per cent of oxygen. But when we look to the amount of nitrogen in urea as compared with its amount in proteine, we find a very great difference, the percentage of nitrogen in urea being 47, while in proteine the percentage is no more than 14. Thus, several like quantities by weight of proteine in the muscular tissue must be decomposed for every like quantity by weight of urea produced. And this is indicated by the equivalents of the two compounds—that of urea being 60, while that of proteine is more than six times greater, namely, 395. What becomes of the hydrogen and oxygen unprovided for, when several proportions of proteine are decomposed to furnish the requisite amount of nitrogen for one equivalent of urea, is subject for investigation. There is also a large proportion of carbon in the equivalent of proteine, as compared with its amount in urea, to be accounted for. This last point is more easily explained than that which precedes. For the decomposition, for example, of muscle under contraction is the result of the energy produced when the oxygen acquired by the blood in respiration attacks the proteine atoms, and seizes their carbon, so as to reduce it to the less proportion in which it exists in urea. It would appear, then, that if a small allowance be made for nitrogen existing in a few other azotised proximate principles in the urine, uric acid, kreatine, and kreatinine, and for a small proportion of the same element existing in the alvine excrement, the amount of nitrogen in the urea daily excreted with the urine would seem to be a good index of the amount of flesh-formers required for the support of an animal under the several different circumstances of existence.

In all the nicer kinds of inquiry of this description, our facts must, in the first instance, be drawn from what has been determined in regard to man. Yet that is hardly an inconvenience in a work that does not treat of one animal but of several animals, respecting each of which it would have been tedious to enter into the details of such a subject as now engages our attention, and which, indeed, notwithstanding some existing difficulties, promises to become an investigation of the utmost practical value in reference to the rules for feeding the animals of the farm.

When the importance of familiarising our minds to views of this kind is considered, it may not seem out of place to dwell for a moment on such a speculative topic as the following :—

The chemical equivalent of proteine, which may be taken to represent the muscular tissue, is 395, and the equivalent of urea 60. Under the contraction of the muscular fibre—that is, during its disintegration—oxygen is supplied by the blood, as we may assume, without limit. If, then, we suppose 395 grains of proteine or muscular tissue to be disintegrated, there will be afforded of—

Carbon,	216	grains.
Hydrogen,	27	,,
Nitrogen,	56	,,
Oxygen,	96	,,
	395	,,

But 120 grains, or two equivalents of urea, contain exactly the same amount of nitrogen, while in these 120 grains of urea there are also of—

Carbon,	. .	24 grains.
Hydrogen,	. .	8 ,,
Nitrogen,	. .	56 ,,
Oxygen,	. .	32 ,,
		120 ,,

If enough of oxygen be supplied to abstract a sufficient amount of the carbon and of the hydrogen, then the 395 grains of proteine will pass into 120 grains of urea. The residual carbon is 192 grains, requiring 256 grains of oxygen for its conversion into 448 grains of carbonic acid. The residual hydrogen is 19 grains, requiring 152 grains of oxygen for its conversion into 171 grains of water; but as the oxygen in the 395 grains of proteine exceeds that in the 120 grains of urea by 64 grains, there will not be required jointly for the reduction of the proportions of carbon and hydrogen 256 + 152, or 408 grains, but only 408 — 64 grains, or 344 grains ; that is to say, 344 grains of oxygen would be consumed for every 395 grains of proteine or muscular substance disintegrated during muscular contraction, while 448 grains of carbonic acid and 171 grains of water would be generated. If four times 120 grains of urea are excreted in 24 hours, then 1580 grains of proteine would be disintegrated in that period, while 1792 grains of carbonic acid and 684 grains of water would be produced ; that number of grains of carbonic acid containing 488 grains of carbon, and that quantity, when burnt with oxygen, affording to 16,143 ounces of water one degree of Fahrenheit, or one degree of Fahrenheit to 1009 lb. of water ; but 1009 × 772 = 778,948 foot-pounds,—that is, the combustion of 488 grains of carbon with oxygen represents a mechanical effect equal to the raising 778,948 lb. to the height of one foot. If 8 times 120 grains of urea are excreted, then there would be soluble that number of foot-pounds, or 1,557,896.

The two essential facts to be borne in mind in this kind of inquiry are, first, that in an animal which is stationary in point of weight, the quantity of carbon in the whole daily food is an index of the amount of carbonic acid produced in the body during that time; and that the quantity of carbonic acid thrown off by the lungs in that time is, with a merely trifling exception, a measure of the entire work performed in the meanwhile by such an animal body, including vital work, heat work, mechanical work, and mental work—the rate being equal to the elevation of 685,150 lb. of matter to the height of one foot for every ounce of carbon contained in the carbonic acid so produced: and again, that in a stationary animal, the quantity of urea excreted in 24 hours will to a certain extent indicate, by the amount of contained nitrogen, how much azotised matter has been consumed in that period.

Such is the view which Professor Playfair adopts, in the belief that the daily excretion of urea in a hard-worked man may reach nearly 2 oz., or enough to represent, on the data stated on the preceding page, a daily effort of a million and a half foot-pounds (1,557,896). Several high authorities, however, have more recently raised considerable doubts on this point. These do not, indeed, deny that urea, and the other nitrogenised constituents of the urine and fæces, represent the disintegration of the azotised constituents of the solids and the blood, but they contend that such nitrogenised constituents of the excretions do not represent more than a part of the mechanical work done by the living frame within a corresponding time. They say that the amount of urea excreted in a given time is not an index of the mechanical work done in that period—not only because it falls short of the required amount, but also because a part of it may be derived from an excess of nitrogenised aliment that has never become incorporated with the living solids. This controversy is one of much moment; but as it is going on with great activity, it will probably be soon brought to an end. To enter into it to any extent would lead us too far from our proper objects. We decidedly incline to Professor Playfair's view, both as respects the correspondence between the quantity of urea excreted in a given time and the amount of muscular effort performed in that time, and also as respects the restriction of the non-nitrogenised aliment to the office of producing sensible animal heat.

When a fascicle (a fasciculus or bundle of muscular fibres) contracts between two bones connected by a flexible joint, the bone more movable at the moment approaches to that which is more fixed. This is a purely mechanical act, produced by the shortened state of the muscle. Here no conversion of heat into mechanical effect is requisite, but the shortening of the fascicle is the result of a movement among the organic elements of each of the contained fibres. This is plainly the movement into which heat is converted. It is known that the presence of oxygen is essential to this movement; and what is more probable than that the heat generated by its presence, through its effect in combining with the carbon of the tissue, is the sole source of the heat available for the mechanical effort? Any heat generated in the mean time by non-azotised principles is wholly external to the agents in operation, and could aid in the effect no more than a red-hot hammer would increase the force of the muscles with which the blacksmith deals his blows to the anvil. If the urea formed in a given time do not always correspond to the amount of muscular exertion, as when it is very violent, it is far more probable that other nitrogenised products are then generated—such as ammonia—than that heat, arising from the combustion of non-nitrogenised principles, is converted into mechanical force.

A few words of recapitulation, in reference to Professor Playfair's conclusions, will appropriately wind up the views hitherto taken: 2 oz. of flesh-formers in the daily food suffice to keep a man alive; $3\frac{1}{2}$ oz. of flesh-formers must be in the daily food to preserve a man in health under moderate exercise; 6 oz. of flesh-formers ought to be in the daily food when a man is subjected to hard labour; $2\frac{1}{2}$ oz. of flesh-formers, or the difference between the quantity of flesh-formers required to keep the body in health under moderate exercise, and the quantity of the same necessary for a hard day's work, represent a man's productive labour in a day—that is to say, flesh-formers to the amount of $2\frac{1}{2}$ oz., over and above the $3\frac{1}{2}$ oz. indispensable daily for health and moderate exercise, render a man capable of severe exertion during a working day of 10 hours. So much does this correspondence between the supply of proper food and the capability of efficient exertion stand in the relation of antecedent and consequent, that it is said railway contractors set a watch on their men at meal-times, and take an early opportunity of dismissing from their service such men as fail to eat what they consider a sufficiency of food.

The force, then, which an animal expends in labour is derived solely from the potential energy in the flesh-formers of the food, and the oxygen by which these flesh-formers, or their representatives in the muscular tissue, are chemically transformed. Professor Playfair says, "The daily waste of tissues, secreted as urea by the kidneys, would, after supporting fully all the vital functions of the body and the limited mental functions of a labourer, enable him to execute such mechanical labour as would raise about 1,000,000 lb. to the height of one foot." But 792,000 lb. to the height of one foot being the utmost that the hardest-working labourer can accomplish of evident mechanical labour, the difference, or the force necessary to raise 208,000 lb. to the height of one foot, is that expended on animal heat, and vital and mental work.

The following is Moleschott's estimate of the admixture of ingredients constituting an average complete food for an adult man in good health. In a thousand parts there should be—

Water, ...	812.07	parts.
Flesh-formers, . . .	37.70	„
Fat, ...	24.36	„
Starch, sugar, &c., . .	117.17	„
Mineral matter, . .	8.70	„
	1000.00	„

With respect to the horse, the feeding of which is always for the purpose of keeping him in good health and strength to do such service as is required of him, it is manifest that we have in the human labourer a type and model by which to shape our proceedings. And most of the particulars now stated in respect to man become correct for the horse when multiplied by the rate at which the work of a horse exceeds that of a man.

When the several kinds of food within our reach are examined with respect to their suitableness, the three points of essential consequence to be determined are, 1, the proportion of flesh-formers; 2, the proportion of heat-givers; 3, the proportion of ash, and, as far as possible, its chemical characters. It were needless to add the proportion of refuse or useless matter, since that will be sufficiently shown by the residue.

Heat-giving and Fat-forming Principles.—Little has hitherto been said as to the heat-giving proximate principles in the food of the farm animals.

To recur to Professor Dick's formula for feeding the horse—namely, 12 lb. of hay and 5 lb. of oats when at rest, and 14 lb. of hay, 12 lb. of oats, and 2 lb. of beans when under work (p. 508), we find the sum of the first diet in ounces is 272, while the sum of the second diet in ounces is 448, the difference between them in ounces being 176.

As a rule, the heat-giving proximate principles also form the fat which becomes deposited throughout the living frame, that deposit being the overplus at any time laid up for future use in the function of animal heat. It will be convenient, then, in speaking of the animals of the farm, to join the two epithets, and to call such proximate principles the "heat-giving and fat-forming substances." In the 12 lb. of hay belonging to Professor Dick's first diet, as above, there are 103 oz. of heat-givers and fat-formers, 16.7 oz. of flesh-formers, and 11 oz. of mineral matter. In the 5 lb. of oats belonging to the same diet, there are 47 oz. of heat-givers and fat-formers, 12.2 oz. of flesh-formers, and 2 oz. of mineral matter; these results being brought out thus:—

Hay,	100	:	53.8	: :	192 oz.	:	103.0 oz.	heat and fat givers.
„	100	:	8.7	: :	192 oz.	:	16.7 oz.	flesh-formers.
„	100	:	6.10	: :	192 oz.	:	11.0 oz.	mineral matter.
Oats,	100	:	59.5	: :	80 oz.	:	47.0 oz.	heat and fat givers.
„	100	:	15.3	: :	80 oz.	:	12.2 oz.	flesh-formers.
„	100	:	2.54	: :	80 oz.	:	2.0 oz.	mineral matter.

There are thus, in the normal diet of the horse at rest, 150 oz. of heat and fat givers, 28.9 oz. of flesh-formers, and 13 oz. of mineral matter.

In the 14 lb. of hay belonging to Professor Dick's second diet, there are 120 oz. of heat and fat givers, 19.48 oz. of flesh-formers, and 13.66 oz. of mineral matter. In the 192 oz. of oats belonging to the same diet, there are 114 oz. of heat and fat givers, 29 oz. of flesh-formers, and 4.8 oz. of mineral matter. In the 32 oz. (2 lb.) of beans belonging to the same diet, there are 17 oz. of heat and fat givers, 10.4 oz. of flesh-formers, and .992 oz. of mineral matter; these results being brought out thus:—

Hay, .	100	:	53.8	: :	224 oz.	:	120.00 oz.	heat-givers.
„ .	100	:	8.7	: :	224 oz.	:	19.48 oz.	flesh-formers.
„ .	100	:	6.10	: :	224 oz.	:	13.66 oz.	ash.

Oats,	.	100	:	59.5	: :	192 oz.	:	114.0	oz. heat-givers.
„	.	100	:	15.3	: :	192 oz.	:	29.3	oz. flesh-formers.
„	.	100	:	2.54	: :	192 oz.	:	4.8	oz. ash.
Beans,	.	100	:	54.5	: :	32 oz.	:	17.0	oz. heat-givers.
„	.	100	:	32.5	: :	32 oz.	:	10.4	oz. flesh-formers.
„	.	100	:	3.10	: :	32 oz.	:	.992	oz. mineral matter.

Thus, in the daily diet of the horse under labour there are 251 oz. of heat and fat givers, 59.1 oz. of flesh-formers, and 19.39 oz. of ash or mineral matter.

In the first daily diet, or that under rest, the heat and fat formers constitute not far from a half of the whole quantity, the sum of the articles in ounces being 272, while the sum of the heat and fat givers therein is 150 oz., $\frac{272}{150} = 1.8$. In the same diet the flesh-formers constitute no more than a ninth part, $\frac{272}{28.9} = 9.4$, where 272 is the sum of the diet in ounces, and the divisor, 28.9, the total of the flesh-formers in ounces. Again, in the same diet the sum of the mineral matter is 13 oz., or nearly a twentieth of the whole. In the second daily diet, or that of the horse under labour, the sum of all the articles of food in ounces is 448. Of this number of ounces, 251, or less than two-thirds, $\frac{448}{251} = 1.78$, are heat and fat givers; 59.1 oz. are flesh-formers, being about one-seventh of the whole, $\frac{448}{59.1} = 7.5$; and 19.39 oz. are mineral matters or ash, being less than one-twentieth of the whole, $\frac{448}{19.4} = 23.0$.

It may be remarked further from these figures, in the comparison between the daily diet of the horse at rest and his daily diet under exertion, that in the labour-diet the heat and fat givers, in round numbers, are increased by two-thirds of their original quantity, the flesh-formers are doubled, and the mineral matter increased by a third of the original quantity, thus—

251	— 150	=	101	Difference between diet at rest and diet under exertion, heat-givers.
59	— 28.9	=	30.1	do., flesh-formers.
19.4	— 13	=	6.4	do., mineral matter.

It is usual to describe the function of animal heat as a provision to maintain the system at a standard temperature in a medium, like the earth's atmosphere, almost uniformly colder than itself; but under severe bodily exertion much more heat is generated than is sufficient for this purpose, so that there is a superfluity of heat thrown off, apparently without serving any useful end. This is an important subject for speculation, but of too great magnitude to be entered upon here. For example, it does not clearly appear that in augmenting the daily diet of the horse from that sufficient for the state of rest to that requisite for the state of labour, it is absolutely necessary to increase the amount of heat and fat giving principles, as well as that of the flesh-forming principles. This, it must be confessed, is at present merely a speculative question, because we can hardly increase the amount of the flesh-formers without necessarily increasing that of the heat and fat giving, since both are usually bound up together in one article of food. Nevertheless, speculative as it is, it is desirable it should be investigated and settled as opportunities offer. Some facts have been ascertained bearing on this subject. Thus, Beclard found that the heat developed in a muscle is in inverse ratio to the mechanical effects produced, as, in trying to raise insuperable weights, more heat is evolved than in lifting lighter weights; and Hern has shown, by direct experiment on a treadmill, that less heat is evolved for each gram of oxygen taken into the body when hard work is done outside the body.*

* See Playfair, Lecture, p. 38.

Mineral Matters.—A similar difficulty arises with respect to the mineral matters. It is not possible that a horse, even under the severest labour, can require so much mineral matter for the repair of the tissues as is contained in the food, for example, of the working diet—namely, 19.39 oz. Much of this the horse certainly does not require, yet it is not practicable to give enough of the requisite heat and fat givers and flesh-formers without this superfluity of mineral matters, for the simple reason that the articles of food within our reach do contain more than enough of such mineral materials. The illustration commonly chosen by physiologists on this point, in the case of herbivorous animals, is potash, which abounds in all vegetable food, and yet hardly enters into the composition of the animal solids or fluids, so that there seems to be a necessity for its being thrown out from the animal system simply as a foreign body. It is true that in the human body soda is the alkali of the blood and of the solids; but as the alkalinity of the blood in herbivorous animals depends on the presence of alkaline carbonates, it is possible that the potash of their food may be necessary to render their blood alkaline, before it is separated from the system by the urine. Thus, though potash constitutes no part of the muscular tissue, the waste of which under bodily exertion chiefly takes place, it would be unsafe, without further inquiry, to give food for the repair of waste in such animals that did not contain potash. The proportion of potash in the ashes of meadow-hay is 21.7 per cent; in the ashes of oats, 9.6 per cent; in the ashes of beans, 23 per cent: the entire ashes in meadow-hay being 10.03 per cent; in oats, 2.59 per cent; in beans, 3.10 per cent.

The most important of the mineral matters with reference to the choice of food is phosphoric acid. From 45 to 47 per cent of phosphoric acid has been found in the ash of horse-flesh, and here it is said to be chiefly combined with potash, and but sparingly with lime and magnesia. The composition of horse-flesh requires further scrutiny, being commonly taken on trust by analogy with other kinds of muscle.

Rearing of Horses at the Farm.—It is advantageous for the farmer to rear his own horses; and for every six pairs employed upon the farm, two mares may bear foals annually without much encroachment on their share of work, and without injury to themselves.* These mares, while with foal, are quite fit for the work of ploughing, almost up to the time when the foal is brought forth. They should not, however, be put into the cart for the highway, or into the horse-course of the thrashing-machine. Any two mares with foal may be advantageously worked together in the plough.

To bestow some care in the selection of the food for mares with foal will be well worth the farmer's while. There can be no doubt that the chance of obtaining a good foal is in a very high degree increased by the certainty that the food of the mother, during her pregnancy, has been all that it ought to be in point of quality and quantity. It appears to be established that any, even very temporary, failure in the quality or quantity of the food of the mother, at any period of her pregnancy, during the many complicated changes incident to the body of the foal in its development, proves the source of some one or another defect in the organisation of the foal throughout life, and, therefore, perhaps of some serious vice in its permanent constitution. Too much care, therefore, cannot be bestowed to avert any failure of this kind that may be attended with a consequence so serious.

The materials out of which the body of the foal is constructed are altogether drawn from the blood of the mare. The food, therefore, allowed to the mare during pregnancy

* See 'Book of the Farm,' vol. ii. p. 312.

must be sufficient, not only to maintain her blood in a state adequate to supply the ordinary wants of her own system, but also to bear the additional drain put upon it for the development of the various textures entering into the structural composition of the offspring which she carries in her womb.

To determine theoretically what addition should be made to the ordinary food of the mother, in order to enable her to bring the work of reproduction to a perfectly successful termination, it would be necessary to institute a comparison between the quantity and kind of material required for the repair of the periodical loss in the substance of the mother's body, under the amount of work obtained from her, with the quantity and kind of material adequate at each particular stage of pregnancy, to produce the development of the fœtus in the like periods. It cannot be assumed in theory that a mere increase of the ordinary kind of food will suffice to supply all that the fœtal foal requires for its perfect development; for that assumption would imply that the textures in the mother which are undergoing waste by labour must, throughout pregnancy, be the same, or of the same composition, as those which are, at the same period, acquiring development in her offspring within the womb.

Physiological chemistry has not yet reduced to an exact measure, fit to be expressed in figures, the precise additions to be made to the food of such an animal as the mare during the successive stages of her pregnancy, in order to insure the perfect development of the foal. Nevertheless, there are some considerations that may not be without their use towards the attainment of this object.

The preliminary remark is, however, necessary, that a strict attention to the food of breeding-mares should not supersede a regard to the other circumstances that are conceived to exert an influence in the production of what is called a hit, or signal instance of success, in obtaining a perfect foal. The farmer should pay attention to the kind of mare he is to breed from, as well as to the merits of the stallion of which he makes choice. "If he has an under-sized, or a blemished or unsound mare," says Youatt, "let him continue to use her on his farm. She probably did not cost him much, and she will beat any gelding; but let him not think of breeding from her. A sound mare, with some blood in her, and with most of the good points, will alone answer his purpose. She may bear about her the marks of honest work (the fewer of these, however, the better), but she must not have any disease. There is scarcely a malady to which the horse is subject that is not hereditary. Contracted feet, curb, spavin, roaring, thick wind, blindness, notoriously descend from sire or dam to the foal."* But this is too wide a subject for our limits. It is enough to have called attention to it as a necessary point of view, besides regard to the feeding of the mare when breeding.† As bearing on this subject, the following opinion of an eminent authority deserves consideration: "The farmer who keeps one or two 'nag' mares is the only person who can be said to rear hacks without loss; and he only does so because he begins to use them for his own slow work as soon as they are three years old."‡

Before considering how far theory may be applied to the feeding of the breeding-mare, it will be useful to review what practical men say on the subject. The following sensible observations are from Stonehenge: "When the mare is in foal, if not intended to be kept at work, she should be turned out in good pasture, but it should not be so rich and succulent as to disagree with her stomach, or make her unwieldy from

* Youatt, 'The Horse,' p. 92.

† See also Walsh (Stonehenge), 'The Horse in the Stable and the Field,' pp. 137-155.

‡ Stonehenge, 'The Horse in the Stable and the Field,' pp. 137-155.

fat. The former mistake is a constant cause of miscarriage, the bowels becoming relaxed from the improper nature of the food: on the other hand, if it is not sufficiently good, the mare will become thin, and will starve her foal in its growth. Mares that have been corned highly all their lives should have a feed or two daily after they are six months gone, and especially if the autumnal grasses are not rich and plentiful. Most half-bred animals, however, do very well till about Christmas, after which hay and corn, with a few carrots, should be liberally given them, still allowing them to pick up what grass they can find in their paddocks. Excessive fat is a state of disease, and interferes with the due nutrition of the fœtus, while it is very dangerous at foaling time, when it not only interferes with the process, but also tends to produce fever. Supposing the mare to be at work, she should have some kind of green food, lucerne being the best, and vetches being perhaps the worst for the purpose, the latter being too heating, especially to the organs contained within the pelvis. Any of the grasses or clovers answer well; and after they are done, carrots form an excellent *succedaneum*, given sliced in a bran-mash every night. By adopting these articles of food, the mare is kept free from inflammation, and yet the foal is well nourished, which are the two essential points to be considered." *

With respect to the adjustment of the kind of food of the breeding-mare to the exigencies of the state of pregnancy, it seems obvious that it is not the mere quality of being nourishing in general which should be attended to, but that what is called its mineral composition—that is, the composition of its ash—should be in particular strictly inquired into. The food must possess that general nourishing quality which consists in supplying freely what are known as the plastic or albuminoid

* Stonehenge, 'The Horse in the Stable and the Field,' pp. 160, 161.

proximate principles, otherwise called proteine compounds—namely, fibrine, albumen, caseine, or legumine. These proximate principles may be regarded as common to all kinds of food rightly described as perfectly nourishing, or as flesh-formers. But as the framework of the body even of the foal requires not only carbon, hydrogen, oxygen, and nitrogen, but also such simple substances as chlorine, fluorine, sulphur, phosphorus, silicon, potassium, sodium, calcium, magnesium, iron—it is necessary to ascertain that these last-named mineral substances are sufficiently supplied in the food of the mare to enable her system to impart them to the embryo foal with that freedom which perfect development requires.

The pregnancy of the mare lasts for eleven months, and during all this period there is a drain on the mother to supply the materials necessary for the development of the frame of the foal. In the early stage of her pregnancy, the drain is of course very small, but it grows greater and greater as the pregnancy advances. How mysterious soever may be the connection between the blood of the mother and the blood of the fœtus in the placenta, it is certain that the development of the bodily frame of the foal takes place exclusively at the expense of the blood of the mother. Thus there is no room for doubt that the blood of the mother during pregnancy, when proper food is supplied, undergoes changes of a kind to fit it to afford, at each succeeding stage, such materials as the exigencies of development in the fœtus at that stage require. The only well-marked change that has been observed on the blood in mammals during pregnancy is an increase in the proportion of fibrine. This has long been known, as respects the human race, by the fact that blood drawn from a vein during pregnancy uniformly shows the same buffy coat, composed of fibrine, which is present in blood drawn during acute inflammation. The presence of fibrine in larger proportion in the blood during pregnancy implies the simultaneous accession of sulphur and phosphorus in corresponding proportion. Though it is by no means a perfectly settled point in physiology, we may in the mean time take it for granted that a larger amount of food affording fibrine, and, by consequence, sulphur and phosphorus, is required by the breeding-mare than by the same mare when merely employed in ordinary farm or other work. The distinction between vegetable fibrine and vegetable albumen cannot always be drawn in the analysis of the grasses and other articles of food fit for the farm quadrupeds. This distinction is, however, very manifest in the seeds of the cerealia or corn-grasses: thus the gluten, as it is termed, of wheat consists essentially of fibrine—hence the value of the advice as to giving corn to breeding-mares offered in the quotation made above from Stonehenge.

Fibrine, gelatine, and chondrine may be regarded as the proximate principles most abundant in the embryo colt, as of other embryos, during the period of its development. As to fibrine, there is a sure resource in the grains of the cereal grasses, but physiological chemistry is as yet far behind in regard to the origin of gelatine and chondrine. Both are nitrogenous proximate principles, and hence obviously must require nitrogenous vegetable proximate principles to afford them. There is, however, this difficulty in reasoning concerning them, that neither gelatine nor chondrine exists in the blood of mammals; nor, as far as is yet known, is there any compound in vegetable nature corresponding to either. But as gelatine and chondrine, or compounds which represent them, are continually supplied by the blood of adult animals to their living frame, it seems probable that the blood of the mother, when duly recruited by the use of common nourishing food, is capable of affording these proximate principles to the embryo in the requisite quantity.

All the ordinary prized forage grasses, and the artificial grasses, contain most probably in sufficient proportion the mineral simples required for the development of the fœtus—chlorine, sulphur, phosphorus, silicon, potassium, sodium, calcium, magnesium, and iron. Fluorine, which is required in very small proportion, probably exists in most articles used as food, though it appears to have hitherto escaped detection in most vegetable substances. It would not be a very outrageous application of theory to mingle a little powdered fluoride of calcium (common fluor or Derbyshire spar) with the food of breeding-mares and of foals, by way of insuring the perfect chemical composition of the young bones and teeth.

The treatment of the mare during parturition hardly falls within the plan of this treatise. For instructions on this head, such works as the 'Book of the Farm,' and 'The Horse in the Stable and the Field,' may be consulted.*

The mare recovers quickly after parturition, so that, in fine weather, she may be allowed to go to grass on the second day, which is usually early enough for the foal to be perfectly able to follow her. If the grass be not far enough advanced to support her sufficiently, recourse should be had to boiled turnips or carrots and corn for a mess at night, and warm bran-mashes during the day.† At first the oats should be given in the shape of gruel, made slightly tepid. Rye-grass is cultivated and cut for the mares by those who have early foals; but though it is better than hay, it is not accounted so proper as good upland clover-grass. "Lucern," Stonehenge says, "is excellent; but it cannot be grown so early as rye-grass, particularly Italian rye-grass." All these articles of food contain enough of albuminoid material to maintain the blood of the mare in a state fit to afford a properly nutritive milk, and the ash of the same is

* Stephens, vol. ii. pp. 153-157; Stonehenge, pp. 136, 157-161.

† 'Book of the Farm,' vol. ii. p. 189.

not deficient in the mineral elements corresponding to the salts of the blood. The nourishment supplied to the colt in the milk of the dam must contain, in particular, the elements necessary for the ossification of cartilage and the growth of the bones—that is to say, the food supplied to the mare must contain lime and magnesia and phosphoric acid, or the constituents of the phosphate of lime and the phosphate of magnesia, which constitute so large a proportion of the bones; and also enough of lime, besides, to afford the carbonate of lime therein present. It may be remarked in regard to the preference given above to the clovers over rye-grass, that both red and white clover contain a great deal more lime than rye-grass, and that lucern contains more lime than the clovers. In lucern there is not much more magnesia than in rye-grass, but as the proportion of phosphate of magnesia in bones is not great, both probably contain enough of this base for the required purpose. The red clover contains more magnesia than the white, but the proportion in both is considerable. Phosphoric acid is most abundant in lucern, yet neither rye-grass nor the clovers are in this respect very deficient.

The farm-mare should remain on grass without working for at least a month, to enable her body to recover sufficiently to bear the fatigues of labour; and for some time the work she is put to should be of a light character. At the end of a month, or even earlier, the foal will eat bruised oats. While the foal is dependent on the mother's milk, some attention to the proper kind of food to enable her to supply a sufficiency of nutritive milk should be bestowed. There are no very complete analyses of the mare's milk, though numerous scattered notices of its composition are to be met with. As already stated (p. 283), it is of considerable specific gravity, indicating that it contains a large proportion of solid constituents. Its specific gravity is greater than that of women's milk, of cows' milk, asses' milk, and even of sheep's milk. It contains 16.2 per cent of solid residue, the caseine being in small proportion (1.7 per cent), but the fat and sugar in large proportion—the fat being 6.95 per cent, and the sugar 8.75 per cent. The ashes of milk in general consist principally of common salt and the earth of bones. There are also found in the ash, potash and the oxide of iron. The only plants which contain caseine, or a proteine compound very similar to caseine, are the leguminous plants, such as beans and pease. Of these, a due proportion should be mixed with the food of the mare while she is suckling the foal. These plants also contain notable proportions of phosphoric acid and potash, as well as lime and magnesia, with which phosphoric acid produces bone-earth. The more succulent foods, which, by their nature, seem well adapted to promote such a secretion as milk, do not contain so great a proportion of phosphoric acid or of potash, or of lime and magnesia; yet the large quantities in which such foods can be taken often sufficiently compensate for this deficiency. Of this description are turnips, carrots, mangold-wurzel, and parsnips. It is manifest, however, that if the mare, while she suckles the foal, is kept at labour, a larger quantity of food becomes requisite than would suffice for the same amount of labour, when no such drain as that of the secretion of milk is made on her.

The food of the foal, from the time when, but a month old, he begins to eat bruised oats, does not deserve less attention.

The following passage from Stonehenge has an important bearing on the subject: "Highly-bred young stock are generally allowed from this time, first a single quartern, and then by degrees two quarterns, of oats. Half-breds, and even cart-horses, would be the better for this stimulus to development; but if it is begun, it should be continued; and unless the foal shows such promise that it is expected to turn out extraordinarily well, the extra expense will not be reimbursed. The half-peck of oats cannot be put down as costing less than six pounds a-year; and thus, at five years of age, the colt will have cost thirty pounds more than if he had been fed on hay and grass alone. Now, between a race-horse reared on corn and another confined to hay and grass, the difference in value would be 1000 per cent; and in first-class hunters, though not so great as this, it would be very considerable. But among inferior horses, on the average, it would scarcely reach the sum I have named as the prime cost of the oats; and therefore, though in the depth of winter a quartern or half a peck is generally given with a little bran, yet when there is good grass this is neither necessary nor is it economical." *

Here, then, a problem presents itself, the solution of which is of much importance to the farmer who breeds horses—namely, what grasses or other kinds of cheap food will best supply the place of oats during the growth of the young horse. It may be taken as an established conclusion, that all articles of food allowed to be generally nutritious contain enough of the proximate chemical principles to supply the blood of the foal with its due proportion of fibrine, albumen, hæmato-globuline, and the like; and if the food, when in due abundance, be at any time insufficient to insure the perfect progressive development of the frame, the deficiency must arise from an insufficiency in mineral materials, more particularly of those requisite for the growth of such hard tissues as the bones and cartilages—namely, the phosphate of lime, the carbonate of lime, and the phosphate of magnesia.

It can hardly be owing to a deficiency in the supply of lime or of magnesia in the forage or artificial grasses that they do not equally promote the development of the body of the foal as that diet into which oats enter, for these generally contain a larger proportion both of lime and of magnesia than the

* Stonehenge, 'The Horse in the Stable and the Field,' p. 162.

seeds of the oat. It is to be remarked, however, that the seed of the oat contains a much larger proportion of phosphoric acid. Thus there are, in 100 parts of the ash of rye-grass, of phosphoric acid, 6.3 ; in the same quantity of red clover, 6.2 ; in that of white clover, 11.5 ; in that of lucern, 13.5 ; while in 100 parts of the seed of the oat there are 26.5 of phosphoric acid.

It is allowed to form conjectures in any part of the province of agriculture, only on condition that the truth of such is to be tried on a limited scale before, upon faith in it, any considerable hazard is run. It would be easy to try whether foals would thrive equally by the addition of beans or pease in the ground state to their food, as by such an allowance of oats as that above referred to ; young calves thrive well on pease-meal, why then should not colts also ? The proportion of phosphoric acid in the bean and the pea is even greater than in the seed of the oat. Thus, in 100 parts of the ash of the bean there are 8.7 parts of lime, 6.6 parts of magnesia, and 31.9 parts of phosphoric acid ; again, in 100 parts of the ash of the pea, there are 6.3 parts of lime, 6.6 parts of magnesia, and 34.8 parts of phosphoric acid. It is true that all the nutritive substances, both albuminoid and mineral, are much more concentrated in the oat than in the forage grasses or in the artificial grasses ; and something of the better effect of the oat in the nutrition of the foal may be due to this circumstance. The concentration, however, is equal in the bean and in the pea as in the oat.

Before leaving this point, it should be remarked that, in so far as the food of the foal is to be selected for its sufficiency to afford the materials of ossification, it might be possible to give too much oats or too much of bean or pea meal ; for the proportion of lime in all these grains, compared to their proportion of phosphoric acid, is too small to produce the phosphate of lime or bone-earth. This will be seen at once by comparing the quantities of the substances stated above as present in these grains, with the composition of 100 parts of anhydrous phosphate of lime—namely, 54.2 parts of lime, and 45.8 parts of phosphoric acid. Nor is it enough to debate with ourselves the question, what kinds of food are most suitable for the general development of the foal for the offices to which he is to be put.

The special development of the filly, the gelding, and the stallion, should engage attention long before each has reached maturity. It must be confessed, however, that exact rules, drawn from the special character of certain organs in each, are not yet within our reach ; while the only expedient that can be resorted to for supplying the defect of rules is to take care that the food shall be sufficiently varied at short intervals, and in the mean time to keep a watchful eye on the progress of the young animal, and where condition does not appear to be preserved, to make an immediate change on the style of food and general management.

Such, then, is a specimen of the kind of speculation by which, cautiously and judiciously pursued, it may be hoped that theory will improve and add to the practical rules of the least doubtful character at present acted on in the early management of the colt.

It does not enter into the plan of this treatise to particularise all the points to be attended to in the education of the colt ; for these we must refer, besides the 'Book of the Farm,' to such works as Youatt on 'The Horse,'* and 'The Horse in the Stable and the Field.'

The theory of feeding the horse throughout his life, as has been already remarked, differs somewhat from that of feeding the animals destined for the food of men. The object in the case

* See, in particular, Youatt, p. 320-324.

of the horse is to select food in such quantity and of such quality as shall best promote, maintain, and repair the full energies of health and strength. Even when a defined course of feeding is known to supply all the materials contained in his entire frame, a change is from time to time expedient. The usefulness of a variety of food is most probably dependent on the simple substances essential to the due composition of the frame being extracted more easily in the series of digestive processes from one article of food than from another, though to appearance equally accessible in both.

The first thing to be ascertained in respect to any proposed article of food is that it is a flesh-former, and not a mere supporter of animal heat; the next, that it contains such mineral materials, or so-called mineral materials, as, being continually thrown off by the excretions, are manifestly derived from the disintegration of the animal solids, which require, therefore, to be continually recruited by a new supply of the same.

Application of Theory to the Feeding of the Ox.—The type of food for the ox already cited from Playfair (p. 508) was that of an ox employed in field-labour—a practice now almost, if not altogether, extinct in this country. Nevertheless, it may be worth while to exhibit the several orders of constituents contained in that type of the daily food of a labouring ox. It consists of 50 lb. of mangold-wurzel, 3 lb. of beans, and 17 lb. of wheaten straw. The roots of mangold-wurzel contain, dried, 76.7 per cent of heat and fat giving proximate principles, chiefly sugar, 3 per cent of flesh-formers, and 9.56 per cent of mineral matter in the ash, thus—

100	:	76.7	: :	(50 lb.) 800 oz.	:	613 oz.	heat-givers.
100	:	3	: :	„ 800 oz.	:	24 oz.	flesh-formers.
100	:	9.56	: :	„ 800 oz.	:	76 oz.	mineral matters.

Wheat-straw contains 36.7 per cent of heat and fat givers, 1.6 per cent of flesh-formers, and 5.11 per cent of mineral matters in the ash.

Wheat-straw,	100 : 36.7 : :	(17 lb.) 272 :	102	oz. heat-givers.
„	100 : 1.6 : :	„ 272 :	4.35	oz. flesh-formers.
„	100 : 5.11 : :	„ 272 :	13.89	oz. ash.
Beans, .	100 : 54.5 : :	(3 lb.) 48 :	25.5	oz. heat-givers.
„ .	100 : 32.5 : :	„ 48 :	15.6	oz. flesh-formers.
„ .	100 : 3.10 : :	„ 48 :	1.48	ash.

Heat-givers. oz.	Flesh-formers. oz.	Mineral matter in ash. oz.
613.0	24.00	76.00
102.0	4.35	13.89
25.5	15.60	1.48
740.5	43.95	91.37

The 43.95 oz. of flesh-formers are somewhat above the result brought out by Playfair, who, however, does not give the data on which he proceeds. Such slight differences need not surprise us, since in different analyses even the substances subjected to that process at different times and under opposite circumstances must vary not a little in composition. But the constant very close relation, in the present day, between the proportions assigned to the different orders of constituents cannot but give us great confidence in the general accuracy of such analyses.

Playfair makes the labour flesh-formers in the food of the horse 27 out of the 56.5 of the total plastic or flesh-forming food, so that if we make a proportion in which the whole plastic food of the horse is set down as bearing the same ratio to the labour plastic food of the horse as the whole plastic food of the ox to the labour plastic food of the ox, then the last term will be determined thus—

56.5 : 38.6 : : 27 : 18.4, the labour plastic food of the ox.

Hence in the case—the common case in this country—in which the ox is not fed for labour, but for the market, the amount of flesh-formers in the above standard of the food of the labouring ox should be diminished by 18 ounces—that is, the daily amount of the flesh-formers should be 43.95 – 18.4 = 25.55; or, to take Playfair's number, 38.6 – 18.4, or 20.2 oz. This would be accomplished if the beans were taken away, and about 8 lb. of the mangold-wurzel—that is, nearly a sixth part of the 50 lb. of that food. It must not be forgotten, however, that, along with the diminution of unnecessary flesh-forming principles, there is also a reduction in the amount of heat and fat givers to the extent of the proportion of the heat and fat givers in the 3 lb. of beans and the 8 lb. of mangold-wurzel curtailed; thus—

Mangold-wurzel,	100 : 12.4 : : (8 lb.) 128 : 17 oz.	heat and fat-givers.
Beans, .	100 : 54.5 : : (3 lb.) 48 : 26 oz.	"

or, in all, 43 oz. of heat and fat givers.

It has been already remarked more than once that the usual object of feeding the ox in this country is not for labour, but for the market; hence some other standard of his daily food must be sought out than that used above in comparing the labour and food of the horse with the labour and food of the ox. Oxen vary in size and breed, also in some other particulars, on which the appropriate quantity of food in each case materially depends. The live weight, as it is called, of a good fat ox—that is, its weight when alive—approaches, on an average, to 1200 lb. The mean weight of sixteen heifers and bullocks was found by Lawes and Gilbert to be 1141 lb. The mean weight of eleven fat bullocks was 1182 lb. The mean weight of two fat heifers was 853 lb. The mean weight of two fat calves was 250 lb.

The following table, drawn from the same authorities, exhibits the component materials of the bodies of the ox at different stages of life and condition. The weights in pounds denote per cent in carcass.

	Mineral matter (ash).	Nitrogenised compounds, dry.	Fat, dry.	Total, dry.	Water.
Fat calf, . .	4.8	16.6	16.6	37.7	62.3
Half-fat ox, .	5.56	17.8	22.6	46.0	54.0
Fat ox, . .	4.56	15.0	34.8	54.4	45.6

But short-horn steers of four years old have attained the great weight of 2100 lb.

When the constituents of a particular kind of food, or of a particular diet, are not known according to the exact percentage of flesh-formers and of heat and fat giving principles, but are more rudely divided into nitrogenous and non-nitrogenous principles, some care is required in estimating the actual amount of nourishment received. With respect to the nitrogenous products of vegetables, it must be ascertained whether or not all of those present are really digestible and nutritious, and not injurious; and as to the non-nitrogenous, it must be considered whether cellulose or woody fibre does not form any important proportion of the mass. When cellulose, called also celluline or woody fibre, is in its most tender and most delicate state, as in many common food-stuffs, it is now known to be sufficiently digestible, and stands probably, as a nutritive substance, on the same footing as starch and sugar; but when it belongs to a more advanced state of the vegetative process it is utterly indigestible, and is passed by the animal from the bowels unchanged along with the excrement. It appears, moreover, that the pectine compounds have a less feeding value than starch or sugar. On the contrary, according to the conclusions of Lawes and Gilbert, a given amount of fatty matter in food may be considered as equivalent to about 2½ times its weight of starch or sugar. At the same time, it is to be borne in mind that both starch and sugar within the animal body are convertible into fat.

From the experiments of the same gentlemen, it may be inferred with confidence that an ox of about 1400 lb. weight taken from the grass and put under cover will thrive so as to gain about 20 lb. weekly on the following daily food:—

Crushed oilcake, . .	8 lb.
Clover-hay chopped, . .	13 „
Turnips, ...	47 „
	68 „

This diet, when reduced to ounces of flesh-formers, heat and fat givers, and mineral matter, according to our tables, stands thus:—

Oilcake, 8 lb.

Flesh-formers, . . .	22.14 per cent.
Heat-givers, . . .	51.00 „
Ash, ...	6.00 „

100 : 22.14 : : 128 oz. : 28.3 oz. flesh-formers.
100 : 51.00 : : 128 oz. : 65.0 oz. heat-givers.
100 : 6.00 : : 128 oz. : 7.7 oz. ash.

Clover-Hay, 13 lb.

Flesh-formers, . . .	12.0 per cent.
Heat-givers, . . .	55.7 „
Ash, ...	8.0 „

100 : 12.0 : : 208 oz. : 25.0 oz. flesh-formers.
100 : 55.7 : : 208 oz. : 115.0 oz. heat-givers.
100 : 8.0 : : 208 oz. : 16.64 oz. ash.

Turnips, 47 lb.

Flesh-formers, . . .	0.3 per cent.
Heat-givers, . . .	6.9 „
Ash, ...	0.6 „

100 : 0.3 : : 752 oz. : 2.25 oz. flesh-formers.
100 : 6.9 : : 752 oz. : 51.88 oz. heat-givers.
100 : 0.6 : : 752 oz. : 4.51 oz. ash.

Flesh-formers.	Heat-givers.	Ash.
28.30	65.00	7.70
25.00	115.00	16.64
2.25	51.88	4.51
55.55	231.88	28.85

Such, then, may be taken as a typical formula of the daily food in respect to flesh-formers, heat-givers, and mineral matters in the fattening of oxen for the market.

This subject, however, would be incomplete without some reference to the several modes in which oxen are put up during winter in the course of feeding them for market. We find cattle are fattened during winter in what are called in Scotland byres—that is, in buildings like cow-houses—or in boxes, or in what are named hammels, or in sheds with a court attached, fit to accommodate several oxen. In the byres or cow-houses, the oxen, being closely tied by the neck, each in its stall, all the winter, and permitted barely any movement, can hardly be supposed to carry on the natural actions of a living frame in a manner fit to produce flesh of the best quality, while it is at the same time to be feared that they must be rendered more liable to fall into such diseases as are prevalent in any season. No doubt, if things go on well by the absence of any epizootic distemper, the animal may, by the interruption of all waste by exertion, attain a greater weight at a smaller cost than by any other kind of management. Yet it should not be forgotten that this advantage may be obtained for a time at the risk of great subsequent loss by the violation of the indubitable maxim, that the more naturally an animal is kept the better is it able to resist the invasion of epizootic disease.

What is called feeding oxen in boxes, is keeping one large ox or two small oxen in a covered crib, in which the animal or animals have room to turn about, and may at their will stand or lie upon their litter. This is, *cæteris paribus,* a more natural state of living than being tied up by the neck in a stall.

In what is termed feeding in hammels, there is a shed at one end fit to hold two oxen, with a court of corresponding size at the other end, so that the inmates can keep under cover or go into the open air as they choose. This is a still more near approach to the natural life of an ox in the field, and the improvement on the flesh of the animal by this method of treatment is shown by the preference given by butchers to animals fed in this manner over those fed in stalls or boxes.

A large court surrounded by sheds, to and from which the animals have unrestrained liberty, is objectionable merely on account of the fights apt to arise when a number of animals of different degrees of strength are fed together.*

An unusual interest has of late arisen among agriculturists in respect to the means of keeping up the temperature of the body of the ox during his confinement in being fattened for the market. This excitement appears to have taken its rise in some remarks made by Liebig on the importance of guarding fattening animals from cold. But the idea has been so overstrained as to leave the fact forgotten that oxen, like other animals, are not mere physical machines, to be influenced without limit by material agencies, and that, in dealing with living action, all our proceedings must be in accordance with the laws of living action. It is very doubtful if close-covered apartments and artificial heat, as some propose, will ever be advantageously employed in the rearing and feeding of oxen. Doubtless the advocates of such plans urge ventilation at the same time ; but they can have hardly considered how difficult ventilation becomes under the use of artificial heat in close apartments, and how greatly the risk must be increased attend-

* For a more particular account of these several arrangements and their advantages and disadvantages, see the 'Book of the Farm,' vol. i. p. 293.

ant on the admission of cold air upon the bodies of animals kept in an artificially-heated atmosphere.*

The use of oxen in the labours of the field is perhaps irrecoverably obsolete in this island. There are a few places where traces of this usage still may be met with. Nevertheless it is proper to consider whether or not this ancient practice has any advantage to recommend its revival. It is stated as a fact that an ox, after having been employed constantly in field-labour for six or seven years, may be fattened for the market, so as to furnish flesh of a far superior quality to that afforded by younger animals. It may throw some light on this point to repeat what was referred to before in Professor Playfair's comparison between the amount of labour and the amount of food respectively in the horse and in the ox. The food of the horse in flesh-formers is 56.5 oz., the food of the ox in the same, 38.6 oz., while the labour of the horse in foot-pounds is 12,400,000, and that of the ox in the same is 8,640,000.

But 56.5 : 38.6 :: 12,400,000 : 8,471,506, so that the work of the ox in foot-pounds is greater than the proportion of his food as compared to that of the horse by 8,640,000 — 8,471,506 = 168,494 foot-pounds daily.

Hence this point deserves the serious attention of economists in agriculture. It is to be remembered that the respective estimates of the work of the horse and of the ox here stated are not speculative deductions, but figures actually ascertained by the use of familiar facts. If it be asked, how it is psssible, on the principle of "the conservation of energy," that more external mechanical work can be performed by one animal than by another in proportion to the respective amounts of flesh-formers consumed? the answer is, that there is always a waste of energy in the working of a machine intended for a definite

* See 'Journal of Agriculture,' Nov. 1866, p. 265.

effect, and that the daily work of which an animal is capable invariably falls short more or less of the estimate derived from the consumption of the material whence the energy is derived. Thus there is no difficulty in the supposition that the ox may perform its day's work with less proportionate waste of flesh-formers than the horse.

Application of Theory to Feeding the Cow.—The theory of feeding the cow, as distinguished from that in accordance with which the ox is fed, is to be drawn from the composition of the milk, for the yielding of which the cow is kept.

The composition of cows' milk, before the calf is allowed to suck, is—

Caseine, ...	15.0
Butter, ...	2.6
Sugar, ...	3.6
Ashes, ...	0.3
Water, ...	78.5
	100.0

What is remarkable in this analysis is, that the proportion of caseine is very much greater than what is found in the milk of dairy cows. Caseine is a proteine compound, one of the albuminoid proximate principles—in short, a flesh-former. How it comes to be so much more abundant in the first milk after calving than at a subsequent period it is not very easy to understand. During the period of pregnancy no caseine is produced within the system of the mother, the demand of material for the development of the calf being sufficiently answered by such other proteine compounds as albumen and fibrine. It is plain, however, that as soon as parturition takes place, the extra demand for albumen and fibrine ceases, and thus, as it may be supposed, these principles, in so far as they are not necessary for the maintenance of the cow itself, become changed to the caseine of the milk. Chemists believe that the albumen of the serum of the blood can be changed to caseine by the addition of caustic potash; but the conversion of the albumen and fibrine of the blood of the cow into caseine after parturition bears too much the character of the processes termed vital to permit us to expect that any mode of feeding or management could do much towards increasing the proportion of caseine in the milk of the dairy cows. Nevertheless the subject is worthy of attention. The proteine compound that comes nearest to caseine is legumine, the principle existing in the seeds of the leguminous order of plants, to which beans, pease, and the artificial grasses belong. Experiments on the proportion of caseine in the milk of animals fed largely on such food, as compared with its proportion in those fed on other kinds of food, deserve to be set on foot. Beans are a favourite food with dairymen for their cows, chiefly in the form of bean-meal. The effects on the milk produced by food containing a more than usual proportion of potash should also be inquired into. Playfair says "Potash is perfectly indispensable to the formation of milk; indeed this alkali seems to be the means by which the albumen in the body of the cow is rendered soluble, and consequently converted into caseine." * The sugar and butter contained in milk suggest the use of mangold-wurzel and linseed-meal in the food of the milch cow. The following analysis is the average of several experiments made on the milk of the cow in the field :—

Caseine, ...	4.0
Butter, ...	4.6
Sugar of milk, ...	3.8
Ashes, ...	0.6

From 100 parts of milk, the produce of two cows, the following proportions of salts were procured :—

* 'English Journal of Agriculture,' vol. iv. p. 246.

Phosphate of lime,	0.310	0.344
Phosphate of magnesia,	0.042	0.064
Phosphate of iron,	0.007	0.007
Chloride of potassium,	0.144	0.183
Chloride of sodium,	0.024	0.034
Soda,	0.042	0.045
	0.569	0.677*

The following experiments, made by Playfair at the same time, illustrate the general effect of food on the milk, and disprove the idea of Dumas, that the fat of animals is wholly derived from the fatty matter contained in their food :—

"1. On the second day the cow received 28 lb. of hay, which contained 0.43 lb. of fat, and 2½ lb. of oatmeal, containing 0.050 lb. of the same constituent. The cow produced (calculating according to its specific gravity) about 19 lb. of milk, in which were 0.969 lb. of butter. But the food altogether contained only 0.486 lb. of fat, so that 0.483 lb. of butter must have been produced from other sources.

"2. The food received by the cow on the third day consisted of 28 lb. of hay, 2½ lb. of oatmeal, and 8 lb. of bean-flour.

28 lb. of hay contain	0.436 lb. of fat.
2½ „ oatmeal „	0.050 „
8 „ beans, „	0.056 „
In the food,	0.542 „

The milk of that evening amounted to 10.34 lb., and contained 0.4 lb. of butter; that of the morning to 11.61 lb., and contained 0.5 lb. of butter, the whole amounting to 0.9 lb., of which only 0.542 lb. could possibly have been furnished by the food, assuming that the fat in the food could only be converted into butter.

* 'English Journal of Agriculture,' vol. xiii. p. 24.

"3. The cow received on the fourth day 14 lb. of hay, 8 lb. of beans, and 24 lb. of potatoes.

14 lb. of hay contain .	. .	0.218 lb. of fat.
8 „ beans „ .	. .	0.056 „
24 „ potatoes „ .	. .	0.072 „
In the food,	. .	0.346 „

The evening's milk amounted to 12.9 lb., and contained 0.86 lb. of butter ; that of the morning to 10.32 lb., and contained 0.50 lb. of butter. The cow therefore furnished during the day 1.36 lb. of butter. The fat in the food only amounted to 0.346 lb., therefore 1.064 lb. must have been obtained from other sources.

"4. On the fifth day the cow received 14 lb. of hay and 30 lb. of potatoes.

14 lb. of hay contain .	. .	0.218 lb. of fat.
30 „ potatoes „ .	. .	0.090 „
In the food,	. .	0.308 „

The milk of the evening amounted to 13.18 lb., and contained 0.606 lb. of butter ; that of the morning to 12.20 lb., containing 0.597 lb. of butter. The cow therefore furnished 1.203 lb. of butter. The fat in the food amounted only to 0.308 lb. ; hence 0.895 lb. of butter must have been produced from other sources." *

Thus it cannot be doubted that the starch and sugar contained in the food contribute, along with its fatty material, to the production of butter. Any considerable amount of exercise must diminish the proportion of butter in milk by the additional consumption of oil, starch, and sugar which such exercise occasions, owing to a greater activity of the respira-

* 'Transactions of the Chemical Society of London,' vol. i. See also 'English Journal of Agriculture,' vol. xiii. pp. 27, 28.

tion. The increase in the quantity of the butter shown in the above experiments, when the cow was in part fed on potatoes, indicates the formation of fat from starch. This fact stands in contrast with the opposite fact, that the proportion of caseine is increased when beans and oatmeal enter largely into the food.

Connected with the interesting object of obtaining a continued supply of milk from the cow, there is a very singular belief that has not yet obtained an attention commensurate with its importance. If the functions of the organs concerned in lactation have been once called into full activity by the act of breeding in the cow, it would appear that the function of the ovaries may be put an end to, and yet that those of lactation may continue in uninterrupted vigour for years. This is the theoretical foundation of a proposal to remove the ovaries from (to spay) a young cow after its first calf, subsequently to which proceeding it is said to afford milk uninterruptedly for many years.

Theory of Feeding the Cow during Gestation.—The observations made with respect to the necessity of attention to the food of the mare during the state of gestation equally apply to the cow when in that condition. During the chief part of gestation the cow has not merely to nourish her offspring in the womb, but also to yield a supply of milk to her owner. This supply of milk she yields when in the unimpregnated state in great abundance even for a succession of years; and such a supply generally continues undiminished during the earlier months of pregnancy. During the later months the secretion sensibly diminishes, and for some weeks previous to parturition it is, for the most part, entirely suspended. It appears that, on an average of cases, by the fifth month of conception a diminution of one-third of its quantity has taken place; by the sixth month, two-thirds; and soon after the seventh it is usually altogether suspended.* As the ordinary kinds of food, if given in sufficient quantity, can hardly fail to supply the requisite amount of flesh-formers and heat-givers, the principal point to be attended to is, that the sum of the diet shall contain enough of the earthy salts required for the bones of the fœtal calf, and of such other saline matters as are contained in its fluids and in the other solids.

The food in the later period of pregnancy should also have reference to her after milk-giving. "The health and condition of the cow before calving greatly influence subsequent results. A late-milked, lean, raking, ill-cared-for beast, has oftentimes an easier parturition than those that are better furnished in these respects. But her after-milking has a tale to tell of neglect somewhere; and a scraggy 'set' condition of the calf throughout its course often arises more from this cause than from any other. Hence we would say, dry the cows a *fair time* before calving, and see that she has something better than barley-straw to live on, else the calf and its owner will assuredly lose by it. But what is regarded as a fair amount of time for being dry? If a cow brings her first calf when from two to three years old—which the majority probably do, though all will admit that it is too early—we should not care to milk her more than five or six months after calving. By this means she will grow and increase in size and value before her second calf. But a cow from the fourth to the eighth year, if in good condition, need not be dry more than six weeks or two months before calving—*i. e.*, if fed with a thoroughly liberal hand throughout the year. If more sparingly fed, or if the cow exceeds the latter age, then we should prefer her being dry three months before calving." †

* Barlow, 'Journal of Agriculture,' 1843 to 1845, p. 444.

† Prize Essay on 'The Rearing of Calves,' by Thomas Bowick: 'English Journal of Agriculture,' vol. xxii. p. 139.

To rear calves with profit much care is necessary, and ample directions to that end are to be found in the prize essay just quoted, and in a memoir in the same volume of the 'English Journal of Agriculture,' by Major S. M'Clintock. We quote the following passages from the prize essay on a safe and economical plan for the early management of calves, or how to rear good calves with comparatively little new milk. "As regards the quantity of milk which is needful to keep a moderately-bred short-horned calf in a thriving condition, we have found the following allowance to come pretty near the mark, although the appetite of calves varies, both in individuals and at different times with the same animal:—1st week with the dam, or four quarts per day at two meals. 2d to 4th week, five to six quarts per day at two meals. 4th to 6th week, six to seven quarts per day at two meals. And the quantity need not during the ensuing six weeks (after which it is weaned) exceed a couple of gallons per day. This implies that the calf is fed upon new milk only, and that no other feeding liquids are employed. We manage to turn out from twenty-five to thirty calves annually—such as will pass muster anywhere—and never use at any time more than six gallons of new milk daily. For this purpose, as well as to obtain a regular supply of milk for other purposes, the calves are allowed to come at different periods, extending from October to May. Hence the calf-house (previously described) has generally a succession of occupants throughout the season; and as one lot are ready to be removed, and placed loose in a small hovel with yard attached, others fill their places. We begin with new milk from the pail, which is continued for a fortnight after leaving the cow. Then skim-milk—boiled, and allowed to cool to the natural warmth—is substituted to the extent of one-third of the allowance. In another week the new milk is reduced to half, and at the same time, *not before*, boiled linseed is added to the mess. Five lb. of linseed will make about seven gallons of gruel, and suffice for five good-sized calves. As soon as they take freely to this food, the new milk may be replaced with that from the dairy, and the calf is encouraged to indulge in a few sliced carrots, green hay, or linseed meal, or finely-crushed oilcake. Among the multitudes of substitutes for milk that have, at different times, been recommended, we have found nothing better than those previously referred to, or linseed two parts, and wheat one part, ground to meal, and boiled to gruel of moderate thickness, and then mixed with an equal quantity of skimmed milk. It is true we have omitted any allusion to the 'Irish Moss' which calves seem to relish well, though it does not prove of a fattening nature. For the lot of calves named (25 to 30) a couple of hundredweight of this article is found a desirable addition, and lasts throughout the season." *

One of the great objects of our treatise is to point out the sources of the errors into which a blind aim at economy carries the practical farmer, as well as the opposite errors into which the amateur falls by a determination to succeed at any cost. The too great use of skimmed milk in the early feeding of calves has proved a very false economy.

Playfair says, "It sometimes occurs in England that calves are allowed to suck only for a few days, and afterwards are fed upon skimmed milk. In separating cream from milk, we remove most of its butter as well as part of the caseine. Skimmed milk is therefore destitute of the principal ingredient destined by nature for the support of respiration and sustenance of the temperature of the young animal. The proportion between unazotised and azotised matter is completely altered, and the nutrition of the animal is placed in an unnatural condition."

* Bowick, 'English Journal of Agriculture,' pp. 140, 141.

The precise chemical relation between new milk and skimmed milk has hardly been ascertained, but the amount of nutriment contained in a pound of linseed, substituted by Mr Bowick after three weeks for one-half of the full allowance of new milk, may be thus deduced :—

Linseed, 5 lb. for five calves. Linseed per cent—18.8 flesh-formers, 25.5 heat-givers, 4.63 ash.

				oz.		oz.
Flesh-formers, . .	100	:	18.8	:: 80	:	15
Heat-givers, . .	100	:	25.5	:: 80	:	20.4
Mineral matter or ash, .	100	:	4.63	:: 80	:	3.7

The quantities thus obtained, being divided by five, give the allowance of each calf over and above a half ration of new milk :

$$\frac{15}{5} = 3 \text{ flesh-formers}\ ;\ \frac{20}{5} = 4 \text{ heat-givers}\ ;\ \frac{3.7}{5} = 0.7 \text{ mineral matters.}$$

We quote two passages more from Mr Bowick's prize essay. " As spring advances, the supply of roots to the calves will necessarily be greater, according to their increasing age and ability to masticate. But it is nowise desirable or economical to send them out to grass early in the season. . . . And you will do well to begin by giving them only a few hours afield during the day, bringing them in again at night to their pound of cake, with a bit of hay chaff (chopped hay) for the older ones, and the mess of skim-milk and linseed-gruel for the younger stock."*

When calves after three months are allowed to take their will of good pasture, there is not much risk of their failing to thrive ; and when such pasture is not accessible, there is no better rule than to watch the effect of what food they get, and regulate accordingly. Major M'Clintock says in his paper, " It is very difficult to lay down an exact rule for feeding calves, as far as quantity is concerned ; nor can a time be fixed for wean-

* 'English Journal of Agriculture,' vol. xxii. p. 144.

ing; the appearance of forwardness in the animals being the best rule to go by. However, as a general mode, supposing a calf to be dropped in March, I would suggest that pure "mother's milk" should be given for a fortnight, then by degrees an admixture of the oilcake gruel (one quart of cake, ground fine, to 4 quarts of boiling water) introduced, and a sufficient drink allowed at each meal, so as to remove all hollowness from the flank. In a few weeks, 6 gallons will be taken by the calf; and when the weather is favourable, it should be allowed to run in some well-sheltered place where the pasture is sweet. In three months, calves have an appetite for grass, and it is then that the process of weaning should begin." *

A bull-calf intended to be reared for service deserves particular attention. One calved early in the season should be preferred. He should get as much new milk as he can take, and should not be weaned till the young grass is fully ready to support him. The object is not to fatten, but to give vigour to the several parts of the body in order to the strengthening of the general constitution. Sufficient exercise at an early period should be allowed.

When male calves are not designed to be kept entire, castration should be performed about a month after birth.

On Feeding of Sheep.—On the feeding of sheep there are many treatises, so that the subject in its general character is nearly exhausted. It may be useful, however, to consider some of the most common kinds of food employed in feeding sheep in respect to the proportion contained in each of flesh-formers, of heat and fat givers, and mineral matters.

The following experiment by Dr Voelcker indicates distinctly a standard fattening sheep diet. Four sheep were fed for seven weeks (forty-eight days)—namely, from 22d March

* 'English Journal of Agriculture,' vol. xxii. p. 152.

to 10th May (year not mentioned), upon 196 lb. of clover-hay chopped, 49 lb. of linseed-cake, 33 cwt. 1 qr. 19 lb. of mangolds. This gives daily for each sheep 16.3 oz. of clover, 4.08 oz. of linseed-cake, and 312 oz. of mangold-wurzel. And if this diet is reduced to the three heads of flesh-formers, heat and fat givers, and mineral matter, it affords 4.45 oz. of flesh-formers, 53.77 oz. of heat and fat givers, and 4.88 oz. of mineral matter, in accordance with the following calculation:—Red-clover hay contains 12 per cent of flesh-formers, 55.7 per cent of heat and fat givers, and 8 per cent of mineral matter. Linseed cake contains 22.14 per cent of flesh-formers, 51.3 per cent of heat and fat givers, and 7.25 per cent of mineral matter. Mangold-wurzel undried contains 0.48 per cent of flesh-formers, 13.54 per cent of heat and fat givers, and 1.09 per cent of mineral matter. Whence—

1. Red-clover hay—

100 : 12 : : 16.3 : 1.9 oz. flesh-formers.
100 : 55.7 : : 16.3 : 9.07 oz. heat-givers.
100 : 8 : : 16.3 : 1.20 oz. mineral matter.

2. Linseed-cake.

100 : 22.14 : : 4.08 : 0.903 oz. flesh-formers.
100 : 51.3 : : 4.08 : 2.09 oz. heat-givers.
100 : 7.25 : : 4.08 : 0.29 oz. mineral matter.

3. Mangold-wurzel.

100 : 0.48 : : 312 : 1.497 oz. flesh-formers.
100 : 13.54 : : 312 : 42.244 oz. heat-givers.
100 : 1.09 : : 312 : 3.4 oz. mineral matter.

Sum :—

Flesh-formers.	Heat-givers.	Mineral matter.
1.9	9.07	1.20
0.903	2.09	0.29
1.497	42.24	3.34
4.300	53.40	4.83

In this experiment the sheep No. 1 weighed, March 22, 153 lb., and May 10, 170.5 lb.—gain 17.5 lb. No. 2 weighed, March 22, 134 lb., and May 10, 151.5 lb.—gain 17.5 lb. No. 3 weighed, March 22, 170 lb., and May 10, 187 lb.—gain 17.5 lb. No. 4 weighed, March 22, 135 lb., and May 10, 155 lb.—gain 19 lb.*

An analysis of the following experiment, reported in 'The Book of the Farm,' will give a farther insight into the typical diet of sheep; in this case the sheep were only in their second year. They were fed for three months—viz., between the 4th January and 31st March 1845—on Swedish turnips and hay:—

	Each gained.	Each consumed.	
		Hay.	Swedes.
	lb.	lb.	lb.
Leicesters, .	15	255	4027
South-downs, .	14	252	4110
Half-breds, .	17½	261	4255
Cotswolds, .	17	276	4862

It will be enough to give the particulars of one sheep from among the Leicesters; number of days, 85.

Daily allowance of hay, 3 lb.
" Swedish turnips, nearly 47 lb. 6 oz.

Ounces of hay per day, 48.
" turnips do., 758.

Per cent of flesh-formers	in hay, .	.	8.70
" heat-givers	" .	.	53.82
" mineral matters	" .	.	6.10
Per cent of flesh-formers	in turnips,	.	0.72
" heat-givers	"	.	7.67
" mineral matters	"	.	0.84

Whence—

100 : 8.70 : : 48 : 4.17 oz. flesh-formers in hay.
100 : 53.82 : : 48 : 25.82 oz. heat-givers "
100 : 6.10 : : 48 : 2.92 oz. mineral matters "

* 'English Journal of Agriculture,' vol. xxi. p. 104.

Also—

100 : 0.72 : : 758 : 5.45 oz. flesh-formers in turnips.
100 : 7.67 : : 758 : 58.13 oz. heat-givers „
100 : 0.84 : : 758 : 6.36 oz. mineral matters „

	Hay. oz.	Turnips. oz.
Flesh-formers, . .	4.17	5.45
Heat-givers, . .	25.82	58.13
Mineral matters, . .	2.92	6.36

		oz.
Total flesh-formers in diet per day, .	4.17 + 5.45 =	9.62
„ heat-givers „ „ .	25.82 + 58.13 =	83.95
„ mineral matters,„ „ .	2.92 + 6.36 =	9.28

There is a considerable contrast between this daily diet of a sheep and that deduced before from Voelcker's experiment (p. 565), the daily amount of flesh-formers being larger in the last case by 9.62—4.45 = 5.17 oz.; that of heat and fat givers by 83.95—53.77 = 30.18 oz.; and that of mineral matter by 9.28—4.88 = 4.40 oz.

But it should be observed that the sheep in this last experiment had but entered their second year, and therefore growing, and accordingly the weight respectively at the commencement of experiment was, in Voelcker's case, sheep No. 1 weighed 153 lb., while the heaviest sheep in the last detailed case weighed no more than 56½ lb.

Whence results the necessity in estimating the amount of a sheep's diet to take into account its age, or at least whether it be in a growing state or already in a state of maturity, besides what relates to its pregnancy and the suckling of the young.

On Feeding the Pig.—The pig is naturally omnivorous, though, even in the wild state, it does not attack living animals for the sake of food, confining itself for the most part to roots and fruits. In the wild state it is said to be even delicate in its choice of food—for example, that in the American orchards it refuses the peaches which have lain some time on the ground after falling, and that it will wait patiently even for hours till a fall of fresh peaches occurs.

Few kinds of food come amiss to the pig. It may be fattened on potatoes, turnips, carrots, parsnips, mangold-wurzel, or on barley, oats, pease, beans, rice, Indian-corn. Boiled food is found to answer best with the stomach of the pig. It would be needless to dwell at length on the theory of feeding the pig. A short commentary on the following passage from 'The Book of the Farm' will suffice. "It has been ascertained in England that 2 pecks of steamed potatoes, mixed with 9 lb. of barley-meal and a little salt, given every day to a pig weighing from 24 to 28 stones, will make it ripe fat in nine weeks. Taking this proportion of food to weight of flesh as a basis of calculation, and assuming that two months will fatten a pig sufficiently well, provided it has all along received its food regularly and fully, I have no doubt that feeding with steamed potatoes and pease-meal (both seasoned with a little salt), and lukewarm water with a little oatmeal stirred into it, given by itself twice a-day as a drink, will make any pig from 15 to 30 stones *ripe fat* for hams. The food should be given at *stated hours* three times a-day—namely, in the morning, at noon, and at nightfall. One boiling of potatoes—or turnips, where these are used—in the day, at any of the feeding-hours found most convenient, will suffice, and at the other hours the boiled roots should be heated with a gruel made of barley or pease-meal and boiling water, the mess being allowed a while to incorporate and cool to blood-heat. It should not be made so thin as to spill over the feeding-trough, or so thick as to choke the animals, but of that consistence which a little time will soon let the feeder know the pigs best relish. The quantity of food given at any time should be apportioned to the appetite of the animals fed, which should be ascertained by the person who feeds them; and it will be found that less food in proportion to the weight of the animal will be required as it becomes fatter. It is the duty of the dairymaid to fatten the bacon pigs, and of the cattle-man to keep them clean and littered."*

In the first place, let us find out how many ounces of flesh-formers, how many of heat and fat givers, and how many of mineral matter, are in the standard diet referred to in this passage. 2 pecks of steamed potatoes make about 340 oz. of potatoes; 9 lb. of barley-meal are 144 oz. of barley-meal.

The flesh-formers in potatoes are 1.4 per cent; the heat-givers in potatoes are 22.7 per cent; the mineral matters in potatoes are 1 per cent.

The flesh-formers in barley-meal are 8 per cent; the heat-givers in the same are 78.8 per cent; the mineral matters in the same are 6.9 per cent.

Whence in potatoes—

100	:	1.4	: :	340	:	4.76	oz.	flesh-formers.
100	:	22.7	: :	340	:	77.18	oz.	heat-givers.
100	:	1.0	: :	340	:	3.40	oz.	mineral matters.

In barley-meal—

100	:	8	: :	144	:	11.52	oz.	flesh-formers.
100	:	78.8	: :	144	:	115	oz.	heat-givers.
100	:	6.9	: :	144	:	9.93	oz.	mineral matters.

The sum is

Flesh-formers.	Heat-givers.	Mineral matters.
oz.	oz.	oz.
4.76	77.18	3.40
11.52	115.00	9.93
16.28	192.18	13.33

The first thing to be remarked in this result is the high ratio which the heat and fat givers bear to the flesh-formers—

* Stephens's 'Book of the Farm,' vol. i. p. 348.

namely, 20.48 to 260, or nearly 1 to 12. In the diet of man at rest or under moderate exercise, this ratio is no more than 1 to 5 in round numbers; and in that of men under bodily exertion, as that of soldiers during war, it is, on an average, 1 to 4.35. In the normal diet of the horse at rest, the ratio between the amount of flesh-formers and that of heat and fat givers is 28.9 to 150, or nearly 1 to 4.4; and the ratio between the same when the horse is under exertion is 59.1 to 251, or nearly 1 to 4.2. In the diet of the ox when intended for the market, the ratio of flesh-formers to heat and fat givers is 56.3 to 253, or as 1 to 4.5 nearly.

This difference in the ratio of the flesh-formers to the heat and fat givers in the pig is exactly what might be anticipated, since in our piggeries the life of the animal is reduced almost to vegetation, so that there is little waste of muscular tissue, and a rapid accumulation of fat. The small quantity of salt directed to be used in the formula of diet on which we are commenting is not to be forgotten. Salt—that is, chloride of sodium—is essential to the digestion of mammals in general. It is, indeed, contained in the ordinary articles of food; nevertheless, when nutrition is forced, as in the case of animals fed for the market, it may be required to be added separately, to insure complete digestion, by supplying freely the hydrochloric acid on which stomach-digestion is believed to be dependent. Nevertheless it is held to be possible to retard the fattening of an animal by the use of an excess of salt, for which statement we have the authority of Liebig. Here, then, is a point for inquiry. Chloride of sodium is uniformly present in the urine of mammals. If the normal proportion can be ascertained, under a given mode of management, without the direct use of salt, any failure in that normal quantity will be an indication for the addition of salt to the food.

When a sow is breeding—which she is fit for twice a-year, and from a very early period of life, though it is better postponed till she is at least a year old—her diet should manifestly include a good share of flesh-formers and proper mineral matter, in order that her progeny in the womb may be rightly developed. Again, while she suckles her brood, care must be taken that her diet is proper to sustain the due secretion of milk. Further, during the growth of the pig, before the process of fattening is commenced, care must be taken that there is a sufficiency of flesh-formers in the diet. But, in particular, when a boar-pig is to be reared to breed from, he must be allowed exercise, and a proportionately larger amount of flesh-formers in his food.

It might be conceived that a boar, after having attained mature age, must be altogether unfit for food. Nevertheless, this is a mistake. After castration such an animal takes on fat readily, and when killed furnishes pork of a quality very far beyond, for ham, what can be obtained from pigs killed at the usual age.

On Feeding Dogs.—Few materials exist from which to determine the normal diet of dogs, under the different circumstances of their existence. The dog is a purely carnivorous animal, and yet, in the domesticated state, he is fed very much on vegetable food. The following passage from Youatt affords some insight into the feeding of fox-hounds:—"Sixty-five couples of hounds in full work will consume the carcasses of three horses in one week, or five in a fortnight. The annual consumption of meal will be somewhat more than two tons per month. In feeding, the lighter should be let in first, and a little extra flesh distributed on the surface of the food, in order to coax those that are most shy. Some hounds cannot be kept to their work unless fed two or three times a-day; while others must not be allowed more than six or seven laps, or they would get too much.

"In summer an extra cow or two will be of advantage in the dairy; for the milk, after it has been skimmed, may be used instead of flesh. There must always be a little flesh in hand for the sick, for bitches with their whelps, and for the entry of young hounds. About Christmas is the time to arrange the breeding establishment. The number of puppies produced is usually from five to eight or nine; but in one strange case eighteen of them made their appearance. The constitution and other appearances in the dam will decide the number to be preserved. When the whelps are sufficiently well grown to run about, they should be placed in a warm situation, with plenty of fresh grass, and a sufficient quantity of clean but not over-stimulating food." * In round numbers, the allowance for each hound per day is 3 lb. of horse-flesh and 18 ounces of oatmeal.

The shepherd's dog, the rearing of which more especially belongs to the farmer, deserves all the care that can be bestowed upon him. In respect to his food, daily attention to his condition and appetite will teach more than any rules drawn from theory.

On Feeding of Poultry.—On the rearing of poultry there are a good many observations made in the 'Book of the Farm.' Some extracts from these, with a few additional observations, will suffice under the present head. "Of all the animals reared on a farm," it is said, "none are so much neglected by the farmer, both as regards selection of their kind and disposition to fatten, as every sort of domesticated fowl. . . . Few farmers kill their own mutton,—that is, keep fat sheep for their own use. Lamb they do kill in the season; but as to beef, it is

* Youatt, 'The Dog,' p. 83.

always purchased, so that, situate as the farmer's family usually is, the produce of the poultry-yard and pig-sty should constitute the principal fare upon their board. And why should they not have them in the highest perfection? . . . The ordinary fowls on a farm are—the cock (*Phasianus gallus*), the turkey (*Meleagris gallopavo*), the goose (*Anas anser*), the duck (*Anas domestica*), and the pigeon (*Columba livia*), the white-backed or rock dove, which was long confounded with the blue-backed dove (*Columba œnas*)—all of which may be fed on nearly the same kind of diet.

"First, in regard to the condition of the hen. As hatchings of chickens are brought out from April to September, there will be broods of chickens of different ages in winter—some as old as to be capable of laying their first eggs, and others mere chickens. The portion of the broods taken for domestic use are the young cocks and the older hens, there being a natural reluctance to kill young hens which will lay eggs largely in the following season. At all events, of the hen-chickens the most likely to become good layers should be preserved. The marks of a chicken likely to become a good hen are—a small head, bright eyes, a tapering neck, full breast, straight back, full ovoidal-shaped body, and moderately long grey-coloured legs. Every yellow-legged chicken should be used, whether male or female, their flesh never being so fine as the others. As to the colour of the feathers, that is not a matter of much importance—some preferring to have them all white, others all black; but I believe there is none better for every useful purpose than the mottled grey. Young fowls may be either roasted or boiled, the male making the best roast, and the female the neatest boiled dish. The older birds may be boiled by themselves, and eaten with bacon, or assist in making broth, or that once favourite winter soup in Scotland—*Cockieleekie*. A chicken never eats more tenderly than when killed a short time before being dressed; but if not so soon used, it should hang in the larder for three or four days in winter. An old fowl will become the more tender on being kept for a week before being used. The criterion of a *fat* hen when alive is a plump breast and the rump feeling thick, fat, firm on being handled laterally between the finger and thumb. The skin of the abdomen should be thick and fat, and fat should be found under the wings. White flesh is always preferable, though poulterers insist that a yellow-skinned chicken makes the most delicate roast, which I very much doubt. A hen is deprived of life by dislocation of the neck on being overdrawn, and there the blood collects and coagulates.

"Turkeys being hatched in May will be full-grown in stature by winter, and if they have been well-fed in the interval, will be ready for use. Indeed, the Christmas season never fails to create a great demand for turkeys; and, it must be owned, there are few more delicate and beautiful dishes presented at table, or a more acceptable present to a friend, than a well-fed turkey. Young cocks are selected for roasting, and young hens for boiling, and both are most relished with a slice of ham or of pickled ox-tongue. The varieties in common use are white, black, or mottled-grey; and of these, the white yields the fairest and most tender flesh. Young turkeys attain to great weights. I have had, year after year, young cocks weighing at Christmas 18 lb. each in their feathers. Norfolk has long been noted for its turkeys, where they are fed on buckwheat, and large droves are annually sent to the London market. A turkey is deprived of life by cutting its throat, when it becomes completely bled. The barbarous practice of cutting out its tongue and hanging by the feet to bleed slowly to death, for the alleged purpose of rendering the flesh white, ought to be strictly forbidden.

"Geese having been hatched in the early part of the summer, will also be full-grown and fit for use in winter. I believe little difference in flavour or appearance as a dish exists between the young male and female goose, though there may be of size. The criterion of a fat goose is plumpness of muscle over the breast and thickness of rump, when alive; and in addition, when dead and plucked, of a uniform covering of white fat under a fine skin on the breast. It is a good young goose that weighs in its feathers 12 lb. at Christmas. The goose is a favourite dish at Michaelmas in England, and at Christmas in Scotland; but people tire sooner of geese than of turkey, and in consequence it is not so frequently served at table. A green goose, however, is considered a greater delicacy in England than a turkey poult. Geese are always roasted in Britain, though a boiled goose is not an uncommon dish in Ireland; and their flesh is certainly much heightened in flavour by a stuffing of sage and onions, with an accompaniment of apple-sauce. A goose should be kept a few days before being used. It is bled to death by an incision across the back of the head, which completely frees it of blood. . . .

"Ducks being also early hatched, are in fine condition in winter, if they have been properly fed. Ducklings soon become fit for use, and are much relished with green pease in summer. I believe there is no difference in flavour and delicacy betwixt a young male and female duck. They are most frequently roasted, and stuffed with sage and onions, though often stewed; and if smothered among onions when stewed, few more savoury dishes can be presented at a farmer's table. A duck never eats better than when killed immediately before being dressed. It is deprived of life by chopping off the head with a cleaver, which completely drains the body of blood.

"Hens and turkeys are most easily caught on their roost at night with a light, which seems to stupify them; and geese and ducks may be caught at any hour in the out-house they may be driven into.

"As young pigeons alone are used, and as pigeons do not hatch in winter, they require no other notice at present than what regards their feeding; and to give an idea of their gastronomic powers, of three rock-doves sent to Professor MacGillivray, 'the number of oat-seeds in the crop of the second amounted to 1000 and odds, and the barley-seeds in that of another were 510. Now, supposing,' he observes, 'there may be 5000 wild pigeons in Shetland or in Fetlar, which feed on grain for six months every year, and fill their crops once a-day, half of them with barley and half with oats, the number of seeds picked up by them would amount to 229,500,000 grains of barley, and 450,000,000 grains of oats, a quantity which would gladden many poor families in a season of scarcity. I am unable,' he adds, 'to estimate the number of bushels, and must leave the task to the curious.' * I was one of the curious to undertake the task, and found the result to be 422 bushels, or 52 quarters 6 bushels of barley; and 786 bushels, or 98 quarters 2 bushels of oats—or 151 quarters of grain in all." †

The quantity of oats and barley consumed by pigeons sounds very large when, as above, looked at in the aggregate as the accumulation of the food of 5000 such birds. But when it is regarded simply as the food of one pigeon, it does not strike so much. A thousand oat-seeds weigh about 10 drachms —that is, 2 drachms more than one oz. Troy; and 500 barleycorns weigh about 7 drachms. The proportion of flesh-formers in oats, per cent, is 16, that of heat-givers 76.4, that

* MacGillivray's 'History of British Birds,' vol. i. p. 285.

† "I ascertained the result by weight, and as the facts may be worth recording, I may mention that in an average of 3 drachms there were 75 grains of chevalier barley in each drachm, of a sample weighing 56½ lb. per bushel; and 97 grains of Siberian early oat in 1 drachm, of a sample weighing 46 lb. per bushel. Of Chidham wheat, a favourite food of pigeons, weighing 65 lb. per bushel, there were 86 grains in the drachm."—'Book of the Farm.'

of mineral matter 3. The proportion of flesh-formers in barley is 8, that of heat-givers 71, that of mineral matters 3.

OATS.

Whence 100	:	16.0	: :	10	:	1.6	drachm	flesh-givers.
100	:	76.4	: :	10	:	7.6	,,	heat-givers.
100	:	3.0	: :	10	:	0.3	,,	mineral matters.

BARLEY.

100	:	8	: :	7	:	0.56	drachm	flesh-formers.
100	:	71	: :	7	:	4.97	,,	heat-givers.
100	:	3	: :	7	:	0.21	,,	mineral matters.

TOTALS.

Flesh-formers.	Heat-givers.	Mineral matters.
1.60	7.60	0.30
0.56	4.97	0.21
2.16	12.57	0.51

These, doubtless, are large quantities both of flesh-formers and heat and fat givers, when the small weight of the body of a pigeon is considered. But when the rapid flight of a pigeon is taken into account, it is seen that there must be an immense expenditure of bodily energy, and when the high temperature is considered likewise, that there must be a large combustion to maintain it undiminished.

Fowls, turkeys, ducks, and geese should be put up in separate sheds. Every morning at an early hour, according to the season of the year, they should all be let out to roam and pick about for an hour or two. They are then to get their morning meal at a separate place for each kind of poultry. The best place for the fowls and turkeys is a plot of grass. These pick their food most easily and cleanest when it is scattered among the grass. A common practice is to put their food into a dish or dishes, out of which every one must strive to get a share, some necessarily getting too much and others too little.

Another still more objectionable mode is to throw the food in lumps upon the ground or road, however dirty, and to let the creatures scramble for it as they best can.

The best place for feeding ducks and geese is near a water-pond, or at least there must be a supply of water near, as geese cannot well swallow their food without water.

In winter they should all be fed twice a-day—namely, in the morning and in the afternoon; in summer, three times a-day—morning, noon, and afternoon. The afternoon meal should always be in time to allow the fowls, as is their custom, to go to roost before sunset.

For fowls and turkeys, boiled potatoes in their skins, a little warm, and broken to pieces with the hand at their place of feeding, make excellent food. In winter, with both meals, a few grains of wheat, barley, oats, or Indian-corn, are thrown down along with the potatoes, and also some morsels of hard-boiled oatmeal porridge. In summer the grain food is given only with the noontide meal. The same course suits well with the ducks. Geese thrive best on grass as pasture. In winter geese feed well on turnips, and even on raw potatoes cut small for them. In summer the geese at the noontide meal should get the like allowance of grain as the fowls, turkeys, and ducks.

If such a course be followed, there is no occasion for any special mode of fattening the poultry, and especially of cramming—they will always be ready for the kitchen, and disease among them will hardly be known.

In winter some economical means of heating their sheds artificially should be adopted.

In a poultry stock conducted on this plan, cock-turkeys may be obtained of 18 lb. weight by Christmas, and hen-turkeys of 15 lb., geese of 12 lb., ducks of 8 lb., and chickens and fowls quite plump and fat.

For each kind of poultry there should be a separate place for incubation and for rearing the young.

For young turkey-poults, the best food during the first three weeks of their lives is hard-boiled eggs, minced. With young chickens this kind of food may be stopped after two weeks. When soft food is given to turkey-poults, they are very apt to suffer from scouring, and to die off. The hard-boiled eggs prevent scouring, and keep the bowels in good condition. After two weeks the chickens, and after three weeks the turkey-poults, should eat hard warm oatmeal porridge and grains of rice. Ducklings should have soft food, but should not be allowed to go into the water until they are three weeks old. Goslings thrive best on tender grass in a warm exposure. Care must be taken to keep them on their feet, as when they fall on the back, as they are apt to do, they die. They die also when drenched with rain.

It is not necessary for poultry only, to insure their thriving condition, that they should be fed at regular times, but for all kinds of animals. There are none that, when the usual hour for food is allowed to pass by, will not show their discontent by loud wailings—a stinging rebuke to the careless farmer.

Table of the Chemical Composition of some Principal Articles of Food.

Explanation.—The column of "Heat and Fat givers" signifies—I., Starch; II., Sugar; III., Fat or Oil.

Name.	Water.	Flesh-formers.	Heat and Fat givers.	Equivalents of Starch.	Mineral matters.	Total Carbon.
Barley,	15.1	8.0	I. 74.0 III. 2.0	78.8	0.9	38.69
Beans,	12.0	26.0	I. 57.0 III. 2.0	61.8	3.0	40.84
Bread,	44.8	8.2	I. 44.5 III. 1.0	46.9	1.5	24.93
Buckwheat, seed,	dried at 212°	10.7	I. 52.3 II. 8.3 III. 0.4	58.48	1.4	31.74
Buttermilk,	89.1	4.0	II. 4.6 III. 1.5	7.6	0.75	5.147
Cabbage,	89.42	1.45	I. 7.01 III. 0.08	7.2	0.12	3.89
Carrots,	86.5	1.3	I. 6.3 II. 5.0 III. 0.15	11.3	0.80	6.11
Cat's-tail grass,	57.21	4.86	I. 22.85 III. 1.5	26.45	2.26	14.64
Cheese (cheap kinds),	40.0	30.0	III. 26.0	62.4	4.0	36.16
Clover (red),	81.01	4.27	I. 8.45 III. 0.69	10.1	1.32	6.785
Clover (white),	79.71	3.8	I. 8.14 III. 0.89	10.27	2.08	6.607
Cock's-foot grass,	70.0	4.06	I. 13.3 III. 0.94	15.54	1.59	9.09
Cotton-cake (decorticated),	9.28	41.25	I. 16.45 III. 16.05	54.4	8.05	46.0
Eggs,	75.0	12.6	III. 11.0	26.4	1.4	15.26
Flour, *see* Wheat.						
Furze,	16.2	6.7	II. 15.2	20.2	1.37	12.580
Hay (meadow),	14.0	7.0	I. 40.4	47.84	5.25	25.02
" (red clover),	dried at 212°	22.55	I. 44.47 III. 3.67	53.27	9.56	35.804
" (white clover),	Do.	18.76	I. 40.04 III. 4.38	50.55	10.29	27.883
Indian corn,	12.0	11.0	I. 68.5 III. 7.0	85.3	1.5	41.72
Italian rye-grass,	75.61	2.45	I. 14.11 III. 0.8	16.03	2.21	8.93
Lentils,*	12.5	27.0	I. 55.0 II. 2.5	61.0	3.0	40.86

* 10 parts of fat are accounted equal to 24 of starch, hence, for example, in lentils, 10 : 24 : : 2.5 : 6, but 55.0 + 6 = 61, set down as the starch equivalent of lentils.

TABLE OF THE CHEMICAL COMPOSITION OF SOME PRINCIPAL ARTICLES OF FOOD—*Continued.*

Name.	Water.	Flesh-formers.	Heat and Fat givers.	Equivalents of Starch.	Mineral matters.	Total Carbon.
Linseed, . .	14.0	18.8	I. 19.2 III. 14.0	51.2	4.63	32.86
„ cake, .	10.05	22.14	I. 39.1 II. 11.93	67.1	7.25	41.7
Lucern, . .	69.95	3.83	I. 13.62 III. 0.82	15.58	3.04	8.98
Mangold-wurzel, .	dry	3.0	II. 73.0	69.0	6.3	32.2
Milk (new), . .	87.2	4.0	II. 4.6 III. 3.5	12.5	0.7	6.687
„ (skim), .	88.6	4.0	II. 4.6 III. 2.0	8.8	0.77	5.532
Oats, . . .	dried	17.0	I. 53.0 III. 6.5	68.6	2.54	39.63
Oatmeal, .	13.0	16.0	I. 62.0 III. 6.0	76.4	3.0	40.95
Pea, . . .	dry 15.0	22.6	I. 58.5 III. 2.0	63.3	2.5	39.35
Parsnip, . .	85.1	1.4	I. 10.0 II. 2.5	12.4	1.0	6.245
Poa pratensis, .	67.14	3.41	I. 14.15 III. 0.86	16.21	1.95	8.93
Potato, . .	75.0	1.4	I. 22.5 III. 0.1	22.7	1.0	11.468
Rib grass, . .	84.78	2.18	I. 6.06 III. 0.56	7.4	1.35	4.548
Rice (grain), .	13.0	6.5	I. 79.2 III. 0.8	81.1	0.5	39.278
Rye (grain), . .	15.0	8.8	I. 62.7 II. 2.5 III. 2.9	71.2	1.36	39.9
Sainfoin, . .	76.64	4.32	I. 10.73 III. 0.7	12.33	1.84	7.7
Straw, *see* Wheat.						
Turnips, . .	91.1	1.2	I. 3.2 II. 3.0	6.2	1.5	3.39
Wheat (grain), .	12.9	12.9	I. 68.0 II. 6.0	74.0	1.9	40.2
„ (flour), .	13.3	14.0	I. 70.0 III. 1.5	73.6	1.2	38.61
„ (straw), .	44.04	1.5	48.55	—	5.91	22.37
Yarrow, . .	—	10.34	I. 45.46 III. 2.51	51.48	9.0	28.4

GLOSSARY.

ABDOMEN.—One of the two cavities into which the trunk of mammals is divided by the midriff, the other being the thorax or chest.

ABOMASUM.—The fourth or true stomach in ruminants.

ABORTION.—The non-development of a part in organic nature. Abortion not unfrequently occurs in cows, and is known by the expression "slipping the calf." When one cow in a cow-house slips her calf, the same accident is apt to occur to the other cows shut up with her, or it spreads like an epidemic. When she is removed from the rest of the cows the spread of the epidemic ceases. This kind of abortion cannot usually be traced to any cause. It has been ascribed to a large draught of ice-cold water in the morning—to sudden fright—to being pursued by a dog; and so current is the belief that the smell of the blood of slaughtered animals brings it on, that in farm-steadings the slaughter-house is recommended to be built as distant as possible from the cow-houses. It is remarkable that the same tendency to abortion does not occur in the mare, the ewe, and the pig.

ABSORPTION.—The act by which certain vessels or textures carry away matters from a living surface or substance.

ACARI.—*See* Parasite.

ACIDS, MINERAL.—The acids formerly termed mineral acids are the sulphuric or vitriolic acid, the nitric acid or aquafortis, and the hydrochloric acid, called also muriatic acid and the spirit of salt.

ACIDS, ORGANIC.—The ternary and quaternary acids—that is, acids consisting of three and four elementary substances, which, existing in the organic kingdoms of nature, are named organic acids. *See* p. 336 to p. 343.

ACIDS (*Oxyacids*).—Chemical bodies having often a sour taste, very generally changing the blue colours of vegetables to red, and having the essential property of combining with oxides of metallic bodies to form neutrals. *Hydracids.*—In hydracids the radical unites with the pure metal: thus when hydrochloric or muriatic acid is added to potassa (the oxide of potassium), the chlorine or radical unites with the potassium, while the hydrogen unites with the oxygen of the potassa, and forms water.

ACINI.—A term derived from the Greek word signifying a grape-stone, applied to the minute constituent parts of such glands as the kidneys, having for their general character rounded groups of vesicles containing gland-cells, and opening, either occasionally or permanently, by a common central cavity into minute ducts.

ACOTYLEDONOUS.—Applied to plants having in a seed no cotyledons or lobes of the embryo, of which ferns and seaweeds are examples.

ACROGENS.—Applied to plants having a stem that grows at the summit, forming a subdivision of the acotyledons, which includes the ferns, the horsetails, the mosses, and liverworts.

ADIPOCERE.—A substance formerly confounded with cholesterine: the fatty matter into which the bodies of animals are converted when decomposed slowly in a moist soil.

ADIPOSE TISSUE.—The tissue, consisting of minute cells, in which the fat is deposited.

AFFERENT.—A word signifying "carrying to," opposed to efferent, "carrying from," and applied to minute vessels and minute nerves. An afferent vessel is a minute vessel going to a glandular organ; an afferent nervous filament is one going to a central nervous organ. *See* Efferent.

AFFINITY, or CHEMICAL ATTRACTION.—Applied to the attraction holding together particles of matter different in kind—opposed to the attraction of aggregation, which holds together particles of matter the same in kind. The stronger or weaker affinity which particles of one kind have for particles of other kinds is the great source of chemical action.

AGGREGATE.—In clusters.

AIR-CELLS.—The same as the pulmonary cells. The very minute cells of the lungs into which the atmospheric air penetrates by the bronchial tubes or ramifications of the windpipe—larger in carnivorous mammals than in man, in whom they vary from the 200th part of an inch to three times that diameter.

ALBUMEN (*in Botany*).—The nutritious matter stored up with the embryo in the seed, called also perisperm and endosperm.

ALBUMEN (*in Organic Chemistry*). — A proximate principle of the vegetable and also of the animal kingdom, having the same composition in both. In the vegetable kingdom the juice of turnips, carrots, and cabbages becomes turbid when heated, owing to the presence of vegetable albumen; in the animal kingdom the white of egg, sometimes called ovalbumen, and the coagulum obtained by heating the serum of blood, called at times seralbumen, exemplify this principle. *See* p. 305.

ALBUMINOID.—Applied to the proximate principles of organised nature capable of developing or repairing the living frame, called also proteine principles and flesh-formers—viz., albumen, fibrine, caseine, legumine—the equivalent of proteine being $C^{36}H^{27}N^{4}O^{12}$.

ALCOHOL is the proximate principle common to such domestic spirits as brandy, rum, hollands, whisky. When free from water it is termed absolute alcohol, its density being 0.795; with 16 per cent of water it is called rectified spirit, the density being 0.838; when diluted so as to have the density 0.920 it is called spirit of wine. The chemical name of absolute alcohol is hydrate of oxide of ethyl, $C^{4}H^{6}O^{2}$. The term alcohol is also extended to a series of analogous bodies which are hydrated oxides of hydro-carbon.

ALGÆ.—The seaweed order in botany, consisting of cellular plants found in the sea, in rivers, lakes, marshes, and hot springs all over the world.

ALKALIES.—A group of chemical substances soluble in water, forming soaps with oils and with resins, and giving a brown colour to yellow vegetable colours. Potassa, soda, and lithia are oxides of the simple metallic bodies, potassium, sodium, lithium; ammonia, the volatile alkali, consists of hydrogen and nitrogen, NH^{3}.

ALVEOLI.—The sockets of the teeth.

AMMONIA.—*See* Alkalies.

AMNION.—The lining membrane of the ovum in which the fœtus of mammals is contained—hence liquor amnii, the fluid which surrounds the fœtus in gestation.

AMNIOS.—The fluid or semi-fluid matter in the embryo sac of seeds in vegetable physiology.

AMORPHOUS.—Without definite form.

AMPHIBIA.—A word signifying animals capable of living in air or in water. It was made by Linnæus his third class, including reptiles, serpents, and cartilaginous fishes. Of late the term has become ambiguous: it is at present most commonly applied to the frog tribe, batrachia, and the perenni-branchiata or siren group, the latter being the only true amphibious group; but it is heard applied also to mammals that can remain long under water, as the seal and the morse, in which last sense it is used by Cuvier.

AMYLACEOUS.—Starchy.

ANALOGOUS, ANALOGUE.—Employed in physiology in contrast with homologous. Analogous is applied to two parts in functional correspondence; homologous to two parts in structural correspondence. The wing of a bat or of a bird is homologous with the arm of a man, but not analogous to it; the gills of a fish are analogous to the lungs of a man, but not homologous with them. The wing of a bat is the homologue of the arm of a man; the gill of a fish is the analogue, but not the homologue, of the lung of a man.

ANASTOMOSIS.—The same as inosculation,—the communication between two blood-vessels.

ANIMAL FUNCTIONS.—The functions by which chiefly animals are distinguished from vegetables—viz., the functions of locomotion and sense, called also functions of relation.

ANUS.—The fundament.

AORTA.—The trunk of the arterial system, springing from the left ventricle of the heart.

APONEUROSIS.—A thin tendinous expansion, taking the form of a membrane.

APPENDIX VERMIFORMIS.—A process like a goose-quill hanging from the cæcum in man.

ARCHETYPE.—Original plan or model.

AREOLAR TISSUE.—The same as cellular tissue and cellular substance; the general connective tissue throughout the living frame.

ARTERY.—The aorta or any of its branches. Pulmonary artery—the vascular trunk which arises from the right ventricle of the heart to convey the dark-coloured blood to the lungs.

ARTICULATION.—The union of bones together to form joints more or less movable.

ASPHYXIA.—Insensibility of an animal, beginning with interruption of the respiration. Death by asphyxia—death commencing with interruption of respiration.

ASSIMILATION.—The conversion of nutriment by a texture into its own substance.

ATROPHY.—General waste of organic parts or of organic force. There is a kind of atrophy in oxen and sheep which much concerns the agriculturist—namely, that loss in live weight which takes place, not merely when such stock is driven on foot long distances, as from Scotland far into England, but also when conveyed by railway for any considerable length of way. It is estimated that cattle and sheep lose so much live weight on a long journey on foot, that they may require two months of careful feeding to restore them to the condition in which they were when they set out. This loss occurs even in young cattle, such as one might think were supple enough for a long journey. Moreover, it is observed even when the cattle and sheep are carefully fed and rested by the way. It seems an enigma to the farmer, but doubtless finds its explanation in the great amount of muscular exertion called forth in even a short daily journey, as compared with what is put forth every day when the animal feeds in the pastures of the farm. The loss which cattle and sheep sustain in railway journeys is perhaps mainly attributable to causes that might be remedied, such as the want of food and drink, and the violent jostling against each other which they are apt to suffer. Every railway truck conveying cattle and sheep ought to be provided with buffers.

A bull belonging to the late Mr Bates of Kirkleavington, the eminent breeder, near Yarm, Yorkshire, lost 40 stones in the journey to and from Oxford, where he gained the highest prize at the English Agricultural Society's first show there.

Auricles of the Heart.—The two cavities of the heart to which the venous trunks lead, the right receiving the two venæ cavæ and the coronary vein, the left receiving the four pulmonary veins.

Automatic.—Not voluntary, not the result of the will. When the infant sucks immediately after birth it does so automatically. When the will becomes established it governs, or at least regulates, such automatic acts. "The power of the will when fully developed in man is especially exerted in controlling and directing 'the automatic' activity of the cerebrum, regulating the course and succession of ideas, as well as the degree of emotional excitement, by its power of fixing the attention on any object of thought which it may determine to pursue, and of withdrawing it from whatever it may desire to keep out of the mental view. This seems to be the most distinctive attribute of the human mind in its highest phase of evolution; and it is this which gives to every individual the freedom of action which every one is conscious to himself that he is capable of exerting."—*Carpenter.*

Axilla.—The arm-pit.

Axis.—The middle line of any extended part or organ.

Azote.—The same as nitrogen.

Azygos.—Without a fellow, as the vena azygos, *vena sine pare.*

Basement Membrane.—A constituent part of any secreting apparatus, whether gland or surface, the other essential parts being blood-vessels and cells. The basement membrane is apparently structureless.

Blastema.—An ancient medical word, of obscure signification, now employed to denote the fluid substance called germ substance, in which molecules and granules, and finally cells, arise.

Blind Gut.—*See* Cæcum.

Bonnet.—*See* Honeycomb.

Breeding, Cross, and Breeding In-and-in.—Cross-breeding, and breeding in-and-in, are two very important subjects in the rearing of farm live-stock. Cross-breeding is less practised in the case of horses than in that of cattle and sheep. It is the usage to keep the breeds of horses pure. It is, however, a favourite practice to put a thorough-bred stallion to mares of other breeds for the purpose of procuring roadsters and harness horses.

The cross most in favour in the case of black cattle is to put a pure-breed short-horn bull to a cow of any other breed. The immediate effect of such a cross is to fine down the extremities, to give breadth and roundness to the carcass, to superinduce a disposition to fatten, and a tendency to a mellowed state of the skin. A bull, however, obtained by such a cross is of no value, never begetting offspring of any worth, and being itself inferior in shape and all other prized qualities.

In sheep, the cross that stands highest in favour is to use a pure-breed Leicester ram with other breeds of ewes, particularly the Cheviot and black-faced ewe. The progeny is enlarged and improved in the carcass, in the length of the wool, and in the disposition to fatten early. A ram obtained by this kind of cross is not an animal to be prized; and yet, to the detriment of the sheep throughout the country, such a ram is much too often employed, merely because the farmer is too apt to grudge paying a good price for a suitable animal.

In regard to breeding in-and-in in the case of horses, the farmer is generally averse to the practice, on the ground that the parents are too near akin in blood. Any ill effects of this plan are not much seen in horses, unless the small weedy racehorses bred nowadays be taken as examples. It is, however, the belief of good judges, that of late nearly an equal number of good horses have been obtained by adopting either plan; yet it is allowed that no first-rate horse has been obtained when the parents had the same dam. Again, it is to be remembered, that in domestic animals generally, very close in-breeding cannot be continued long without developing whatever weak points may exist in the breed. This fact makes a very important rule for our guidance. The breeder knows thus what he has to fear, and while he cannot expect to reach the quality he is in quest of in less than two or three successive trials, he will stop short of the generation in which weak points may come forth.*

On cattle, very singular effects are produced by breeding in-and-in. The extremities become fine and delicate, the eyes enlarge, the general sensitiveness is much increased, the back becomes arched, the hair smooth and close, the ears thin, red coloured, and almost destitute of hair: animal passion is cold. The frame is reduced in size. Flesh is easily gained, but attains only light weights. The animal becomes subject to diseases, especially of the lungs, and to what are called "clayers" in the throat.

In sheep, the effects of breeding in-and-in are to produce fine and delicate extremities, to bare the head of wool, to render the ears thin and red. The carcass remains well enough formed, but is diminished in size. The fattening takes place early, but does not exceed light weight. The animal is very susceptible to cold, and subject to diseases, such as hydatids and rot.

In-and-in bred rams and bulls may be used for the coarser breeds

* Stonehenge, p. 142.

of their respective kinds. Their effect upon the progeny is immediate and striking, as giving thereto a blood-like character.

But in-and-in breeding may produce valuable results in particular circumstances. When it is desired to improve a coarse native breed of cattle or sheep, and after a certain degree of improvement has been attained by selection of individual animals, all progress towards perfection would be arrested were in-and-in breeding not resorted to, since no superior animals are to be found elsewhere. Examples of this practice may be adduced. Bakewell found a coarse breed of sheep in Leicestershire, which he imagined had such points that, if permanently developed, would form a valuable breed of sheep, both as regards mutton and wool. He was obliged to breed in-and-in for a considerable time, and by so doing produced the favourite high-bred Leicesters of the present day. After the dissemination of a portion of his flock throughout the country, a crossing could then be maintained, which kept up the breed to the mark, and at the same time avoided the evils of in-and-in. Upon the same principle Bakewell improved the long-horn cattle. So did the Culleys produce the fine race of short-horns from the coarse Teeswater cattle. The polled Angus cattle were improved much in the same way by Hugh Watson.

Bromine.—A simple non-metallic body analogous to chlorine and iodine, found in sea-water. When free it has a powerful smell, and exists at common temperatures in the liquid state. Its combinations with metallic bodies are termed bromides.

Bronchi.—The air-tubes or subdivisions of the trachea or windpipe, extending to the air-cells of the lungs.

Bronchial Arteries and Veins.—Blood-vessels in the lungs distinct from the pulmonary blood-vessels of the lungs. The bronchial vessels belong to the general circulation, and are concerned in the nutrition of the lungs; the pulmonary vessels constitute a separate circulation for the aëration of the whole blood in its passage through the lungs.

Brunner's Glands.—Glands confined to the duodenum, and found most abundantly at its commencement, visible to the naked eye, provided with permanent ducts, and supposed to possess a function like that of the pancreas, which they seem to resemble in structure.

Bursæ Mucosæ, more properly termed synovial bursæ.—Minute shut cavities situated near the surface of the body, or beneath tendons that glide over bones, containing a lubricating fluid resembling the synovia of the joints.

Cæcum.—The blind gut: a spur of greater or less dimensions, formed by the insertion of the end of the small intestine into the side of the great near its commencement. It is called also *caput cæcum coli.*

CALCIUM.—One of the earth metals, the oxide of which is common lime. It is a light metal, and decomposes water readily with the evolution of hydrogen. It may be obtained from the iodide of calcium by means of sodium. It exists abundantly in organic nature. *See* p. 304.

CALEFACIENT or CALORIFIC FOOD.—The same as non-azotised food.

CALYCES.—The calyces of the kidney are the extremities of the subdivisions of the pelvis of the kidney which receive the urine from the apices of the cones of Malpighi ; less numerous than the apices of the cones, because more than one apex is often inserted into one calyx.

CAPILLARIES.—The capillaries form a network of blood-vessels at a medium diameter, about 1-3000th of an inch, interposed between the arterial system and the venous system.

CAPSULES OF MALPIGHI.—Small flask-shaped dilatations at or near the commencement of the minute *tubuli uriniferi* in the kidney. Within or attached to these capsules lies a Malpighian corpuscle or tuft, the ultimate structure of the kidney.

CARBON.—A simple non-metallic combustible body, existing in mineral nature chiefly in combination with oxygen under the form of carbonic acid ; its common type is the charcoal of wood. It is an essential constituent of all organic substances. *See* p. 297.

CARBONIC ACID.—A gaseous acid, consisting of carbon and oxygen. It exists in small proportion in the atmosphere, whence plants draw it as a principal part of their food. It exists abundantly in mineral nature as combined with lime and magnesia. Several carbonates are found in animal nature, as the carbonate of potash, the carbonate of soda, the carbonate of lime.

CARDIA.—The upper or œsophageal orifice of the stomach.

CAROTIDS.—The principal arteries supplying blood to the several parts of the head and brain.

CARTILAGE.—The same as gristle.

CASEINE.—A proximate principle of organic nature azotised, obtained from poor cheese. *See* p. 307.

CASTRATION.—*See* Genital organs.

CATALYSIS.—Catalytic action in chemistry is when a body, without being itself changed, by its mere presence originates chemical action between other bodies ; for example, spongy platinum being present in a mixture of oxygen and hydrogen, these last unite to form water.

CAUDA EQUINA.—The spinal marrow terminates in a slender filament, which, being surrounded by the roots of many nerves, is termed the horse-tail, or cauda equina.

CELL.—A vesicle. Cells, such as epidermis cells, lymph cells, consist of a cell-wall and nucleus, or cytoblast, with a contained fluid ; cells in the most developed state, as the blood-corpuscles of mammals, have no nuclei or cytoblasts. The cell-wall is generally made transparent by acetic acid, and if it disappears it may be brought again into view by neutralising the acid by means of potash or soda. The nuclei of some cells, as those of epithelium cells and pigment cells, contain nucleoli, or nucleus corpuscles.

CELLULAR TISSUE and CELLULAR SUBSTANCE.—*See* Areolar Tissue.

CELLULOSE, or CELLULINE.—The proximate principle composing the basement tissue in vegetable bodies, nearly pure in cotton, linen, and elder-pith. It passes into lignine or woody tissue by becoming encrusted with a deposit lining the cells originally composed of pure celluline. *See* p. 333.

CENTRIFUGAL, CENTRIPETAL.—Terms applied to nerve-fibres. Centrifugal, passing from the nervous centres, the same as efferent; centripetal, passing to the nerve-centres, the same as afferent.

CEREALIA.—The grasses, the fruit of which affords bread, or supplies the place of bread.

CHEST.—*See* Abdomen.

CHILOGRAMME, CHILOMETRE.—*See* Weights and Measures.

CHLORINE.—A simple gaseous body, known in nature only in combination with metallic substances; as with sodium in common salt, the chloride of sodium. Its compounds with metallic bodies are known as chlorides.

CHOLESTERINE.—A proximate principle of the animal body found in bile, in blood, in the brain, in the yolk of egg. It is a non-azotised body.

CHONDRINE.—A proximate principle of the animal body allied to gelatine: both are azotised principles; they are not, however, held to be flesh-formers—nay, it is doubtful if they be at all nutritive. Chondrine exists in the cornea of the eye and in the permanent cartilages. *See* p. 309.

CHYLE, CHYME.—Chyle is the liquid derived from the digested food of the alimentary canal as taken up by the lacteals. Perfect chyle is that obtained from the thoracic duct after it has been subjected to the action of the mesenteric glands. Chyme is the pultaceous mass which the stomach delivers up to the duodenum or highest part of the intestines after the food has undergone ventricular or stomach digestion—that mass is not homogeneous, yet more or less so.

CHYLOPOETIC, CHYLOPOIETIC.—Applied to the organs concerned in digestion—the stomach, intestines, omenta, and mesentery—the assistant chylopoetic viscera being the liver, pancreas, and spleen.

CILIA, CILIARY MOTION.—Cilia are minute processes of the epithelium in certain parts of the body, no more than the 1-5000th part of an inch in length, which, during life, and for a short time after death, are in incessant motion.

COAGULATION.—A change on a fluid like that produced by rennet on milk.

COAGULUM.—*See* Albumen.

CŒLIAC.—Relating to the cavity of the abdomen: thus cœliac axis, the short arterial trunk supplying the stomach, liver, pancreas, and spleen with blood.

COLOSTRUM.—The milk first secreted after parturition; it has an evacuant quality, and therefore serves to expel the meconium or first excrement of the new-born animal.

CONCEPTION.—The effectual contact of the spermatozoon produced in the testicle with the matured ovum expelled by the ovary.

CONGENITAL.—Applied to what already exists formed in the new-born animal, in contrast with what is afterwards developed.

CONGLOBATE.—A term formerly opposed to conglomerate as applied to glands. The use of conglobate now is to signify the glands of the lymphatic and lacteal systems as a less vague term than lymphatic ganglia. According to present views, the glands of the absorbent system, or the conglobate glands, have for one office the production of white corpuscles, which by a farther development become the red corpuscles of the blood.

CONGLOMERATE.—Heaped together; applied to glands consisting of lobules united under the same membrane.

CONTRACTILITY.—The property in a muscular fibre in consequence of which it contracts or shortens itself on the application of a stimulus directly to itself or to the sentient nerve spread upon it, the will being a stimulus which acts on it through a motor nerve. It is the same property in muscles which was formerly called irritability.

CORPUSCLES.—Applied to microscopic objects in the animal fluids; for example, exudation corpuscles, the organisable nuclei contained in fibrinous fluids, which are the origin of the new tissues formed from such fluids.

CREATINE, CREATININE.—*See* Kreatine, Kreatinine.

CROSS.—*See* Breeding.

CUD.—*See* Rumination.

CUTICLE.—*See* Derma.

CYTOBLASTEMA.—The structureless formative substance in which the nuclei and cells are imbedded in many tissues in progress of formation; it is the same as blastema, which last word is preferable, as involving no hypothesis of cell formation.

CYTOBLASTS.—In cells the same as nuclei.

DECUSSATION.—The crossing of two filaments or two fasciculi of filaments, like the crossing of the two lines forming the letter X.

DEFŒCATION.—The evacuation of the bowels.

DEGLUTITION.—The act of swallowing.

DEHISCENCE.—Opening—as the opening up of a ripe seed-vessel.

DENSITY; SPECIFIC GRAVITY.—These expressions are used synonymously to signify the comparative weights of equal bulks of any two substances. Thus a cubic inch of platinum, the heaviest metal known, very nearly weighs as much as two cubic inches of silver. It is therefore said that the density of platinum is nearly twice the density of silver. But silver is, in round numbers, ten times heavier than water—that is to say, one cubic inch of silver weighs as much as ten cubic inches of water; and platinum is more than twenty times heavier than water; so that if the density of water be taken as a standard, and said to be 1.000, or, in popular language, a thousand, then the specific gravity of silver is expressed by 10.000, and the specific gravity of platinum is expressed by 20.000, or more popularly thus, with the same relative quantities—silver, 10,000; platinum, 20,000; water being taken at 1,000—for 1,000 : 10,000 : : 1. : 10.; and 1,000 : 20,000 : : 1. 20. Silver is really 10.5 heavier than water, and platinum twenty-one times heavier.

When we can discover the weight of any bulk or measure of a body relative to a given weight of water, for example, to a thousand grains of water, then we know its specific gravity—that is to say, we know how many grains of such body occupy the same space as a thousand grains of water; and if water be called 1000, then the weight of the equal bulk of that other body in grains expresses its specific gravity. Thus, a vessel that contains exactly a thousand grains of distilled water at 60° Fahrenheit, and while the barometer stands at 30°, holds 793 grains of absolute alcohol, whence it follows that the density of absolute alcohol is to the density of distilled water under these circumstances as 793 : 1000; or, in the language adopted in science, the specific gravity of absolute alcohol is, if water be called 1000, 793, or .793, if water be called 1.000.

If the body, the specific gravity of which is required, be a solid insoluble body, it is to be weighed first in air, and then in water. Its weight in water is less than its weight in air by the weight of its own bulk of water which it displaces. Thus we have obtained a number denoting the weight of a bulk of water equal to the bulk of the body under examination. We have discovered, therefore, the comparative weights of equal bulks of water and the body in question; for the weight of that body in air, and the difference between its weight in air and its weight in water, denote the comparative weights of equal bulks of that body and of water.

If the body is lighter than water, it must be sunk by means of a weight, and the calculation is rendered a little more complex.

If the body be soluble in water, some fluid, such as alcohol, ether, or oil of turpentine, must be chosen, in which it is insoluble. When the comparative weights of equal bulks of the body and water have been obtained in any of these cases, the rule of three shows the same relation when the density of water is taken as 1. Thus, if the body weigh in air 75 grains, and in water 60 grains, then 75 – 60 or 15 : 75 : : 1 : 5—the body in this case being found to be five times heavier than water.

The specific gravity of gaseous bodies is usually taken in reference to atmospheric air as a standard; sometimes, also, in reference to hydrogen, the lightest known body. It is plain that if a flask capable of containing any definite measure, such as a hundred cubic inches, of air, be weighed carefully when filled with different gases, the relative densities of each will be discovered.

The hydrometer is a convenient instrument for ascertaining the density of liquids. It is a tubular instrument, closed at both ends, and being loaded, for example, with mercury at the lower part, floats upright, while the very slender upper part, of perfectly uniform diameter, rises above the surface of the fluid in which it is immersed. When put into water, it sinks to the beginning of an ascending and descending scale. When put into a heavier fluid, it rises so many degrees in proportion as that fluid is heavier than water. If put into a fluid lighter than water, it sinks so that an ascending scale shows how many degrees that fluid is lighter than water. The instrument is delicate in proportion as that part of the stem to which the scale is attached is more slender and uniform in diameter throughout.

DENTINE.—The substance that forms the body of a tooth, more or less allied to bony substance.

DERMA.—The true skin, *cutis vera*, or *corium*—often incorrectly termed dermis: epidermis, for cuticle or scarf-skin, is correct; but there is no such word as dermis.

DERMATODECTES.—*See* Parasite.

DEXTRINE.—The same as British gum—obtained from starch by heat, or by heat and sulphuric acid. *See* p. 329.

DIAPHRAGM.—The midriff, or muscular partition between the chest and abdomen.

DIARRHŒA.—Looseness of the bowels. It is sometimes produced by certain kinds of food. Thus young green turnip-leaves, in the beginning of winter, often bring both cattle and sheep severely down from their condition acquired at grass; even on cows, while such food augments the yield of milk, it is apt to produce severe looseness. Potatoes often produce scouring in cattle till they have become accustomed to this kind of food. Horses are never so affected by potatoes, and potatoes are not given to sheep.

DIASTALTIC.—Applied to the reflex system of nerves, their effect being produced through the spinal marrow.

DIASTOLE.—Opposed to systole; diastole signifying the dilatation of a cavity of the heart, or of an artery.—*See* Systole.

DICOTYLEDONOUS.—Applied to the great division of plants in which the embryo has two cotyledons; this division coincides with Exogenous Plants.

DUODENUM.—The part of the small intestine between the stomach and jejunum.

EFFERENT.—*See* Afferent and Centrifugal.

EMBRYO.—The early stage of the young mammal in the womb ; the same in the later stages is called fœtus.

ENCEPHALON.—The parts of the nervous system contained within the skull, composed principally of the cerebrum, the cerebellum, the medulla oblongata, and the pons varolii.

ENDOGENOUS.—*See* Monocotyledonous.

ENDOSMOSIS, EXOSMOSIS.—When an organic membrane, or even a porous mineral lamina, is placed between two fluids that differ in density, the less dense fluid passes in large proportion to the side of the membrane in contact with the denser fluid, while a less proportion of the denser fluid passes in the opposite direction, till an equilibrium of density is established. This is osmosis. Endosmosis is the entrance into a vessel on this principle ; exosmosis the opposite.

ENDOSPERM.—*See* Albumen.

ENERGY, CONSERVATION OF ENERGY.—Whatever puts matter before at rest into motion is an energy ; whatever accelerates the motion of matter already in motion is an energy ; whatever stops or retards the motion of matter in motion is an energy. There is never any generation of energy out of nothing ; there is never any loss of energy ; and this last proposition is what is signified when the conservation of energy is spoken of. When two bodies of equal magnitude and equal density are supposed to be moving with equal velocity towards each other in free space in a straight line, so that they must meet, their evident motion is extinguished, and the united mass comes to repose. The amount of mechanical motion which belonged respectively to each is resolved into heat—namely, the invisible movement of the particles of matter composing each of the two masses, and the measure of heat produced, is in a fixed ratio to the sum of the two velocities at the moment of collision.

ENTOZOA.—*See* Parasite.

EPIGLOTTIS.—A leaf-like cartilage which covers the orifice of the larynx in deglutition.

EPITHELIUM.—A term originally applied to the cuticle or scarf-skin, now employed to signify the thin outer covering of membranes in general on their free surface.

ETHYL, HYDRATE OF OXIDE OF.—*See* Alcohol.

EXCRETIONS.—The excretions are those secreted matters which are thrown off from the body as useless or hurtful, the only perfect example of which, as a fluid, is the urine.

EXOGENOUS.—*See* Dicotyledonous.

FALLOPIAN TUBES.—The oviducts, by one of which the ovum passes from the ovary to the uterus.

FAVUS.—*See* Parasite.

FLEA.—*See* Parasite.

FLESH-FORMERS.—*See* Albuminoid.

FŒTUS.—Embryo.

FIBRINE.—A proximate principle of the organic kingdoms of the albuminoid group ; also a proteine compound, a flesh-former in nutrition. *See* p. 306.

FLUORINE, FLUORIDE OF CALCIUM.—A substance believed to be simple, and to be analogous to chlorine, iodine, and bromine. Fluor-spar, commonly called Derbyshire spar, is supposed to consist of fluorine and calcium, being named fluoride of calcium. Fluoride of calcium, in minute proportion, exists in the bones and teeth of mammals.

FUNGUS.—*See* Parasite.

GAD-FLY.—*See* Parasite.

GANGLION.—The ganglia are enlargements in the course of nerves, containing grey nervous substance, supposed to be subordinate nervous centres. The glands of the lymphatic and lacteal systems are sometimes called ganglia.

GASTRO-PULMONARY.—Applied to the mucous membrane that lines the air-passages and the alimentary passages.

GELATINE.—A proximate animal principle, azotised, yet not certainly known to be nutritive : it possibly does not exist in the living body ; hence what represents it in the living body is sometimes called the gelatigenous proximate principle, or that which by boiling affords gelatine. *See* Chondrine ; also, p. 309.

GENITAL ORGANS, CASTRATION, SPAYING.—Castration is the removal of the testicles—that is, of the essential organs of sex in the male ; spaying is the removal of the corresponding organs, or the essential organs of sex, in the female, named the ovaries. The effect of these operations on the animals subjected to them in respect to nutrition, and indeed to the whole character of the individual, is very remarkable. The effect of each operation, especially when performed in early life, is, in general terms, to bring the individual of each sex subjected to it nearer to the natural character of an individual of the opposite sex.

The gelding lays aside the crested neck and unruly disposition of the entire horse, and gains an approach to the form and quiet demeanour of the mare.

But the improvement of the flesh in the animals fed for the table is the most important result of this operation, especially on the male sex. It is in delicacy and flavour that the improvement takes place. Such a change is very striking in the case of the common domestic cock, which, when cooked, is very indifferent fare compared with the luxury of a capon.

A cause of sterility in the male sometimes escapes attention till much time has been lost and cost incurred. It occurs in the stallion, the bull, and the ram ; and what is surprising, it has been at last discovered in some of the most strikingly-formed and best-developed animals, such as judges have pronounced of the most perfect character. It is produced when the testes do not hang freely down within the scrotum, but remain pressed close to the surface of the posterior part of the belly. In short, the testes have not freely escaped from the inguinal canal, and therefore, becoming developed in its lower part, have their function impeded by the pressure to which their vessels are subjected.

The proof of sufficient freedom in the position of the testes is that the hand can grasp the scrotum between the testes and the belly. A very fine four-year-old black stallion obtained the highest prize in Berwickshire, yet on being put to eighty mares, not one of them proved with foal—the testes being too high hung was plainly the cause of his sterility. A pure white short-horned bull carried off the first prize at the Border Union Show at Kelso, yet he never begat a calf ; here also the sterility was shown to arise from the testes being too high hung. A Leicester ram well known to one of us, and of the most promising character, never begat a lamb, and the sterility was at last proved to be in the testes being too high hung.

Genito-Urinary.—Applied to the mucous membrane that lines the urinary and the genital cavities.

Gizzard.—The strong muscular stomach of granivorous birds.

Gland.—A name somewhat vaguely applied to organs that secrete or otherwise prepare matters within the animal body ; it is applied to the liver, to the kidney, to the sweetbread, and to minute bodies composed of cells and nuclei on the surface and in the substance of membranes. The same name is given to the aggregations of ducts and blood-vessels seen in the lymphatic system.

Globuline.—A substance allied to albumen, found in the crystalline lens and in the blood-globules : it is sometimes called crystalline from the former source ; and in the latter source, being combined with hæmatine or colouring matter, it is spoken of as hæmato-globuline.

Glomerules of the Kidney.—The same as the Malpighean corpuscles.

Glottis.—A word somewhat vaguely used to signify the upper narrow part of the larynx, which the epiglottis has the power of closing. In man, the glottis is on a level with the lower part of the arytenoid cartilages : it is bounded laterally by the vocal cords, two on each side ; between the two lower vocal cords, or true vocal ligaments, is the *rima glottidis,* the aperture of the glottis —thus the *rima glottidis* is at the lower part of the glottis.

GLUTEN.—The substance which remains after the separation of the starch from the flour of the cereals. It is a compound principle regarded by some chemists as consisting of fibrine, caseine, and glutine, which last strongly resembles albumen.

GRISTLE.—The same as cartilage.

GULLET.—The same as œsophagus: the canal leading from the pharynx or back part of the mouth to the stomach.

GUM.—A form of arabine of which gum-arabic is an example. *See* p. 330.

GUTS.—The same as intestines.

HÆMADYNAMOMETER.—An instrument for measuring the force of the blood in an artery, by the height to which the column of blood raises a column of mercury in a vertical tube.

HÆMATO-CRYSTALLINE, HÆMATOSINE or HÆMATINE.—The first is a modification of the colouring matter of the blood sometimes found in old extravasations—that is, cavities of the solids in which blood has been deposited; the second is the true colouring principle of the blood.

HÆMATOPINUS.—*See* Parasite.

HIPPOBOSCÆ.—*See* Parasite.

HIPPURIC ACID.—An acid found in the urine of herbivorous animals, as of the horse; also more sparingly in the urine of man. It is an azotised chemical body. *See* p. 311.

HOMOLOGOUS.—*See* Analogous.

HONEYCOMB.—The same as reticulum, bonnet, and king's-hood, the second stomach in ruminants.

HYDROGEN.—The lightest substance known; a simple body, forming water along with oxygen, and existing in the organic frame of plants and animals. *See* p. 296.

ILEUM or ILIUM.—The last part of the small intestines, terminating in the caput cæcum coli.

INGLUVIES.—The same as paunch.

INTEGUMENTS.—The outer coverings of the body: viz., the cuticle or epidermis, and the corium, called also cutis vera, true skin; and derma, improperly dermis; together with the hair, nails, or hoofs, pigmentary matter, sebaceous and sudoriferous glands.

INTESTINES.—The same as the "guts:" the long canal which, under the several successive names—duodenum, jejunum, ilium, cæcum, colon, rectum—leads from the lower orifice of the stomach to the fundament.

JEJUNUM.—The second portion of the small intestines between the duodenum and ilium.

KILOGRAMME, KILOMETRE.—*See* Weights and Measures.

KREATINE, KREATININE ; also CREATINE, CREATININE.—Two crystalline substances, the first having more distinct alkaline qualities than the second, found in the juice of flesh, and also in the urine ; both seem, like urea, to be products of the decomposition of the contractile fibre in the actions of the living body, and are azotised principles. *See* p. 311.

LACHRYMAL.—Of or belonging to the tears.

LARYNX.—*See* Epiglottis.

LICE.—*See* Parasite.

LIEBERKUHN'S GLANDS.—Tubular glands found over the whole internal surface both of small and great intestines.

LIGHTS.—The same as lungs.

LINE.—The twelfth part of an inch in its ordinary acceptation ; but Johnson, in his Dictionary, quotes from Locke that a line is the tenth part of an inch. In this work it is used to express the twelfth part of an inch.

LIQUOR SANGUINIS.—The blood apart from the blood-corpuscles : that is, the blood consists of a vesicular part, or blood-corpuscles, and blood-plasma, or the remaining fluid—*i. e.*, the liquor sanguinis.

LITHIC ACID.—The same as uric acid.

LUNGS.—Called "lights" in common quadrupeds ; highly vascular organs subservient to the change of the blood from venous to arterial, composed of minute cavities into which the air of the atmosphere enters, and having two sets of blood-vessels—namely, the bronchial arteries and veins destined for the nutrition, and pulmonary arteries and veins concerned in the special function of these organs.

MAGGOTS.—*See* Parasite.

MALPIGHI, PYRAMIDS OF ; CAPSULES OF ; CORPUSCLES or GLOMERULES OF.—The pyramids of Malpighi in the kidney are the conical bundles of uriniferous tubes in the medullary substance of the organ which open by their apices into the calyces or cups of the infundibula ; the capsules of Malpighi are flask-shaped sacculi connected with the minute tubuli uriniferi in the cortical substance of the kidney ; the corpuscles of Malpighi belong to the ultimate structure of the kidney, vascular tufts. Each corpuscle is suspended by a short pedicle composed of its artery and vein, and lies within a capsule ; the secretion takes place from the subdivision of the vein, analogous to that of the bile from the twigs of the vena portarum.

MAMMALS.—Animals that suckle their young.

MANGE.—*See* Parasite.

Manyplies.—The same as omasum and psalterium—the third stomach in ruminants.

Margarine, Margaric Acid.—Margarine, one of the proximate principles of oils and fats; margaric acid, the acid produced in the saponification of margarine.

Mastication.—The trituration of the food by the action of the teeth.

Mechanical Equivalent of Heat.—When a pound of water is let fall through the height of 772 feet, it acquires an additional heat of one degree Fahrenheit. The same is true of other bodies falling through the same height. The same is true of any other quantity than a pound. If an ounce of water fall through 772 feet, its temperature rises one degree Fahrenheit. If a ton of water fall through 772 feet, its temperature rises one degree Fahrenheit. This number, then, 772, is the mechanical equivalent of heat on Fahrenheit's scale. But a different number must be used under the centigrade scale. If a chilogramme (kilogramme) of water fall through 772 feet, its temperature will rise one degree Fahrenheit. To discover, then, from what greater height a chilogramme of water must fall to raise its temperature one degree centigrade, the following proportion will suffice:—100 : 180 : : 772 : 1389.6. But 1389 feet are equal to 423 metres; thus the mechanical equivalent of heat, according to the French system, is 423 metres, by falling through which a chilogramme of water rises through one degree centigrade.

Meconium.—The first discharge from the bowels after birth.

Medulla Oblongata.—The prolongation of the spinal marrow upwards within the skull.

Mesentery.—The fold of the peritoneum in which the small intestines hang suspended as in a sling, and between the layers of which are their vessels and nerves.

Mesocephalon.—A name applied to the tuber annulare or pons varolii: the protuberance between the medulla oblongata and the crura cerebri and crura cerebelli within the skull.

Midriff.—*See* Diaphragm.

Mites.—*See* Parasite.

Mitral Valve.—The valve which commands the auriculo-ventricular opening on the left side of the heart.

Monocotyledonous.—Applied to the great division of plants in which the embryo has but one cotyledon; this division coincides with Endogenous Plants.

Mucous Membrane.—The membrane which lines all the cavities of the body that communicate with the external air.

Mucus.—A word rather vaguely used, but chiefly to denote the fluid secreted by the mucous tissue, and abounding in epithelial scales detached therefrom.

Mycelium.—*See* Parasite.

Nævus, Nævi, Mother's Marks.—Spots of various kinds on the surface of the body at birth are called nævi, and, like malformations in general, have been ascribed to the influence of the mother's imagination. It is quite probable that events or circumstances that make a violent impression on the mother's sensibilities during pregnancy may be the immediate cause of malformation in her offspring, because such a state of things may, by disturbing her functions, derange the regular nutrition, and therefore the normal development of her offspring for a time; and such an effect may be the more extensive and remarkable because the embryo of the higher animals is not developed onwards in straight lines, but forms structures of a temporary kind that are to be removed by absorption at fixed epochs, and if not removed at the appointed era, then not at all, but remain monstrosities at birth; whence disturbances of nutrition in the mother at any period of pregnancy, by impairing the energy of fœtal action, may cause either deficiencies or superfluities at birth. But the kind of monstrosity is not determined by the kind of impression made on the mother's sensibilities, but by the period of development through which the embryo is passing at the time the disturbance occurs. If a pregnant woman should witness a criminal broken on the wheel, it is credible enough that she may bring forth an infant marked by some malformation, but not that her infant shall present any close resemblance to the state of the victim of this horrid punishment as she saw him on the wheel.

The kind of connection, however, which exists throughout pregnancy between the mother and the embryo or the fœtus, is very different from that which still continues before the time of conception up to the moment when the ovum is detached from the ovary. It seems not improbable, then, that impressions made on the mother's sensibilities at the time of semination, at which time the ovum may not be detached, may give rise to appearances on the offspring having a connection with the nature of the impressions so made.*

What seems an authentic example of this view occurred in the experience of one of the authors of this treatise. He purchased a five-year-old work mare for the purpose of breeding from. The mare, though still so young, ceased to breed after having had three foals, the cause of which was, that after being covered she immediately threw off the seminal fluid. The next time of covering, on the horse leaving her, he desired a bucketful of water to be thrown quickly under her tail. This had the desired effect of retaining the seminal fluid; but the foal she produced was marked with a patch of darker hair under the tail, like the appearance made by the water upon her mother.

* That there may be a considerable interval between semination and conception, see Matthews Duncan, 'Fecundity, Fertility, and Sterility,' p. 320.

NITROGEN.—The same as azote: a constituent of the atmosphere, amounting to about four-fifths of the whole; contained also in the flesh-forming proximate principles of the food of organic nature. *See* p. 297.

NUCLEUS, NUCLEOLUS.—*See* Cells.

ŒSOPHAGUS.—The gullet.

ŒSTRUS.—*See* Parasite.

OMASUM.—The same as manyplies.

OMNIVOROUS.—Feeding jointly on vegetable and animal food.

OSMAZOME.—This is an extract of meat, or of muscular flesh, which was formerly supposed to give to it, and to the soups made with it, their peculiar flavour. Osmazome has not stood its ground, but has almost dropped out of the list of proximate chemical principles. Nevertheless, as flavour is an all-important quality in the meats derived from the animals fed for the table, it seems proper to retain the name osmazome, and some of the particulars attached to the name, till chemistry brings out something definite in respect to the principles in organic nature on which flavour depends. It seems almost self-evident that every distinct smell or flavour must represent a distinct chemical body; and if this be really the case, how far behind is chemistry in this department, notwithstanding the recent progress made under the head of alcohols and ethers!

There can be no doubt that the food on which an animal is fed imparts its flavour to the flesh; and again, that if an animal has been fed with a particular kind of food just before being slaughtered, its flesh will partake of the flavour of that last food, often in a very high degree.

Several cases, illustrative of this matter, have been communicated to us by a proprietor farmer in Linlithgowshire. He had sold a well-fattened heifer that had been fed exclusively on turnips and straw. He was surprised to hear that some of those who purchased portions of her carcass complained that the meat had the flavour of turnips. He found, on inquiry, that she had been taken away by the butcher and killed immediately after her morning meal—in short, while her stomach was still full of turnips; and on inquiry among those experienced in this matter, he found it to be known that the flesh of a turnip-fed animal would have the flavour of turnips if killed immediately after a meal. On another occasion he was over-persuaded to let a butcher have an under-fed ox, which, owing to the scarcity of turnips, had been fed daily on 10 lb. of linseed-cake, with straw. Those who obtained portions of the carcass complained that the meat had a strong taste of tallow-candles; and he has since learned from the butchers that this is a common complaint against meat obtained from animals largely fed with linseed-cake up to the time of slaughtering them.

He mentions the case of a neighbour of his who, in sowing down a field, used a mixture of grass-seed with some parsley-seed, upon which the mutton obtained from the sheep fed in this field gained the flavour of parsley. On this subject, he calls attention to the fact, that boiled and pulped turnips do not give to the milk and butter of cows fed thereon the same amount of turnip flavour as when consumed raw.

To these cases may be added one in the experience of one of us, where the milk of cows acquired the flavour of almonds, on account of having eaten the prunings of a laurel bay that lay by the road-side. The milk was rather prized for this flavour, but a boy who used much of the milk daily was nearly poisoned.

OSMOSIS.—*See* Endosmosis.

OVALBUMEN.—*See* Albumen.

OVARIES.—*See* Genital Organs.

OXYGEN.—The gaseous constituent of the atmosphere essential to animal life. It makes about one-fifth part of common air, and is one of the constituents of organic structure. *See* p. 292.

PANCREAS.—The sweetbread.

PARASITE, PARASITIC.—Words applying to both plants and animals, that instead of leading an independent existence, live on or in the bodies of plants or of other animals, and draw their substance therefrom. The subject of parasitic existence grows in importance every day. The misletoe (*Viscum album*) is an example of a parasitic plant ; it grows chiefly on apple-trees. *Cuscuta dodder* is a genus of parasitic plants, of which the *Cuscuta epilinum*, flax dodder, is sometimes very injurious to flax crops. Under the name of epiphytes, parasitic vegetable structures of a character most destructive both to living plants and living animals have been observed and described. These epiphytes are of microscopic character, and belong to the lowest order of vegetable existence—namely, to the fungi. By their presence they produce blights in plants, and diseases of the skin and of the mucous membrane in animals. Fungi of this description commit inconceivable ravages under circumstances favourable to their propagation among silk-worms. Tinea or scald-head owes its origin to a fungous growth of this nature. Some forms of tinea can be propagated from horses and oxen to men, by the transmission of the parasite to which it owes its origin. Favus, which is a kindred cutaneous disease, is believed to be propagated to children from cats, dogs, and mice, by means of a fungus which obtains its first development on the mouse. Animals seem to contract such diseases from the human body; and the fungus on which the mange in the cat is dependent, seems to be the same on which tinea depends in man.

Little is yet known of the parasitic fungi that form on mucous membranes, or in the organs covered by mucous or serous membranes; they seem, however, to be secondary in character, and of much less pathological importance than those of the outward surface.

The nature of the alteration produced in man and animals on the outer surface of the body by parasitic fungi is the infiltration or destruction of hairs and epithelial structures by the sporules of the fungus, which, in the progress of their development uniting, grow into a branched mycelium.

There is reason to think that the number of species of fungi capable of this kind of existence is extremely limited.

There must be some peculiar condition of nutrition which disposes a plant or animal to become the abode of such fungi—some failure in the vital power of the parts of the organic tissue affected, so that they cannot any longer carry on efficiently the processes of life, whence, like dead organic matter, they become a prey to new though inferior living organisms.

Such a notice as this must confine itself to partial views of the whole subject of parasitic organisms. The mites or *acari* which connect themselves with certain states of the surface in living animals should not be passed by. From an early period it had been suspected, and is now fully settled, that itch in the human body depends on the presence of an *acarus* or mite, named now the *Sarcoptes scabiei humana.* Different species of *Sarcoptes* have been described; thus there is a *Sarcoptes equi*, a *Sarcoptes suis*, a *Sarcoptes canis.* The *Sarcoptes* from the human body do not live on other animals in general; the *Sarcoptes equi* may live on man, developing the form of mange observed in the horse. Parasites that do not penetrate the skin, but simply hold on by it, have been named *Dermatodectes;* and those which only pierce the cuticle in search of nourishment have been called *Symbiotes.* The *Dermatodectes equi* cannot live except on the horse; and the *Symbiotes equi* cannot induce the same disease as in the horse, in either the ox, sheep, pig, or dog. Mange is less common in the ox than in the horse, yet two distinct parasites are described in the ox, one belonging to the genus *Dermatodectes,* the other to the genus *Symbiotes.*

The parasite on which scab in sheep depends is not an *Acarus* or *Sarcoptes,* as is usually said, but a *Dermatodectes*—that is to say, it does not pierce the skin or burrow in the skin.

The mange of the pig, however, is due to a *Sarcoptes.* It appears that the mange of pigs may be communicated to man; but it is not certain that the *Sarcoptes suis* can live on the horse, ox, sheep, or dog.

The mange in dogs depends on a *Sarcoptes;* it may live for a while on the human body, but after three or four weeks spontaneously becomes extinct.

No management of the health in animals will save them from scab and mange if contact with affected animals be permitted ; nothing but the effectual separation of the diseased from the healthy can be of any avail.

Maggots—for example, those of the large blow-fly (*Musca vomitoria* or *Sarcophaga carnaria*), from which sheep often suffer so dreadfully—are not properly parasites ; even men are not exempt from the attacks of such maggots.

Lice, however, are unquestionably within the description of parasites. Some naturalists have bestowed much attention on this subject, and they have been carefully reduced to orders, sub-orders, families, genera, and species. It will be enough, however, to refer to some of the best-known genera and species. *Hæmatopinus* is a large genus, in which the louse of the ox, the calf, the pig, and the dog are found. A species of the same genus frequents the skin of the ass, and the same is sometimes found on the horse. The *Hæmatopinus vituli* is said never to be found on the ox. The *Hæmatopinus canis* is not of common occurrence, but is said to be found also on the ferret.

Trichodectes is another genus in which parasites commonly known as lice affect some of the animals of the farm.

Trichodectes equi, louse of the horse, is common both on the horse and ass, especially when fresh from pasture.

Trichodectes scalaris, louse of the ox, is common on cattle, especially on the mane. It is sometimes found also on the ass.

Trichodectes sphærocephalus, the louse of the sheep, has an orbicular head.

Trichodectes latus, the louse of the dog, is more especially common on puppies.

The common flea (*Pulex irritans*) is but approximatively a parasite. It frequents the skins of animals in general, but does not breed there. One of the best remedies is the Persian insect-powder, obtained from the *Pyrethrum roseum*, and sold in india-rubber balls.

The gad-fly (*Œstrus bovinus*) has called forth long dissertations. It attacks the ox, the cow, the horse, and even human beings.

Ticks are found on the skins of horses, cattle, sheep, and dogs.

The *Hippoboscæ* must be distinguished from ticks. The *Hippoboscæ* live exclusively on quadrupeds and birds. The ass suffers much more from them than the horse. They abound most on white and light-coloured horses. Several allied genera occur in this country, and are found on various birds. The *Craterina hirundinis* deposits its eggs like a cocoon in the nest of the swallow.

Metophagus ovinus attacks the sheep ; it is commonly called sheep-louse.

Phthiriasis equi, poultry-lousiness in the horse. Under this name has been described a most tormenting malady in the horse, originating, as it would seem, from the vicinity of an ill-kept hen-house to the stable.*

For the *Entozoa*, or internal parasites, we must refer to the special treatises on such subjects.

PAUNCH.—The same as rumen and ingluvies : the first stomach in ruminants.

PELVIS.—A basin : applied, in the skeleton, to the bones forming the framework with which the thigh-bones are articulated ; in the kidney, to the expansion of the ureter within the body of the organ.

PEPSINE.—An albuminoid body present in the gastric juice, held to act an important part, along with free acid of the stomach, in digestion. It has the character of a ferment.

PEPTIC CELLS, PEPTIC GLANDS.—The peptic glands are the tubular depressions in the inner surface of the stomach, forming a columnar structure at right angles to the lining ; the peptic cells are minute cells or corpuscles contained in the depressions in various stages of development, concerned in the secretion of the peculiar gastric fluid.

PEPTONE.—The same as albuminose : a low form of albumen, into which the nutritive principles are conceived to be first converted in the process of assimilation.

PERISPERM.—*See* Albumen.

PERISTALTIC ACTION.—The movement of the bowels by which their contents are propelled onwards.

PEYER'S GLANDS.—Glands occurring exclusively in the small intestines either solitary or agminated, the latter being named Peyer's patches. These glands contain a minute sacculus, but have no discoverable opening.

PHARYNX.—The funnel-shaped muscular bag at the back part of the throat from which the gullet descends to the stomach.

PHOSPHORIC ACID.—Phosphoric acid consists of phosphorus and oxygen, and when free from water is called phosphoric anhydride. It combines with water in three proportions, and each compound obtains a distinct name : the protohydrate of phosphoric acid being named pyrophosphoric acid—the deutohydrate, metaphosphoric acid—and the tritohydrate, tribasic phosphoric acid ; the last forms the phosphates met with in organic nature. *See* p. 301.

PHOSPHORUS.—A simple non-metallic combustible largely present

* We are indebted for much that is said above to Gamgee, 'Our Domestic Animals in Health and Disease.'

under the combined state in the animal body. It exists in plants; these draw it from the soil, into which it passes by the disintegration of rocks constituting part of the crust of the earth. *See* p. 300.

Plastic Food.—The same as flesh-forming.

Pollen.—To the pollen of the rye-grass, when abundant in windy weather, is ascribed a very severe form of *ophthalmia* in sheep—so severe, that in seasons when the cause operates at a maximum, the sheep affected seldom recover their sight.

Poultry-lousiness in the Horse.—*See* Parasite.

Primæ Viæ.—*The first passages*, or the alimentary canal from the mouth to the fundament.

Proteine.—The common proximate principle supposed to represent fibrine, albumen, and caseine. *See* p. 308.

Psalterium.—The same as manyplies.

Pulex.—*See* Parasite.

Pulmonary Cells.—*See* Air-Cells.

Rectified Spirit.—*See* Alcohol.

Red.—Reed or reid, the rennet or abomasum, the fourth or proper stomach in ruminants.

Reflex Acts.—Acts performed by the spinal cord without the intervention of volition, but which for the most part may be either directly or indirectly controlled or modified by volition.

Respiratory Food.—The same as non-azotised food and calefacient or calorific food.

Rumen.—The first of the four stomachs in the ox and sheep, called also the paunch and ingluvies.

Rumination.—The same as the chewing of the cud; the act of masticating and insalivating the food a second time, after it has been brought up into the mouth from the first and second stomachs.

Saccharine Food.—Food consisting of some form of sugar, or capable of being changed into sugar.

Salivary.—Of or belonging to saliva or spittle.

Sanguification.—The production and continual repair of the blood—that is, both of the vesicular portion or blood-corpuscles, and of the blood-plasma or liquor sanguinis. Into the blood-corpuscles or red particles, the chyle-corpuscles and the lymph-corpuscles derived from the glands of the absorbent system, formerly termed conglobate, become gradually developed. The fibrine and albumen of the blood-plasma are derived from the albuminose into which the proteine compounds of the aliment are changed in the alimentary canal and in the process of absorption by the villi of the intestines. It is certain the red corpuscles have no power of reproduction; perhaps they elaborate some material for the blood-plasma—

perhaps they nourish the blood-plasma by their decay; certainly they grow at the cost of the plasma.

SARCOLEMMA.—The structureless membrane enclosing the primitive fibrils of a muscle.

SCAB.—*See* Parasite.

SCARF-SKIN.—*See* Derma.

SEBACEOUS GLANDS.—Glands of the skin, composed of an aggregate of small vesicles filled with opaque white substance like soft ointment.

SECRETION.—A word used in several different significations. In its largest sense it denotes the separation of any material from the blood, for whatever purpose or by whatever apparatus. When contrasted with excretion, it signifies the separation of fluids of some definite use within the body, while excretion signifies the separation of something that would prove hurtful if retained. In this contrasted sense the pancreatic juice is a secretion, the urine an excretion. If material be ever separated from the blood directly by blood-vessels, in which sense exhalation was formerly used, then secretion, contrasted with exhalation, denotes separation from the blood by glands or a glandular apparatus.

SEMILUNAR VALVES.—The valves in the orifice of the aorta and pulmonary artery by which the blood is prevented from returning into the ventricle during its diastole.

SENSATION.—The state of consciousness that succeeds impressions made on the peripheral extremities of certain nerves.

SENSIBILITY.—The property of transmitting impressions to the nervous centre, so that a sensation may be excited. The sensibility of a tissue depends on the presence of filaments of nerves of sense in that tissue. In short, when a texture or part is said to possess sensibility, it is the local seat of such sensations as belong to the nerves, the filaments of which are therein diffused. It is in the sensibility of such parts or textures that matter and spirit come into union and communication. Thus, though sensations are states of consciousness—that is, conditions of spirit—yet they have a local seat in every instance. The sensibility of the membrane of the nose to odours depends on the presence of filaments of the olfactory nerves spread therein. That the brain is the fountain of the sensation of smell, like that of all other sensations, is indeed an inference of physiology, but that the membrane of the nose is the seat of the sensation of smell, in the ordinary apprehension of every individual, is a primitive fact, independent of all speculation. And the same thing is true of all other sensations. When the point of a needle touches a spot on the surface of the skin, the impression the needle makes is felt in that spot; and yet physiology makes it certain that there is another spot in the brain or nervous centre, by communication with which alone that spot of the skin is made capable of feeling the impression of the needle, and discovering the relation in position which itself has to the adjacent parts of the skin. Were a bayonet struck forcibly into the skin instead of a fine needle, the perception of the position of the spot struck would be much less distinct. The indefiniteness of the perceptions attendant on violent impressions upon the extremities of sentient nerves, depends on the number of nervous filaments, and their corresponding terminations on the nervous centre, simultaneously affected, both directly and indirectly—that is, by what is called the radiation of sensation, by which sensations arise in parts not in close proximity with that immediately under impression. It is, as it would seem, by a mere extension of the same kind of effect that very intense impressions give a shock to the whole nervous system, and thereby to the whole of the vital organs, so that not only insensibility or fainting, but even death, may occur in a moment. From a sudden blow on the pit of the stomach, instant death has been often known to take place in the pugilistic prize-ring. Opposite to the pit of the stomach, a part that readily yields to sudden force, many nerves congregate. Here, indeed, the trunk is at its shallowest, and the fist of the pugilist may bury itself in his antagonist's body deeper than at any other part where blows in such encounters are dealt. It is within the experience of one of us, that a smart blow on the snout, where the nerves of sense are very numerous, proves instantly fatal to a good-sized pig ; and it is well known that a horse is sometimes instantly killed by a sudden blow on the cantel—that is, before the ears—with the butt-end of a heavy hunting-whip.

SERALBUMEN.—*See* Albumen.

SHEEP-LOUSE.—*See* Parasite.

SIGMOID VALVES.—The same as the semilunar.

SILICIC ACID.—The earth silica.

SILICON or SILICIUM.—One of the most abundant substances in mineral nature ; the basis of flint and of many mineral substances ; in small proportion both in plants and animals. *See* p. 302.

SPAYING.—*See* Genital Organs.

SPECIAL SENSE, is such a sense as that of sight or hearing, as distinguished from general sensibility of the skin and other tissues.

SPHINCTER MUSCLES.—Muscular fibres, the ordinary state of which is contraction, being designed to guard the orifices of such cavities as the rectum.

SPIRIT OF WINE.—*See* Alcohol.

SPORULES.—*See* Parasite.

STARCH.—A non-azotised proximate principle of the vegetable kingdom ; one of the heat and fat giving principles of food ; the same as amylum and fecula. *See* p. 320.

STIMULI.—The agents in the stimulation, for example, of the muscular fibres to contraction. These are sometimes reduced to such orders as, 1, mechanical; 2, chemical; 3, electrical; and, 4, mental.

STOMACH.—The same as *ventriculus* in Latin, and as γαστηρ in Greek; the proper stomach, having its cardiac, or higher orifice, in the gullet, and its lower orifice in the duodenum; the organ in which chyme is formed by the gastric juice.

STRIPED AND UNSTRIPED MUSCULAR FIBRES.—The striped muscular fibres correspond with the fibres of the voluntary muscles; the unstriped with the involuntary muscular fibres, with the exception of the heart, the fibres of which are striped. The stripes are transverse.

SUDORIPAROUS GLANDS.—Glands existing everywhere in the skin, but particularly in the palms of the hands and soles of the feet, composed of a lobular mass apparently formed of a coil of tubular gland-duct, surrounded by blood-vessels, and imbedded in the cutaneous adipose tissue.

SULPHUR.—A non-metallic simple combustible, existing largely in mineral nature, chiefly in combination with metals; entering also into the constitution of plants and animals. *See* p. 299.

SULPHURIC ACID.—One of the most powerful of the acids, consisting of sulphur and oxygen (SO^3). The salts which it forms are called sulphates. The sulphates found in the animal body are the sulphate of potash, the sulphate of soda, the sulphate of ammonia, the sulphate of lime.

SUPERFŒTATION.—The supposed conception of a new embryo in a female that has already conceived. Its possibility has often been denied; and, indeed, except at a very early period, it is impossible.

The following case occurred to one of the authors of this treatise:—He had a greyhound bitch, all white, from which he wished to breed when in season, and accordingly procured a well-bred dog, all fawn, with which the greyhound was shut up for a fortnight. After which, the greyhound's period being, as he thought, over, he sent away the dog. Nevertheless the greyhound admitted, the day after, the embrace of a smooth-haired pointer, white, with large patches of black, which had long been her companion. In due time the greyhound brought forth two pups—one a pure-breed fawn-coloured greyhound bitch, the other an apparently pure-breed rough setter white and black bitch. The latter, it could not be doubted, was the progeny of the pointer dog, as the former was no less certainly that of the greyhound dog. The exact parentage of the pointer was unknown.

SYMBIOTES.—*See* Parasite.

SYMMETRY, SYMMETRICAL.—Terms in physiology most commonly applied to the organs or parts which are double, one situated correspondingly on each side of the plane dividing the body vertically into two equal portions: thus the right eye is symmetrical with the left eye, the right ear with the left ear, the right temporal muscle with the left temporal muscle. There are also non-symmetrical organs: thus the liver and the stomach extend to the right and left of the mesian plane, yet in both organs the part on the right does not correspond in figure to the part on the left. On a more close inspection it is found that the organs concerned in sense and locomotion, or in the functions of relation, are double and symmetrical on each side of the mesian plane, whereas the organs concerned in assimilation, and even those concerned in reproduction, are non-symmetrical, notwithstanding that the organs of reproduction are double, and that even a few of the organs of assimilation, though double, are non-symmetrical. The organs of circulation, of respiration, of digestion, are in the highest degree non-symmetrical on the opposite sides of the body. The left kidney is not exactly symmetrical, either in figure or position, with the left; the testes are not exactly symmetrical, nor are the reproductive organs in the female exactly symmetrical.

The term symmetry is used also in another signification—namely, to denote that kind of appropriate relation in size, figure, and position between the several parts of the external figure which constitute form or beauty in the species, variety, or individual. The appreciation of this quality, or combination of qualities, is of the greatest importance in the choice of the animals that are to be maintained to breed from. For, however inexplicable it may be, it is certain that all the most prized qualities in the horse, the ox, the sheep, the hog, the dog, and even in poultry, are most readily developed by careful feeding and training in those individuals in which such relations of symmetry are conspicuous, even when the parts themselves concerned in the symmetry have no immediate connection with the qualities in question. In the cultivation of this symmetry, some points of form, good or bad, often descend, after long interruption, from distant ancestors. No unsymmetrical animal should be allowed, even for once, to take part in the parentage; and not even a male of undesirable form should be permitted to beget offspring at any time on a female of the race, because it sometimes happens that the influence of such an undesirable sire extends beyond his own immediate progeny to the subsequent offspring of the female.

SYMPATHETIC NERVE, or the sympathetic system of nerves, also termed the ganglionic system of nerves and the nervous system of organic life.

SYNOVIAL FLUID or SYNOVIA.—The fluid contained in the cavities of the joints and in the bursal cavities.—*See* Bursæ Mucosæ.

SYSTEMIC CIRCULATION.—The circulation of the blood over the body at large, as distinguished from the circulation through the pulmonary artery and pulmonary vein, which last is subservient to respiration.

SYSTOLE.—Opposed to diastole, systole signifying the contraction of the cavity of the heart or of an artery.—*See* Diastole.

TAPE-WORM.—*See* Parasite.

TEMPORARY GLANDS.—Glands consisting of a sacculus, containing cells and nuclei, which, having elaborated materials within their cavities, discharge them by the absorption or dehiscence of their walls, and then disappear.

TESSELATED EPITHELIUM.—The same as pavement epithelium,—that spread over the mouth, pharynx, and œsophagus, the conjunctiva of the eye, the vagina, and entrance of the female urethra, &c., being the most common variety of epithelium.

THERMOMETER.—The scale in Fahrenheit's thermometer, between the freezing point and the boiling point of water, has 180°; the scale in the centigrade has 100° between the same two points—whence the degree in the centigrade is to the Fahrenheit degree in length as 180° to 100°. But in comparing a temperature measured by Fahrenheit with a temperature measured by a centigrade, 32° must be deducted from the number in the Fahrenheit notation, because the zero of Fahrenheit begins at the temperature produced by a mixture of snow and salt 32° below the temperature of freezing water. Thus the temperature of the human body is 100° Fahrenheit: to find the corresponding temperature centigrade, $100 - 32 = 68°$. But the degree centigrade being longer than the degree Fahrenheit in the ratio 180 : 100, expresses a greater amount of heat.

$$180 : 100 :: 68 : 37.75.$$

The following formulæ are also used to convert Fahrenheit into centigrade, and *vice versa* :—

FAHRENHEIT TO CENTIGRADE.

$$\tfrac{5}{9}\ F.° - 32° = C.°$$

$$\tfrac{9}{5}\ C.° + 32° = F.°$$

Thus for animal temperature—

$$F.°\ 100. \quad 100° - 32° = 68°$$

$$\frac{68}{9} = 7.55, \text{ but } 7.55 \times 5 = 37.75.$$

$$C.°\ 37.77. \quad \frac{37.77}{5} = 7.55$$

$$7.55 \times 9 = 67.95;\ 67.95 + 32 = 99.95.$$

THORAX.—*See* Abdomen.

TICKS.—*See* Parasite.

TINEA.—*See* Parasite.

TISSUES.—The more or less compound solids out of which the organs and parts of the living body are constructed.

TRACHEA.—The windpipe.

TRICHODECTES.—*See* Parasite.

TRICUSPID VALVE.—The valve commanding the auriculo-ventricular orifice on the right side of the heart.

TYMPANUM, MEMBRANA TYMPANI, TYMPANIC CAVITY.—The drum of the ear in which the bones of the ear are lodged. Membrana tympani, the membrane which divides the drum of the ear from the external passage of sound.

UNITS OF HEAT.—A mode of speaking devised to facilitate the expression of the amount of heat developed in the combustion of given quantities of combustible bodies in oxygen, chlorine, and other supporters of combustion. A unit of heat, though at first sight it seems not to be an absolutely definite quantity, yet is really definite, in which it differs from a degree of heat; for the amount of heat that constitutes a degree depends not merely on the scale of the thermometer used, but in a very great degree on the amount of mercury or spirit contained in the bulb and stem. A unit of heat is the quantity that raises an ounce of water one degree Fahrenheit, or a gramme of water one degree centigrade. Its quantity then, like that of a degree, is not positive but relative to the amount of water which it can raise one degree on the scale employed. An ounce of carbon, by being burnt in oxygen, produces 14,200 units of heat—that is, as much heat as can raise 14,200 ounces of water through one degree Fahrenheit. It is plain, then, that in this statement a unit of heat signifies the quantity required to raise one ounce of water one degree Fahrenheit. Again, a gramme of carbon, by being burnt in oxygen, produces 8080 units of heat—that is, as much heat as can raise 8080 grammes of water through one degree centigrade.

But it is manifest that a unit of heat is a definite quantity, because the amount of it is the heat required to raise a definite quantity of water through a fixed range of temperature. The modes of expression differ, but the quantities are unalterable.

UREA.—The principal organic constituent of the urine. *See* p. 310.

URETER.—The name of the canal by which the urine is conveyed from each kidney to the posterior part of the bladder.

URETHRA.—The canal by which the urine issues from the bladder, passing in the male through the yard or penis, and in the female ending at the lower part of the orifice of the vagina or passage leading from without to the uterus or womb.

URIC ACID.—An organic acid of the urine—the same as lithic acid, but quite distinct from urea. It is an azotised chemical substance. *See* p. 311.

VAGUS NERVE or PAR VAGUM.—The eighth pair of cranial nerves.

VALVULÆ CONNIVENTES.—Transverse folds of the mucous membrane of the small intestines, by which the extent of its surface is very much increased. They extend in man from the duodenum to the middle of the ilium. They are much less conspicuous in other animals.

VASCULAR GLANDS.—Ductless glands which abstract material from the blood as it circulates through them, and then restore the elaborated matter to the blood within their own boundary, or to the lymphatic vessels that issue from them.

VENA PORTÆ or VENA PORTARUM.—The vein which enters the liver and is distributed like an artery. It is a trunk formed from all the veins that correspond to the cœliac axis—the superior mesenteric and inferior mesenteric arteries, even the hepatic artery, finally communicating its blood to the minute branches of the vena portarum within the liver.

VILLI OF INTESTINES.—Minute vascular processes of mucous membrane, each containing a delicate network of blood-vessels and one or more lacteals, by means of which the chyle is conveyed from the small intestines into the lacteal system.

VOCAL CORDS.—*See* Glottis.

WEIGHTS AND MEASURES.—The standard of weight used in this country is the avoirdupois pound, which contains 7000 grains. In this pound there are sixteen ounces, so that each ounce contains 437.5 grains. In an imperial gallon there are 70,000 grains of distilled water; that is to say, 10 lb. avoirdupois. A cubic inch of distilled water contains 252.456 grains at 62° Fahr. with the barometer at 30 in.; in vacuo, at the same temperature, the weight is 252.722 grains. In an imperial gallon there are 277.276 cubic inches.

It is hardly possible at present to dispense with a knowledge of the modern French system of weights and measures.

The measures of length stand first in the French system, and of these measures the metre may be called the basis. The metre exceeds the English yard by nearly three inches and a-half, being equal to 39.37079 English inches. It is a little more than the fifth part of an inch longer than a pendulum which beats seconds in vacuo at the level of the sea in the latitude of Greenwich. Forty millions of metres make a great meridional circle of the globe. The metre is divided into tenths, hundredths, and thousandth parts, termed respectively decimetres, centimetres, and millimetres. A millimetre is nearly the 25th part of an English inch, or nearly half an English line ; a centimetre is nearly 2-5ths of an English inch. A thousand metres is called a kilometre, better in English a chilometre, though the first form of the word is still the most common. A chilometre is nearly 2-3ds of an English mile.

A cubic decimetre is the basis of the French measures of capacity. The decimetre is equal to 3.937 English inches ; and here it may be remarked how easily the French system admits of division by decimal points. Thus a metre is 39.37. This number expresses the decimetre in English inches, by moving the decimal point to the left, thus, from 39.37 to 3.937 ; and the decimetre, 3.937, in English inches, becomes the centimetre in English inches by moving the decimal point still farther to the left : thus, the decimetre, 3.937 in English inches, becomes .3937 the centimetre ; and the millimetre is got out of the centimetre by another like movement of the decimal point ; thus, 0.03937. But to return from this digression, the cubic decimetre is termed a litre, and contains rather more than one and three-quarters of an imperial pint. The litre is subdivided into tenths or decilitres, hundredths or centilitres. A cubic decimetre or litre of distilled water weighs a gramme, and this gramme is the basis of the French weights. The definition of a gramme, then, is the weight of a cubic decimetre of distilled water. It weighs 15.432 English grains ; that is, it is nearly the fourth part of a drachm in troy and apothecaries' weight. The gramme is subdivided into tenths or decigrammes, hundredths or centigrammes, and thousandths or milligrammes. In the ascending scale a thousand grammes is called a kilogramme or chilogramme. The chilogramme is something less than $2\frac{1}{4}$ lb. imperial, or consists of 15432.3 English grains. The chilogramme is the commercial unit of weight in France, as the gramme is the basis of scientific weights. The gramme now begins to be written gram in English, to which there seems to be no reasonable objection, and even kilogramme is written chilogram.

WHITE CORPUSCLES or LYMPH-CORPUSCLES.—The white corpuscles of the blood are held to be the same as the lymph-corpuscles of the lymphatic vessels and the chyle-corpuscles of the higher lacteal trunks, being produced in the conglobate glands and forming the germ of the future red corpuscles.

WHITE SUBSTANCE OF NERVE FIBRE.—The medullary or white substance of Schwann, the outer white part of the nerve tubule within which is contained the axis cylinder, the same as the primitive band of Remak.

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