# NATURE'S HYGIENE

## A SYSTEMATIC MANUAL OF NATURAL HYGIENE

KINGZETT

*FOURTH EDITION*

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## A Systematic Manual of Natural Hygiene

CONTAINING ALSO A DETAILED ACCOUNT OF

*THE CHEMISTRY AND HYGIENE OF EUCALYPTUS,*
*PINE, AND CAMPHOR FORESTS,*
*AND INDUSTRIES CONNECTED THEREWITH.*

BY

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FOURTH EDITION.

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# ERRATUM.

Page 291, line 7, *for* ' to Lister ' *read* ' by Lister.'

# PREFACE TO THE FOURTH EDITION.

THE third edition of this work has been out of print for some time, and I have at last yielded to the pressure of friends to bring out a new one, which will, I hope, be found to give a comprehensive, if brief, description of the various important subjects with which it deals.

The work has been carefully revised, and I have added a chapter on some new developments of bacteriological science (in relation to the subjects of Phagocytosis and Immunity), and also a chapter on Alimentation and Foods. My assistant, Mr. D. Homfray, B.Sc., has rendered me considerable help in the preparation of the last-mentioned chapter and in revising some of the other sheets.

The results of my further investigation of the chemistry of the aerial oxidation of Turpentines and other Essential Oils are also embodied.

It will be seen that the book has gradually grown from a series of scientific essays into a systematic treatise on Hygiene.

I take this further opportunity of emphasising the importance of allocating to skilled chemists, some of the duties which are at present entrusted to medical officers of health and engineers. The organisation of the Institute of Chemistry has done much towards qualifying the present-day chemists to effectively deal with many matters concerning public health; and the possession of the Fellowship of that Institute may be accepted by the public, as sufficient guarantee of the ability of its holders to satisfactorily discharge such duties as I have referred to in the prefaces to previous editions of this work.

It is satisfactory to me to note that, in the interval which has elapsed since the third edition of 'Nature's Hygiene' was published, bacteriological research has made still more apparent the fact that micro-organisms are connected with the production of disease (as I have always contended) only by reason of the chemical products to which they give rise under certain specific conditions. Much of the bacteriological work at present in vogue is practically worthless, and I am convinced that no further material advancement of knowledge can take place in this direction until the chemistry of the subject has been explored in a thorough manner, and conducted side by side with properly-designed physiological experiments.

C. T. KINGZETT.

ELMSTEAD KNOLL,
CHISLEHURST, KENT,
*March*, 1894.

# PREFACE TO THE THIRD EDITION.

IN preparing this further edition of 'Nature's Hygiene,' I have carefully revised the whole work, with the view of bringing it into thorough accord with existing information of the subjects which are dealt with therein; and I have added an account of my own recent investigations concerning the comparative action of a number of antiseptics, the precise chemical history of various fermentative and digestive processes, the chemistry of Camphor Oil and Russian Turpentine, and some other subjects.

The account of Camphor Forests and the collection of Camphor Oil and its uses, is a new feature of the work; and in addition to enlarging most of the chapters, so that they deal more comprehensively with all aspects of Nature's Hygiene, I have throughout the book endeavoured, as opportunity offered, to clearly indicate the precise relations, as cause and effect, which are now known to exist between micro-organic life and so-called infectious or contagious diseases. In this connection, it is gratifying to be able to record the fact that by the investigations of later years it has been well established that micro-organisms do not produce disease in any direct manner or by their mere mechanical presence in or upon the body, but that the real poisons are of the nature of chemical (toxic) products which result from changes in the media in which the microbes develop and upon which they grow and multiply. This view I have for many years past persistently and consistently advocated, although it received little credence until quite lately.

In conclusion, I renew the expression of my opinion, that chemical officers are urgently needed to act side by side with medical officers of health and engineers, to effectively deal with the many important matters affecting public health and the rating of the community at large, which were referred to in the preface to the second edition of this book. While the development of chemical science in recent years has been most marked, sanitary authorities have not sufficiently availed themselves of its services, but have relied much too confidently upon mere engineering skill. The disposal of the London Sewage as at present effected will serve to exemplify my meaning, and may be taken by way of illustrating the disastrous results that may ensue from such an unfortunate reliance. The water-carriage system of sewage has grown in London from a blessing into an unmitigated and terribly costly evil.

C. T. KINGZETT.

*March*, 1888.

# PREFACE TO THE SECOND EDITION.

DURING the four years that have elapsed since the first edition of this work was issued, so much attention has been paid to sanitary matters, that I have found it necessary to rewrite the greater part of it, and to add several new chapters dealing with Water Supply, Sewage, Infectious Diseases, and the Treatment of the Sick. At the same time I have given even more attention than in the first edition, to the process of oxidation as carried on in nature ; and I think the book will be found to contain an accurate account of present knowledge concerning the relations of micro-organisms to disease. All matter relating to the chemistry and hygiene of the eucalyptus and the pine has been retained ; but it has been found desirable to divide the work into two parts, one dealing in particular with this subject (which has been my special study), and the other with the general principles of natural hygiene.

I take this opportunity of expressing my opinion that great public benefit would result from the appointment of chemical officers to act in conjunction with medical officers of health. It is notorious that medical men and engineers are not qualified, by their special education and training, to deal with many questions which are of the greatest importance to public health and wealth ; and I entertain a strong conviction that by the appointment of efficient chemists as officers to act under Sanitary Authorities and Local Boards, a saving would be effected to ratepayers generally. Chemical officers, if appointed in accordance with my suggestion, should do the work at present conducted by public analysts, and to them should be referred all matters in connection with water supply, gas supply, and the disposal and utilisation of sewage and refuse. In order to obtain the services of efficient chemists, it would, of course, be essential to offer adequate remuneration for the duties that would be imposed upon them. I beg to commend this suggestion to the earnest attention of my readers, and to Members of Parliament in particular.

In conclusion, I hope this new edition of my book will prove useful to many.

CHARLES T. KINGZETT.

*December*, 1884.

# PREFACE TO THE FIRST EDITION.

OF the many scientific subjects which, during recent years, have strongly arrested the attention of the public, few have excited more interest than that which has been manifested, from time to time, regarding the reputed sanitary properties of the eucalyptus-tree.

But while this interest extended even to several European and other Governments, and although the hygienic value of the eucalyptus is based upon an abundant and increasing amount of evidence, yet no satisfactory explanation of this influence has ever been presented to the public.

During some years I have spent much time in the study of what are known to chemists as processes of slow oxidation, and have communicated the results of my researches to various scientific societies. These investigations, conducted, so to say, in the laboratory of Nature, furnished a full and sufficient explanation of the sanitary properties of the eucalyptus-tree, and they also proved that the pine-tree exhibits characters of the same important order.

In bringing this work, therefore, before the public, I am really endeavouring to place before them a scientific research in a popular manner. In so doing, however, I have not merely described my own experiments, but have also given particulars of those of all others who have worked upon the subject, and have incorporated the results in a number of chapters, which deal with a variety of questions more or less intimately concerned with Nature's Hygiene.

Each chapter will be found to form a complete essay in itself, and thus the book combines the features of a continuous study of some processes of Nature's chemistry and hygiene, and of a series of articles on scientific subjects.

Wherever an educated public is to be found, there must also exist a demand for popular scientific literature; and it is towards feeding such a demand that I have ventured to contribute this work, trusting it may not be received altogether without favour.

CHARLES T. KINGZETT.

*March* 31*st*, 1880.

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# NATURE'S HYGIENE.

## *PART I.*

## CHAPTER I.

INTRODUCTORY — CONSTITUTION OF MATTER — CHEMICAL ELEMENTS—CHEMICAL COMPOUNDS—LAW OF COMBINING PROPORTIONS — SYNTHESIS AND DECOMPOSITION — VALENCY — SYMBOLS — FORMULÆ — REACTIONS AND EQUATIONS—LAW OF GASEOUS VOLUMES.

THE processes which are concerned in the study of hygiene are, to a very large extent, chemical in essence, consequently there will be frequent references in the following pages to chemical principles and chemical changes, thus rendering it desirable that readers should be prepared in the onset to understand such matters as they arise.

By the science of chemistry it has been ascertained that our globe — comprising all substances that are found in it and upon it, whether entering into the composition of minerals, vegetables, or animals—is built up of a number of principles (termed elements), and of compounds resulting from their chemical combination. The word 'element' is employed to represent a substance which cannot undergo change of nature, and which cannot therefore be resolved into two or more distinct bodies. Whether elements are really ultimate and absolutely distinct is not known. It may be that means will yet be found by which chemists will be enabled to decompose them into more simple principles, or it may also be that they are really identical in substance—that they are, in fact, composed of primordial matter (*Protyle*), and only differ in properties according to the various conditions under which they are revealed to us as so-called elements. Personally I am strongly inclined to the last-named view,* which is now entertained by many eminent men, and I have advocated it for some years. Quite lately, what may be regarded as some evidence of its correctness has been furnished by Mr. Crookes,† who has found that by starting with a substance hitherto believed by chemists to be homogeneous—for example, the rare earth *ytria*—he has succeeded by a long series of fractional precipitations in obtaining products which yield different phosphorescent spectra. This seems to indicate that the material with which he started, although elemental in the ordinary sense of that word as used by chemists, may yet be made to yield a number of different substances which it is difficult to separate from each other. Much more might be added in favour of the view that the ultimate character of the so-called

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* See *Chemical News*, vol. xxiv., p. 131; vol. xxvi., pp. 138 and 202; vol. xxviii., p. 288.

† *Ibid.*, vol. lv., pp. 83 and 95.

'elements' is not persistent, but that they represent uniform matter revealed under differing combinations of the forces to which they are subjected in nature.

The elemental state, as hitherto represented by chemists, may be illustrated by figures. Just as numbers are composed of units, so are chemical compounds composed of elements; and in the same sense that a numerical unit cannot be divided, so also the chemical units or elements are indivisible. From metallic lead, nothing but metallic lead can be extracted; from gold, nothing but gold can be obtained, and so on.

There are three well-defined *states* of matter, not different in essence, but dependent upon pressure and temperature. To illustrate this fact we may refer to the elemental metal called mercury (quicksilver), which at the ordinary temperature of the atmosphere is a fluid: if heated, it assumes the state of vapour, and it may be distilled just as water is subjected to that process in order to purify it: on the other hand, it can be frozen into a hard solid.

A chemical compound results from the combination of two or more chemical elements, but it must not be supposed to be a mere mixture of them. A quantity of sulphur may be admixed with lead shots, but the admixture is not a chemical combination; in proof of this, there is the fact that the shots may be mechanically removed one by one from the sulphur, thus dividing the lead wholly from the sulphur. A separation of this sort is in no sense related to the process which is known in chemistry as decomposition. If, on the other hand, the mixed lead and sulphur be placed in a crucible and strongly heated by fire, real chemical combination occurs ; the lead disappears and the sulphur disappears, and the product is a substance which is called sulphide of lead, the properties of which are not those of a mere mixture of the lead with the sulphur, but are peculiar to the combination. The formation of rust on articles made of iron, which takes place on their exposure to the air, affords a more familiar example of chemical combination.

Again, if metallic mercury be gently heated in a suitable vessel while exposed to the air, it absorbs oxygen therefrom and becomes coated with a yellow substance, which we know to be an oxide of mercury; but by no mere admixture can oxygen and mercury be made to assume this form. The use of heat, light, electricity, or some other agency, is generally requisite to bring about chemical change.

Further, if the yellow oxide of mercury, produced as above described, be exposed to a greater heat than that employed in its production, it is then decomposed, yielding, once more, oxygen gas and metallic mercury as its products.

The number of elements at present more or less well known to chemists is about seventy, exclusive of certain new ones said to have been discovered a few years since in rare Scandinavian minerals by Krüss and Nilson. The following is a list of the more important elements, together with their chemical symbols (that is, representative letters) and combining weights :

| Name. | Symbol. | Combining or Atomic Weight. |
|---|---|---|
| Aluminium | Al | 27·04 |
| Antimony | Sb | 119·61 |
| Arsenic | As | 74·91 |
| Barium | Ba | 136·86 |
| Bismuth | Bi | 207·5 |
| Boron | B | 10·9 |
| Bromine | Br | 79·76 |
| Calcium | Ca | 39·91 |
| Carbon | C | 11·97 |
| Chlorine | Cl | 35·37 |
| Chromium | Cr | 52·45 |
| Copper | Cu | 63·18 |
| Cobalt | Co | 58·6 |
| Fluorine | F | 19·06 |
| Gold | Au | 196·2 |
| Hydrogen | H | 1 |
| Iodine | I | 126·54 |
| Iron | Fe | 55·88 |
| Lead | Pb | 206·39 |
| Magnesium | Mg | 23·94 |
| Manganese | Mn | 54·8 |
| Mercury | Hg | 199·8 |
| Nitrogen | N | 14·01 |
| Nickel | Ni | 58·6 |
| Oxygen | O | 15·96 |
| Phosphorus | P | 30·96 |
| Platinum | Pt | 194·3 |
| Potassium | K | 39·03 |
| Silicon | Si | 28 |
| Silver | Ag | 107·66 |
| Sodium | Na | 22·99 |
| Strontium | Sr | 87·3 |
| Sulphur | S | 31·98 |
| Tin | St | 117·35 |
| Zinc | Zn | 65·1 |

The few compounds which have been hitherto named are very simple in character. In illustration of a more complex one, limestone may be instanced. This substance is composed of calcium, carbon, and oxygen. When heated, as in a kiln, a gas is given off which is known as carbonic anhydride (carbonic acid), and lime is left behind. Here we have the case of a compound which, by the agency of heat, is resolved into two other compounds; for carbonic anhydride is composed of carbon and oxygen, and lime is composed of calcium and oxygen.

Heat is by no means the only agency which may be employed to effect the decomposition or synthesis of compounds. For instance, an electric current may be employed to decompose water into its constituent elements (oxygen and hydrogen), and an ordinary photograph is but the result of a chemical change effected in a silver compound by the agency of light.

Many of the compounds which are present in the bodies of living beings are of a very complicated nature. For instance, albumin (white of egg) is composed of five elements—carbon, hydrogen, nitrogen, oxygen and sulphur ; and by its gradual disintegration, or degradation, a great number of intermediate and less complex substances may be obtained before arriving at the most simple products. Nor is albumin the most highly complex substance, for there are several substances present in brain matter, for example, which have, probably, even larger molecular proportions.

The synthesis and decomposition of substances may also be effected by other than simple physical causes ; they are often brought about from so-called acts of vitality. Complex substances present in the body of man are thus resolved into simple substances, while comparatively simple substances taken as food are also elaborated in the animal body into complex compounds. What is true of man is true also, in degree, of other living organisms, even to the simple forms of cell-life known as microbes, and man may and does often become the prey of minute organisms effecting decomposition in his living body.

The well-known process of putrefaction is one of decomposition effected by micro-organisms ; and fermentation is another instance of chemical change brought about by microbic life.

Then, again, it is not always necessary to make use of outside agencies to effect chemical change. Chemical affinity, as it is termed, is often sufficient of itself to effect combination or decomposition. The chemical affinity of phosphorus for oxygen is so strong that, ordinarily, it is requisite to preserve phosphorus under water. When exposed to air or oxygen it greedily combines with the oxygen, and heat is generated so rapidly in consequence that the phosphorus bursts into flame. The remark may here be interposed that flame is merely gas raised to such a temperature that under certain other conditions it emits light as well as heat. Oxides of phosphorus result from the combination of phosphorus with oxygen. The process itself is known as one of oxidation, but there are degrees of oxidation. For instance, if the phosphorus be partially submerged in water when exposed to the air, the temperature is thus kept down, and the oxidation proceeds much more slowly; and, what is more important to note, the products of the chemical changes that take place are more numerous and are not identical with those obtained in the dry oxidation; for, in addition to an oxide of phosphorus, there are produced ozone and peroxide of hydrogen, two very interesting substances about which we shall have more to say later on.

Another example of chemical affinity is shown in the decomposition of water as effected by sodium, which metal enters into combination with the oxygen of the water, hydrogen being, at the same time, liberated in the gaseous state.

The chemical elements differ in relative weight or specific gravity. Hydrogen is the lightest known substance (air being 14·43 times as heavy), and platinum is the heaviest known substance.

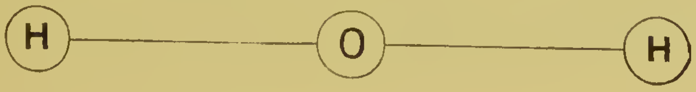
The so-called density of a chemical element in the state of gas represents the relative weight of a given volume thereof at a standard pressure and temperature, the same volume of hydrogen being taken as unity; and the densities of all the chemical elements which assume, or may be made to assume, the gaseous state, are identical with their combining weights or multiples thereof.

Chemical combination always takes place between definite proportions of the different substances. For instance, when sulphur is burnt in the open air (as in fumigating a room), about every 32 parts of sulphur always combine with about twice 16 parts of oxygen. We say twice 16 parts of oxygen rather than 32, because it is possible for 16 parts of oxygen to enter into other combinations, but less than 16 parts are never involved in any chemical change.

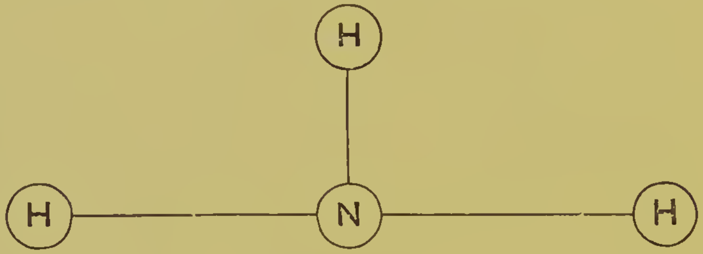
With respect to the combining proportions of the elements, hydrogen is taken as the unit, since it enters into combination with the lowest equivalent weight. The atoms of hydrogen are not supposed to be any smaller than the atoms of other elements, but only lighter; and the combining proportions of the elements represent, generally speaking, their atomic weights. At least, it is found, practically, that they combine in these constant proportions, or in multiples of them. It is in this precise quantitative way that chemical combination occurs. Common salt, for example, contains in every 58·36 parts, 22·99 parts by weight of the metal sodium, and 35·37 parts of the gas chlorine. The molecular weight of common salt (chloride of sodium) is therefore 58·36, and it means that in order to produce a molecule of the compound, one atom of each of its two constituent elements must be combined; the atom of each being the smallest relative weight of each (compared to hydrogen taken as the standard) that ever enters into chemical combination. This explains the figures (atomic weights) that are placed against the names of the chemical elements in the preceding table. Atoms are, of course, invisible to the eye; indeed, to use a simile of Roscoe's, it has been said that, if the minutest organisms which we can see with the aid of microscopes which magnify from 6,000 to 8,000 times were provided with equally powerful microscopes, these beings would perhaps be able to see atoms.

There is another capability of atoms to which attention must be called, namely, their *valency* or power of combination with other elements. The atom of each element possesses a power of combination (*adicity*) more or less peculiar in character. For instance, *hydrogen* is a so-called monatomic or *univalent* element; that is to say, it has only *one* capability of attachment to another element—thus hydrochloric acid is composed of one atom of hydrogen and chlorine, as is here represented:

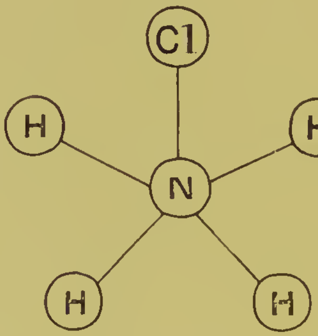
On the other hand, *oxygen* is a diatomic or *divalent* element, and combines with 2 atoms of hydrogen or other univalent element, as here shown:



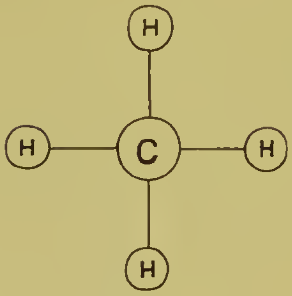
*Nitrogen* is generally regarded a triatomic or *trivalent* element, the formula for ammonia, one of its combinations with hydrogen, being as follows :



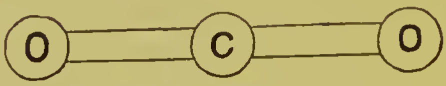
In some of its combinations, however, as in chloride of ammonium, it is to be regarded as pentavalent, thus :



*Carbon* is a so-called *tetrad;* that is to say, it has the power of combining with four atoms of hydrogen, or with two atoms of oxygen, as in the following examples, and so on :



MARSH GAS.



CARBONIC ANHYDRIDE.

We are now in a position to understand the use which is made of symbols and formulæ in chemistry. For the sake of brevity, chemists indicate the metal aluminium by the symbol Al; bromine by Br; sodium by Na (derived from the word natrium); potassium by K (derived from kalium), and so forth. But Na does not merely indicate sodium, but it stands for what is called one atom of the element; that is, 22·99 parts by weight, that being its combining proportion. Similarly, chlorine is represented by the symbol Cl, which means 35·37 parts by weight, or its combining proportion, that being the quantity which invariably combines with 1 part of hydrogen, represented by the symbol H, and taken as unity. Thus, HCl stands for hydrochloric acid; its molecular weight is 36·37, and every 36·37 parts by weight are found upon analysis to yield 35·37 parts by weight of chlorine, and 1 part by weight of hydrogen. From such analytical facts, the percentage composition of any substance may, of course, be readily calculated.

The formula, then, for hydrochloric acid is HCl; that for sulphuric acid is $H_2SO_4$; that for nitric acid $HNO_3$.

Baryta, or oxide of barium, is represented by BaO; peroxide (di-oxide) of barium is formulated $BaO_2$. Now, when peroxide of barium is placed in contact with hydrochloric acid, a chemical change or *reaction* takes place, and it is indicated by the equation—

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

This chemical equation is intended to represent the fact that 1 molecule of peroxide of barium, when placed in contact with 2 molecules of hydrochloric acid, results in the production of 1 molecule of chloride of barium, and 1 molecule of peroxide of hydrogen. It is evident that the sum of the products is equal to the sum of the substances originally employed. Thus we have employed—

| | |
|---|---|
| 1 atom or 136·86 parts of barium<br>2 atoms or 31·92 parts of oxygen | Present in 1 molecule of peroxide of barium. |
| 2 atoms or 2 parts of hydrogen<br>2 atoms or 70·74 parts of chlorine | Present in 2 molecules of hydrochloric acid. |

And we obtain as the result of the chemical action—

| | |
|---|---|
| 1 atom or 136·86 parts of barium<br>2 atoms or 70·74 parts of chlorine | Present in 1 molecule of chloride of barium. |
| 2 atoms or 2 parts of hydrogen<br>2 atoms or 31·92 parts of oxygen | Present in 1 molecule of peroxide of hydrogen. |

It will be seen that altogether there are employed 241·52 parts by weight, and that there are obtained 241·52 parts by weight.

This equation affords an incidental proof that matter is indestructible ; its form may be changed, but the substance cannot disappear or be destroyed. If, therefore, in the study of any chemical change the sum of the products found upon analysis is not equal to the parts by weight of the substances originally used, it is known to the operator that the analysis is imperfect, and that some product has been missed.

There is one further consideration worth mentioning in connection with this subject of chemical combination. The formula $H_2O$ not merely implies that 2 parts by weight of hydrogen are combined with 15·96 parts by weight of oxygen in each molecule of water : it also expresses a relation by volumes of the chemical elements in combination. If a molecule of water be subjected to analysis, it yields 2 volumes of hydrogen and 1 volume of oxygen.

Again, the formula $HCl$ (hydrochloric acid) implies a combination of equal volumes of hydrogen and chlorine; and the formula $NH_3$ (ammonia) implies a combination of 3 volumes of hydrogen with 1 of nitrogen.

From this it will be seen that equal volumes of different elementary gases have the relative weights represented by their chemical combining proportions, taking hydrogen as unity; or, to put the matter in another way, 1 gramme of hydrogen, 15·96 grammes of oxygen, 35·37 grammes of chlorine, and 14·01 grammes of nitrogen, all occupy the same volume when examined in the gaseous condition at the same temperature and pressure. In other words, equal volumes of gases, when so compared, contain the same number of molecules.

Chemistry has been well defined as 'the study of the laws of changes of matter'; that is to say, of the reactions which take place between substances under all sorts of conditions. This study concerns living matter and vital processes, just as much as lifeless materials and the chemical changes to which they are subject.

Hygiene is, indeed, largely concerned with the chemical composition and properties of air, water, and animal and vegetable substances, and what has gone before will assist in enabling the reader to duly understand what has to be said in relation to these subjects in later portions of this treatise.

# CHAPTER II.

OXYGEN AND OXIDATION—OZONE—NITROGEN AND NITRIFICATION—CARBON DI-OXIDE—HYDROGEN—WATER—PEROXIDE OF HYDROGEN; THE OCCURRENCE OF THESE SUBSTANCES IN NATURE, AND THEIR GENERAL CHARACTERS—CONTACT ACTIONS.

## *Oxygen.*

*Symbol O. Atomic Weight* 16.

IN the early days of the Royal Society, when its meetings were held at Oxford, the Hon. Robert Boyle directed the attention of its members to a number of interesting experiments which he, together with his assistant, Dr. Hooke, had made with ordinary air. As one of these observations he showed that animals which were confined in a limited volume of air died after a short time. John Mayow, who attended these meetings, became greatly interested in this subject, and continued the research thus originated. He ascertained (1674) that in breathing, animals do not consume the whole of the air which is inspired, but only its oxygen, and that, indeed, the air consists of two gases, one of which, viz., nitrogen, is of no direct use in sustaining life, and is expired.

It will be seen that Mayow had, as a matter of fact, discovered oxygen gas, although in a negative sort of way; but, owing to the erroneous views then prevalent, his discovery was allowed to be forgotten, or nearly so, for a hundred years. Then Priestley, who occupied himself with continued observations upon gases, succeeded—it may almost be said accidentally—not only in rediscovering oxygen, but also at the same time in making it from a solid substance. It will be remembered by all students of chemical history that, in 1774, Priestley obtained this gas by exposing the red oxide of mercury to a high temperature; and it further appears that Scheele (a famous Swedish apothecary) made the same discovery both simultaneously and independently. Priestley not merely collected oxygen gas; he also ascertained its powers of supporting combustion and maintaining life. At that time he wrote, 'Who can tell whether this pure air may not at last become a fashionable luxury? As yet, only two mice and myself have had the privilege of breathing it.'* In spite of all this, he very imperfectly understood his own results.

Lavoisier (a Parisian, born in 1743) was a man of the time. After revolutionizing chemical science, he himself was sacrificed to a political revolution. He introduced the balance into chemistry, and whereas Priestley had obtained oxygen and mercury from the red oxide, Lavoisier reconstructed the

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* 'Short History of Natural Science,' Buckley, p. 234.

compound from its elements, and showed that upon heating a given quantity of the oxide, it evolves just the same amount of oxygen gas as is consumed in its preparation. In short, he thus demonstrated the fact that mercury and oxygen combine in definite proportions. The masterpiece of Lavoisier's work, however, was his explanation of the phenomenon of combustion. The most generally accepted theory on this subject at that time was what is known as the Phlogiston theory, the chief exponent of which was the great German chemist, Stahl.

According to this theory, all metals and combustible bodies generally, contained a subtle principle called Phlogiston, which they gave up when heated or calcined ; thus, when lead was heated in the air it gave up its Phlogiston, and was converted into a yellow-looking powder, litharge, which they called dephlogisticated lead.

Lavoisier, with the aid of his chemical balance, struck a fatal blow at this theory. He showed that when a metal is heated in the air, instead of diminishing in weight owing to the loss of Phlogiston, it actually increases in weight ; thus the litharge that is formed on heating lead is found to weigh more than the original lead ; in other words, combustion is a process of combination, and not of decomposition, as was previously supposed.

The discovery by Priestley, in 1774, of oxygen, a gas eminently adapted for supporting combustion, enabled Lavoisier very soon afterwards to complete this theory by first proving that this gas is a constituent of the air, and then by showing that it is this constituent with which bodies combine in the process of combustion. In other words, Lavoisier was the first to give the true explanation of the phenomenon of combustion, by showing that it is simply a process of combination with oxygen, or, as we now call it, a process of oxidation.

Oxygen may be prepared in the laboratory by a number of methods, the simplest of which consists in exposing certain metallic oxides* to high temperatures, when decomposition occurs; oxygen is thus liberated in the gaseous state, while the metals or their lower oxides are left behind.

Oxygen is best known, however, as a constituent of the air we breathe, serving in the process of respiration to oxidise or burn up the carbonaceous and other matters present in the blood and tissues of animals, with which it comes into contact through the medium of the lungs. The details of this process and its results will be studied in another chapter.

At the ordinary atmospheric temperature and pressure, oxygen is a colourless, tasteless gas; but it has been demonstrated in recent years by M. Raoul Pictet and M. Cailletet severally, that when reduced to a temperature of 140° C. under a pressure of 320 atmospheres, oxygen assumes the liquid form. More recently Dewar has succeeded in obtaining it in the solid form.

As Liebig is reported to have said that the best

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* Combinations of metals with oxygen.

test for ammonia is the nose, so it may be said oxygen is characterised by its power of oxidation. In cases where this process is carried on rapidly, so that it is attended with the evolution of light and heat, combustion is said to occur. For instance, if a piece of charcoal be heated to redness and then placed in a globe filled with oxygen, the oxidation, which in the atmosphere merely kept the charcoal at a dull red heat, is now so intensified that the combustion is continued with great avidity.

In an ordinary grate fire we have the best illustration of the process of oxidation: coal and wood, being of a carbonaceous nature, only require the application of heat to enable the oxygen in the atmosphere to enter into chemical combination with their constituent particles, and when once this process of combination has commenced, the heat with which it is attended is sufficient to keep the combustion (oxidation) going. In this way the carbon of the fuel combines with the atmospheric oxygen to form carbon dioxide, thus:

$$C + O_2 = CO_2.$$

Much the same process goes on when ordinary illuminating coal gas or candles are burned.

Beyond its powers of maintaining life and supporting combustion, oxygen gas furnishes but few direct chemical reactions that are not also exhibited by ozone and peroxide of hydrogen. It differs from these two last-named substances, however, in being less active in its properties. Thus, when brought into contact with a solution of iodide of potassium, it exercises no influence upon it. It has no colour, taste, or smell; it is only slightly soluble in water, 100 volumes of this fluid dissolving 4·11 volumes of the gas at 0° C., and 2·99 volumes at 15° C. (the ordinary temperature of the air).

Oxygen has no action on litmus paper, and does not oxidise silver, while it is stable at all temperatures. In oxygen, therefore, we have a substance of such marked general negative characters that we can readily and unmistakably discriminate between it on the one hand and ozone and peroxide of hydrogen on the other hand.

### *Ozone.*

*Molecular Symbol* $O_3$. *Molecular Weight* 47·88.

About ten years after the discovery of oxygen, Van Marum, of Holland, observed that when that gas was subjected to the passage of electric sparks it acquired a peculiar fishy odour; and it is said that shortly afterwards Cavallo discovered the disinfecting value of the product, and applied it as a remedy to fœtid ulcers.*

In 1826 Dr. John Davy recognised the presence of a similar principle in the atmosphere, thus explaining the odour often referred to in history as having been observed during storms and periods of electrical disturbance. It was not, however, till 1839 that any precise knowledge was obtained regarding the

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* 'Ozone and Antozone,' by Dr. Cornelius B. Fox, p. 4.

substance in question. M. Schönbein, of Basle, who was then engaged in an investigation of the electrolytic decomposition of water, noticed the same odour in the apartment in which he conducted his experiments, and this led him to a prolonged research, having for its object the elucidation of the nature and properties of this gaseous principle, which from its odour he named ' ozone.'

He ascertained that a certain amount of this substance is mixed with the oxygen which is evolved at the positive pole during the voltaic decomposition of water, and further observed a number of its oxidising effects.

The nature of ozone proved a very difficult problem for chemists to solve, and the task was only accomplished by men, some of whom are yet living.

Schönbein at one time considered ozone to be a compound of oxygen with hydrogen. Peroxide of hydrogen being oxygenated water,* or a substance containing in its molecule more oxygen than water does, and its oxidising characters being considered as due to the ease with which it parts with the extra oxygen, Schönbein was led to regard ozone as peroxygenated water, or, in other words, a still more highly oxygenated compound than peroxide of hydrogen. Thus, to use the notation now employed by chemists, Schönbein represented ozone as $H_2O_3$, peroxide of hydrogen being $H_2O_2$, water being $H_2O$.

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* This must not be understood as aërated water, or water containing dissolved oxygen, but water chemically combined with more oxygen and not simply admixed.

Williamson supported Schönbein in this opinion, which was afterwards proved to be erroneous by a long series of investigations conducted by numerous chemists, among whom may be named Becquerel, Frémy, Marignac, De la Rive, Andrews, Soret, and Brodie. It was, first, shown that pure ozone is free from hydrogen, and therefore yields no water during combustion; next, it was demonstrated that the matter of ozone is identical with the matter of oxygen; and finally, by the classical researches of Andrews and Brodie (the latter of whom particularly investigated the volumetric relations of ozone), that ozone is oxygen in a condensed state. Not condensed in the sense that a given volume of gas may be made to occupy a smaller space by the influence of compression, but in the sense that the constituent atoms are so innately arranged that each whole molecule of ozone contains three atoms in the space occupied by a molecule of oxygen consisting of two atoms. While this demonstration was due to Andrews and Brodie, the view which it proved to be correct is to be credited to Odling, who, with a characteristic keenness of intellect, discerned the truth before it was experimentally established.

The superior oxidising powers of ozone, as compared with those of ordinary oxygen, are supposed to be due to the state of its density, to which reference has just been made.

The best proof that can be given of the identity of the matter of oxygen with that of ozone consists in the ease with which it is possible to convert oxygen into ozone, and to effect also the converse change. Suppose that we take 100 volumes of oxygen gas, and subject it to the electric discharge until it measures 92 volumes, we shall by this time have produced a definite amount of ozone. This can be shown by removing some of the gas and submitting it to different tests. But if, instead of taking away any of the condensed gas, we raise it to a temperature of, say, 240° C., we shall find that for the 100 volumes of oxygen originally employed we now once more obtain 100 volumes when measured at the same temperature and pressure. In other words, ozone is resolved at an elevated temperature into ordinary oxygen.

This identity of oxygen and ozone is not the least more remarkable than the identity presented by carbon in its ordinary forms, and is only an example of so-called *allotropy.* As another example of allotropy we have carbon in the forms of the diamond, graphite, and lamp-black; and the properties of these substances are as diverse as those of ozone and oxygen.

One fact in particular must be stated here, because, when we get further on, we shall find it of considerable importance. It is this: whereas, when ozone is exposed to contact with many chemical substances, it suffers decomposition, yielding up its third atom of oxygen to the oxidisable matter and becoming ordinary oxygen, yet when submitted to contact with ordinary turpentine the whole molecule of the ozone is absorbed; no oxygen remains behind. For a knowledge of this fact we are indebted to Soret.

The presence of ozone in the atmosphere was first assumed when Dr. John Davy obtained certain reactions with ordinary air, which were then considered to be characteristic of ozone; and as Cavallo and others had found ozone to possess marked disinfecting powers, more importance was attached to atmospheric ozone than the subject, perhaps, deserved.

The observations of Dr. Davy were repeated and extended by others, and as the oxidising powers of ozone became better known, there arose in the minds of men the idea that this substance constitutes nature's great purifier. This idea received the more credence since Schönbein had taught that every process of slow oxidation occurring in nature is accompanied by the formation of ozone, and because Kossman and Daubeny had stated that, under certain conditions, the same substance was produced by the green parts of plants.

The amount of work which has been devoted to the study of ozone as occurring in the atmosphere, and its relation to storms and winds, is almost beyond belief, and the task of collecting or summarising such investigations would be, perhaps, one of supererogation. It will certainly not be attempted here, and more particularly since Dr. Fox has very carefully performed the task already. To his work* we refer the reader who may feel disposed to proceed upon the study, while for the purposes of this treatise it will suffice to bring some few facts prominently to the

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* 'Ozone,' etc., by Dr. Cornelius Fox. Churchill.

reader's attention. In the first place, then, the majority of persons undoubtedly attach great importance to atmospheric ozone, and believe it to be the greatest purifying influence in nature; many going so far as to assert that zymotic disease exhibits a definite relation to ozone in the sense that when ozone is absent from the atmosphere, disease occurs and spreads, and that where present, zymotic disease is almost unknown. It seems a vast pity to upset notions which have taken so deep a root in men's minds, but the truth must be told by scientific men, and the truth is that nearly all the observations which have been made on the subject are inconclusive.

It was pleasant enough to resort annually to the seaside in the firm belief that there ozone was to be met with in plenty, and miasmatic poisons could not endure; but, as a matter of fact, there is little evidence to show that, so far at least as ozone is concerned, the seaside is any healthier than the flats and marshes of Lincolnshire or the hills of Devonshire.

And now one word in explanation. The chemical reagents and tests which were applied by different observers in determining the presence and amount of ozone in the atmosphere under various circumstances are not alone influenced by ozone; they are also influenced by peroxide of hydrogen, and there is, at present, no reliable and practicable method for testing and estimating the one substance without including the other.

There is, however, generally some germ of truth in any doctrine or belief which may be held by a large number of persons, and as readers of the foregoing sentences may have suffered some discomfort in feeling that their pet theory is therein demolished, it is pleasant to restore their comfort, and place it upon a more enduring basis. My readers, then, may rest content with the assurance that even if ozone does not occur in the air so freely as previously believed, yet another substance does, and one, too, of greater sanitary value, viz., peroxide of hydrogen.

Although it cannot be said with certainty that ozone ever occurs in the atmosphere at all, its presence in minute amount is extremely probable, and more particularly because there are times and conditions when ozone must, presumably, be produced in the atmosphere. It should, however, be distinctly understood that there is no applicable test for ozone as a constituent of the atmosphere, which is not also affected by peroxide of hydrogen, although in the laboratory these substances may be readily distinguished.

When Dr. Daubeny in 1866* stated that his researches tended to show that atmospheric ozone is generated almost exclusively by the green parts of plants, he was guided by the fact that the oxygen which is emitted by plants in the daytime, when brought into contact with iodide of potassium, liberated iodine therefrom; this result, however, is

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* See *British Association Report*, also *Journ. Chem. Soc.*, 1867, 19.

producible by peroxide of hydrogen, and also by ordinary oxygen in the presence of sunlight.

Dr. Daubeny was supported in his views by M. Kossman and others; but M. Cloez, from some carefully conducted experiments, arrived at the conclusion that the liberation of iodine and consequent coloration of the ozone test-papers in Daubeny's experiments was due to the combined action of humid oxygen and solar light upon the iodide of potassium, and this conclusion was confirmed by the more recent observations of the late Dr. Angus Smith.

Bellucci* passed currents of air (free from ozone) through bell-jars containing living plants or recently cut branches and leaves, and he also found that if the tubes containing the air were protected from daylight, when it came in contact with the potassium iodide test and after contact with the plants, then no ozone reaction was obtained, thus supporting the statement of Cloez.

In experiments of the kind just described, care must be taken not to employ plants of an aromatic nature, since, as will be afterwards explained, peroxide of hydrogen is certainly produced by them. As plant life, therefore, does not seem to generate atmospheric ozone, its source must be looked for elsewhere.

Now, as in the laboratory, ozone is most easily prepared by the action of electrical discharges upon

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* *Compt. Rend.*, lxxviii., 362.

oxygen or air, and as electrical discharges are constantly occurring in the atmosphere, it is most probable that we shall find in this fact the explanation we are looking for. Moreover, there are numerous sources of atmospheric electricity. Of course, in storms attended with lightning, there is the strongest reason for believing that ozone must necessarily be produced, and peroxide of hydrogen also.

A. Houzeau calculated[*] that country air contained a maximum of $\frac{1}{450000}$th of its weight, or $\frac{1}{700000}$th of its bulk of ozone, and considered it to be produced by atmospheric electricity constantly acting in the manner of a huge-sized condenser between the soil and the clouds.

It is very probable that the friction of waterdrops as they fall in the form of rain against the air produces negative electricity, as it is also certain that the spray of a fountain, waterfall, or cascade, likewise gives the surrounding air a negatively electrical character, which so influences the oxygen of the air as to give rise, in all probability, to the formation of ozone. That this is so, is supported by various experiences which have been summarised by Bellucci in a most interesting paper.[†] In this communication he calls attention to the following circumstances :

1. Lender noticed an ozone reaction in the air near the columns where the concentration of brine

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[*] *Compt. Rend.*, March 11th, 1872.

[†] *Gaz. Chimica Italiana*, vi., 88—97.

is carried on at Kissingen at which place the air is filled with the spray of the salt-water.

2. Gorup-Besanez found that a similar reaction could be observed with a spray of water not containing salt, and that the ozone formed by a spray of water issuing under pressure was greater in proportion as the evaporation was more rapid.

3. Morin and Monte also found that ozone is produced during the pulverisation of water.

4. He (Bellucci) observed at Terni, near the falls, a similar ozone reaction, and concluded that it is traceable to the electrical state induced by friction of the minute waterdrops.

Now, if it be true that the friction of waterdrops against the air is sufficient to give rise to the production of ozone, then how great must be the quantity produced over the surface of the oceans! Thus, after all, it may be that sea-air abounds in ozone. At the same time it must be remembered that the fact has not been demonstrated by unequivocal tests.

In concluding this part of the subject, it may, then, be safely assumed that ozone is a tolerably constant ingredient of pure air, although never present except in traces. The amount of it present in different places is extremely variable, as its production is dependent upon conditions not always in operation, and because it is readily destroyed by oxidisable matters generally, and particularly by organic matter in a state of change or decomposition.

In the laboratory, ozone is prepared by the action of electricity upon air or oxygen. Andrews and

Tait found that, to produce the maximum amount of ozone, it is best to transmit the electrical discharge silently, as the passage of the spark itself destroys a quantity of the ozone previously formed. Or, as Siemens first showed, ozone may be obtained by submitting a current of oxygen to the action of induced electricity. It forms no part of the present work to describe the different arrangements of apparatus for preparing ozone. Many of these have been described by Dr. Fox in his work on ozone, while all of them are constructed upon the principles stated above. We pass on, therefore, to consider the properties of ozone.

In its natural state, ozone is a gas of greater density than oxygen, so that a given amount of it occupies a less volume than that of the oxygen from which it is made. Indeed, the preparation of ozone from oxygen may for purpose of illustration be thus written :—$3 0_2 = 2 0_3$. That is to say, three volumes of ordinary oxygen become, under the influence of electrical action, transformed into two volumes of ozone. At temperatures a little above the boiling-point of water, ozone is slowly retransformed into oxygen, and this change is instantaneous at 300° C. With the change back into oxygen, there is an increase of volume exactly corresponding to the diminution observed when oxygen is converted into ozone; and, of course, all the ozonic properties are simultaneously lost, being substituted by those of ordinary oxygen.

There still seems to be some doubt as to the solubility of ozone in water. Most writers state that ozone is quite insoluble in water, while Soret asserted that water absorbs a certain amount of ozone. This statement of Soret has been confirmed by L. Carius,* who passed ozone (obtained from the electrolysis of a large surface of dilute sulphuric acid at 0° C.) through water maintained at 2° to 4° C., and found that in this way the water absorbed about 4 or 5 cc. of ozone. He also found an 'ozonised water,' sold as such in Germany, contained a similar quantity of ozone, and was quite free from peroxide of hydrogen. On the other hand, C. Rammelsberg† found that it contained 0·16 per cent. active chlorine (which would give the same reaction with potassic iodide as that by which Carius estimated his ozone), and that such a product could be obtained by passing air first through a solution of bleaching powder (chloride of lime), and then into water. In all his experiments made with a view of obtaining true ozonised water, he failed.

Em. Schöne,‡ however, experimenting with ozone got by the silent discharge method, found that ozone is soluble in water to the extent of about 8·81 cc. ozone per litre, and that no peroxide of hydrogen is formed by action of the ozone upon the water.

Air highly charged with ozone exerts an irritating effect upon the respiratory organs; and when an excess of ozone is breathed, certain symptoms reminding of catarrhal and bronchial affections are induced.

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* *Phil. Mag.* (4), xliv., 544.

† *Deut. Chem. Ges. Ber.*, vi., 603—605.

‡ *Ibid.*, vi., 1208 and 1224—1230.

This is not surprising, for even pure oxygen cannot be breathed with impunity, and, naturally, ozone must exercise in the system a much more powerful action than ordinary oxygen. Of course it will be readily understood that these facts express the pathological rather than the physiological influences of ozone, and that, as a matter of fact, they are only exhibited by such an excess of ozone as can never occur in nature.

The idea that ozone is naturally generated in the blood through an action exerted by the red corpuscles upon oxygen, is one which does not rest upon a satisfactory basis.

Ozone exhibits powerful bleaching powers, and converts blue indigo into colourless isatin : curiously enough, however, it seems to have little action upon the colour of flowers, a fact pointed out by A. R. Leeds,* and noted by him as an economical feature in 'nature's purifier and disinfectant.'

The oxidising effects of ozone are very powerful, and are exhibited even towards such metals as silver and mercury ; silver becoming peroxidised under its influence, whereas it is not at all affected by oxygen. Ozone also oxidises iodide of potassium, setting free the iodine from its solution ; and it is by this reaction that the estimation of ozone is most readily effected. There are easy chemical methods by which free iodine can be estimated ; hence, when ozone is present in sufficient amount, nothing is easier than its deter-

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* *Chem. News*, vol. xxxviii., pp. 224, 235, 249, 257.

mination by estimating the quantity of iodine set free by it. If it be very small, it can be judged of by the depth of colour it imparts to a paper previously steeped in a mixture of iodide of potassium and starch. Unfortunately, however, other chemical principles act upon potassic iodide in the same way, and thus experiments of this kind, except under special circumstances—as, for instance, when the substance is known to be pure ozone—are of little conclusive value.

The oxidising effects of ozone are very readily demonstrated by the ease with which it deodorises putrid meat and effusions. Thus, in 1854 Drs. Wood and Richardson* exposed a pint of coagulated ox blood to the air for a whole twelvemonth, by which time the mass had become a most offensive fluid. In 1862, and when it was still most horribly offensive, it was subjected to a current of ozonised air, as generated by Siemens' apparatus. By this means the evil odour was gradually and entirely removed, and the resulting product was perfectly sweet to smell.

Schönbein observed† that 'air containing only $\frac{1}{3240000}$th of ozone has the power of disinfecting its own volume of air loaded with the effluvium emitted in one minute from four ounces of flesh in a highly putrid state.'

A. Boillot‡ also noticed that fresh beef could be preserved in ozonised air for more than ten days, while

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* See Fox's work on Ozone, p. 30.

† *Ibid.*, p. 94.

‡ *Compt. Rend.*, lxxxi., 1258.

in ordinary air a part of the same beef went bad in five days.

The experiments described by Schönbein, and the views that he expressed, led chemists generally to believe that nearly all slow processes of oxidation are attended with the production of ozone. By the expression 'slow processes,' it is intended to indicate the chemical changes that result when such substances as turpentine, eucalyptus oil, ether, and phosphorus are exposed to the air, or to air and water.

I have made many of these processes the subject of careful investigation for many years, but the matter is one which, from its nature and extent, demands and receives exhaustive treatment in special chapters.

As regards the slow oxidation of the ethers, I studied this process to a limited extent some years ago, on which occasion I satisfied myself that ozone never results from such reactions. On the other hand, the process was found to yield peroxide of hydrogen, exhibiting all its well-known reactions and qualities.* More recently, M. Berthelot has stated that when ether is exposed to the action of ozone there is obtained a peculiar compound, which he styles 'ozonised ether,' and this, when shaken with water, produces peroxide of hydrogen.†

Some further information concerning the production of peroxide of hydrogen from ether has since

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* *Chem. News*, vol. xxxiv., p. 135.

† *Compt. Rend.*, lxxxvi., 71—76.

been afforded by Dunstan and Dymond,* and A. Richardson.†

In the first edition of this work, I had to give expression to the doubts that then existed concerning the supposed production of ozone by the aerial oxidation of phosphorus, and reasons were stated why peroxide of hydrogen might be expected to result from the process. Since then the whole subject has been very carefully studied, and in a report‡ which I presented to the Chemical Society late in 1880, an account is given of my own researches and those of others, including the investigation conducted simultaneously by Dr. A. R. Leeds. It is now quite certain that when phosphorus is partially submerged in water and exposed to a current of air, both ozone and peroxide of hydrogen are produced in considerable amount. The ozone is carried off in the current of air, and the peroxide of hydrogen dissolves mainly in the water in which the phosphorus is placed.

The manner in which these facts were ascertained may be briefly described in this place.

The apparatus used in my experiments was specially constructed for the purpose, and consisted of a number of wide-mouthed bottles, each of 300 cc.§ capacity, and provided with well-fitting solid glass stoppers having two apertures. Through these aper-

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* *Journ. Chem. Soc.*, 1890, pp. 574 and 988.

† *Ibid.*, 1891, pp. 51—58.

‡ *Journ. Chem. Soc. Trans.*, 1880, p. 792.

§ 300 cubic centimetres.
1000 cc. = 1 litre, and 4·54 litres = 1 gallon.

tures with ground surfaces passed tubes which were enlarged and ground at the requisite positions, so that when they were properly inserted, the joints were perfectly tight, and could be easily disconnected or renewed. This special form of apparatus was adopted in order to avoid the use of oxidisable materials in the construction of the joints, and it is apparent that a perfect battery of such oxidisers could be used, the tubes of the various members being connected in the manner described by the late Sir Benjamin Brodie, viz., by coupling them together with larger glass tubes coated internally with melted paraffin wax.

In each of five such oxidisers there was placed a stick of phosphorus, scraped clean just before use, and then sufficient water to half submerge the phosphorus, leaving the other half exposed to the air in the bottles. The sixth vessel was charged with 200 cc. water, to serve as a wash-bottle, and then the series was connected together, and a current of air, previously filtered through cotton-wool and washed in water, was in each experiment blown through by means of a rotating fan.

Operating thus, it was found that the air which had passed over the phosphorus, contained ozone, which substance was identified in a thoroughly satisfactory manner. It possessed the characteristic odour of that principle; it was entirely absorbed by oil of turpentine, and was destroyed at a temperature of 240° C. It liberated iodine from an acidified solution of potassic iodide, and by determining the iodine thus set free, the amount of the ozone was ascertained.

The presence of peroxide of hydrogen in the water in which the phosphorus was partially submerged, was proved also by a practical examination, in which it was found that the solution could be concentrated by evaporation, and it gave all the qualitative and quantitative reactions which will be described in greater detail when we come to describe that substance and its properties.

## *Nitrogen.*

*Symbol N. Atomic Weight* 14·01.

Nitrogen constitutes the larger proportion of the atmosphere, and may be prepared in the pure state, among other methods, by the combustion of phosphorus in a vessel containing air standing over water. The phosphorus burns at the expense of the oxygen with which it enters into combination, leaving nearly pure nitrogen gas behind. It is colourless, tasteless, inodorous, and almost insoluble in water. At an extremely low temperature and when subjected to a great pressure it liquefies, in common with hydrogen and oxygen gases.

While nitrogen cannot be described as a poisonous gas, it has no power to maintain life ; on the other hand, when breathed in the pure state it destroys life, for the same reason that it cannot sustain combustion, viz., because it puts an end, for want of oxygen, to both processes, which are, as we have seen, dependent upon active oxidation.

In respiration, nitrogen is not assimilated by the blood as oxygen is, but is expired in the breath. Notwithstanding this, it enters very largely into the composition of animal and vegetable tissues, being obtained in the human body from the nitrogenous constituents of the food. It also occurs in the mineral world in the state of nitrates of sodium, potassium, and calcium.

The production of nitrates in soils is of a continuous character, and proceeds more actively in the hotter climates. The manner of their formation is extremely interesting, and the recently conducted investigations of MM. Schlœsing and Muntz, in France, and of Mr. Robert Warrington in this country, have led to some important results. It is now known that 'nitrification' is due to the action of two living ferments which cause the oxidation, in the soil, of ammonia and the nitrogen of organic bodies. Ammonium carbonate is oxidised, and the nitrogen converted into a nitrite by one micro-organism; while another converts the nitrites into nitrates. If a small quantity of fresh soil be added to a dilute solution of urine, active nitrification is induced, and the ammonia or urea is converted into a nitrate. It is necessary for the production of nitric acid in this way that some base should be present wherewith it may enter into combination. The presence of gypsum (native sulphate of calcium, $CaSO_4$) greatly facilitates the nitrification of urine. The solution of urine, nitrified as above described, then possesses the power to induce the process in other solutions of urine. These facts are comparable with the more widely known and better understood features of alcoholic fermentation, in which, as a correlative phenomenon of a vital act, sugar is converted into alcohol.

Although it appears that the nitrifying micro-organisms may exist to a depth of about six feet, nitrification is practically confined to the surface soil.

The production of nitre on the artificial plan has for a long period been carried on in Europe. Mould, rich in nitrogenous matter, is formed into heaps of a porous character, so as to allow free admission of air, and treated from time to time with urine and water in regulated quantities. After two years of such treatment, care being taken to protect the heaps from rain, they become sufficiently rich in nitrates to be worth extracting. The chief nitrate thus formed is nitrate of calcium, the potassium salt being made from it by treatment with wood ashes or with carbonate of potassium. In this way about 5 lbs. of nitre can be obtained from each 1,000 lbs. of the nitrified soil. It is worthy of remark that it is from nitrates present in the soil that plants, in the main, derive their nitrogen, and thus we can appreciate the importance of nitrates from a manurial point of view, or, what is equivalent thereto, the importance of using nitrogenous manures.*

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* See Mr. Warrington's paper read before the Society of Arts, vol. xxx., p. 532, and his remarks on the Chemistry of Bacteria in the *Chem. News*, vol. lxvii., p. 175.

At present our knowledge concerning nitrogen as the main constituent of the atmosphere, and in its natural relations, is of a very limited character. There is no proof that the nitrogen of the air contributes in any way towards the formation of nitrates in the soil, and the extent to which free nitrogen is contributed to the air by animal and vegetable matters in a state of decay or putrefaction has not been accurately ascertained. It is known, however, that in ordinary putrefaction some nitrogen gas is evolved, and that an abundance of oxygen causes the evolution of much nitrogen; indeed, it then becomes the principal gas.

Combustion of nitrogenous organic matters also gives rise to the production of some free nitrogen

### *Carbonic Anhydride* (*Carbon Dioxide; Carbonic Acid*).

*Formula* $CO_2$. *Molecular Weight* 43·89.

Carbonic anhydride is a constant constituent of the atmosphere, although its proportion differs with place and time, varying from 2 to 10 parts in 10,000 of air. The amount present in the air is greater in summer than in winter; it increases during the night, and decreases after sunrise. It is given off from the human body as an excretory product in the breath, and it is formed by the slow decay, as also by the rapid combustion, of organic matters generally. Carbonic anhydride is decomposed by the leaves and other green parts of plants, but the decomposition takes place only during daylight, and to the greatest extent during bright sunshine. In this process oxygen gas is set free, and the carbon is taken up by the plants in some manner at present imperfectly understood. During darkness, plants evolve carbonic anhydride, and this may account for the increased amount of that substance which is found present in the atmosphere by night.

The quantity of carbonic anhydride contained in the air of houses and closed inhabited spaces, is in excess of the amount found in the open air, and one of the objects of ventilation is to reduce the amount as far as possible.

In the laboratory, carbonic anhydride is best prepared by acting upon marble (carbonate of calcium) with hydrochloric acid, as illustrated by the following chemical equation :

$$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2.$$

Carbonic anhydride (carbon dioxide) is a colourless and nearly inodorous gas, which can be readily reduced to the liquid and solid states. It is about 1·5 times heavier than air, and is soluble in water to a very considerable extent ; one volume of water at 0° C. dissolves 1·797 volumes, but at 20° the quantity dissolved is only 0·901 volume.

When present in the air in any considerable proportion, carbonic acid acts as a poison, as will be more fully explained in the chapter on Respiration : on account of its poisonous effect, fuel (of any kind) should never be burned in rooms except in fireplaces connected with efficient chimneys, and because carbonic acid is one of the products of burning gas, the necessity of efficiently ventilating dwelling apartments is at once apparent.

Although air only contains on the average 4 volumes of carbon dioxide in 10,000 volumes, the absolute amount thus presented in nature is enormous, as may be readily proved by calculation. It also occurs in the air of mines and old wells, and is commonly known as 'choke-damp.' Common chalk and marble (carbonate of calcium, $CaCO_3$) are compounds of carbonic acid with lime.

Soda-water of commerce is an aqueous solution mechanically charged with a large amount of carbonic anhydride, and it is this gas which escapes so briskly when the cork is removed from a bottle containing that fluid.

Spring water is often charged with carbonic anhydride, derived from the gradual oxidation of vegetable organic matters held in solution by the action of the air, and it is to its presence that the so-called 'hardness' of water is in part due (see chapter on Water and Water Supply).

## *Hydrogen.*

*Symbol H. Atomic Weight* 1.

In 1766 Cavendish first obtained 'hydrogen' gas by the action of diluted sulphuric acid upon zinc, thus :

$$Zn + H_2SO_4 = ZnSO_4 + H_2,$$

and upon examining its properties, he found that a mixture of it with ordinary air exploded upon the application of a flame, with the consequent production of water. But it was not until after Priestley had made oxygen that Cavendish became fully aware of the fact that the explosion in question was owing to the combination of hydrogen with oxygen. He repeated his experiments with pure oxygen, and thus formed water.

The production of water in this way may be expressed as follows :

$$H_2 + O = H_2O.$$

Hydrogen is the lightest body in nature, being fourteen and a half times lighter than air, but notwithstanding this, it has of late years been reduced to the liquid state, as already mentioned.

Its properties do not call for any extensive treatment in this place, since it is only important (in connection with the subject of this volume) as a constituent of water and peroxide of hydrogen.

Hydrogen gas is combustible, and when it is burned in the air or in oxygen it enters into combination with the oxygen, yielding water as the product. This reaction is remarkable in so far as it illustrates the direct formation of a liquid substance by the chemical combination of two gases.

Hydrogen is not poisonous in the ordinary sense of that expression, although of course it cannot support life. In this respect it resembles nitrogen.

## *Water.*

*Formula* $H_2O$. *Molecular Weight* 17·96.

The occurrence of water in nature, and its general properties, are matters of such common knowledge that it is altogether unnecessary to dwell upon them. It is important, however, to bear in mind that it exists in the air in the dissolved state, a matter to which more particular reference will be made hereafter.

Water is always produced by the combustion of organic substances containing hydrogen, and it accompanies carbonic anhydride, as a product of respiration. As its formula implies, it is a combination of two volumes of hydrogen with one volume of oxygen. It may be described as a perfectly neutral substance, exhibiting no active characters and possessing no power as an oxidising agent, although every 18 parts by weight contain 16 parts of oxygen. All its oxygen is utilised, so to speak, in retaining the hydrogen in combination, and in this respect it is widely different from peroxide of hydrogen or chemically oxygenated water, which is the substance that will be next considered.

Water plays an important part as an atmospheric constituent, inasmuch as it acts as a screen in preventing radiation of heat from the earth. In this direction the observations which were made by Tyndall are of special interest. In the forms of ice and steam its uses and properties are perfectly well understood, and are of the most important order. It is indispensable to animal and vegetable life, and it enters very largely into the composition of animal and vegetable tissues, even to the extent of from eighty to ninety per cent.

As a potable substance and in its relations to the subject of hygiene, we shall deal with it hereafter (see Chapter V.).

### *Peroxide of Hydrogen* (*Hydrogen Dioxide*).

*Formula* $H_2O_2$. *Molecular Weight* 33·92.

This substance was discovered by Thenard in 1818. He obtained it by acting upon barium dioxide with dilute hydrochloric acid, thus :

$$BaO_2 + 2HCl = BaCl_2 + H_2O_2.$$

In many of its properties it resembles ozone, and is, indeed, formed together with that substance during the electrolysis of acidulated water. When water is electrolysed, the theoretical amount of oxygen that should be obtained according to the equation $H_2O = H_2 + O$ is not yielded ; there is always a slight deficiency, a fact which is explained by the formation of peroxide of hydrogen.

Peroxide of hydrogen differs essentially from ozone and oxygen in being a liquid at the ordinary temperature and pressure of the atmosphere (although, in point of fact, a pure solution—that is, undiluted with water—has not, so far, been obtained). Moreover, whereas ozone is a gas which is very slightly soluble in water, peroxide of hydrogen is extremely soluble in water.

It will be seen from what has preceded that the composition of these two substances is perfectly distinct, but some few years ago their chemical nature was less clearly understood; hence some of the confused ideas that still prevail. F. Le Blanc believes that the peroxide of hydrogen which is produced during the electrolysis of acidulated water is due to the action of ozone upon the water.* This, however, is very improbable, and while there is no evidence in favour of the notion, Schöne has expressly satisfied himself to the contrary by careful experiments.

Peroxide of hydrogen may be prepared by suspending baric dioxide in water and passing a current of carbon dioxide gas through the mixture. The following equation represents the changes which occur:

$$BaO_2 + H_2O + CO_2 = BaCO_3 + H_2O_2.$$

That is to say, the carbonic anhydride unites with baryta to form the insoluble carbonate, whilst the second atom of oxygen in the dioxide of barium unites with the water to form the hydric peroxide.

As made in this way, the peroxide is very dilute, so that for all practical purposes it is better obtained by treating the peroxide of barium suspended in water with the theoretical amount of dilute sulphuric acid required to fully react upon it, as follows:

$$BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2.$$

or, as better shown:

$$BaOO + H_2OSO_3 = BaOSO_3 + H_2OO.$$

The sulphate of barium forms a white insoluble pre-

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* *Compt. Rend.*, lxxv., 537.

cipitate, while the peroxide of hydrogen passes into solution at once.

For commercial uses, it is generally prepared by a similar process to that just described, only in the place of sulphuric acid, hydrofluoric acid or hydrofluosilicic acid are sometimes used, in which latter cases insoluble fluoride or fluosilicate of barium are formed, peroxide of hydrogen alone remaining in solution.

The occurrence of peroxide of hydrogen in nature attracted but little attention until quite recently, and the fact is not surprising if it be reflected that there were but slight means of distinguishing between it and ozone. Moreover, many of the natural processes now well known to generate peroxide of hydrogen were up to the last few years regarded exclusively as sources of ozone. In fact, peroxide of hydrogen, giving the same tests, was mistaken for ozone.

Not only Schönbein and Dumas thought it probable that peroxide of hydrogen should occur in the atmosphere under certain circumstances more guessed at than determined, but Prof. Struve* claimed, in 1869, to have demonstrated its presence in the air as a product of simultaneous formation with ozone, and stated that the colouring of iodized starch paper when exposed to the atmosphere, is the joint result of the influences of ozone and peroxide of hydrogen. He also pointed out that peroxide of hydrogen may be condensed in rain-water.

Since that time, much attention has been given to

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* *Compt. Rend.*, 1869.

this subject by various observers, and particularly so since I discovered that all kinds of aromatic plants produce peroxide of hydrogen liberally. The way in which they do this is reserved for special description in a later chapter, and here the mere statement may be submitted, that probably all plants and flowers of perfume (at least, all those which are known to secrete essential oils) generate peroxide of hydrogen into the atmosphere, by the joint or successive action of air and water upon their essential oils.

Em. Schöne* found more peroxide of hydrogen in a litre of dew or hoar-frost during the summer months than during the winter months. In a lecture-hall which had been closed for some weeks, he also found about 0·17 cc. peroxide of hydrogen ($H_2O_2$) in 1,000 cubic metres of the air.

It will be understood that, as peroxide of hydrogen is abundantly soluble in water, its presence in rain-water or dew is not at all surprising. As the rain or waterdrops fall through or condense from the air containing the peroxide of hydrogen, this substance, of course, dissolves in the water.

In a subsequent investigation† Schöne found that 'the higher above the earth's surface the condensation of atmospheric aqueous vapour takes place, the richer in peroxide of hydrogen is the resulting precipitate.' This also is quite intelligible, since peroxide of hydrogen, like ozone, is unstable, and is readily

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* *Ber. Deut. Chem. Ges.*, No. 6, 1878.

† *Ibid.*, No. 8, 1878.

decomposed by organic matters generally, and these are most abundant near the earth's surface.

Then, again, Schöne finds* that in the strata of the atmosphere accessible to investigation, the amount of peroxide of hydrogen is greater the higher the sun rises above the horizon (both during the day and the year), and the smaller the obstructions to the sun's rays. He considers, therefore, that the amount of peroxide of hydrogen should notably increase towards the equator. This consideration is very probably a correct one, for in the tropical regions vegetation abounds most freely; and there it is that we meet with the greatest known source of peroxide of hydrogen. In those huge areas of vegetable life, every oil-secreting tree or plant is continuously giving rise to the production of peroxide of hydrogen as before mentioned.

M. Sergius Kern, following up the experiments of Schöne, has more fully examined rain-waters,† and he finds that equatorial winds bring rains much richer in peroxide of hydrogen than the rains carried by polar winds, thus lending confirmation to the above-expressed views.

Further, it has been pointed out by A. R. Leeds‡ that papers which have been moistened with potassic iodide and starch (Osann's test-papers) are not generally coloured at Hoboken, but only tinted on rare occasions. On the other hand, in Keene Flats, N.Y., the days were few on which no indication was

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* *Ber. Deut. Chem. Ges.*, No. 9, 1878.

† *Chem. News*, vol. xxxvii., p. 34.

‡ *Ibid.*, vol. xxxviii., pp. 224, 235, 249, 257.

obtained. It should be stated that the place of investigation in Keene Flats was 700 feet above the sea-level, and the surrounding vegetation was chiefly deciduous. At a point near the upper end of Upper Saranac Lake, which is even at a much greater altitude, and surrounded with miles of primitive forestry, embracing hemlocks, pines, larches, and spruces, the woods being often redolent with balsamic odours and extensively used as a health resort by large numbers of patients, Mr. Leeds found the most intense and frequent reaction with the test-paper. Although, in his published papers, he assumes this active constituent of the air to be ozone, the test employed, as already explained, is one equally sensitive to peroxide of hydrogen, whose very home is forestry embracing pines and spruces. It is certain, indeed, that the coloration of the test-paper was due to peroxide of hydrogen.*

M. J. Clermont† avers that he has detected the presence of peroxide of hydrogen in the juices of many bruised plants, such as the tobacco plant, the vine, lettuce, etc. The test, however, which he employed is just as characteristic of nitrites (which are far more likely to be present) as it is of peroxide of hydrogen. His statement having received no kind of confirmation, and a direct refutation at the hands of Prof. G. Bellucci,‡ it may be dismissed as erroneous.

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* *Chem. News*, vol. xxxvii., p. 243 (critical note by the author).

† *Compt. Rend.* No. 25, June 28th, 1875.

‡ *Gaz. Chim. Ital.*, Anno viii., 1878. Fasc. vii. and viii.

S. Cohné[*] has described some few simple experiments which, according to his interpretation, go to show that certain parts of plants, by contact with peroxide of hydrogen, give rise to ozone. In the same journal[†] I have critically examined Cohné's experiments, and have shown that his results admit of another and more plausible explanation. Peroxide of hydrogen, even in dilute solutions, undergoes slow spontaneous decomposition into water and free oxygen, and this decomposition is accelerated by contact with many substances. For instance, meat fibrin exhibits this contact-power in a remarkable degree; and it is not improbable that the fibrin of plants possesses a similar power, more particularly since, as Cohné himself shows, a stem is most active where it has been cut through. Now, in such a decomposition of peroxide of hydrogen, the oxygen escapes from a solution which is known to react with the test-mixture employed, and as the bubbles of gas escape from the fluid, they are probably saturated with the peroxide of hydrogen, just as ordinary air contains moisture. It is this escaping peroxide of hydrogen (which might also be carried up as spray) that Cohné evidently mistook for ozone. Thus, there is, as yet, no proof either that ozone in the presence of water yields peroxide of hydrogen, or that ozone is ever formed from peroxide of hydrogen.

Nevertheless, A. Houzeau[‡] thinks that in certain

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[*] *Chem. News*, vol. xxxiv., p. 4.

[†] *Ibid.* vol. xxxiv., p. 20.

[‡] *Compt. Rend.*, lxxv., 349—351.

cases—for instance, when ozone acts upon sulphindigotic acid—peroxide of hydrogen is intermediately formed in solution. This is by no means improbable; indeed, it is certain that other processes of oxidation also give rise to peroxide of hydrogen, both intermediately and finally. Thus, P. Schützenberger, in the course of some interesting experiments,* obtained results which led him to the conclusion that peroxide of hydrogen is intermediately produced by the action of air or oxygen upon hyposulphite of sodium. It is also formed as a final product of the atmospheric oxidation of the class of hydrocarbons known as terpenes, and of which turpentine is illustrative.

Having now briefly considered the various processes by which peroxide of hydrogen is formed, we may examine its nature and more important reactions.

It has been stated (see p. 42) that water was found by Cavendish to consist of hydrogen in combination with oxygen. In other words, two volumes, or atoms, of hydrogen, when exploded with one atom or volume of oxygen, combine and form one molecule (two volumes) of water :—

$$H_2 + O = H_2O.$$

Now, peroxide of hydrogen contains one more atom or volume of oxygen than does water in its molecule, and so it is represented by the formula $H_2O_2$.

It is this additional atom of oxygen that gives to

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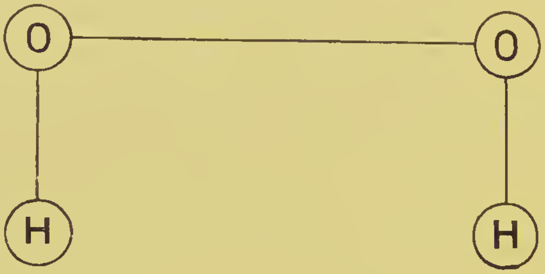
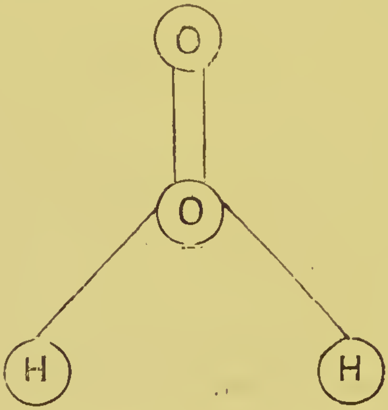
* *Bulletin de la Société Chim. de Paris*, vol. xx., p. 135. 1873

peroxide of hydrogen its important character as an oxidising agent.

The constitution of peroxide of hydrogen is not thoroughly understood. Generally, its constitution is structurally represented in this manner :—



which would signify that each atom of oxygen (here regarded as a dyad in atomicity) is directly combined with the other atom of oxygen, and with one atom of hydrogen. Such a formula altogether fails to explain the oxidising effects of the substance, and in my opinion it is to be regarded not so much as a peroxide of hydrogen in the strictly chemical sense, as an oxide of water, or oxygenated water. If my view be correct, then the constitution of peroxide of hydrogen may be represented thus :—



Here oxygen is represented as a tetrad in atomicity; the one atom is directly combined with two atoms of hydrogen, as in water; whereas the second atom of oxygen is combined only with oxygen, thus readily accounting for the best known properties of the substance. My view* is, I think, supported by certain observations which were made by M. Berthelot.†

By careful evaporation of a dilute aqueous solution of hydric dioxide *in vacuo* at low temperatures, it may be concentrated to a syrup which is colourless, and has a faint odour reminding both of chlorine and ozone. The product is, however, very unstable, and slowly undergoes decomposition, even at ordinary temperatures, as follows:

$$H_2O_2 = H_2O + O$$

the oxygen gas escaping in the form of minute bubbles. This decomposition is assisted by the presence of many substances (notably alkalies), and particularly of those which are themselves in a state of change or decomposition. On the other hand, the presence of a little ordinary ether restrains the decomposition; and, not unlikely, the reason for this is to be found in the fact elsewhere noticed, that ether itself gives rise to the production of peroxide of hydrogen by contact with air or oxygen and water.

If the syrupy solution of peroxide of hydrogen be heated to the boiling-point of water, it suddenly

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* *Chem. News*, vol. xlvi., 141.

† *Compt. Rend.*, 90, 572—577.

decomposes, and the oxygen escapes with explosive violence.

Peroxide of hydrogen is miscible with water in all proportions, and it is generally stated in chemical treatises that, although dilute solutions are more stable than strong ones, yet even they are immediately decomposed on ebullition. Indeed, this method has been advocated for estimating the strength of solutions by measuring the evolved gas. Experience does not bear out this statement. Early in my researches on the oxidation of the essential oils of plants, there was occasion to compare the properties of peroxide of hydrogen otherwise obtained with some of the products obtained in my experiments, and it was then found* that not only might dilute solutions of peroxide of hydrogen be boiled for some minutes without any appreciable decomposition, but that the presence of a quantity of chloride of zinc did not increase the amount of change. Mr. G. E. Davis has since obtained similar results,† and finds that a dilute solution may be concentrated, by evaporation, to half its bulk without driving off more than two-thirds of its active oxygen.

To illustrate the rate of decomposition of solutions as kept in the laboratory, Mr. Davis's figures may be quoted. The solution he operated upon was what is known as a "10-volume" one; that is to say, it was capable of evolving from its own solution ten times its own volume of gaseous oxygen when

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* *Journ. Chem. Soc. Trans.*, 1874, p. 14.

† *Chem. News*, vol. xxxix., p. 221.

fully decomposed. Thus, 100 cc. would evolve 1000 cc. oxygen ; in other words, it would contain 3·04 per cent., by weight, of peroxide of hydrogen ($H_2O_2$), and evolve 1·43 per cent. oxygen by weight :—

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| On August | 2nd, 1878, | the strength | of the | solution | was | 9 | volumes. |
| ,, | 9th, | ,, | ,, | ,, | ,, | 8·4 | ,, |
| ,, | 24th, | ,, | ,, | ,, | ,, | 8·0 | ,, |
| Sept. | 1st, | ,, | ,, | ,, | ,, | 7·9 | ,, |
| ,, | 24th, | ,, | ,, | ,, | ,, | 7·8 | ,, |
| Oct. | 24th, | ,, | ,, | ,, | ,, | 7·2 | ,, |

By adding a few drops of ether, this strength was maintained, for on testing two months later it was found to be the same as on October 24th.

Dilute solutions of peroxide of hydrogen, then, are tolerably stable, and particularly if they be of slightly acid reaction ; if, however, they be alkaline, owing to the presence of traces of soda, potash, or ammonia, then they are much less stable, and in particular evince a tendency to decompose entirely upon heating. The growing importance of the substance for commercial and surgical employment led me to make a careful investigation respecting the influence of a large number of substances upon it, and in the end I was successful in devising a chemical means of preserving it from any appreciable loss of strength by spontaneous decomposition. Full particulars of my observations will be found in the paper referred to at foot of this page,* and the 'Preserved Peroxide of Hydrogen' is now available as an article of commerce.† An alkaline solution of peroxide of hydro-

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* *Journ. Soc. of Chem. Industry*, Jan. 31st, 1890.

† It is made and sold under that name by the Sanitas Co., Lim., of Bethnal Green, London.

gen is partially decomposed by mere agitation, and the statement has been made that agitation with air is sufficient to entirely decompose even pure peroxide of hydrogen in course of time. Mr. Davis does not corroborate this result, and, indeed, finds that by the passage of fifteen cubic feet of air per twenty-four hours through a dilute solution, no peroxide is destroyed ; but, on the other hand, he has found at the end of the experiment an excess, even in the presence of caustic soda.

Two facts in connection with the last-named circumstance may be cited with interest. One has been pointed out previously, viz., that of the apparently well-ascertained production of peroxide of hydrogen or ozone by friction of waterdrops against atmospheric air. The other fact may have some connection, perhaps, with the possible behaviour of the caustic soda. Cuprous oxide ($Cu_2O$) shows no tendency to absorb oxygen and pass into cupric oxide ($CuO$) when it is suspended in water and subjected to a current of air. If, however, the water contains a very minute quantity of caustic soda, then, as I have ascertained, cupric oxide begins at once to form,* and goes on increasing until the whole of the red cuprous oxide is converted into the black (higher) oxide.

It is difficult to explain these facts, except on the supposition that caustic soda has the power, under given conditions, to absorb oxygen, and pass tem-

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* *Chem. News*, January 5th, 1872.

porarily into a higher state of oxidation. From this state it may be immediately reduced to its former condition by the action of the cuprous oxide, which seizes its excess of loosely combined oxygen for itself. No more attention can here be given to this subject, except to remark that, in common with many similarly interesting instances of slow oxidation, it calls for much further study and observation before an absolutely satisfactory explanation can be obtained.

There are several methods by which the strength of pure peroxide of hydrogen may be determined :

1. A given volume is taken and placed in a tube with excess of potassium dichromate ; on agitation over mercury, a quantity of oxygen gas is evolved, which, supposing 1 cc. of the peroxide of hydrogen has been taken, expresses its strength in so many volumes. Thus 1 cc. of a 10-volume solution would yield 10 cc. of oxygen at 0° C. and 760 mm. Bar.

2. A given volume of the peroxide is treated in a measured tube over mercury, with excess of acidified solution of permanganate of potassium, when oxygen gas is instantly evolved, according to the equation :—

$$Mn_2O_7 + 5H_2O_2 = 2MnO + 5H_2O + 5O_2.$$

It will be seen from this equation that only one-half of the evolved oxygen is derived from the peroxide of hydrogen ; and if this quantity be corrected for temperature and pressure, it agrees with the result furnished by the next method.*

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* In illustration of both these methods I have given examples in my papers published in *Journ. Chem. Soc. Trans.*, 1875 (p. 9 of paper), and *Ibid.*, 1880 (pp. 10—15 of paper).

3. When peroxide of hydrogen is added to a solution of potassic iodide which has been acidulated with pure dilute sulphuric acid, there is a liberation of iodine, which is revealed by the red colour acquired by the solution. The ultimate result of the reaction may be expressed thus :—

$$2KI + H_2SO_4 + H_2O_2 = K_2SO_4 + 2H_2O + I_2.$$

If starch be added to the mixture, the free iodine combines with it to form a splendid blue compound, which, by its depth of tint, serves to render the determination of the iodine more accurate. This estimation is effected by ascertaining how much hyposulphite of sodium of known strength is required to decolorize the solution thus :

$$2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6.$$

Before passing on to other considerations, it must be stated that the action of peroxide of hydrogen upon potassic iodide is by no means instantaneous in character. A certain amount of decomposition occurs at once ; but the rest of the decomposition is effected only very slowly, so that often half an hour ór more is required for its completion. The process is therefore tedious as ordinarily practised, and for many purposes the second method is preferable. I have, however, more recently ascertained that the process may be greatly expedited by the free use of acid, and if a great excess of acid be employed, the decomposition is completed almost immediately, so that the iodine which is liberated may be at once and accurately determined.* When the solution to be tested is stronger, it should be first diluted down to about 2-volume strength; that is to say, of such a strength that when appropriately decomposed it shall not be capable of giving more than twice its own volume of oxygen gas. It then suffices to take 10 cc. of this dilute solution, and add it to a previously prepared mixture of 20 cc. of a 10 per cent. solution of potassium iodide with 20 cc. of dilute sulphuric acid (strength 1 : 5 of water). Decomposition of the $H_2O_2$ is instantaneous and thorough, and the iodine thus liberated may be at once estimated by titration in the usual way.

In contact with pure potassium iodide, no acid being present, peroxide of hydrogen is resolved into water and oxygen, but iodine is not set free.

The decomposition that occurs between peroxide of hydrogen and permanganate of potassium in the presence of acid is not always explained by chemists in accordance with the equation given above, but in a recent paper† Messrs. Carpenter and Nicholson have confirmed the entire accuracy of the results, not only of my previously conducted study of the same reaction, but also those attending the estimation of peroxide of hydrogen generally.

The other reactions of peroxide of hydrogen are both interesting and numerous; but attention will be

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* See my report (part iv.) in *Journ. Chem. Soc. Trans.*, 1880, p. 802; and my more recent paper on the "Estimation of Peroxide of Hydrogen" in *The Analyst*, 1887.

† *The Analyst*, vol. ix., p. 36.

confined, in this place, to the more important ones only.

Peroxide of hydrogen furnishes a beautiful reaction with chromic acid, which first of all gives a blue colour with the peroxide of hydrogen; oxygen is then gradually evolved, the colour fading at the same time :—

$$2CrO_3 + 3H_2O_2 = Cr_2O_3 + 3H_2O + 3O_2.$$

If an excess of peroxide of hydrogen be used in this experiment, then a further reaction occurs, in which the $H_2O_2$ loses exactly double the amount of oxygen lost by the chromic acid, so that the ultimate result is—

$$2CrO_3 + 6H_2O_2 = Cr_2O_3 + 6H_2O + O_9.$$

Peroxide of hydrogen bleaches litmus and many other vegetable colours, and in recent years has been largely employed for bleaching human hair, to which it imparts a golden hue.

It oxidises sulphides, and thus converts black sulphide of lead into the white sulphate :—

$$PbS + 4H_2O_2 = PbSO_4 + 4H_2O.$$

It is decomposed by many metals when these are added to it in a state of fine division: gold, silver, and platinum, all occasion its decomposition in this way without being themselves thereby apparently influenced. This kind of action is well known in chemistry as contact action, but is at present without a satisfactory explanation.

The oxides of the three metals just named also decompose peroxide of hydrogen; and not only this, but they are themselves thereby reduced to the metallic state. If the peroxide, in a very concentrated state, be allowed to fall, say, upon argentic oxide, this double decomposition is attended with explosive violence, owing to the rapidity with which the large quantity of oxygen gas is liberated.

Peroxide of hydrogen, as we have seen, unless specially protected against such an occurrence, gradually undergoes spontaneous decomposition from the moment of its formation, and immediately that it comes in contact with bodies like argentic oxide, it gives a similar impulse to their molecular constituents, with the consequence of double and accelerated decomposition.

Brodie explained this fact by assuming that the second atom of oxygen in the hydrogen peroxide exists in a polar condition different from that of the oxygen in the oxide of silver; consequently, one being negative and the other positive, they exert a mutual tendency to combination, thereby forming a neutral molecule of oxygen.

All such actions and reactions may be explained in a general way which assumes nothing, while it suffices as an explanation. It is this. All substances, as we know and recognise them, exist subject to certain conditions; and the more easily these conditions can be influenced from without, the more easily do such substances undergo change. In brief, mechanical, chemical, or any other kind of motion, exerts an influence on the powers which determine the state of a body.

Peroxide of hydrogen is not alone decomposed by metals and their oxides, but by almost every substance which admits of being oxidised. Thus, ferrous sulphate is oxidised to ferric sulphate, and sulphuretted hydrogen is decomposed as follows :

$$H_2O_2 + H_2S = 2H_2O + S.$$

That is to say, water is formed in solution and sulphur is deposited.

Peroxide of hydrogen, as prepared by chemical processes, is now largely used in commerce for bleaching woollen and other fabrics, oils, wax, ivory, tobacco, blood serum, and engravings and paintings. For such purposes, or some of them, it is employed after being rendered strongly alkaline by the addition of caustic ammonia.

The therapeutic properties of peroxide of hydrogen will be more particularly described hereafter, and readers who are interested in this subject and the industrial applications of the same substance will find a good deal of information in my paper,* which is referred to below.

All animal and vegetable substances in a state of change or decomposition are rapidly acted upon by peroxide of hydrogen, much more vigorously, indeed, than by ordinary air or even pure oxygen ; and hereafter we shall see what an important part this substance plays as a natural disinfectant. It not only exercises a disinfecting action by virtue of its power

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* *Journ. Soc. of Chem. Indus.*, Jan. 31st, 1890.

to give up oxygen to decomposing matters, but it can absolutely arrest decomposition, and is destructive of the micro-organisms that breed putrefaction and various contagious diseases, as also the poisonous (toxic) bodies which are often produced by them when growing in suitable media.

These valuable properties of peroxide of hydrogen are well exhibited in the treatment of diphtheria by that substance, for, when applied locally, it destroys alike the micro-organisms which are intimately concerned with the disease, the so-called false membrane, which otherwise forms in the throat, and the poisonous products, the absorption of which into the system constitutes the greatest danger to be apprehended in cases of this disease.

Peroxide of hydrogen is perfectly innocuous, being non-poisonous, and without deleterious action on the skin or clothes, and it may be justly described as nature's own bleaching and purifying agent ; for it is often found present in dew and white frost, while as an atmospheric constituent, it constitutes the active principle in the so-called grass-bleach.

The natural production of this substance by certain processes has already been described, but the exact manner in which it is produced on a prolific scale in the atmosphere of pine, eucalyptus, and camphor forests, is reserved for special description hereafter.

# CHAPTER III.

## CHEMISTRY AND HYGIENE OF THE ATMOSPHERE—RESPIRATION—DIFFUSION OF GASES—VENTILATION.

THE atmosphere is a mixture of gases, consisting chiefly of nitrogen and oxygen. Carbon dioxide, aqueous vapour, ammonia, nitric acid, ozone, peroxide of hydrogen, and other sustances are, or may be, present in small proportions; while in the air of towns are also to be found carburetted hydrogen, sulphuretted hydrogen, and sulphurous anhydride, which substances are derived from the combustion of fuel (coal and coke) containing sulphur. Ignoring, for the moment, the substances that are present in minute quantity, air may be described as a mechanical mixture, containing in each 100 volumes, 79 volumes of nitrogen and 21 volumes of oxygen.

The water vapour present in the air exists in a dissolved condition in the other gases, and its amount varies with the latitude and season, being chiefly dependent upon temperature. Air, in nature, always retains the gaseous form, but the aqueous vapour which it is capable of taking up (absorbing) may be more or less condensed or separated therefrom, a fact which accounts for considerable variations in the composition of the atmosphere. The circulation of the air constantly exposes it to fresh conditions; at one time a part of the aqueous vapour may be precipitated as dew, or absorbed by dry tracts of land; while at other times, an additional quantity may be assimilated from rain, or from the ocean, or moist surfaces of land. Obviously the density of the air depends in part on the quantity of its contained aqueous vapour.

The amount of aqueous vapour present in the air varies with the latitude and the season, and in some localities, as, for example, the British Isles, even from day to day; thus one day we may have a cold, dry east wind blowing and the next day we may have a south-west wind coming off the Atlantic saturated with moisture. The amount of moisture which the air can contain, increases with a rise of temperature and *vice versâ;* so that if we have a quantity of warm air nearly saturated with moisture, and gradually cool it, we shall very soon reach the dew-point, or point of saturation, after which, on still further cooling, we shall find that the air being no longer able to contain all its moisture gives it up in the form of a fine rain. Thus, in England we get most of our rain with a south-west wind, the reason being that the air after coming over the Atlantic is both warm and saturated with moisture; therefore, when it reaches us and gets cooled down by contact with colder masses of air, or the cold sides of mountains, etc., it becomes supersaturated and is thus forced to give up some of its moisture in the form of rain or snow. On the other hand, if we take a mass of fairly moist cold air and heat it up, it becomes dry in character ; thus in winter, on going into a room heated with a stove, a very unpleasant sort of feeling is often experienced, in order to avoid which it is usual to evaporate a little moisture into the air by placing a saucer full of water on the top of the stove.

It is therefore evident that air containing a certain amount of moisture will, if heated, become what we call dry, whilst air containing the same amount of moisture when cold would be wet.

The amount of moisture present in the air has a marked effect on health, and it is found that most persons can stand very much greater extremes of both cold and heat when the atmosphere is dry than when it is moist.

The weight of one litre of dry air at 0° and 760 mm. of pressure is 1·2932 grammes. A cubic foot of air weighs at 60° F. and 30 inches Bar. 536·96 grains, but its density is known to diminish as we recede from the earth, which it surrounds as an atmospheric envelope to a calculated height of about 45 miles. We are enabled to register the constantly varying pressure of the atmosphere at the surface of the earth by means of the barometer.

The average composition of the atmosphere in this climate is expressed in the following table :—

| | |
|---|---|
| Oxygen - - - - - | 20·61 |
| Nitrogen - - - - - | 77·95 |
| Aqueous vapour - - - - | 1·41 |
| Carbonic Anhydride - - - | ·04 |
| | in 100·00 volumes. |

It is upon the oxygen which is contained in air that animal life depends, supporting as it does the process of respiration. It is also of great importance to plants, to which, in part, it is carried by the solvent action of water.

Some, at least, of the ammonia which is found present in the atmosphere and upon nearly all articles exposed to the air, even to the furniture of dwelling-houses, is produced by the decomposition of organic matter which is constantly taking place. This fact formed the subject of many interesting speculations and practical observations by the late Dr. R. Angus Smith,* and, indeed, he attempted to make the ammonia detected upon exposed surfaces serve also as the measure of organic matter present. Not only is ammonia derived from living organisms, but it results also from the decay of vegetable and animal matters; being volatile, it escapes into, and can always be detected in, the air, and generally in all water supplies also. 'A room that has a smell indicating recent residence will, in a certain time, have its objects covered with organic matter, and this will be indicated by ammonia on the surface of objects.' 'When a room is shut up even for a day, unless the room be very large indeed, there is always that peculiarity observed by sensitive persons to which there is given the name of closeness. To me,' Dr. Angus Smith continues, 'it seemed perfectly clear that the character of closeness was connected with

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* See *Sanitary Record*, Oct. 15th, 1883.

the existence of organic matter, and the organic matter with the ammonia.' Oxygen, as contained in fresh air, removes this closeness by freely oxidising the organic matter, the gaseous products being carried away in the currents of air which we admit into our dwelling rooms with the very object of getting rid of the closeness. The precise mode of action of the atmospheric oxygen involved in this process and that of purification generally will he dealt with hereafter.

It will suffice in this place to state that oxygen in one form or another is the great purifier that nature has provided for cleansing the air, the earth, the waters that are on the face of the earth, and all things that are in our houses and upon our bodies, from impurities that are more or less intimately associated with disease. No matter how concentrated the organic matter or disease-producing filth, atmospheric oxygen is all-powerful, if time and sufficient quantity be employed, to rob these matters of their power for evil, and even to transform them by oxidation into innocuous and useful products.

No better example of the beneficent action of atmospheric oxygen can be taken than that afforded in the process of respiration.

This process is of such high importance in relation to health, that we must now consider it somewhat in detail. By the action of the heart, the blood is pumped through the lungs at a rate which has been variously estimated as equal to from 10 lbs. to 27 lbs.

in one minute. The blood thus conveyed into the pulmonary capillaries is venous in character; that is to say, it is dark in colour and is charged with carbonic anhydride, which it has collected throughout the system as a product of the oxidation which is continually taking place within our bodies. This carbonic anhydride is an excretory product, and it is the very essence of respiration to get rid of it and aqueous vapour, and to introduce into the blood a new supply of oxygen, thus converting it into bright-coloured arterial blood.

The carbonic acid present in blood is there in two conditions. It partly exists in the state in which it is present in soda-water, and partly in combination with alkaline bases, notably soda. By certain chemical changes that occur, the whole of the carbonic anhydride is set free in the lungs, and it escapes along with watery vapour through the lung tissue into the respiratory passages. In exchange, the oxygen present in the inspired air is absorbed by the blood, where it enters partly, at least, into combination with its colouring matter, and is in consequence conveyed thereby to all parts of the body.

The manner in which arterial blood performs its oxidation in the system has been beautifully illustrated by an experiment devised by Schützenberger. He caused bright red arterial blood to circulate through a long system of hollow tubes constructed of gold-beater's skin, immersed in a mixture of yeast diffused in fresh serum (without globules) at a temperature of 35° C. (95° F.). As the blood traversed the tubes, it gradually parted with its oxygen to the yeast through the walls of the tubes, and then passed out at the end black and venous.

This parting with oxygen through the walls of the gold-beater's skin tubes serves also to illustrate the manner in which the blood becomes oxygenated in the lung tissue. The blood in the pulmonary capillaries (which are wide and thin-walled, forming an extensive network of small meshes) is separated from the air only by their own walls and the delicate lung membrane. Under these circumstances, it is easy to appreciate how the blood parts with its carbonic acid and becomes oxygenated. Gas which is mechanically held in solution has a tendency to diffuse into any atmosphere until it is present therein in a proportion corresponding to that remaining in solution. In this way the carbonic acid escapes from the blood. Again, gases separated from each other by a porous partition, diffuse into each other with a rapidity inversely proportional to the square roots of their densities. This law applies to the carbonic anhydride set free from the blood, and to the oxygen contained in the air on the other side of the lung membrane. Indeed, the exchange in question is promoted and not prevented by the intervention of the membranes of the lungs and the coats of the blood-vessels.

The composition of ten thousand parts of ordinary air, and the same quantity of expired air, respectively, is set forth in the following table* :—

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* Huxley's 'Elements of Physiology,' p. 85.

| | 10,000 *parts ordinary air.* | 10,000 *parts expired air.* |
|---|---|---|
| Oxygen | 2,100 | 1,500—1,600 |
| Carbonic Acid | 4 | 470 |
| Nitrogen | 7,900 | 7,900 |

The quantity of air that passes through the lungs of an individual in twenty-four hours varies with individual habits and bodily conditions. Dr. E. Smith gives from 804,780 cubic inches to 1,568,390 cubic inches; whereas Huxley, in his book already quoted, states that, taking no exercise, it is estimated at 350 to 400 cubic feet.

The water given off through the lungs in twenty-four hours has been estimated by Smith at an average of 311 grms., and the carbon (as carbonic anhydride) at from 7·144 to 11·7 ozs.

Oxidation in the human body is more active in youth than in advanced age; it is increased by cold and decreased by heat. Muscular exertion is the great incitive to active respiration, and by it the amount of carbonic anhydride which is expired, may be doubled or even trebled.

Asphyxia results whenever the amount of carbonic anhydride present in tidal air reaches 10 per cent.; but uneasiness and headache are caused when even less than 1 per cent. of the atmospheric oxygen is replaced by other matters. This is important, as indicating the necessity of keeping the air we breathe, fully oxygenated: the smallest diminution in the amount of oxygen present in the air suffices to cause serious results.

Poisoning by carbonic anhydride is rather the result of interference with the ordinary functions of oxygen than that of any direct action.

According to Huxley, every man, in order to be supplied with sufficiently pure air, should have at least a breathing space of 800 cubic feet, and that space should be in direct and intimate contact with the open air, as otherwise the oxygen originally contained in the air of the apartment becomes seriously diminished in quantity.

Of the total oxygen consumed by the body, about 85 per cent. is given off therefrom in combination with carbon as carbonic anhydride, and the remaining 15 per cent. combines with hydrogen, and is given off as aqueous vapour, also in respiration. Altogether, then, we find that 26·7 ozs., or more than 1½ lbs., of oxygen, are consumed daily by every adult. This weight of oxygen measures, at the ordinary temperature and pressure, no less than 529,400 cubic centimetres, or about 117 gallons.

The figures above given, give a concrete idea of the process known as respiration, and lead to the perception that respiration is not adequately expressed by saying it maintains life. It is seen to mean something more than this; for if we take the quantity of oxygen absorbed daily by each individual, and multiply it by the number of the world's inhabitants, we shall obtain an astounding figure representing the sum total of oxygen daily removed from the atmosphere by human beings. Of course this quantity is increased by the amount also consumed by other animals and in other natural processes, and it at once becomes evident that there must exist some natural compensating process of restoration to the atmosphere of the oxygen thus removed, or otherwise in the course of ages the atmospheric proportion of this gas would get so small that life would become impossible.

Upon inquiry, it is found that plant life furnishes back to the atmosphere the oxygen which animal life takes away from it. It is a fact that the growth and development of vegetation depends upon its elimination of oxygen from the very carbonic anhydride which animal life pours into the atmosphere. Priestley, who discovered oxygen, observed, for instance, that a pot of mint kept under a bell jar containing air which had been rendered impure by breathing, influenced the air in such a way as to make it fit to breathe over again. In short, the mint decomposed the carbonic acid, assimilating the carbon and restoring the oxygen to the air. What mint did in this simple experiment is also performed by the green parts of all plants and vegetables, and particularly by the leaves. In this way, the composition of the atmosphere is kept practically constant and universal.

Of course it will be understood that, although the composition of the atmosphere is of a fairly constant nature, yet its actual percentage composition is not entirely uniform. For instance, in the midst of a dense assembly of men in a room, there is found proportionately more carbonic acid and less oxygen in the air than in fresh country air; but there exists a law of nature which militates against such circumstances, and eventually overpowers all such localised effects. If we mix castor oil and water together, they will eventually separate, in spite of any amount of shaking, into two layers; but a similar behaviour is not observed with gases of different densities. Thus, if a heavy gas be brought into contact with a much lighter gas, the two will uniformly diffuse one into the other, and will not afterwards separate. This can be readily appreciated if it be borne in mind that gases consist of particles of matter widely separated from each other; hence, the particles of one gas can move into the spaces between those of another. This power or force of gaseous diffusion serves to prevent any evils which might arise from variations in the composition of the atmosphere owing to local circumstances. In the vicinity of limekilns, as in the neighbourhoods of human habitations, much carbonic acid is generated into the surrounding air; but, instead of remaining in these localities, it is carried away by the power of diffusion, and uniformly distributed in atmospheric space. Aërial currents (winds) materially assist, of course, in carrying out this process.

If we consider that oxygen is truly what the ancient chemists termed it—viz., vital air—it is not surprising that a small animal should be able to live longer in a confined space filled with that gas than in an equal volume of air containing, as it does, a large proportion of nitrogen. Nevertheless, oxygen cannot be breathed with impunity for any length of time; and, indeed, when inhaled in the pure state, it exercises a severe poisonous effect. M. Paul Bert, who devoted much time to the study of this subject, found that oxygen acts as a rapid poison when arterial blood contains 35 per cent., that is, nearly double the normal amount; the convulsions and death which result are due to a great exaggeration of the excito-motor power of the spinal cord. Compressed air behaves similarly. In dogs, convulsions begin when the external pressure of oxygen is about 3½ atmospheres, or 17 atmospheres of air, and death occurs at 5 atmospheres of oxygen.

As found, however, in nature, the oxygen of the atmosphere is diluted to a large extent with nitrogen which is innocuous to health. It is by this dilution that the oxygen is rendered powerless to produce the evil results which follow when the pure gas is breathed, while its power to oxidise the matters presented to it in the blood is not in any way impaired.

Respiration is a sort of combustion, since the same kind of thing goes on in the two processes, and is attended with identical results; the only difference between combustion and respiration being one of outside conditions.

If the atmosphere consisted entirely of nitrogen, it would be just as impossible for a fire to occur as it would be for animals to exist, because combustible matters and the oxidisable principles of blood and the tissues equally require oxygen wherewith to combine.

This process of oxidation or combustion is one which will have to be considered more fully hereafter, and the few words said about it here will pave the way for more important considerations.

Water and carbonic anhydride are not the only excretory products which result from oxidation within the living body. Other excretory products are passed through other channels; thus, urea, uric acid, and a number of allied compounds are carried away in the urine. Now, if the requisite amount of oxygen cannot be obtained by the body, two evil consequences result; on the one hand, active oxidation is repressed and vitality is hence lowered; and on the other hand, waste substances accumulate in the blood instead of being carried off, regularly, so soon as produced. Such a state of things inevitably leads to disease; the tissues of the body do not obtain proper nutrition, and headache, palpitation, and hurried breathing are among the less serious results. Anæmia and consumption are among the more serious consequences of breathing air deficient in oxygen. Ventilation is therefore designed to replace vitiated air with a fresh supply, care being taken at the same time to avoid a draught. From the results of some observations made by Dr. De Chaumont and others, the limit of respiratory impurity allowable is 2 parts of carbonic acid per 10,000 parts of air over and above that which is ordinarily contained, viz., 4 parts. In other words, when air becomes charged with carbonic acid to the extent of 0·6 per 1,000 parts, it is not longer fit for breathing.

As on the average an adult exhales 0·6 of a cubit foot of carbonic acid per hour, it follows that, in order to maintain the air of proper purity, fresh air must be admitted to the extent of 3,000 cubit feet per hour. It is not requisite to describe here the innumerable devices that have been made for ventilating purposes: they necessarily vary with circumstances and many local conditions.*

In practice it is found that in our climate the air of a living room cannot be changed more than from three to four times in the hour without causing a draught. If, therefore, a room has a cubic capacity of 750 cubic feet, it should be changed four times in the hour; while if the cubic capacity be 1,000 cubic feet, it should be changed three times per hour. For hospitals it is better to allow a cubic space for each individual of from 1,500 to 2,500 feet. It is, of course, desirable, where practicable, to warm or cool the air, according to circumstances, before it enters the room; the inlet should be in the lower part of the room, and the distribution should be made as uniform as possible, so as to avoid the production of a draught; on the other hand, the outlet for the fouled and heated air should of course be in the upper part of the room.

Artificial ventilation may be effected either by extraction of the fouled air, or by propulsion of fresh air into buildings. As a rule, however, neither of

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* A description of some of the better-known forms of ventilators will be found in 'Laws of Health,' pp. 36-44, by W. H. Corfield, M.A. (Longmans, Green, and Co.).

these methods is required for ordinary dwellings, into which it is sufficient, as a rule, to make adequate provision for the admission of the fresh air from without, to replace the impure air that is within. The superior density of the air gaining admission, thus effects the replacement of the lighter foul air.

300 cubit feet for each adult is the quantity of air space specified in the Model Bye-Laws relating to Common Lodging Houses, while two children under ten count as one adult.

For our soldiers, an air space of 600 cubic feet is allowed, and Allan* states that in consequence of this limited quantity, phthisis is very prevalent in the army. He also considers that the ideal initial air space should be from 1,000 to 1,200 cubit feet for each person. In connection with this subject, it must be borne in mind that gas-flames use up oxygen in burning, and allowance must be made for this loss in calculating the amount of fresh air that should gain access to a room in a given time. Corfield† states that 'two hard candles or one good oil-lamp consume as much oxygen and give out as much carbonic acid as one man,' and that one gas-burner is as prejudicial in fouling the atmosphere in this way as four or five men. As a rule, a means of escape for the vitiated air is provided by the chimney or flue. No doubt, the open fireplaces which are generally used in this country are wasteful of fuel

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* 'Aids to Sanitary Science.' By Dr. Francis J. Allan. (Baillière, Tindall and Cox.)

† 'Laws of Health' (Longmans), p. 30.

and baneful when viewed with regard to the production of smoke in towns; but they are beneficial to the extent that by their use the air of dwelling rooms is kept in constant change.

These facts are sufficient in themselves to indicate the great importance of having dwelling apartments properly ventilated; but they may be extended. It is known beyond all doubt that infection occurs through the air; that is to say, that the air may serve as the carrier of the germs of communicable diseases, and in proportion as the air is foul, the danger of infection increases, for the very foulness serves as food for the germs which produce many diseases. The poison of typhus fever, whatever its nature, whether it be a living micro-organism or a chemical compound, is particulate, and in the dry state it can float in the air and be sucked into the living body with the air we breathe. When the poison thus imbibed finds a home in the intestines, typhus fever may result. The same is in all probability true of the cholera poison, and of other infectants. By efficient ventilation, if such poisons be present, they are either carried off from the immediate neighbourhood of our bodies, or the air containing them is diluted by the fresh air to such an extent that the poisons are robbed of their power to produce disease.

It will be shown in a later chapter that mere dilution serves also to kill disease germs that may be present in water.

It is with the view of preventing infection by the passage into the system of poisons floating unseen in the air that we resort to fumigations, and to the employment of respirators. By fumigation we seek to evaporate into the air, chemical compounds known to be inhibitive to infectants, and by respirators we endeavour to strain off such infectants from the air we breathe, by means of a filtering medium, such as cotton wool (impregnated, it may be, with a suitable disinfectant).

Air may be rendered impure in various ways. It is greatly polluted, as we have seen, by the breath of animals ; it is polluted by the chemical products that are evolved from decaying and putrefying animal and vegetable matters, and also by the micro-organisms which originate these processes and are themselves multiplied thereby. It is further polluted by the smoke which is emitted from fires in dwellings, and by sewer gas which often escapes from the ventilators that are attached to sewers in towns, and sometimes, too, from the closets in our houses.

The atmosphere in the neighbourhood of chemical works for the manufacture of soda is generally contaminated with hydrochloric acid, which substance is very destructive of vegetation, and liable to produce pneumonia and bronchitis.

Carbonic acid ($CO_2$) is of course given off from every chimney, and is produced by the burning of gas, coal, coke and wood, not only in dwelling-houses, but also in factories. When present in the air to the extent of 50 to 100 parts per 1,000 it is capable of producing fatal results, while 15 parts per 1,000 generally produces headache and other indications of sickness.

Carbonic oxide ($CO$) is given off into the air from iron and copper furnaces, also from brickfields and cement works. It is an extremely dangerous substance, but, fortunately, by reason of the natural law of diffusion of gases, it is rarely present in the air in any dangerous quantity.

Sulphuretted hydrogen ($H_2S$) is another very poisonous substance which is sometimes found present in the air. It is for the most part evolved from chemical works, but it is also formed in smaller quantities during the ordinary combustion of coal and coke containing sulphur.

Sulphurous anhydride ($SO_2$) is a very objectionable impurity of the air we breathe, and is known to produce anæmia and bronchitis, when present in any considerable proportion, while it is almost as destructive of vegetation as hydrochloric acid. It is not only given off from copper smelting works, but also in the combustion of fuel in locomotives and furnaces. The air, for instance, of the tunnels of the Metropolitan Railway Company in London, is largely impregnated with this dangerous gas.

Decay and putrefaction are processes that should not be allowed to proceed in the vicinity of human dwellings, for not only are some of the immediate products poisonous, but filth is believed to afford the best nutriment to those dangerous micro-organisms which prey upon mankind. To prevent such processes from occurring in our midst we employ antiseptics and disinfectants.

The presence of smoke in the atmosphere is objectionable, because it is unnatural, and because it causes irritation in the air-passages of the lungs, by introducing therein, matters for the disposal of which nature has made no provision.

Closely related to the presence of smoke in the air is the production of town fogs, which prevail for the most part under the joint influences of a high barometer and a moist state of the atmosphere. Under these circumstances, the moisture is deposited in a particulated condition, and the particles aggregate and envelop the carbonaceous matters that may be present in the air at the same time. The increase of black fogs in London, Manchester, Glasgow, and other large towns, has been shown to bear relation to the increased consumption of coal. Such fogs are terribly injurious to animal and vegetable life, both by the stoppage of light as also by the toxic effects of the sulphurous acid and other impurities that are locked up in them.

While fog prevails, the proportion of sulphurous acid present in the atmosphere is enormously increased, and according to experiments carried out by a committee of the Manchester Field Naturalists' Society, the ratio of the minimum to the maximum was determined as 1 to 26. During a three days' fog, analytical observations proved that more than 1½ cwts. of sulphuric acid per square mile was deposited in the centre of Manchester, while at an outlying station 1 cwt. of the acid and 13 cwts. of 'blacks' per square mile were deposited in the same time. Such fogs are well known to cause a large increase in mortality from some chest affections and anæmia, although Dr. Theodore Williams has found that persons suffering from bronchitic asthma have, in some cases, benefited from London fogs and the air of the Metropolitan Railway. Asthma, is however, a very capricious disease, and as Mr. Ernest Hart* then pointed out, such a factor has no serious weight in considering the influence of black fogs on public health—an influence which may be regarded as entirely bad in character.

As for sewer gas, as a contaminating ingredient of the atmosphere, it is not merely objectionable because it contains a number of ingredients poisonous in themselves; it is more especially to be dreaded inasmuch as it is liable to contain in suspension some of the micro-organisms which are more particularly associated with specific communicable diseases. It is not too much to say that sewer gas should not be allowed to escape into the atmosphere of residential neighbourhoods at all, until it has been subjected to some treatment which has been proved to be efficient for the destruction or removal of the organisms to which reference has been made. Water-closets, as they are too often constructed, serve only, through their connection with the sewers, as ventilators thereto, and are instrumental in admitting direct into the air of dwellings the very poisons that are to be most dreaded. Where such arrangements cannot be readily remedied, we again rely upon the use of antiseptics or disinfectants, to supplement the action of the atmosphere.

The precise manner in which the oxygen of the air acts as a purifying agent is one which will be further studied in the next chapter.

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* See *British Medical Journal*, Aug. 15th, 1891, p. 372.

## CHAPTER IV.

### OXIDATION—PHYSIOLOGICAL COMBUSTION—NATURAL DECAY—FERMENTATION—PUTREFACTION—SANITARY BEARINGS OF THESE PROCESSES — MICRO-ORGANISMS AND THEIR RELATIONS TO THESE PROCESSES.

IN a previous place it has been pointed out that the processes of respiration and combustion may be regarded as identical in essence, both being of the nature of oxidation. It will be necessary, here, to define this latter process somewhat more fully, and to follow out its natural history.

Oxidation, then, may be said to occur when one substance gives up oxygen to a second one, and the substance which receives the oxygen is said to undergo oxidation; in other words, it is oxidised.

Charcoal, in burning, combines with oxygen from the atmosphere; it is oxidised, and the product of the combustion is carbonic anhydride, thus:

$$C + O_2 = CO_2.$$

If a jet of hydrogen gas be inflamed in an atmosphere of air or oxygen, oxidation also occurs, and water is produced, thus:

$$H_2 + O = H_2O.$$

Again, if any hydrocarbon, such as benzene or turpentine, be burnt in contact with sufficient air or oxygen, it undergoes oxidation, and yields water and carbonic acid gas as the ultimate products. For instance—

$$C_6H_6 + 15\,O = 6\,CO_2 + 3H_2O,$$
$$\text{and } C_{10}H_{16} + 28\,O = 10\,CO_2 + 8H_2O.$$

In the same way, every organic substance which exists in nature or can be produced in the laboratory, is amenable to this process of combustion. It is only necessary to properly mix the substance with something capable of giving up oxygen at the temperature employed, or to subject the substance to a current of air or oxygen at a suitable temperature, in order to decompose it by the act of oxidation which always results in the production of carbonic acid and water.

Of course, substances like sugar, which contain some oxygen as a constituent, require relatively less oxygen to burn them than they otherwise would, since the self-contained oxygen serves, in a measure, to consummate the process ; thus, sugar, in burning, becomes oxidised as here represented :

$$C_6H_{12}O_6 + 6\,O_2 = 6\,CO_2 + 6\,H_2O.$$

It is seen that if the sugar contained no oxygen in itself, its carbon and hydrogen would require 18 atoms of extraneous oxygen for perfect combustion, instead of 12, as is the case.

Even with carbon compounds of the greatest complexity, as also with organised matters, the law of combustion holds good. For instance, albumin—

which contains, besides carbon and hydrogen, nitrogen, sulphur, and oxygen, is, during combustion, similarly decomposed. The carbon forms carbonic anhydride ; the hydrogen forms water ; the sulphur forms sulphurous anhydride ($SO_2$), and finally sulphuric anhydride ; the nitrogen may be also oxidised, at least in part.

These, then, are the changes which organic compounds undergo when burnt or combusted in air or oxygen.

Respiration is combustion under different conditions and at a lower temperature ; and in this process a number of carbon compounds, or waste products of the living body, are, in the blood or tissues, converted by oxidation into carbonic anhydride and water, which are finally given out in the breath. It must be observed, however, that this process does not take place with the living matter of the body, or, at least, it has not been proved to take place therewith.

The actual process of physiological combustion is one about which there is a deal of dispute. While Carl Voit* insists that oxidation in the body results as a consequence of tissue decomposition, and forms products by the combination of the inspired oxygen with the substances resulting from tissue change, other physiologists, such as Hoppe-Seyler,† maintain that the combustion of albuminous matters in the organism takes place in the living cells of the

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* *Zeitschrift für Biologie*, viii., 297—388.

† *Pflüger's Archiv*, vii., 399—428.

tissues, and not in the lymph in which they are bathed, or in the blood, as held by some.

The bulk of evidence seems to be in favour of Voit's opinion, that the primary cause of tissue change is due either to ferments or some inherent cause which results in the production of certain proximate products of change, and that these being liberated into the juices of the body, combine with the oxygen there presented to them.

However that may be, it is accepted as generally true that no organised substance, whether it forms part of a vegetable or an animal, is subject to oxidation while it is vital. But, apart from the component parts of living tissues, there is no organised substance which can resist the process of oxidation as it is carried on in nature.

While life lasts, organised substances are protected from ordinary chemical influences of the kind under consideration, by reason of the concatenation of forces which govern their molecules; but when these combined forces are sufficiently disturbed, disease results, and when they are annihilated then death ensues, and the matter which was previously invincible by air and moisture now succumbs to their and other influences.

As respiration, although a rapid process of oxidation (seeing that 8·5 ozs. of carbon are daily oxidised in the body), is yet a slower one than that of ordinary combustion, so ordinary decay is very much slower than respiration. Nevertheless, it acts universally, and is omnipotent in its results.

In many places where mighty forests once stood, and where the soil must have been impregnated for countless ages with humus and loaded with vegetable substances, there can now be found no trace of organic remains. It is said that a few years suffice to clear the soil once occupied by the primeval forests of America, of organic matters.

Under ordinary conditions, humus slowly decomposes, and the carbonic anhydride and other products are absorbed by the roots and other parts of plants, and converted into starch, gum, sugar, etc.; but if the plant life be cleared away, then the access of air to the soil is facilitated, and the molecules of organic matter are rapidly acted upon by the air and moisture, and leave the soil as carbonic anhydride and water.

The same process of slow oxidation occurs in cemeteries, where the dead bodies are gradually burned up, leaving only their mineral parts behind in the earth.

Naturally, there are conditions which specially favour this process, as well as others which militate against it. Eremacausis (as Liebig termed it) proceeds most favourably in the presence of water, and at a slightly elevated temperature. On the other hand, if the access of air be limited, as it is, for instance, in a clay soil, then, as compared with a sandy soil, the process goes on but slowly. Accordingly, it is found that, under such conditions, or where the air has been entirely precluded, organic matter may exist for a very long time. Thus, as all the world knows, dead bodies are preserved to a large extent from decay by a method of embalming and wrapping, which keeps away the air and moisture so essential to slow oxidation. Indeed, the very existence of a mummy is, in its way, the best negative proof that could be submitted of the power of slow decay.

This marvellous process of oxidation is of infinite importance. By its action, the remains of animal and vegetable life are converted into the carbonic acid and water that are so necessary for plant life, and this, in its turn, gives back to animal life the oxygen which is essential to it. Thus, the round of nature's operations is completed, and living matter is continually and for ever being reproduced from the same original substances.

The process of natural decay, however, does not complete itself in one direct step, and this it is very important to understand. That is to say, compounds of vegetable and animal origin are not, by mere contact with the air, resolved by one direct step into carbonic anhydride and water. This undoubtedly occurs in combustion—at least, for all practical purposes, it may be assumed so to do—but it is otherwise with eremacausis. That process is gradual, and it occurs in several steps or by degrees.

In some cases, the oxygen of the air so influences organic matter that, by its combination, two or three or more distinct substances result, and only one or all of these may be subject to a further degree of oxidation, and each may take a different time to fully undergo the process.

Again, a complex substance such as albumin (white of egg) may be split up, by certain influences (as by hydration), into several distinct substances, before the oxygen of the air exercises any action whatever. That action, however, afterwards begins, its work being concerned with the derived or secondary compounds thus ready prepared for its effects.

To make this clearer, it may be stated that when white of egg or blood albumin is boiled in the laboratory with certain reagents, maybe under a little pressure or otherwise, it is resolved into a number of distinct substances, all of which undergo oxidation if they are then exposed to suitable influences, giving rise to quite a new (second) series of substances ; and these again can, by suitable means, be finally resolved into carbonic anhydride and water.*

No doubt, within the body (in respiration) and in other phases of nature, these conditions obtain, since within the body there are ferments, while widely distributed in nature there are very low forms of life (micro-organisms), both of which are of sufficient influence to split up albumin into a number of proximate constituent principles before the air (or oxygen) has exerted any kind of influence. Indeed, it appears from the life-long labours of Pasteur and others that the process of slow oxidation really depends upon the development of organisms in the interior or upon the surface of the substances which are in course of

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* Here, of course, for the sake of argument, we are only dealing with the carbon and hydrogen.

decomposition, and that in the absence of such organisms slow oxidation or combustion cannot occur. Just as the acetification of wines and beer depends upon vegetable growths (such as *Mycoderma aceti*) which possess the property of exciting oxidation in the solutions into which they may be introduced, so all other processes of slow combustion depend upon similar causes; and here we get a glimpse of the inutility of using agents like carbolic acid for the destruction of such living forms. For they are ubiquitous, and have a great function; it is their natural province to cause slow oxidation in refuse matters, that is to say, in matters of animal and vegetable origin; and if we could by any possible means exterminate this branch of natural beings, we should interfere with the way which was originally created and intended to serve as one of the greatest sanitary measures for human welfare. We may, however, rest assured that this is not possible.

Putrefaction is a different process, although it is allied to slow oxidation. The germs which initiate putrefaction cannot exist in the free presence of oxygen, and as we shall see hereafter, the chemical act which they perform is not one of oxidation, but, so far as has been ascertained, only a splitting up by hydration (absorption of the elements of water).

Since, in the first edition of this work, I dwelt upon the processes of slow decay and putrefaction as the grandest natural measures afforded by Providence for the disposal of organic matters, the same subject has been discussed by the late Dr. Angus Smith, who took up the consideration of this subject in an address delivered before the Sanitary Institute, in 1883. Speaking of the impurities that pollute the Clyde, and of the population that has grown up along the banks of that river, he said, 'If nature has contrived no method of destroying such seeds of death, populations such as this is would never have grown up. And what is the method? The method is, first, putrefaction; at least, I know of none other, except the concluding portion of the work, viz., thorough oxidation. When, therefore, you see the Clyde seething with gases of putrefaction, and when you smell it to such an extent that a feeling of loathing is produced, you may remember this—that the work of destruction is going on with a wonderful rapidity, and that the enemies of life are being slaughtered there, millions upon millions, never to appear again in a similar form, though other generations of them may rise up.' It will be seen by the reader that Dr. Angus Smith made the assumption that putrefaction *must* be the preliminary step to oxidation, but I doubt whether that assumption is well founded. Dry rot in wood is not preceded by putrefaction, and yet it is an active process of atmospheric oxidation carried on through the agency of micro-organisms. Again, the fermentation of alcohol into acetic acid is a process of oxidation carried on directly by the action of a cryptogam of the genus *Mycoderma*, and it is typical of a number of processes initiated by living organisms, which serve as media between atmospheric oxygen and the fermentable matter. While, therefore, I admit that putrefaction often, and very largely, precedes the oxidation of organic matters, I still think that it does not necessarily precede it. There are, I believe, many other processes of fermentation carried on by the life agency of micro-organisms which equally suffice to prepare the subject-matters for thorough oxidation.

In any case, putrefaction is a process which cannot lightly be allowed to proceed in and about human dwellings, because not only are many of the intermediate chemical products poisonous in character and capable of producing disease in man, but the process is too often associated with particular micro-organisms greatly to be feared. The process is a sanitary one in its ultimate results, and when it is carried on at a proper distance from the dwellings of men. Direct processes of oxidation may be allowed to proceed in and around our dwellings.

The chemistry of putrefaction will be studied more intimately in a later place, but it is worth while adding here, that sewage intended for use as manure is injuriously affected by putrefaction, for the process causes, and indeed is correlative with, a loss of substance, and constitutes the best preparation for a further loss of substance and value by the more direct and rapid process of ultimate oxidation which it induces.

Now, whatever oxygen, as air, is capable of doing in nature, in the shape of harmless oxidation, ozone and peroxide of hydrogen are much better qualified to do. Whereas air is a mixture of gases containing only 21 per cent. oxygen, ozone is a dense form of this substance, being many times more active than even pure oxygen; moreover, when strong enough, it is, in all probability, fatal to those low forms of life which cause putrefaction, and others which are very intimately concerned in producing disease. In support of this, it may be mentioned that Tyndall found that when infusions of highly putrefactive matter were subjected to the action of ozone, they remained quite sterile, while the action of condensed air neither prevented their putrefaction nor kept them free from germ life.

Peroxide of hydrogen also contains oxygen in a most powerful and active form: it no sooner comes into contact with oxidisable matters than it at once gives up its oxygen to them, in not only a pure but also a nascent state; and be it remarked that this is, universally, the most active state of gases. Moreover, by its liquid form (its wetness, so to write) it is particularly qualified to come readily into absolute contact with substances. It has, also, been shown that peroxide of hydrogen is fatal to many kinds of germ life, including those known to produce certain specific diseases. Putrefaction cannot occur in animal or vegetable substances protected by it.

The probable influences of ozone and peroxide of hydrogen, so far as they concern sanitation, will be more fully discussed later on; here it is sufficient to point out that, as compared with the atmosphere, and weight for weight, they act far more rapidly and powerfully as oxidants. The importance of this fact becomes at once apparent when we consider that, although some germs cannot live without oxygen, yet when it is presented to them in the form either of ozone or peroxide of hydrogen, they are either killed, or else prevented from carrying out their normal functions in compounds of an animal or vegetable origin. Septic organisms certainly cannot exist in the presence of peroxide of hydrogen.

Moreover, ozone and peroxide of hydrogen exhibit another and significant feature. To illustrate this: It has been already stated that there are degrees of oxidation. If turpentine be heated in contact with water and a stream of air, it suffers a change of a definite kind, but it is one which is gradual, and, amongst other products, peroxide of hydrogen is produced; but if turpentine be heated with nitric acid (also an oxidant, only far more violent in its action than air) it suffers a radical and quick change; the whole of the oil disappears, and if continued sufficiently long, the process gives only carbonic acid and water as ultimate products. Now let us pass from turpentine to albumin. If this substance be exposed to the air, it softens, and by the united action of water and air (under the primary influence of ferments) undergoes a complex process termed putrefaction, which is attended with the production of a number of substances, some of which are known, and some of which have not been determined. In process of time, however, the putrefaction passes away, and oxidation proceeds further, until the whole of the mass is oxidised into ultimate products. But if the albumin, instead of being exposed merely to the air, be boiled with dilute nitric acid, the end result is reached in a period of time which is infinitely more brief than that occupied by the more natural process of destruction.

Ozone and peroxide of hydrogen being similarly stronger agents of oxidation than the air, although not destructive and caustic like nitric acid, also have the power of preventing the putrefactive process to which allusion has been made; or if that process has already occurred, then of burning up or oxidising its products which are of a noxious character. If, now, it be reflected how much matter of animal and vegetable origin is given back to nature—and particularly among human populations—for disposal in a way which shall restore their elementary principles to a useful purpose without the attendance of disease, we obtain an insight into the importance of the process of oxidation, and can see why, at particular times and in special places, peroxide of hydrogen and ozone, two substances which are generated naturally, should exercise notable and beneficial influences.

Putrefaction is a process of such vast importance that it is necessary in this place to bestow upon it some little further special study.

In the first place, it may be remarked that the number of putrescible substances is not great, but they are universally distributed, being derived, as they are, from every organised being. Indeed, putrescence is a property almost or quite exclusive to the albuminous substances of which the flesh of animals is mainly composed, and which also enter into the composition of vegetable principles. It is these very substances which succumb most readily to decomposing influences. To understand this subject clearly, it must be borne in mind that no kind of substance has an inherent tendency to change except real living, germinal matter. No distinctly chemical substance has any tendency to change, although we often speak of certain substances being unstable, or having such a tendency. What is really intended, is to express the fact that some matters are more sensitive to extraneous influences than others.

Albumin is a chemical substance which, like all other chemical substances, exists in virtue of certain forces of combination acting between its constituent atoms; and by protecting it from outside attacks, it may be kept unchanged for an indefinite length of time, or eternally. But when it is exposed to ordinary air in the presence of water, it is open to the attacks of certain low forms of life which abound therein, and to which it becomes pabulum, and under their initial influence putrefaction sets in, and oxidation into ultimate products ends the history.

Liebig knew very well that if blood be protected from the air it does not pass into putrefaction; but he was wrong in supposing that it was the air itself which caused the blood to putrefy in course of time. It is not the air, but something which is in the air, viz., germs, or minute forms of life (micro-organisms or microbes), which are invisible to the naked eye under ordinary conditions, but which are known to form part of the motes to which a ray of light passing through a darkened chamber owes its visibility (*Tyndall*). That this is so has been well confirmed in some later experiments made by Lister, in which he demonstrated the fact that newly collected blood neither coagulates nor putrefies if care be taken, while collecting it, to exclude the presence of the micro-organisms which are contained in ordinary air. This may be done in several ways well known to scientific men. Air can be freed from its contained living matter either by heating it to a temperature sufficiently high to destroy it, or by filtering it through plugs of cotton wool, the meshes of which retain the micro-organisms, etc.

Recent researches have shown that germ-life is ubiquitous, and embraces an immense variety of species, so that the atmosphere is ordinarily loaded with a large number of forms. Accepting, therefore, the views of Pasteur, who has devoted his life to such studies, and taking blood serum to illustrate a putrescible substance, the history of putrefaction may be thus described:—One or more micro-organisms (vibriones) fall into the fluid, and by feeding in the medium which is suitable to their development, they propagate their species. Since they live upon the albumin which is in the serum, they thereby decompose it, splitting it up into a variety of products. Simultaneously, a film of other micro-organisms (bacteria, mucors, and mucidines) forms on the surface, owing to the introduction of other germs. Now, the life act of the vibrione is the impulse requisite for the decomposition of the albumin—for the initiation of putrefaction—and it may be fairly compared with the power of the liver to prepare bile from the albumin presented to it in the blood. It is even conceivable, if not probable, that the vital function of the vibrione is one of hydration (fixation of water), that is, an act which results in the same products, or some of them, as are obtained when albumin is boiled in the laboratory, say, with baryta water or dilute sulphuric acid.

Oxygen is fatal to the vibriones which are here mentioned, but being beneath the surface of the fluid, they are practically protected from its effects. On the other hand, the bacteria which grow on the surface of the serum, require oxygen for their very existence, so that they excite and accelerate the slow combustion of the first products which are generated by the initial impulse communicated by the vibriones to the albumin. As a final result of these changes vibriones and bacteria also die, pass into putrefactive change, and become oxidised with the rest of the matter.

Now, the particular forms of life which thus induce putrefaction, and those other living germs by whose agency slow combustion is eventually carried out, are, apparently, quite harmless in themselves when present in their ordinary numbers, since, being ubiquitous and freely inspired with the air and contained in the water we drink, no evil result is produced. Nevertheless, vibriones can convert serum of blood, which is perfectly harmless when fresh, into a poisonous mass. It has been shown by Panum and Burdon-Sanderson that putrilage, even when absolutely freed from every kind of germ-life, yet contains a particular chemical product which, if introduced into the blood system of animals, produces septicæmia.

The reader, to thoroughly appreciate the meaning of these facts, which have been ascertained with extreme care and with great precision, must keep his mind free, for the time, from all other considerations. Here a clear issue is presented: germ-life, harmless in itself under ordinary conditions, produces in the process of putrefaction a blood or septic poison. Whether this is the direct consequence of a vital act—the septic poison thus resulting as a chemical product of the pabulum consumed — or whether, as seems more likely, the organisms secrete a ferment which does all the chemical work, has not yet been satisfactorily decided. Such a chemical ferment or secretion may possibly have for its function the preparation of the dead matter as pabulum for the organisms, just as gastric juice prepares food for assimilation in the human body.*

Hereafter, more particular attention will be paid to the subjects of germs and infectious diseases.

In concluding this chapter, it is only proper to admit the great extent to which we are indebted to Pasteur

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* See Dr. Drysdale's Essay on the Germ Theories of Infectious Diseases, pp. 5 and 6.

for his masterly researches on putrefaction and fermentation. It is no exaggeration to say that we owe the larger part of our knowledge of these processes to his investigations. It was in 1863 that he defined[*] putrefaction as a fermentative process induced and sustained by animal ferments of the genus *vibrio.* This definition subsequently received confirmation from Traube and Gscheidlen[†] (among many others) in 1874.

More recently, M. Pasteur has found it necessary to divide micro-organisms into two large classes, which he designates *ærobies* and *anærobies.* The first class require for their growth the presence of oxygen; while the second group can entirely dispense with it. Thus, as has already been shown, septic vibriones are killed by free oxygen; and, indeed, putrefaction cannot be induced in a substance until certain other organisms (mucors) have first of all used up any oxygen which may be present. It was my privilege to confirm the general history of putrefaction and oxidation, as herein related, by some special experiments, of which a description was communicated to the Chemical Society in 1880.[‡] Some further account of micro-organisms in relation to the chemical processes which they are capable of initiating will be found in another chapter.

Finally, it must be remembered that slow oxidation

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[*] *Compt. Rend.*, lvi., 1189; *Jahresb. f. Chem.*, 1863, 579.

[†] *Dingl. Polyt. J.*, ccxxii., 352.

[‡] Contributions to the History of Putrefaction, Part I., *Journ. Chem. Soc.*, January, 1880.

or eremacausis is a process which must be deemed to occur in nature apart from putrefaction, at least in most cases. The two processes are in essence quite distinct, and depend upon entirely different micro-organisms. At times, undoubtedly, putrefaction either precedes or progresses simultaneously with slow combustion. Sanitary science cannot materially interfere with Nature's grand law of slow combustion; but it can, and does, aim at preventing putrefaction, together with all the evils that are apt to follow in its train when it occurs in or near human habitations; but when it takes place far away from populated places, putrefaction itself must also be considered as a sanitary process of the very first order.

The use of chemical substances for preventing the process of putrefaction in or near our homes is a subject which will be considered at some length in another part of this work. Many of the substances selected for this purpose act as poisons to the micro-organisms which induce the process ; others render the substances, which would otherwise putrefy, unfit food for them, and so on. It will be seen that the use of antiseptics or disinfectants for the purpose of preventing putrefaction is absolutely inexcusable when viewed apart from the main object of conserving the health of the people.

# CHAPTER V.

RAIN WATER—SPRING WATER—SEA WATER—RIVER WATER—WATER SUPPLY—SEWAGE CONTAMINATION—OXIDATION IN RUNNING STREAMS—MICRO-ORGANISMS AND WATER—NATURAL PURIFICATION OF RIVERS—THAMES WATER—PURIFICATION OF DRINKING WATER — FILTERS — CHEMICAL EXAMINATION AND ANALYSES OF WATERS.

WATER is not found in nature in a perfectly pure condition. Its solvent powers are so great that it dissolves from the atmosphere and from the earth, a variety of substances which, from a strictly chemical point of view, must be viewed as impurities. That is to say, they have nothing to do with the composition of water as water, and are indeed foreign to it. Nevertheless, they are not necessarily objectionable from a sanitary point of view.

Rain water collected after some continued fall, is as nearly pure as it can be found in nature, but even then it contains about 2½ volumes of air dissolved in each 100 volumes by measure. Such rain water is to be regarded as practically pure, and while upon this subject it may be remarked that it is a great pity that its collection for domestic employment is not more extensively carried out. The earlier fall of rain water which is collected after dry weather, is contaminated with traces of nitrates and nitrites, salts of ammonia, and some organic impurities; but none of these impurities are of very serious moment, and efficient filtration would make such rain water quite fit for many purposes, and the later portions would be even safe for drinking use.

After water has once come into contact with the soil, it becomes a solution of a number of saline substances which are contained therein, and it may also take up from animal and vegetable sources, a considerably larger proportion of organic matter. The nature of the salts thus entering into solution depends, of course, upon the character of the soil, but among the most usual impurities are chloride of sodium (common salt), carbonate of calcium (chalk), sulphate of calcium (gypsum), and sulphate and carbonate of magnesium. The increase in the quantity of nitrates and salts of ammonia found present in town waters is owing to contamination with decaying organic matters or with sewage which is undergoing oxidation by the air.

Most spring waters are charged with a considerable quantity of carbonic anhydride, which increases the solvent action of the water in respect of calcium carbonate. This explains why the waters derived from calcareous springs around London contain from 18 to 20 grains of chalk per gallon; this quantity is diminished upon exposure to the air, as during such exposure, carbonic anhydride escapes from the water, and this causes the precipitation of part (amounting on the average to one-third) of the chalk. The so-called 'hardness' of water is due to the presence of these dissolved substances collectively, and in the main to the mineral constituents. The mineral (inorganic) constituents, however, are otherwise comparatively unobjectionable in drinking-water; it is the organic matter that more often renders the water unfit for potable purposes. A general support is given to this statement by the well-known fact that so-called 'mineral' waters are taken on account of their reputed medicinal value, which is due to the salts that are present in large quantities.

Of course I do not wish it to be understood that all mineral constituents are harmless; their nature and quantity have to be considered. Lead and copper are very objectionable, and even salts of magnesia may be present in unsafe amounts.

Still more largely impregnated with dissolved salts is sea water; this has a specific gravity of about 1025 to 1027, and contains very large quantities of common salt and chloride of magnesium. The water of the British Channel contains 28·05 parts of common salt, 3·66 parts of magnesium chloride, and 4·7 parts of other mineral substances in each 1,000 parts of the solution.

River water is of the greatest importance from our point of view, since it is from rivers that most of our large populations derive water for drinking purposes. It often contains less saline matter than spring water, but is much more liable to be contaminated with organic matter derived from the extensive tracts of country which are drained into it. This organic matter is partly suspended and partly dissolved. The coarser suspended parts (weeds, fish spawn, leaves, twigs, grass, and fine mud) can be readily removed by subsidence and filtration, but ordinary filtration does not materially affect or remove dissolved organic matters, and is not supposed to remove micro-organisms in any great numbers, although they are in suspension.

The further elucidation of this subject may be as well carried out by taking up the study of Thames water, from which the London water supply is mainly taken.

The Thames is liable to contamination from persons who occupy house-boats during the summer, and who bathe in the stream; also by the dogs and other animals that are washed and drowned in it; it also derives a great deal of organic matter from the land on its banks, and particularly after the application of night-soil and other manures thereto, followed by a downfall of rain. Further, and chiefly, it is polluted by the untreated sewage of towns which in the upper Thames basin alone have a collective population of 72,628 persons, and the treated sewage of towns with a total population of 196,593 persons. The treatment of sewage, as here referred to, means the removal therefrom of the whole of the suspended matters, but it does not seriously affect the composition of the liquid part (effluent) which is then discharged into the river.

At first sight, it would appear reasonable to condemn such a river as the Thames as the chief source of the water supply for London upon the mere evidence that sewage is conveyed into it, but the analysis of the water which is actually delivered does not lend confirmation to this view; for, the total solid matters contained in the water amount to about only 28 parts in 100,000, and of this quantity only 0·174 consists of organic carbon, and 0·031 of organic nitrogen. That is to say, the organic substances present in 100,000 parts of the water furnish, upon analysis, the recited quantities of carbon and nitrogen.

The dissolved organic matter in potable water rarely amounts to more than from $\frac{1}{5000}$ to $\frac{1}{1000}$ of a per cent., and it cannot be pretended for a moment that anything more than a minute fraction of this small quantity is of a living nature; the bulk of it is certainly innocuous.

The following table is taken from a paper by Odling*:—

*Means of Eighteen Monthly Analyses*, 1883—1884.

| Source. | Proprietary. | Organic Carbon. | | Organic Matter. |
|---|---|---|---|---|
| | | Parts per 100,000. | Grain per gallon. | Grains per gallon estimated. |
| Chalk Springs | Kent Company | ·047 | ·033 | 0·083 |
| River Lea and Springs | New River Company | ·087 | ·062 | 0·156 |
| Mixed | Birmingham Corporation | ·132 | ·093 | 0·231 |
| River Lea | East London Company | ·139 | ·098 | 0·245 |
| Loch Katrine | Glasgow Corporation | ·147 | ·103 | 0·257 |
| River Thames | The Five Companies | ·164 | ·115 | 0·286 |

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* *Journ. Soc. Arts*, vol. xxxii., p. 934.

A consideration of these analytical figures shows that the organic impurities present in Thames water amount to barely twice the quantity which is contained in unpolluted waters, and the conviction is forced upon us that some great system of purification must be at work in the river Thames, and indeed in all running streams.

One of the opinions of the River Commissioners, expressed in their Sixth Report, was as follows: 'Rivers which have received sewage, even if that sewage has been purified before its discharge, are not safe sources of potable water.' It is our province in this chapter to seek to ascertain wherein lies the danger, or whether that opinion is not to be accepted as representing the truth. There can be no doubt of the fact that the Thames is heavily contaminated throughout a great part of its course with organic matter (say sewage). How is it, then, that the water taken from the river, and delivered for consumption in the Metropolis, is so comparatively pure, anyhow as regards the actual quantity of foreign substances present therein? No doubt, a very large proportion of the solid parts of excremental matter carried into the river, becomes deposited upon the bed of the stream and upon its banks, while the soluble impurities are diffused in the mass of the water, which is diluted from time to time by heavy falls of rain; for it must be remembered that the Thames drains an enormous tract of country, and, although it receives impurities throughout its course in consequence, it also receives continually increasing quantities of comparatively unpolluted water derived from the rainfall. This water is naturally aerated; that is to say, it contains dissolved oxygen; and then, again, the water in the river is exposed over its whole surface to the atmosphere, and being a running stream, new surfaces are being continually brought into direct contact with the oxygen of the atmosphere. Under these circumstances, oxidation rapidly proceeds by the operation of those laws which have been described in some detail in a previous chapter, and it is at least comparable with the rapidity with which nitrification takes place in soils which are laden with organic refuse. Further, it must be borne in mind that the vegetable growths which line the banks and bed of the river, as also the fish which inhabit the water, and the birds and winged insects which resort to the water for food, all act as scavengers to the stream, and assist in its purification.

That oxidation does proceed in the manner referred to, is best proved by the analysis of Thames water as delivered to the consumers, although there is no good reason for disputing it. The late Dr. Meymott Tidy endeavoured to obtain direct evidence upon this point,* and while he, in my opinion, claimed too much for the process (that is to say, he sought upon several occasions to credit the process of oxidation with an amount of work it cannot perform in a given time), yet he materially assisted the education of the public upon this important subject.

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* *Journ. Chem. Soc. Trans.*, 1880, p. 307.

In his experiments he employed 'a series of twenty troughs each ten feet long, and constructed of two pieces of wood joined together at a right angle. Each trough was so placed that it had a fall of one inch, the water from one trough being discharged into a second placed under, but a few inches distant from it.' Subsequently, he was compelled to line the trough with glass, and to take many precautions to keep out 'blacks' and other impurities. I will now quote the results of one of his experiments. Water was allowed to flow from a cistern placed above the uppermost trough, over the entire length of troughs, and then pumped up again to the highest trough, and so forth. In this way six gallons of New River water, containing 5·55 per cent. of added sewage, travelled one mile in 8½ hours, the temperature of the air ranging from 57° to 64° F., and that of the water from 55° to 61° F.

*Analysis:*

| | Oxygen required. | Organic Carbon. | Organic Nitrogen. | Chlorine grains. |
|---|---|---|---|---|
| | | Parts per 100,000. | | |
| Before experiment | 0·391 grains. | 0·436 | 0·156 | 1·40 |
| After experiment | 0·181 ,, | 0·274 | 0·100 | 1·44 |
| Results | – ·210 ,, | – ·162 | – ·056 | + 0·04 |

This and his other experiments may be accepted as giving evidence of the oxidation which proceeds in running water freely exposed to the air, but at the same time it cannot be accepted as substantiating the statement said to have been made by Dr. Tidy, to the effect that the polluting matter from sewage entering the river Colne was 'entirely destroyed after proceeding half a mile.' I think this statement represents a great exaggeration of the power of atmospheric oxidation, and I say this advisedly, having paid much attention to the study of various processes of air-oxidation.

In a paper* which was communicated to the Chemical Society in 1880, I brought forward some experimental evidence as to the manner in which organic matter present in water is gradually destroyed by the agency of micro-organisms, and I endeavoured to show by analytical figures that the primary chemical act of putrefaction thus induced is one of hydration, the secondary change being one of oxidation carried on by the agency of a distinct class of micro-organisms. Later on, when the subject of water supply was prominently before chemists, I described in another paper† some further observations of the same class, and also an experiment the result of which gave support to Dr. Tidy's experimental results above recited.

An aqueous extract of meat was allowed to pass into putrefactive decay, and periodically its oxygen-absorbing capacity was experimentally determined. Expressing the results in grammes and gallons, it was found that, whereas, at the start (when fresh), a gallon of the extract used up 6·656 grms. of oxygen (from the oxidising agent employed), after 39 days a gallon only used 5·79 grms., and after 155 days

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* *Journ. Chem. Soc. Trans.*, 1880, p. 15.

† *Chem. News*, vol. xli., p. 254.

only 3·243 grms. The diminution in oxygen thus consumed indicates the amount of oxidation which had proceeded in the meantime; the oxygen being absorbed from the air. A current of air was now blown through a quantity of the putrid extract during twenty-four hours, after which it was found that the oxygen-absorbing capacity had fallen per gallon from 3·243 grms. to 2·234 grms. oxygen. The difference represents oxygen used up from the current of air during the twenty-four hours.

That sewage, therefore, will under ordinary circumstances be destroyed in a river cannot be disputed. It is only a question of time, temperature, and length of the river. It is, however, of the greatest importance to bear in mind the fact that this destruction depends upon the life of certain organisms; indeed, if they be wanting, or if they be killed by chemical agents, the destruction of the organic matter will be postponed, the chief condition requisite for purification being wanting. Although the oxidation of organic matter dissolved in water is carried out through the agency of micro-organisms, oxygen itself is necessary as a correlative part of the phenomenon, and in connection with this subject I may quote some figures employed upon a recent occasion for illustrating the same truth, by Odling.* At a summer temperature of 70° F. water contains 1·8 cubic inches of dissolved oxygen per gallon, and 2·2 cubic inches at a winter temperature of 45° F.

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* In a lecture delivered before the Royal Institution on May 16th, 1884. See abstract in *Pharm. Journ.*, May 24th, 1884.

The smaller quantity thus held in solution amounts to 2·58 tons of oxygen per 10,000,000 cubic feet of water, and the larger quantity is 3·16 tons. According to a calculation that has been made, 64,000,000 cubic feet of water pass through Teddington Lock in each twenty-four hours during dry weather, and this contains 17¼ tons of dissolved oxygen; by the time this body of water reaches Somerset House it is found to have lost from 12 to 13 tons of oxygen, and this loss is supposed to represent the quantity used up in the meantime in the oxidation of sewage matter.

In connection with the subject of the self-purification of water, the observations recently made by Dr. Pehl* upon the water of the Neva are of some interest. This water is stated by him to be poor in bacteria, since it contains only about 300 germs in each cubic centimetre. After heavy rains the number rises to 4,500, and during the thawing of the river to 6,500. On the other hand, the water in the canals of St. Petersburg, which are fed with the water from the Neva, is infested with bacteria, their number reaching 110,000 in a cubic centimetre even in good weather. At the same time the chemical composition of this water is nearly identical with that of the Neva. He explains this anomaly upon the assumption that the purification of water is to be attributed in some measure to its rapid motion, and in order to test the matter he

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* Abstract of a paper in the *Journal of the Russian Chemical Society*, given in *Sanitary Record*, vol. v., p. 597.

brought water into rapid motion (in contact with air ?) by means of a centrifugal machine during one hour, and found that the number of developing germs was reduced by 90 per cent.

Personally, I do not attach any very great value to such bacterioscopic measurements, although it must be understood that by this remark I do not seek to throw any discredit upon the observations of Dr. Pehl. I rather wish to emphasise the fact that such bacterioscopic measurements may be exact or inexact ; there is great doubt about the matter on account of the minuteness of the objects, and the very small quantities of materials that are operated upon. It is different, however, with the larger animals met with in fresh water, and this is a subject which has recently been studied by Sorby,* who has endeavoured to ascertain the number contained per gallon, of the various small animals which are large enough not to pass through a sieve the meshes of which are about $\frac{1}{200}$ part of an inch in diameter. The chief animals met with in fresh water are various entomostraca, rotifera, and the worm-like larvæ of insects, and Sorby has found that the number per gallon and percentage relationships of these, mark in a clear manner changed conditions in the water, 'the discharge of a certain amount of sewage being indicated by an increase in the total number per gallon, or by an alteration in the relative numbers of the different kinds, or of both.'

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* *Journ. Soc. Arts*, vol. xxxii., p. 929.

Entomostraca will eat dead animal matter, and Sorby has kept them alive for many months by feeding them on human excrement, while they soon died without it; this fact, however, must not be taken to indicate that they are entirely dependent upon it. Now, although, as in the case of larger animals, a considerable part of their own excrements must consist of putrescible organic matter, there can be no doubt that the amount of sewage matter they consume is very great, and as a net result the dissolved organic matter present in water must be considerably diminished by their multiplication and their life processes.

Minute plants (diatoms, desmids, and confervoid algæ) may also play an important part in the purification of water, since when exposed to the light they decompose carbonic anhydride, and liberate oxygen which is required by animal life.

Dr. Jabez Hogg,* however, thinks that Sorby's examination of 'the coarser and more palpable contaminations of water will, under any circumstances, be of little moment. It is the minuter forms of organic life with which medical men are much concerned, and which are known to be of vital importance as matters of hygiene,' and he has called particular attention to the fact that the presence of large numbers of the various entomostraca, etc., is, in itself, the best evidence of the impurity of the water in which they abound, and that they have

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* *Journ. Soc. Arts*, vol. xxxii., p. 939.

often been known to produce serious outbreaks of illness (diarrhœa and dysentery). Without disputing the truth of Dr. Hogg's statements, I think they do not diminish the force of Sorby's contention; for it cannot be denied that animal life, no matter in what medium it be carried on, is sustained at the expense more or less of the pabulum upon which it subsists, and although it may be dangerous to drink water at a time when it abounds in animal life of a comparatively high pronounced type, the water is made less dangerous by the fact that it is thus rid of some of its organic impurities, and therefore affords less nourishment for the development therein of those still more subtle and dangerous micro-organisms to which Dr. Hogg exclusively confined his attention.

Mention has been made in an earlier place, of the argument which is advanced by many to the effect that when once a water-course has been contaminated with sewage matter, the water is rendered unfit for drinking purposes for all time. Not that some of the persons who advance this argument deny the purifying influences which have been described as being at work in running streams, but because disease germs may be introduced with the sewage matter, and it is contended that such germs are not destroyed along with the dissolved organic matter. In taking part in a recent discussion of this matter, Frankland said: 'From a strictly physiological point of view, the admission of sewage into the water supply of a town did not necessarily affect the health of the inhabitants drinking the polluted water; but if you have fever epidemics occurring upon the banks of such a river, if you have abnormal or infected sewage discharged into it, then you run a very great risk; you run a risk probably proportionate to the number of infected persons contributing to the sewage.'

In the same discussion, Dr. Jabez Hogg on the same side referred to 'the remarkable instance which occurred at Caterham Waterworks, where, by the merest accident of one workman suffering from typhoid fever, who went down into the well and worked there a few hours, and defiled the well, thus contaminating hundreds of millions of gallons of water which were pumped out and distributed to the townspeople round about, four hundred cases of typhoid followed the next week, and seventy or eighty deaths occurred in consequence.'

It may not be out of place to say just a few words here concerning those diseases which it is highly probable are, to a large extent, brought about by drinking impure water. Starting with the inorganic impurities, we find that the cause of goitre has from very early times been attributed to impurities in the drinking water, the principal evidence on the subject being that in places where goitre prevails there is nearly always a calcareous soil. Thus, in our own country we have what is often spoken of as the 'Derbyshire throat,' Derbyshire being the county where goitre is most frequently met with. The precise cause of the disease has not been satisfactorily established. It has, at different times, been attributed to excess of magnesium salts and others, which contribute to the hardness of water; again, to an insufficiency of iodine; but the evidence is very conflicting, and the subject is one which calls for investigation. Diarrhœa is also no doubt sometimes produced by drinking water containing impurities of an inorganic nature in excess, although organic impurities are probably more often the cause. Water containing a considerable proportion of sulphate of magnesium is known to be a strong purgative, as also water containing certain gases—for example, the Harrogate water, which contains large quantities of sulphuretted hydrogen.

Passing on to the more formidable foes which we imbibe with the water we drink, we come to cholera and typhoid fever. That these terrible diseases are very largely propagated by waters polluted with excremental matter there cannot be a shadow of doubt, the evidence on the subject is so extensive and so conclusive. It may, however, be interesting to quote the following case as an example: In 1854 the people of a well-to-do and healthy district of London round Soho Square suffered most terribly from the ravages of cholera, the death-rate for this small district for the month of September being 609, or 14·2 per thousand. In the centre of this district was the Broad Street pump, from which most of the inhabitants obtained their water, and upon inquiry, the fact was elicited that a child had died of cholera at No. 40, Broad Street, and that its excreta had been emptied into a cesspool about three feet away from the well. It was further discovered that the bricks of the cesspool were loose, and permited its contents to drain into the pump-well. But this is not all. A woman who had formerly lived in Broad Street was in the habit of having some water sent her every day from this well up to the West End, where she now resided. This woman and a niece of hers, who also took some of the water and afterwards returned to her home at Islington, both died of cholera, though at the time there were no other cases of cholera in the neighbourhood. The Caterham Waterworks epidemic above mentioned is a very similar instance. We thus see the danger of drinking water in any way contaminated with sewage, though a small amount of excreta from a healthy person would not necessarily make the water dangerous. To prove this, Dr. Emmerich, of Munich, drank daily for two weeks from ½ litre to 1 litre of very filthy water, in fact, nothing less than sewage, without any ill effect; moreover, he even claims that it improved a small gastric catarrh from which he was suffering at the time.

It has been urged that neither dilution nor oxidation of bad water will make it good, and a cursory examination of the subject will often give rise to the idea that disease germs are all but indestructible; some of them, or their spores, are said to require hours of boiling to kill them, and to be unaffected by such chemical reagents as cyanogen and sulphurous anhydride and other equally poisonous substances. Now, as regards the experiments with poisonous gases, which were conducted for Frankland, I could urge several excellent reasons why they should not be regarded as furnishing acceptable evidence of the contention he has based upon them, such as the insolubility of some of the gases with which he experimented, the insignificant qualities of other substances, and so forth ; but this is not the place for a detailed criticism of that kind. Boiling, even for a short time, may, it is admitted on all hands, be fairly well relied upon as sufficient to kill any disease germs that may be present in water.

Disease germs are of the same order in nature as the micro-organisms which breed common putrefaction ; they have the same short life-history. The history of their life-actions corresponds in all respects with the history of the vital actions of the vibriones that induce putrefaction, and the bacteria that cause oxidation of organic matter in water ; they die themselves and pass into putrefactive decay ; and just as micro-organisms of putrefaction can be readily killed by a thousand chemical reagents, so, in all probability, are the micro-organisms of disease subject to the same or similar influences. Their action can be arrested, diverted, or totally annihilated by the means which are commonly employed in medical practice for the treatment and cure of infectious diseases. The idea that micro-organisms have such a persistent vitality as is often represented arises, in my opinion, from a confusion of facts. The truth is that these low forms of life multiply very rapidly so long as pabulum (food) be afforded and the other conditions necessary to their existence be present; and too often, I believe, in course of observations, successive generations have been confused with the original organisms from which they proceeded. The yeast cells which give rise to the production of alcohol in a solution of sugar, are themselves killed by this very product when its proportion present in the solution rises to a certain definite extent, and so, also, other classes of ferments are destroyed by the products of their own life-actions, not to speak of outside influences which may be brought to bear upon them at will. It is not to be denied that, as in the Caterham case above mentioned, the introduction of disease germs into a water used for drinking purposes may lead to an epidemic, but it must be remembered that in this case the water was *immediately* delivered for consumption, and certainly it was not exposed to those conditions which must be accepted as constituting purifying influences, extending even to the destruction or removal of disease germs. Had the contamination, for instance, occurred at Oxford, then, I believe, the Thames water, as delivered at London, would not have caused further cases of the disease; and the proof is near to hand, if further proof be wanted: it is furnished by statistics, if statistics prove anything at all. Mr. Baldwin Latham has compiled a paper, in which he has compared the zymotic death-rate of those districts which derive their water supply from the River

Thames with those districts which obtain theirs from the chalk, and taking diarrhœa as a disease peculiarly attributable to bad water, it is seen that the death-rate in the district supplied by Thames water is actually slightly lower than that supplied by the Kent Water Company. Such a fact as this is simply irresistible. The fact is that atmospheric oxygen not only resists putrefaction, but it is absolutely fatal to a large class of micro-organisms, and it is idle to deny to atmospheric oxygen in nature the properties it has been proved to possess in the laboratory by men like Pasteur, who is a very apostle of the new teachings of sanitary science. Further, the difference in composition of Thames water and the deep chalk waters of Kent is so slight, and the proportion of organic matter dissolved in Thames water is so small, that even if it could be shown that the liability of different waters to contain disease germs in active vitality was in proportion to the relative amounts of dissolved organic matter, the relative superiority of the one water over the other for potable purposes is practically insignificant.

As directly bearing upon this subject, Odling made an interesting communication to a recent meeting of the British Association, as joint author with Mr. Crookes and the late Dr. Tidy. The virus of splenic fever (the well-known 'wool-sorter's disease') was disseminated in either sterilised distilled or sterilised river water in order to obtain a dilute infected water, and after standing a certain number of hours, portions of this water were added to an animal (cultivating) fluid in which the bacillus is known to be capable of reproducing its species, in order to ascertain whether or not the virus retained its capability of reproduction. The micro-organisms thus treated preserved sufficient vitality to allow of their propagating themselves for five or six hours, but the authors found that propagation does not take place after eighteen hours ; it would therefore appear that mere dilution effectively protects us from these organisms by impairing or destroying their vitality.

Thus, it is easy to see how the inhabitants of London escape infection from contamination with the sewage of Oxford and other towns which are situated up the River Thames. To infect the water supply of London with the same proportion of virus which was employed in the experiment just described, 1,000,000 gallons would be required. Computing the water supply taken from the Thames as it passes over Teddington Lock, it may be calculated that 50,000,000 gallons of infected solution would be required to pollute the Thames water to the extent of the pollution employed in that experiment, and even if this enormous and practically impossible quantity of infected matter could be imparted to the water, the experiments would seem to show that the resulting dilution would render it absolutely innocuous.

It should be added that these experiments were made with the bacillus and not with the undeveloped spores. Further experiments in that direction are promised.

There can be no doubt, then, that the provisions afforded by nature for the purification of the atmosphere are equally effective for the purification of water in a running stream. The air of towns is largely contaminated with organic matter, and is directly polluted, in the most real sense of that expression, with the germs that initiate disease. These germs are given off from the bodies of persons suffering from infectious disease, both externally (from the skin) and internally (with the breath and excreta), and must pass, in great measure, directly into the atmosphere. What is the consequence? To some extent, of course, the germs infect other persons, but by far the larger number must die either by a process of starvation, or by the action of sunlight* and fresh currents of air. Air which has been contaminated with sewage, or even with the most virulent germs of disease, thus again becomes fit to be breathed, and it is idle to deny that the same process of purification takes place in running water freely exposed to the air. If we are to condemn for all time, water which has once been contaminated with sewage, we must equally condemn our air-supply, and with the same zeal look out for a new one.

As a summary of what has preceded, and in order to resume the thread of our considerations, it may be stated that while Thames water, as now delivered to London for drinking purposes, is sound in quality, it is desirable that all possible means should be taken to exclude sewage contamination throughout the

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* Sunlight has been proved to kill bacteria with tolerable quickness (Koch).

course of the river, and in particular at Oxford, and thence to the pumping-stations near Teddington. This is desirable, because the germs which cause cholera and typhoid fever (not to mention any other diseases) are contained in the stools of patients suffering from these affections, and if they be swallowed while living, they may communicate the diseases to further persons: it is also desirable, because all the organic matter that is introduced into the river has to be oxidised or otherwise destroyed, or removed; and the less therefore that is introduced, the smaller is the tax made upon the purifying agencies that are at work or have to be pressed into service. Moreover, it may be conceded that an impure water, loaded with fæcal matter, affords much better pabulum for the maintenance and reproduction of disease germs than a pure water practically devoid of suspended and dissolved organic matter. In my opinion, therefore, no untreated sewage should be allowed to enter the Thames from its source to its mouth. Wherever there is sewage to be disposed, it should be so treated that the solid parts are removed or separated from the liquid parts. The solid parts should never be allowed to enter the river, and if the liquid parts can be passed over land before entering the river, or exposed to some well-advised chemical treatment, so much the better; but the impurities conveyed by the liquid parts are insignificant as compared to the solid parts, and are destroyed in course of time by oxidation.

In connection with this part of the subject, I am entirely at one with Mr. Cresswell* in thinking that the public at large owe a debt of gratitude to the companies who have risked much capital and expended much labour and time in seeking to remove from sewage its solid parts by precipitation or otherwise, and thus keeping it out of the River Thames. A similar debt of gratitude is due to all reformers in sanitary science, and to all who increase the means of lessening human suffering, no matter in what direction.

As regards the purification of water by artificial means, very few words will suffice. We have seen with what good effects the oxidation of organic impurities is carried out naturally ; it is, therefore, justifiable to believe that the purification could be carried still further, when desirable, by an artificial process, in which the water before or after filtration should be exposed to a current of air. This current of air might be pumped, under pressure, into the water contained in a suitable vessel, or led into the water contained in the reservoirs. For this latter purpose all that is required is a series of perforated pipes, lying upon the bed of the reservoirs, and conveying air direct from the pump. I have a very strong opinion that the London and other water companies might profitably make use of this suggestion.

Since the second edition of this work was issued the purification of water supply by means of aëration has been put forward in America as a new discovery. Dr. A. R. Leeds, it is stated, found that the advantageous action of air upon water was increased by

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* *Society of Arts Journal*, vol. xxxii., p. 450.

bringing the two substances into contact under pressure, the purification, indeed, being to some extent proportionate to the pressure. In some experiments made at Philadelphia, where air was forced into the main, the percentage of oxygen in the aërated water was 17 per cent. greater than before; that of carbonic acid was 53 per cent. greater, and that of the total dissolved gases 16 per cent. greater; on the other hand, the free ammonia was diminished 1·5 of its former amount. Public attention in America has been directed to these results by a report of Dr. W. H. Wahle, the Secretary of the Franklin Institute.

In a recent paper,* Mr. W. Anderson, M.I.C.E., described the purification of water by means of iron on a large scale. The process consists in bringing the water into intimate contact with a mixture of spongy iron and gravel, and has been applied for some extended period to the water of the river Nethe at Antwerp. Acting upon a suggestion make by Sir Frederick Abel, to the effect that, if iron exerted a purifying influence on water, it would obviously exert it to the greatest extent in a given time if the surfaces of the iron and water coming into contact were constantly renewed, Mr. Anderson made use of a revolving cylinder, fitted with inlet and outlet pipes, and with shelves or ledges for scooping up the iron, etc. In actual use he managed to get 166 gallons of water passed through the 'revolver' per minute: this gives a contact of about 3½ minutes, and is said to be amply sufficient. The charge of

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* *Society of Arts Journal*, vol. xxxii., p. 963.

iron is about 500 lbs., and the water takes up (dissolves) and mechanically carries away about 0·176 grain per gallon. Mr. Anderson adds: 'By making suitable arrangements, and choosing a favourable time with respect to the demands of the town, we were able to obtain samples of water that have been purified by the "revolver" only, and after proper exposure to the air, followed by filtration through one of the large sand filters, the result obtained has been that the colour was very little different from distilled water, the free ammonia was reduced from 0·032 grains per gallon to 0·001, and the albuminoid ammonia from 0·013 grains to 0·0045.'

The iron used in this process may be supposed to act in several ways; firstly, as a mechanical agency for bringing the particles of water into intimate contact with particles of air contained in the vessel; secondly, as a filtering or screening agent, aggregating to itself the suspended particles of organic matter previously contained in the water; and thirdly, by passing to a small extent into solution, in which case it may be supposed to act as a chemical carrier of oxygen to the organic matter dissolved in the water; for the iron in solution would presumably be first oxidised to the ferric state, and alternately reduced to the ferrous state. The purification of the water, however, is not entirely due to the action of the iron: it is partly due to subsequent exposure to the air, and also to the filtration through sand. Whatever action iron may have, it can only assist in the process of purification, which is really effected by the agency of oxygen.

These few remarks lead us to the subject of domestic filters, which primarily act as strainers. Few of them do more than remove from the water the larger suspended particles. There is a notable exception, however, to this class of filters, and that is the so-called Berkefeld filter of which a description is given below. The agents which are used in ordinary filters (such as prepared charcoal, silicated carbon, spongy iron, and so on) are not known to be destructive of toxic products, and considering their insolubility, it is almost impossible that they can act as germicides. If, therefore, the use of such filters promotes the purification of water, apart from removing the coarser solid suspended particles, it is by bringing the water into intimate contact with aerated surfaces of the filtering medium which is employed; but this implies that due provision is made (and, as a matter of fact, it is not generally made) for renewing from time to time the efficiency of the said medium by freely exposing it to the air. In the absence of such a provision of an effective character, the offensive matter abstracted from the water accumulates in the filter and chokes it, and unless it is removed from time to time, water may be rendered impure, instead of becoming purified by its passage through the filter.

The Berkefeld filter is constructed on the same principle as the older Chamberland-Pasteur filter, in which latter the filtering medium consists of biscuit porcelain, the water being made to filter through a candle or bougie made of that substance from without, the delivery being from within the said candle. The use of this filter in the French army has been attended, it is said, with the most satisfactory results,* particularly in diminishing cases of, and deaths from, enteric fever. The Chamberland-Pasteur filter undoubtedly sterilises water by mechanically removing the micro-organisms which may be present therein; but, unfortunately, the amount of water that can be filtered in a given time is very limited, even when pressure is employed to assist the passage of the water through the filtering medium. This objection does not lie to nearly the same extent with the Berkefeld filter, in which a different filtering medium is employed. It consists of prepared Kieselguhr (fossil earth), which is composed of the siliceous skeletons of diatomaceæ. These skeletons are ladder-like and interlacing, and furnish an enormous number of very minute pores or spaces, thus affording a free passage for the flow of liquid through them, while at the same time the passage of all solid particles, and even micro-organisms (bacteria, etc.), is arrested. The impurities which are thus removed from water in course of its filtration through candles of this prepared compressed Kieselguhr, collect on their outside surfaces, and can readily be removed from time to time by brushing. Moreover, when required, the candles themselves can be sterilised by placing them in warm water and boiling for an hour or so.

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* See a review of the Army Medical Department Report for 1891 in *Lancet*, Sept. 9th, 1893.

The investigations of Mr. William Thomson, F.R.S.E., of Manchester, Dr. Percy Frankland, and many other authorities, have satisfactorily established the fact that the Berkefeld filter really sterilises water, by removing therefrom all microbic life. The importance of this fact is paramount, and the use of the filter by the public at large will beyond question give most material assistance to securing immunity from such diseases as cholera and typhoid fever, which are too often spread through impure water supplies.

In the chemical examination of water, regard is had not only to suspended matters, hardness, and to the determination of the amount of organic matter in the filtered water, but also to the presence of chlorine, ammonia, nitrites, and nitrates. A hard water is understood to mean a water which uses up a good deal of soap before a lather is produced in washing operations; the destruction of soap arising from the formation of insoluble salts by the combination of the fatty acids of the soap with the lime and magnesia present in the water, and it is not until these mineral salts have become exhausted that there is produced a lather. As already explained, this hardness arises from the collective presence of the dissolved matters, including minerals salts, carbonic anhydride, and organic substances.

For softening very hard waters, which owe their hardness, in part, to carbonate of calcium held in solution by the agency of carbonic anhydride, the process originally devised by Dr. Clark, and improved by Mr. Porter and Mr. Atkins respectively, is often employed. The process practically consists in the use of lime either as a filtering medium, or added in the form of milk, by which means the carbonic anhydride enters into chemical combination with the lime to form insoluble carbonate of calcium, and, as a further consequence, some of the dissolved carbonate of calcium is precipitated from the water.

Water may be, also, softened by boiling; the decrease in hardness thus produced is termed the 'temporary hardness,' while that which remains is styled 'permanent hardness'; together they equal the 'total hardness' of the water. The 'temporary hardness' is due to the presence of carbonic acid, which escapes upon boiling, and to that amount of carbonates of calcium and magnesium which is at the same time deposited out of the solution in which it was previously dissolved by the agency of the carbonic anhydride; so that softening by boiling resembles softening by means of lime, as in Clark's process.

Chlorine is present in water chiefly in the form of common salt, and it is of importance to determine the quantity, since it may indicate existing pollution with sewage which contains a large proportion of chlorine. The amount present in good waters varies from 0·22 part to above 5 parts per 100,000, and represents common salt dissolved out of the air and soil by rain. Urine contains about 500 parts of chlorine per 100,000 parts, and 58 samples of sewage from midden and water-closet towns were found by

Frankland* to contain an average of 11 parts per 100,000.

Ammonia, when found present in water in any considerable proportion, is supposed to indicate the presence of animal matters in the earlier stage of decomposition. In rain-water collected in the country, the proportion of ammonia is about 0·03 part, whereas town rain-water may contain as much as 0·21 part per 100,000; this larger quantity is dissolved from the air. The average amount in river water is about 0·01 part per 100,000. In sewage, the ammonia varies from 2 to 10 parts per 100,000.

The nitrates and nitrites found present in water are derived by, oxidation, from the ammonia formed at an earlier stage; or they may be produced directly from nitrogenous organic matter, as explained in an earlier chapter. Rain-water may contain about ·04 part of nitrogen in the form of nitrates per 100,000, but when collected in towns, the quantity is often much greater. Frankland puts down the average quantity present in upland surface waters at ·009 part per 100,000. Thames water contains about 0·2 part nitrogen (combined in the form of nitrates and nitrites) per 100,000 parts, whereas from the deep wells in the chalk the quantity rises to 0·426 part. No doubt the amount of nitrates found present in deep well water often represents previous sewage contamination, but it also indicates the purification that has taken place by oxidation during the filtration of the water through the chalk hills.

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* 'Water Analysis' (Voorst), p. 19.

Surface wells often yield water which is fouled by recent drainings from cesspools, cultivated land, and refuse matters.

By the logical use of the results obtained from the analysis of waters, combined with a knowledge of their history and a microscopical examination, it is not difficult for chemists to form a thoroughly sound judgment as to whether they are or are not fit for drinking use, notwithstanding all that has been said to the contrary by engineers and biologists.

If chemists cannot pronounce positively concerning the absence or presence of disease germs in water (and, at least, they are as well qualified to express an opinion even on this subject as any others), they can at least ascertain from its composition and history whether it is likely to contain and sustain them or not. Engineers can do nothing in this direction, and biologists cannot provide any better tests of the purity of water.

It may be remarked that very frequently water is sufficiently pure for all cleansing and washing operations, and yet may be dangerous for drinking. Wherever any doubt exists, it is best to have recourse to the use of a Berkefeld filter.

The following analytical figures, showing the chemical contents of various waters, are extracted by consent from tables given in Frankland's treatise on water analysis, to which reference has been previously made :

## TYPICAL ANALYSIS OF WATER. PARTS PER 100,000.

| Description. | Total Solids. | Organic Carbon. | Organic Nitrogen. | Ammonia. | Nitrogen as Nitrates and Nitrites. | Chlorine. | Hardness. | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Tempo-rary. | Perma-nent. | Total. |
| *Rain.* | | | | | | | | | |
| Rothamsted . . | 2·16 | ·062 | ·007 | ·027 | 0 | ·10 | .. | ... | ·8 |
| London . . . . | 2·76 | ·383 | ·040 | ·210 | ·008 | ·50 | ... | 1·1 | 1·1 |
| *Deep Well.* | | | | | | | | | |
| In Devonian rocks and mill-stone grit . . | 32·68 | ·068 | ·012 | ·005 | ·294 | 2·70 | 8·8 | 8·6 | 17·4 |
| In magnesian limestone . . | 61·14 | ·076 | ·030 | 0 | 1·426 | 4·31 | 16·9 | 26·9 | 43·8 |
| In chalk below London clay . | 78·09 | ·093 | ·028 | ·048 | ·068 | 15·02 | 9·7 | 8·7 | 18·4 |
| *River.* | | | | | | | | | |
| Thames . . . . | 28·03 | ·201 | ·033 | ·0006 | ·210 | 1·73 | ... | ... | 20·4 |
| Lea . . . . . | 27·82 | ·128 | ·023 | ·0004 | ·201 | 1·77 | ... | ... | 20·9 |
| *Shallow Well.* | | | | | | | | | |
| Twickenham . . | 82·08 | ·739 | ·093 | ·740 | 2·708 | 7·8 | 22·5 | 21·8 | 44·3 |
| Tottenham . . | 130·44 | ·108 | ·053 | ·002 | 3·974 | 8·4 | 35·2 | 39·8 | 75·0 |

## AVERAGE COMPOSITION OF UNPOLLUTED WATER. PARTS PER 100,000.*

| Description. | Total Solids. | Organic Carbon. | Organic Nitrogen. | Ammonia. | Nitrogen as Nitrates and Nitrites. | Chlorine. | Hardness | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Tempo-rary. | Perma-nent. | Total. |
| Rain Water . . | 2·95 | ·070 | ·015 | ·029 | ·003 | ·822 | ·4 | ·5 | ·9 |
| Upland Surface Water . . . | 9·67 | ·322 | ·032 | ·002 | ·009 | 1·13 | 1·5 | 4·3 | 5·8 |
| Deep Well Water | 43·78 | ·061 | ·018 | ·012 | ·495 | 5·11 | 15·8 | 9·2 | 25·0 |
| Spring Water . . | 28·20 | ·056 | ·013 | ·001 | ·383 | 2·49 | 11·0 | 7·5 | 18·5 |

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* To convert parts per 100,000 into grains per gallon multiply by seven, and divide the product by ten. To convert grains per gallon into parts per 100,000, multiply by ten, and divide by seven.

# CHAPTER VI.

## COMPOSITION OF THE EXCRETA—SEWAGE: ITS NATURE, DISPOSAL, AND TREATMENT BY IRRIGATION AND CHEMICAL PROCESSES—THE AIR OF SEWERS, AND THEIR VENTILATION—DRY SYSTEM.

THE sewage of different towns varies in composition, not only according to the system of drainage employed and the amount of water supply, but also with the various trades or manufacturing processes which are carried on locally. In some towns a 'separate' system of drains is employed for sewage proper, the rain-water which is collected from the housetops and streets being drained off quite apart and discharged into the nearest watercourse without treatment. There can be no objection to this proceeding provided that the said watercourse is not immediately utilised as a source of water supply for drinking purposes, so that the water may become purified (by the agencies described in the last chapter) before it is abstracted for distribution. This separate system of drainage is to be commended since, when used, the sewage from any one town is of tolerably constant composition and bulk, and the total quantity to be dealt with is much less than in those cases where rain-water is admixed with the sewage and carried off in the same channels. It will be readily appreciated that a plan of treating sewage adapted to a given quantity of a given composition is often not applicable to the same quantity of impurities contained in a much larger bulk of liquid ; indeed, as a matter of fact, it not infrequently happens that in times of flood, the sewage of towns, where the separate system is not used, cannot be purified for this reason. Moreover, the expense attending the purification or the utilisation of sewage is very much in proportion to the bulk to be dealt with, and this consideration is made all the more important by virtue of the fact that the cost of sewage works has, it is said, in many cases exceeded the whole rateable value of the districts immediately concerned.

Before proceeding to describe the various methods of dealing with sewage, it will be well to make ourselves acquainted with its general character and chemical composition.

It contains human and animal excrements, soap-suds, hair, and the impurities removed from human bodies, dwellings, and the streets of towns, by general cleansing operations. In many towns it is also mixed with the effluents from various trades or manufacturing processes. The several constituents are contained partly in solution and partly in suspension in a great volume of water, which is universally employed as the carrying agent to effect their removal. The fluid part is the more valuable in a manurial sense.

An average healthy man excretes by the kidneys about 50 to 60 ozs. of water per day, and in this solution there are dissolved about 500 grains urea ($CH_4N_2O$) and about 10 to 12 grains of uric acid ($C_5H_4N_4O_3$); other constituents, amounting to from one-third to the same quantity of the urea present, include common salt, chloride of potassium, phosphates and sulphates of potassium, sodium, calcium, and magnesium. Urine also contains small quantities of other nitrogenous organic matters, besides urea and uric acid. The phosphoric acid amounts, on an average, to about 54 grains per man, per day. The urine of a population of 10,000 adults amounts to about 3,750 gallons per day.

Fresh urine contains, on the average, about 3 per cent. of total solids, and according to Way, the analysis of a sample gave the following results:

| | |
|---|---|
| Water - - - - - - | 97·000 |
| Organic matter (containing nitrogen 0·58; equal to ammonia 0·71) - - - - | 2·026 |
| Insoluble siliceous matter - - - - | ·003 |
| Oxide of iron - - - - - - | ·002 |
| Lime - - . - - - - - | ·018 |
| Magnesia - - - - - - - | ·014 |
| Phosphoric acid - - - - - - | ·040 |
| Sulphuric acid - - - - - - | ·014 |
| Potash - - - - - - - - | ·055 |
| Chloride of potassium - - - - - | ·162 |
| Chloride of sodium - - - - - | ·566 |
| | 99·900 |

Of these various constituents, the nitrogenous organic principles are considered to be by far the most valuable from a manurial point of view; but unfortunately, urea, the principal of them, is rapidly decomposed in the sewage by a process of fermentation, into carbonic anhydride and ammonia, thus,

$$CH_4N_2O + H_2O = CO_2 + 2NH_3.$$

and both of the products, being gaseous, escape more or less from the solution, and are lost in proportion.

Fæces represent the undigested and altered portions of the food which have refused absorption; like urine, its quantity and composition, therefore, necessarily vary with the nature and amount of the food as well as other circumstances.

According to analyses of the late Professor Way, fresh human fæces contain in 100 parts:

| | |
|---|---|
| Water - - - - - - - - | 75·00 |
| Organic matter (containing nitrogen 1·50; equal to ammonia 1·82) - - - - | 22·13 |
| Insoluble siliceous matter - - - | ·37 |
| Oxide of iron - - - - - - | ·13 |
| Lime - - - - - - - - | ·43 |
| Magnesia - - - - - - - | ·38 |
| Phosphoric acid - - - - - - | 1·07 |
| Sulphuric acid - - - - - - | ·06 |
| Potash - - - - - - - - | ·30 |
| Soda - - - - - - - - | ·08 |
| Chloride of sodium - - - - - | ·05 |
| | 100·00 |

The amount of water contained in fæces varies from 73 to 75 per cent., and the solid matters (dry at 100° C.), therefore, amount to from 25 to 27 per cent., upon an average of quantities ranging from 17 to 31 per cent. Little nitrogen is present in fæces; according to Dr. Edward Smith, the daily elimination of nitrogen by the bowels amounts, on the average, to about 46 grains. The quantity of fæces yielded by a healthy adult varies from 5½ to as much as 8 ozs.; but taking men, women, and children collectively, an average of 4 ozs. per day may be taken as approximately correct.

Fæces generally contain but small quantities of salts, consisting of phosphates of calcium, magnesium, sodium, and potassium. Albumin is met with in a soluble form, and in certain diseases (cholera and typhus) the proportion found present is considerable. The bulk of organic matter present in fæces is represented by the altered biliary substances, fat, starch, cellular and muscular fibres, etc. Playfair is stated to have found, in a sample of fæces which he examined, as much as 15 per cent. of nitrogen and 45 per cent. of carbon,* but quite apart from these figures I entertain a strong conviction that even the solid parts of sewage are not so valueless as they are often assumed to be. I cannot believe that the value of manure is so nearly limited to phosphoric acid, potash, and available nitrogen as is generally represented.†

Curiously enough, no paper is ever seen in the sewage of London at the outfalls; it becomes reduced to an impalpable state of division *en route*, and is deposited from sewage in a sparingly pervious layer on the surfaces of filter-beds and sewage fields.

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* I should think these qualities must have been calculated upon dried fæces of abnormal composition.—AUTHOR.

† See papers in *Journ. Soc. Arts*, May 18th, 1877, by Voelcker, on the Agricultural and Commercial Value of Prepared Night-soil Manures, and by Tidy in *Journ. Soc. Arts*, October 8th, 1886.

The following analyses of sewage are taken from Frankland's work on water analysis (pp. 115 and 118):

| Description. | Total solids. | Organic Carbon. | Organic Nitrogen. | Ammonia. | Chlorine. | Suspended Matter. | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Mineral. | Organic. | Total. |
| Tunstall . . | 114·40 | 4·858 | 1·692 | 4·300 | 14·15 | 18·12 | 34·36 | 52·48 |
| Crewe . . . | 98·08 | 5·014 | 1·780 | 1·65 | 16·0 | 83·72 | 262·08 | 346·00 |
| Fresh sewage: average from 16 water-closet towns . . | 72·2 | 4·696 | 2·205 | 6·703 | 10 66 | 24·18 | 20·51 | 44·69 |
| Fresh sewage: average from 15 midden towns . . | 82·4 | 4·181 | 1 975 | 5·435 | 11·54 | 17·81 | 21·30 | 39·11 |

Tidy gives in his paper* the following details of the average composition of London sewage as examined by Frankland and him between 1883 and 1884, the results being stated in grains per gallon:

| | Maximum. | Minimum. | Average. |
|---|---|---|---|
| Matters in solution - | 49·77 | 28·42 | 45·213 |
| Matters in suspension - | 163·90 | 21·40 | 48·65 |
| Ammonia - - - | 6·527 | 2·515 | 3·012 |
| Chlorine - - | 8·33 | 5·67 | 7·21 |
| Organic Carbon - - | 3·847 | 2·118 | 3·069 |
| Organic Nitrogen - - | 2·676 | 0·964 | 1·738 |

Average ratio of N to C = 1 : 1·77.

These results take no note of storm sewage.

Summarising these and other results, he shows that 'every 10,000 persons in London contribute, on an average, 375,000 gallons of sewage daily, and that

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* *Journ. Soc. Arts*, October 8th, 1886.

this includes about 1,671 lbs. of organic matter containing 333 lbs. of nitrogen, and 335 lbs. of mineral matter containing 94 lbs. of phosphoric and 69 lbs. potash.'

The total quantity of sewage to be dealt with varies in towns with a number of circumstances; but in London 80 per cent. is represented by the water supply.

Upon the estimate that each head of the population (taking men, women, and children collectively) gives 4 ozs. of fæcal matter per day, London, calculating its contributory population at about 4,000,000, yields daily 446 tons of fæcal matter, and taking this to contain 75 per cent. of moisture and 25 per cent. of dry solid matters, it is seen that above 111 tons of dry fæcal matter were until recently daily poured into the Thames at Barking and Crossness. This amount of impurity was, of course, greatly increased by the heavier solid matters that are contributed by the street drains, and the whole quantity was contained in a bulk of liquid measuring about 170,000,000 gallons.

Of this quantity, that which is discharged at Barking is collected from the London area north of the Thames, measuring 53 square miles, and is temporarily received in reservoirs of 9½ acres, the capacity of which is 35,000,000 gallons, or 5,600,000 cubic feet. South of the Thames the London area is 66 square miles, and the sewage is collected at Crossness in reservoirs of 6½ acres, which are capable of holding 25,000,000 gallons, or 4,000,000 cubic feet.

Thus, in the course of a year, the lower Thames received about 60,000,000,000 gallons of sewage, in which the amount of suspended matter was estimated by Dr. Frankland, so long ago as 1879, at 1,354,000 tons.

At high-water time, the sluice-gates of the reservoirs were opened for four hours during the ebb, and the sewage was thus conveyed into the tide-water. Some was, no doubt, carried out to sea, but a large quantity, and perhaps the bulk, would only travel a certain distance down the river, and be borne back again by the next tide, while some of it would reach up the river even as far as Chiswick. The fact is, that the volume of the river is insufficient to carry away such an enormous quantity of sewage.

A large proportion of the heavier parts of the solid matters was deposited upon the bed of the river, extending up to Chiswick and down to Southend, and the river between these places became converted into a great sewer, the contents of which, in hot weather, was in a more or less putrid condition.

So serious was the nuisance caused some few years since that a great, but natural and perfectly justifiable, outcry followed, the more so since on more than one occasion the country has been threatened with an epidemic of cholera. As a result of this outcry, large quantities of chloride of lime and permanganate of potassium were, at first, thrown into the river, and later on mixed with the sewage as it was discharged; but such a proceeding on the part of the governing authority could only be expected to mitigate, in a very incomplete measure, the nuisance caused by the emission of gases from the putrefying sewage, and that at a stupendous cost. The quantity of chemicals thus employed was wholly inadequate to oxidise or destroy, in a chemical sense, the enormous mass of organic matter contained in the sewage, and, indeed, the effect was confined to the deodorisation in some measure of the ready-formed products of putrefaction, including gases containing sulphuretted hydrogen, etc. The cost of such a proceeding is much too great, and the effect far too little, to warrant anything like its regular adoption. The sewage of London demands chemical treatment, and the clear effluent alone should be discharged into the Thames.

According to experiments made by Mr. W. J. Dibdin (the chemist of the London County Council), no practical advantage accrues from the addition to each gallon of the sewage of London of more precipitating matters than 3·7 grains of lime and 1 grain of sulphate of iron ($FeSO_4 7H_2O$), which he considers is all that is necessary for facilitating the natural tendency of the solids to deposit. Mr. Bailey Denton has stated that this conclusion is opposed to all past experience, amounting, in his opinion, to a demonstration of its falsity. These materials and quantities are, I understand, in use at the present time for assisting in the precipitation of the solid matters contained in the sewage of London, and the precipitate is subsequently carried out to sea and discharged into it, the effluent only passing into the river.

The fluid sludge that is produced by this lime and iron process contains 90 per cent. of water, and is pumped direct into the vessels that carry it out to sea. It is said to cost 9d. per ton to get rid of it in this way.

Respecting the average composition of pressed sewage sludge from Crossness, the following analyses are those of Mr. Dibdin :

| | | |
|---|---|---|
| Moisture | 58·06 | per cent. |
| Organic matter | 16·69 | ,, |
| Mineral matter | 25·25 | ,, |
| | 100 00 | |

The organic matter contains :

| | | |
|---|---|---|
| Saline ammonia | 0·035 | per cent. on sludge. |
| Organic nitrogen, calculated as ammonia | 1·025 | ,, ,, |

The mineral matter contains :

| | | |
|---|---|---|
| Carbonate of lime | 7·94 | per cent. on sludge. |
| Free lime | 2·45 | ,, ,, |
| Silica | 8·08 | ,, ,, |
| Oxide of iron | 0·97 | ,, ,, |
| Alumina | 3·39 | ,, ,, |
| Phosphoric acid (= Phosphate of lime 1·44) | 0·658 | ,, ,, |
| Magnesia | traces | |

The sewage sludge of the Metropolis amounts to about 4,000 tons per day ; one ton containing 90 per cent. water is yielded by 45,000 gallons of sewage from 1,000 persons, and this quantity is equal to about 2 cwt. of dry precipitate.

Mr. Phillips Bevan* has expressed the opinion that the only plan, and the cheapest one, of dealing with

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* *The Sanitary World*, August 30th, 1884.

London sewage, is to convey it across the Essex marshes to Foulness Island, a little to the north of Shoeburyness, and there, if possible, cast it into the German Ocean. Land is cheap, and space is of little account, at Foulness or Wallasea Islands, and Mr. Bevan thinks that if our boasted scientific knowledge is worth anything, it should enable the proper authorities to convert the useful parts of sewage into a good practical manure, in which a brisk trade could be done.

Some few years ago, Sir John Lawes suggested that, after all, it may prove to be more profitable to cast the sewage of London into the sea than to apply it to land. The broad line of his argument may be taken as follows: enormous quantities of fish are removed from the sea near our shores, and they contain great quantities of phosphate of lime, potash, and nitrogen. The former of these ingredients exists in sea-water in very small amount, and yet it is as essential to fish as an article of food as to mammalia. By discharging sewage into the sea we should thus atone for the food material which is being constantly removed, and Sir John Lawes thinks that, in this way, continued and increased prosperity would be secured to our fisheries.

This disposal of sewage would, however, have its attendant evils. The finely diffused solid particles of sewage are exceedingly hurtful to fish, choking their gills and suffocating them. Moreover, fish breathe by means of the free oxygen which is contained in the water in which they natate, whereas, not only does sewage contain no such oxygen, but it deprives the water into which it is discharged of its oxygen also. This fact alone would necessarily limit the amount of sewage that could be poured into any circumscribed area of sea water. Then, again, while fresh sewage is very good food for fish, bad or stale sewage is poisonous to fish. Whatever, therefore, is to be said of the advantages of Sir John Lawes' suggested plan of dealing with sewage, its execution would probably diminish the fish supply in the immediate neighbourhood, however it might in a wider area increase the available supply.

For my part, I agree very largely with Mr. Bevan, but I go further, and venture to express the opinion, notwithstanding all past discouraging experiences, that a reasonable sum of money expended on the spot in experimental work would enable chemists to make other valuable commercial commodities from sewage in addition to manure.

One of the greatest difficulties experienced in adequately dealing with sewage lies in the enormous bulk to be operated upon, and it is therefore reasonable to suppose that could some simple mechanical appliance be devised by which a considerable proportion of the clearer liquid could be drawn off and separated from the more solid parts, it would greatly assist in the efficient treatment of sewage. Such clear liquid need not necessarily be passed directly into a watercourse ; it could be first distributed over a considerable tract of land, for which it would serve as a useful manure, and by which it would be efficiently filtered and greatly purified.

Sewage passes very rapidly into a putrefactive state, and the gases that are generated in sewers are capable of producing a peculiar kind of fever; but whether the illness is to be regarded as the direct effect of inhaling the mixed chemical gases, or as an expression of the consequences of inspiring a micro-organism which is reproduced in the human body, is not known to medical men, who are, however, perfectly familiar with the illness.

In course of a recent investigation, Messrs. Carnelly and Haldane found that the air of sewers which were examined by them was in a much better condition than might have been expected. The carbonic acid was about twice, and the organic matter rather more than three times, as great as in the outside air at the same time, whereas, the number of micro-organisms was less. The sewers examined were, it should be stated, well ventilated. Concerning the micro-organic life present in the air of sewers, the authors concluded that it is not mainly derived from the sewage itself, but rather from the outside air. The number of micro-organisms observed to be present in the sewer air, as compared with those found present in the outside air, was as 9 to 16; further, the number increased with the efficiency of the ventilation, and, as resulting therefrom, confirmatory evidence is furnished by the fact that the average proportion of moulds to bacteria remained the same as in the outside air at the same time.

That no sewer is air-tight is certain; consequently, when, for some reason, such as a sudden flow of water into the sewer, we have a rapid increase of pressure, some of the sewer gas will be forced out, and often through those openings in respect of which we should least desire any escape to be made, viz., such as faulty traps. It is, therefore, absolutely necessary to provide means of exit for the foul gases, either by gratings opening directly into the streets, or else, and preferably, by ventilation shafts of a good height.

The methods of purifying sewage which are at present in use depend either upon filtration through soil (irrigation) or upon the precipitation of the solid parts by the agency of added chemicals.

In what is called broad irrigation, sewage is distributed over the surface of drained and cultivated land, by which means the solid parts are arrested, and the fluid part gradually percolates through the land, and is finally carried off by the natural or artificial drains. The fluid part, however, does not merely soak through the land, but its constituents are subjected to oxidation in the process.

This oxidation is carried on by the agency of micro-organisms, as fully explained in an earlier chapter, and one chief direction in which it occurs is that of so-called nitrification, to which reference has also been made in some detail. The solid parts which are left in the soil are also attacked, and gradually succumb to the influences of hydration and oxidation, yielding as products, substances which afford food to the plants growing upon the land.

Of course there is a limit to the capacity of oxidation, and so the land has to be divided into plots, which are successively worked, care being taken that too great a tax is not thrown upon the land, as in that case it becomes choked, and oxidation does not proceed actively, as it should do.

'Intermittent downward filtration' differs in no wise from broad irrigation except in the fact that the land is drained to a greater depth, and so a greater quantity of sewage may be applied to a given surface of land, which, however, is not worked continuously, but, as in the other case, successively in plots. In the periods of repose the soil is supposed to become re-charged with oxygen, but it must not be forgotten that the oxidation which is carried on does not altogether result from the mere contact of oxygen with the organic matters, but is, at least in part, the result of the vital actions of millions of micro-organisms which utilise the oxygen which nature so bountifully supplies near at hand.

The following figures, illustrating the purification of sewage by irrigation, are taken from a table given by Dr. P. F. Frankland in a paper on Thames water*:—

| Description of Process. | | Average percentage of dissolved organic pollution removed. | | Average percentage of suspended organic pollution removed. |
|---|---|---|---|---|
| | | Organic Carbon. | Organic Nitrogen. | |
| Intermittent downward filtration | Best result . . . | 88 5 | 97·5 | 100 |
| | Worst result . . | 32·8 | 43·7 | 100 |
| | Average result . | 72·8 | 87·6 | 100 |
| Broad irrigation | Best result . . . | 91·8 | 97·4 | 100 |
| | Worst result . . | 42·7 | 44·1 | 84·9 |
| | Average result . | 68·6 | 81·7 | 97·7 |

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* *Soc. Arts Journ.*, vol. xxxii., p. 433.

These results prove that, practically, it does not much matter which kind of irrigation be used, the choice being determined by local conditions, such as the price and character of the land. On the whole, probably, considering the expense of draining land to the greater depth required for intermittent downward filtration, the ordinary process is to be preferred.

According to M. Lefeldt, an acre of land is required for the excreta of every twenty to thirty-five persons; but even if that quantity of land would serve for each hundred persons, the total acreage thus required is far in excess of the available quantity. Sewage when kept in motion and brought quickly in limited amount into contact with soil, air, and vegetable life, is, I believe with the late Dr. Carpenter, changed in a direction contrary to that which is necessary for the propagation of disease germs. All the same, it has been pretty well established that the *putrefactive* decomposition of sewage in soils may give rise to the production of malarial and parasitic diseases when it takes place near towns, and that when sewage is applied in excess, as is often the case, the solid organic matters, after a time, form a solid cake upon the land, which gives off an offensive and dangerous effluvium. Again, the subsoil water is liable to be charged with decomposing matters resulting from the sewage, and Pettenkofer is not alone in his opinion that there is no more fruitful source of disease than such a subsoil water which is constantly changing in its level.

The mere fact that in this country, at least, the available land is insufficient for the disposal of sewage by irrigation, is sufficiently condemnatory of the process as an exclusive means of utilising sewage. London alone would require above 200,000 acres, and when it is reflected that some classes of soil are not suitable for irrigation, and that great expense has to be incurred in preparing the land by drainage and otherwise to receive sewage, it becomes apparent that for these and local reasons irrigation does not nearly supply the want that is experienced.

At the same time, it is to be clearly understood that, given suitable land, of sufficient extent, and in dry weather, we can by irrigation very completely purify sewage. This is proved by the analytical results obtained by Dr. R. Angus Smith upon the examination of the effluents obtained from sewage by different processes of treatment, and communicated to the Local Government Board in 1879.*

As pointed out in a paper on Sewage Disposal† contributed to the Sanitary Institute meeting at Dublin (1884) by Professor Henry Robinson, clay land can be utilised for irrigation purposes by digging it out to a depth of six feet, burning it into ballast, and replacing it in layers, interposed with an occasional layer of open alluvial soil, and if well drained, this prepared filtration area will continuously clarify the sewage of 1,500 people to the acre. The

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* See *Chem. News*, vol. xli., p. 50.

† *Sanitary Record*, October 1884.

cost of preparation, however, amounts to from £750 to £1,000 per acre, besides which, he adds that the larger particles in the sewage should be first removed by a process of straining conducted upwards. The separated solids can be utilised for making up low-lying land.

According to the same authority, open porous land with a good free subsoil, drained six feet deep, will effectually deal, per acre, with the sewage of from 600 to 700 people.

This is, however, a very high estimate of the purifying capacity of land, and, in my opinion, would prove very excessive upon continued use.

I shall not attempt to give an account of all the many chemical processes that have been advocated for the treatment of sewage, but shall be content with describing the so-called A B C process, and a few of the other more prominent ones that are now in use or have been suggested.

The A B C process of the Native Guano Company is in work at the present time at Kingston-on-Thames, where, I am informed by the Secretary of that company, it is dealing with the sewage of over 40,000 people, comprising the district of Kingston, Surbiton, and Hampton Wick. The works have been in operation for five years, and are carried on by the company for a fixed annual rate of 3*d*. in the £1 on the net rateable value of property within the district, which payment relieves the authorities from all further expense, risk, and trouble as regards the purification and disposal of the sewage.

To the sewage, as it is admitted into the works by channels, is first added a mixture of ground clay, charcoal, and blood, previously made into an emulsion with water, and at a later stage a solution of sulphate of aluminium is run in. The particles of clay assimilate the suspended organic matters of the sewage, and when the blood albumin becomes coagulated by the action of the alum solution, the whole solid matters become entangled or enveloped in the meshes of the coagulating substance, and are deposited to the bottom of the tanks through which the treated sewage slowly flows. The clay is also stated to enter into combination with some of the ammonia present in the sewage, and the charcoal is supposed to absorb a further quantity, and to exercise a deodorising influence. The action of the alum solution in precipitating the clay and blood is promoted by the alkaline nature of the sewage, which causes the separation from the sulphate of aluminium of gelatinous flocks of alumina. As the mass of treated sewage flows through two successive tanks, it deposits practically the whole of the suspended matters originally contained in the sewage, together with the added chemicals, and the effluent passes away to the river, clear, purified to a great extent, and nearly odourless.

The following analyses are published by the company :

## *Analysis.*

RESULT IN GRAINS PER GALLON.

| SUSPENDED MATTERS. | SEWAGE. | EFFLUENT WATER. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | DR. WALLACE. | DR. WALLACE. | DR. ANGUS SMITH. | DR. TIDY. | PROFESSOR WAY. | DR. KEATES. | PROFESSOR WANKLYN. | DR. WALLACE. | Standards of Rivers Pollution Commission. |
| Organic . . . | 24·9 | traces. | — | ·04 | — | — | — | none | ·70 |
| Inorganic. . . | 12·9 | ,, | — | ·18 | — | — | — | ,, | 2·10 |
| Total . . | 37·5 | ,, | — | ·22 | — | — | — | ,, | 2·80 |
| Free Ammonia . | 5·18 | 2·73 | ·714 | ·60 | 1·12 | 1·75 | ·61 | 1·19 | no standard |
| Albuminoid do. | ·58 | ·12 | ·049 | — | ·07 | ·18 | 0·3 | ·112 | ·21 |
| Oxygen required to oxidise the organic matter | 2·17 | ·91 | — | ·25 | — | — | — | ·23 | — |

In a report published by Dr. Angus Smith in 1879, at the request of the Local Government Board, he found, taking samples over a month at unexpected times, that the organic carbon in the dissolved organic matter present in the sewage operated upon was reduced by the process from 6·76 to 0·63, or by 90 per cent.; the albuminoid ammonia was also reduced from ·66 to 0·07, or very nearly 90 per cent., and the free ammonia from 4·00 to 1·02, or 75 per cent.

These analyses appear to indicate that beyond the precipitation of the suspended organic matters, some small part of the dissolved organic matters is removed from sewage by this process.

The precipitated sludge is pumped from the tanks, deprived by pressure of its superabundant water, and further dried by artificial heat, till it attains the consistency and appearance of dry earth, in which state it is sold to farmers and gardeners as Native Guano, and judging from the statements published in a pamphlet by Mr. Crookes,* who was for some years scientific adviser to the company, and the reports from farmers and others, the product is a more or less valuable manure. It is not so valuable when judged by the somewhat arbitrary standard in common use by chemists, as, according to this standard, value is attached only to the contained ammonia and phosphoric acid. But it is questionable how far this standard is a reliable one as applied to the manurial value of a product, for it ignores to a large extent its collective organic nature and its physical condition.

The late Dr. C. Meymott Tidy and Professor Dewar have also more recently reported favourably upon this process. They found that it completely and immediately deodorises the sewage, and that there is no escape of offensive odours into the surrounding air. The effluent is described by them as being practically clear, free from suspended matter, and devoid of smell, the perfection of the precipitation increasing with the strength of the sewage. The mean amount of suspended matter in the sewage on three separate occasions was 18·8, 59·97, and 234·63 grains per gallon, and practically the whole of this was precipitated. The organic matter pre-

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* 'The Profitable Disposal of Sewage.' By W. Crookes, F.R.S.

cipitated from solution amounted to 61·4 per cent. in the second series of observations, and to 57 per cent. of the whole in the third series.

With respect to the composition of the so-called Native Guano, the same report states that the percentage of combined nitrogen is remarkably constant, and amounts on the average to 3·8 per cent. calculated as ammonia in the perfectly dry manure, or with 20 per cent. of water to 3 per cent. of available ammonia.

As to phosphoric acid, which is also an important ingredient from a manurial point of view, it was found in four samples to amount to an average of 5 per cent. reckoned as tricalcic phosphate.

In a recent paper by Mr. William Santo Crimp, read before the Institution of Civil Engineers, the author called attention to the use of filter presses at Wimbledon as adapted to dealing with sewage sludge. By the use of two of Johnson's presses the then weekly production of 250 tons of sludge was reduced to about 50 tons of cake containing 50 per cent. of water, at a cost of 2*s.* 6*d.* per ton for labour, lime, fuel, cloths, etc., to which has to be added interest on capital and depreciation, say 1*s.* per ton more. The precipitation of the suspended matters in the sewage was effected by lime and sulphate of alumina, the average daily quantity used being equal to 0·91 ton for precipitating and pressing. As regards the value of this pressed sludge-cake as manure, Professor Munro has shown that it is superior to stable manure of good quality. With crops of hay, potatoes, mangolds, cabbages and swedes, the average production per acre was in the case of sewage sludge-cake 13·15 tons, with superphosphate 12·60 tons, and with farmyard manure 12·27 tons, while the unmanured plot yielded 11·72 tons. Potatoes were especially benefited by the dressing of sewage-cake.

Among other processes officially investigated by the late Dr. R. Angus Smith was that employed at Coventry, consisting of precipitation by alum and iron salts, and lime, followed by irrigation of the effluent. In consequence of this double system, the water eventually obtained from the sewage is of a very high quality, as the following figures demonstrate :

| | Organic Carbon. | Free Ammonia. | Albuminoid Ammonia. | Nitric Acid. | Total Solids. | |
|---|---|---|---|---|---|---|
| Crude Sewage . . | 11·33 | 2·58 | 1·70 | None | 99·0 | Parts per 100,000 contained in the water. |
| Filtered Effluent . | 1·418 | 2·40 | 0·245 | ,, | 71·0 | |
| Effluent after irrigation . . . . | 0·587 | 2·12 | 0·205 | | 77 | |

Another mode which has been proposed for dealing with sewage consists in heating it with milk of lime, condensing the ammonia that is evolved, and separating and pressing the sludge which remains behind. This sludge has little value (in common with all lime precipitates) as a manure, and it would hardly pay to burn it with the view of regaining the lime in a caustic condition for use over again. The amount of ammonia that could thus be obtained even from fresh sewage would probably not suffice to cover the cost of production, while from stale sewage much less would be obtained.

'Hanson's process' consists in treating the sewage with lime and alkali waste. At one time it was in use at Aldershot, and, judging from the analytical results furnished by P. F. Frankland, it is not so effective as the A B C process.

The following are the results referred to*:—

RESULT OF ANALYSIS IN PARTS PER 100,000.

| | Dissolved Matters. | | | | | | Suspended Matters. | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total Solid Matters. | Organic Carbon. | Organic Nitrogen. | Ammonia. | Total Combined Nitrogen. | Chlorine. | Mineral. | Organic. | Total. |
| Raw Sewage | 132·72 | 7·441 | 2·234 | 0·90 | 2·975 | 5·7 | 4·96 | 44·70 | 49·66 |
| After Treatment | 120·16 | 4·777 | 1·802 | 0·80 | 2·461 | 7·1 | 2·36 | — | — |

I do not know if the process is still employed.

In the process devised by the late General Scott, the idea of obtaining a valuable manure from sewage was abandoned, and the total precipitate obtained by the addition of lime, or lime and clay, was collected, dried, and burned, in order to make cement. Precipitation by lime, however, yields an effluent which, from its comparative impurity and alkaline character, soon passes into a state of putrefaction, and the lime which passes into solution is fatal to the fish contained in river water. Moreover, the process is not unattended with nuisance, and it is not profitable.

Of all the processes of chemical precipitation that

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* *Journ. Soc. Arts*, vol. xxxii., p. 434.

have been hitherto suggested for adoption, none have been free from a feature which altogether condemns most of them, viz., the employment of expensive chemicals in considerable quantities (for they must be employed in considerable quantities if they are to be effectual) for the purpose of extracting from the solution certain matters which are therein dissolved in small quantity, with the object of increasing the manurial value of the precipitate. The cost of the chemicals which must be thus employed is at least dangerously near to, if not greater than, the increased value given to the product. Chemicals, so far as they may be used in the treatment of raw sewage, should be confined to the limits of preventing nuisance. Separation of the solids from the fluid of sewage is, however, essential, and it is to be advocated that the effluent should be disposed of by a process of irrigation over land, where that can be done: the employment of such a process is the more recommendable because, when a process of *separation only* has been employed as contradistinct from a process of *precipitation with chemicals*, the effluent is richer in organic substances available for the nutrition of plant-life. As an alternative, and in the absence of special objections, the effluent may, with practical immunity, be discharged into a tidal or other river having a sufficient volume and flow, for the oxidation which occurs so rapidly in running streams suffices to render innocuous, in a very short time, the organic matters which are held in solution.

In cases where raw sewage is treated by an essentially chemical process, the effect of the chemicals is, unfortunately, by no means confined to the substances which are held in solution ; the greatest effect is exercised upon the solid matters in suspension ; in other words, the chemicals are largely wasted. The process of precipitation, therefore, which should be employed for the purpose of separating the solids from the fluid part of sewage, should be as simple and as economical as possible, consistently with preventing nuisance or danger to the public health ; and I claim for a process which I some years since introduced (Specification No. 10,879 of 1885) that it is at once the most simple and innocuous, the most effective and the most economical that has yet been proposed for that purpose. It consists in adding to the raw sewage a material in the form of powder, which has the property of absorbing ammonia, sulphuretted hydrogen, and other offensive gases ; of deodorising the sewage as a whole, and (what is most important) of giving to the precipitate which is obtained certain most important physical qualities. The material in question is *powdered coke*, or 'breeze,' which I found, by experiments conducted in my laboratory, to be practically of equal value with animal charcoal, while no material that is so readily and universally obtainable can be obtained at such small cost. In conducting my process of treatment and utilisation of sewage, the powdered coke may be first admixed with a certain proportion of clay for the purpose of increasing the density of the precipitate, and then added to and well mixed with the sewage in certain proportions. The deposit which is thus obtained, unlike ordinary sludge, can be easily pressed, and it constitutes a fairly good manure, which may be usefully employed, where practicable, for making up low-lying lands of a suitable nature, or for incorporation with clayey, chalky, or sandy soils, which are naturally deficient in organic matters, thereby improving them for agricultural production. Its peculiar value for this purpose is derived from its physical quality, for, by the use of coke, the sludge is rendered *particulate* or *granular* in character, so that when applied to land it does not choke up its pores in the way that ordinary sewage sludge does, and, in consequence, the air finds easy access to all parts of the soil, while plants more readily assimilate the organic matters which are contained in the dressing.

The utilisation of the precipitate is not, however (and this is a very important matter to public bodies which have to do with the disposal of sewage), confined in any sense to its employment as a manure. After pressure, it may be air-dried and employed as ordinary fuel for use in boiler and other furnaces, for it will be observed that not only have the solid parts of sewage an organic character, but the bulk of the material which is added to the sewage consists of carbon, which is in itself a good fuel ; or it may be roasted, and thereby reconverted into a carbonised material fit for use again in precipitating and purifying further quantities of sewage. Further, the coke precipitate obtained from sewage may be ground up with more clay and converted into bricks ; or it may be admixed with such other materials as are ordinarily employed and converted into ballast for use by sanitary authorities and others in the construction of footpaths and foundations of buildings.

These applications of the precipitate obtained by this process of treating sewage are really practicable, and the process does not involve any great liability for expensive chemicals or elaborate plant.

The purifying effect of common coke has been since confirmed by some experiments of Dr. P. Frankland,* in which it was proved that powdered coke exercised a sterilising effect upon micro-organisms equal to that of spongy iron, and far greater than that of animal charcoal.

The following is another system which was proposed by Captain Liernur, and known as the 'aspiration method.' The excreta, admixed with water, are allowed to fall into an earthenware pipe, which is connected with a smaller iron siphon-pipe, from which they are periodically extracted by exhaustion with air. This plan has been adopted at Amsterdam and other Dutch towns, and also to a small extent at St. Petersburg, apparently with very fair success, and seems well adapted for towns lying in a flat country, where sewerage by gravitation is extremely difficult to carry out.

Which of the various methods for removing sewage which have been described, is the best, depends to a great extent on the situation of the town that has to be dealt with. For London, and cities similarly situated

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* Proceedings Royal Society, No. 238, 1885.

on the banks of rivers, where water can be obtained with comparative ease, and where there is not much difficulty in getting rid of the sewage-water, the most desirable method seems to be the water-system; whilst for large inland towns, such as Birmingham, where water is scarce and where the removal of the sewage-water presents great difficulties, a dry system such as pail-closets seems to present advantages.

The following analyses by Dr. R. Angus Smith show what sort of an effluent is obtained from sewage by precipitation with lime:*

| | Organic Carbon. | Free Ammonia. | Albuminoid Ammonia. | Nitric Acid. | Total Solids. |
|---|---|---|---|---|---|
| Crude Sewage (Burnley) . | 20·33 | 1·45 | 1·20 | None | 197 |
| Effluent . . . . . . . . | 3·737 | 1·33 | 0·305 | 1·2 | 54 |
| Crude Sewage (Birmingham) | 20·44 | 2·70 | 1·05 | None | 177 |
| Effluent from Settling Tanks | 4·09 | 3·22 | 0·66 | 2·13 | 100·5 |
| Effluent after irrigation . . | 2·303 | 1·275 | 0·21 | 1·19 | 112·5 |

The use of lime is to be deprecated; it gives a sludge which is generally slimy and difficult to deal with in consequence, while it yields an alkaline effluent which is very apt to pass into a putrefactive condition.

Certain experiments which were made by Dr. Angus Smith led him to think that by driving air through sewage matter, in order to produce oxidation, not only would nitrates be readily produced, but the excess of air would be offensive to the micro-zymes, notwithstanding that some air is necessary for their

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* *Chem. News*, vol. xli., p. 51.

activity. Further investigation concerning the aeration of sewage showed that in all cases, putrefaction was delayed by aeration, and that ammonia is contained in the air that has passed through the sewage. He continues, 'The dissolved oxygen also recovers itself in the aerated specimens better than in the non-aerated. This shows that aeration not only prevented putrefaction, but prevented also the chemical action consequent upon it. It had, in fact, to a large extent, and for a considerable time, rendered the organic matter inert, or nearly so. Nitrates are also formed more readily in the aerated than in the non-aerated specimens.' In the same communication,* Dr. Angus Smith quotes the results obtained by M. Lauth, who had conducted similar observations (see *Compt. Rendus*, lxxxiv., 617—620). M. Lauth filled two bottles, one with ordinary sewage, and the other one with sewage saturated with air, and then placed both on one side to watch the results. The non-aerated sewage soon became black and offensive, whilst the aerated sewage was inodorous after two months. He also found that lime had an effect similar to that of air, and he studied the effects of liming and aerating the sewage. The following analytical results were obtained by him :

| | Insoluble Nitrogen. | Soluble Nitrogen. | Nitrogen as Nitric Acid. | Nitrogen as Ammonia. | Total Nitrogen volume |
|---|---|---|---|---|---|
| Before Aeration . . | 14·70 | 20·65 | 1·176 | 8·4 | 38 |
| After Aeration . . | 8·05 | 26·95 | 1·122 | 14·0 | 38 |
| Treated with Lime . | 10·15 | 25·55 | 2·60 | 18·20 | |
| Treated with Lime and Aerated . . | 6·65 | 28·87 | 2·12 | 21·35 | |

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* *Sanitary Record*, vol. v., p. 159.

It is seen from these results that the process of liming sewage, as also that of aerating it, both result in the increased production of ammonia and nitrates.

According to M. Lauth, sewage contains from 4 to 7 grains ammonia to the gallon, but, unfortunately, this amount of ammonia, though considerable in itself, is insignificant in comparison with the amount of water in which it is contained; hence the difficulty in extracting it.

The late Dr. James Young (of Kelly) found that by the distillation of 5 per cent. of a sewage mixture at 100° C. the bulk of the ammonia was obtained in the distillate; while by increasing the temperature and pressure, it still increased, until at 70 lbs. pressure, almost all the ammonia could be obtained by distilling over 1½ per cent., the expulsion of it being accelerated by the injection of a small quantity of air.

Later on, he found that a low temperature was desirable, and that by the use of an exhausting air-pump, and at a temperature of 26·6° C. (80° F.), sewage containing 5 grains ammonia per gallon could be almost entirely deprived of it in a few minutes. Instead of passing air through the sewage, it was sufficient to pass steam at a very low tension, and consequently with an enormous bulk. 'When he passed the sewage down a coke-filled tower, which was rendered vacuous,* and which gave, from a great expansion of surface, a ready means of evaporation,

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* Vacuum of half-inch or 12·7 mm. mercury.

he considered that he had put the problem in a satisfactory form.'

Up to the present, no commercial results have followed from these various experiments.

Dr. Angus Smith calculated* that, if only one grain of ammonia could be taken out of each gallon of sewage, there would be obtained from 1,000,000 gallons about 140 lbs. Now, the Glasgow sewers alone convey daily 50,000,000 gallons, and this quantity upon the same calculation would yield 7,000 lbs. ammonia, which would give about 1,100 tons per annum, equal to a value of nearly £60,000, while the London sewage upon the same basis of calculation would yield ammonia equal in value to about £200,000.

During recent years a good deal has been heard respecting the electrical treatment of sewage, but writing as a chemist, I cannot see how at anything like a reasonable cost, such treatment can do more than deodorise the liquid part to some extent. Indeed, as Thresh has put it,† sceptical people regard the process merely as 'a roundabout way of producing a soluble iron salt to act as the precipitating agent.'

The Amines process consists essentially in adding a mixture of herring brine and milk of lime. Trimethylamine and other associated chemical products are thus generated *in situ*, with the result, it is said,

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* *Sanitary Record*, vol. v., p. 159.

† *Brit. Med. Journ.*, August 15th, 1891, p. 382.

of sterilising the liquid part, while the solids are precipitated by means of the lime. Such a process does not dispose of the sewage. The precipitate quickly passes into a putrefactive condition when removed from the active agency of the 'Amines' (which exist in the liquid only), while the liquid part itself requires purification from the purifying agent, either by irrigation or otherwise, before it can be allowed with safety and freedom from unpleasant smell to pass into any water-course. In the end, at any rate, the solids have to be disposed of in some other way.

Quite recently much more attention has been paid to the use, in a number of different forms, of iron salts as precipitating agents for the treatment of sewage, and no doubt they may often be very usefully employed. The preference is probably to be given to so-called ferric salts, rather than to ferrous salts, but their employment is, in common, damaging to the value of the precipitate, so far as its uses for manurial purposes are concerned. I do not think their effect is so beneficial as that of coke, but they have the advantage of not increasing the quantity of the sludge to be afterwards dealt with.

With the view of reducing the total volume of sewage to be dealt with, and thus concentrating its valuable constituents, it was proposed to provide London in 1854 with the separate system mentioned at the beginning of this chapter; but the area is so immense, the cost would be so great, and the disturbance so enormous, that the suggestion has been considered by high authorities to be hardly practicable. It is generally admitted that the quantity of sewage proper (that is to say, the quantity that would flow from houses and general drainage, without any admixture of rain or spring water) is fairly measured by the amount of the water supply, which is given in Mr. Baldwin Latham's table at 144 million gallons *per diem.* So that the difference between this quantity and the total quantity actually discharged from London, viz., 170 million gallons, amounts to about 26 million gallons, and represents rain and spring water accidentally mixed with the sewage.

In concluding the study of the water-carriage system of removing sewage and its subsequent disposal, we may sum up as follows :

1. Where practicable, a separate system of drains should be employed for sewage proper and rain water.

2. Rain water thus collected is necessarily polluted with organic refuse, but it may be adequately purified without danger to the public health, either by filtration through a properly drained porous soil, or by natural oxidation in a running stream of sufficient volume.

3. Sewage, whether admixed with rain water or not, should be so dealt with (by screening, subsidence, precipitation, or otherwise), that the solid parts are wholly removed from the liquid parts. The liquid parts should then either receive chemical treatment, so as to obtain, if possible, valuable products therefrom, or be used for irrigation purposes, failing or after which, it may be allowed to flow into some

water-course of sufficient volume, and preferably one that is not used as a source of drinking water.

The solid parts of sewage merit chemical treatment, whereby they may be made to yield valuable products, failing which they should be at once ploughed into the earth, or be treated in a way that will make them innocuous until they are subsequently utilized as manure.

If the solid and fluid excreta of human beings really have the value that is ordinarily attached to them, private enterprise would surely be rewarded (at least in places where the water-carriage system is not employed) for their collection and utilization. Thus, a small portable apparatus might be supplied to each house, provided with a strainer, whereby the urine would be separated from the solid parts ; and this receiver could, under a properly organized system, be collected daily and a clean one left in its place. The receivers containing the excreta should be taken direct to the factory, where ammonia could be profitably obtained from the urine ; and the solid parts could be also utilized, either as a source of ammonia and certain salts, or they could be dried and utilized as fuel for distilling the urine. Or again, the excreta collectively could be worked up with other substances into an innocuous and valuable manure ready for immediate application to the soil. On the other hand, if the human excreta be of little value, one of the arrangements for sprinkling the refuse matters with ashes or dried earth should be used, and the resulting mixture should be daily utilized on the spot for gardening purposes, or be carted away daily with the general house refuse. Treated with ashes or earth, the urine and fæces in a fresh state are no more dangerous to health when contained in an iron or galvanized iron dust-bin, than are the bones and other decomposing vegetable and animal matters that are usually stored therein, until they are removed by the local health authorities. All slops should, under such circumstances, be thrown upon the garden or waste land, or drained off from the houses to a suitable distance and locality.

Connected with the subject of earth closets, one of Dr. A. Carpenter's papers* may be perused with much profit and interest. He therein gives the experience gained with some twenty earth closets which were erected at a cost of about £3 each ; the pails which were used being collected and changed weekly between the hours of 5 and 6 A.M. The expenses of this system during two years and a quarter were as follows :

| | £ | *s.* | *d.* |
|---|---|---|---|
| Man and boy used for collecting - | 47 | 4 | 6 |
| Horse and cart - - - - - | 14 | 12 | 6 |
| Saw-dust for urinal pail - - - - | 8 | 9 | 0 |
| | 70 | 6 | 0 |

The collected excreta was sold at 2s. 6d. per yard, reducing the cost to 8s. 3d. per week.

Thus 22 houses occupied by 122 persons were provided for at a cost of £1 8s. 5d. per house, or 5s. 1½d. per person per annum ; or, deducting the

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* *Society of Arts Journ.*, May 18th, 1877.

value of the product, at 3s. 6¼d. per annum, or a trifle under £1 per house. From certain considerations which he adduces, he thinks the cost on a larger scale could be reduced by one-half. On this basis, a village of 200 houses of average ratable value £15, would entail a rate of 9d. in the £1 to provide for the removal of excreta by a dry-earth system; at the same time no debt would be incurred, and no mortgage of rates would be necessary.

Dr. T. M. Lownds (retired Surgeon-Major H.M.I. Medical Service) has published a very interesting pamphlet, in which he dwells upon the feasibility and the advisability of some proceedings for 'antiseptic drainage and utilization of the whole of the products of excrete,' and, personally, I am strongly inclined to think that a dry system of collection in villages and small towns, even if not in larger centres of population, is to be recommended in preference to the water-carriage system. Upon economical grounds alone it has immense advantages, while for the agricultural welfare of the country it is impossible to estimate the value.

In concluding this chapter, I beg to refer my readers, who may be desirous of making themselves intimately acquainted with the details of many phases of the subject of the treatment and utilization of sewage, to the admirably exhaustive paper of Dr. Meymott Tidy,* and to the account of the discussion which followed that communication.

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* *Journ. Soc. Arts*, Oct. 8th, 1886; Dec. 3rd and 17th, 1886.

# CHAPTER VII.

INFECTIOUS AND CONTAGIOUS DISEASES—CHEMICAL AND GERM THEORIES—GENERAL RELATIONS OF MICRO-ORGANISMS WITH DISEASE—BIOPLASM AND THE GRAFT THEORY—PREVENTION OF INFECTION.

ONE of the most important facts of which history takes note, is the liability of human beings to be attacked by diseases of an epidemic nature. The Sweating Sickness of 1485, as also the Black Plague of London (1499), may be cited in illustration.

According to Short, the historian, there was in 1625 a mortality from plague, in London alone, of upwards of 36,000. Then, again, in the years 1635 to 1636 there was a plague mortality of 14,000; while in the years from 1663 to 1665 there occurred in the same city, it is said, between 70,000 and 80,000 deaths.

In brief, from the year 1490 B.C., when 624,000 Israelites were destroyed by plague in the wilderness,* till the recent outbreaks of cholera in Europe, history teems with the records of wholesale destructions of mankind by diseases of an epidemic character.

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* Numb. xi. Josephus' Antiq. Jews.

Of one disease alone—viz., typhoid fever—it is on record that nearly 100,000 cases occur annually, and of these about 15 to 20 per cent. prove fatal !

If we consider these facts, and 'the almost total impotence of medicine for direct cure, we may indeed consider this a question more for statesmen and governing bodies than for physicians. Nevertheless, it is necessary that the efforts of the former should be guided by such knowledge of the nature and causes of these diseases as the science of the day can afford. Nor is such knowledge less to be desired for the people in general, in order to counteract the baneful effects of ignorance and prejudice.'*

Let us now endeavour to ascertain how far science is able to indicate the nature and causes of infectious diseases, and to provide the means of preventing or arresting them.

In the first place, it may be useful to remind my readers that the terms 'infectious' and 'contagious' are not absolutely synonymous ; all contagious diseases are infectious, but all infectious diseases are not necessarily contagious.

Infectious diseases are naturally divisible into three classes, viz. (1) those which depend upon poisons which originate outside the body and are not contagious ; (2) the contagious diseases arising from contagions or specific excitants, which are reproduced in or upon the bodies of the sufferers ; and (3) diseases in which the contagion is not so readily transmitted

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* 'The Germ Theories of Infectious Diseases,' p. 1. By John Drysdale, M.D. London : Baillière, Tindall & Cox.

from person to person, but which at the same time is, it is believed, always derived from a prior case, the poison being carried in the secretions.

As examples of the first class, we may instance malarial fever and septicæmia. In the first of these it is supposed that under favourable conditions, as regards moisture and temperature, vegetable matter undergoes a process of decomposition, resulting in the formation of a specific poison, which, by its reception (or that of the micro-organisms which produce it) in the living body, produces either remittent or intermittent marsh fever. The disease known as septicæmia is really very similar to this in many respects, although there is no doubt as to the non-living nature of the virus (sepsin),* for the poison is produced during the putrefaction of albuminous compounds; and when it is introduced into the blood-system, gives rise to the disease in question.

Both sepsin and the malarial poison are always generated outside the body itself, and neither disease is communicable from one person to another, in the ordinary sense of that expression, and excluding inoculation.

Small-pox, measles, scarlet fever, plague, and glanders, etc., are members of the more contagious class of diseases. It is said they never originate spontaneously, but are always communicated from one person to another, the specific contagia upon

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* Consult Dr. Burdon-Sanderson's papers contained in the Reports of the Medical Officer of the Privy Council, etc. No. 3, 1874, and No. 8, 1876.

which they depend being evolved from one person, and reproduced in the contaminated organism. In small-pox, the virus is thrown off from the skin; in measles, from the mucous glands of the nose and air passages; in scarlet fever, by the glands of the throat in particular, and so forth. How virus, after transplantation, establishes and reproduces itself, will be our study hereafter.

Of the third class, it appears that the virus of any one disease may be carried in the secretions, and is capable of undergoing development outside the body. Thus in typhoid fever and cholera the contagion is elaborated or reproduced by or in the glands of the intestines, and hence passes away with the fæces. In these it resides, and maybe partly develops, being ready at any future time to attack those persons who may become exposed to its influence. Supposing that such infectious matter be not immediately altered or destroyed, its possibility for harm is unlimited; for as the fæces dry, its particles may be carried either into drinking water or the atmosphere, and woe to the man who either drinks the one or breathes the other when they are so contaminated!

Even in ancient times infectious diseases were supposed by Hippocrates, and later on by Diodorus, to be connected with putrefactive processes. So also in the middle ages, Fracastori ascribed a host of diseases to the same sources.

Later, there arose in the minds of men another theory of disease, which, however, to do modern investigation justice, until recent years rested upon a most insignificant basis. This theory which may be said to have originated with the remarkable investigations conducted by Leeuwenhoek in 1683, in course of which he discovered the existence of active microscopic organisms, was revived by Henle in 1840, and again, in his *Rationelle Pathologie*, in 1853. Although since then, the classical researches of Pasteur on fermentation, and those of Tyndall and many others on germ life, have added much to the data, the theory itself has undergone no material change. In 1840 Henle taught that 'infection in contagious diseases is caused by living beings, and that scabies is to be regarded as a type of contagious diseases.'* To this, Liebig replied that such an opinion was founded on the principle that like effects imply like causes, and he goes on to add, 'This is the very principle which for centuries impeded the progress of natural science, and which, even in the present day, leads to so many errors.'

Liebig did not deny the existence of parasitic diseases; on the other hand, he readily admitted that there are many diseases which are caused by parasites which are reproduced in and upon the bodies of animals, and live at the expense of the constituents of their bodies. Scabies (or the itch) is such a disease; and muscardine, a disease to which the silk-worm is liable, is of a similar nature—in truth, there is no lack of examples. He, however,

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* Henle, *Zeitschrift*, ii., 305, and Liebig's 'Animal Chemistry,' English edition, 1846, p. 210.

maintained that, excluding parasitic diseases, which naturally require no chemical or any other theory to explain their communication, the true contagious diseases (such as small-pox) depend upon perfectly distinct and different causes. He writes,* 'The condition which determines in a second individual, his liability to the contagion, is the presence in his body of a substance which, by itself, or by means of the vital force acting in the organism, offers no resistance to the cause of change in form or composition operating upon it. If this substance be a necessary constituent of the body, then the disease must be communicable to all persons; if it be an accidental constituent, then only those persons will be attacked by the disease in whom it is present in the proper quantity, and of the proper composition. The course of the disease is the destruction and removal of this substance; it is the establishment of an equilibrium between the cause acting in the organism which determines the normal performance of its functions, and a foreign power by whose influence these functions are altered.'

In brief, Liebig looked upon fermentation and the true contagious diseases as processes in which, alike, a substance in process of change imparts by virtue thereof a disturbance to the equilibrium of the elements of other bodies. Beyond this general definition he did not attempt to define the nature of the contagia, but merely contended that all contagia

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* Page 205 of his 'Animal Chemistry.'

are not parasites. He adds,* 'In the contagion of small-pox, of plague, of syphilis, of scarlet fever, of measles, of typhus, of yellow fever, of dysentery, of gangrene, of hydrophobia, the most conscientious observation has not been able to detect animals, or even organized beings at all, to which the powers of propagation could be ascribed.'

Nearly fifty years have elapsed since these words were written, and although many conscientious and untiring workers have laboured in these paths of investigation, to-day's science can give no better theory of contagion, or better indicate the manner in which the contagia act upon the living body.

The further consideration of this subject, which is one of great scope, will be best treated by stating the chief established facts without any discussion, except of some salient features.

Following the discovery made by Leeuwenhoek, there came the researches of Cagniard la Tour and Schwann, by which it was proved that the globules of yeast are living plants which multiply indefinitely under favourable circumstances; since then, it has been established by the researches of Pasteur and others, that the ordinary processes of fermentation are so many instances of a biological reaction manifesting itself as the result of a special force residing in organisms; or, in other words, fermentation is essentially 'a correlative phenomenon of a vital act, beginning and ending with it.'†

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* Page 209 of his 'Animal Chemistry.'

† See Schützenberger's work on Fermentation, p. 39. H. S. King and Co., London.

Indeed, a ferment, such as yeast, behaves towards a chemical substance, such as sugar, just in the same kind of way that a parasite behaves towards the body on which it preys. The two phenomena are correlative and parallel.

As yeast splits up sugar (or rather, as a matter of fact, seems to yield a product which does the chemical work), and lives upon it, reproducing itself; so also, certain forms of germ life behave towards albuminous compounds as previously explained. The one phenomenon is called fermentation, the other is known as putrefaction.*

The microbes which induce putrefaction are undoubtedly ubiquitous, and this is a fact which it will be important to bear in mind hereafter. All the water and air we drink and breathe, ordinarily swarm with germs of the three natural groups of the lower fungi,† viz., the mould fungi, the spreading or yeast fungi, and the bacteria. These groups comprise a great variety of septic and alcoholic ferment-organisms and monads, and form part of the organic matter of the air, which amounts, according to Angus Smith, to one grain in 200,000 cubic inches in the case of pure country air, and one grain in 8,000 to 10,000 cubic inches of less pure town air.

To understand the infinitesimal size of these organisms, it may be mentioned that Naegeli has calculated each to weigh only the thirty thousand

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* See the Author's paper, *Journ. Chem. Soc.*, January 1880.

† Stated by Dr. Drysdale, partly on the authority of Naegeli. See p. 24 of his essay.

millionth of a milligram! 'Consequently,' writes Dr. Drysdale, 'all animals and vegetables on the face of the earth are continually receiving abundance of fungus-germs in the water essential to their existence. Thus, in the air we breathe, in all that we eat and drink, and touch, and lie on, we are continually exposed to the reception of germs. Accordingly, bacteria and various fungi and germs have been detected on all parts of the surface, and of the mucous passages open to the air, and in the organs communicating with the mucous membrane. They are found in myriads on the tongue and in the tartar of the teeth, in the nose and throat, and all through the alimentary canal, into which countless myriads are continually poured with our food and drink. Even developed bacteria have been found in the liver and spleen, and in the blood of healthy animals in certain cases; but the germs or spores are diffused through the interstices of the tissues, where under favourable circumstances they may come to maturity, as bacteria are sometimes found in abscesses shut off from the air. They are found also in the perspiration of the axilla, the face, and other parts; also in the fluid of blisters raised artificially. Nay, even, they are found in seeds or ova; the pink mould has been found in the middle of a nut, and the *Dactylium soyerium* in an unbroken egg. The cells of plants produce fungi, which fructify within them. In short, we may take it as established, that the whole of the higher organisms are interpenetrated perpetually with the germs of the lower fungi, and these may even develop in small numbers without much disturbance of health.'

According to Klebs,* members of the three groups of hyphomyceta, algæ, and schizomycetæ, occur in the animal and human organisms in infectious diseases. The first of these groups requires an abundant supply of oxygen, and as they run their course chiefly on the surface of the body, they are not deemed to be of the greatest importance. The group includes the forms *achorion, trichophyton, oïdium, aspergillus,* and are considered to be the causes of favus, ringworm, thrush, and possibly madura-foot and actinomycosis.

Of the algæ, only one, viz., *leptothrix,* is considered known as a producer of disease. It is supposed by Klebs, not only to give rise to deposits of carbonate of lime in the teeth, but also in the urinary bladder (calculi); and when the organisms attack the teeth, they are stated by Leber and Rottenstein to cause caries.

The schizomycetæ is the most important group, and it comprises two widely different series of forms, viz., *bacilli* and *cocco-bacteria.*

The bacilli consist of threads, in the interior of which permanent or resting spores are found, which, when they become free, develop under the influence of oxygen into new threads. The splenic disease of

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* 'On the Relations of Minute Organisms to Certain Specific Diseases,' *Brit. Med. Journ.*, August 13th, 1881. See also 'Micro-Organisms and Disease,' by Dr. E. Klein, and an account of the Biological Laboratory at Health Exhibition in *Brit. Med. Journ.*, August and September, 1884.

cattle is caused by such organisms; so also is hog cholera (Klein), etc. Cholera and yellow fever are also supposed by some to be caused by members of this series. They are longer in proportion to their thickness than bacteria; sometimes their ends are rounded, and at other times square. Some have a cilium, and have rapid motions, while others have not. They all multiply by fission.

The second series of the same group consist of *micro-cocci* (oval or spherical bacteria). When multiplying, they become dumb-bell shaped, and then divide transversely. They often break up by division into chains, and lead again to the production of resting masses of cocci. This series is further subdivided by Klebs into *microsporina* and the *monadina*, in the former of which the organisms are collected into spherical lumps, and in the latter into layers. The one class is developed in artificial cultivations at the bottom of the fluid, and requires a medium poor in oxygen, while the other genera require much oxygen and therefore develop on the surface. To the *microsporina* Klebs attributes the septic processes, and also diphtheria, and the *monadina* are believed by some to produce inflammatory processes, such as rheumatic affections of the heart, kidney and liver affections, and in general, the inflammatory processes which do not lead to suppuration, but to the formation of connective tissue, also acute exanthemata (including variola-vaccina, scarlatina, and measles), and infective tumours (including tuberculosis, syphilis, and glanders).

Cohn gives a different classification, which has been adopted by Klein; it is as follows: (1) Bacteria proper; (2) micro-cocci; (3) bacilli; (4) spirilla.

Bacteria, generally, are minute organisms, multiplying by fission (division), and they are composed of protoplasm invested with a delicate membrane. It is this membrane which enables them to resist, to some extent, the action of caustic chemicals. Bacteria while alive are generally very active, their movements being produced by means of delicate thread-like processes termed *cilia* or *flagella.* Bacteria proper are oval or slightly elongated rods, having round ends; they elongate before fission, and as they separate they develop the *cilia.* Their movements cease under certain circumstances, and a resting stage is attained during which the individuals become embedded in a kind of gelatinous matrix.

Of the *micro-cocci* and *bacilli* we have already given descriptions.

*Spirilla* are corkscrew-shaped bacteria, varying very much in size; the largest measuring about ·03 millimetres in length, with a long flagellum at each end. They are often found in putrid organic infusions. One well-known spirillum produces a rose colour often visible to the naked eye, and other bacteria often produce pigments in the media of their development.

Pasteur, as mentioned elsewhere, divides bacteria broadly into *œrobes,* which require free access of oxygen, and *anœrobes,* which grow without free oxygen. They all require food containing carbon and nitrogen and certain inorganic salts. Most bacteria are destroyed by freezing and by drying, but the spores of *bacilli* constitute an exception; they survive exposure to − 15° C. Micro-cocci are destroyed at a temperature of 60° C., bacilli at 100° C., and all spores are killed by a temperature of 120° C. to 140° C., if sufficiently sustained. Many chemical substances are inhibitive to their growth.

These micro-organisms present a remarkable power of endurance, when compared with that of human beings and animals in general, but it must not be forgotten that their type of life is altogether of a different order. Thus, Miquel has cultivated a bacterium which lives and thrives in a medium charged with sulphuretted hydrogen, and it has been well established that growth or multiplication by scissiparity or spore-production, can take place up to 55° C., according to Cohn, or 74° C., according to Van Tieghem.* Already, in an earlier chapter, mention has been made of the experiments made by the late Mr. F. Hatton for Dr. E. Frankland, who concluded that bacteria can be cultivated in an atmosphere of either carbonic oxide, cyanogen, sulphurous anhydride, nitrogen, nitrous oxide, carbonic anhydride, or coal-gas. Mr. Hatton observed that in an atmosphere of air, the organisms present in a meat-solution, absorbed oxygen and eliminated carbonic anhydride. An atmosphere of

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* See paper by F. J. Faraday, F.L.S., *Chem. News*, vol. l., pp. 71—74, 90—93.

hydrogen was not affected, and did not apparently affect the bacteria. Cyanogen seemed fatal to the bacteria when in solution in that form, but its decomposition into ammonium salts and azulmic acid was assisted by their presence. Sulphurous anhydride, even when present in the meat solution to saturation, was apparently without influence on the bacteria. Salicylic acid, strychnine, morphine, narcotine, and brucine, Mr. Hatton found to be 'without any effect upon bacteria, even when quite large quantities are put into the solution containing the germs.' On the other hand, it was noted that phenol, spongy iron, alcohol, and permanganate of potassium destroyed bacteria with great rapidity.* With regard to these experiments, it is to be observed that some of the substances employed are insoluble in meat solutions, so that unless it can be proved that bacteria breathe as do human beings, it cannot be supposed that a mere envelope of gas prejudices their existence. Further, it must be remembered that the chief function of micro-organisms, so far as has been ascertained, is the destruction by oxidation of organic refuse at large. To accomplish this destruction, oxygen is necessary, and if the bacteria cannot get it in a more ready manner, they are able to decompose comparatively stable substances, and rob them of their constituent oxygen. It would, indeed, appear, from the description and results of Mr. Hatton's experiments, that he actually experienced this fact. Thus,

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* *Journ. Chem. Soc. Trans.*, 1881, p. 247.

in an atmosphere of carbonic oxide, the bacteria unmistakably decomposed it, or caused its decomposition, utilising its oxygen for purposes resulting in the production of carbon dioxide; a similar process would appear to have taken place in an atmosphere of nitrous oxide.

Mr. W. M. Hamlet also conducted an investigation about the same time, and it will be interesting to direct attention to some of his results.* He used various solutions for cultivating the bacteria, viz., Pasteur's fluid with sugar, beef-tea, hay-infusion, urine, brewers' wort, and extract of meat, and employed flasks similar to those used and described by Pasteur. Mr. Hamlet confirms the results obtained by Mr. Hatton in respect of the behaviour of oxygen towards bacteria; they make use of it to convert dissolved organic matter into ultimate products including carbon dioxide. This is strictly in accordance with the known history of putrefaction as worked out by Pasteur. After describing his experiments, he writes: 'These results show that amounts of chloroform, phenol, and creosote, varying from ¼ to 3 per cent., do not destroy bacteria, although their functional activity is decidedly arrested while in contact with these reagents.' They are subdued in activity, but not deprived of their vitality, which they regain when restored to more congenial surroundings. He continues: 'Upon both classes of bacteria, oxygen has a most important action. To the anærobian,

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* *Journ. Chem. Soc. Trans.*, 1881, p. 326.

oxidation is rapid and fatal as a poison to the higher animals, while the ærobian, less easily oxidised, are resolved by complete oxidation into nitrogen, carbon dioxide, and water.'

'We may conclude, therefore, that those bodies which destroy bacteria are those capable of exerting an immediate and powerfully oxidising action, and it seems, after all, but stating a truism to say that (extremes of temperature, of course, excepted) it is active oxygen which must be regarded as the greatest known enemy to bacterial life, whether from the action of chlorine, nitric oxide, ozone, or peroxide of hydrogen. It also follows that these bodies are the best disinfectants.'

Without entering further upon this study, it may be taken for granted that some micro-organisms exhibit a wonderful power of endurance. Some of them may be strongly heated and nearly frozen, dried, and the matter containing them pulverised, and still they live; they may be exposed to various gases, or cast into certain chemical solutions, and yet they are not killed. It is, however, far more important to ascertain under what conditions they can be influenced or are killed. They are all destroyed by a sufficiently high temperature; they can be killed by a process of starvation adapted to the peculiarities of their life-history, and many chemical reagents either arrest or divert their functional activity, or kill them outright.

It is to the action of such micro-organisms that the germ theory attributes all the contagious diseases to which man is liable!

It will be seen that to a certain extent, the ubiquity of germs is a very telling argument against this theory when applied in its widest sense, and it may be safely said that its upholders, in their zealous search for germs, and hoping to find them associated with infective inflammations and contagious fevers only, have indeed found them pretty well everywhere—much to their discomfiture. If it be true that germ life is *per se* contagium vivum, then it can no longer surprise us that infectious disease is of common occurrence. On the other hand, it devolves upon the germ theorists to explain the escape of any one individual from such an all-pervading contagium.

In spite of all that has been said and written on the side of the germ theory, its very advocates cannot but admit that so far as small-pox, and most of the principal contagious fevers are concerned, 'their connection with pathogenic organisms is, as yet, a matter of pure inference' (*Roberts*).* Nay, more, it is scarcely a matter of inference; it is one of pure hypothesis. It must be obvious to all, that if the true contagious fevers are attributable to specific germs, then small-pox, scarlatina, and typhus should originate spontaneously, instead of which they seem to be entirely dependent upon previous cases.

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* 'Reports on the life History of Contagion.' By Dr. Braidwood and Mr. Vacher. Also Dr. Roberts' address, *Brit. Med. Journ.*, 1877.

This, at first sight, would appear to be an insurmountable difficulty, but the theorists have invented a way out of it.

It is true that the constant presence of a particular species or genus of germ may be microscopically demonstrated in the case of certain diseases, but it is also true that the same observation may often be made in cases where there is no disease. For instance, Dr. T. R. Lewis, of the Army Medical Department, found* that the comma-shaped bacillus, identical in size, form, and reaction with dyes, with that described by Koch as the specific cause of cholera, is present in the secretions of the mouth and fauces of perfectly healthy persons: what is more, Klein does not believe in Koch's cholera *bacillus*, and is stated to have swallowed the bacillus and to have experienced no ill result.

The theorists evade such difficulties by crediting certain of these low forms of life—not distinguishable by appearance or ascertained life history from others known to be harmless — with pathogenic powers. That is to say, they view them as physiologically distinct, often, at least, without sufficient warrant for so doing. Thus, it is urged against the observations of Dr. Lewis that the mode of growth of the comma-shaped bacillus in gelatinised meat infusion, should be relied upon as affording a means of distinction between the innocent germs and the pathogenic organisms of Koch; but it seems to me

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* *Brit. Med. Journ.*, September 20th, 1884.

rather to rest with Koch to prove that this suggested distinction has a real existence, although, failing that, it might have been hoped that Dr. Lewis would himself make this proposed test of identity a matter of experimental observation.

Against the germ theory, pure and simple, it may be further urged that it is almost, if not quite, practically impossible to perform an inoculation experiment in which, with absolute certainty, only one specific micro-organism is employed, and that in a state free from any secretion or product which may possibly constitute the virus.

It must be admitted, on the other hand, that there are several diseases which, it is now generally and confidently asserted (and not without considerable reason) are caused by micro-organisms. To these a little attention must be devoted before we proceed to study another doctrine, which, in some respects, is of a more acceptable nature.

Dr. Obermeier, of Berlin, was the first to observe spiral micro-organisms in the blood of patients suffering from relapsing fever, and since that time the observation has been often repeated. This disease is not contagious in the ordinary sense of that word, but may be communicated by inoculation with the blood of a patient, provided the blood be taken during the paroxysmal periods, when spirilla are present; they are absent at the crises (a remarkable fact, in itself, and affording, it seems to me, good reason for doubt as to the true cause of the disease). From this it is concluded that the spirilla constitute the infectant.

It is admitted that ocular evidence of the germ in question is all but absent, and all attempts to cultivate the spirilla out of the body have failed. Whether, therefore, the disease is, after all, not communicated by some other constituent of the blood, is not absolutely certain.

In 1855 Polender discovered minute staff-shaped bacteria in the blood in cases of splenic fever, since when it has been ascertained that they also exist in the spleen, the lymphatic glands, etc., etc. Cohn and Koch having devoted particular attention to this subject, they have concluded that *bacillus anthracis* is the true virus of the disease—a view which is now pretty universally held.

Here, again, the contagium is communicated by actual contact of the blood or other exudations of a diseased subject, but it is not communicated by placing animals in the closest proximity to the diseased ones; in short, there is no infection through the air. It is also to be observed that the infective power of the blood disappears on the appearance of putrefaction. It is not necessary to go through the life history of this microbe; it will suffice to state that Koch seemed to have proved beyond cavil that, in suitable nutriment, spores are formed, and these reproduce the rod-bacilli, a cultivation of which is then competent to produce splenic fever in living animals. Whether, however, this result is actually brought about by the germs in question, or by anything accompanying or produced by them, is not quite clear. The test was a crucial one; but, as admitted by more than one well-known pathologist, there exists some reason to doubt whether Koch obtained the bacillus quite free from other possibly poisonous matter.* The reason is the greater since Professor Cohn could not distinguish *bacillus anthracis* from *bacillus subtilis* (of the butyric fermentation) in a morphological sense. Under the microscope they are indistinguishable.

More recently Klein, by an investigation† of infectious pneumo-enteritis in the pig (pig typhoid, so called), came to the conclusion that this disease is caused by a microphyte admitting of artificial cultivation outside the body, and which, when so cultivated, even to the eighth generation, is capable of producing the original disease in a healthy pig. No one can question the extreme care and skill with which these experiments have been conducted; but at the same time there still exists the doubt as to whether the disease is really caused by the germ itself (or some toxic substance accompanying it), or is owing to some product to which either it, or some secretion from it, gives rise in the body of the pig.

To illustrate the full intent of this argument, it will be convenient to recall the facts concerned in septicæmia. In that disease the poison has been proved not to consist of germs, but of a non-living substance elaborated by micro-organisms in a suitable

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* See Dr. Drysdale's Essay, p. 16. Also my 'Animal Chemistry,' p. 438.

† Seventh Annual Report of the Local Government Board (1877-78).

medium; and so similarly, for aught that is known, both splenic fever and pneumo-enteritis of the pig may be directly produced.

The position may be summed up in a few words.

If it be admitted that splenic fever and so-called pig-typhoid are directly caused by microphytes, then I contend that such diseases must be taken out of the class of ordinary contagious diseases, and be henceforth viewed as parasitic diseases, being placed side by side with scabies, fungus-foot, and the horrible disease caused by the *trichina spiralis* when introduced into the living body.

It has been mentioned already that Cohn failed to distinguish *bacillus anthracis* from *bacillus subtilis*. Büchner went further than this: he thought that he had established their convertibility, but both Klein and Koch have published an account of experiments which, in their opinion, upset this idea. I refer to this, in order to call attention to the hypothesis of Von Nägeli as to the convertibility of the different species of micro-organisms generally. This hypothesis has not received the support of Pasteur, who believes that each special process of fermentation or disease has its own special originating micro-organism. While, however, he does not admit their polymorphous character, he himself has called attention to the means of attenuating their activity to such an extent that it might almost be believed that convertibility has taken place. He states* that if the most

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* Address on Vaccination in relation to Chicken Cholera and Splenic Fever. By M. Pasteur. *Brit. Med. Journ.*, August 13, 1881.

minute drop of blood be taken from a fowl about to die from chicken cholera, and placed in some clear *bouillon de poule* previously sterilised under a temperature of 115° C., and kept under conditions in which neither the outer air nor the vessels employed can introduce exterior germs, at a temperature of 25° to 35° C., the inoculated liquid grows turbid and full of tiny micro-organisms. From this cultivated solution successive solutions can be inoculated to the hundredth or thousandth generation, and if from the last of the series the most minute portion be inoculated under the skin of a previously healthy fowl, the bird will die as surely as though it had been inoculated with the blood taken direct from the fowl which furnished the original source of the poison, and with the same symptoms.

On the other hand, if a considerable interval of time, say a fortnight, a month, three months, or ten months, be observed between the artificial cultivations of the virus, then the virulence of each succeeding product is lessened, notwithstanding the abounding presence of the tiny micro-organisms (shaped like the figure 8), until a product is obtained which, when inoculated into a healthy fowl, will make it ill, but will not kill it. 'When the fowls have been rendered sufficiently ill by the attenuated virus, which the vital resistance has arrested in its development, they will, when inoculated with virulent virus, suffer no evil effects, or only effects of a passing character.' Here, Pasteur says, we evidently touch the principle of vaccination, and he endeavours to show that it is by the agency of atmospheric oxygen that the attenuation of the virus is brought about, for in the absence of oxygen the virulence of successively cultivated solutions is not appreciably impaired. Others have since shown that a similar attenuation can be brought about much more quickly by mixing the virus with peroxide of hydrogen. What, then, is the action of the oxygen? Can it be supposed to alter the very function of the germs themselves? or does it oxidise some virulent chemical secretion or poison which the germs intermediately elaborate or produce? Unless there be an actual process of evolution by which the germ of chicken cholera is morphologically converted into an innocuous form by the agency of oxygen—a supposition which meets with little favour from the highest authorities—the attenuation, it seems to me, must be brought about by a chemical change between oxygen and the real poison, which in that case must be regarded as a chemical substance resulting from the life function of the germ, just as sepsin is elaborated in the process of putrefaction. The accuracy of this view is supported by the fact that there is no fundamental distinction between the effects of well-known chemical poisons, such as prussic acid, chloroform, arsenic, strychnine, and the symptoms of diseases of the class of chicken cholera, except, perhaps, the greater intensity of the poisons that are associated with micro-organic life. I am confirmed in this view for another reason, which I have set forth in a short critical note of Pasteur's work on this subject.* The interpretation placed by that eminent investigator upon his own observations, necessitates the assumption of the presence in the human body of a number of distinct substances, each forming the proper and distinctive food of a particular parasite, and the further assumption that vaccination in some undetermined way gets rid of such substances, or converts them into products not fit to serve as food. In the inflicted process of vaccination with an attenuated virus, the body becomes ill, but does not die. It does not die because, if Pasteur be correct, the parasites do not sufficiently multiply. Why do they not so multiply? It cannot be on account of the insufficiency of the pabulum, for when death follows inoculation of an attenuated virus, it results, so Pasteur says, from the very profusion of the growth of the parasite. The pabulum, which is sufficient to support a given number of parasites, is of necessity able to support a smaller number thereof!

Moreover, there is an utter disregard of quantitative evidence in these various assumptions, for although we are tolerably familiar with the very considerable decompositions effected by parasites, as for example in the processes of putrefaction and alcoholic fermentation, it can scarcely be supposed that even, say in three successive inoculations, the pabulum afforded by the body of a fowl to the virus of chicken

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* *Chem. News*, vol. lxiii., p. 28.

cholera, can be entirely used up; if it be, then its amount must be extremely limited, and its nature is a mystery.

For my part, I have always thought and taught that this is an entirely erroneous line of theory, and if we are to believe in the existence of diseases initiated by germs (and I fail to see how this can be doubted) we must, at least, seek for the real poisons that cause death in the secretions of the parasites or in the chemical products to which they can give rise in suitable media. It is easy to understand how oxygen and other chemical substances and conditions may change purely chemical products, but such changes cannot be conceived as occurring in the parasites themselves. It is only a difference of form, as Klebs expresses it, that corresponds to a difference of function, and if we outstep this boundary we must assume the possibility of the transformation of species, an assumption which is, so far, utterly unwarranted and far-fetched.

All the same, Nägeli contends that the contagious organisms are derived from the miasmatic, and these again from the putrefactive, the latter having an unlimited variability of form and action. Much the same view has been advocated by Dr. Hueppe, who argues that all the so-called specific bacteria owe their origin to putrefactive bacteria on the Darwinian principle of modification by descent. As I have already stated, investigation has failed, so far, to produce any acceptable proof of such contentions. It is far more likely that a number of different organisms are capable of producing the same disease by production of the same chemical product, each multiplying under suitable circumstances ; that is to say, in appropriate but not necessarily the same media. Or, instead of the chemical products being absolutely identical, it is conceivable that within certain limits they may vary both as to amount and exact constitution, the consequence being that, as observed in medical practice, cases of infective fevers present equally variable features even when diagnosed as being identical in kind.

Why should we not be content with the chemical theory, which rests only upon well-ascertained facts?

The fermentation of sugar into alcohol is carried on by the agency of yeast cells, that is to say, by the life function of a living organism, and one of the chief products of the chemical change thus induced is alcohol,

$$\underset{\text{(Cane-sugar.)}}{C_{12}H_{22}O_{11}} + \underset{\text{(Water.)}}{H_2O} = \underset{\text{(Alcohol.)}}{4C_2H_6O} + \underset{\text{(Carbon dioxide.)}}{4CO_2}.$$

The fermentation may be carried on until the amount of alcohol thus obtained in solution is inhibitive to the functions of the yeast, or even destructive of the cells themselves, notwithstanding that strychnine has no effect on the properties of yeast. Thus, the production of alcohol is precisely parallel to the formation of sepsin and other poisonous products by putrefaction : these poisons are fully capable, when introduced in sufficient quantity into the bodies of animals, of causing death. Alcohol itself, in excess, produces poisonous effects, and that it is not more actively poisonous is a mere chemical accident, and is no more to be wondered at than the fact that prussic acid is more poisonous than carbolic acid. By the introduction of another ferment into the alcoholic product, in presence also of air, the alcohol becomes oxidised into acetic acid,

$$C_2H_6O + O_2 = C_2H_4O_2 + H_2O,$$

until it entirely disappears. In like manner, it is easy to understand how other poisonous products of fermentation can be destroyed or converted into innocuous ones by subsequent acts of fermentation or purely chemical change, so that, even if such considerations do not afford a direct explanation of vaccination, they, at least, afford a solution to the process of attenuation with which Pasteur and others have acquainted us.

There is a further matter which requires attention in connection with this subject, and is, in my opinion, of the very greatest importance, and that is the power of the micro-organisms, or ferments, to produce products *varying with the media* in which they are cultivated. Pasteur has shown that the property of exciting alcoholic fermentation is not confined to the cells of yeast, but extends to the elementary organs of plants in general. In brief, the mode of life of micro-organisms enables them to live under very various conditions and in many different media; and corresponding with the difference in chemical composition of the pabulum, there must be differences in the products of their life function, so that sometimes poisonous products may result, and, at others, innocuous products, and according as the one or the other is introduced into the human body, so illness or death may be the consequence, or health may not be impaired.

It must be borne in mind that any one medium does not suit the wants of all kinds of micro-organisms; in other words, while many classes can live upon and develop in one particular cultivating fluid or solid, others cannot. Some require mineral matter, not only of a special kind, but also of a special quantity; some, again, like an alkaline medium and others an acid condition; some require oxygen, and others are killed by oxygen. Yeast likes lime, nitrifying organisms like gypsum, and so forth. I shall show in detail hereafter, that wide as is the variety of substances and conditions in and under which various micro-organisms live, in all probability the nature and properties of the chemical products which are thus elaborated are equally numerous and diverse.

Before passing on to the study of other subjects, attention may be usefully called to the precise manner in which some acts of fermentation are induced. It is thought that fermentation does not represent the immediate result of the presence of micro-organisms, but rather, the chemical changes brought about by a secretion of the micro-organisms which is elaborated in the act of life, after some such manner as saliva is secreted by man. These products are collectively termed zymases, or soluble ferments, and are all derived directly from living organisms: they cause fermentation, however, by purely chemical means. It is in this way that diastase (from malt, vetches, etc.), maltin (malt), emulsin (from sweet and bitter almonds), ptyalin (saliva), pepsin (gastric juice), give rise to the peculiar chemical changes that are so well known in connection with their agency. Thus ptyalin converts the starch of food into sugar; and emulsin converts amygdaline into glucose, oil of bitter almonds, and prussic acid. The soluble ferments are all uncrystallised albuminoid derivatives elaborated by organisms, coagulable by heat and precipitable by alcohol. Taken collectively, their chemical function is that of hydration; that is to say, they influence substances just in the same way that vibriones (or a secretion of vibriones) act upon albuminous principles: they, in other words, split up chemical substances by the fixation of the chemical elements of water.

If now it be conceded that micro-organisms cause disease in man by the poisonous action of their secretions or the chemical products derived directly or indirectly from their life actions, then, since these products may vary enormously with the nature of the media in which they are produced and other circumstances, we may expect to find different diseases or modifications of the same disease, induced by one and the same micro-organism acting under different conditions, and this is actually the case. Proceeding further with the argument, it follows that, the presence of a particular micro-organism in the body does not necessarily imply the presence of a specific disease, for a specific disease can only arise when the conditions surrounding the life of the micro-organism are of a definite character, and adapted to the production of poisonous products by its chemical action or that of its secretion. We shall see hereafter that this is literally the case. After all, then, it is not impossible that the comma-shaped bacillus observed by Dr. Lewis in the mouths of healthy persons, is identical with the micro-organism to which Koch attributes the propagation of cholera.

There is another theory of disease, to obtain a proper understanding of which it will be necessary, first of all, to explain a few fundamental facts taught by physiological science.

Microscopical examination of the structures and tissues of the living body reveals the presence of a matter termed by physiologists 'protoplasm,' or 'bioplasm'; and it has been ascertained that all forms of animal and vegetable life are derived in the beginning from this substance. It is a living, moving, and growing transparent matter, which exists in every part of the body, and it has the power of taking up or assimilating lifeless material, as its pabulum, which it changes in such a way that its elements lose their inorganic nature, become organized, and form part of the living bioplasm. In other words, bioplasm, or germinal matter, feeds upon dead matter, and thereby grows, increasing its mass. As this operation proceeds, the mass of bioplasm divides and subdivides into multitudes of smaller parts, and each of these parts gradually assumes a definite form or structure.

It is in this way that, at the birth of an animal, the different organs and parts of the fully developed body are formed ; and while life lasts, every organ and part is sustained by the formation of new material by the same process. The blood conveys the nourishment, from which the bioplasm resident throughout the organism appropriates the proper elements, and converts them into matter like itself, and this afterwards assumes structural form ; the newly organized tissue is attached to the parent tissue, replacing that which is destroyed by the act of life. That is to say, in life, the tissues are worn down or away, being resolved into products which are removed in the breath, sweat, urine, and fæces. Every thought and act wears out, in this manner, some part of the living body, which is repaired in the manner above set forth.

This grand fact, although long known in principle, was largely proved in detail by the researches of Lionel Beale.* He has shown that bioplasm, occurring in every part of the living body, is germinal matter possessed of a power of selection of elements from the pabulum supplied to it, by which it converts dead or lifeless matter into living matter. By the specific changes which happen in bioplasm at certain stages, tissue results, and hair, skin, bone, nerve, and muscle are produced.

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* 'Bioplasm,' etc. By Lionel S. Beale, M.B., F.R.S. J. and A. Churchill, 1872.

Thus we see that every different part of the body has its own bioplasm, by the growth, division, and change of which so many different types of matter and the secretions are formed. All this is certain, and it is true, not only of animal, but also vegetable life.

So long as normal changes go on, the life of the animal or vegetable is normal, and the products of the change in the bioplasm are physiological in nature. But if these normal changes be influenced extraneously, then other products—departures from the normal type—are formed, and these are pathological in nature.

Such ideas as these, although not so clearly perceived, have existed for ages in the minds of thinking men, and Dr. Drysdale has directed attention to the fact* that, 'in Fletcher's Pathology it is laid down more particularly that the exciting cause of all contagious diseases consists of diseased secretions thrown off by animals affected with the same disease; while miasms, or malarious poisons, consist in diseased secretions thrown off by vegetables in a state of disease.' This amounts in substance to what has just been stated regarding the normal and abnormal changes of bioplasm, and furnishes us with a theory of contagious disease at once simple, natural, and not necessarily at variance with the so-called germ-theory as already described.

Mucus and saliva, like all other substances formed

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* See p. 33 of his afore-cited Essay.

in the body, are derived from bioplasm, and so also is the poison secreted by rattlesnakes; and yet the latter substance is terribly poisonous to man. It is not, however, by such obvious outside influences alone that the normal secretions of the body are influenced. They are liable to be perverted or diseased by a great number of causes, some of which may be even of a mental origin, and thus the body itself becomes irritated and diseased. It is, then, surely natural to believe that, if this can take place in the body of one individual, the vitiated secretions which are thrown off from the body are also competent to graft themselves upon or in the bodies of others, and similarly influence them.

To perceive all this clearly, it must be borne in mind that just as nerve and muscle grow from bioplasm, so also do the secretions generally; indeed, all living or growing matter necessarily depends upon bioplasm; hence, just as mucus, when examined under the microscope, reveals the presence of bioplasts (the particles of bioplasm), so also do diseased secretions similarly exhibit such particles. If, now, such vitiated thrown-off particles come into contact with another person, they have the power, by virtue of the bioplasm which is contained in them, of grafting themselves in or upon the body, and thus disease is communicated. This is the theory of Dr. Lionel Beale.*

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* See Beale's work on 'Disease Germs: and on the Treatment of Diseases caused by them.' Also Dr. Ross's work on the 'Graft Theory of Disease.'

Now, as bioplasm, whether normal or diseased, may also be called germinal matter, since it is literally living matter, it may be allowable to speak of disease germs: but if this be done, it should also be pointed out that by this expression it is not intended to imply parasitic organisms of definite morphological characters. Such organisms are not comparable with bioplasm, for they themselves grow and develop by means of their own bioplasm, and hence they are only comparable in this sense with other organisms possessing structure, such as man. Bioplasm has no structure.

Since, however, the public at large have been misguided in the use of the word 'germs,' it is better to describe this as the 'graft theory of disease.'

In the face of what has just been described, it is particularly interesting to turn back to the views maintained by Liebig against those other scientific men of his day who advocated the parasitic theory. Liebig admitted the existence of vital force in a primary sense, and he maintained that (which to-day cannot be disputed) the life of an organism follows, in the main, a predeterminated course which results in a definite form and composition of the parts. While this process continues it is normal, and the result is health. If opposed by extraneous influences, the vital power of the organism resists them, or succumbs to them, according as to which is the more powerful process. Should the foreign power prevail, then the normal performance of function is interfered with, and the results are pathological.

It is seen that Liebig's teaching also establishes the individual power to resist disease, some persons being more susceptible than others, thus succumbing more easily to its attacks. This individuality depends upon a great variety of conditions affecting personal history and surroundings.

In illustration of the graft theory of disease, it will be instructive to mention a few facts.

In health, the clear colourless fluid called mucus is a product of the transformation of the bioplasm of the mucous membranes; but floating about in it there are particles of living bioplasm which have been derived by division from the resident masses. Now, if there be an excessive supply of nutriment, or if, from some cause, over-stimulation of the activity of the resident bioplasm results, then instead of mucus being produced, an imperfectly elaborated, or degenerated product is formed, viz., pus. In the same way as pus may take the place of mucus, so other parts of the organism may be similarly degraded, owing to the interference and influence of an extraneous power, and diseased products thereby result.

While health lasts, as already stated, every different tissue and part of the body grows from its own specific bioplasm; but pus is a fluid containing a common degraded form of bioplasm or germinal matter, which goes on living and reproducing itself, but which cannot form tissue. It is common, in the sense that every kind of bioplasm may, by similar degradation, give rise to it.

Here we have a remarkable instance of the conversion of a living matter, which ordinarily would go to make tissue of some kind, into another living matter which has no power of forming tissue, but only the power to reproduce itself and to produce a fluid (pus), which is liable in itself to be both acrid and irritating, and which, when further changed as by the putrefactive process, can and does produce even fatal results.

Similarly, the specific contagia of the fevers and other contagious diseases may possibly be degraded forms of bioplasm, which exhibit great powers of resistance (owing to their vital nature); they may be preserved in the moist or partially dry state, within certain limits, and when imperfectly desiccated may be carried hither and thither by air or in water.

Without overstraining the analogy between ordinary infective processes, and the infective process of a cancerous growth, Dr. Creighton's investigations* of this last-named disease are of extreme interest, if viewed side by side with the graft theory.

Dr. Creighton has shown that cancerous diseases are characterised by the chronic self-propagative nature which they exhibit. When the elements of the originally diseased parts are carried by lymph or blood-streams to other parts, these latter are impregnated, and the tumour grows out of the original textural type. This result is not known to be due to any specific organisms resident in the parent tumour,

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* Reports of the Medical Officer of the Privy Council. New series, No. 3, 1874, and No. 8, 1876.

but rather to a ferment-like power of the transported elements which induces previously healthy parts to grow after the manner of the infectant.

These observations are vastly important, because it seems that in such studies the actual process of infection can be watched, and, indeed, far better watched than in processes of inoculation with cultures of micro-organisms floating in liquids of unknown chemical composition ; and, so far as at present determined, the process strictly accords with what might be expected to take place, assuming that the secondary infection is due to the influence of degraded bioplasts derived from the primary growth.

Enough has been said to show the grounds upon which the graft theory of disease is founded ; and it can be well understood that, just as one kind of plant or tree may be grafted on to another, by virtue of the living matter contained in the graft ; so also graft bioplasts may exist that are capable of attaching themselves to, and growing upon, the previously healthy body, thereby producing a departure from the normal life history, or, in other words, instituting disease.

The phenomena of infective processes are thus well explained ; and, granted that parasitic germs can and do produce disease also, it is practically certain that this is owing to their products rather than to themselves as living bodies preying upon the host.

Evidence of an extensive and comprehensive nature is wanted ; and until more facts are ascertained by strictly conducted and accurate investigations and observations, we shall not make any further material advance in our knowledge of the nature of contagious diseases.

Writing of those diseases which now never arise, it is supposed, except from infection, Dr. Drysdale says 'their origin is hidden in the night of time;' and 'although we may circumscribe the area of their operation, yet we can never hope that good food, virtue, drainage, and ventilation will extinguish them altogether, as long as man is a social animal.'

Again, writing of another class of infectious diseases, —such as the catarrh and erysipelas group—he says that as long as these 'arise from the operation of mere common non-specific causes, if by any chance they were swept clean out of the land, they would infallibly reappear, so long as poverty, dirt, overcrowding, famine, war, vice, etc., afflict the human race.'

It has, then, been shown that there are :

1. Diseases which are due directly or indirectly to parasites and micro-organisms.

2. Diseases which depend, perhaps, upon graft-germs (degraded forms of bioplasm) or diseased matters of an animal origin (possibly ferments).

3. Diseases which are undoubtedly due to mere chemical products, as is probably the case with the blood-poisoning produced by sepsin.

Finally, it is seen that all these diseases originate from matters of an animal or vegetable origin which may be directly derived from organisms by certain processes of change induced by degraded bioplasm or by microphytes (as in putrefaction).

And now having reviewed the various theories of disease, and the facts upon which they are based, to what conclusion are we impelled as regards the practical prevention of epidemics? The only conclusion points to the necessity of observing cleanliness of the body as of paramount importance with the health of the mind, and of securing pure air, water, and food as also absolutely essential to sanitation.

While, however, the hope of ever extinguishing the contagious diseases is built upon a poor foundation, it must still be borne in mind that there exists a terribly large amount of actually preventible disease.

To use the words of Professor Corfield* : 'People who are living in the midst of general unsanitary conditions are in a worse plight than people living in the crater of an extinct volcano ; for not only may any one of the severest epidemic diseases break out among them at any time, but they are continually sacrificing unnecessary victims to the demon filth.'

It is beyond doubt, that were the evacuations of typhoid-fever patients destroyed or properly treated in good time, there would be an end to, at least, a vast majority of the 100,000 cases that occur every year. Then, again, all the fever that owes its origin to well-pollution by drainage from the farmyard and its abominable heaps, is likewise preventible. Further, all diseases due to the putrefaction and decay of animal and vegetable matters are mere expressions of insanitary conditions, and could be wholly avoided ;

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* Address to the Sanitary Congress at Croydon, 1879.

while as regards such diseases as small-pox, scarlet fever, and the other members of the more contagious class of diseases, it is in human power to prevent also the majority of cases by a judicious circumscription of the area of disease in the application of strictly scientific methods.

With respect to the distribution of disease, it is not possible to enter into any detailed consideration here, but it may be laid down as a general proposition, fairly well established by Mr. Haviland, that disease has a geography.* He finds that certain districts are store-beds of particular infections, and he thinks he is able to trace a connection between such states and local conditions. Thus Cheshire and Lancashire show the greatest death-rate of all the counties in England and Wales from scarlet fever : 'in them scarlet fever seems ever to be stored, ready at a moment's notice to be carried far and near.' Then, again, the Thames runs through a vast cancer-field ; and there does not exist an important river in England or Wales, subject to seasonal floodings, that does not flow through high mortality districts.

These and similar facts brought forward by Mr. Haviland demonstrate that places exist where the local conditions are such as either originate or favour certain specific diseases. These conditions are no doubt very multifarious, and partly concern climatic influences, geological particulars, water supply, and so forth.

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* See a paper by Alfred Haviland, M.R.C.S., *Journal of Society of Arts*, vol. xxvii., p. 157 ; also his work on the Geography of Heart Disease, Cancer and Phthisis. Smith, Elder and Co.

In the following pages it will be my aim to ascertain more particularly the exact chemical changes that can be initiated by certain classes of micro-organisms, seeking at the same time to utilise the facts thus elicited, in explaining the production of infectious diseases through their agency. Based upon the same considerations, an endeavour will be made to ascertain how far the use of antiseptics and disinfectants assists in the accomplishment of such a desirable end as the prevention of epidemics. Taking the classification of infectious diseases given on a preceding page (211), it is seen that, practically, there is the choice of the following classes of substances for employment in this way :

1. Substances which either destroy, or effectually interfere with, the life of parasites and micro-organisms by preventing the production of the toxic product which cause disease.

2. Substances which destroy graft germs, or effectually interfere with the grafting process.

3. Substances which chemically change, and thus destroy, the toxic substances or diseased matter which are produced by micro-organisms.

The production of communicable disease is evidently most intimately associated with so-called cell-life, and no doubt, in due time, chemical and biological research will throw quite a new light on this important subject.

# CHAPTER VIII.

## BACTERIOLOGICAL STUDIES—PHAGOCYTOSIS—IMMUNITY—CHEMISTRY OF BACTERIAL LIFE.

IN an address on the subject of Bacteriological Research made by Dr. R. Koch in 1890,* he said: 'It must now be regarded as completely proved that bacteria, like the higher vegetable organisms, form constant species, though the limits of these are sometimes difficult to define.' He also pointed out that a species of bacteria, under unfavourable conditions of nourishment, may present stunted forms, and some of its properties, such as the formation of colouring matter, may permanently disappear; these fluctuations, however, are only observed within certain limits, and hence it is not necessary to admit transformation into new or other known species.

Whether or not transformation of species is effected does not appear to me, however, to be the most important consideration. It is the change of properties that strikes me as being of far greater importance, and the question naturally arises, whether this change

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* Address delivered before the International Medical Congress at Berlin. See *Brit. Med. Journ.*, August 16th, 1890, pp. 380—383.

is ever so great that bacteria, which at one time may undoubtedly be capable of producing an infectious disease in the animal body, are at other times incapable of producing such a result. Koch would probably answer this question in the negative, but such an answer by no means satisfactorily disposes of the difficulty. On the other hand, there is distinct evidence to the contrary. Klein, for example, has shown that the *bacillus anthracis,* after passing through white mice, loses the property of infecting sheep and cattle with anthrax. Surely, if this fact has any meaning at all, it must be taken as evidence that cases of infection of anthrax do not merely depend upon the introduction into the animal body of this particular bacillus, but are also dependent in some degree, at least, upon other factors which have not yet been ascertained. This is a very important matter, and the more so, perhaps, because it breaks down one of the conditions which Koch himself has stipulated as essential in identifying the precise relationship of pathogenic bacteria with disease. For, as one of those conditions, it is necessary that a pure culture of *bacillus anthracis* should invariably produce the disease when introduced into the living body.

In the same address, Koch called attention to the important fact now well demonstrated, that all bacteria can grow only under moist conditions ; that is to say, in the presence of water or other suitable fluids, and that they cannot of their own accord pass from wet surfaces into the air. It therefore follows that pathogenic bacteria can be taken up by the air only in the form of dust, and this again limits them, speaking generally, to such as can retain their vitality for a long time in a dry state. Bacteria cannot multiply in the air, as was formerly held to be the case.

Koch has described some interesting experiments with reference to tubercle bacilli cultivated in pure cultures, and found that a number of substances are capable by their presence of hindering the growth of the bacilli, cyanide of gold being most efficacious, of the substances then tested, in this respect; thus, a solution of 1 in 2,000,000 parts checks their growth. All these substances, however, remain absolutely without effect if tried on tuberculous animals. This failure, however, did not discourage him in prosecuting his search with a view of discovering a growth-hindering remedy, and in his communication, now under notice, he stated that he had hit upon a substance which has the power of preventing the growth of tuberculosis bacilli, not only in a test-tube, but also in the body of an animal. Guinea-pigs are, as is well known, very susceptible to tuberculosis; but if they are exposed to the influence of the substance referred to by Koch, they cease to react to the inoculation of tuberculous virus, and that, even in respect of guinea-pigs suffering from general tuberculosis to a high degree, the morbid process can be brought completely to a standstill without the body being in any way injuriously affected.* From the results of this investigation, Koch drew the conclusion that it is possible to render

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* Since then Koch's remedy for tuberculosis has proved a failure.

pathogenic bacteria in the living body harmless without injury to the latter; but I fail to see that this conclusion could have been doubted after the earlier observations made by Klein with reference to the *bacillus anthracis*, as previously described.

As to the relations of micro-organisms with infectious diseases generally, Koch argues that if it can be proved, first, that the parasite is met with in each individual case of the particular disease, and under conditions which correspond to the pathological changes, and the clinical course of the disease; secondly, that in no other disease is it found as an accidental non-pathogenic guest; and thirdly, that if completely isolated from the body, and cultivated in pure cultures with sufficient frequency, it can reproduce the disease, then it can no longer be considered an accidental accompaniment of the disease; but in that case no other relation between the parasite and the disease can be admitted than that the parasite is the cause of the disease. It is now, however, known that a particular bacillus does not necessarily produce disease when present in an animal body; other conditions must also prevail before the disease can be produced. This fact is to my mind a serious impediment, while the morphological characters of bacteria are insufficiently distinct for Koch's second condition to be observed in any strict sense.

At one time it was represented that a particular disease must consequentially ensue upon the introduction into the body of a particular bacillus, and while, of course, the experiments of Klein, with reference to the *bacillus anthracis* above referred to, do not perhaps suffice to upset the doctrine of specificity, they constitute a very great obstacle in the way of its absolute and general acceptance. If the so-called specific diseases result, as is now supposed, from the production of poisons within the living body by the agency of bacteria, it almost necessarily follows that the same, or equally virulent poisons, may be produced by a great variety of bacteria ; and further, that they are capable of producing different poisons according to the conditions in which they are developed, and therefore, of course, varying with the substances which they encounter. Such a revelation, if thoroughly established, would after all be only on a par with the fact that many different micro-organisms, when developed in chemical media, give rise to some extent to the production of one particular product, as well as to a variety of others. Before leaving this subject, I wish to make it clear that, so far as bacteria are the active agents of disease, they are only indirectly so, and that the effects of disease are in reality due to the chemical products which the bacteria originate. Further, that inasmuch as the action from which these products result is chemical in character, the nature of them must of necessity vary according to the substances which yield them, and with many other factors which may assist or retard or modify the chemical processes.

Koch admits that, in respect of a great number of infectious diseases, bacteriological research has left workers entirely in the lurch. 'This is the case,' he says, ‘ most conspicuously with the entire group of infectious exanthemata, such as measles, scarlet fever, small-pox, and exanthematic typhus. For not one of these have we succeeded in discovering even the least clue as to the nature of the agents which produce it. Even vaccinia, which is always at our disposal, and can so easily be made the object of experiments on animals, has obstinately resisted all endeavours to discover the real agent which produces it. The same thing holds good with regard to rabies.’

‘ Again,’ he continues, ‘ we know nothing as to the generating factors of influenza, whooping cough, trachoma, yellow fever, cattle plague, pleuro-pneumonia, and many other undoubtedly infectious diseases.’ As a way out of this dilemma, Koch is inclined to think that in these diseases the causal agents belong to quite another group of micro-organisms, and not to the class of bacteria at all.

Even in respect of those diseases as to which bacteriologists are agreed as to the causes, Koch has felt it incumbent to accentuate the difficulties attached to the identification of the specific bacteria, and has gone so far as to admit, for example, that even a very skilful bacteriologist cannot with absolute certainty distinguish other bacilli from the real typhoid bacilli, which they very closely resemble.

His own work has furnished evidence tending to show that the bacillus which produces tuberculosis in fowls is not identical with that which produces the disease of the same name in man and other animals, although they very nearly resemble each other both in appearance and properties. In his address, Koch stated that there is now a unanimity of opinion respecting the bacillus which is regarded by him as the causal agent of cholera. He may be right, but certainly it was well known only a short time since that Klein, one of the most advanced bacteriologists in this country, did not endorse that view.

In connection with the diseases which are caused by bacteria, much attention has been paid during the last few years to the subject of so-called phagocytosis, a doctrine which is connected with the name of Dr. Metschnikoff, to whom is generally credited the proof (arising from a study of the amœboid movements of certain cells) that they possess the power of including other cells and bacteria, and digesting or absorbing same. He states that when a virulent virus is introduced into the body of an animal, and if the animal proves to be non-resistant, no such phenomena of phagocytosis can be observed, and the microbes remain free to do their evil work; and from such observations he concludes that the phagocytes are specially charged with the defence of the human organism, and enter into conflict with the parasites which are known to affect mankind.

One of Metschnikoff's most striking experiments on the absorption of bacilli by phagocytes or leucocytes was as follows: he introduced under the skin of a frog a membranous tube (made of the lining of the common large grass which grows on the banks of rivers) containing the spores of anthrax bacillus, with the result that very soon the little tube was filled with lymph which was found not to contain any leucocytes, the membrane being impermeable to them. A similar experiment was made with another tube, the ends of which were left open, so that leucocytes could enter. In a day or two both tubes were examined. The contents of the closed tube swarmed with bacilli, but in the open tube the spores had been so effectually disposed of by the leucocytes that the contents could be inoculated into susceptible animals without effect. In a review* of the subject by Professor J. Burdon Sanderson, attention is called to the consideration that incorporated or englobed bacilli are not necessarily defunct. He also expresses the opinion that Metschnikoff's theory has been received, on the whole, with little favour by pathologists, and that many of the facts to which Metschnikoff has redirected attention were known more than forty years since. The interpretation alone is for the most part new. In conclusion he says: 'Let us avoid attaching any other meaning to the unquestionable fact of phagocytosis, excepting first that the emigration of leucocytes is an essential part of the process of inflammation, and that there is an antagonism between this process and the process of general infection.'

An excellent paper on the subject of phagocytosis has been published by Dr. Harold C. Ernst,† and much of the following information has been taken from that source.

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* The Croonian Lectures on the Progress of Discovery relating to the Origin and Nature of Infectious Diseases. See *Brit. Med. Journ.*, Nov. 14th, 1891, p. 1033.

† See *Pharm. Journ.*, Oct. 14th and 21st, and Nov. 11th, 1893.

The so-called phagocytes do not come solely from the leucocytes (the white blood corpuscles); some, at least, are produced from the fixed cells of the surrounding tissue. Beyond the power of englobing bacteria which is exhibited by leucocytes, it is said that a further exceedingly important property has been established, and that is so-called 'chemiotaxis,' which may be described as the property that movable cells have of responding to irritation of any kind, either chemical, as in the case of simple chemical irritants, or vital, as in the case of invading bacteria. This response is of an active kind, and is manifested by actual movement towards or away from the irritant material, as must be familiar to everyone who has seen a swelling in any of the vital tissues resulting from any sort of irritation.

One of the great opponents of Metschnikoff's theory is Christmas-Dirckinck Holmfeld, who has paid great attention to the changes which take place at the seat of inoculation, and who employed rabbits, mice, and rats with anthrax bacilli for material. It should be stated that rabbits and mice are very susceptible, while rats are very insusceptible, to inoculations of the bacilli of anthrax. His results may be briefly described. In respect of bacilli of full virulence, in the case of mice and rabbits there was little reaction at the seat of inoculation, and suppuration never occurred; the bacteria quickly found their way through the organisms, and the animals died. With slightly susceptible animals (rats) a perceptible suppurative reaction was produced in the tissues, and the pus formation was in proportion to the greater or less susceptibility of the animals experimented upon; the less the susceptibility, the greater was the amount of pus formation. The same thing is true of many infectious diseases; the more virulent and more suddenly fatal the disease, the less is the pus formation. Holmfeld considers that the means by which the bacteria are rendered harmless is more in the nature of a chemico-biological action than absorption by phagocytes, and he maintains that most of Metschnikoff's work having been carried out on cold-blooded animals, the results do not hold good for warm-blooded animals.

Baumgarten (another opponent of Metschnikoff) states that the results of experiments carried out in his laboratory were widely different from those of Metschnikoff, while Bitter, who has given a long review of all the work done on this subject up to that time (*Zeit. f. Hyg.*, Bd. IV., S. 378), drew the conclusion that Metschnikoff's work and that of his supporters does not afford absolute proof that phagocytes take up and destroy specific disease-producing bacteria.

Now, so-called immunity is conjectured to arise either in consequence of the power of leucocytes and other cells to englobe and destroy virulent microbes, or to the absorption of the virus by the cells, and numerous facts have been alleged showing, as above mentioned, that microbes which may be contained within the phagocytes are not really degenerated or dead. Sir J. Lister has directed attention* to some

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* See *Brit. Med. Journ.*, August 15th, 1891.

experiments in which it was observed that in lymph taken from the body of a pigeon or rabbit which had been inoculated with virulent bacteria, numerous bacilli were imprisoned in the leucocytes, and they were also seen to grow, and eventually make their escape. Again, even in refractory animals, the microbes were found to increase when kept out of the reach of the leucocytes; thus, if a rabbit were inoculated in the anterior chamber of the eye where there were no cells, the bacteria would be observed to grow freely, and their development was only checked when the leucocytes had, after a time, migrated in large numbers, and proceeded to englobe the microbes.

The way in which inoculation with an attenuated virus is supposed to produce immunity is as follows: if the animal has not been inoculated, the products of the microbes (of the particular disease) repel the leucocytes, whereas if the animal has been inoculated, the phagocytes which have already become habituated to the products of the microbes are attracted to the point of inoculation. M. Gamaleia and M. Pfeiffer have shown that animals completely inoculated against infection are just as susceptible to toxic doses of sterilised cultures as animals not inoculated at all.

Hankin has made some important contributions* to this subject of immunity, as produced by injection of the soluble products of the life of microbes; that is to say, by chemical means as distinguished from

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* See *Brit. Med. Journ.*, July 12th, 1890, and *Medical Press and Circular*, August 26th, 1891.

vaccinal means. All attempts to produce immunity by means of the poisonous alkaloids called ptomaines have failed, and Hankin suspected that not ptomaines, but poisons of an entirely different stamp—so-called albumoses—are concerned in the production of chemical immunity. This consideration led him to make experiments with a view of isolating the albumose of anthrax cultures, and having been successful in that endeavour, he has, by means of the product, been able to produce immunity not only in rabbits, but even in mice. In one of his papers he calls attention to the work of many scientists—chiefly German—who have shown that the cell-free blood is sometimes capable of destroying bacteria; thus, Bouchard has shown that the blood serum of an ordinary rabbit will serve as a culture medium for the *bacillus pyocyaneus*; if, however, a rabbit be made immune against the disease which is produced by this bacillus, its blood serum will be found to have acquired the power of attenuation, and even of destroying the microbe in question. Similar results, it is said, have been obtained with the microbes of cholera, anthrax, and other diseases.

Again, in other diseases, such as tetanus and diphtheria, the microbes do not spread through the body as is the case with anthrax, but, on the contrary, remain at the immediate seat of inoculation, where they elaborate their deadly poisons which produce such disastrous effects. Behring and Kitasato found that the serum of a rabbit immune from diphtheria exerts no bactericidal action upon the diphtheria bacillus ; it possesses, however, the remarkable power of destroying the poison which is produced by that microbe, and it has thus been found possible to cure both diphtheria and tetanus in mice and guinea-pigs ; indeed, Behring is said to have cured mice of tetanus in which the disease had so far progressed that several of the limbs were in a condition of spasm.

The question naturally arises, What is the nature of the substance on which this bactericidal action of blood serum depends ? and, as stated above, Hankin was led from theoretical considerations to suspect that it was a particular ferment-like proteid, known as cell-globulin B. He proceeded to search for the necessary proof by a study of the defensive proteid of the rat. This animal is known to be highly resistant to anthrax, and he soon found that the serum of this animal (which is known to be peculiarly alkaline) contained a proteid body possessing a well-marked alkaline reaction, and a power of destroying anthrax bacilli. When injected into mice along with fully virulent anthrax spores, it prevented the development of the disease. Again, rats fed on bread instead of meat were observed to become susceptible to anthrax, while at the same time the amount of this above-mentioned defensive proteid became very much diminished.

These defensive proteids appear to be albuminous bodies of a ferment-like character, and Hankin thinks that the discovery of them is not necessarily to be regarded as a serious blow to the phagocytes theory, for he conceives that it is possible they are the weapons used by phagocytes in their conflict with microbes, and that only after the death of the cells do these substances find their way into the blood serum.

It is now considered to be well proved, that immunity from various diseases can be produced by the injection of the soluble products of the life of microbes. All the poisons that are supposed to possess the property of suppressing the bactericidal power of the body are albumoses, or at least connected with them. The juice of the papain-tree, according to Rossbach, contains a poisonous albumose which, when injected into the blood in sufficient quantity, causes a sort of septicemia. After the death of an animal caused in this way, the blood is found to be teeming with bacteria, none of which it is said (or rather assumed) are pathogenic in character, but all decay-producing microbes, which, owing to the action of the papain, are enabled to wander from the intestine into the blood and tissues. Further substances of this class will be referred to in a later chapter, including the poison which is contained in jequirity seeds, and apparently also the albumose of the snake-poison.

In the same way that Hankin succeeded in isolating the so-called albumose of anthrax, Roux and Yersin have, they believe, isolated the corresponding poison of diphtheria, which is described also as a proteid body soluble in water, and giving all the reactions of albumoses.

Dr. Sidney Martin has communicated to the Royal

Society* a paper in which it is stated that he has succeeded in separating from anthrax cultures a poisonous alkaloid and two poisonous albumoses, and that, with both the alkaloid and the albumoses, he has succeeded in reproducing all the symptoms of anthrax.

Hankin has also isolated a globulin from lymphatic glands which has the power of killing anthrax bacilli. He concludes one of his papers† with the following remarks :

'The fact that I have succeeded in obtaining immunity with the anthrax albumoses is a proof that these bodies form one of the factors in the conflict between the organism and the microbe. If ever it could be shown that cell-globulin has, or tends to have, a similar action in the living body to that which it has in a test-tube, the question would arise as to whether the anthrax bacillus defends itself from the cell-globulin by means of its albumoses. For this possibility of an albumose destroying a ferment an interesting parallel can be found. Mr. Dickinson, of Caius College, Cambridge, has recently proved that the active principle of leech extract is an albumose ; and just as the leech albumose destroys fibrin ferment, so is it possible that anthrax albumose destroys the ferment-like cell-globulin. Whether or not this is the case I hope to be able shortly to decide, so far as this can be done by a test-tube experiment.'

These remarks may be left to carry their own

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* Proc. Royal Soc., 1890.

† Report to the Scientific Grant Committee of the Brit. Med. Assoc. (*Brit. Med. Journ.*, July 12th, 1890, pp. 65—68)

inferences. I will only add that it is evident, from the results of an immense amount of investigation, of which it would be impossible to give an adequate description in these pages—

1. That micro-organisms when cultivated in the laboratory, or successfully inoculated in living bodies, give rise to the formation of chemical poisonous products, all of which exhibit definite characteristic (pathological) effects, and that they necessarily vary to some extent with the culture medium and the animal.

2. The chemical principles of the blood and tissues of animals exhibit more or less bactericidal properties, and are capable of effecting chemical change in the composition of the products which result from the cultivation of micro-organisms, while they are also susceptible of chemical change as the result of being placed in contact with the same products. It therefore follows that the whole result of inoculating or infecting an animal with micro-organisms or their culture-products is, to a large extent, strictly chemical in character, and necessarily varies with the composition of the substances thus introduced.

3. That until we know immensely more than is at present known respecting the chemistry of the living body, and of the substances that are produced incidentally in the culture of micro-organisms, both in the laboratory and in the living body, as also of their physiological effects, it is really preposterous to write dogmatically or with any assumption of certainty respecting the precise relations of bacteria and disease. Although, then, the germ theory of

disease is now very generally held, and many micro-organisms have been isolated, demonstrated, and cultivated, little is yet known as to the precise method by means of which they set up disease. We have an inkling of the truth, but not much more than that.

As regards the general and chemical properties of the so-called albumoses, they are bodies which are soluble in water, and have been, in several instances, prepared from cultures by filtration through the Chamberland-Pasteur filter, which, in common with the Berkefeld filter, suffices to remove all solid particles and micro-organisms. The albumoses can be precipitated from their concentrated aqueous solutions by means of absolute alcohol. Roux and Yersin found that the diphtheritic albumose is destroyed at 100° C., and that its virulence is weakened even by long-continued exposure to 58° C. (doubtless owing to partial decomposition). The same substance as prepared by Brïeger and C. Frankel after repeated purification, was snow-white in colour, and when in aqueous solution was found to be precipitated therefrom by strong mineral acids, ferrocyanide of potassium and acetic acid. It also gave the biuret reaction, the red coloration with Millon's reagent, and the xantho-proteic reaction. It was extremely poisonous, and when injected into animals produced the same symptoms as the culture. It was accompanied in the original filtrate by a second non-poisonous albumose.

The albumose which was described by Martin was prepared by the cultivation of the anthrax bacillus in alkali-albumin, and was similarly purified by filtration, the filtrate being found free from micro-organic life. He observed that in aqueous solution the albumose was strongly alkaline in reaction.

In connection with this subject, it should be mentioned that before Hankin obtained the albumose of anthrax, Nuttall had in 1888 observed the bactericidal character of fresh blood or blood serum, an observation which was confirmed by Buchner and Nissen shortly afterwards. Emmerich and Mastbaum found that the microbes of pig-typhoid are killed by the blood serum of immunised rabbits, and they also successfully employed such serum to cure the disease in other susceptible animals.

Ogata has, by methods similar to those used by Hankin, extracted a bacteria-killing substance from the blood serum of various animals, whilst Tizzoni and Cattani have arrived at the conclusion that the 'anti-toxic' substance which is contained in the serum of a dog that has been rendered immune to tetanus, is a proteid ferment-like body.

In conclusion, note may be taken of the fact, as demonstrated by some recent experiments of Klein,* that under certain circumstances one bacillus may protect the body against the evil effects of others—doubtless by the production of a bactericidal substance. For example, 'guinea-pigs which had survived a first intra-peritoneal injection of the living or sterilised vibrio of Finkler, of the *bacillus coli*, or the

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* *Lancet*, March 25th, 1893, p. 653.

*bacillus prodigiosus*, respectively, were found refractory against the peritoneal injection of otherwise fatal doses of the living cholera bacilli of ordinary culture, as well as of the "virus fort" of Haffkine.'

Incidentally, these observations of Klein upset certain conclusions of Haffkine regarding the specific action of the cholera bacillus, and are remarkable as affording some evidence that these different bacteria produced, apparently, the same or nearly allied poisons, for they all acted alike, giving rise to the same disease in these experiments. The peritoneal introduction of agar-culture of (1) the vibrio of Finkler, (2) *bacillus coli*, (3) bacillus of typhoid fever, (4) *proteus vulgaris*, and (5) *bacillus prodigiosus* (whether sterilised or not), all produced, Klein states, the same disease, viz., intense acute peritonitis, and when the injection was made subcutaneously, there was produced the same local soft œdematous tumour, gradually becoming smaller and firmer, and occasionally leading to localised necrosis and ulceration of the skin.

As the production of a number of diseases has been shown to be intimately associated with the chemical processes which are induced by micro-organisms in various media, it will be of some interest to note in this chapter some further facts that have been ascertained concerning the chemistry of micro-organic life. S. Arloing has ascertained* that *M. septicus puerperalis* of recent cultivations, and

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* *Journ. Chem. Soc. Abstracts*, 1886, p. 170.

also the anærobic virus of *gangrenous septicæmia*, set up fermentations in solutions of glucose, dextrin and inulin. Hydrogen and carbonic anhydride are evolved in varying proportions; the solutions become acid, and are found to contain glucose, while the deposits which are formed during the fermentations are capable of inducing similar chemical changes in fresh solutions.

The recently dried virus from *septicæmia* and *anthrax* give similar results, unless its activity has been lessened by the action of heat or prolonged dryness.

Adrian J. Brown has studied the chemical action of pure cultivations of *Bacterium aceti.** He shows that this organism, which is strictly ærobic, oxidises ethylic alcohol to acetic acid, and that the acetic acid so formed is subsequently destroyed by the ferment. It also oxidises normal propylic alcohol into propionic acid, while it is without action upon methylic alcohol, isoprimary butylic alcohol, and amylic alcohol. It converts dextrose into gluconic acid, and similarly influences milk, sugar, and starch. Mannitol is completely acted upon by the *B. aceti*, the main product being lævulose.

All these changes may be described, in common with those which I personally and previously investigated,† as brought about by the fixation of either water alone, or of water and oxygen, into the molecules of the substances acted upon, thus produc-

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* *Journ. Chem. Soc. Trans.*, 1886, p. 172.

† See Chapter XV.

ing new products by the processes of hydrolysis, or hydrolysis and oxidation. The same general explanation applies to all chemical actions which micro-organisms are capable of initiating, not merely in laboratory experiments, but also, probably, when acting pathologically in the human body.

In a later paper* Brown has continued his study of *B. aceti*, and shows that by its action the dihydric alcohol, 'glycol,' is oxidized into glycollic acid only, and that the action is favoured by the presence of calcic carbonate, which neutralizes the acid so soon as it is formed.

The trihydric alcohol, 'glycerol,' is completely decomposed into carbonic anhydride and water, and this substance appears to favour the growth of *B. aceti* exceedingly.

Thus it is clearly established that micro-organisms exercise a selective influence on substances with which they come into contact, and can initiate a variety of chemical changes by hydrolysis and oxidation ; in consequence, the products vary with the nature of the pabulum or medium in which they are cultivated.

If the *Bacterium aceti* be introduced into a part of the human body, and glycerol be found present, then, in the ordinary course of things, the glycerol will be decomposed. If, however, an antiseptic be first admixed with the *Bacterium aceti*, the chemical change will probably not take place, and the bacterium itself will be absorbed by the cells of the

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* *Journ. Chem. Soc. Trans.*, 1887.

human body. Similarly, there appears to be some substance present in the human body which is decomposed by *B. anthracis*, and as one of the products is poisonous, the process is apt to lead to disease and death. If, however, an antiseptic, such as "Sanitas" fluid, should be first admixed with the bacterium-culture, then in all probability it would be found that the *Bacterium* is prohibited from setting up the change in question, and that it would be absorbed or destroyed by the cells of the human body before it could do any harm.

Since all the changes which can be initiated by micro-organisms can be classified as acts of hydrolysis or of oxidation, and since I have shown that "Sanitas" fluid, when present in sufficient quantity, prohibits *every such change* (so far as examined) from taking place, it follows of necessity that it is equally capable of preventing pathogenic micro-organisms from initiating disease (see Chapter XV.).

In another contribution, Mr. Adrian J. Brown has demonstrated the fact, that a pure cultivation of so-called 'vinegar plant,' or 'mother' (which is to be regarded as a distinct organism from *B. aceti*), gives all the reactions of cellulose like that which is obtained from cotton-wool, but which *B. aceti* does not show. The cellulose thus formed is converted by strong sulphuric acid into dextro-rotary sugar, and in this respect it resembles ordinary cellulose. The fermentative properties, however, of this growth are identical with those of *Bacterium aceti*.

Further experiments showed that the vinegar plant converts dextrose, mannitol, and lævulose all into cellulose and gluconic acid, but that cane-sugar, starch, and ethylic alcohol do not yield cellulose. Brown has named this cellulose-producing organism *Bacteria xylinum.*

The fermentation of calcium glycerate by *Bacillus ethaceticus* has been investigated by P. F. Frankland and W. Frew.* The products obtained in this fermentation were principally ethylic alcohol and acetic acid, together with smaller proportions of formic and succinic acids. In the case of each completed fermentation there was also found a quantity of a fixed acid amounting to about one-half of the glyceric acid employed; this acid turned out to be one of the two optically active glyceric acids, of which, according to Van t Hoff's hypothesis, ordinary inactive glyceric acid is composed.

It has been shown by P. F. Frankland, A. Stanley and W. Frew, in an investigation† of the fermentation induced by the pneumococcus of Friedländer, that this organism is capable of producing fermentative changes in glucose and cane-sugar, as previously stated by Brieger. They also found that it ferments maltose, milk-sugar, raffinose, dextrin, and mannitol, but that, like *Bacillus ethaceticus*, it does not attack dulcitol. The authors made a special study of the fermentations of glucose and mannitol, the products in each case being ethylic alcohol, acetic acid (generally

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* *Journ. Chem. Soc. Trans.*, 1891, p. 81.

† *Ibid.*, 1891, p. 253.

accompanied by a little formic acid and a trace of succinic acid), carbon dioxide and hydrogen : both the glucose and the mannitol were only partially fermented, the decomposition of the glucose, especially, being incomplete.

In a study of the fermentation of arabinose by *Bacillus ethaceticus*, P. F. Frankland and J. McGregor,* found that the products are qualitatively the same as in the fermentation of glycerol by the same organism, *i.e.*, ethylic alcohol, acetic acid, carbonic anhydride, hydrogen, traces of succinic acid, and another unidentified volatile acid. They also make a quantitative determination of the products of the change, from which they conclude that in the fermentation of arabinose by *Bacillus ethaceticus* the proportion of acetic acid to alcohol is greater than in that of dextrose, and still greater than in that of mannitol and glycerol, but less than in that of glyceric acid.

In a paper† which was recently communicated to the British Association, Warrington points out that it is well known all ordinary soils contain organisms possessing a vigorous power of oxidising—of bringing about, that is to say, a combination between the oxygen of the air and various organic and inorganic bodies.

The organisms producing nitric acid have been made the subject of study by many chemists, and after much labour and many disappointments they have been satisfactorily isolated.

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* *Journ. Chem. Soc. Trans.*, 1892, p. 737.

† *Chem. News*, vol. lxviii., p. 175.

It is now known that the production of nitrates in the earth is accomplished by two organisms. By one, ammonium carbonate is oxidized, and the nitrogen converted into a nitrite ; by the second organism, nitrites are converted into nitrates (see p. 37).

These organisms grow and exercise their functions in dilute solutions of appropriate composition ; it is, therefore, possible to study the exact mode of their chemical nutrition.

Like all other living organisms, they require the presence of certain inorganic salts, *i.e.*, phosphates and sulphates of calcium, potassium and magnesium.

The nitrogenous food is amply furnished either by ammonia, or by a nitrite which may be intentionally added to their culture solutions.

We now come to inquire the source of carbon for these organisms, and we are confronted by the startling novelty that it is unncessary to supply these organisms with any carbonaceous food save carbonates, bicarbonates being preferred. The fact of the conversion of carbonates into organic cell substance has been conclusively proved in the case of the nitrous organism, and it is assumed to be true also of the nitric organism, as this also requires the addition of no organic carbon to its nutritive solution.

It is, of course, well known that green plants when exposed to sunlight are capable of forming organic bodies from the carbonic anhydride of the atmosphere ; but here we have a colourless cell growing in the dark, capable of decomposing that compound. Now, the decomposition of carbon dioxide requires a certain amount of energy, which in the case of plants and trees is supplied by the sun, but in the case of nitrifying organisms must have some other source. This is explained as follows: this nitrifying organism attacks carbonic anhydride in its combination with ammonia, *i.e.*, ammonia carbonate, and the formation of an organic compound proceeds at the same time as the oxidation of ammonia, the result of the whole reaction being a liberation of heat, or, in other words, a surplus of energy.

Another organism which occurs in soil, and which has been studied by Winogradsky, possesses the remarkable power of assimilating free nitrogen from the atmosphere.

In order to study this bacillus, some of it was grown in a solution of sugar containing the necessary non-nitrogenous salts. Under these circumstances a vigorous growth of the bacillus takes place, the sugar undergoes butyric fermentation, and nitrogen is assimilated from the air. Using 7 grms. of sugar, 14 grms. of nitrogen were assimilated.

That a vegetable organism should be able to acquire from the air the whole of the nitrogen which it needs is certainly very remarkable, and is an extraordinary fact both to the physiologist and the chemist.

NOTE.—Students who desire to make themselves more thoroughly acquainted with the details of bacteriology may consult the following works on the subject, in addition to the others which are referred to in the text: 'Photography of Bacteria,' by Crookshank (Lewis: London); 'Manual of Bacteriology,' by Crookshank (Lewis: London); 'Manual of Bacteriology,' by Griffiths (Heinemann's Scientific Handbooks).

# CHAPTER IX.

## ANTISEPTICS AND ANTISEPTIC SURGERY——DISINFECTANTS AND DISINFECTION.

THE scientific use of chemical reagents for the purpose of preventing infectious diseases is necessarily governed and controlled by what is known respecting the causes of these diseases.

In the two preceding chapters it has been shown that, undoubtedly, certain diseases are primarily caused or originated by living micro-organisms. Respecting, however, the more important contagious diseases, including small-pox, scarlet fever, measles, typhus fever, syphilis, etc., no such absolute proof has been forthcoming, and in considering the means to be employed for their prevention, we have to depend upon general considerations and experience.

For the sake of argument, let it be conceded that all infectious diseases are originated by micro-organisms which prey upon the human body: how, then, are we to prevent their spread? That is the question which is involved in the scientific use of disinfectants. Fantastical definitions of the terms 'antiseptic,' 'disinfectant,' 'germicide,' and so on, merit no consideration: we have simply to deal with the prevention of diseases which we will assume to have a common originating cause in micro-organisms* (germs).

This being assumed, the next point to consider is, how these micro-organisms produce disease and death; and in answer to this question scientific investigation of a practical kind has not, so far (as we have shown), provided an unequivocal reply.

In investigating the relationships of micro-organisms and disease, with the object of proving that a particular infectious disease is due to a particular micro-organism, Koch and Klein have pointed out† that the following conditions must be observed:—

1. It is absolutely necessary that the micro-organism be found present either in the blood or the diseased tissues.

2. It must be possible to take the micro-organism from its nidus and cultivate it artificially in some suitable medium to successive generations, care being taken to exclude the introduction of all other micro-organisms. The object of this proceeding is to free the particular micro-organism from every kind of extraneous matter derived from the animal body which furnished the microbe originally.

3. It must be shown that the cultivated microbe is capable of producing the particular disease by inoculation of the healthy body of an animal.

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* Consult the pamphlet by Dr. Charles Cameron, M.P., on 'Microbes in Fermentation, Putrefaction, and Disease.' Baillière and Co., London.

† *Die Milzbrand-Impfung.* Cassel und Berlin, 1883 (Koch). *The Practitioner*, March, 1884, p. 171 (Klein).

4. The micro-organism must be found associated with the disease in the body of the animal thus secondarily infected.

It will, however, be seen at once that it is absolutely impossible to dissociate any particular micro-organism from its own secretions and life products, for successful artificial cultivation implies the presence with the microbe of a suitable medium, in which it lives with ease and multiplies. So that, after all, such investigations can only indicate micro-organisms to be the originating cause of disease, but they are not adapted to the elucidation of all the contingent circumstances. It is not even sufficient to separate the solid from the fluid parts of cultivation liquids, and to prove that the sedimentary or solid parts are infective, while the fluid parts may or may not be inactive. This is proved by the experiments of Panum and Burdon Sanderson, in which it was demonstrated that in certain sterilised cultivation-mixtures it was the solid particulate parts that induced septicæmia in animals, and that these particles consisted of a chemical substance (sepsin) elaborated by micro-organisms. Further, filtration through clay, or gypsum, removes sepsin from cultivation-mixtures, and allows an innocuous liquid to pass through the filter, while in other cases it has been shown that the liquid filtrate thus freed from bacterial life constitutes a virulent poison. Processes, then, of sedimentation and filtration cannot be resorted to with the assurance that they remove the micro-organisms only. Any test which may be applied to such filtrates must be of an imperfect character.

Rather, means must be found of sterilising cultivation-mixtures, so that, after an assurance of the absence of living micro-organisms is obtained, tests may be made with the mixtures, to ascertain if they can induce disease in animals. The difficulty in applying such tests is to make sure that the means adopted for sterilisation do not affect or alter the chemical nature of any substances that may have been elaborated by the micro-organisms in the cultivation-mixtures.

Since the last edition of this work was published, some such experiments have been made, and a general description of them will be found in Chapter VIII. The results have entirely justified my consistent contention that we must look for the real poisons that cause disease, among the chemical products of bacterial life. Such substances are the albumoses.

For the purpose of testing some statements made by Sattler, Klein prepared an infusion of jequirity seeds (*Abrus precatorius*), and made a number of interesting observations therewith. Among other results, he proved that the infusion contains a very poisonous principle, which produces violent ophthalmia when inoculated into the eyeballs of healthy rabbits, and that this principle is a natural constituent, having no relation whatever to the peculiar bacilli which can be cultivated in the infusion, and to the action of which Sattler had attributed the ophthalmia. This poisonous principle is destroyed by boiling, and comports itself something like the pepsin ferment. Warden and Waddell have since isolated this substance, and named it *abrin.* A similar substance exists in castor-oil seed (*ricine*). Both are intensely toxic bodies, minute fractions being fatal to many mammals when directly introduced into the circulation. They are much less active when introduced into the stomach, and Ehrlich has shown that by feeding animals with a diet into which they enter, immunity is in time conferred in respect of what would otherwise prove to be toxic doses of these poisons, although the immunity of each case does not apply to the poison of the other. There is supposed to be some chemical relationship between these toxalbumens and the albumoses which are produced by micro-organisms, and Ehrlich's experiments are held by some to throw a considerable light upon the subject of immunity from disease.

In taking into consideration the method by which pathogenic micro-organisms produce disease, Klein, after pointing out* that their chemical influences on animal tissues are yet unknown, and that even in artificial cultures their chemical effects have not been ascertained, admits: 'It is quite possible that the pathogenic, like the zymogenic, organisms have this special character; that if the soil (animal body) contains a certain chemical substance, they are capable of growing, and thus capable of producing a definite zymogen or ferment.' Although he admits this, he points out a distinction that exists between septic and zymogenic organisms, and pathogenic

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* 'Micro-organisms and Disease,' by Dr. E. Klein, chapters xviii. and xix.

organisms, viz., the fact that the former two absolutely refuse to grow in the living tissue of a living animal; they can only grow where the once living tissue has become dead through the operation of other influences. After all, this distinction is but a matter of accident, in my opinion, for each micro-organism, irrespective of class, requires special conditions and substances for growth. In the absence of sugar, yeast cannot produce alcohol, and in the absence of alcohol, the acetic ferment cannot, of course, produce acetic acid; so also, so-called pathogenic organisms require certain conditions for their propagation; and it is a mere chance that such conditions are presented by living tissues. In this sense, it is absolutely impossible, by any number of successive artificial cultures, to clear a pathogenic micro-organism from its adhering chemical virus, because the micro-organism cannot live except in the presence of suitable pabulum, and that condition being observed, it must give rise to new chemical products by its very life. Thus, although we may admit that pathogenic organisms originate specific diseases, it cannot be admitted that they themselves, by their mere presence in the living tissue, produce all the characteristic symptoms and consequences; but it stands to reason that they chemically alter some substances upon which they feed by the agency of a product that they immediately produce.

Zymogenic and septic organisms cannot live in real living tissue, because it is, or it contains some chemical substance which is, inhibitory to their growth. The same substances may constitute food to other (pathogenic) organisms. In brief, a micro-organism cannot be identical with the virus of any disease; it can only produce the virus by a chemical change of a substance or substances present in the culture-medium or living body in or upon which it grows and multiplies.

Vaccination may be supposed to give protection either by introducing a chemical substance into the body, which is inhibitory to the infective process, or by the chemical alteration of parts of the body, rendering them immune to small-pox.

Klein is forced to admit* that pathogenic organisms act, in all probability, by the production of chemical poisons, but there he stops short, and does not apparently see that if this be so, then two further inferences must be made: in the first place a pathogenic micro-organism can never exist apart from its products (containing possibly some virus), for its life-function is identified with their production; secondly, since the virus is the true infectant, three classes of chemical substances must be employed in the treatment and prevention of specific diseases: (1) substances (true disinfectants) which chemically change and destroy the virus; (2) substances (antiseptics) which, by inhibition of the growth of the micro-organisms, prevent the production of the virus; (3) substances (germicides) which may be proved to be fatal to micro-organisms and their spores, if such substances can be found and applied locally.

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* *Practitioner*, September and October, 1884.

Germicides, if otherwise available, cannot be exclusively relied upon for the cure of diseases; for their introduction into the human body may be as fatal to the host as to the parasites; and while some of them are equally poisonous as the true virus of any infectious disease, they may, for all that is known to the contrary, be without action upon the virus itself, even if the micro-organisms are killed off. As Koch has well put it,* 'it is not necessary, as has often been erroneously assumed, that the bacteria should be killed in the body: in order to make them harmless to the body it is sufficient to prevent their growth, their multiplication.' Among such substances he includes the essential oils, B naphthylamin, paratoluidin, xylidin; many of the so-called tar dyes, such as fuchsin and methyl blue, and many compounds of mercury, silver, and gold.

In every sense, then, non-poisonous disinfectants of the two classes first named are to be preferred, both for the prevention and the cure of infectious diseases.

Chemistry has, unfortunately, been too much neglected in all the recent studies bearing upon infectious and contagious diseases, and its application to them at the present time is perhaps the most patent requirement in the whole range of human wants.

Finally, it must be clearly understood that, so far, the exact nature of the connection between micro-organisms and infectious diseases has not been satis-

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* *Brit. Med. Journ.*, Aug. 16th, 1890, p. 383.

factorily established even in the best studied cases, including septicæmia, relapsing fever, splenic fever, chicken cholera, glanders, swine plague, erysipelas, and puerperal fever. As regards consumption, malarial fever, leprosy, gonorrhœa, and rinderpest, there is yet no final evidence indicating the causes ; while in respect of small-pox, scarlet fever, typhoid fever, typhus fever, cholera, diarrhœa, diphtheria, measles, whooping-cough, chicken-pox, and syphilis, the information is, if possible, still less precise in character.

That readers may not altogether confine their attention to the germ theory to the exclusion of all other theories of disease, I beg to refer them to Chapter VII., in which there is given an account of the graft theory, as it is called, and also a study of the infective process witnessed in cancerous growths.

After all, we have still to depend very much upon the scientific use of the imagination in drawing up measures for the prevention and cure of infectious and contagious diseases.

It is utterly unscientific to suppose, as was once the case, that the mere presence of micro-organisms in the body causes death ; it must be conceded that disease and death are due to certain effects of their presence, and not to the mere mechanical lodgment of living matter in the wrong place. Irritation and local disturbances alone could arise from such mere lodgment. To ascertain their effects we must make ourselves acquainted with the chemical aspect of their life-history. We know that, in common with all living organisms, they require food, and reproduce their kind. These acts of life are attended with the production of excretions and secretions, and all recorded information concerning the chemistry of the living body would point to some product (being either a secretion or a product of its action on other substances) as constituting the direct cause of death to the higher organisms preyed upon by these micro-organisms.* Indeed, practical investigation has, as we have already seen, afforded what may be regarded as a proof of this statement.

The fermentation of sugar and the resulting production of alcohol is not induced by the mere presence of yeast cells in the solution, but it is the consequence of a chemical change imparted to the sugar by a secretion of the yeast cells; this secretion is a product of the life-action of the yeast cells. A similar chain of reasoning applies to the toxic albumoses that are produced by microbes. Thus, it will now be readily understood that blood-poisoning, which results from the introduction of putrilage into the system, is not brought about by micro-organisms in any direct sense, but only indirectly. In a suitable medium these organisms live and flourish, and elaborate a purely chemical poison, termed sepsin. This substance is a chemical product derived from the albumin upon which the micro-organisms depend for food.

Allied to sepsin (the poison found in putrid meat)

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* Compare 'Infectious Diseases in the Army,' by Professor Rudolph Virchow. Translated from the German by John James, M.B., London, F.R.C.S. (H. K. Lewis).

are the various substances now termed albumoses, while the so-called *ptomaines* or noxious alkaloids found *post-mortem,* etc., are frequently found associated with them. As a rule, the action of these ptomaines is of a tetanising nature, acting particularly on the nervous system.

O. Bocklisch* found that by the action of a pure culture of *vibrio proteus* upon chopped beef in water, an innoxious alkaloid termed cadaverine was produced amongst other substances; but when the microbes of putrefaction were introduced into the nutritive medium (care being taken to also introduce those bacteria which are always found present in the contents of the intestines) a toxic substance termed methyl guanidine was formed.

W. Nicati and Riltsch† found that the product of the culture of the so-called *comma bacillus*, which exercises a poisonous effect when injected into the veins of dogs, depends for its effect, not upon the micro-organisms themselves, but a poisonous compound which they produce in the cultivation fluid.

Tyrotoxicon is the name which has been given to another chemical product, having an intense poisonous character, which can be obtained from milk and cheese and articles like ice-cream made partially with milk. Victor C. Vaughan‡ claims to have established the identity of this tyrotoxicon with the chemical product termed diazobenzól, and has shown that it

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* *Berl. Ber.*, 1887. 1441.

† *Journ. Chem. Soc. Abstracts*, p. 169, 1886.

‡ *Pharm. Journ.* (3), vol. xvi., p. 147, and December 10th, 1887.

can be readily produced by inoculating normal milk with the butyric acid ferment, and keeping the mixture in a closely-stoppered vessel for some eight days. It may be added that tyrotoxicon is rapidly decomposed upon exposure to the air (another proof of the disinfective value of the process of oxidation).

In common with other putrefactive poisons, tyrotoxicon produces nausea, vomiting, and diarrhœa.

From these statements it will be seen that, in all probability, the introduction into the human body of microbes, results in the production of quite a large number of distinct chemical products, which are the outcome of the chemico-physiological changes which these organisms set up in the protoplasmic elements with which they come in contact.* Some of these products are poisonous, others are inert, while their interaction may result in the formation of yet further substances, all of which, acting upon the human organism, contribute to determine the symptoms of the disease or to ensure immunity from it.

If these views be correct—and to my mind no other position is tenable—then, as Koch has also pointed out (see p. 248), practical disinfection does not demand the destruction of the microbes themselves, but only the prevention of the production of the poisons which they excrete, secrete, or elaborate concurrently with their development in a suitable medium. To use the words of Professor Virchow, 'These secreted poisons are conceivably

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* For some further account of the chemical changes brought about by micro-organisms, see Chapter VIII., pp. 232-240.

isolable from the micro-organisms which have hatched them; their activity is not tied to the presence of the fungus any more than the fungus itself is of a poisonous nature.'

It is altogether absurd and unscientific to argue that a disinfectant must also be a poison. There is absolutely no foundation for such a statement, and I am surprised that Mr. A. Wynter Blyth should have given support to such a ridiculous view.

Unaided morphological studies of microbes will not lead to any final conclusions respecting the causation of infectious diseases; chemical studies supplemented by physiological experiments will alone suffice for that purpose.

In a word, the method of investigation originated by Panum and continued by Burdon Sanderson should be prosecuted in connection with the microbes which are associated with various diseases. This method has for its object the separation of the microbes from the chemical products to which they give rise under ascertained circumstances, and the identification of the chemical products, with the view of ascertaining the consequences of inoculating animals with them severally and in combination.

Many investigators are of opinion that each infectious disease is originated (indirectly of course) by one particular microbe, but morphological investigations can scarcely be said to have given an adequate proof of this contention (see p. 218), and in any case it would be hopeless to attempt the universal extermination of the micro-organisms which originate or are intimately associated with the production of disease, for they are apparently ubiquitous, and constitute an order in creation. Collectively, indeed, they constitute a most useful and necessary order in creation, for by their agency, or that of some of them, putrescible organic matter at large is converted by hydrolysis and oxidation into innocuous and useful, nay, essential ultimate products. But while it may be injurious to have such micro-organisms at work in our houses, it may be even more prejudicial to health to have them or others at work in or upon our bodies. If they effect a residence in or upon the human body, and the conditions necessary for their reproduction be present, disease may result and death may supervene.

What chemical means and agents, then, are to be employed for the prevention of such diseases ?

They are both general and special.

The general means include cleanliness, the studied exclusion of decomposable and putrescible matters and the process of putrefaction in and near human dwellings, and a due provision of pure air and pure water. Every medical practitioner and every sanitarian, irrespective of theories as to the causation of preventible disease, is assured of the help which filth and insanitary surroundings give to contagious illnesses. That being so, every chemical reagent which admits of being usefully employed in ensuring chemical purity is a disinfectant in the best sense of the word.

Liebig pointed out that miasmatic diseases are endemic in places where the decomposition of organic matter is constantly taking place, as in marshy districts, and that these diseases become almost surely epidemic when a marshy area is dried up by continued heat.

Besides this, it has been shown that animal substances, in a state of decomposition, can excite a diseased action in the bodies of previously healthy persons. This is often experienced in anatomical theatres ; the slightest wounds made with instruments which have been used in dissecting putrefied bodies not rarely lead to dangerous and even fatal results. In such cases, poisonous matter is communicated to the blood in the living body, and, even in such infinitesimal amounts, is capable of producing the most terrible results.

Mr. Haviland, who has made a special study of the geographical distribution of disease, writes as follows :* 'Typhoid fever has no reason for existing at all, but whilst the porous soils of the sites of our villages are being polluted as they are, we must expect well-contamination and its sequel—fever. One great source of well-pollution, which I have known to be the origin of much fever, is the farmyard and its manure-heaps. At present, the rural sanitary authorities are generally composed of farmers and others who cannot, or will not, see anything wrong in their barbarous muck-heaps. The medical officer of health sees their effect daily. The effect of vegetable decomposition on the human system is varied, but marked. Let us take first the decomposition which

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* See his paper previously quoted on p. 213.

produces ague and other forms of fever, as witnessed in the Fenlands, the Pontine marshes, and in other swampy grounds. Or remember the peculiar fever that is the result of living near the localities where flax is steeped and decomposed, or where indigo is allowed to ferment. Then, again, we must not forget that during the American civil war, some few years ago, a form of fever arose, simulating measles, which was traced to the decomposition of the straw on which the soldiers were bedded.'*

Attention has already been directed to the peculiar infectant which is contained in putrilage, and which Burdon Sanderson has shown to be of a particulate non-living nature. It is a most virulent blood-poison, and must, from the method of its production, inevitably result as a product of the putrefaction of flesh wherever it may occur. That being so, it is most probable that its formation also results from the putrefaction of other animal and vegetable matters containing albumin, since its production from flesh is traceable to the same chemical principle. Sepsin, as this poisonous matter is termed, is a mere chemical product of change capable of exerting a physiological effect in the same manner as hundreds of other chemical substances exhibit peculiar physiological effects. Thus, the inhalation of chloroform produces insensibility to pain, and if taken in excess results in death. Similarly, if a septic poison be received

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* See also Professor Virchow's pamphlet previously referred to. It is full of most valuable and precise information on this subject.

into the system, it will produce effects which, when recognised, are expressed as fever, and from which death may result.

It may be borne in mind that many years ago Dr. Semmelweis established the fact, that a number of deaths occurred in a lying-in hospital at Vienna from the conveyance of putrescent matters to the genitals of the patients in an extraordinary manner. The physicians in attendance on the women were largely employed in dissecting, and it was known that these same operators would often leave the dissecting-room to examine women in labour, and thus introduce on their hands the poisonous matter which led in so many cases to puerperal fever, and finally to death.*

It is true that the precise connection of all this with infectiveness is not quite so clear as might be wished ; but we are left in no kind of doubt that at least many, if not all, infectious diseases have their origin in putrefactive and allied processes, and that sepsin and the albumoses are to be regarded as types of infectants.

It may, indeed, be taken for granted that the whole experience of the world in all ages goes to show that much preventible disease originates in the putrefaction of animal and vegetable matter going on in the midst of human habitations.

Hence, in sanitary practice we aim at preventing

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* See Appendix to Liebig's 'Letters on Chemistry,' p. 530. This instance is by no means singular.

putrefaction under given conditions, and the agents employed to prevent such processes are termed antiseptics. Indeed, an antiseptic may be defined as a substance which, when properly applied, prevents the formation of septic poisons in its vicinity. Such substances are also not rarely termed disinfectants, and, indeed, it seems clear that if putrefactive change gives rise to infection, then agents which will either prevent or arrest this process may be fairly termed disinfectants.

Dr. Gamgee,* writing on this subject, says, 'I am now convinced that every good antiseptic is really a destroyer of disease germs: an arrest of development is ensured.'

If a beefsteak be placed in contact with air and water and allowed to putrefy, the resulting product constitutes a most virulent fever-producing product; but if we place with the beefsteak a certain quantity of antiseptic material, the putrefaction does not occur, and the poison is not formed. This is clear, and it is certain. Moreover, it is certain that the poisonous matter, even if it be allowed to form, may be afterwards destroyed by certain other chemical substances which have the power of oxidising and changing its nature, just as all the organic matter in nature is oxidised under ordinary atmospheric influences. In this way, as already stated, tyrotoxicon, for example, is quickly destroyed by exposure to the air.

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* *Chem. News*, January 27th, 1871.

The special means available for the prevention of infectious disease are of the same order, but resolve themselves into the use of antiseptics or disinfectants more locally, as also when possible, at the seat of disease, with the object of avoiding the results that follow from the unimpeded development in the human body, of micro-organisms and their chemical products.

Unfortunately, these microbes, or some of them, exhibit very tenacious powers of resistance (a feature which has received special attention in previous chapters), and some of their spores, at least, survive the application of parasiticides, even if employed of sufficient strength to poison the patient (host). The fully developed micro-organisms are more amenable, however, to such reagents than are the spores or immature germs to which they give rise, and by which they are reproduced to successive generations.

We must include, then, among disinfectants, those substances which destroy the life of microbes (irrespective of kind; for any one parasiticidal agent is not necessarily fatal to all kinds of micro-organisms). Among such simple substances are peroxide of hydrogen and the permanganates of potassium and sodium (which are at least fatal to anærobies generally), and thymol, iodoform, corrosive sublimate, chloral and phenol, each of which acts destructively to certain classes of micro-organisms (particularly ærobies).

The application of such chemical reagents to putrid mixtures results in the cessation of putrefaction, and the reason why such application remains efficacious is, either that the presence of the chemicals prevents the development of further spores into the mature state, or else that they kill off each organism as it is developed. They act in precisely the same way towards the microbes that initiate diseases.

The precise modes of action of disinfectants must necessarily be various in character. It is possible, for instance, that, in addition to its valuable powers of oxidation, peroxide of hydrogen acts as a direct poison to anærobic germs of the putrefactive type. It may asphyxiate microbes, that is to say, by its active oxygen, just in a similar way to that in which carbolic acid acts as a direct poison to man. Some preparations (such as pyrogallic acid) may act in the directly opposite manner, viz., by absorbing the oxygen necessary for the life of other microbes. Other chemical reagents (such as tannin and alum) may render the medium in which the micro-organisms exist, unfit for their further sustenance, by entering into combination with the albuminous principles upon which they may have hitherto depended for food, thus converting them into substances which they cannot decompose. In this way they may be starved out of existence. Or yet again, just as a man may be anæsthesiated by chloroform or ether, so also may be micro-organisms. Thus, Claude Bernard has shown that the sensitive plant loses its irritability when placed in contact with the vapour of ether, but regains it if the ether be removed. If not removed the plant dies. Again, if the yeast plant (which is a type of disease-organisms) be placed in an etherised sugar solution, it will no longer act as a ferment, and ceases to be reproduced until and unless the ether be removed. If not removed, the cells succumb to the ether, and finally die.

It will be evident, then, that there are better ways of preventing disease than by attempting to annihilate micro-organisms. They can be starved out of existence, or they may be anæsthesiated, or the general conditions surrounding their existence may be so influenced that further life becomes impossible. Collectively, all chemical agents, which lead by their employment either to the effectual interference of their chemical processes or to the death of the micro-organisms which breed diseases, are disinfectants in the truest sense. Among such chemical reagents, are to be chosen those which exercise such an influence over microbic life that, without necessarily destroying it, its functions are so diverted as to be carried on without danger to health. That is to say, instead of poisonous products, innocuous ones may be formed by their life functions.

Heat should not, of course, be referred to as a disinfectant, but only as a disinfecting agency.

Prevention is better than cure, for if the microbes of disease obtain access to the organs and tissues of the body, then the host may first succumb to the chemical reagents that are used with the view of destroying the parasites alone. The use of disinfectants for internal administration greatly limits their available number, and this is a subject that has received far too little attention. Almost the only direction in which it can be said to have been seriously tried is in connection with the treatment of throat and lung complaints by the process of inhalation.

According to Behring,* there are four possible ways of effecting internal disinfection :

(1) By killing disease-producing germs.
(2) By hindering their growth.
(3) By counteracting disease-producing properties.
(4) By antagonising the action of or destroying altogether the various toxic substances produced by the bacteria.

Behring in his paper points out that, if a small piece of the spleen of a mouse which has died from anthrax be injected into another mouse, the latter also dies from anthrax ; but the fatal results may be postponed or prevented by subsequent injection of a mixture of corrosive sublimate and chloroborate of soda.

He also states that by inoculating guinea-pigs with the blood of a guinea-pig suffering from diphtheria, they are rendered immune to this disease. He concludes that the healing action of the blood of immune animals is not dependent on its living elements, or at least is not limited to them, as is shown, he thinks, by the fact that it is exhibited by the extravascular cell-free blood serum ; on the contrary, the healing action is rather to be traced to the circumstance that the extravascular blood, and the

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* 'Disinfection of the Living Body,' *Brit. Med. Journ.*, Aug. 22, 1891, p. 406.

blood serum of immune animals, possess the property of destroying this specific diphtheritic poison without destroying the diphtheria bacilli.

The disinfecting action of the blood in animals affected with diphtheria is, therefore, to be sought for in the destruction of the substances produced by the diphtheria bacilli.

The bacteria-killing properties possessed by the living body, which were first referred to the cells of the body, are now explained by a great number of observers as being due to the property of the cell-free blood. Illustrative of this we have Professor Ehrlich's very instructive experiments, which have shown that mice and rabbits may in a short time be rendered so immune against certain vegetable poisons —castor-oil, for example—that they can withstand a dose a thousand times stronger than the originally fatal dose ; and other animals may also be protected by the injection of the blood of animals which have been rendered immune in this way.

Some years ago Dr. Cash, when working for the Local Government Board, tested a number of disinfectants by administering them for a prolonged period to animals which were ultimately inoculated with pathogenic micro-organisms. In this way he examined the action of sulphocarbolate of soda, phenylpropionic acid and its salts of potassium and sodium, all of which were practically valueless with regard to anthrax and tuberculosis. With perchloride of mercury (corrosive sublimate), however, he claims to have succeeded in producing an immunising action by administering minute doses daily to rabbits before inoculation of anthrax took place.

Elsewhere I have referred to similar observations made by Behring respecting terchloride of iodine in relation to tetanus. I cannot, however, share the view which he has expressed,* that we may achieve a brilliant reward by further work in this direction. If such an inquiry is to be recommended at all, it should be made subservient to a chemical appreciation of the issues that are involved, and instead of experimenting haphazard with corrosive and poisonous chemicals, there should be employed substances, rather, which, like peroxide of hydrogen (alone or associated with innocuous antiseptics), may be reasonably expected to produce a result of the kind that is wanted, viz., the prevention of the formation of toxic bodies in the living body, and the destruction of them, if and when formed.

If Dr. Cash had made his experiments with, say, 'Sanitas' fluid, the results might have proved much more serviceable.

There are many who think with Drysdale, that probably the best means of protecting persons against such diseases as small-pox will be found in the extended art of vaccination, and that the most efficient treatment of other diseases, such as ophthalmia, is the practice of inoculation. Unfortunately, we are at present without sufficient information to warrant the employment of such methods on any serious scale in other diseases.

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* In an address reported in *Pharm. Journ.*, Nov. 25th, 1893.

In the use of disinfectants for the prevention of infectious diseases (in contradistinction to their cure), regard must be had also to their general characters and their influence on health.

Dr. R. Angus Smith has said tersely enough, 'We live in air, and the air flows continually into our blood; no wonder, then, that we are influenced by climate, which means the condition of the air.* Now, commercial carbolic acid (in common with many coal-tar derivatives) is a deoxidising agent which, when added to the air, vitiates it both by diminishing the available oxygen, and by its mere poisonous presence. Similarly, sulphurous anhydride uses up useful and life-giving oxygen by becoming oxidised into sulphuric acid, although for fumigating purposes it may often be usefully employed. For such purposes the sulphur candles which I have recently introduced have great advantages (see p. 287).

For universal use, a disinfectant must have the following characters :†

'Firstly, it should not be dangerous if by any chance it be taken internally, and we know that in the case of carbolic acid, for instance, fatal accidents from its use are of constant occurrence. Secondly, it should not be destructive of any substances to which it is applied, as such a quality would necessarily limit its action, and it could not be used, as noted above, to saturate sheets and cut off infection. Thirdly, it ought not to be offensive, for, even postu-

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* 'Air and Rain,' p. 3.

† *Standard*, September 11th, 1878.

lating the efficacy of an evil-smelling disinfectant, it is never likely to become popular, and it is to the general, we might almost say the universal, use of disinfectants that we must look for any permanent mitigation of the evil exhalations that so often pollute the atmosphere, and which almost invariably carry with them the germs of disease. Many disinfectants offered to the public fulfil one or two of these requirements; while others, though effectual enough, contain recognisable elements of danger. Only one or two may be used with confidence wherever a disinfectant is needed, always remembering that as the nation is reputed happiest which has no history, so that individual may be esteemed the most fortunate who manages so to purify his premises and order his household as to have no need to use a disinfectant at all.'

Of the few disinfectants which may lay claim to all these characters, there are none better than the so-called 'Sanitas' preparations and appliances, for the existence of which I am personally responsible.

The following is a list of some of the better-known antiseptic and disinfectant reagents:

'Sanitas' products (containing in their several forms Peroxides, Thymol, soluble Camphor, etc.).
Peroxide of Hydrogen.
Ozone.
Permanganates of Potassium, Sodium, and Calcium.
Chromic Acid.
Carbolic Acid (Phenol), and its Homologues.
Salicylic Acid.
Phenylpropionic Acid.
Phenylacetic Acid.
Sulpho-phenic Acid.
Perchloride of Mercury (Corrosive Sublimate).
Eucalyptus Oil.

Thymol.
Chloride of Zinc.
Sulphate of Zinc.
Sulphurous Anhydride.
Iodoform.
Subnitrate of Bismuth.
Chloride of Lime (Bleaching Powder).
Chlorine (Gas).
Sulphate of Iron.
Chloride of Copper.
Sulphate of Copper.
Lime.
Perchloride of Iron.
Iodine.
Creasote.

Each of these substances acts in its own special chemical manner, but, broadly speaking, those disinfectants which are also oxidants are to be preferred for two excellent reasons: firstly, because they are antagonistic to the whole class of anærobic germs; and secondly, because they have the power of chemically altering, by oxidation, the products of the life action of germs in general, thus assuring the destruction of the organic poisons contained therein.

As regards the comparative antiseptic action of various chemical compounds in relation to organic matters, and quite apart from any consideration of their values as disinfectants for use either generally or in the specific treatment of disease, the following results of an investigation* which I conducted a few years since will be found interesting.

In the earlier stage of the investigation, the comparative antiseptic values of the several substances were determined in respect of two standard mixtures, viz., extract of beef and flour-paste. As, however, the results were mutually confirmative, there was no

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* *Journ. Soc. of Chemical Industry*, November, 1887, and November, 1888.

occasion to employ in the later observations more than one standard, for which purpose extract of beef was chosen.

In reviewing the results which were first published in connection with these experiments, several medical papers commented upon the fact that putrefactive agencies were alone examined, and this was coupled with an expression of regret in one case that specific micro-organisms isolated from all others, and known or assumed to be the direct or indirect cause of specific diseases, were not studied. Now, in reference to this matter, I may at once state that such experiments were not required for the purpose I had in view. Moreover, not only is it very difficult to obtain such specimens, but, as a matter of fact, the prohibitive effects of various chemical agents are more or less general in character in the sense that, as they act in relation to any one micro-organism so they do to others, either by destroying them or so altering the composition of the medium that it becomes either incapable of sustaining the life or development of the respective species.

It is now generally taken for granted that micro-organisms do not of themselves give rise to disease, but that under favourable circumstances, that is to say, by development in suitable media, they cause the formation of certain chemical products which are noxious in character and behave as poisons to the human organism. This is the view I have consistently taken since I have interested myself in such subjects, and I am glad to know that, while when first propagated it was held up to a good deal of scorn, it is now universally accepted, but of course, as is usual in such cases, but few writers now remember to have held or expressed any other view of the case.

If, then, this view be correct, it is not at all improbable that the same or allied poisons may be elaborated or produced through several distinct agencies, that is to say, by different micro-organisms ; and if it can be shown that antiseptics act uniformly as a class in prohibiting the processes of chemical change or fermentation by which such poisonous products arise, my earlier experiments, in common with those about to be described, are truly comparative in character, and are reliable for guidance in dealing with sanitary matters and the prevention of disease.

That antiseptic agents act more or less uniformly, and are therefore to that extent comparable, is borne out by the fact that the processes, for the inhibition of which they are applied, are also uniform in character. Writing broadly, it is fair to state that most processes of fermentation or chemical change induced by micro-organic life depend upon two chemical acts, the one hydration and the other oxidation ; that is to say, more or less complex molecules (like albumen) are split up in the first place into a certain number of more simple bodies, and oxidation of these or some of them proceeds simultaneously or subsequently. It is not improbable that the more active poisons are produced when the chemical changes are mainly hydrolitic in character.

As further bearing upon these views, it may be noted that in course of some observations made by Dr. Burdon Sanderson, F.R.S.,* upon the results of an experimental investigation then lately carried out by Dr. Klein and Mr. Lingard, he has characterised them as affording 'solid ground for the anticipation that whatever means may be found effectual as prophylactics against septic infection, will also be effectual, *in so far as they are applicable*, against tuberculosis.'

In commenting upon the same researches, Dr. George Buchanan† has carried the argument even further, and finds 'one noteworthy point vouched for by Dr. Klein,' viz., that 'when it is possible to recognise, as in the case of anthrax, tubercle, and swine-fever, the minute organisms that play an essential part in the disease, and to compare them with other and similar organisms which are not so much infective as putrefactive, it is found that chemical agencies which are wanting in destructive effect upon the putrefactive organism have a power, often when present in extremely minute quantity, of arresting or destroying the life of the infective organism.'

In order to bring the later results of my observations into general accordance with the former ones, I deemed it advisable to repeat the whole of the tests originally made with chlorides, nitrates, and sulphates in respect of extract of beef. For this purpose, 5 lb. of lean fresh beef was minced and

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* 'Report Med. Off. Local Gov. Board,' 1884, p. 184.

† *Ibid.*, p. xxxiii.

then digested with water at a temperature under 40° C. during three hours, after which the extract was made up to 4 litres, and when cold was strained several times through fine muslin, to remove the undissolved portions and the solidified fat. In each observation 95 cc. of this extract was taken, and to it was added 5 cc. of the particular antiseptic solution to be tested. These antiseptic solutions, except where otherwise noted, were of 5 per cent. strength; but in cases where the substances were not perfectly soluble, the solutions containing the undissolved particles in suspension were used. The series of experiments first to be described were commenced on November 19th, 1887, and the following table will show the respective days on which the several mixtures became putrid.

### *Chlorides.*

On the fourth day, the mixtures containing the following chlorides had become putrid: Chlorides of potassium, sodium, ammonium, barium, strontium, calcium, and magnesium, as also the standard extract.

On the ninth day, the chlorides of iron, lead, zinc, and tin.

On the fifteenth day, chloride of aluminium.

The mixtures containing the chlorides of copper and mercury remained intact.

### *Nitrates.*

On the fourth day, the nitrates of potassium, sodium, ammonium, barium, strontium, calcium, magnesium, and iron.

On the sixth day, nitrate of zinc.

On the ninth day, nitrate of lead.

The mixtures containing nitrates of copper and mercury alone remained intact.

### *Sulphates.*

On the fourth day, the sulphates of potassium, sodium, ammonium, magnesium, iron, and manganese.

On the fifth day, sulphate of zinc.

On the eleventh day, sulphate of aluminium.

The mixtures containing the sulphates of copper and mercury alone remained intact during the whole period of observation, viz., sixteen days.

It may be noted, as a rule, that as the mixtures became putrid, the colour changed from a dull dirty red to bright scarlet, a change probably associated with the initiation of oxidation by the agency of ærobic micro-organisms.

The next lot of observations were made in February, 1888, using a similar extract of beef (containing 1·796 grms. of total solid constituents dry at 100° C.) with some selected chlorides, nitrates, and sulphates, and the following other substances :

5 cc., 10 cc., 15 cc., and 20 cc. of ordinary 'Sanitas' fluid of commerce, and

5 cc. 'Mercuric Bactericide' (that is a solution containing 5 per cent. mercuric chloride in 5 volume peroxide of hydrogen).

The mixtures broke down in the following order :

On the third day, the standard solution was putrid.

On the fifth day, the sulphate of zinc and nitrate of lead mixtures.

On the sixth day, the 5 per cent. 'Sanitas' mixture.

On the seventh day, the chlorides of lead and tin mixtures.

On the twelfth day, nitrate of mercury and chlorides of iron and aluminium mixtures.

On the fifteenth day, chloride of zinc mixture.

On the twenty-first day, nitrate of zinc mixture.

In this series it will be observed that nitrate of mercury broke down on the twelfth day, thus confirming the general evidence adduced by the earlier series of experiments, that this salt is not so reliable as either the chloride or the sulphate.

The mixtures containing 10 cc. 'Sanitas' fluid and upwards remained quite free from putrefactive change collaterally with the mixtures containing 'Mercuric Bactericide' and the chlorides and sulphates of copper and mercury during the whole period of observation, viz., thirty-four days.

These results give the information which was asked for, in course of the discussion on my earlier paper, by Mr. A. H. Hutchinson, concerning the antiseptic value of 'Sanitas' fluid, 10 cc. of this reagent being equal in effect with 5 cc. of a 5 per cent. solution of mercuric chloride.

The remaining series of observations were made with solutions of peroxide of hydrogen of so-called five-volume strength having dissolved therein 5 per cent. of the following substances respectively :

Potassium hydrate (caustic potash), potassium chlorate, bisulphate of potassium, borax, borax neutralised with boric acid, sodium benzoate, ethylic ether, glacial acetic acid, quinine disulphate, quinine sulphate dissolved in a slight excess of sulphuric acid, chloroform,* phenol (absolute carbolic acid), chloral, pure hydrochloric acid, oxalic acid, boric acid, and sulpho-phenic acid.

On the second and third days, the standard extracts broke down in all cases; so also did the sodium benzoate and neutral borax mixtures.

On the third day, the ether and caustic potash mixtures.

On the fourth day, the quinine disulphate mixture.

On the fifth day, the potassic chlorate mixture.

On the seventh day, the chloroform mixture.

On the tenth day, the borax mixture.

On the thirteenth day, the boric acid mixture and the mixture containing quinine sulphate dissolved in an excess of sulphuric acid.

On the seventeenth day, the mixture containing bisulphate of potassium.

On the nineteenth day, the acetic acid mixture.

On the twenty-fourth day, the chloral and oxalic acid mixtures.

On the twenty-seventh day, the sulpho-phenic acid mixture.

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* This antiseptic mixture was made up as follows:—5 cc. chloroform + 50 cc. absolute alcohol + 45 cc. of 10 vol. $H_2O_2$.

After thirty-nine days, the following mixtures were still good—hydrochloric acid and phenol.

Now, in dealing with these results, it must be borne in mind that all the test solutions contained peroxide of hydrogen, which exhibits of itself a considerable antiseptic property, so that the comparative results of the experiments present the specific additional values, so to speak, of the dissolved substances.

Of course, also, the tests, in common with the previous series, were somewhat severe, as they only give the antiseptic values of 5 cc. of 5 per cent. solutions when diluted twenty times.

One of the most interesting facts elicited by this inquiry is the pronounced antiseptic value of chloral, which may henceforth find, therefore, an extended use in the domain of medical practice.

Only somewhat less pronounced is the antiseptic character of potassium bisulphate.

Again, sulphate of quinine, if administered together with sulphuric acid, may be expected, not only to act as a tonic, but also to produce an antiseptic state of the human body.

It is interesting also to observe that borax is much more effective than when neutralized with boric acid, notwithstanding that that substance has a higher antiseptic value than borax.

Of the other pronounced antiseptics, phenol is, of course, well known, but its application is limited on account of its dangerous character.

The influence of the acid reaction is significant ;

acetic, oxalic, sulpho-phenic, and hydrochloric acids exhibiting very marked antiseptic action.

Acetic acid has been known for ages to be a good antiseptic, whilst hydrochloric and other mineral acids formed the subject of study by Dr. John Dougall,* and were then found to be powerful antiseptics and disinfectants. Unfortunately, they are much too corrosive to be of extended use, either in the household or for medical applications.

Sulpho-phenic acid (in common with phenylacetic and phenylpropionic acids) is strongly antiseptic in character, but in the human organism it would probably yield phenol, and thus exhibit toxic effects.

As regards sulphuric acid (the influence of which is perhaps seen in the result of the observations made with quinine sulphate dissolved in it, and with bisulphate of potassium), it may be remarked that Mr. J. P. Laws has made some interesting observations† concerning the restraining and killing power of that substance, both of which he found to be considerable. The antiseptic properties of chloroform water have been studied by E. Salkowski,‡ but in the form of an alcoholic solution they do not appear at any rate to be so pronounced as those of borax.

As a matter of fact, experience so far seems to point to corrosive sublimate as the most powerful antiseptic yet discovered. Klein takes this view,

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* 'Trans. Nat. Assoc. for the Promotion of Social Science,' 1874, pp. 708—719.

† 'Report Med. Off. Local Gov. Board,' 1884, p. 208.

‡ *British Medical Journal*, May 5th, 1888.

while Koch claims that a solution of 1 in 5,000 can be relied upon for perfect disinfection, since it suffices, according to him, to annihilate all life in micro-organisms and their germs within a few minutes. Klein, I think rightly, regards this statement as an exaggeration of its powers, but there is no doubt of the effects of somewhat stronger solutions. Unfortunately, again, the terribly poisonous nature of the substance absolutely disqualifies it for use except by medical men.

Useful as corrosive sublimate is in the practice of medicine and surgery, it is, however, deficient in one respect, and that is power of oxidation. It is capable of killing all germs and spores, but it has no power of oxidation over the toxic products which may exist in association with them, and this is the more important because these products give rise to the toxic effects which are witnessed in many diseases; in fact, they constitute the real infectants. I have therefore introduced a compound solution of this substance with peroxide of hydrogen (Mercuric Bactericide) and a number of other solutions, all containing peroxide of hydrogen, and definite percentages of various antiseptics under the name of 'Bactericides.' It was the preparation of these fluids that involved me in this and the preceding investigation of a similar character.

It is only fair that I should again insist upon the great value of 'Sanitas' fluid as a disinfectant for popular and medical use, being wholly innocuous and thoroughly reliable as a germicide, as an antiseptic and as an oxidant; in point of antiseptic power it has been shown that 10 cc. is equal in effect to half that quantity of a 5 per cent. solution of perchloride of mercury.

With respect to the comparative antiseptic values of the better-known chlorides, nitrates, and sulphates, the results confirm generally the earlier ones, but the chloride of aluminium appears to have a somewhat higher value than that formerly assigned to it.

It may be said by way of summary that the chlorides, nitrates, and sulphates of the alkalies exhibit but slight antiseptic effects, and those of the alkaline earths are not much better. The compounds of manganese, zinc, tin, iron, lead, and aluminium are all of more or less pronounced value. As a rule the chlorides are to be preferred. The compounds of copper and mercury are comparatively most effective; the nitrate of mercury is, however, not so reliable as the chloride, which is the most active antiseptic amongst these classes of substances.

The general results will, I hope, be of service in this way, among others, that when a so-called new disinfectant or antiseptic preparation is submitted to the public, directly the composition is known the approximate value may be ascertained by reference.

The use of antiseptics in the practice of surgery has now become almost general, thanks to the advocacy, in particular, of Lister. A large part of the total mortality experienced in surgery was due to blood-poisoning, which resulted from the absorption into the system of decomposed secretions from wounds.

The decomposition in question is common putrefaction initiated in the secretions by air-borne micro-organisms; and the practice of using antiseptics for preventing putrefaction in wounds is sometimes termed 'antisepsis.' Some writers view this prevention of the development of bacteria in wounds as something quite distinct from disinfection proper, by which expression they seek to represent the annihilation of micro-organisms alone ; but this distinction is, in my opinion, altogether too nice and unreal. At least, it matters not at all whether we speak of disinfecting wounds or keeping them in an antiseptic condition, so long as the object of the process, viz., a healthy state, be attained and maintained. So also, through the whole range of disinfection, the same argument applies, and we may freely disregard the fine-drawn distinctions and illusory differences, that too often find expression, and are apparently employed to cause alarm or actual distrust by many writers on the subject. To use Lister's own word's,* 'We do not require any scientific theory in order to believe in antiseptic treatment ; all you have to believe is that there are such things as putrefaction and other septic agencies ; that our wounds are liable to these ; that they are very pernicious ; that these things come from without ; and that we have the means of preventing them by various chemical agencies.'

A wound which is attacked by atmospheric germs becomes infected ; any chemical reagent which, by

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* *Lancet*, November 3rd, 1883, p. 765.

its presence, prevents this infection is an antiseptic, and if any such substance removes existing infection, as proved by the restoration of the wound to a healthful condition by its use, then that antiseptic is also a disinfectant, and it is downright nonsense to combat the statement.

The practice of antiseptic surgery depends, then, upon the employment of measures (notably cleanliness and filtration of air) for keeping air-borne germs out of wounds, and (what is more important) for preventing their development in the wounds, if introduced, by the use of antiseptics.

There is one great danger in the practice of antiseptic surgery, although it is by no means unavoidable, and that is, the possibility of poisoning patients by the absorption of noxious antiseptics. Iodoform, subnitrate of bismuth, and corrosive sublimate exhibit very powerful toxic effects, while hundreds of lives have been lost owing to the general use of carbolic acid as a disinfecting agent. Now that there are better preparations known to science, such as ‘Sanitas,’ which is non-poisonous, the necessity for using poisonous antiseptics and disinfectants no longer exists, and their employment is to be condemned in the strongest possible terms, since it unnecessarily exposes suffering humanity to danger of life and limb from their toxic effects.

It is a mistake often made by surgeons, even, I believe, to Lister himself, to imagine that in the practice of antiseptic surgery they require to use the most corrosive and actively poisonous substances they can command. It should be remembered that the process of putrefaction does not attack living tissue, but only dead matter, and the surgeon should as carefully remove (by cleansing operations) dead tissue, thus minimising the chances of infection, as he attends to the use of his antiseptics, for it is this dead matter that constitutes the pabulum of disease germs in the case of wounds.

Disinfection, then, should be practised with the object of interfering with the multiplication of the microbes associated with specific diseases, or of so influencing the conditions of their life that they shall cease to produce the poisonous substances constituting the real direct causes; for in all probability it will be found that the microbes themselves are universally distributed in nature, and that it is idle to think of exterminating them. But although they cannot be exterminated, they can be controlled in relation to disease, just as it can be done in connection with the process of putrefaction as observed in the laboratory. This process, in all probability, amounts to the same thing as disease, with this difference, that it is best known in connection with lifeless matter derived, however, from living sources.

The various ways in which microbes can be controlled have been already described, and it only remains to indicate the general manner in which disinfection is to be carried on in connection with each particular disease. This will be studied in the next chapter.

For accounts of the prohibitive and destructive effects of some chemical substances upon particular micro-organisms, I may refer my readers to the publications of the Medical Officer of the Privy Council and Local Government Board, 1870—1887; but at the same time, I am bound to add that the more recent investigations, although of great value in themselves, are not calculated to determine the practical value of the substances investigated as disinfectants for general use.

Most antiseptics and disinfecting agents are also more or less germicidal in character; thus, for example, 'Sanitas' fluid and oil are powerful germicides (see Chapter XV.). All the same, it is conceivable that some active bactericidal substances are quite powerless to destroy the much more dangerous albumoses to which it is now known bacteria can give rise.

# CHAPTER X.

## TREATMENT OF THE SICK——NOTES ON THE CHIEF INFECTIOUS DISEASES——MEASURES OF DISINFECTION TO BE OBSERVED IN EACH.

PERSONS who are attacked with any infectious disease should be immediately isolated from friends and relations, and the nurse and doctor should alone visit them. The sick-room intended for occupation in such cases should be as near the top of the house as possible, and requires some preparation beforehand. It should be well ventilated, and all superfluous furniture and effects should be first removed. There should be no carpets, curtain hangings, pictures, books, or unnecessary clothing in the room, which should be provided only with absolutely necessary articles.

It is best to keep a fire in the room, with the object of promoting ventilation, and carrying any infective particles which may be floating about in the air of the room, through the fire or up the chimney.

Outside the door of the sick-room, it is well to hang a sheet, so arranged that before the door is opened it can be restored, so as to make a tolerably perfect screen for intercepting the air that may come from inside the room. This air may be contaminated with the virus of the disease, and hence it requires disinfection, which is carried out by keeping the sheet moistened with a disinfectant, such as pure 'Sanitas' fluid, or, better still (on account of its deliquescent character), sea-water 'Sanitas.' A spray-producer may be used for moistening the sheet from time to time, and also for spraying the fluid about the sick-room. Nothing is more grateful to the patient than the free use of 'Sanitas' fluid in this way: 'It has a most pleasant, agreeable smell, and refreshes and purifies the room' (Henry C. Burdett), besides which it keeps the air disinfected.

The ventilation of the room can be well carried out by a plan first suggested by Mr. Hinckes Bird, which consists in raising the lower sash some few inches, and placing beneath it a bar of wood, so as to entirely close the space; air can then freely enter the room (up between the overlapping sashes) without creating a draught.

Personal cleanliness of patients is of the highest importance, and, subject always to the opinion of the doctor in attendance, copious ablution is to be recommended. It is a good plan to keep all water used for such operations in an antiseptic state by the addition of a little 'Sanitas' fluid or other suitable chemical reagent.

Before removing any linen or clothing from a sick-room, it should be first steeped in a disinfectant solution and then wrung out, and, after removal, instantly boiled with plenty of soap and some disinfectant.

Cups, glasses, spoons, and other articles which have been handled by the patient should also be immersed in a 20 per cent. solution of 'Sanitas' fluid and water before removal from the sick-chamber.

The dresses and clothing worn by attendants should be as non-porous as possible, cotton stuffs being for this reason much preferable to woollen garments.

Any dry food not eaten by the patient should be burned in the fire in the room, and any liquid food, together with all slops and the excreta, should be mixed with some disinfectant before removal. 'Sanitas' powder or crude 'Sanitas' fluid or sulphate of copper may be used for this purpose. Disinfection of the excreta in cases of cholera, typhoid fever, and dysentery is of special importance.

The expectorations of sick persons should be received in vessels provided for the purpose, containing a strong disinfectant.

It is a good plan also to keep the air and contents of a sick-room in an antiseptic condition by the evaporation of a little 'Sanitas' oil floating on water, from time to time.

Handkerchiefs should not be allowed for use by the patient, but only rags that can afterwards be burned in the room. The breath of patients should not be inhaled by attendants.

The medical officer of health for the district should immediately be made acquainted with the outbreak of any case of infectious disease.

*After recovery* of the patient, everything in the sick-room that is not valuable, and that can be burned, should be destroyed in the fire. All linen should be steeped in some disinfectant solution before removal, and then well boiled with plenty of disinfectant soap.

Clothing and bedding should not be removed until after fumigation of the room, and if then there is an opportunity of getting them disinfected in a heating apparatus such as is employed by many sanitary authorities, so much the better. Before the patient leaves the sick-room, if possible, and in any case before he mixes with other members of his family, he should take a bath containing plenty of 'Sanitas' fluid, and be washed all over, using disinfectant soap.

Fumigation may be carried out by closing the windows, doors, chimney, and keyholes, and evaporating in the room plenty of 'Sanitas' oil. This evaporation can be conducted by the use of an appliance sold under the name of the 'Sanitas' fumigator; or failing that, an iron saucepan or kettle may be employed, charged with plenty of water (say one quart) and a small teacupful of the oil. The saucepan or kettle is to be boiled over a gas-lamp (due precautions being taken against the occurrence of fire), during at least one hour. So long as there is plenty of water in the apparatus there is no fear of an accident, and, of course, more water can be placed in the vessel when required, as the escape of the antiseptic vapour from the room into the house will do no harm, and is not even disagreeable, so that a person may enter the room from time to time to see that all is well.

Before conducting the fumigation, any articles of wear or bedding unavoidably left in the room should be spread out as much as possible, or hung on lines so as to freely expose them to the fumes of the disinfectant.

If preferred, sulphur may be burned in the room instead of 'Sanitas' oil, and for this purpose nothing is more convenient than the sulphur candles which I have introduced for the purpose.* They take fire directly a light is applied to the cone or ribbon, which projects from the surface of the candles, and continue to burn steadily and thoroughly. Each candle contains 1 lb. weight of sulphur, and is sufficient for the disinfection of at least 1,000 cubic feet. The cubic capacity of a room is ascertained by multiplying the length by the width and the height. In one form of these candles (that is the one I particularly recommend) there is a water-jacket, from which water is evaporated by means of the heat generated by the burning sulphur, and as this condenses gradually on all objects in the room, it brings the sulphurous acid gas as the disinfecting agent into material contact with them, thus securing efficient disinfection, for the gas is soluble in water.

It is best to strip the walls of all paper, and to burn it afterwards, and the ceiling and walls should

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* They are made by the Sanitas Company, Limited, and sold as 'Kingzett's Patent Sulphur Fumigating Candles.'

be limewashed, or whitened with 'Sanitas' distemper. All furniture, woodwork, and metal-work should be polished with 'Sanitas' disinfectant furniture paste, and the floor should be scrubbed with disinfectant soap, using water containing in each bucket, say, half a teacupful of 'Sanitas' emulsion. Before use, the room should be left, with opened windows, unoccupied for at least a week. In case of death, the body should be well sprayed with 'Sanitas' emulsion diluted ten times with water, and burial should take place as early as possible.

During infection, the children (if any) should be kept from school, and not allowed to go again until the medical attendant gives his consent.

*Small-pox* belongs to the class of eruptive fevers, and is altogether a terrible disease. The incubation takes about fourteen days, after which headache and backache come, and then spots appear on the face and wrists, which are sometimes mistaken for signs of measles. In this disease, the scales and powder which brush off the skin are highly infectious. To prevent their general diffusion, which would, if not guarded against, very likely infect other persons, it is advisable to anoint the body of the patient daily with a mixture of 'Sanitas' oil (1 part) with olive oil (7 parts), or with a mixture of 'Sanitas' oil and vaseline. After recovery, some weeks should elapse before the patient is allowed to mix with other people.

According to Weigert, the lymphatics of the skin in the region of the pocks are filled with micrococci;

but similar micrococci occur also in the fluid contents of vesicles in the skin produced by non-infective inflammations, and there is as yet no proof of any intimate causal relation between these germs and small-pox.

The best protection against small-pox is afforded by vaccination in infancy, and it is generally considered advisable to revaccinate children at fifteen years of age in order to ensure perfect protection thereafter.

*Scarlet Fever* and *Scarlatina* are names for one and the same disease. This is also an eruptive fever, the first sign of which is, generally, sore throat, accompanied or quickly succeeded by shivering, headache, heat of skin, and, perhaps, vomiting. On the second or third day the eruption appears on the neck, face, or chest, or on the arms near the elbows. Later on, the breath may become offensive, and an offensive discharge may pass from the nose.

In this disease, the skin requires anointing, as in small-pox; indeed, the greatest care should be taken to prevent dissemination of the meal-like particles or flakes that may peel off the skin. The oiling of the skin should be commenced almost from the first recognition of the disease, and continued until the cure has been completed. Attention should also be paid to the disinfection of the discharges by means of 'Sanitas' powder. After some time, baths taken daily, or on every alternate day, are permitted to the patient, but of course the water should be used warm and in an antiseptic state, and after each bath the skin should be again anointed. In severe cases of fever, the skin may also be sponged with tepid water containing some 'Sanitas' fluid.

The throat affection, when present, is best treated by inhalation of the mixed vapour of 'Sanitas' oil and water; or the throat may be sprayed several times a day with 'Sanitas' fluid, diluted with from twice to four times its own volume of water; or a gargle of this mixture may be employed.

Six weeks should be allowed to elapse after the skin has ceased to peel before the recovered patient is allowed to go amongst other persons.

Micrococci (*Micrococcus scarlatinæ*) have been described as occurring in the blood, ulcerations of the throat, and adhering to the scales of the desquamating epidermis in scarlet fever; but, notwithstanding recent investigations, which have led, according to some, to the identification of the organisms which cause this fever, the precise relations of them to the disease remain to be ascertained.

From an investigation made by Dr. Klein, and some inquiries conducted by Dr. Power, it would appear that there is some near relationship between scarlet fever and scarlatina of the cow, and that milk not infrequently conveys the infection to human beings.

*Typhoid Fever* (enteric or gastric fever) begins with a feeling of illness and diarrhœa, and the patient is generally more or less delirious in this disease. It is wholly preventible, inasmuch as it owes its origin to sewage contamination of air, food or drink. It is often accompanied by ulceration of the bowels, which not infrequently results in fatal hæmorrhage.

The eruption consists of a few (sometimes many) scattered rose-coloured spots, which can be felt with the finger, and they occur in successive crops. The contagion is eliminated in the discharges from the bowels, and hence it is of the very highest importance to disinfect these by the addition of plenty of 'Sanitas' emulsion or powder, or some other agent, such as sulphate of iron. Similarly, soiled linen must be very carefully disinfected.

Although Klebs and Eberth have described bacilli found in inflamed Peyer's glands, mesenteric glands, spleen, larynx, and lungs of patients who had died from typhoid fever, Klein has expressed the opinion that it is doubtful whether they can be considered as necessarily and ultimately connected with the disease, 'seeing they are not constant, and only occur in the mesenteric glands and spleen, *i.e.*, in localities into which an immigration of putrefactive bacilli from the bowels may easily take place.' He adds that the bowels in typhoid fever always contain innumerable masses of micrococci in colonies.*

Fraěnkel and Simmonds claim to have produced a form of typhoid fever in monkeys, mice, and rabbits, by inoculating them with a culture of the so-called *Bacillus typhosus*. This bacillus quickly loses its life by exposure to a temperature of 55° C. (Janowski), and light is detrimental to it.

*Typhus Fever* is said to be often indistinguishable from typhoid fever, and until recently it was regarded

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* *Practitioner*, June, 1884, p. 410.

as the same disease. It is, however, rarely accompanied with diarrhœa, and the rash comes out about the fifth to the eighth day of the fever, whereas in typhoid it begins from the seventh to the fourteenth day.

The treatment of both diseases is practically identical, but in typhus great advantage is derived from the employment in the sick-room of aerial disinfectants and free ventilation. The use of an antiseptic mouth-wash by the patient is also to be recommended.

*Cholera*, in its origin, is probably related to typhoid fever, in the sense that it is more or less a filth disease, and the contagion is carried with the discharges from the bowels. Intemperance in eating and drinking is supposed to facilitate infection, and in times of threatened attack, unripe and over-ripe fruit, tainted vegetables and fish, etc., are to be specially avoided.

The use of adequately filtered water would greatly reduce the number of cases of typhoid fever and cholera ordinarily, as well as when these diseases are epidemic, and the Berkefeld filter is the best that can be employed, in my opinion, because it gives a plentiful supply, and absolutely sterilizes the water by screening off all bacteria that may be contained in it.

I have already pointed out, in an earlier chapter, that the comma-shaped bacillus (*Spirillum choleræ Asiaticæ*), supposed by Koch to cause cholera, or at least, a growth which cannot with certainty be distinguished from it, has been found by Lewis in the mouths of healthy persons, and Klein has not given his support to Koch's views. Koch found that it was necessary to have the nourishing medium alkaline in character, and that the bacilli are killed by drying. Their habitat is the intestinal canal, and they are said to be always present in the 'rice water' stools of cholera patients.

*Diarrhœa* is allied to cholera, and in both diseases special attention has to be paid to the disinfection of the discharges.

*Diphtheria* begins with general depression and sore throat, followed by stiffness of the neck and swelling. In fact, it has been described as a contagious and epidemic sore throat. The poison which causes this disease is supposed to be often carried in sewer gas. In bad cases, the leathery false membrane which spreads over the throat, covering the larynx and extending to the palate, uvula, nostrils, cheeks, and gums, produces suffocation by obstructing the air, and is accompanied with much sloughing and fœtor of the breath. Sometimes the disease is followed by sudden attacks of temporary paralysis.

In this disease, obviously, the mouth and throat, and all discharges therefrom, particularly require disinfection. Local application of disinfectants, such as dilute 'Sanitas' fluid (1 : 2), made by means of a spray-producer and the douche, are to be advocated, or, instead, 'Sanitas' oil may be applied to the mouth and throat by means of an atomiser.* A gargle, of a strong solution of peroxide of hydrogen (5 volumes strength), is also to be recommended, as, in common with 'Sanitas' fluid and 'Sanitas' oil, it destroys the infection and the leathery membrane which is produced by it.

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* See *Brit. Med. Journ.*, July 23rd, 1881.

The infective agent is supposed by some to be the so-called Klebs-Löffler bacillus (*Bacillus diphtheriæ*), and many interesting observations have been made by injecting the poison—a deutero-albumose, accompanied by an organic acid—obtained from diphtheritic tissues, into rabbits. Weakness of the hind-legs is thus caused ; a wasting of the body, and partial or complete paralysis. The bacillus, when inhaled by human subjects, is supposed by Roux and Yersin to produce a local ferment which, when absorbed, digests the proteids of the body, and forms the albumose and organic acid above spoken of. These act on the nerves, and cause the weakness of limbs or paralysis, which are observed. The diphtheritic poison is obtained for the most part from the spleen in cases of the disease (see pp. 226, 228). In endocarditis (involving heart disease) a similar poison, producing, however, fever instead of paralysis, is found present in the spleen.

Several observers have shown that in diphtheria the membranes include micrococci, but Klein remarks, in his work already referred to, 'cultivations and inoculations with pure cultivations of this micrococcus are still wanting.'

*Measles* is ushered in with fits of sneezing, dryness of the skin, and watering of the eyes ; and after some days, a mulberry-coloured rash breaks out on the forehead, and gradually extends to other parts of the body. It is 'catching' before the rash appears. In this complaint, patients exhibit a tendency to contract bronchitis and other lung complaints ; hence it is essential to protect them from draughts, and to keep the temperature of the room higher than usual. It is also best to keep the room darkened, as the glare of light is painful to the eyes.

It is only the putrid or malignant form of the disease that is eminently dangerous.

All discharges should be disinfected, and such general measures of isolation and disinfection are to be taken during the treatment of the disease as have been recommended in cases of scarlet fever.

There is at present no absolute proof that this affection is caused by micro-organisms, although Drs. Canon and Pielicke of Berlin claim to have recently discovered the true *bacilli.*[*]

*Whooping-cough* commences with the usual signs of fever accompanied with a cough, and often precedes or succeeds measles. The froth which children affected with this complaint spit out should be collected in some vessel and disinfected. Handkerchiefs which are used for wiping the mouth should also be disinfected before sending to the wash, but, preferably, pieces of rag should be used instead and burned afterwards. The inhalation of the vapour of 'Sanitas' oil gives great relief in the treatment of this disease.

Afanassief detected the presence of a bacillus in the phlegm of patients suffering from whooping-cough, and is said to have produced an affection resembling that complaint by injecting a culture of the microbe into the trachea of dogs and cats.

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[*] See Griffiths' 'Manual of Bacteriology' (Heinemann), p. 332.

*Chicken-pox* is a mild eruptive disease which is infectious in character. At first there is a slight feverishness, followed by small conical pimples having a white head, which appear on the breast, shoulders, and neck. On the second day they develop into a form reminding of blisters, and on the following day the fluid which they contain becomes opaque, after which they break up and fall off piece-meal. Probably the vesicles contain the infectant, and disinfecting measures should be taken accordingly by inunction with a mixture of 'Sanitas' oil and olive oil (1 : 7).

*Erysipelas* appears somewhat suddenly, and is generally preceded and accompanied by signs of fever; the affected skin is red, hot, and tender, and is often blistered. It is frequently associated with sore throat, and generally appears on the head or face, which sometimes swell enormously. It is an infective disease which requires treatment under general measures of disinfection, and particularly so when persons suffering from wounds are near at hand. Very serious consequences result from the infection of wounds, and women in confinement, with erysipelas.

It would appear from the investigations of Lukowsky, Orth, and Fehleisen, that erysipelas is intimately connected with a micrococcus (*Micrococcus erysipelatosus*), which is smaller than that which is found associated with vaccinia, and which abounds in the lymphatics of the skin at the margin of an erysipelatous zone.

The micrococcus was successfully cultivated by Fehleisen, who is stated to have produced typical erysipelas in the human subject by inoculation with the cultivated microbe.* The vitality of the micrococcus is destroyed by antiseptics.

*Phthisis (Pulmonary Consumption).* — Nearly 100,000 persons die annually from this disease in Great Britain, and it has been calculated that, of all premature deaths, 26 per cent. result from disease of the lungs. Although the lungs are more particularly affected in this disease, the whole body becomes involved, and there is a gradual wasting away, or consumption, as it is termed. The disease may last only a few months, or it may drag its course over long weary years. Tuberculous consumption is characterised by the formation of cheese-like matter, termed tubercles, in the lungs. They vary in size from a millet-seed to a bean, and occur both separately and massed together, and being deposited upon the surfaces, they gradually cause the destruction of the breathing structure, a process which in course of time, unless arrested, results in death.

Tubercles are often found present in the expectoration (sputa) of consumptive persons, and there is practically no doubt that the disease is infectious to the extent that it may be conveyed by breathing an atmosphere contaminated with the virus or its products (tuberculous matter). Koch has concluded that 'in all the morbid processes which, on account of their course as well as of the characteristic microscopical structure and the infectious properties of their

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* See Woodhead's 'Bacteria and their Products,' p. 327.

products, must be considered true tuberculosis, there always occur in the tuberculous centres rod-like formations (tubercle-bacilli), which can be demonstrated with the aid of particular methods of colouring. This holds true both with the tuberculosis of man and of different animals.' Koch, in fact, affirms these bacilli to be the specific cause of the disease, and he has performed the usual cultivations and inoculations which are deemed to furnish the necessary proof.

Klein,* however, disputes the identity of human miliary tuberculosis and tuberculosis of cattle, and finds that the bacilli found in the two affections are morphologically distinct, and are differently distributed. Neither does he agree with Koch, Watson Cheyne, and others, who maintain that 'each tubercle owes its origin to the immigration of the bacilli, for there is no difficulty in ascertaining that in human tuberculosis, in tuberculosis of cattle, and in artificially induced tuberculosis of guinea-pigs and rabbits, there are met with tubercles in various stages—young and adult—in which no trace of a bacillus is to be found; whereas in the same section, cheesy tubercles may be present, containing numbers of tubercle-bacilli.' What, then, seems to be absolutely proved beyond doubt is that tuberculous matter alone produces tuberculosis, but that tubercles do not owe their origin to the immigration of the bacilli. Is tuberculous matter, then, another non-living infectant comparable with the albumoses?

It is worth mentioning that Schuchardt and Krause

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* *Practitioner*, August, 1884, p. 81.

found tubercle-bacilli in fungoid and scrofulous inflammation, and other observers have found them in the tissue of lupus.

It should also be stated that Klebs, Toussaint, and Schüller maintain that tuberculosis is due to a micrococcus, and not to a bacillus at all. In the presence of such conflicting evidence what is to be believed ?

At the same time, the experiments make by Dr. Burdon Sanderson must not be forgotten. He showed that in a number of guinea-pigs inoculated with pyæmic matter, and which outlived pyæmic poisoning, the lungs, liver, and spleen became tuberculous after a certain time ; and he therefore regards it as 'open to inquiry whether or not injuries which are of such a character that air is completely excluded from contact with the injured part, are capable of originating a tuberculous process.'

As regards the existence of the *Bacillus tuberculosis*,* there can, it is said, be no doubt ; but it is possible that it only acts in common with other irritants, and that consumption ensues only in those instances where the ground, so to say, is favourable for the propagation of the micro-organisms. That is to say, the germ itself may be, and probably is, ubiquitous, but it is only propagated in large numbers, and produces its characteristic products, in the lungs of persons who are by numerous circumstances predisposed to the disease. In other words, phthisis may,

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* Consult Dr. R. Douglas Powell's paper on 'The Causative Relations of Phthisis,' and the discussion which follows it. *Brit. Med. Journ.*, October 11th, 1884. Also paper by Dr. J. H. Bennett. *Ibid.*

perhaps, occur without tuberculosis, and, on the other hand, phthisical patients may become tuberculous.

Impure or imperfectly oxygenated air is considered to be particularly conducive to consumption, and, indeed, the causes may be stated to be all those which occasion debility, such as hereditary predisposition, want of proper nourishment, overcrowding, impure air, etc.

As regards the use of disinfectants* in connection with this disease, if we believe that consumption is essentially tuberculous, and that tubercle is dependent on either a micrococcus or a bacillus, we must resort for a cure to a disinfectant which will arrest the development of the micro-organism without harming the host. Such an agent is 'Sanitas' oil, which may be used to keep the atmosphere of an apartment constantly aseptic, and the vapour of which, also, may be freely inhaled, with impunity to the health of the patient. Whether or not it kills the micro-organisms in the lung-tissue, it can hardly fail to prevent their development and prevent putrefactive decomposition and fever. I should think also that the administration of a dilute solution of peroxide of hydrogen, under medical control, would be found of great value by reason of its power of oxidation.

The sputa of consumptive patients should, of course, be disinfected.

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* Compare papers by W. Williams, M.D., M.R.C.P., and J. Carrick Murray, M.D., *Brit. Med. Journ.*, July 23rd, 1881, and by A. W. Mayo Robson, *Brit. Med. Journ.*, June 21st, 1884. Also Lectures on Consumption, by Dr. Burney Yeo (J. and A. Churchill).

*Acute Croupous Pneumonia* is supposed to be caused by a micrococcus which can be conveyed in the sputum.

*Relapsing Fever* is of a periodic character, as its name implies, and only occasionally visits some of our large towns. It is sometimes called famine fever, which denomination it has obtained from the liability of the starving members of a population to be chiefly attacked. It attacks very suddenly, and is accompanied by shivering and chilliness, a white tongue, high temperature, and quick pulse. The temperature rises also towards the crisis, and often reaches 106° F. Its cessation is as sudden as its onset.

The disease is a comparatively mild one, and is by no means dangerous if carefully attended. It is supposed to be caused by a spirillum, which is found in large numbers in the blood of persons during the onset of the attack, but which is absent during the intervals. This micro-organism has not been cultivated outside the living body, although Vandyke Carter produced relapsing fever in monkeys by inoculation with human blood containing the spirillum.

*Influenza* is a disease of much the same order, and the inhalation of the vapour of 'Sanitas' oil is to be recommended, both for its prevention and its cure. Drs. Pfeiffer, Kitasato and Canon claim to have discovered a bacillus which causes this disease.

*Yellow Fever*, an epidemic disease, which is attended with yellowness of the skin, hæmorrhage of the bowels, and delirium, has its habitat mainly in tropical climates. Occasionally it has occurred in

Spain and France. As in typhus, one attack gives immunity from a second. It is not very, if at all, contagious.

Dr. Domingos Freire has given a report of experiments which are said to have established the facile transmissibility of yellow fever by inoculation, and the specific cause is said to be a cryptococcus. The same investigator claims, also, to have found a means of attenuating the virus of the disease, which consists in the cultivation of other micro-organisms known to be antagonistic to the cryptococcus.

*Puerperal Fever*, *Pyæmia*, *Septicæmia*, and *Blood-poisoning* are states of disease directly produced by the introduction into the system of poisons, of which the substance named sepsin (Burdon Sanderson) is illustrative. These poisons are elaborated by the micro-organisms which are found in putrid mixtures.

In puerperal fever, micrococci have been found in the form of zooglæa in all affected organs.

In septicæmia, Klein has found in the bloodvessels of the swollen mesenteric glands, large numbers of minute bacilli ; and in gangrenous septicæmia around wounds, Arloing and Chauveau also found short bacilli.

In open wounds and closed ulcers, micrococci and bacilli are found in abundance.

The use of disinfectants, such as 'Sanitas' fluid and oil, for the purification of air and wounds largely contributes to the prevention of such complaints and their consequences.

*Woolsorters' Disease and Malignant Pustule* are said to be caused by the bacillus which also causes splenic fever or anthrax in cattle.

The spores of anthrax are of an extremely resistant character,* but the fully developed germs are readily killed by a number of chemical reagents. It is probable that these micro-organisms are very widely distributed in Nature, and that they only produce disease when they propagate under special conditions. Assuming, that is to say, that they produce disease, indirectly, by virtue of certain chemical poisons which they elaborate or secrete, such poisons are only produced under special conditions. It is almost certain that if admixed with antiseptic or disinfectant preparations under conditions which would otherwise lead to disease, they are innocuous.

That they indirectly lead to disease seems to be well proven.

As reported in an earlier chapter (see p. 216), Klein states that by passing *Bacillus anthracis* through different species of animals they become endowed with different properties. Thus, the blood bacillus of sheep or cattle dead from anthrax, invariably kills other sheep or cattle by inoculation ; but after passing through white mice it loses this virulence, a transitory illness is all that it can then produce in sheep or cattle. The explanation of this astonishing

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* 'According to a Berlin bacteriologist, the spores of anthrax are not destroyed after twenty minutes' immersion in a 1 per 1,000 solution of corrosive sublimate ; after thirty-eight days' immersion in a 7 per cent. solution of carbolic acid the spores were still capable of growing.'—*Medical Press and Circular*, August 20th, 1890.

fact is altogether wanting: at first blush it would appear to indicate morphological change of the germs themselves, but this is a conclusion that cannot be entertained; and if the fact points to anything at all, it is to the conclusion that germs do not constitute *contagium vivum*, but only produce contagious poisons. It would be of the highest importance to make experiments with *Bacillus anthracis*, similar to those conducted in connection with septicæmia by Burdon Sanderson; for example, to cultivate pure growths in different media, and make comparative tests of the effects produced in animals by inoculation; also to sterilise such mixtures in a way that would not chemically alter their composition, with the view of ascertaining if the effects are still producible; that is, whether they are due not to the bacilli, but to their products; and again, to mix disinfectants with the mixtures containing the cultivated bacilli, and ascertain then the effects of inoculation with the disinfected mixtures. It is by the application of such tests that precise information concerning the disinfecting qualities of different substances is to be obtained. It is insufficient to test disinfectants by ascertaining their effects on the bacilli themselves. That is a matter which, after all, may more intimately concern micro-organisms than ourselves.

*Malarial Fever.*—This disease is attributed by Klebs and Tommasi Crudeli to a bacillus which occurs in the soil, and they produced by inoculation of rabbits a febrile disturbance which they considered to correspond with malarial fever in man; but this has been disputed by Sternberg upon the basis of experiments with material taken from the soil of malarious districts in America. On the other hand, Laveran and others claim that certain micro-organisms named *Plasmodium malariæ,* which are allied to the *Flagellata,* occur in the blood of patients suffering from malaria, and they are said to produce intermittent fever in man by intravenous injection.* Professor Tommasi-Crudeli does not concur in the view that the *Plasmodia* are the cause of malaria. Some further reference to this disease will be made in a later chapter (see pp. 327-329).

*Glanders* is attributed to the *Bacillus mallei,* which was studied by Schütz and Löffler in 1882, and is found in the organs of horses and sheep dead or dying from this disease.

*Swine Plague* has formed the subject of special investigation by Klein, who attributes it to a bacterium identical in morphological respects with *Bacillus subtilis.* The respects in which they differ have yet to be ascertained. *Bacillus subtilis* is very widely distributed, but is considered innocuous.

*Cattle Plague* (Rinderpest).—Micrococci are supposed (upon the usual basis of cultivation and inoculation experiments) to cause this disease, but their specific nature is not considered well established.

*Gonorrhœa* is stated to be caused by the *Micrococcus gonorrhœa,* but according to evidence furnished

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* See lecture on the Parasite of Malaria, by Dr. Patrick Manson, in *Lancet,* January 6th, 1894.

by Welander* proof of the pathogenic nature of the gonococcus is still wanting.

*Syphilis* has been attributed to a *Bacillus* which has been studied by Lustgarten, while Eve and Lingard have also observed and isolated a *Bacillus* from the blood.

Some forms of *Sore-throat* are also attributed to micro-organisms.

The poisons, whatever they be, that are associated with local ulcerations such as gonorrhœa, syphilis, and with diphtheritic sore-throat, gangrenous wounds, and so on, are undoubtedly destroyed by chemical oxidants to the extent that they can be placed in contact with them, and in this clearly defined direction, therefore, the use of disinfectants (among them 'Sanitas' fluid) in connection with these complaints is obvious. They are to be employed exactly upon the same principles that antiseptic surgery is practised. The peroxide of hydrogen, which is one of the constituents of the fluid above named, is capable of destroying by oxidation, all these poisons that are of the nature of ptomaines or albumoses, while both it and the other constituents† prevent their further formation, and destroy the microbes which give rise to them.

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* See *Brit. Med. Journ.*, October 18th, 1884.

† See Chapter XIII.

# CHAPTER XI.

## ALIMENTATION AND FOODS.

LIFE is sustained, of course, by means of food, which is required not merely to make good the losses that are continually taking place, but also to supply the animal heat of the body.

It is computed that on an average a man requires daily, rather more than 1 lb. 2 oz. of chemically dry solid matter to maintain his body weight, and as nearly $1\frac{1}{2}$ lbs. of oxygen, by weight, are partly absorbed through the lungs, the total quantity of solid and gaseous matter thus assimilated, amounts to nearly $2\frac{3}{4}$ lbs. daily. The waste takes place partly through the alimentary canal (equal to about 800 grains of dry solid matter per day), and the rest is lost through the agency of the lungs, the skin, and urine. These various excretory products amount, of necessity, to about 17,000 grains per day, being, of course, approximately equal in amount to the dry solid food which is taken, and the oxygen which is absorbed through the lungs. It will be understood that they constitute the waste products resulting from the metamorphosis of the animal tissues. Some foods being nearly identical in chemical nature with some of the substances entering into composition of the tissues, presumably require but little change before they admit of assimilation, while others are not assimilated at all, but only undergo and induce changes in the human body, serving incidentally other functions equally important in character.

While it is possible to sustain life upon a restricted number of kinds of foods, it is far preferable to use a mixed diet, comprising nitrogenous, saccharine, amyloid, and saline compounds, so that all the various substances necessary for repairing the tissues of the body may be available in the food.*

Roughly speaking, we may divide food into two classes—(1) Inorganic, (2) Organic. In the first class we have water, and certain salts, such as sodium chloride, phosphates of calcium and iron; whilst in the second class we have three different types of food: (*a*) nitrogenous food, which consists chiefly of albuminates; (*b*) fats and oils; (*c*) carbohydrates, under which head come starch and sugar.

## CLASS I.

The principal function of the water is to dissolve the food, and so enable it to be conveyed to the different parts of the body; it also materially assists in the removal of the waste or excretory products from the living body, and, by evaporation from the

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* For full details concerning the chemical composition of the different parts of the human body, and the chemistry of nutrition, etc., see Kingzett's 'Animal Chemistry' (published by Longman and Co.).

skin, causes the temperature of the body to be lowered when from any cause, such as violent exercise, it is abnormally raised.

The mineral salts are essential for the growth and repair of all the tissues of the body; thus phosphates are necessary for the formation of bone, and iron salts for the red-blood corpuscles and colouring matters present in the muscles, whilst chlorine in combination plays a very important part in the process of digestion.

(*a*) *Nitrogenous Foods.*—The presence of nitrogen is an absolutely essential condition for all organic life, and no manifestation of energy can take place in any tissue from which it is absent. Up till quite recently it was thought that muscular force was entirely dependent on the changes which take place in the muscular tissue, and that it could therefore be measured by the amount of urea which is excreted (urea being the chief product of such a change).

Drs. Fick and Wislicenus have, however, shown by their experiments in connection with the ascent of the Faulhorn, that a non-nitrogenous food will sustain the body during severe exercise for a short time, and without any notable increase in the formation of urea, whilst, on the other hand, the excretion of carbonic acid and water is found to increase proportionately to the amount of exercise. It therefore appears that the energy of the body is due principally to the oxidation of the non-nitrogenous food-stuffs, *i.e.*, fats and carbohydrates, the amount of this oxidation being determined, as Pettenkofer and Voit have shown, by the nitrogenous substances composing the tissue.

(*b*) *Fats and Oils.*—These bodies are compounds of glycerol with the fatty acids. They are not acted on either by the saliva or the gastric juice, and therefore do not undergo any change until they reach the little intestine, where they are emulsified by the bile and pancreatic juice, and so rendered capable of absorption by the lacteal vessels. The chief function of this class of foods is to renew the fatty tissue, and by oxidation, to supply the body with heat and energy; they also assist in the digestion of other foods, and in the removal of the excreta.

(*c*) *Carbohydrates.*—These bodies are compounds of carbon, hydrogen, and oxygen, the hydrogen and oxygen being present in the same proportions as in water, hence the name carbohydrate. In the process of digestion, starch, cane-sugar, dextrin, and milk-sugar, are partially converted into grape-sugar by the saliva; they then pass through the stomach without undergoing any further change, and on reaching the small intestine, the conversion into grape-sugar is completed by the pancreatic juice; the grape-sugar thus formed is then taken up by the blood and carried along the portal vein to the liver, where it is stored up as glycogen or liver-starch, ready for subsequent use, either for the formation of fatty tissue or else for increasing the heat and energy of the body. Although, as we have shown, the functions of the fats and carbohydrates are very similar, it does not appear that they can entirely replace one another without interfering with the health of the body.

The vegetable acids, such as acetic acid, tartaric acid, oxalic acid, etc., form another small but very important item in the human diet. They are mostly present in the food in the form of alkaline salts, which are converted in the body into carbonates, thus preserving the alkalinity of the blood, tissues, and secretions. When these organic acids have been absent for some time from the food, the blood becomes impoverished and the disease known as scurvy results. Formerly, sailors used to suffer a great deal from this complaint, owing to the difficulty they have in obtaining fresh meat and vegetables, which are the chief sources of these acids. Of late years, however, scurvy has become much less common, owing largely to the use of beverages such as lime-juice,which contain organic acids.

In order to preserve health for any considerable period of time, it has been found absolutely necessary to have a diet containing all these different groups of food-stuffs, although fats and carbohydrates appear to be to a certain extent interchangeable. With respect to the quantity and nature of the food which should be consumed in the course of the day, in order to keep up the strength of the body, without at the same time overtaxing the digestive and excretory organs, no very definite rule can be laid down, as it varies so much with the age and sex of the individual, with the amount of work that is done, and also to a certain extent with the climate ; we may, however, take Moleschott's figures for medium work, in the annexed table, as representing the proper average diet for an adult man ; whilst for an adult woman the average diet should be from three-fourths to four-fifths of this amount.

| | Medium Work. | | | | Severe Work. | |
|---|---|---|---|---|---|---|
| | Moleschott. | | Pettenkofer & Voit. | | Moleschott. | |
| | grms. | oz. | grms. | oz. | grms. | oz. |
| Proteids - - - | 130 | 4·59 | 137 | 4·83 | 140 | 4·94 |
| Fat - - - - | 84 | 2·96 | 117 | 4·12 | 90 | 3·17 |
| Carbohydrates - - | 404 | 14·26 | 352 | 12·40 | 434 | 15·31 |
| Salts - - - - | 30 | 1·06 | 30 | 1·06 | 32 | 1·13 |

As already mentioned, the amount of food required to preserve health varies very much with age, and to a smaller extent with each individual. During childhood, from birth to puberty, the body is developing, and therefore food has to be supplied for the growth of the tissues as well as for maintaining the heat and energy of the body, so that a working lad really requires more food than a working full-grown man; on the other hand, in old age the supply of food should be diminished.

The following table ('Physiologie des Kindsaters,' Tübingen, 1877) shows the minimum daily supply of food necessary at different ages:

| Condition. | Weight in Grammes. | | |
|---|---|---|---|
| | Proteids. | Fats. | Carbohydrates. |
| Child up to 1½ years (average) - | 20-36 | 30-45 | 60-90 |
| From 6 to 15 years (average) - | 70-80 | 37-50 | 250-400 |
| Man (moderate work) - - - | 118 | 56 | 500 |
| Woman (moderate work) - - | 92 | 44 | 400 |
| Old man - - - - - - | 100 | 68 | 350 |
| Old woman - - - - - | 80 | 50 | 260 |

A mere chemical analysis of a food—that is to say, a determination of the amount of nitrogen, carbon, and salts which it contains—is, however, not sufficient to determine its nutritive value ; we must also know to what extent it is capable of being assimilated by the digestive juices. Comparing animal and vegetable foods with respect to their digestibility, it appears that the animal proteids and fats are more digestible than those obtained from vegetables. There is also an appreciable difference in the digestibility of different kinds of flesh ; thus, fish has been found to be less digestible than meat, while beef is more digestible than either pork or veal. The following details may be taken as giving a rough average of the time the different kinds of food remain in the stomach. The flesh of animals remains from 2½ to 4, or even 5 hours in the stomach ; starchy foods, such as boiled rice and sago, from 1½ to 2 hours ; white bread about 3 hours, and brown bread still longer.

Cooking is also a matter of great importance to be considered in connection with this subject. All vegetables are found to be rendered much more digestible by cooking ; but with meat this is not so ; indeed, raw meat is, if anything, more digestible than when cooked, particularly if the meat has been at all overdone. On the other hand, cooking makes the food more palatable, and also enables us to take our nourishment hot, which in the case of a weak digestion is a great advantage, as no energy has then to be wasted in heating it up to the temperature of the body. Another great advantage of cooking is, that it destroys all the numerous parasites which are often present in meat, though it appears that it does not kill all the bacteria and other micro-organisms which are present.

Sleeping diminishes digestion; it is therefore undesirable to take a heavy meal shortly before going to bed, and also, for a similar reason, it is best to sit quiet immediately after a meal, and not to take violent exercise too soon. It is also a bad thing to take food too often and at irregular intervals. There is no doubt that, at the present day, the habit of taking a great deal more food than is necessary is very frequently to be met with, particularly among men of the upper classes. The primary effect of gluttony is to cause indigestion with diminished absorption, but also more food may be absorbed than is required by the body for carrying on its functions, in which case the body gains weight chiefly in the form of fat.

The effect of eating too much meat is to overtax the liver, kidneys, and other excretory organs, with the result that gout and diseases of the liver and kidneys may set in. An excess of fats and carbohydrates, on the other hand, tends to produce dyspepsia and obesity. On the complete withdrawal of food, general weakness, more especially of the heart and respiratory organs, sets in, combined with a gradual wasting of the body, followed by death. Of more interest and importance, however, is the effect of an insufficient supply of food; for in our prisons and workhouses, where care is very properly taken not to give more than the necessary amount of food, it may sometimes happen that the food supply is insufficient. Dr. G. Wilson says, for example, that when he was medical officer at the Portsmouth convict prison, he proved from observation that the full labour diet

$$C = 5{,}289 \text{ grains}$$
$$N = 255 \text{ grains}$$

was inadequate to sustain prisoners employed at hard navvy work for any length of time, and their average loss of weight was so great, that they had constantly to be shifted to lighter labour in order to enable them to recover. Generally speaking, an insufficient supply of food-stuffs leads to a weakening of the body, which is thus less able to withstand the effects of cold and disease; more especially is this so if work has to be done at the same time.

*Meat* consists chiefly of proteids and fats, but it also contains a small amount of salts; carbohydrates are absent or only occur in small quantities in meat. Although the meat of animals suffering from disease may in some cases be none the worse as food, or at any rate only slightly deteriorated, yet, on the other hand, it is usually unwholesome, and often dangerously so. The same remark applies to meat in which decomposition has begun; for when putrefaction first commences the meat is quite wholesome, and many people eat game and venison with impunity when putrefaction is pretty far advanced.

*Milk* is the natural food for the young of all mammalia, and it contains all the different groups of food-stuffs mentioned in the standard diet; the proportions of these food-stuffs varies, however, very much with different animals, and we may therefore presume that the milk of one animal is not altogether suitable for nourishing the young of another species: certain it is that a baby thrives very much better on its mother's milk than when fed artificially with cow's milk. The chief source of difference between human milk and that of the cow is that the latter contains a much larger proportion of casein, and when in the process of digestion the milk is curdled by the gastric juice, the curd of human milk is found to form loose flocculent masses, whilst the cow's milk forms a much more compact curd, which is much harder to digest. If, therefore, cow's milk be used for nourishing babies, it should be diluted with water, or preferably barley-water, which has the effect of making the curd looser and consequently more digestible, and a little sugar or, better, milk-sugar should be added. The average per cent. composition of cow's milk is, according to Wynter Blythe:

| | |
|---|---|
| Fats - - - - - - - | 3·50 |
| Casein - - - - - - - | 3·98 |
| Albumen - - - - - - | 0·77 |
| Milk-sugar - - - - - - | 4·00 |
| Water - - - - - - - | 86·87 |

From which it will be seen that milk is a very valuable article of food, though it contains too large a percentage of albuminates to be used as a diet entirely by itself. Milk after it has stood for some time becomes sour, owing to the conversion of the sugar into lactic acid by means of a small bacillus (*Bacterium lactis*), and in this state it is decidedly unwholesome, particularly for infants. On standing still longer the milk becomes turbid, the lactic acid is converted into butyric acid, and putrefaction sets in. For persons who are unable to digest milk it is best to curdle it first by adding a little rennet or acetic acid.

Milk is preserved in various ways: one method is to boil it for a short time and then seal it up directly, before it has time to cool; another method is to evaporate it to dryness under reduced pressure and keep the dried residue. The most usual and best means of preserving it, however, is to concentrate it down to about one-third of its bulk, after the addition of sugar, and then seal it up in tins. This is the ordinary 'Swiss Condensed Milk,' which is very largely used by children of the poor as a substitute for fresh milk. For very young children it is usual to dilute it with four or five times the amount of water; but the mixture thus obtained has too large a proportion of nitrogenous food-stuff, whilst it also contains too much sugar and too little fat. In some forms of condensed milk the addition of sugar is omitted, but in this case the milk will not keep good long when once the tin has been opened; whereas the ordinary 'Swiss Condensed Milk' will keep some weeks. One great source of danger in milk is the disease germs which it may contain, due either to dilutions with impure water, or else introduced by contact with someone (either the milkman or the dairyman) who may be suffering from some disease. Many epidemics, particularly of scarlet fever, have of late years been traced to an infected milk as their supposed source. Milk also has a very powerful absorbing capacity for gases, and if allowed to stand in an unwholesome atmosphere, it may absorb foul and poisonous gases, and so become dangerous. Milk obtained from diseased cows is also a source of danger, though to what extent is not at all certain. There is, however, very strong evidence to show that cows suffer from a disease very similar to scarlet fever, and that the milk from an animal having this disease may cause an outbreak of this epidemic among those who drink it. Cows, particularly if stall-fed, are also subject to tuberculosis, the infectious nature of which disease seems now to be pretty well established, and it is quite possible that the comparatively large mortality among children from this complaint may be due, in part, to the milk, of which they consume much more than those more advanced in life. Outbreaks of illness have also been traced to milk from cattle suffering from foot and mouth disease, whilst in cows suffering from anthrax and cattle-plague the supply of milk stops at an early stage.

*Butter* is usually made by violently agitating cream, or sometimes milk, when the fat globules coalesce to form a thick mass, which after some further treatment makes its appearance as butter. The chief constituents of butter are the fats or glycerides of the fatty acids, fresh butter containing about 83 per cent. of these fats, and about 14 per cent. of water.

*Margarine* is made chiefly from beef-fat, which is first chopped up very fine, and then churned up with milk in order to give it the flavour of real butter. The chief difference between butter and margarine is that the former contains about 6 per cent. of the volatile fatty acids, principally butyric acid, whilst margarine contains less than 1 per cent.

*Cheese*, another product obtained from milk, is also a very valuable food, as it contains a large amount of proteids and fats in a small bulk; it is, however, not nearly so digestible as butter, and many people are unable to take it for this reason.

*Bread.*—The art of bread-making is prehistoric, and no doubt dates back to a very early period in the civilization of man. We know it to have been practised in the Stone Age, for not only have the stones for grinding the grain been discovered in the lake dwellings of Switzerland, but also some of the bread, which has been preserved by charring. The cakes, which were somewhat round, were made of partially crushed corn, portions of the grains being in some cases plainly discernible (Keller's 'Lake Dwellings'). The making of bread is also mentioned very early in history, as, for example, in the Book of Genesis, where it is referred to on two or three occasions. Bread was originally made by simply mixing the flour into a paste with water and then baking it, and is still made in this way in some parts of the world. Later there came the addition of leaven, that is to say, a portion of the dough kept from a previous baking, in which the process of fermentation is far advanced; and then, still later, we find yeast taking the place of leaven. The effect of adding yeast or leaven to the dough is to cause a process of fermentation in the gluten of the flour, which partially converts the starch, first into sugar, and then into alcohol and carbonic acid gas; the result is that the dough swells out, and is filled with small bubbles of gas, and the bread when baked is both much more digestible and also more palatable. Bread is rich both in proteids and carbohydrates, but poor in fats; it is therefore usual to eat it with butter, bacon, cheese, or other bodies rich in fat, when it forms one of the most wholesome and nutritious foods that we possess. Bread is sometimes made by forcing carbonic anhydride into the dough under pressure, and also by the addition of baking powders, which cause the liberation of that gas. This unfermented bread is supposed to be better for not containing any alcohol, acetic acid, or other fermentation products; the advantage is, however, doubtful, as the yeast itself begins the process of digestion by converting the starch into sugar. Bread is now nearly always made from wheat flour, though other grains, such as rye and oats, are used to a certain extent in some localities. The chief adulterations of bread are other kinds of starch (such as rice-flour and potatoes), alum, and borax. The addition of different kinds of flour can mostly be detected by examination of the starch-grains under the microscope. Alum is added to bread to whiten inferior flour, and also to arrest fermentation ; its harmful effects are rather doubtful, it is, however, an adulteration, and should therefore not be permitted.

*Coffee* is obtained from the seeds of *Caffea arabica*, a plant which grows in the tropics. It contains about 10 to 12 per cent. of nitrogenous substances, about 12 per cent. of fat, about 8 per cent. of sugar and dextrin, and about 1 per cent. of 'Caffeine,' to which it is supposed to owe its stimulating action.

In order to prepare this beverage, the berries are first roasted and then ground, after which hot water is poured on to the grounds, allowed to stand for a short time, and then strained off. Coffee acts as a powerful stimulant on the nerves, and also increases the action of the heart and the respiratory organs ; it is a most valuable stimulant in cases of fatigue or hard work, and, unlike alcohol, it produces no subsequent collapse. The chief adulterations of coffees are starch and chicory.

*Tea* consists of the dried leaves of the plant *Camellia thea*, which is grown in China, India, and Ceylon, and the beverage is made by pouring boiling water on to the leaves and then allowing it to stand for a few minutes. Tea appears to considerably increase the action of the lungs ; it also tends to induce perspiration, thereby cooling the body. Its most important property, however, is its stimulative action on the nervous system, which makes it a most valuable restorative in case of fatigue. Taken in excess, it produces nervous depression and insomnia, and many people are unable to sleep if they take tea in the evening ; it also injures the digestion, owing to the astringent properties of the tannin.

The active principle of tea is the same as that of coffee, although it is more often named 'Theine.'

*Cocoa and Chocolate* both contain a large quantity of fatty food ; they also contain a body, theobromine, which, like Theine and Caffeine, acts as a nerve stimulant.

*Alcohol.*—Under this head we have to consider the effects, beneficial or otherwise, produced by beer, wine, and spirits. When taken into the stomach, alcohol seems to be absorbed without any alteration, and can be detected in nearly all the organs of the body shortly after ; it also very soon begins to pass out of the body by the lungs, skin, and urine. How much of the alcohol thus passes out unaltered is a much-debated point, but it is generally admitted now that a good deal undergoes metamorphosis in the body, though as to what are the products of this transformation we are, at present, in the dark. It does not seem probable that alcohol is decomposed into $CO_2$ and $H_2O$ in the body, as the amount of $CO_2$ given out by the lungs diminishes after a dose of alcohol. A more probable theory is that it is converted into acetic acid, though the evidence on this point is very conflicting.

In small doses alcohol appears to aid digestion, but in large doses it undoubtedly checks it ; it also appears to slightly lower the temperature of the body, though a fairly strong dose of alcohol given to a man accustomed to take wine and spirits does not seem to have any appreciable effect on his temperature. It appears that if a healthy man takes more than from one to one and a half fluid ounces of alcohol in twenty-four hours, it makes its appearance in the urine, and may therefore be considered injurious. For women the injurious dose is probably less, whilst healthy children should not take alcohol in any shape.

Alcohol acts on the nervous system chiefly as a stimulant, and tends to make people more genial and unreserved, which is, no doubt, the chief cause of its popularity. It also produces a sensation of comfort and warmth, for which reason it is very usual to take spirits when exposed to cold and wet, 'just to keep out the cold,' as the saying is, though in cases of prolonged exposure, alcohol should be avoided, as it appears to diminish the power of resistance to intense cold, as also to disease.

Alcohol increases the action of the heart, and at the same time allows the bloodvessels to dilate more easily, but for which there would be great danger of their rupturing. As we have seen, it is not a food, but wine and beer contain other substances in addition to alcohol, some of which are food-stuffs. Thus, in wine we have a small amount of albuminates, and a very considerable amount of sugar and vegetable salts, whilst beer contains a very valuable tonic in addition.

Wine and beer should, therefore, be drunk in preference to spirits, not only on this account, but also because there is a danger with spirits of not sufficiently diluting them with water. Even wine and beer, however, should only be taken in moderation, as otherwise they lead to gout and other diseases.

# PART II.

## CHAPTER XII.

### MALARIAL FEVER AND ITS CAUSES.—THE EUCALYPTUS GLOBULUS AND ITS SANITARY PROPERTIES.—HYGIENIC UTILITY OF CAMPHOR, PERFUMES, ETC.

IN preceding chapters, attention has been directed to the putrefactive changes to which animal and vegetable matters are subject, and it has been shown that these changes are intimately associated with the production of infectious diseases.

It has, indeed, been demonstrated that many infectious diseases have their origin in putrefactive processes, while certain miasmatic diseases are both endemic and epidemic in places where organic matters are constantly undergoing change, as in marshy and damp districts. It will now be our object to illustrate this last-named statement somewhat more fully.

In his 'Letters on Chemistry' (p. 230), Liebig says: 'In no case may we so securely reckon on the occurrence of epidemic diseases as when a marshy surface has been dried up by continued heat, or when extensive inundations are followed by intense heat;' and in the appendix to the same treatise there are recorded the following historical observations, which lend great weight to this view:

In constructing the railway from Strasburg to Basle, it was found necessary to excavate certain fields to a depth of two or three feet, thus causing a number of hollows in the neighbourhoods of Bollweiler and Feldkirch. In spring and autumn these hollows filled with water, and this partially drying up in the summer, created perfect morasses, abounding in the infusorial life characteristic of stagnant water. Thus, there was introduced intermittent fever into the neighbourhoods, and year after year the epidemic became worse and worse.

In 1843, of the 1,446 inhabitants of Bollweiler, 36 were attacked with intermittent fever; 166 cases occurred in 1844; 743 in 1845; and 1,166 in 1846. The mortality increased in a corresponding proportion.

Again, in 1843, of the 480 inhabitants of Feldkirch, 2 were attacked with the same disease; 20 were attacked in 1844; 135 in 1855; and 376 in 1846; and the annual mortality rose from 11 to 18.

These particulars were augmented and confirmed by similar facts embodied by Drs. Weber, Sanger, and West, in a report to the Prefect of the Upper Rhine.

Under these circumstances, Dr. Dollfus-Ausset appealed to the Paris Academy of Sciences to use its influence and knowledge in instructing the administration concerning the best means of checking the plague which had already decimated two villages, and was then threatening others.*

It does not, however, call for any such special cases to prove the source of malarial fevers. It is an observation which has grown with the world in age, that wherever there is matter of animal or vegetable origin in course of putrefactive or allied change, danger to human health is also lurking in the water and floating in the surrounding air. The mere presence of organic matter in the soil does not necessarily indicate danger to the neighbourhood, because, supposing the soil to be of a porous nature, and in free contact with the air, the organic matter is very rapidly oxidized into innocent compounds—innocent compounds, that is to say, so far as infectious disease is concerned.

In writing of the effects of the surface of the soil on air, Dr. Angus Smith used these words :†

'If soil affects the atmosphere, how does it happen that it is such an excellent disinfectant ? Substances are not purified in the air to the same extent in the same time as in the soil. The great amount of surface presented by the porous soil is mainly the cause of the rapid action, but the acid humates act, and probably other substances, chemically. There are modes of oxidising in the air beyond the power of ordinary

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* *Comptes Rendus*, Séance du 5th March, 1847, p. 779.

† 'Air and Rain,' p. 507.

oxygen; one of these is by means of nitrogen oxides, and another by ozone; but even these require great time and space. If we throw sulphuretted hydrogen water or its compound with ammonia on a few inches of soil, it passes through, oxidised in a few minutes; we obtain such an action in the air only in great volumes, although in the end the work done may be better for its purpose.'

Nevertheless, as shown when treating of sewage disposal by irrigation, it is possible to overload even porous soils which oxidise the most rapidly. That is to say, it is possible, in a given case, to have more organic matter than, under existing circumstances, admits of oxidation in a certain time; putrefaction is the first result, and this may lead on to intermittent fever and other diseases.

Again, Dr. Angus Smith truly says,* that 'there seems to be a confusion in many minds between peat-bogs and marshes, but the difference is very great. No peat-bog gives out marsh fevers and agues, although the cold and wet may induce rheumatism. The acid peat prevents decomposition, and so removes all the results of putrefaction, which some people suppose to be the origin of the evil in marshes.'

The miasms of marshes, then, are matters which accompany, or result from, the processes of decomposition comprehended in the term 'putrefaction.'

Klebs and Tommasi-Crudeli (*Practitioner* for

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* 'Air and Rain,' p. 520.

August, 1879) claim to have established malarial fever to be due to the action of *Bacillus malariæ* (see p. 304), as they name a micro-organism which they have detected in the soil and air of malarial districts. They found that the malarial poison exists in quantity in the soil of malarious districts, even at times when man is not affected with the disease, and that the poison may be detected at such times in the strata of air immediately above the soil. What is remarkable among the results of Klebs and Tommasi-Crudeli is, that they find large quantities of water render the germs inactive. Their method of experiment consisted in subcutaneously injecting liquids obtained from the soil into animals, and noting the rise of temperature experienced. This was from the normal one to 41·8° C. Similar observations were made with the so-called artificially cultivated germs. The doubt attached to the interpretation of such experiments lies in this—that the subcutaneous injection of many solid matters would probably produce corresponding results. Even these investigators found that the fluid freed from the bacillus produced an intermittent increase of body temperature!

The bacillus is developed in the presence of free oxygen, and thus belongs to the *Aerobii* of Pasteur.

According to Marchiafava, *Bacillus malariæ* also occurs in the blood of patients suffering from malaria, but Sternberg has stated that the febrile disorder produced by inoculating rabbits with material derived from the soil of malarious districts in America, has nothing in common with the human intermittent fever, and can be induced, indeed, by other bacilli.*

Apart, however, from the doubt that exists as to the precise relation between malarial fever and the *bacillus* observed by Klebs and Tommasi-Crudeli, there can be no question that the real virus is a chemical poison originated by micro-organisms during a putrefactive or allied change in organic matter contained in soil. In this respect they may be supposed to comport themselves just as do the micro-organisms in putrefying flesh; that is to say, they elaborate, under suitable conditions, products of chemical decomposition, which by their reception or formation in the human system initiate disease. In decomposing flesh, sepsin is produced, and it is the active virus in septicæmia; similarly, in decomposing vegetable matter present in soil, a hypothetical substance is produced, which may be termed malarin, and it constitutes the active virus of malarial fever. The micro-organism studied by Klebs and Tommasi-Crudeli may possibly be the originating cause, but that is not finally proved.

Laveran and others claim that the disease is produced by certain micro-organisms allied to the *Flagellata* termed *Plasmodium malariæ*,† but this is contested by Tommasi-Crudeli.

Having said so much by way of preface, we may at once proceed to the more immediate purpose in

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* Klein on Micro-organisms and Disease, *Practitioner*, June, 1884, p. 415.

† See paper by Dr. P. Manson in *Lancet*, January 6th, 1894, p. 6.

view, viz., that of describing the sanitary properties of the *Eucalyptus globulus*.

The *Eucalyptus globulus* was discovered* by Labillardière, in the Island of Tasmania, in 1792; but its fever-destroying characters first attracted the attention of M. Ramel in 1856. In that year he sent some of the seeds to Paris, and in later years forwarded further supplies, claiming for it, at the same time, the power of destroying the miasmatic influence of marshy districts. Considerable credit is also due to Baron Sir Ferd. von Mueller (the Government botanist in Victoria), who originally brought the *Eucalyptus globulus* to the notice of M. Ramel; and a meed of praise is also merited by Sir W. Macarthen, of Camden, Sydney, Australia, who also exported some seeds in 1860, and claimed anti-miasmatic properties on behalf of the tree.

Since this now well-known tree was first brought before the notice of the public, its fame has been a rapidly increasing one, the evidence in its favour forming an almost unbroken chain down to the present time.

In a memoir by Prof. Gubler,† there is adduced particular testimony to the fact that this so-called 'fever tree,' or 'fever-destroying tree,' exercises marked effects in relation to intermittent fever. It

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* See Professor Bentley's (1874) lecture on the *Eucalyptus globulus*, and his more recent one printed in the *Pharm. Journ.* for March 4th, 1878.

† *Journ. de Pharm. et de Chimie*, December, 1871 (*Pharm. Journ.*, New Series, vol. ii., p. 703).

is pointed out that, in marshy districts near eucalyptus forests, the fever is practically unknown, and this state of things is attributed to the aromatic vapours which emanate from the tree, and the preservative powers of the branches and leaves which fall upon the marshy soils. It was upon the basis of this knowledge that the Algerian and Corsican plantations, of which more will be said hereafter, were made.

In 1871, M. Raveret-Wattel published a report* to La Société d'Acclimatation, in which he said: 'Science is far from having said her last word respecting the part that may be played by these useful plants'—meaning the eucalypti; and these words have since been verified in a singular manner. M. Raveret-Wattel specially dwelt upon the importance which M. Ramel attached to the sanitary power of the eucalyptus, and points out that it was very much doubted when first claimed. He thinks, however—and justly so—that the plantations which were effected in the most unhealthy parts of Algeria have quite established the correctness of M. Ramel's views. The endemic fever in these districts is stated to have been perfectly annihilated by the plantations in question; and the use of an infusion of the leaves of the tree became so popular as a remedy against fever (even in many cases where quinine is said to have been administered in vain), that M. Alurmada had his trees completely stripped of their bark by

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* *Pharm. Journ.*, New Series, vol. iii., pp. 22, 43.

the populace. M. Raveret-Wattel remarked that the oil of eucalyptus would no doubt become very useful as a remedy in putrid fevers, and for application in cases of fœtid suppuration, etc.

In a paper contributed to the Californian Academy of Sciences* in July, 1872, by Mr. R. E. C. Stearns, the author quotes from a letter written by Dr. A. B. Stout, in which occur these words :

'There can be little doubt but that the oil of eucalyptus, when it can be procured, will be an available remedy against malarious diseases of all types, and that the presence of the trees cultivated in gardens, contributes to sanify the atmosphere from those emanations which give rise to epidemic diseases.'

As already stated, the anti-miasmatic power of the grown-up eucalyptus was particularly tested in Algeria, and the results were communicated by M. Gimbert to the French Academy of Sciences.†

This report instanced the case of a farm situate twenty miles from Algiers, and notoriously known to possess a pestilential atmosphere, in which 13,000 trees were planted, with the effect of absolutely stamping out the previously endemic fever.

A Dutch landed proprietor also planted a number of eucalyptus-trees on the banks of the Scheldt, where he owned some property in a very malarious district. The effect was that the particular spot was rendered quite salubrious, while the surrounding

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* *Western Lancet*, vol. i., p. 696 ; *Pharm. Journ.*, vol. iii., p. 603.

† See *Pharm. Journ.*, vol. iv., p. 494.

neighbourhood remained as fever-stricken as originally.

A further and an interesting contribution to the history of the eucalyptus in Algeria was made a few years since,* to the pages of the *Pall Mall.* The writer pointed out that it was only so recently as 1867 that the Algerian plantations became at all extensive in character, and then he goes on to describe what he himself had witnessed but a few days prior to writing. He had visited the estates of M. Ramel, M. Trottier, and M. Cordier, whose trees had all been grown from seeds. On M. Trottier's estates at Hussein Dey, the trees were fifty feet high. 'In this evergreen wood, all around us, were tall reddish smooth stems, with the bark hanging down in a ragged, untidy manner—for the tree sheds its bark in winter—and gray, willow-like leaves were waving on flexible boughs. . . . It produced a curious impression to walk in the dim twilight of this Australian-African forest, and to think that this was also a wood of the miocene period. Beautiful is not the word I should apply to its appearance; but in exchange for bare sun-baked earth or deadly swamps, I must say these eucalyptus forests are most grateful, and the smell delightfully resinous, warm, and gummy. . . . There seemed to be a general impression that the eucalyptus was a fever-destroying tree, and of the greatest importance to the colony from that point of view.'

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* *Pharm. Journ.*, vol. iv., p. 731 (taken from the *Pall Mall*).

I have not been able to obtain any reliable figures as to the distribution of *eucalypti* in various parts of the world, although they are very widely distributed, plantations having been established all over the world. Thus, in South California, the *Eucalyptus globulus* is now planted by thousands, and it has been estimated that the gain in growing the timber is even a greater one than that derived from cereals.

Mr. Bosisto, the well-known distiller of eucalyptus oils, has given some idea of the extent of area covered by *eucalypti* in Australia,* and its freedom from fever. In a paper communicated to the Pharmaceutical Conference some years since, he wrote, 'Of the whole indigenous vegetation of the Australian Continent, which is 2,500 miles west to east, and 2,000 miles north to south, and in area amounts to some 3,000,000 square miles, the *eucalypti*, numbering 150 kinds or species, forms four-fifths.' The country, on the whole, may be said to be pretty free from violent endemic or miasmatic poisons; indeed, he adds, 'they might be said to exist only as the eucalyptus receded.'

In his report to the Commissioners of the Exhibition, Mr. Skene, writing of Victoria, states that the area of the whole colony amounts to 55,644,000 acres. Of this 5,560,000 acres are covered with

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* *Pharm. Journ.*, vol. v., p. 270, from a paper read by Mr. Bosisto before the Royal Society of Melbourne. See also *Pharm. Journ.*, vol. xvii., p. 13.

dense mallee scrub ; 6,225,000 acres consist of mountainous ranges, deeply wooded with gums, while the area of the open timbered country amounts to 38,922,000 acres. Upon the basis of these figures Mr. Bosisto has calculated that the extent of mallee country in New South Wales and South Australia is twenty times that of the area in Victoria.

From these and other considerations, which will be dealt with presently, Mr. Bosisto also concludes that the eucalyptus is established beyond all doubt as a fever-destroying tree.

Italy has also furnished some evidence upon this question. In a paper read before the Roman Academy of Medicine, on April 30th, 1876, Dr. Fedeli* alleged that wherever plantations of the eucalyptus existed, malaria was unknown, and where the malaria had been endemic, the cultivation of this tree sufficed to mitigate in all cases, and in some instances to entirely remove, the disease. A long discussion followed the reading of Dr. Fedeli's paper as to the specific manner in which the eucalyptus exercises its powers ; but while different views were taken of this question, the testimony borne to its febrifugal virtues was perfectly unanimous.

It is of interest to note that since the reading of Dr. Fedeli's paper, the Italian Government has supplied landholders with large quantities of slips of the tree for forming plantations in all malarious districts.

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* *Pharm. Journ.*, vol. vi., p. 912.

According to a report made some years ago, 500,000 eucalyptus-trees were to be planted in Mexico as some kind of protection against yellow fever, and with the view of modifying the rainfall, but I am unaware whether this proposal has been carried out.

Some years since, at a Réunion at the Sorbonne, Dr. de Pietra Santra, a delegate from the Climatological Society of Algiers, recited some of the results of the investigations made in Algeria with the view of determining the value of the eucalyptus in its relation to public health. The reports received from fifty localities, boasting the possession of more than 1,000,000 trees, showed, in the first place, that the eucalyptus exhibits a sanitary effect of the most unquestionable nature; secondly, that wherever the tree is cultivated, the intermittent fever decreases both in intensity and frequency; and lastly, that large tracts of marshy and uncultivated lands have been rendered healthful, and indeed quite transformed, by the agency of the eucalyptus. Dr. de Pietra Santra also stated that in Corsica, where more than 600,000 plants are growing, similar results have been observed.

Between Nice and Monaco there existed, until recently, such a very unhealthy district, that the Paris, Lyons, and Mediterranean Railway Company were compelled to change their watchmen, who did service at a crossing in the neighbourhood, every few months. Some time since, however, a plantation of the *Eucalyptus globulus* was made there, and now there is said to be no more fever; and the necessity therefore for perpetual change of watchmen (to prevent death) is abolished.*

There is yet one other instance† of the wonderful hygienic properties of the eucalyptus which may be mentioned here, although briefly. In a desolate part of the Campagna there stands an old monastic institution upon a spot consecrated by tradition as that whereon St. Paul was martyred. For centuries this part of the Campagna was a stronghold of pestilential fever, and prolonged residence in the monastic institution in question surely led to death. Some few years ago, a band of Trappist monks planted the eucalyptus in its cloisters, and the trees have since grown to a great height. What is more important, however, is that the place is now once more habitable, and fever, it is said, reigns there no more.

That this effect is largely due to the eucalyptus plantation there can be but little doubt. The place in question was the execution-ground and burial-place for criminals of old Rome, and it is said that 700 cartloads of human bones have been removed. The ground around has been deeply cultivated, thus assisting to make the spot habitable. As to the bones that have been removed, it cannot be supposed that at this remote time from the days of old Rome, any organic substance forming part of the once-buried bodies could remain in the soil and have successfully resisted oxidation by the atmosphere. Bones themselves

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* *Chem. News*, December 22nd, 1876, from *Le Mondes*.

† *Pharm. Journ.*, vol. vi., p. 624.

are for the most part inorganic and harmless, and it would be more reasonable to look for malarial fever at Kensal Green than to search for it in an old Roman burial-ground, so far as it may be connected with the burials that have taken place at either locality. No doubt the fever which once infested the Trappist Monastery at Tre Fontane, near Rome, has been overcome by general sanitary measures, but foremost amongst these was the cultivation of the eucalyptus plantation.

Some years since, Dr. Laughlan Aitken, of Rome, called in question* the value of the plantations at Tre Fontane, although he admitted that they had been kept in a flourishing condition by the zeal and activity of the Trappist monks, who add to the revenue of the monastery by the sale of 'eucalyptus elixir' which they prepare. Any improvement, he stated, which may be claimed, was due quite as much to the necessary subsoil draining and preparation of the ground as to any influence of the young gum-trees. That may be so, but I think that Dr. Aitken might, without damaging his scientific reputation, have given credit to the value of the eucalyptus-tree seeing how far it has been substantiated by good chemical and other practical evidence.

Professor Tommasi-Crudeli, of Rome, is also of opinion that plantations of the eucalyptus are of no value† in preventing the occurrence of malaria. He

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* Letter to *Brit. Med. Journ.*, September 27th, 1884.

† See his address to the International Medical Congress, 1884, *Brit. Med. Journ.*, August 30th, 1884.

cited several instances from his experience in the Campagna, where these trees had been used, and where they had for a long time given perfect satisfaction, until suddenly in 1882 a severe attack of malaria occurred, while other districts where malaria used to manifest itself were free from attack. Such an experience really proves very little, because malarial fever is an infectious disease, the poison of which may be conveyed in the air and in water, and in order to obtain general protection against attack, it would be necessary not only to have plantations of the eucalyptus covering the whole area under observation, but also to shut off contamination from exterior sources. The eucalyptus certainly gives some protection, even if absolute immunity cannot be claimed for it.

This protection is to some extent due to the essential oil which is given off in a vaporous condition from the trees, but mainly to the products of its atmospheric oxidation in presence of moisture, and no doubt it is also due in part to the action of the trees in absorbing water from the soil. The shoots of the roots throw out thousands of thread-like fibres, forming a dense sort of woolly mat, which suck up a great quantity of water, and that which is not utilised in the rapid growth of the trees, is ultimately evaporated with the essential oil from the leaves.

All quarters of the globe have furnished evidence* of the sanitary value of the eucalyptus, and no one

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* See also Consul Playfair's Report on the Febrile Virtues of the Eucalyptus, 1877.

who is open to conviction, can fairly withstand the conclusion that has been arrived at, after the study and experiments of the last half-century, which is to the effect that the *genus* is both fever-preventing and fever-destroying. Any doubt, however, on this matter, will probably be removed by the chemical evidence which I shall furnish hereafter.

In addition to the direct evidence as to the hygienic importance of the eucalyptus already adduced, there is a large amount of indirect evidence leading to the same conclusion, and it is important enough to be briefly described in this place.

In his various papers, Dr. Gimbert, of Cannes, directed attention to the fact that the oil of eucalyptus is not merely of a pleasant balsamic nature, but that it speedily removes all unpleasant odours. He used the leaves largely, instead of lint, for dressing wounds, with very satisfactory results, and showed that when eucalyptus oil is mixed with albumin or fresh fibrin, putrefactive change is entirely prevented.

M. Gubler has also given testimony to the value of tinctures, infusions, and decoctions of the oil in surgery; while M. Marc used fresh young leaves to stimulate small wounds which were slow to cicatrize, and employed an aqueous infusion with great success in purulent catarrhal affections of the urethra and vagina. In consequence of these and similar observations, a large quantity of the alcoholic tincture of the leaves was for some years exported from Australia for use in European countries.

Mr. Stearns who compared the disinfecting properties of oil of eucalyptus with those of carbolic acid, remarks :—" Its chief value is as a sedative and antiseptic in asthma and throat diseases, nasal catarrhs, and affections of the mucous membranes.' In his own investigations he used both the alcoholic tincture and the spray of the pure oil.

Dr. Gimbert observed that the oil of eucalyptus and its various preparations diminish the vascular tension, and, from inducement of a sense of comfort, tend to bring about sleep.

The success which attended the use of the same preparations in mitigating and curing ague, etc., led to the idea that the leaves of the eucalyptus contained some alkaloidal principle identical with, or similar to, quinine. This idea, however, was refuted by the experiments of Mr. Broughton, the Government chemist of Ootacamund, and later on by M. Rabuteau.* Mr. Broughton examined the leaves and bark, and states that neither quinine nor the other alkaloids of cinchona bark exist in the plant in any proportion. M. Rabuteau established the absence of all other alkaloids.

It is on record that in the Mauritius an infusion of the leaves of the eucalyptus was used, on one occasion, with such great success in the treatment of malarial fever, that the leaves were sold at sixpence each !

Another application of the eucalyptus was dis-

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* *Comptes Rendus*, lxxv., 1431.

covered in its effects in the treatment of rheumatic complaints: 'Branches and leaves are put into hot water, and I am assured by those who have tried it that such baths remove rheumatic pains, neuralgia, and the debility left by the malaria incidental to the country.'*

Again, at a meeting of the Paris Société de Pharmacie, on November 4th, 1874, M. Vidal communicated a note on the vermifugal characters of essence of eucalyptus when employed in the form of an enema, and gave details of the case of a Zouave who was afflicted with the presence of a number of *Oxyuris vermicularis*, which all ordinary vermifuges had failed to remove. He was completely cured in nine days, by using each evening an enema containing from fifty to sixty drops of the oil to a quart.†

A watery infusion of eucalyptus leaves is known in France to be useful in medicine and pharmacy, and it is now to be found in the French Pharmacopœia.

The mere preservative properties of oil of eucalyptus are well known; and since the date of my own earlier researches, they have been also investigated by Mr. T. Taylor.‡ He found that, although the oil of eucalyptus is but sparingly soluble in water, yet such a solution has powerful antiseptic and deodorising powers, and is capable of considerably

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* Quoted from the contribution to the *Pall Mall* previously referred to.

† *Pharm. Journ.*, vol. v., p. 474.

‡ *Ibid.*, January 12th, 1878, being an extract from the Report of the United States Commissioner of Agriculture.

retarding certain fermentative changes and the putrefaction of albuminoids. He stated that: 'The fleshy sides of the skins of animals may be preserved from putrefaction by rubbing on them eucalyptus oil. It may also be combined with plaster and injected into the veins and arteries of animals for the purposes of preservation.'

The anti-miasmatic power of eucalyptus and pine forests has been long supposed to have some connection with the volatile oils which are naturally secreted by them, and which find their way, by evaporation, into the atmosphere. But in explanation of these results, it has been generally held that the volatile oils have the power, in some way, of giving rise to ozone—a substance which, judging from its chemical properties, may be supposed to oxidise, or burn up, the malarial matter infesting the soil and atmosphere of marshy districts.

Mr. Taylor perceived that the oxidant need not necessarily be ozone; he was, however, quite satisfied that the oils of eucalyptus and turpentine, etc., do exhibit oxidising effects, and he cited experiments in support of this view.

In connection with the salutary properties of pine, eucalyptus, and camphor forests, and before we give the correct explanation, it will be of interest to take notice of a few facts which have become matters of general experience; facts which, known from very early times, have come down to posterity without any adequate explanation.

For instance, it has been known for ages that the atmosphere of pine forests is most favourable to invalids suffering from pulmonary affections, and even at the present time it is customary to send invalids to breathe the exhalations of the coniferæ. Such exhalations are generally, although quite erroneously, supposed to be strongly ozonic in character.

Dr. Cornelius Fox, in his very interesting work on Ozone, dwells upon this subject, and alludes to the fact recorded by Herodian, that, 'in a plague which devastated Italy in the second century, strangers crowding into Rome were directed by the physicians to retreat to Laurentum, now San Lorenzo, that by a cooler atmosphere, and by the *odour of laurel*, they might escape the danger of infection.'*

Referring to the hygienic utility of essences and perfumes, Dr. Fox says they 'demonstrate that the disciples of Empedocles were not in error when they planted aromatic and balsamic herbs as preventives of pestilence.' The investigations to which Dr. Fox makes reference were directed to the supposed production of ozone by the atmospheric oxidation of essential oils; and he goes on to say that, 'The ancient custom amongst physicians of furnishing the handles of their canes with vinaigrettes, the fumes of which might protect them from the noxious exhalations of their patients; and the old practice of strewing aromatic herbs, such as rue, before filthy prisoners in the dock of a criminal court, so that the olfactory nerves of the lawyers might be offended as little as possible; as well as that of providing the chaplain

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* 'Ozone,' p. 121. By Dr. Cornelius Fox.

with a bouquet when accompanying a criminal to Tyburn, lose their absurdity under the light of these investigations. The efficacy of certain perfumes in warding off disease during exposure to fœtid air, which was thoroughly believed in by our ancestors, may be, perhaps, explained by the researches above referred to.'*

Patchouli oil is produced in enormous quantities, and is sent direct to Mecca, the Arabs believing in its health-giving properties and the protection it affords against infection.

Again, we have the case of camphor, which from time immemorial has enjoyed a reputation as an antiseptic, and which is to this day worn by thousands of persons about their clothes as a protective against infectious diseases, such as influenza.

Lastly, the efficacy of wooden hospitals in inducing the rapid convalescence of patients has been attributed to the resinous and turpentine-like substances existing in the wood, and which, by their evaporation into the atmosphere, pass, by way of the breath, into the patients' bodies.

Reviewing, now, the facts recited in the foregoing pages, we are presented with a mass of indisputable evidence, showing: firstly, that the eucalyptus-tree prevents malarial fever; secondly, that the oil of eucalyptus also exhibits peculiar vermifugal, antiseptic, and disinfecting properties; thirdly, that pine forests exercise important hygienic influences; fourthly, that turpentine, camphor, and other volatile

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* 'Ozone,' p. 122.

products generated naturally in pine and other forests, possess certain properties which render them valuable as sanitary appliances.

Disregarding all doubtful evidence, there yet remains the most abundant evidence of the hygienic value of eucalyptus, pine, and camphor forests, and a large amount of positive data regarding the antiseptic, disinfecting, and healthful properties of certain products natural to these forests. Still more striking is the fact that there is an intimate relation between the hygienic value of pine, eucalyptus, and camphor trees; for not only are all these trees healthful, but their products exhibit similar properties, and are, as I shall presently show, chemically allied. How far this resemblance holds good on further investigation, and the extent to which the hygienic properties of these trees is connected with the volatile oils furnished by them, will be fully explained in the ensuing chapters.

Some time after the first edition of my book was published, eucalyptus oil was adopted by Lister for use in antiseptic dressings, in place of carbolic acid. He found that its antiseptic properties are quite as reliable as those of phenol, while it is free from irritating and toxic effects. Its volatility, while being advantageous in other respects, tells against its use to some extent, for gauze prepared from the oil is apt to lose its strength by keeping.

The testimony of Lister to the value of eucalyptus oil as an antiseptic for use in surgery, was supported by the results of Professor Schulz and Dr.

Siegen,* of Deutz, and by its subsequent more or less general use.

'Sanitas' oil, which is obtained by the atmospheric oxidation of turpentine or eucalyptus oil, is, however, far superior to the raw oil of eucalyptus, and is now largely used as an antiseptic dressing, and still more extensively for the treatment of lung and throat affections by inhalation.

The value of eucalyptus oil formed the subject of a publication by Professor Hugo Schulz, of Griefswald, in 1881,† in which is brought together a great deal of recorded information respecting the chemical, physiological, and medicinal properties of this substance; but my earlier researches on the aerial oxidation of essential oils (including eucalyptus), and the study of the antiseptic and disinfectant properties of the products, were conducted and published long before that date, and through the oversight or the neglect of my investigations, Schulz gave himself a great deal of unnecessary labour, and, after all, elaborated an erroneous chemical theory regarding the oxidation and action of eucalyptus oil.

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[*] *Lancet*, September 4th, 1880.

[†] The reader may also consult with advantage the articles forming a review of that book by Baron Sir Fred. von Mueller, contributed to *The Australian Medical Gazette* for October, November and December, 1883.

# CHAPTER XIII.

## ESSENTIAL OILS AND THEIR ATMOSPHERIC OXIDATION IN NATURE, THE LABORATORY, AND THE FACTORY—THE CHEMISTRY OF THE PROCESS.

IF we seek to establish the precise way in which the eucalyptus, the pine, and the camphor tree exhibit a hygienic influence, we are forced by exclusion of other reasons to consider it mainly in relation to the essential oils naturally formed in these trees, and to the emanation of which, in a vaporous condition, they owe their grateful fragrance. We may pass lightly over the drainage power of the trees, because, although this is a valuable feature of them, it is one which does not immediately concern us; moreover, it is common to all trees, although particularly exhibited in those which, like the *Eucalyptus globulus*, grow so rapidly. Any sanitary effect due to mere drainage of water from the soil is of a purely negative character; whereas the hygienic influences of these trees are of a positive character. They are healthful in themselves, and the emanations which they diffuse into the atmosphere are specifically efficacious both as regards protection from the malarial poison and its destruction, as also for the cure of lung diseases. What, then, is the nature of this influence? is the question that must now be solved.

It was for a long time erroneously supposed that the oils, to which plants and flowers owe their perfume, when exposed to the action of atmospheric oxygen, influence it in such a way that ozone is produced; and hence it is stated, in most of the older treatises on chemistry, as a fact, that ozone is produced. It was beyond dispute that an active agent resembling ozone in its properties is formed in this way; but the actual nature of this agent was (until established by my researches) entirely an open question.

There was a great difficulty, however, in strictly diagnosing ozone from peroxide of hydrogen; and as the last-named substance was practically unknown outside the laboratory, whereas ozone was known to occur naturally in the atmosphere, the assumption, which came to be regarded as an established fact, was somewhat excusable.

Schönbein, who was a great chemical authority a generation ago, thought that oil of turpentine gives rise to ozone by contact with air, and by-and-by others taught this as a fact, and thus it passed into the text-books. For instance, it is stated in Gmelin's 'Hand-book,' and in the earlier editions of Miller's 'Elements of Chemistry.' Lawes, Gilbert, and Pugh expressed their belief that the supposed ozone existing in the vicinity of vegetation is due to the oxidation of the hydrocarbons evolved by plants;[*] and in a paper communicated to the Royal Irish Academy on January 9th, 1871, Professor C. R. Tichbourne stated that when light resin oils are exposed to the action of the atmosphere under the influence of light, they produce an abundance of ozone, the boiling point of the oil being raised simultaneously. This last fact may be at once explained: the oil absorbs atmospheric oxygen, giving rise to the formation of oxidised compounds, which boil at a higher temperature than the original hydrocarbons, and peroxide of hydrogen (not ozone) is a characteristic product of the oxidation.

It is not surprising that the difficulties which Schönbein and Berthelot (who also examined the oxidation of oil of turpentine) could not overcome, should also have misled others in more recent times.

Thus, Professor Paolo Mantegazza[†] arrived at the conclusion that a large quantity of ozone is discharged by odoriferous flowers, including those of the narcissus, heliotrope, hyacinth, and mignonette. Similarly, he concluded that among plants, the cherry-laurel, clove, lavender, mint, lemon, and fennel produce ozone as well as the following perfumes: eau-de-cologne, oil of bergamot, extract of millefleurs, essence of lavender, and the oils of nutmegs, aniseed, thyme, peppermint, etc., etc.

In the well-known treatise on 'Inorganic Chemistry,'

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[*] *Journ. Chem. Soc.* (2), 1, 1863, p. 100.

[†] *Rendiconte del Reale Instituto Lombardo*, vol. iii., fasc. vi.

by Eliot and Storer,[*] there occur the following words: 'The disinfecting power of ozone is interesting in connection with the observed facts, that ozone is abundant in the air of pine forests where turpentine abounds, and that pine forests are, as a general rule, remarkably free from malaria.'

At the time when that treatise was written, chemists knew no better regarding the nature of the active principles engendered by the oxidation of turpentine. In 1878, however, and indeed long before, there existed better knowledge of the subject, and hence it is somewhat surprising that the old error should find its way into the generally excellent 'Treatise on Chemistry' by Roscoe and Schorlemmer.[†] They wrote: 'Turpentine and several other essential oils, when acted upon by atmospheric oxygen, transform a portion of it into ozone'—whereas they do nothing of the kind.

So also, Dr. Moffatt[‡] has published a number of papers in which it is stated that he has found the oils of juniper and turpentine, etc., to produce ozone by contact with the air.

H. Fudakowski[§] and E. Schaer,[||] and numerous other chemists, have made the same mistake.

When I commenced my examination on this subject about the summer of 1871, I was not acquainted

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[*] Second Edition, 1868, p. 145. Van Voorst, London.

[†] Published in 1878. Second Edition, p. 200.

[‡] See *Sanitary Record*, October 26th, 1877.

[§] *Deut. Chem. Ges. Ber.*, vi., 106—109.

[||] *Ibid.*, vi., 406—410.

with any of the publications of the late Dr. Day of Geelong; but late in 1875, and when I had arrived at and published my main results, they were brought to my notice. Dr. Day made a large number of interesting observations upon various essential oils and certain fatty matters in connection with which he had noticed the formation of an active agent resembling peroxide of hydrogen in its properties; but the tests which he employed to detect it are equally influenced by ozone; and, moreover, as he seems, in such of his papers as were published before any of mine, to speak of the substance not only as peroxide of hydrogen, but also as antozone (as if this were a distinct substance), his investigations did not materially advance our knowledge of the subject in question. It will be seen that my object was not only to establish the exact nature of the active principles, but the actual method of their formation. In this I was happily successful.

It may, however, be at once admitted that Dr. Day, with great intelligence, applied his knowledge to the explanation of the hygienic influence exerted by the eucalyptus and also by wooden hospitals. While this is readily granted, it must be understood that, after all, his experiments did not satisfactorily settle the vexed question as to whether ozone or peroxide of hydrogen is produced by the oxidation of the essential oils.

Moreover, in common with all others whose names have been mentioned in connection with the study of the hygienic properties of the pine and eucalyptus, Dr. Day totally ignored the formation of those organic compounds which I discovered to accompany peroxide of hydrogen as products of oxidation, and to which the antiseptic powers of these trees is principally due.

With these preliminary observations it will now be of interest to describe my experiments in as simple a manner as the nature of the subject admits. Those scientific readers who wish to acquire a more precise knowledge of the work can do so by consulting the publications* referred to below.

The plants which furnish essential oils in nature are very large in number, and comprise not only the members of the coniferous and aurantiaceous orders, but also the order *myrtaceæ.* It is to the essential oils emitted by these plants at ordinary temperatures, or to products of their atmospheric oxidation, that their intense odour is due.

In the *umbelliferæ* the oil is most abundant in the seeds; in the *aurantiaceæ* both fruits and flowers yield volatile oils; the *rosaceæ* contain oil only in the petals, while the *myrtaceæ* and the *labiatæ* supply it mainly from the leaves.

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* 'On the Oxidation of the Essential Oils.' By C. T. Kingzett.
Part i. *Journ. Chem. Soc.*, Ser. 2, vol. xii., p. 511.
,, ii. *Ibid.*, ,, xiii., p. 210.
,, iii. *Chemical News*, ,, xxxii., p. 138.
,, iv. *Ibid.*, ,, xxxiv., p. 127.
,, v. *Ibid.*, ,, xxxix., p. 279.
,, vi. *Journ. Chem. Soc. Trans.*, 1894.
See also *Pharm. Journ.*, December 2nd, 1876; *Journ. Soc. Arts*, February 16th, 1877, and March 8th, 1878; *Brewers' Guardian*, September 18th, 1877; *Sanitary Record*, December 13th, 1878, and January 15th, 1880; *Journ. Soc. Chem. Industry.*

As is well known, many so-called essential or volatile oils, such as otto of roses, lemon, orange, bergamot, etc., are prepared on a large scale for commercial purposes.

In the following list the figures which are given represent the quantity in parts by weight of essential oil which, in the experience of Messrs. Schimmel,* is yielded by one hundred parts of the raw material mentioned. The botanical names used by Messrs. Schimmel have been retained, although in some cases they differ from those now applied to the respective plants in this country.

Ajowan seed—*Ptychotis Ajowan*—3 per cent.
Almonds, bitter—*Amygdalus amara*—4 to 7 per cent.
Angelica seeds—*Archangelica officinalis*—1·15 per cent.
Angelica root, Thuringian, ditto, 0·75 per cent.
Angelica root, Saxon, ditto, 1 per cent.
Anise seed, Russian—*Pimpinella anisum*—2·8 per cent.
Anise seed, Thuringian, ditto, 2·4 per cent.
Anise seed, Moravian, ditto, 2·6 per cent.
Anise seed, Chili, ditto, 2·4 per cent.
Anise seed, Spanish, ditto, 3 per cent.
Anise seed, Levantine, ditto, 1·3 per cent.
Arnica flowers—*Arnica montana*—0·04 per cent.
Arnica root, ditto, 1·1 per cent.
Asafœtida—*Ferula asafœtida*—3·25 per cent.
Asarum root—*Asarum Europæum*—1·1 per cent.
Basilicum herb, fresh—*Ocymum Basilicum*—0·04 per cent.
Bayberry leaves—*Pimenta acris*—2·3 to 2·6 per cent.
Bearberry—*Arctostaphylos Uva Ursi*—0·01 per cent.
Betel leaves—*Piper Betle*—0·55 per cent.
Birch tar—*Betula alba*—20 per cent.

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* Abstracted from a Report (? 1888) of Messrs. Schimmel & Co. of Leipzig.

Buchu leaves—*Barosma crenulata*—2·6 per cent.
Calamus root—*Acorus Calamus*—2·8 per cent.
Canella—*Canella alba*—1 per cent.
Caraway seed, cult. German—*Carum Carvi*—4 per cent.
Caraway seed, cult. Dutch, ditto, 5·5 per cent.
Caraway seed, cult. East Prussian, ditto, 5 per cent.
Caraway seed, cult. Moravian, ditto, 5 per cent.
Caraway seed, wild German, ditto, 6 to 7 per cent.
Caraway seed, wild Norwegian, ditto, 6 to 6·5 per cent.
Caraway seed, wild Russian, ditto, 3 per cent.
Cardamoms, Ceylon—*Elettaria cardamomum*—4 to 6 per cent.
Cardamoms, Madras, ditto, 5 per cent.
Cardamoms, Malabar, ditto, 4·25 per cent.
Cardamoms, Siam, ditto, 4·3 per cent.
Carrot seed—*Daucus carota*—1·65 per cent.
Cascarilla bark—*Croton Eleuteria*—1·75 per cent.
Cassia flowers—*Cinnamomum Cassia*—1·35 per cent.
Cassia lignea, ditto, 1·5 per cent.
Cedar wood—*Juniperum Virginianum*—3·5 per cent.
Celery herb—*Apium graveolens*—0·2 per cent.
Celery seed, ditto, 3 per cent.
Celtic nard root—*Valeriana celtica*—1 per cent.
Chamomiles, German—*Matricaria Chammomilla*—0·285 per cent.
Chamomiles, Roman—*Anthemis nobilis*—0·7 to 1 per cent.
Chekan leaves—*Myrtus Chekan*—1 per cent.
Cinnamon, Ceylon—*Cinnamon zeylanicum*—0·9 to 1·25 per cent.
Cloves, Amboyna—*Caryophyllus aromaticus*—19 per cent.
Cloves, Bourbon, ditto, 18 per cent.
Cloves, Zanzibar, ditto, 17·5 per cent.
Clove root—*Geum urbanum*—0·04 per cent.
Clove stalks, ditto, 6 per cent.
Copaiba balsam, Para—*Copaifera officinalis*—45 per cent.
Copaiba balsam, E.I.—*Dipterocarpus turbinatus*—65 per cent.
Coriander seed, Thuringian—*Coriandrum sativum*—0·8 per cent.
Coriander seed, Russian, ditto, 0·9 per cent.
Coriander seed, Dutch, ditto, 0·6 per cent.
Coriander seed, East Indian, ditto, 0·15 per cent.
Coriander seed, Italian, ditto, 0·7 per cent.
Coriander seed, Mogador, ditto, 0·6 per cent.
Cubebs—*Piper Cubeba*—12 to 16 per cent.

Culilawan bark—*Laurus Culi awan*—3·4 per cent.
Cumin seed, Mogador—*Cuminum Cyminum*—3 per cent.
Cumin seed, Maltese, ditto, 3·9 per cent.
Cumin seed, Syrian, ditto, 4·2 per cent.
Cumin seed, East Indian, ditto, 2·25 per cent.
Curcuma root—*Curcuma longa*—5·2 per cent.
Dill seed, German—*Anethum graveolens*—3·8 per cent.
Dill seed, Russian, ditto, 4 per cent.
Dill seed, East Indian—*Anethum Sowa*—2 per cent.
Elder flowers—*Sambucus nigra*—0·025 per cent.
Elecampane root—*Inula Helenium*—0·6 per cent.
Elemi resin—*Icica Abilo*—17 per cent.
Eucalyptus leaves, dried—*Eucalyptus globulus*—3 per cent.
Fennel seed, Saxon—*Anethum Fœniculum*—5 to 5·6 per cent.
Fennel seed, Galician, ditto, 6 per cent.
Fennel seed, East Indian—*Fœniculum Panmorium*—2·2 per cent.
Galanga root—*Alpinia Galanga*—0·75 per cent.
Galbanum resin—*Galbanum officinale*—6·5 per cent.
Ginger, African—*Zingiber officinalis*—2·6 per cent.
Ginger, Bengal, ditto, 2 per cent.
Ginger, Japanese, ditto, 1·8 per cent.
Ginger, Cochin China, ditto, 1·9 per cent.
Heracleum seeds—*Heracleum Sphondylium*—1 per cent.
Hop flowers—*Humulus lupulus*—0·7 per cent.
Hyssop herb—*Hyssopa officinalis*—0·4 per cent.
Iris root—*Iris Florentina*—0·2 per cent.
Iva herb—*Iva moschata*—0·4 per cent.
Juniper berries, German—*Juniper communis*—0·5 to 0·7 per cent.
Juniper berries, Hungarian, ditto, 1 to 1·1 per cent.
Juniper berries, Italian, ditto, 1·1 to 1·2 per cent.
Laurel berries—*Laurus nobilis*—1 per cent.
Laurel berries, California—*Oreodaphne Californica*—7·6 per cent.
Laurel leaves, ditto, 2·4 per cent.
Lavender flowers, German—*Lavandula vera*—2·9 per cent.
Ledum—*Ledum palustre*—0·35 per cent.
Lignaloe wood—*Elaphrium graveolens*—5 per cent.
Lovage root—*Levisticum officinale*—0·6 per cent.
Lupulin—*Humulus lupulus*—2·25 per cent.
Mace—*Myristica moschata*—11 to 16 per cent.
Marjoram herb, fresh—*Origan. Majorana*—0·35 per cent.

Marjoram herb, dried, ditto, 0·9 per cent.
Masterwort—*Imperatoria Ostruthium*—0·8 per cent.
Matico leaves—*Piper angustifolium*—2·4 per cent.
Matricaria herb—*Matricaria Parthenium*—0·03 per cent.
Melissa herb—*Melissa officinalis*—0·1 per cent.
Michelia bark—*Michelia Nilagirica*—0·3 per cent.
Milfoil herb—*Achillea Millefolium*—0·8 per cent.
Musk seed—*Hibiscus Abelmoschus*—0·2 per cent.
Mustard seed, Dutch—*Sinapis nigra*—0·85 per cent.
Mustard seed, East Indian, ditto, 0·59 per cent.
Mustard seed, German, ditto, 0·75 per cent.
Mustard seed, Russian—*Sinapis juncea*—0·5 per cent.
Myrrh—*Balsamodendron myrrha*—2·5 to 6·5 per cent.
Nigella seeds—*Nigella sativa*—0·3 per cent.
Nutmegs—*Myristica moschata*—8 to 10 per cent.
Olibanum resin—*Olibanus thurifera*—6·3 per cent.
Opoponax resin—*Pastinaca Opoponax*—6·5 per cent.
Parsley herb—*Apium Petroselinum*—0·43 per cent.
Parsley seed, ditto, 3 per cent.
Parsnip seed—*Pastinaca sativa*—2·4 per cent.
Patchouli herb—*Pogostemon Patchouli*—1·5 to 4 per cent.
Peach kernels—*Amygdalus Persica*—0·8 to 1 per cent.
Pepper, black—*Piper nigrum*—2·2 per cent.
Peppermint, fresh—*Mentha piperita*—0·3 per cent.
Peppermint, dried, ditto, 1 to 1·25 per cent.
Peru balsam—*Myroxylon Perieræ*—0·4 per cent.
Pestwort—*Tussilago Petasites*—0·056 per cent.
Pimento—*Myrtus Pimenta*—3·5 per cent.
Pimpinella root—*Pimpinella saxifraga*—0·025 per cent.
Poplar buds—*Populus nigra*—0·5 per cent.
Rhodium—*Convolvulus scoparia*—0·04 per cent.
Rose flowers, fresh—*Rosa centifolia*—0·05 per cent.
Rue herb—*Ruta graveolens*—0·18 per cent.
Sage herb, German—*Salvia officinalis*—1·4 per cent.
Sage herb, Italian, ditto, 1·7 per cent.
Sandal wood, East Indian—*Santalum album*—45 per cent.
Sandal wood, Macassar, ditto, 2·5 per cent.
Sandal wood, West Indian—*Unknown*—2·7 per cent.
Sassafras wood—*Laurus sassafras*—2·6 per cent.
Savin herb—*Juniperus sabina*—3·75 per cent.

Snake root, Canadian—*Asarum Canadense*—2·8 to 3·25 per cent.
Snake root, Virginian—*Aristolochia serpentaria*—2 per cent.
Southernwood herb—*Artemisia abrotanum*—0·04 per cent.
Southernwood root, ditto, 0·1 per cent.
Spearmint—*Mentha crispa*—1 per cent.
Star anise, Chinese—*Illicium anisatum*—5 per cent.
Star anis, Japanese—*Illicium religiosum*—1 per cent.
Storax—*Liquidambar orientalis*—1 per cent.
Sumbul root—*Ferula Sumbul*—0·3 per cent.
Tansy herb—*Tanacetum vulgare*—0·15 per cent.
Thyme, wild—*Thymus serpyllum*—0·2 per cent.
Valerian root, German—*Valeriana officinalis*—0·95 per cent.
Valerian root, Dutch, ditto, 1 per cent.
Valerian root, Japanese—*Patrinia scabiosfolæia.*
Vetiver root—*Andropogon muricatus*—0·2 to 3·5 per cent.
Water fennel seed—*Phyllandrium aquatica*—1·3 per cent.
Wormseed—*Artemisia maritima*—2 per cent.
Wormwood herb—*Artemisia absinthium*—0·3 to 0·4 per cent.
Zedoary root—*Curcuma zedoaria*—1·3 per cent.

The essential oils mainly consist of hydrocarbons —that is to say, substances exclusively composed of carbon and hydrogen—but many of them contain, also, oxidised bodies which, at least in numerous instances, are formed from the hydrocarbons by the action of atmospheric oxygen and moisture. No doubt, many of the gums and resins which occur in nature are intimately related to the essential oils, and are probably, in some cases, derived directly from them.

Ordinary oil of turpentine, representing the hydrocarbon part of the essential oils of different kinds of pine-tree (*Pinus maritima, Pinus australis, Pinus Tæda,* etc.) when analysed, is found to contain 88·23 per cent. of carbon, and 11·76 per cent. of hydrogen; and these figures lead to the chemical formula $C_{10}H_{16}$ as representing the constitution of turpentine. The mere analysis alone is not sufficient to fix this as the true formula: it might be $C_5H_8$, or $C_{15}H_{24}$, or $C_{20}H_{32}$, all of which substances would give the same percentage composition. There are, however, other considerations, of which we shall say more presently, which fix the true formula of oil of turpentine hydrocarbons as $C_{10}H_{16}$. These are called 'terpenes,' in order to diagnose them from other substances which accompany them in the crude oils.

Similarly, other terpenes, or hydrocarbons of the same empirical formula, have been obtained from the oils of lemon, sweet orange, eucalyptus, camphor, bergamot, lime, neroli, coriander, juniper, caraway, camomile, hop, parsley, wintergreen, thyme, valerian, copaiba, cubebs, birch, elemi, etc.

There are other essential oils which, while they do not yield true terpenes, are yet intimately related to these substances. For instance, oil of cloves yields the hydrocarbon $C_{15}H_{24}$, oil of peppermint $C_{10}H_{18}$, and oil of roses $C_{10}H_{20}$.

Although the true terpenes are identical in composition, and are represented by the same formula, they yet comprise a certain number of distinct hydrocarbons; distinct, that is to say, in the sense that all their properties are not uniform, while some of them are shared in common. The explanation of this fact is to be found in differences in the way in which the constituent atoms of the different terpene-molecules are arranged. Such facts are not at all uncommon, and are well understood in chemistry. For instance, carbon exists in the form of the diamond and as coke; oxygen exists also in the state of ozone; and other substances are capable of assuming various natural forms, although identical in mere matter.

A special property of all the terpenes consists in the avidity with which they absorb oxygen, either from that gas in the pure state, or from ozone, or from the atmosphere. In illustration of this fact, there are here reproduced two tables from my papers published at different times. The oils in question were placed along with known quantities of air or oxygen contained in tubes sealed at one end, and after exposure under various circumstances for given periods, the amount of oxygen absorbed was measured by ascertaining the remaining amounts. The results do not indicate the total amounts of oxygen absorbable by the various oils forming the subject of experiment, but merely the comparative amounts absorbed during the period of observation.

| Name of Oil. | Cubic centimetres of oxygen absorbed. | In No. of days. | = Daily. |
|---|---|---|---|
| Turpentine— | | | |
| (*a*) in sunshine . | 220 from oxygen gas | 6 | 36·6 |
| (*b*) in shade . . | 20 ,, ,, ,, | 36 | 0·6 |
| Caraway . . . . | 18 ,, ,, ,, | 6 | 3·0 |
| Bergamot . . . | 12 ,, ,, ,, | 4 | 3·0 |
| Juniper . . . . | 5 ,, ,, ,, | 2 | 2·5 |
| Cubebs . . . . | 4 ,, ,, ,, | 2 | 2·0 |
| Lemon . . . . | 16 ,, ,, ,, | 13 | 1·2 |
| Naphtha . . . . | 25 ,, ,, ,, | 33 | 0·7 |
| Camomile . . . | 6 ,, ,, ,, | 11 | 0·55 |
| Turpentine (in shade) . . . . | 10 ,, air . . . | 14 | 0·75 |

The experiments recorded in the next table were conducted by charging a number of very long sealed tubes with equal volumes of air, oil, and water, and exposing them to summer sunlight for a few hours, and not sufficiently long for the whole of the atmospheric oxygen to be absorbed in any single instance. The residual, unabsorbed gas was afterwards measured in the laboratory. Calling the largest amount of oxygen absorbed 100, then :

| | |
|---|---|
| 1. Russian oil of turpentine absorbed | 100 |
| 2. Swedish ,, ,, | 100 |
| 3. Some turpentine which was obtained in Geneva absorbed | 89·4 |
| 4. American oil of turpentine absorbed | 78·9 |
| 5. Oil of eucalyptus absorbed | 75·0 |
| 6. An evidently adulterated Swedish turpentine absorbed | 52·6 |
| 7. 'Scotch-distilled American turpentine' absorbed | 42·1 |

The oils numbered 1, 2, 4 and 5 were undoubtedly genuine commercial oils ; the oil 3 was, perhaps, French oil of turpentine, and in this case only was the sample rectified by distillation before making the experiment, since it had undergone great oxidation by keeping for many years. The oils 6 and 7 had been sent as samples, and were evidently not genuine ; probably both had been largely adulterated with so-called pine-oil of commerce or with resin-spirit.

The absorption of oxygen (even from the atmosphere) by essential oils and their true chemical terpenes, takes place at the ordinary temperature, although, of course, it happens more slowly at a low than at an elevated one ; more slowly, therefore, in winter than in summer ; more slowly in shade than in direct sunlight; more slowly in the dark than in diffused daylight; but in all cases, even if pure oxygen or ozone be used instead of air, the products are identical.

Now, if the pure hydrocarbons obtained from essential oils be placed in contact with a mixed solution of iodide of potassium and starch, they will not colour this test mixture* at once, but only after standing some time exposed to the air. On the other hand, if the experiment be made with those hydrocarbons which have been previously allowed to absorb oxygen from the air, a coloration is produced at once. The potassic iodide is decomposed; iodine is set free, and this combining with starch, forms a blue compound, causing the coloration in question. Similarly, if the essential oils be exposed to the air in shallow vessels covered loosely with bibulous paper soaked in the same test mixture, the coloration of the paper gradually ensues. That is to say, the oils evaporate slowly and combining with atmospheric oxygen, produce the active principle, whatever it may be, which thus comes into contact with the test-paper and influences it. If the evaporation be assisted by placing the vessels upon a warm metallic plate, the reaction is obtained more speedily and is of a more intense character.

If, instead of soaking the paper in the abovenamed mixture, it be moistened with acetate of lead, or sulphate of manganese, no coloration is then

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* This mixture has been stated in a previous chapter to be a test for both peroxide of hydrogen and ozone.

produced; nor are solutions of these respective substances coloured, even when placed in contact with the oils themselves and on free exposure to the air. This fact seems, at once, to indicate that the active agent is not ozone; for if it were, affirmative results should be obtained.

Moreover, Soret proved that oil of turpentine readily absorbs ozone;* it is therefore utterly impossible that a substance which absorbs ozone should also produce it under identical conditions.

After studying the influence of peroxide of manganese, peroxide of lead, and hyposulphite of sodium upon oxidised oils containing the active principle, and having observed that these substances totally destroyed it, a fact of an important nature was experienced.

Quantities of the oils of turpentine and caraway were, severally, oxidised to a considerable extent; they were then washed with water to remove any peroxide of hydrogen,† and finally introduced into vacuous bottles containing mixed potassic iodide and starch, when the blue coloration was at once produced. It having been proved that the active

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* I have since confirmed this statement, and have ascertained that by the action of ozone upon turpentine, a substance is produced which yields peroxide of hydrogen on treatment with water. It is therefore probably identical with the peroxide which results from the atmospheric oxidation of turpentine. (See my paper *Journ. Chem. Soc. Trans.*, 1880, p. 800.)

† It was previously ascertained that any peroxide of hydrogen either contained in or mechanically attached to the oxidised oils is entirely removed by washing them with water.

principle, as directly formed, could not be ozone, and as the method of experiment excluded the possibility of its identity with peroxide of hydrogen, this new fact admitted of one explanation only, which is as follows :

The essential oils absorb oxygen from the air, pure oxygen or ozone, and there is thus produced an additive product of an organic nature, exhibiting properties resembling to some extent those of ozone and peroxide of hydrogen ; in other words, an organic peroxide is produced.

At the same time, it was observed that the active principle of oxidised oil of turpentine is entirely destroyed by heating it in contact with dry chloride of zinc to a temperature of 75° C. ; whereas, in absence of the chloride of zinc, it was not materially affected by being heated to this point. Similarly, other dehydrating and deoxidising substances were found to destroy the active agent.

Having got so far, steps were next taken to more particularly ascertain the precise conditions upon which the formation of the active substance depends, and it was found to be produced whenever oil of turpentine (for example) is placed in contact with air only ; that is to say, it was ascertained that the presence of water is not essential. It was noticed, however, at an early stage of the research, that the production of the active substance was much facilitated by carrying on the oxidation of the oil (by means of a current of air) *in the presence* of water, at a slightly elevated temperature; and in order to obtain further information, great quantities of turpentine were oxidised in this way. It at first appeared strange to find that the water standing underneath the turpentine after these experiments, contained, beyond question, peroxide of hydrogen. It was found possible to concentrate the solution by carefully-conducted evaporation. With the potassic iodide and starch mixture it gave the blue coloration; with chromic and sulphuric acids it also gave the characteristic reaction wherein the violet perchromic acid is first produced, and subsequently decomposed with evolution of oxygen; while it evolved oxygen gas when treated with an acid solution of permanganate of potassium. In brief, there was obtained an aqueous solution containing so much peroxide of hydrogen, as to be capable, when decomposed, of evolving twice its own volume of oxygen gas.

It was thus proved that during the oxidation of oil of turpentine neither ozone nor peroxide of hydrogen is directly produced, but that the active substance which is first formed, yields peroxide of hydrogen as a secondary product when treated with water. So that if the oxidation takes place originally in the presence of water, peroxide of hydrogen is obtained in the aqueous solution.

All these observations accorded with the conclusion that the oxidised compound first produced is an organic peroxide; and as Brodie had described a method for the production of camphoric peroxide, it seemed that my product might be this same substance.* In any case, it may be supposed to be decomposed by contact with water by some such reaction as is here represented :

Camphoric peroxide + water = soluble camphor + peroxide of hydrogen.

$$C_{10}H_{16}O_4 + H_2O = C_{10}H_{16}O_3 + H_2O_2$$

Assuming the last given reaction to be correct, my camphoric peroxide may be regarded as a hydrated and oxidised product of the composition $C_{10}H_{16}O_3H_2O$.

This idea receives support from the fact that I found soluble camphor (the substance $C_{10}H_{16}O_3$) in the aqueous solution accompanying the peroxide of hydrogen. But whether my camphoric peroxide has or has not the composition as here represented, it is, at any rate, slowly decomposed by contact with

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* More recently (*Journ. Chem. Soc. Trans.*, 1884, pp. 93—99) I have repeated the experiments made by the late Sir Benjamin Brodie, and have shown that camphoric peroxide, or rather a compound of it with barium, is not produced by acting with peroxide of barium upon camphoric anhydride. He represented the reaction by the equation :

$$C_{10}H_{14}O_3 + BaO_2 = C_{10}H_{14}BaO_5\,;$$

whereas I have shown that the reactions which really take place are as follows :

$$C_{10}H_{14}O_3 + H_2O = C_{10}H_{16}O_4$$
$$C_{10}H_{16}O_4 + BaO_2 = C_{10}H_{14}BaO_4 + H_2O_2.$$

That is to say, the camphoric anhydride is first resolved by contact with water into camphoric acid, and this, by reaction upon the peroxide of barium, yields camphorate of barium and peroxide of hydrogen.

This investigation, however, leaves the existence of my peroxide, obtained by the air oxidation of terpenes, where it was, and I retain the name of camphoric peroxide.—AUTHOR.

water, and the aqueous solution is found to contain peroxide of hydrogen, soluble camphor ($C_{10}H_{16}O_3$), and a substance resembling thymol ($C_{10}H_{14}O$).

The great proof that peroxide of hydrogen only results as a product of secondary decomposition, is afforded by the observation that when the oil is oxidised in the absence of water, and afterwards agitated with large volumes of water, it still retains its active properties, and yields more peroxide of hydrogen on further standing with water. The oxidised oil may even be dissolved in alcohol and poured into water, and yet, after separation, it will retain some undecomposed camphoric peroxide. This may be well shown by mixing it with potassic iodide and starch (in the presence of a suitable acid), and estimating the iodine thus set free by means of a standard solution of hyposulphite of sodium. If the oxidised oil contained peroxide of hydrogen in mere admixture, this latter substance would be entirely removed by simply shaking with water: that, however, does not occur.

If the oxidised oil be subjected to fractional distillation it yields, among other products, two oily bodies, one having a camphoraceous odour (possibly Sobrerone), $C_{10}H_{16}O$, and another of the composition $C_{10}H_{16}O_2$. Water is at the same time formed.

The substance left in the retort has the composition $C_{10}H_{14}O_2$, and in properties resembles resin. Probably it is derived from the decomposition of camphoric peroxide, and, as a matter of fact, upon hydration it yields a substance having the composition $C_{10}H_{16}O_3$, and which is, perhaps, identical with the soluble camphor above described.

Oxidised American turpentine gradually deposits a remarkable white amorphous body ($C_{20}H_{28}O_3$), which is soluble only in chloroform and carbon disulphide, but this substance is not formed from oxidised Russian turpentine.

When the strongly oxidised oil of turpentine is placed in a retort and heated to 160° C. (the boiling-point of pure turpentine), the temperature, after some time, suddenly rises spontaneously, and violent decomposition ensues.

Being desirous of establishing some kind of relation between the terpenes of turpentine and the other essential oils, as also to obtain some further explanation of the facts which had been discovered, the later method of experiment—viz., oxidation in presence of water by a current of air—was extended to various different substances. Those examined at that time were :

Cymene, $C_{10}H_{14}$ (from several different sources).
Hesperidene, $C_{10}H_{16}$ (the terpene of oil of orange-peel).
Myristicene, $C_{10}H_{16}$ ( ,, ,, ,, nutmeg).
Menthene, $C_{10}H_{18}$ (from solid Japanese camphor).
Oil of wormwood (containing, according to Wright, much $C_{10}H_{16}O$, and a little terpene, $C_{10}H_{16}$).
Oil of citronella (containing much $C_{10}H_{16}O$, and *no terpene*).
Yhlang Yhlang (containing no terpene).
Hydrocarbon from oil of cloves, being $C_{15}H_{24}$, as shown by Church.
Patchouli (containing no terpene).

The cymene (from every source) yielded peroxide of hydrogen in the aqueous solution, as did also all the terpenes as well as those oils which contained even the smallest quantity of terpene ; menthene ($C_{10}H_{18}$) behaved similarly. On the other hand, the hydrocarbon from oil of cloves ($C_{15}H_{24}$), and those oils which contained no terpene, gave no trace of peroxide of hydrogen.

From these and other experiments which need not be referred to in this place, two inferences may be made :

1. That all essential oils (of which ordinary turpentine is illustrative) which contain a hydrocarbon represented by the formula $C_{10}H_{16}$, as also all pure terpenes, give peroxide of hydrogen when their oxidised products are treated with water.

2. That the production of peroxide of hydrogen in this way is related to cymene, for both Oppenheim and Wright have proved that cymene may be obtained from all the true terpenes ($C_{10}H_{16}$),* and it has been shown that cymene gives peroxide of hydrogen, while menthene gives both cymene and peroxide of hydrogen.

These conclusions were subsequently confirmed by the observation made by Wright, that the $C_{15}H_{24}$ hydrocarbon from oil of cloves, which does not yield peroxide of hydrogen, fails to yield cymene when subjected to the process by which all true terpenes ($C_{10}H_{16}$) yield it.

Another confirmation was afforded by the experiments of Mr. M. M. Pattison Muir, who found†

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* Dr. Tilden has also shown that all terpenes yield the Nitroso derivative $C_{10}H_{15}(NO)$.

† *Year Book of Pharmacy*, 1876, p. 561 ; 1877, p. 498.

that oil of sage absorbs oxygen and produces peroxide of hydrogen. He afterwards showed that the oil contained a quantity of a terpene ($C_{10}H_{16}$).

Whatever worth, then, the above-stated hypothesis may have, the fact is established beyond doubt, that all oils which contain either cymene or terpene (such as oil of eucalyptus, ordinary turpentine, and camphor oil) give rise to the production of peroxide of hydrogen, when subjected to the process described in the foregoing pages.

To revert once more to the atmospheric oxidation of oil of turpentine. There are various kinds of this oil known to commerce, differing according to the species of tree from which they are obtained, and probably (to some extent) upon the climatic and geological conditions of the localities in which the trees are grown. Moreover, all turpentines are not alike in their power of absorbing oxygen, some absorbing it much more freely than others.

It was observed, in certain cases, that an oil of turpentine which absorbs oxygen from the air at any given rate, will absorb it much less rapidly if freed from accompanying oxidised substances, by distillation. In other words, when once the process of oxidation has begun, it continues more and increasingly rapidly, so that the greater the amount of oxidised matter contained in the oil, the greater the oxidation under given conditions.

From these facts it may be inferred that in nature, the process of oxidation which occurs in the immediate neighbourhood of the trees, takes places, in all probability, much more rapidly than in the laboratory; since, as produced in the trees, the oil is accompanied with the products of oxidation, to which reference has been made.

It is indeed remarkable that turpentine, in the act of being oxidised, is capable of imparting to fresh turpentine the same and equal facility to absorb oxygen. The comparatively slow rate at which the atmospheric oxidation of fresh turpentine proceeds, and the greater rate attained after the molecules have undergone that change which induces a rapid oxidation, is seen by the following figures, which relate to an experiment conducted some years ago upon about thirty gallons of turpentine in the presence of water :

| | | | | | |
|---|---|---|---|---|---|
| After 37 | hours' exposure to a current of air each 100 cc. of the aqueous solution contained | | - | 0·0551 | grms. $H_2O_2$. |
| ,, 41 | ,, | ,, | ,, | 0·2000 | ,, |
| ,, 54 | ,, | ,, | ,, | 0·3000 | ,, |
| ,, 58 | ,, | ,, | ,, | 0·4500 | ,, |

As the oxidation of the oil goes on, its density gradually increases by the absorption of oxygen. This fact is illustrated by the following figures :

In one experiment the original density of the oil of turpentine used was 0·864.

| | | | | |
|---|---|---|---|---|
| After 24 | hours' | oxidation | it was - - - | 0·880 |
| ,, 28 | ,, | ,, | ,, - - - | 0·881 |
| ,, 32 | ,, | ,, | ,, - - - | 0·888 |
| ,, 41 | ,, | ,, | ,, - - | 0·949 |

In another experiment—

After 16 hours' oxidation it was - - - 0·8886
,, 20 ,, ,, ,, - - - 0·8996
,, 26 ,, ,, ,, - - - 0·9060
,, 39 ,, ,, ,, - - - 0·9136
,, 46 ,, ,, ,, - - - 0·9366
,, 48 ,, ,, ,, - - - 0·9476
,, 300 ,, ,, ,, - - - 1·2350

It thickens as it increases in density, and acquires a powerful odour, reminding of camphor and peppermint at once.

With the increase in the density of the oxidised oil, its boiling-point also rises, as was shown by the experiment now to be described. The turpentine used in the experiment boiled as in column (1) :

| (1) Original Oil. | | (2) After 24 hours' oxidation. | (3) After 27 hours' oxidation. |
|---|---|---|---|
| 10 per cent. distilled over at | 157° C. | 162° C. | 165° C. |
| 20 ,, ,, ,, | 159 | 165·5 | 166 |
| 30 ,, ,, ,, | 160 | 168 | 170 |
| 40 ,, ,, ,, | 160 | 171 | 171 |
| 50 ,, ,, ,, | 160·5 | 174 | 174 |
| 60 ,, ,, ,, | 161 | 181 | 185 |
| 70 ,, ,, ,, | 162 | 193 | 206 |
| 80 ,, ,, ,, | 164 | 210 | — |
| 90 ,, ,, ,, | 166 | — | — |

The results here tabulated were arrived at by taking 100 cc. of each product, and subjecting to careful distillation, care being taken to record the temperature after the collection of every 10 cc. distillate.

It has been stated above that soluble camphor and a body resembling thymol accompany the peroxide of hydrogen in the aqueous solution which is obtained by atmospherically oxidising turpentine in presence of water. This solution gives all the reactions characteristic of thymol. When evaporated to dryness on the water-bath, all the thymol-like substance is dissipated in the vapour and the peroxide of hydrogen is, of course, entirely decomposed; there remains in the dish a dark-coloured matter, which, when hot, is soft and viscid, and smells like melted sugar. On cooling, it sets into a hard, adhesive mass, bitter to the taste, and possessing remarkable antiseptic properties, of which more anon. This substance constitutes the so-called soluble camphor.

In recapitulation of the foregoing details, it may be stated that, when turpentine is exposed to the action of air it absorbs oxygen, and gives rise to the production of a peculiar organic peroxide which remains dissolved in the body of the oil, and communicates thereto properties resembling those of ozone and peroxide of hydrogen. Inasmuch as the oil is volatile, these properties are communicated also to the surrounding atmosphere. If the oxidised oil be treated with water, or what amounts to the same thing, if the oxidation of the oil be conducted in the presence of water, then, upon examination, the aqueous solution is found to contain peroxide of hydrogen, and it is accompanied by a substance resembling thymol ($C_{10}H_{14}O$) and the other substance named soluble camphor ($C_{10}H_{16}O_3$).

The same products are obtained by the atmospheric oxidation of oil of eucalyptus, camphor oil, and every other essential oil which contains either cymene ($C_{10}H_{14}$), or a terpene (that is, a hydrocarbon of the formula $C_{10}H_{16}$).

It will be observed that my process of atmospheric oxidation of essential oils is an exact imitation of the one which necessarily occurs in nature in connection with every plant that secretes these so-called oils, and which is, of course, attended with the same results. So far, therefore, as the properties of pine, camphor, and eucalyptus forests may be connected with the special presence of peroxide of hydrogen, these are now well explained. In the next chapter, experiments will be described to show that all the different products are powerful antiseptics or disinfectants, and thus we shall finally be enabled to apply the derived knowledge in explanation of some important processes of Nature's Hygiene, which have been described in an earlier place.

Before proceeding to these fresh studies, it will be convenient to so far anticipate the contents of the next chapter, as to assume that the products of the atmospheric oxidation of turpentine possess sanitary properties valuable enough in themselves to make it desirable that they should be commercially available.

The practical conduct of this manufacture may now be briefly described. A number of specially made Doulton-ware receivers or other vessels lined with pure metallic tin, are charged with water and essential oil in the proportions found to be best by experience, and the contents are maintained at a temperature of about 140° F. by placing the receivers in vats of water heated by steam. Under these conditions a current of air is pumped through each oxidiser during a prolonged period varying in practice from 70 to 300 hours. Under these circumstances the air current carries with it, when leaving the oxidisers, a large quantity of turpentine (or whatever other essential oil may be in course of oxidation), in the state of vapour, and this is condensed by passing it into and out of various compartments of cold water, or up and down coke-scrubbers. The turpentine collects on the various surfaces of the cold water, or in the cisterns at the bottom of the coke-scrubbers, and from time to time it is drawn off and restored to the oxidisers. The chemical reactions which occur in these vessels have been already described in the preceding pages, so that here it is only necessary to recapitulate the main particulars. The turpentine absorbs the oxygen from the air which is forced through it, and it is thereby oxidised, giving rise in the first place to the production of camphoric peroxide; then by secondary reactions, the various other substances characteristic of the aqueous product are formed. These secondary products at once dissolve in the water which is below the turpentine in the receivers. At first these changes proceed slowly, but they proceed with increasing rapidity from the first moment, the oil of turpentine growing yellowish red and thicker as the operation goes on. It will be seen from this statement that the strength of the aqueous solution which forms underneath the turpentine depends to some extent upon the time during which the process of air-oxidation is carried on. At the start we have only water and turpentine in contact; but as the turpentine becomes oxidised, it yields to the water those substances which are produced by the secondary reaction of the water upon the oxidised oil.

The successful conduct of this process is not unattended with difficulty. It must be remembered that one of the ultimate products of the process is peroxide of hydrogen. This begins to form from the first moment, and continues to be produced during the whole time; but it is so readily decomposed again that, unless a number of precautions and conditions are carefully observed and maintained, there is a liability of obtaining a product devoid of peroxide of hydrogen. Thus, if the temperature in the vats be allowed to rise too high, or if an insufficient depth of turpentine be kept in the oxidisers, there is a danger of decomposing the whole of the peroxide of hydrogen existing at the time of the neglect. On the other hand, if the temperature be too low, it is produced very slowly.

In fact, the producer seeks to effect the greatest possible atmospheric oxidation of turpentine in the least given time, obtaining thereby the oxidised oil, and the aqueous solution containing as much dissolved camphoraceous principles as possible, together with the maximum quantity of peroxide of hydrogen. This is done because, as will be explained hereafter, the oxidising powers of the aqueous solution are due to the presence of the peroxide of hydrogen, while the strictly antiseptic characters are mainly traceable to the camphoraceous ingredients, notable amongst these being the soluble camphor and thymol. This product, termed 'Sanitas' fluid, is now very largely used as a general disinfectant and as an antiseptic in the practice of modern surgery. It is colourless, non-poisonous, and does not stain linen.

At the termination of the manufacturing operation here so briefly traced, there remains in the oxidisers, floating upon the surface of the solution, a quantity of oxidised oil of turpentine containing a large amount of the camphoric peroxide. This oxidised oil, or 'Sanitas' oil, as it is known in commerce, is sold of specific gravity 950 (compared with water 1000 and turpentine 865), and is much more powerful as an antiseptic and disinfectant than the aqueous solution; it is now largely used as an antiseptic dressing and for the preparation of gauze, disinfecting emulsion, powder, soaps, and other articles; also for fumigating sick-rooms, and especially for the specific treatment of lung and throat complaints by inhalation; it is also used for varnish-making, and for bleaching wax and feathers. It is a powerful parasiticide, makes an excellent embrocation for use in rheumatism, and constitutes one of the best agents for the destruction of ringworms.

By its evaporation, an artificial atmosphere is produced, containing all the active principles which are generated in pine and eucalyptus forests, and thus these are made available for the treatment of phthisis, bronchitis, diphtheria, and other complaints without sufferers resorting to foreign lands for that purpose.

In a paper* communicated to the Society of Chemical Industry some years ago by Dr. H. E. Armstrong, F.R.S., attention was directed to the remarkable differences in the optical character of a number of samples of Russian turpentine ; and from the rotatory powers then given in illustration of that fact, he infers that the proportions in which its two chief recognised constituents are present probably vary considerably, and that they are, perhaps, accompanied with other isomeric hydrocarbons.

I have found† that not only do different samples of Russian turpentine present differences in optical character, but that they exhibit, also, equally striking differences in specific gravity and susceptibility to oxidation by air.

For a long time I entertained the hope that a study of the physical properties of different samples, and the chemical history of their oxidation by air, would lead to the discovery of some simple relation between the results, whereby the behaviour of any particular sample upon exposure to oxidation could be inferred beforehand. While, however, I have not been so fortunate in this respect as I had wished, the results seem to be of sufficient interest to warrant record.

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* *Journ. Soc. Chem. Industry*, 1882, p. 479.

† *Ibid.*, January 29th, 1886, No. 1, vol. v.

Parcels of Russian turpentine bought direct from the importer, derived, it is believed, from a common source, and obtained by the same distillation, are by no means uniform in quality ; the contents of each barrel differ, as a rule, in one or more respects, from those of every other barrel. This variability in composition is, doubtless, attributable in the main to the method of distillation which is practised in Russia, but, in part, to the fact that the turpentine is not yielded by a single species of pine. Although the trees which are employed are chiefly the *Pinus sylvestris* and *Pinus ledebourii*, they are not exclusively used ; and as in the method of preparation the wood itself is subjected to distillation, it necessarily follows that at each stage of the process relatively different quantities of the several kinds will be undergoing both distillation and destructive distillation.

There is no evidence that the oils of turpentine which are furnished by the *Pinus ledebourii* and other kinds of tree are identical with that obtained from the *Pinus sylvestris*. Further, there is reason to believe that the turpentine obtained from the different parts of a tree is not absolutely uniform in composition. For instance, Tilden[*] found that a sample of *Oleum foliorum Pini sylvestris* furnished upon fractionation two terpenes, one of which, smelling like ordinary American turpentine, boiled at 156° to 159°, but was more strongly dextro-rotatory

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[*] *Journ. Chem. Soc. Trans.*, 1878, p. 83.

than australene (a column of 100 mm. rotated the plane of polarisation + 18° 48′); whereas the other terpene boiled at 170°, but was lævo-rotatory (per 100 mm. = − 4°), unlike sylvestrene (b. p. 171° to 171·5°), which is dextro-rotatory (100 mm. = + 17°). Tilden concluded, however, that it was sylvestrene, but this does not appear to be proved. Later on, Atterberg* obtained from the oil extracted from the needles of *Pinus pumilio* a hydrocarbon which he also regards as identical with sylvestrene, but which exhibited rotatory power of − 5·38°. The question arises, then, is this terpene, which resembles sylvestrene in its boiling-point only (so far as yet proved), but which differs from it in its optical character, a distinct hydrocarbon?

Again, 'pine-cone oil,' which is obtained by distilling with water the cones of *Abies pectinata*, differs in properties from 'dwarf pine oil,' which is similarly obtained from the young tops and cones of *Pinus pumilio*, while both of these oils are said to be dissimilar to 'pine-leaf oil,' which is yielded by the leaves of *Pinus sylvestris*, or *Pinus abies*.

Russian turpentine undoubtedly contains products of the destructive distillation of both rosin and the wood, including various hydrocarbons (cymene, benzene, toluene, xylene, paraffins, etc.), creosote, and tar and other acids. Atterberg has demonstrated the probable presence of furfurane (tetraphenol) and sylvane

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* *Journ. Chem. Soc. Abstracts*, 1882, p. 410.

($C_4H_3OMe$), a homologue of tetraphenol, in the low boiling portion of the wood oil obtained by the dry distillation of pine wood.*

Considering all these circumstances, it is not matter for surprise that Russian turpentine should, as found in commerce, present such want of uniformity in odour, colour, boiling-point, specific gravity, optical behaviour, and oxidisibility. Indeed, it would appear that the only method of obtaining an absolutely uniform turpentine oil (irrespective of kind) consists in the separative distillation (as distinct from destructive distillation) of one particular part of the trees belonging to a single species.

With reference to what follows, I should explain that it refers to manufacturing operations having for object the production of 'Sanitas' fluid and 'Sanitas' oil, they being respectively the aqueons and oily products obtained by my process of air-oxidising terpenes in the presence of water at a temperature of about 60° C.

The results of the various experiments cannot be compared together, as the relative quantities of turpentine and water which were employed therein were not uniform, and the oxidation of the turpentine was not carried on for the same period in each experiment. In brief, the results attending the oxidation of any one sample of turpentine can only be compared with the results attending the oxida-

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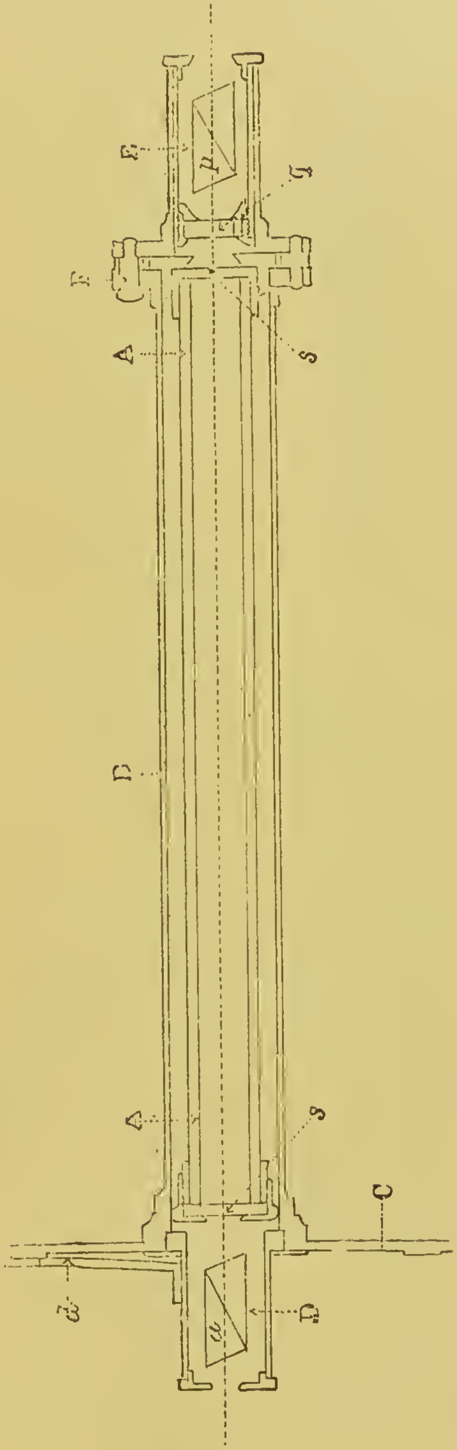
* *Journ. Chem. Soc. Abstracts*, 1880, p. 663.

tion of other samples in the same series. In each series, however, the relative quantities of water and turpentine, the duration of the air-current, and the temperature at which the process was conducted, were as nearly identical as could be arranged upon the scale employed.

The rotatory powers (for columns of 200 mm. of the turpentines used) in the first two series were determined by Dr. H. E. Armstrong, as described in his paper to which reference has been made. In all the other series the reported rotatory values are merely the scale readings obtained upon examining layers of 200 mm. in the 'Portable Saccharimeter' of Carl Zeiss of Jena (supplied by Mr. Baker of London), by turning the rotating eye-piece until both semicircles of the rock-crystal plate acquired as nearly as possible the same reddish-violet colour. I may, however, mention that two samples of American turpentine examined by this instrument gave the same scale reading of 23·5°.

The instrument consists of a glass tube, A, of exactly 200 mm. in length, closed by parallel plates of glass, *s s*, at both ends, which is inserted into a brass tube, B. This brass tube carries a divided circle, C, divided by half-degrees, and upon this circle a shorter tube, D, rotates and contains a Nicol prism, *a* (the analyser). The rotation of D is measured on the divided circle by means of an index-pointer, *d*. The other end of B bears, by means of an eccentric pivot, F, a short tube, E, with another

Nicol prism, *p* (the polariser), and a double plate of rock-crystal, *q*.



The amount of oxygen absorbed by the turpentine in each observation was calculated by multiplying the increase in its specific gravity, by the number of gallons of the product.

The peroxide of hydrogen observed in the aqueous solution does not represent the whole amount obtainable, but only the quantity actually present therein at the time of examination.

The amount of peroxide of hydrogen obtained per lb. of oxygen absorbed by the oil of turpentine, has been calculated in each instance by dividing the grammes $H_2O_2$ by the lbs. of oxygen absorbed.

## SERIES I.

| Rotatory Power, 200 mm. Turpentine used. | Lbs. of Oxygen absorbed by the Turpentine. | Grms. $H_2O_2$ obtained. | Grms. $H_2O_2$ obtained per 1 lb. O. absorbed by Turpentine. |
|---|---|---|---|
| 30·10 | ·96 | 125 | 130 |
| 31·20 | 2·52 | 385 | 154 |
| 32·27 | 1·87 | 255 | 136 |
| 32·27 | 7·50 | 324 | 43 |
| 32·50 | 3·00 | 232 | 77 |
| 34·80 | 3·15 | 264 | 84 |
| 36·18 | 7·75 | 417 | 53 |
| 36·40 | 5·94 | 463 | 78 |
| 37·50 | 5·83 | 630 | 108 |
| 39·44 | 7·15 | 992 | 138 |
| 39·52 | 5·81 | 695 | 120 |
| 39·58 | 3·75 | 477 | 127 |
| 40·42 | 5·04 | 802 | 159 |
| 42·10 | 3·96 | 904 | 228 |
| 44·11 | 3·24 | 422 | 130 |
| 46·45 | 5·83 | 621 | 106 |
| 38·26 (Bulked). | 6·30 | 867 | 137 |
| | 5·28 | 650 | 123 |
| | 5·72 | 686 | 120 |
| | 3·60 | 473 | 131 |
| | 4·80 | 542 | 113 |
| | 3·84 | 394 | 103 |
| | 7·65 | 541 | 71 |
| | 6·75 | 403 | 60 |

I should remark, in respect of this series, that as no accurate record was kept of the quantity of aqueous product, I have been obliged to assume that exactly the same quantity was obtained in all instances. The last eight cases in the series serve to illustrate the difficulty experienced in maintaining as many oxidisers under absolutely identical conditions. Nevertheless, it may be noted that the average quantity of peroxide of hydrogen obtained in these eight cases, where the same bulked turpentine was employed, was 107 grms. per 1 lb. oxygen absorbed by the turpentine, and this figure fairly agrees with the oil of nearest rotatory power in the preceding cases, in each of which turpentine from separate barrels was oxidised.

### SERIES II.

| Rotatory Power (Scale Reading), 200 mm. Turpentine. | Lbs. Oxygen absorbed by Turpentine. | Grms. $H_2O_2$ obtained. | Grms. $H_2O_2$ obtained per 1 lb. Oxygen absorbed by Turpentine. |
|---|---|---|---|
| 31 | 4·93 | 46 | 9 |
| 32 | 4·76 | 128 | 27 |
| 35½ | 11·20 | 675 | 60 |
| 36 | 11·20 | 1131 | 100 |

### SERIES III.

| | | | |
|---|---|---|---|
| 31 | 3·00 | 55 | 18 |
| 38½ | 6·66 | 617 | 92 |
| 39 | 7·00 | 542 | 77 |
| 39½ | 6·50 | 499 | 77 |
| 39½ | 7·35 | 573 | 77 |

### SERIES IV.

| | | | |
|---|---|---|---|
| 30 | 6·80 | 278 | 41 |
| 30½ | 3·36 | 166 | 49 |
| 32 | 3·74 | 129 | 34 |
| 32 | 6·40 | 332 | 52 |
| 32 | 2·88 | 45 | 15 |
| 34 | 4·05 | 219 | 54 |
| 36 | 3·60 | 462 | 128 |
| 37½ | 6·00 | 389 | 65 |
| 38 | 4·80 | 479 | 99 |
| 38 | 4·76 | 336 | 70 |
| 39 | 3·60 | 293 | 81 |
| 41 | 8·05 | 540 | 67 |

### SERIES V.

| | | | |
|---|---|---|---|
| 30 | 4·20 | 324 | 77 |
| 30½ | 3·00 | 263 | 88 |
| 31 | 1·30 | 117 | 90 |
| 31 | 3·00 | 130 | 43 |
| 31 | 10·85 | 701 | 64 |
| 31½ | 9·10 | 631 | 69 |
| 33 | 5·40 | 398 | 74 |
| 33 | 4·95 | 253 | 51 |
| 33½ | 5·75 | 624 | 108 |
| 35 | 3·90 | 239 | 61 |
| 36 | 7·80 | 712 | 91 |
| 36½ | 3·60 | 250 | 69 |

## SERIES VI.

| Rotatory Power (Scale Readings), 200 mm. Turpentine. | Sp. Gr. of Turpentine. | Total Solid Residue left by 100 cc. Turpentine, dry at 100° C. | Lbs. of Oxygen absorbed by Turpentine. | Grms. of $H_2O_2$ obtained. | Grms. $H_2O_2$ per 1 lb. Oxygen absorbed by Turpentine. |
|---|---|---|---|---|---|
| 30 | ·8642 | 1·166 | 4·42 | 681 | 154 |
| 31 | ·8620 | 1·432 | ·78 | 149 | 191 |
| 32½ | ·8722 | 1·330 | 3·84 | 290 | 75 |
| 35 | ·8671 | 1·286 | ·92 | 229 | 246 |
| 35 | ·8703 | 1·750 | — | 161 | — |
| 36 | ·8649 | 1·338 | 2·52 | 320 | 126 |
| 37 | ·8661 | 1·080 | ·93 | 136 | 145 |
| 37½ | ·8696 | 2·370 | 4·46 | 213 | 47 |
| 37½ | ·8706 | 1·300 | 3·74 | 399 | 106 |
| 37½ | ·8721 | 1·372 | — | 146 | — |
| 37½ | ·8670 | 1·370 | — | 267 | — |
| 38 | ·8697 | ·912 | 5·48 | 615 | 112 |
| 38½ | ·8689 | 1·610 | 3·86 | 235 | 61 |
| 38½ | ·8658 | ·738 | 4·80 | 814 | 170 |
| 38½ | ·8633 | ·794 | 1·03 | 375 | 362 |
| 39 | ·8706 | ·920 | 3·60 | 707 | 195 |
| 39 | ·8672 | ·802 | 4·44 | 503 | 113 |
| 39 | ·8632 | ·496 | 1·90 | 272 | 142 |
| 39½ | ·8656 | ·778 | 2·44 | 272 | 111 |
| 39½ | ·8677 | 1·298 | 3·44 | 525 | 152 |
| 40 | ·8698 | 1·400 | 7·24 | 791 | 109 |
| 40 | ·8697 | 1·236 | 5·27 | 984 | 186 |
| 40½ | ·8669 | 1·190 | 5·61 | 534 | 95 |
| 41 | ·8653 | 1·308 | 1·31 | 358 | 272 |
| 44½ | ·8650 | ·990 | 5·40 | 1069 | 198 |

In Series I. to V. the specific gravity of the turpentine was not determined, but was calculated at ·865; in Series VI., however, it was determined by weight in the usual manner, but that of the oxidised oil was still done by the hydrometer.

In Series VII. (see table on following page), the specific gravities of the oxidised oils, as also those of the turpentines employed, were determined by weight. It is seen from these results that Russian turpentine as met with in commerce ranges in specific gravity from ·8620 to ·8722, and that it contains from ·496 to 2·37 per cent. of matter (by weight in volume) which is non-volatile at 100° C.

### SERIES VII.

| Rotatory Power (Scale Readings), 200 mm. Turpentine. | Sp. Gr. of Turpentine. | Lbs. of Oxygen absorbed by the Turpentine. | Grms. of $H_2O_2$ obtained. | Grms. $H_2O_2$ per 1 lb. of Oxygen absorbed by Turpentine. |
|---|---|---|---|---|
| 34½ | ·8646 | — | 66 | — |
| 34½ | ·8662 | — | 612 | — |
| 35½ | ·8683 | 2·010 | 274 | 136 |
| 38½ | ·8666 | — | 562 | — |
| 39 | ·8641 | 1·829 | 311 | 170 |
| 39 | ·8685 | ·465 | 166 | 357 |
| 39 | ·8656 | 3·151 | 591 | 187 |
| 40 | ·8642 | ·232 | 31 | 133 |
| 40 | ·8641 | 2·324 | 427 | 183 |
| 41 | ·8666 | 1·620 | 483 | 298 |
| 41½ | ·8651 | — | 531 | — |
| 41½ | ·8642 | 4·450 | 954 | 214 |
| 44 | ·8660 | 0·588 | 356 | 605 |

It is almost impossible to draw any conclusions regarding the production of peroxide of hydrogen in relation to the rotatory powers of the turpentines examined ; but if it be safe to conclude anything at all, it is that the oils of the higher rotatory values serve best, and that next in order come those of low rotatory value. If this conclusion be drawn, then we must look, not alone to sylvestrene (+ 34° per 200 mm. : Atterberg, confirmed by Tilden) as the source from which the peroxide of hydrogen is obtained, but also to a hydrocarbon of comparatively high rotatory power not identical with the chief constituent of American turpentine (australene), for that substance is not readily oxidisable and is not a prolific source of peroxide of hydrogen.

I, however, hesitate to draw any hard and fast conclusion.

I cannot confirm the statements which have been placed on record regarding the marked physiological effects, including violent headache, induced by Russian turpentine. Such effects have never been observed in the works of the 'Sanitas' Company, Limited, where the air is often loaded with the vapour of Russian turpentine and other essential oils. On the other hand, the atmosphere is balmy, pleasant, and healthful.

In conclusion, I cannot support the claims that have been recently made in respect of the medicinal and sanitary properties of the oil of turpentine furnished by the Pumilio pines, which are grown in the snow. It consists of a mixture of terpenes, having no extraordinary properties or value. Indeed, I contend that in order to carry out a rational pine treatment of lung and throat diseases, recourse must be had, not to raw turpentine of any kind, but to those products of oxidation which are generated therefrom, as I have explained, and of which 'Sanitas' oil (air-oxidised turpentine) is to be regarded as a saturated solution.

## CHAPTER XIV.

### PROPERTIES OF THE INDIVIDUAL AND COLLECTIVE PRODUCTS OF THE OXIDATION OF ESSENTIAL OILS, CONSIDERED AS ANTISEPTICS, DISINFECTANTS, OXIDANTS, AND GERMICIDES.

AS is well known, most of the essential oils—and certainly those of turpentine, eucalyptus, and camphor—possess, even in their raw or natural condition, very decided antiseptic characters. But, since in nature these oils undergo oxidation when volatilised into the atmosphere (containing also aqueous vapour), we must test the properties of the products of oxidation which are thus generated if we would obtain a proper understanding of the sanitary influences of pine, eucalyptus, and camphor trees.

It was from the well-known oxidising effects of peroxide of hydrogen, and its consequent use as a disinfectant, that I was first led to the investigation of this branch of the subject; and during the earlier experiments, it was ascertained that beyond its well-known and valuable powers of oxidation, it also exhibits very peculiar antiseptic properties. This fact was new to science.

The investigation was continued with the view of ascertaining and explaining the antiseptic and disinfecting properties of the aqueous solution ('Sanitas' fluid) and the oxidised oil ('Sanitas' oil), which are obtained by oxidising the oils of turpentine, eucalyptus, or camphor, etc., by air in the presence of water.

The following experiments were communicated to the British Association Meeting of 1876 :

### *Experiments with Peroxide of Hydrogen.*

The solution which was employed was one of what is called '10-volumes strength'; that is to say, it was capable of evolving ten times its own volume of oxygen gas when decomposed in accordance with the following equation :

$$H_2O_2 + H_2O = O.$$

One hundred cubic centimetres of the solution would thus furnish 1,000 cc., or a litre of oxygen gas.

The experiments were conducted during hot summer weather.

10 cc. of the peroxide of hydrogen, added to 400 cc. of fresh milk, preserved it from souring for six days. Oxygen gas was gradually evolved in the meantime. By the eleventh day only, the mixture became thick and sour.

5 cc. preserved 47 cc. grape-must from fermentation for some twenty-four hours, after which bubbles of oxygen gas escaped ; finally, the mixture had an apple-like odour.

5 cc. preserved 15 cc. of white of egg, mixed with 10 cc. water, perfectly fresh for many days.

5 cc. preserved 400 cc. 'bitter beer' unaltered for twenty-six days; it then soured; fungus did not appear.

5 cc. preserved 30 cc. flour-paste for six days free from sourness and mould.

Now the real quantities of peroxide of hydrogen and decomposable substances employed in the above experiments stand about as follows:—

| | | | | | | | Per cent. of $H_2O_2$ = | |
|---|---|---|---|---|---|---|---|---|
| 0·304 | grm. | $H_2O_2$ | and above | 400 | grms. | milk - | 0·076 | per cent. |
| 0·152 | ,, | $H_2O_2$ | ,, | 47 | ,, | must - | 0·3 | ,, |
| 0·152 | ,, | $H_2O_2$ | ,, | 15 | ,, | white of egg solution | 1·0 | ,, |
| 0·152 | ,, | $H_2O_2$ | ,, | 400 | ,, | beer - | 0·04 | ,, |
| 0·152 | ,, | $H_2O_2$ | ,, | 30 | ,, | paste - | 0·5 | ,, |

These experiments were only intended to show that peroxide of hydrogen possesses antiseptic and preserving powers, and were not meant to determine the extent of such influences, but they at least demonstrated that its prophylactic energies are very great.

Messrs. Guttman and Fraenkel, apparently unaware of this prior publication, gave confirmation to my results by some experiments which were published in Virchow's *Archiv*, and to which the *Lancet* (1878, vol. ii., p. 839) subsequently directed further attention. These experiments confirmed the fact that peroxide of hydrogen preserves urine and meat infusions from putrefaction, while it also prevents the fermentation of grape-sugar.

More recently still, the antiseptic properties of peroxide of hydrogen have been studied by M. Baldy, and also by MM. Paul Bert and Regnard.* After the publication of these researches I took occasion to bring my own earlier investigations to the knowledge of the lamented M. Paul Bert, and in reply he acknowledged my claim of priority, and promised to admit and state it to the Academy of Sciences.

The peroxide of hydrogen employed by M. Baldy was prepared after the well-known process of Thénard, care being taken to neutralise the solution by means of argentic sulphate, and diluting it before use so as to work with a solution capable of yielding about twice its own volume of oxygen when subjected to decomposition into water and oxygen.

The observation made by M. Baldy late in 1881, viz., that a small quantity of the peroxide removed the fœtidity from twelve to fifteen litres of putrid water, and further trials convinced him that peroxide of hydrogen is an antiseptic agent which is not inferior in any respect to carbolic acid, and entirely free from the disagreeable and dangerous character of that compound.

MM. Bert and Regnard, confirming my earlier experiments, have shown that an extremely dilute solution of oxygenated water prevents the fermentation of glucose by the agency of yeast, prevents mycodermic growth in red wine, prevents the lactic fermentation in milk, and the putrefaction of albumin, etc. On the other hand, they found that this anti-

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* *Compt. Rend.*, 94. 1383-1386.

septic agent was incapable of arresting the changes induced by soluble non-organised ferments, such as diastase, in suitable media. I, too, have for many years been aware of the fact that the peroxide exercises no effect upon the transformation of starch into sugar by means of saliva. The distinction thus arrived at is most important, because, if peroxide of hydrogen, or 'Sanitas' fluid, be employed for internal administration, we have a guarantee that its presence in the system will not substantially arrest or interfere with the many digestive, assimilative and other processes carried on in the living body by means of ferments of the pancreatic type.

Incidentally, it may be observed that the study of peroxide of hydrogen presents many interesting points of contact with M. Bert's investigations of the action of compressed oxygen. Demarquay is stated to have observed that oxygen gas exercises upon wounds a singular stimulating effect, thus inducing rapid cicatrisation; while Bert thoroughly studied the influence of compressed oxygen upon living organisms to which he found it proves fatal, while it leaves soluble non-organised ferments intact.

It is also of importance to bear in mind the remarkable attenuating influence which M. Pasteur found oxygen to exercise upon such morbific germs as the micro-organisms of chicken cholera and splenic fever, to the existence of both of which peroxide of hydrogen will almost certainly, in my opinion, be found fatal.

It was to be expected, from what has gone before, that this compound would be found of peculiar benefit for the treatment of wounds, and, indeed, throughout the whole range of antiseptic surgery; and the expectation has been amply realised in the practice of M. Baldy, M. Regnard, and in particular of M. Péan, in the hospital of St. Louis. To be brief, it has been demonstrated beyond question that all wounds which are treated with peroxide of hydrogen progress well, healing by first intention, and giving no trouble whatever, the discharges being healthy in character and free from odour. Chronic ulcers, similarly treated, yield equally good results, as, also, cases of gangrene, together with fœtid suppurations and bad ozænic discharges.

M. Péan has performed many important operations in an atmosphere impregnated with peroxide of hydrogen instead of carbolic acid, with more than an average amount of success; and M. Baldy has employed gauze and wool soaked in the peroxide, and kept in contact with wounds by means of bandages, in cases where prolonged contact has been desirable. He has also found that it may with safety be used as an injection for washing out cavities of the body; and he hopes to derive much benefit from its internal administration, particularly in the treatment of diabetes and certain pulmonary affections.

The oxidising effects of peroxide of hydrogen upon animal and vegetable matters in a state of incipient change, or even of advanced decomposition, have been already considered in an earlier chapter.

Dr. Day, of Geelong, believed that it possesses the power of oxidising and annihilating the poisons of small-pox, scarlet fever, and typhoid fever, and has himself furnished some of the data* upon which he arrived at this conclusion, which is evidently not without foundation. Between April 1873, and the same month of 1875, he treated fifty-one cases of scarlet fever, by anointing the bodies of his patients with lard containing peroxide of hydrogen; and in some cases he caused his patients to gargle a very dilute solution of the same reagent. Under this judicious treatment, there was extension of the disease to other persons only in four houses, and there were no deaths. Subsequently, Dr. Day treated other sixty-four cases, and of these only six proved fatal, whilst there was spreading of the disease only in three cases. These facts go far to teach the disinfecting value of peroxide of hydrogen; for while theorists continue to talk at random about the germs of scarlet fever, there actually exists a substance which seems at once to cure the disease, and prevent any extension of the infection.

Although we cannot accurately define the precise manner in which the peroxide of hydrogen acts on the contagious matter thrown off from the skin, we know that diseased matter may thus be rendered powerless to infect, and that is probably owing to its powerful oxidising effects.

In another chapter, reference has been made to

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* *British Medical Journal*, March 10th, 1877. See also paper on 'The Uses of Peroxide of Hydrogen,' by C. E. Shelly, M.B., *Practitioner*, March, 1884.

the further fact that septic vibriones are killed by peroxide of hydrogen even when that solution is extremely dilute.

More recent investigations, as those carried out by M. Miguel, of the Observatoire de Montsouris, appear to establish its claim as one of the most potent destroyers of bacterial life. He states that the smallest quantity of each substance capable of preventing fermentation in 1 litre (2·1 pints) of bouillon was as follows :

| | |
|---|---|
| Hydrogen dioxide water - - - | 0·05 gramme. |
| Iodine - - - - - - | 0·25 ,, |
| Bromine - - - - - - | 0·60 ,, |
| Zinc chloride - - - - - | 1·90 ,, |
| Carbolic acid - - - - - | 3·20 ,, |
| Potassium permanganate - - - | 3·50 ,, |
| Boracic acid - - - - | 7·50 ,, |
| Sodium salicylate - - - - | 10·00 ,, |
| Borax - - - - - - | 70·00 ,, |
| Absolute alcohol - - - - | 95·00 ,, |

Careful comparative tests with antiseptics now much in vogue prove it to be sixty times as powerful as carbolic acid, twenty times as strong as salicylic acid, and forty per cent. more potent than the solution of the bichloride of mercury. However extraordinary or incredible this may appear, experiments seem to have placed it beyond a doubt.

So much for peroxide of hydrogen.

### *Experiments with the Soluble Camphor of the composition* ($C_{10}H_{16}O_3$).

Equally striking are the antiseptic effects of this product of the oxidation of turpentine which is obtained as described in the last chapter. The following account of experiments will sufficiently illustrate this fact.

A solution of white of egg* was made by beating up the whites of four eggs with a quantity of water and filtering from membranous parts. Upon examination, the solution was found to contain 3·97 per cent. albumin dry at 100° C. Next, a solution of the soluble camphor containing 1·664 per cent. was prepared.

One stoppered bottle was charged with 20 cc. of the albumin and 30 cc. water: the mixture grew turbid, and became putrid on the sixth day. The other bottle was charged with 20 cc. of the albumin, 25 cc. water, and 5 cc. of the antiseptic fluid. This mixture kept perfectly sweet for at least thirteen days. That is to say, 0·0832 grm. of the soluble camphor deferred the putrefaction of the albuminous solution at least eight days.

This experiment was repeated, using stronger antiseptic and albuminous solutions, with confirmative results.

In another experiment 0·75 grm. of the camphor was dissolved in 110 cc. of the albuminous solution

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* Further experience has shown me that it is much better to employ a dilute extract of meat for experiments of this kind, the indications being much sharper.—AUTHOR.

(containing 0·8 grm. solid substance, dry at 100° C.). The mixture kept clear and good from February 10th, 1879, till April 21st, after which it was no longer observed. At that time, the solution contained its albumin in a perfectly unchanged state.

### *The Volatile Substance* ($C_{10}H_{14}O$).

Powerful antiseptic properties are also possessed by the thymol-like body constituting the more volatile portion of the solution (to which the odour is chiefly due, and which is obtained on distillation of the fluid). This feature makes 'Sanitas' fluid more valuable, since it is thus better qualified to serve as an air purifier. It is therefore seen that each constituent of the solution in question, contributes towards its total effect as an antiseptic and disinfectant. Of course it will be understood that acquaintance had been made with the characters of the solution as a whole, so far as this was possible, long before the experiments on its individual constituents were conducted, and also long before the solution ever became known to the public in a commercial form, as 'Sanitas' fluid.

### *Experiments with 'Sanitas' Fluid and Oil.*

It is not necessary to reproduce here an account of all the earlier experiments which were made and described in former editions of this work respecting the antiseptic and disinfectant properties of 'Sanitas' fluid and 'Sanitas' oil, but an account is given hereafter of a more recent investigation of a quantitative nature, and of the germicidal properties of both these preparations. 'Sanitas' fluid, even when diluted with eight or ten times its bulk of water, is sufficiently powerful to prevent and arrest putrefactive changes; and when used in a less diluted state, its capacity for work increases accordingly. It does not stain, is perfectly non-poisonous, and is without corrosive properties. On the other hand, indeed, it is pleasantly aromatic in character, and is qualified for universal application. For diffusing into the atmosphere of inhabited apartments and sick rooms, it presents a really great advantage, inasmuch as it easily parts with oxygen, and thus atones to some extent for that which is used up by human beings, etc.

As regards the uses of the fluid in surgery, they may be said to be identical in the main with those of peroxide of hydrogen, already enumerated when describing the properties of that substance, but, in addition, it possesses the valuable antiseptic properties of its other several constituents.

In four experiments made by Dr. J. W. Miller,* in which lymph was mixed with 'Sanitas' fluid in equal proportions, and allowed to stand for eight hours and upwards, the disinfection of the lymph was complete; that is to say, its infectivity was quite destroyed. Unfortunately, Dr. Miller did not make any experiments with 'Sanitas' oil and emulsion.

'Sanitas' oil is very much more powerful than the

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* *Practitioner*, October, 1884, p. 264.

fluid, and ranks, indeed, as one of the most potent antiseptics. Its characters in this respect are quite apart from, and additional to, its power as an oxidising agent, and signifies, as we shall see later, a correspondingly great germicidal power.

Its power as an oxidising agent may be judged from the calculation that, assuming its active oxygen could be obtained in the gaseous state, one gallon of 'Sanitas' oil would give twenty-five litres, or between five and six gallons, of that gas.

'Sanitas' oil is by no means intended to supersede, in any degree, the use of 'Sanitas' fluid, but only to supplement it; indeed, while it is far too powerful in its action to serve the purposes for which the aqueous solution is intended, its physico-chemical properties do not qualify it to meet the same ends. It may be employed for adding to glycerine, or oils, or ointments, when these various substances are applied to the body, either during the peeling stages of several infectious diseases, or when any suppurative action or morbid process requires to be arrested. It can also be used for producing a powerful spray for the antiseptic treatment of wounds and the throat in cases of diphtheria. Further, its evaporation forms an excellent expedient for the fumigation of apartments inhabited by persons suffering from communicable diseases. An ordinary-sized room requires about one fluid ounce of the oil, which should be evaporated from the surface of water in a saucepan or kettle. Any plane surface, such as is presented by flooring and walls, may be effectually disinfected by simply smearing or wiping it over with a cloth or brush dipped in the oil, and in such operations a very minute amount of the substance goes a long way, by reason of its superior spreading qualities. The oil is slowly volatile, and hence it is available for use as an aërial disinfectant. Although not appreciably soluble in water, it may readily be made into an emulsion therewith by the agency of gum acacia, and indeed such a product is now made and sold for general disinfecting purposes under the name of 'Sanitas' emulsion. This product can be used with advantage for watering streets in times of epidemics, also for the deodorisation of wooden pavements and offensive collections of any kind. A crude and powerful fluid is now also available for washing animals and as a sheep-dip.

'Sanitas' oil is soluble in spirit, and readily mixes with other oils. Sprinkled over sawdust, it forms a most effective deodorant for use in urinals, kennels, and other places where a fluid as ordinarily applied is too soon carried away from the scene of action. No doubt many other applications will occur to the minds of readers, but enough has now been said respecting the uses that may be made of this product for antiseptic and disinfecting purposes.

In previous chapters, treating of the relations of micro-organisms to disease, and the science of disinfection, I have shown that micro-organisms are rather the indirect than the immediate causes of certain diseases; indeed, it is not going too far to say that at the present time there is a consensus of opinion amongst those who are best entitled to pronounce upon the subject, to the effect that so-called germ diseases are really due to the physiological effects of chemical substances elaborated by micro-organisms. I claim credit for having all along advocated these views,* which have only recently received general adoption.

Our power to control the life of microbes is necessarily very limited, and is based upon our acquaintance with their life history as ascertained by chemical investigation. We know or can ascertain that they find life possible in certain numerous media, and we also know, or can find out by actual experiment, to what extent their life is destroyed or interfered with by certain chemical substances. To destroy them locally without injury to the human body, to suspend their life actions by means of suitable chemical substances, until that part of the body which has been diseased through their influence has recovered its normal state and strength ; similarly, so to influence, or to interfere with, the life of these micro-organisms that some particular poisons which they are capable of producing shall be no longer formed, or if allowed to be formed, shall be instantly destroyed in a chemical sense : these are the legitimate objects of sanitary science.

The germ theory of disease, as still stupidly misunderstood by many, concerns itself alone with the parasite and utterly ignores the host. Bacteria are observed in diseased parts and the various

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* See *Soc. of Arts Journal*, March 8th, 1878.

tissues, but in what relation to the disease and the tissues they stand — how the tissues (or rather their cells) are affected by the bacteria (or rather their chemical products)—are subjects which still receive scant attention. Virchow has also indicated this defect in current investigations,* and it may be safely predicted that after a time there will be a more or less sudden devotion of scientific attention to the life history of the cells which build up the human body,† and parasitic micro-organisms will then for awhile become the subject of neglect. It is a pity that both subjects should not be dealt with simultaneously.

Until we know more of cell life, it appears to me that progress of necessity depends upon investigation conducted in the chemical laboratory; for chemists can construct many mixtures of known composition upon which micro-organisms will grow, multiply and flourish, and, similarly, they can both qualitatively and quantitatively ascertain in what ways the chemical molecules are broken down and rearranged by the life agencies of the micro-organisms, and thus they can also place a quantitative value upon the action of so-called antiseptics and disinfectants.

It is in this sense that I some few years since conducted an investigation of which the details and results follow.

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* *Archiv. der Path. Anat.*, Bd. 101, Heft. 1.

† These words were originally written by me only a few years since, and already they are becoming verified. (See Chapter VIII., on Phagocytosis and Immunity.)

## *The Chemical History of some Micro-organisms.*

### YEAST AND THE FERMENTATION OF GLUCOSE.

EXPERIMENT I.—A solution of glucose dissolved in water was prepared, containing, as was afterwards ascertained, 1·670 grms. of glucose in each 100 cc.

A pasty solution of ordinary yeast was then made, containing about 12·10 per cent. by weight in volume. A microscopic examination of the yeast solution revealed the presence of numerous yeast cells of ordinary appearance and many other sorts of living micro-organisms.

A quantity (995 cubic centimetres) of the glucose solution was inoculated with 5 cc. of the yeast solution, and the 'total solid contents' of the mixture was determined and found to be 1·690 per cent.

A mixture (A) of 75 cc. glucose and yeast solution with 25 cc. of pure water was placed in one flask, fitted with a cork and bent glass delivery tube, while in a second similar apparatus was placed a mixture (B) of 75 cc. glucose and yeast solution, 20 cc. of 'Sanitas' fluid (as sold)* and 5 cc. water.

After standing at the ordinary temperature of the laboratory during 31 days, a chemical examination of the several mixtures was made. That is to say—the total solid contents of each solution was determined, and the amount of alcohol produced by fermentation was ascertained by distilling a known quantity of

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* This solution upon evaporation to dryness left a residue = to 2·31 per cent.

each mixture, and taking the specific gravities of the distillates. The results are tabulated as follows :

| | Original total solids. | Final total solids. | | Loss in weight. | Percentage of loss. | Alcohol produced. | Alcohol calculated. |
|---|---|---|---|---|---|---|---|
| A. | 1·2675 | 0·486 | = | 0·7815 | 61·6 | ·4576 | ·4000 |
| B. | 1·7295 | 1·700 | = | 0·0295 | 2·3 | None. | — |

The alcohol is calculated upon the basis of the following equation, which represents the fermentation of glucose into alcohol by the agency, as it is supposed, of a soluble zymase, formed by the yeast cells.

$$C_6H_{12}O_6 = 2C_2H_6O \text{ (Alcohol)} + 2CO_2 \text{ (Carbonic Anhydride).}$$

Experiment II.—A fresh solution of glucose was prepared and inoculated with some yeast ; its total solid contents = 8·11 per cent.

A. 75 cc. of this inoculated solution was mixed with 25 cc. water.

B. 75 cc. of the inoculated solution was mixed with 25 cc. of 'Sanitas' fluid (the total solid residue of which dry at 100°C. = 2·694 per cent.).

The two mixtures were placed in flasks as before, fitted with corks and tubes for the delivery of any gas that might be evolved, and kept during seven days. Mixture A gave off a great deal of gas ; it was not accurately measured, but over 375 cc. was roughly measured as collected. Mixture B did not give off even a trace of gas.

The chemical examination of the solutions at the termination of the experiment gave results which are here tabulated as follows :

| | Original total solids. | Final total solids. | Loss in weight. | Percentage of loss. | Alcohol produced. | Alcohol calculated. |
|---|---|---|---|---|---|---|
| A. | 6·0825 | 3·4950 | 2·5875 | 42·5 | 1·44 | 1·32 |
| B. | 6·7560 | 6·7560 | None. | — | None. | -- |

A microscopical examination of mixture A showed the presence of many living yeast cells and a great number of other micro-organisms (many of which were in active motion), including single cells, association of cells in rods and chains and the *Bacterium termo*. A similar examination of mixture B revealed the presence of much fewer yeast cells (not growing), and no moving micro-organisms were to be seen.

One third of the mixture A was now taken while in active fermentation, and to it was added 10 cc. of 'Sanitas' fluid, the mixture being replaced in the original flask. The addition of the 'Sanitas' absolutely put an end to the fermentation; not a trace of gas was evolved, and an examination, which was made after seven days, showed that practically no further loss of glucose had occurred, and consequently, also, no further alcohol was produced.

| Original total solids. | Final total solids. | Alcohol at start. | Alcohol at end. |
|---|---|---|---|
| 1·4344 | 1·424 | ·500 | ·525 |

The trivial change that is noticeable undoubtedly occurred in the interval between the original examination of mixture A and the time when the 'Sanitas' was added.

This result is interesting because it proves that in addition to its property of preventing the development of yeast cells in glucose solution, together with the resulting chemical changes, 'Sanitas' fluid also arrests their development instantly, even when in the most active stage of growth.

Experiment III.—A further solution of glucose, impregnated with yeast, was prepared, yielding a total solid residue of 8·016 per cent. dry at 100° C. Three mixtures of this solution were prepared as follows :

A. 75 cc. of inoculated glucose solution + 25 cc. water.
B. 75 cc. „ „ „ + 5 cc. „ + 20 cc. of 'Sanitas' fluid.
C. 75 cc. of inoculated glucose solution + 25 cc. of a 20 per cent. solution of 'Sanitas' emulsion.*

The 'Sanitas' fluid which was used in mixture B yielded 4·758 per cent. of solid matters, dry at 100° C.

After standing seven days the experiments were brought to a conclusion by a chemical examination of each mixture, and the following tabulated results were obtained :

| | Original total solid contents. | Final solid contents. | Loss in grms. | Per cent. of loss. | Alcohol formed. | Alcohol calculated. |
|---|---|---|---|---|---|---|
| A. | 6·012 | 4·2855 | 1·7265 | 28·55 | 0·870 | 0·882 |
| B. | 6·9636 | 6·9585 | 0·0051 | 0·073 | None. | — |
| C. | 7·3355 | 7·287 | 0·0485 | 0·633 | None. | — |

These results are confirmative of those observed in the earlier experiments, and at the same time show that very small quantities of 'Sanitas' emulsion (and 'Sanitas' oil, from which it is made) act like 'Sanitas' fluid in preventing alcoholic fermentation dependent upon the growth of yeast.

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* = 5 cc. of 'Sanitas' emulsion in the undiluted state, and consequently about 2 5 cc. of 'Sanitas' oil.

## YEAST AND THE FERMENTATION OF STARCH.

I thought it would be of some interest and importance to ascertain, if, by the living presence of yeast in a solution of starch, that chemical substance is resolved into alcohol. Such a result, if established by experiment, would be of importance, not alone from a chemical and technical point of view, but also as bearing upon the germ theory of disease. It is too often assumed, without ascertained foundation in fact, that each particular micro-organism exhibits only one mode of life, so to say; in other words, that each micro-organism has the property of initiating one chemical change only. Thus, by a habit of mind, we identify the yeast plant strictly with alcoholic fermentation, the *Bacterium lactis* only with the souring of milk, and so on. If, however, it can be shown that the yeast plant can split up other chemical substances besides sugar, such, for example, as starch and gum, and produce other products besides alcohol, say, for instance, acetic acid, the field of life-action of minute forms of life is seen to be much larger than was before thought, and we are thereby enabled to understand that, whereas, under one set of circumstances, a micro-organism may give rise to the formation of chemical products which cause disease, under other circumstances merely innocuous products may result, and thus no injury to health will ensue.

EXPERIMENT.—A solution of starch containing about $2\frac{1}{2}$ per cent. was made, and to 145 cc. of it there was added 5 cc. of a thick mixture of yeast suspended in water. The total solid contents of the inoculated mixture, dry at 100° C., were now estimated and found to be 2·300 per cent.

100 cc. of the inoculated mixture was placed in a flask fitted with an india-rubber cork and bent glass tube, the end of which dipped into a bath of mercury. The fermentation of the starch commenced immediately, gas being freely evolved from the 19th of May until June 5th, when, although it had slackened, it was still proceeding. On June 16th, although the fermentation had not then ceased, the experiment was brought to a conclusion, and the total solid contents and alcohol present in the fermented mixture were determined. The total solid contents had fallen from 2·300 to 1·326 per cent., showing a loss of 42·34 per cent., and an actual loss of 0·974 grm. in weight. The alcohol present in the fermented mixture amounted to 0·542 grm., as ascertained by the specific gravity of the distillate of an aliquot part.

Now, if we assume the fermentation of starch experienced in this experiment to have taken place in accordance with the following equation :

$$C_6H_{10}O_5 + H_2O = 2C_2H_6O + 2CO_2,$$

then a loss of 0·974 grm. starch should result in the production of 0·552 grm. alcohol, and there was practically obtained 0·542 grm., which is a closely approximating amount.

It is thus established that yeast cells can split up the molecule of starch into alcohol and carbonic anhydride, just as it can also split up the molecule of sugar into the same products. Whether or not the starch molecule is first of all converted into glucose by the yeast or a soluble ferment produced from it, in this process of fermentation into alcohol and carbonic anhydride, is unascertained.

### YEAST AND THE FERMENTATION OF GUM.

EXPERIMENT.—A solution of East Indian gum in water was prepared and inoculated with 5 cc. of a pasty mixture of yeast suspended in water. The amount of total solid contents dried at 100° C. was now determined and found to be 5·460 per cent.

On May 19th, 100 cc. of this prepared mixture was placed in a flask, which was fitted as described in the preceding section dealing with the fermentation of starch. Until May 28th the fermentation, as judged by the evolution of carbonic anhydride, proceeded but slowly; then there was a somewhat sudden change, and fermentation proceeded rapidly. On June 16th the experiment was brought to a conclusion, and the fermented mixture was chemically examined, with the results now to be described.

The total solid contents dry at 100° C. had diminished from 5·460 grms. to 4·7355 grms., indicating a loss of 0·7245 grm., or 13·26 per cent.

The fermented solution contained no alcohol, but it was strongly acid in character, and the acidity of the distillate obtained from 130 cc. of the fermented solution (which had been made up to 150 cc. by addition of water) was determined, and calculating from the result thus obtained, the total acidity of the whole quantity was equivalent to 54·23 cc. of decinormal caustic soda solution. This acidity is equal to 0·3253 grm. of pure acetic acid, and the identity of the acid was subsequently established by well-known chemical methods. The chemical constitution of gum is, unfortunately, not yet ascertained, and therefore it is not possible to express with any degree of certainty the stages of decomposition of its molecule by the yeast. If, however, we assume the formula of gum to be $C_6H_{10}O_5$ and the chemical change to be as follows :

$$C_6H_{10}O_5 + H_2O + O_4 = 2CO_2 + 2H_2O + 2C_2H_4O_2,$$

then 0·7245 grm. gum should yield 0·536 grm. acetic acid, whereas there was only found 0·3253 grm. It is possible, of course, that oxidation by other agencies (micro-organisms) had proceeded further, and that part of the acetic acid had been resolved into carbonic anhydride and water.

As the product in question contained no alcohol at all, I see no reason for rejecting the idea that the fermentation was of a direct character, and that the immediate products were acetic acid and carbonic anhydride.

In any case, the results are interesting, and while they open up a wide field for new investigation, they accentuate the views to which I have called attention in earlier pages of this chapter.

## BACTERIUM LACTIS AND THE FERMENTATION OF MILK AND MILK SUGAR.

EXPERIMENT I.—A quantity of fresh milk was taken and the milk sugar present in it was determined by first of all greatly diluting it with water (10 cc. with 90 cc. water), and then estimating the sugar by the well-known process which makes use of Fehling's solution volumetrically. It contained 4·422 grms. milk sugar in each 100 cc. It was also experimentally proved to be quite free from lactic acid.

Quantities of the milk were now mixed with water and 'Sanitas' fluid respectively, as follows, and placed in flasks loosely covered with filter paper, on July 7th.

| | | | |
|---|---|---|---|
| A. | 50 cc. milk | + 50 cc. water. | |
| B. | 50 cc. ,, | + 30 cc. ,, | + 20 cc. 'Sanitas' fluid. |
| C. | 50 cc. ,, | + 25 cc. ,, | + 25 cc. ,, ,, |
| D. | 50 cc. ,, | + ... | 50 cc. ,, ,, |

On July 20th the perfect coagulation of each mixture was effected by warming, after which each was filtered; the filtrate was then made up to a known volume by washing the coagulum with warm water, and the sugar present in each filtrate and its acidity were determined.

In order to understand the table that follows, it must be stated that 'Sanitas' fluid reduces

Fehling's solution like sugar, and this capacity was estimated beforehand and calculated into terms of milk sugar (100 cc. of this particular sample reduced 540·5 cc. Fehling's solution = to 3·62 grms. milk sugar). Similarly, the acidity of the 'Sanitas' fluid was determined volumetrically (100 cc. of this particular sample required 90 cc. N/10 NaHO solution).

| | Sugar originally present. | Sugar present at end. | Difference due to fermentation. | Original acidity. | Final acidity. | |
|---|---|---|---|---|---|---|
| A. | 2·211 | None. | 2·211 grms. | — | 28 cc. | N/10 NaHO |
| B. | 2·935 | 2·935 | — | 18 cc. | 18 cc. | ,, |
| C. | 3·116 | 3·116 | — | 22·5 cc. | 22·5 cc. | ,, |
| D. | 4·021 | 4·021 | — | 45·0 cc. | 45·0 cc. | ,, |

The first conclusion to be drawn in connection with these results is that 'Sanitas' fluid, when present in sufficient amount (and that is not a large one), wholly prevents the conversion of milk sugar into lactic acid by the agency of the *Bacterium lactis*. A microscopical examination of the fermented mixture A revealed the presence of a great number of the *bacteria* in question, but none could be observed in the mixtures B, C, D; similarly the *Bacterium termo* was seen to be present in A in a very active state, but it was not present at all in B, C, and D.

Now, to look at the results from a quantitative and chemical point of view, the lactic fermentation is expressed by the following equation :

$$C_6H_{12}O_6 = 2C_3H_6O_3,$$

which indicates the splitting up of 1 molecule of milk sugar into 2 molecules of lactic acid.

From this, it is calculated that a loss of 2·211 grms. milk sugar should yield 2·211 grms. of lactic acid, whereas the acidity of mixture A was only equal to 0·252 grm. lactic acid. How is this difference to be accounted for? In two ways: in the first place, unless the lactic fermentation is stopped precisely when all the milk sugar has disappeared, the lactic acid is itself resolved by subsequent changes into acetic, butyric, and propionic acids, and finally these acids are split up by oxidation into ultimate products (carbonic anhydride and water); in the second place, the lactic fermentation as thus carried out may not be pure in character; that is to say, other ferments are present besides the *Bacterium lactis*, and other products are thus produced, perhaps alcohol amongst them.

Experiment II.—The experiment which has just been described was repeated with another sample of milk containing 3·88 grms. milk sugar in each 100 cc., but using the same sample of 'Sanitas' fluid. The mixtures were made up as before, on August 4th, and the experiments were brought to an end on August 13th.

| | Sugar originally present. | Sugar present at end. | Difference due to fermentation. | Original acidity. | Final acidity. |
|---|---|---|---|---|---|
| A. | 1·940 | 0·980 | ·960 | — | 37·5 |
| B. | 2·664 | 2·664 | — | 18 cc. | 18 cc. |
| C. | 2·845 | 2·845 | — | 22·5 cc. | 22·5 cc. |
| D. | 3·750 | 3·750 | — | 45 cc. | 45 cc. |

Here, again, it is seen that fermentation occurred only in the unprotected milk, and inasmuch as the mixtures were not allowed to stand so long as before, the quantity of lactic acid found in A mixture, in comparison with the loss of sugar, is much greater, as was to be expected from the conclusions drawn in respect of the preceding experiment. If the whole of the 0·96 grm. of milk sugar had been changed into lactic acid, and none of this had been destroyed by other chemical changes, there would have been obtained 0·96 grm. lactic acid instead of 0·3375 grm. actually observed to be present.

Experiment III.—Some 245 cc. of fresh milk was noculated with 5 cc. of very sour milk; then the milk sugar and acidity of the inoculated mixture were carefully determined, and the following mixtures were then made and placed in glasses as before. On this occasion, however, another sample of 'Sanitas' fluid was used. It contained reducing matter equal to 0·87 grm. of milk sugar per 100 cc., and the acidity of the same quantity was equal to 11.5 cc. N/10 NaHO solution.

### Mixtures.

A. 50 cc. inoculated milk + 50 cc. water.
B. 50 cc. ,, ,, + 50 cc. ,,
C. 50 cc. ,, ,, + 25 cc. ,, + 25 cc. 'Sanitas' fluid.

The mixtures were made on August 20th, and were examined on August 24th.

| | Sugar originally present. | Sugar present at end. | Difference due to fermentation. | Original acidity. | Acidity at end. |
|---|---|---|---|---|---|
| A. | 2·185 | 1·675 | ·510 | 0·5 cc. | 44·5 |
| B. | 2·185 | 1·654 | ·530 | 0·5 cc. | 45·7 |
| C. | 2·4025 | 2·4025 | — | 29·25 | 29·25 |

The results of the examination of mixtures A and

B are seen to be thoroughly and mutually confirmatory in character. Taking A, the loss of the milk sugar could produce a maximum of ·510 grm. lactic acid, whereas the acidity of the ultimate mixture was equal to ·4005 grm., showing only ·1095 grm. to be accounted for. It is to be noted that the approximation of the theoretical and actual quantities of lactic acid is much greater than in either of the previous experiments, and doubtless the reason is that the mixtures were only allowed to stand over four days. In order to test the supposition that alcohol might also be found amongst the products, thus accounting for the difference, one half of each mixture A and B was subjected to distillation, and the specific gravity of each distillate after being made up to the original volume was determined, and found to be respectively ·99977 and ·99973. Not unlikely, therefore, alcohol was present in the fermented mixtures in more than sufficient amount to fully account for the deficiency in lactic acid produced. Thus, the deficiency of lactose or lactic acid to be accounted for in A is 0·0995 and in B = 0·0887 grm., whereas the alcohol calculable as present in A = 0·27 grm., and in B = 0·28 grm. Now, 0·0995 grm. lactose would only furnish 0·0508 grm. alcohol. The explanation is this: the alcohol which was presumably present was all derived from the fermentation of lactose; whereas a small proportion of the total acidity of mixtures A and B was derived from butyric and other soluble fatty acids which resulted from the rancidity of the cream or fat contained in the milk, thus swelling the amount of acid which is, as explained, not derived solely from the lactose.

Either, then, the *Bacterium lactis* performs the double chemical change whereby lactose is resolved into alcohol and lactic acid, or it was accompanied in these experiments with other forms of microscopic life which fermented a part of the lactose into alcohol and carbonic anhydride.

Before passing on to other experiments, it should be mentioned that 'Sanitas' fluid, by its acidity, determines more or less the coagulation of milk when mixed therewith, whereas the coagulation of the unprotected milk is of course brought about by the lactic acid produced in the fermentation.

I have ascertained that just as 'Sanitas' fluid protects the milk sugar which is contained in milk from undergoing lactic fermentation, so also it acts towards pure milk sugar. In the unprotected samples the milk sugar solution, when inoculated, steadily decreased in amount, while lactic acid and the other products were formed; whereas when 'Sanitas' fluid was present (even after thirty-seven days in one case), there was no diminution whatever in the amount of milk sugar, and no products of fermentation were obtained.

Similarly, while the *Bacterium lactis* was richly developed in the unprotected mixtures, a microscopic examination failed to detect the presence of the ferment in the mixtures protected by 'Sanitas' fluid.

## AMMONIACAL FERMENTATION.

EXPERIMENT I.—Some urine was placed in a warm situation until it had commenced to ferment and formed a deposit. A quantity of freshly voided urine was then inoculated with some of the deposit from the fermented specimen. The total solid contents of the mixture was then determined, and found to be 4·474 per cent. dry at 100° C. The mixture was neutral in character.

On July 15th the following mixtures were made:

A. 50 cc. inoculated urine + 50 cc. water.
B. 50 cc. ,, ,, + 25 cc. ,, + 25 cc. 'Sanitas' fluid.
C. 50 cc. ,, ,, + 50 cc. ,, ,,

The mixtures were placed in loosely corked bottles, and allowed to stand until July 27th, when each was made up to a known volume, and the total solid contents, and the alkalinity or acidity determined.

Mixture A was dark in colour, and very cloudy, while B and C were perfectly brilliant and sweet.

| | Original total solid contents. | Total solid contents at end. | Original acidity. | Final acidity. | Final alkalinity. |
|---|---|---|---|---|---|
| A. | 2·237 | 1·782 | — | — | 21·0 cc. N/10 $H_2SO_4$. |
| B. | 3·712 | 3·712 | 22·50 | 22·50 | |
| C. | 5·188 | 5·188 | 45·00 | 45·00 | |

From these results, it is apparent that in B and C the urea present in the urine was entirely protected from ammoniacal fermentation, while in the unprotected (A) mixture there was a loss of 0·455 grm. in solid contents, and ammoniacal carbonate was formed in consequence.

According to the equation :

$$CH_4N_2O \text{ (urea)} + 2H_2O \text{ (water)} = (NH_4)_2CO_3 \text{ (carb. ammon.)},$$

the ammonium carbonate actually produced in A was only equivalent to ·0634 grm. urea, as compared with the loss of 0·455 grm. experienced in the solid contents.

Doubtless the *torulaceous* ferment was accompanied with other ferments, and thus the fermentation was mixed in character ; but it is evident that, mixed or unmixed, the presence of 'Sanitas' fluid prohibited the fermentation, and thus there is afforded reasonable hope that this reagent may be used with great advantage in the treatment of those diseases in which the urine is passed from the bladder in an ammoniacal condition.

Experiment II.—In the next experiment the urine was not inoculated as before.

The following mixtures were made on August 5th, and examined on August 17th :

A. 50 cc. urine + 50 cc. water.
B. 50 cc. urine + 25 cc. ,, + 25 cc. 'Sanitas' fluid.
C. 50 cc. urine + 50 cc. ,, ,,

The urine used in this experiment contained 4·147 per cent. matter dry at 100° C., and was acid in character, 100 cc. requiring 10 cc. N/10 NaHO.

| | Original total solid contents. | Total solid contents at end. | Difference due to fermentation. | Original acidity. | Final acidity. | Final alkalinity. |
|---|---|---|---|---|---|---|
| A. | 2·0735 | 1·5075 | 0·5660 | 5 cc. | | 112·05 |
| B. | 3·5490 | 3·5490 | — | 27·5 | 27·5 cc. | — |
| C. | 5·0245 | 5·0245 | — | 50·0 | 50·0 cc. | — |

These figures fully confirm the results of the earlier experiment and the protective character of 'Sanitas' fluid, while they show a better accord with a theoretically pure *torulaceous* fermentation.

Thus, in mixture A, the $(NH_4)_2CO_3$ which was produced, not only neutralised the acid urine, but also required further 112·05 cc. N/10 solution of sulphuric acid, the total alkalinity therefore being equal to 117·05 cc. N/10 $H_2SO_4$.

Assuming the loss of solid contents to be entirely due to urea, it is expressed as 0·566 grm., whereas the ammonium carbonate which was found present required the conversion of 0·351 grm., thus accounting for 62·01 per cent. of the total quantity.

## ACETIC FERMENTATION OF ALCOHOL.

Although I made a great number of experiments, using both chemically prepared alcohol, and also white and red wines, upon the general plan already indicated, they resulted in failure. That is to say, the alcohol was not oxidised into acetic acid, nor did the sugar or the total solid contents (of the wines) diminish appreciably in amount. In some few cases the acidity increased somewhat, but in these it was rather at the expense of some other constituent than sugar or alcohol.

I hope some day to continue this branch of the investigation to a satisfactory issue.

## PUTREFACTION.

EXPERIMENT I.—One pound of beef-steak was extracted with water during two hours at a gentle heat, after which the extract was cooled, filtered, and made up to 250 cc. The total solid contents of this extract amounted to 2·764 grms. in 100 cc.

The following mixtures were now prepared and then placed in clean stoppered bottles:

A. 75 cc. extract of meat + 25 cc. water.
B. 75 cc. " " + 25 cc. 'Sanitas' fluid.
C. 75 cc. " " + 20 cc. water + 1 cc. 'Sanitas' emulsion.

After standing 20 days, the total solid contents of each mixture was again determined, and the results are given below:

| | Original total solid contents. | Total solid contents after 20 days in closed bottles. | Loss due to putrefaction. |
|---|---|---|---|
| A. | 2·073 | 1·862 | 0·211 grm. or 10·18 per cent. |
| B. | 2·7465 | 2·7465 | —— |
| C. | 2·9975 | 2·9975 | —— |

A microscopical examination revealed in A the presence of a large number of the micro-organism, *Bacterium termo*, in active motion, but none were visible in B and C.

EXPERIMENT II.—In the next experiment, the 'Sanitas' fluid which was used gave, upon examination, the following analytical results:

Total solid residue dry at 100° C. = 5·902 per cent.
Acidity of 100 cc. = to 90 cc. N/10 NaHO.
Peroxide of hydrogen in 100 cc. = to 238 cc. N/10 $Na_2S_2O_3$.

An extract of meat was prepared showing, upon examination, the presence in 100 cc. of 2·084 grms. dry at 100° C.

The following mixtures were placed in bottles loosely covered with filter paper :

A. 50 cc. meat extract + 50 cc. water.
B. 50 cc. ,, + 50 cc. ,,
C. 50 cc. ,, + 50 cc. 'Sanitas' fluid.

Mixtures A and B became putrid upon the second day, and then revealed under microscopic examination the presence of a large number of the *Bacterium termo* in very active motion. The mixture C then and thereafter remained quite undecomposed, and it contained no micro-organisms in motion.

After standing ten days, an analytical examination of the mixtures was made, and the following are the results which were obtained :

| | Original total solid residue, dry at 100° C. | Total solid residue at end. | Loss due to putrefaction. | Original acidity. | Final acidity. |
|---|---|---|---|---|---|
| A. | 1·0425 | ·738 | ·3045 | —— | Neutral. |
| B. | 1·0425 | ·735 | ·3075 | —— | Neutral. |
| C. | 3·9935 | 3·9555 | ·0380 | 45 cc. N/10 NaHO | 45 cc. N/10 NaHO |

I regard the insignificant loss of matter experienced by mixture C to be due entirely to the oxidising action of the peroxide of hydrogen present in the 'Sanitas' fluid, and it may therefore be disregarded. The unprotected mixtures lost respectively 29·20 per cent. and 29·49 per cent. of the dry meat extract by putrefaction; that is to say, by hydrolysis and oxidation effected by the life action of micro-organisms, among which the *Bacterium termo* is one of principal importance.

Experiment III.—Now, before the chemical examination which has just been reported was made upon the several mixtures A, B, and C, they were each made up to 150 cc. by the addition of water. Of these diluted mixtures there were now taken respectively 100 cc. (A), 100 cc. (B), and 90 cc. (C), and these portions were allowed to stand further twelve days, after which they were again chemically examined. The results are expressed in such a way that the change is at once apparent :

| | Total solid residue at commencement. | Total solid residue at end. | Loss due to putrefaction. | Alkalinity or acidity at start. | Alkalinity or acidity at end. |
|---|---|---|---|---|---|
| A. | 0·492 | 0·390 | 0·102 | Neutral. | 7·77 cc. N/10 acid. |
| B. | 0·490 | 0·375 | 0·115 | Neutral. | 8·49 cc. N/10 acid. |
| C. | 2·3733 | 2·3733 | Nil. | 27 cc. N/10 NaHO | 27 cc. N/10 NaHO |

Expressing these results in words, it may be said that while the mixtures A and B, during this further period of exposure, lost respectively 20·7 per cent. and 23·4 per cent. of their total solid contents by putrefaction, the mixture C lost no part of its solid contents. Further, it is important to note that, whereas in the earlier stage of the observations no ammoniacal product was formed in A and B (unless, indeed, an acid product able to exactly neutralise it was also formed), in this later stage we have an alkaline product of putrefactive decomposition in mixtures A and B, which required respectively 7·77 and 8·89 cc. of N/10 sulphuric acid to neutralise.

These facts accord with what was previously known regarding the chemistry of putrefaction, and they also assist in forming an accurate mental appreciation of the stages in which that process is completed.* They further established the antiseptic properties of 'Sanitas' fluid and its germ-destroying character, for all the mixtures were equally exposed to the attacks of micro-organisms, which flourished in the unprotected mixtures, but were destroyed by the 'Sanitas' fluid present in the protected mixtures.

## CHEMICAL ACTIONS OF SOLUBLE FERMENTS.

The question arises, To what extent are the various processes of fermentation with which we are acquainted, the consequences of vital functions of micro-organisms? To this question no satisfactory answer has yet been accorded. That the processes are not due to the mere mechanical presence of the living agents is obvious, although realised by few writers upon this subject. The very essence of a process of fermentation is a change of chemical systems, and this necessitates an acting chemical agency; that is to say, fermentation is the result of a chemical impulse communicated to the fermentable substance by chemical contact with another substance secreted by or resulting otherwise from living organisms, and yet otherwise perfectly independent of them. That the real ferments are independent of the living

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* See also my paper entitled 'Contributions to the History of Putrefaction,' *Journ. Chem. Soc. Trans.*, 1880, p. 15.

organisms which produce them is assured by the fact that the organisms themselves do not disappear in the chemical changes which constitute the fermentation proper. It is by such reasoning as this that we arrive at the inference, for example, that before ordinary cane sugar becomes transformed by fermentation into alcohol, it is split up into glucose and lævulose by a chemical act of hydration, which is initiated by a soluble zymase which, in its turn, is secreted by yeast.

Similarly, emulsine is known to transform amygdaline into essence of bitter almonds ; and barley is known to yield by germination and extraction a soluble principle which converts starch into sugar. Well known, also, are the transformations of starch into sugar by the action of ptyalin (the ferment of saliva), and of albuminoids into peptones by the action of pepsin. It is more particularly with these last-named subjects that I shall now occupy some attention.

## SALIVA AND THE FERMENTATION OF STARCH.

EXPERIMENT I.—A solution of starch was made and then inoculated with a small quantity of saliva, after which the total solid contents were determined and found to amount to 1·732 per cent. dry at 100° C.

The following mixtures were then prepared, and placed in open test glasses on July 13th :

A. 50 cc. inoculated starch solution + 50 cc. water.
B. 50 cc. ,, ,, ,, + 25 cc. ,, + 25 cc. 'Sanitas' fluid.
C. 50 cc. ,, ,, ,, + 50 cc. 'Sanitas' fluid.

The 'Sanitas' fluid which was used in this experiment gave 5·902 per cent. total solid residue dry at 100° C., and contained matter which reduced Fehling's copper solution equal in amount to 2·7025 grms. grape sugar per 100 cc.

On July 24th the solutions were made up to a known volume and chemically examined, with the results which are shown in the following synopsis :

| | Reducing matter calculated as sugar originally present. | Reducing matter calculated as sugar present at end. | Difference due to action of ptyalin. | Percentage of starch converted. |
|---|---|---|---|---|
| A. | None. | 0·577 grm. | 0·577 | 60 |
| B. | 0·6756 | 0·700 | — | — |
| C. | 1·44 | 1·3512 | — | — |

It is seen that in the absence of 'Sanitas' fluid the starch in the unprotected mixture was converted to the extent of 60 per cent. by the chemical change :

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6,$$

whereas in the mixtures containing 'Sanitas' fluid practically no change occurred, the slight differences in the quantity of sugar which were found present before and after being within the limits of error of experiment.

Experiment II.—A further experiment was made with an inoculated starch solution, containing 4·472 per cent. matter dry at 100° C., and with another sample of 'Sanitas' fluid containing matter fixed at 100° C. = to 5·975 per cent., and reducing substance, which, calculated as grape sugar, amounted to 0·6493 per cent.; the total acidity of the 'Sanitas' fluid being per 100 cc. = to 115 cc. N/10 caustic soda solution.

Mixtures were prepared as follows on July 30th:

A. 50 cc. inoculated starch + 50 cc. water.
B. 50 cc. ,, ,, + 50 cc. water.
C. 50 cc. ,, ,, + 25 cc. 'Sanitas' fluid and 25 cc. water.
D. 50 cc. ,, ,, + 50 cc. ,, ,,

On August 19th a chemical examination of the mixtures was made, and the results are here appended:

| | Sugar or reducing matter found present. | Sugar or reducing matter originally present. | Gain. | Percentage of starch converted. |
|---|---|---|---|---|
| A. | 0·9025 | None. | 0·9025 | 18 per cent. |
| B. | 0·8808 | None. | 0·8808 | ,, |
| C. | 0·2284 | 0·1623 | 0·0661 | Trace. |
| D. | 0·3304 | 0·3247 | 0·0057 | None. |

From mixture B a minute drop had been taken each morning for testing purposes, thus accounting for the slight difference between the result as compared with that of A.

Generally, the results fully confirm those of the earlier experiment.

Experiment III. — As 'Sanitas' fluid contains peroxide of hydrogen, and is, in terms of this substance, of from one to two volumes in strength, it became of interest to ascertain to what extent, if at all, the anti-zymotic character of the 'Sanitas' fluid is due to that constituent. Accordingly, the following experiment was now made.

A freshly prepared and inoculated (with saliva) solution of starch was prepared, containing in each 100 cc. 3·564 per cent. of substance dry at 100° C.

A solution of pure peroxide of hydrogen was diluted with water so that it should be in strength about equal to that of 'Sanitas' fluid; it contained peroxide ($H_2O_2$) in each 100 cc. equal to 213 cc. N/10 solution of hyposulphite of sodium.

Mixtures were prepared on August 5th, as follows:

A. 50 cc. inoculated starch + 50 cc. water.
B. 50 cc. " " + 50 cc. "
C. 50 cc. " " + 25 cc. " + 25 cc. peroxide solution.
D. 50 cc. " " + 50 cc. " "

On August 18th they were examined as before:

| | Sugar found present. | Originally present. | Gain. |
|---|---|---|---|
| A. | 0·7874 | None. | 0·7874 |
| B. | 0·6345 | None. | 0·6345 |
| C. | 0·7132 | None. | 0·7132 |
| D. | 0·6564 | None. | 0·6564 |

It is apparent from these results that a dilute solution of peroxide of hydrogen is without influence upon ptyalin. This result is not new to science in a general sense, for MM. Bert and Regnard had already pointed out that while a very dilute solution of oxygenated water arrests and prevents fermentations which depend apparently upon the presence of living organisms such as *yeast, Bacterium lactis, Bacterium termo, Mycodermi aceti,* etc., it altogether fails to arrest the changes which are induced by soluble ferments or zymases such as diastase. This fact is now confirmed, and the experiments, therefore, which have been described in this section prove that 'Sanitas' fluid is double-barrelled, so to say—in the sense that it not only acts upon organised or living ferments, but also upon soluble or non-organised ferments. The constituent of 'Sanitas' fluid which acts upon soluble ferments is that which resembles sugar in its reducing properties and extract of hops in its bitterness, viz. so-called 'soluble camphor,' and which is designated by the formula $C_{10}H_{16}O_3$. It forms, indeed, the bulk of the residue which is left upon evaporation of 'Sanitas' fluid to dryness, as this evaporation causes the loss of all the thymol and peroxide of hydrogen which are also contained in the original fluid.

## PEPSIN AND ITS ACTION UPON EGG ALBUMEN.

EXPERIMENT I.—A fresh egg was boiled to coagulate the albumen, and then three portions of the white, each weighing ·324 grm., were cut into thin slices, and placed respectively in 2-oz. wide-mouthed stoppered bottles.

A. To this portion was added 50 cc. of a solution containing 1 per cent. hydrochloric acid.
B. To this portion was added 25 cc. of water acidulated to the extent of 1 per cent. with HCl, and 25 cc. of 'Sanitas' fluid acidulated similarly with HCl.
C. This portion was placed in 50 cc. of 'Sanitas' fluid containing 1 per cent. added HCl.

After standing overnight, there was added to each portion 0·05 grm. of the prepared pepsin sold by

Messrs. Bullock and Co., and the mixtures were then placed in an oven maintained at 38° C.

After 3 hours and 50 minutes the albumen in A had all disappeared, but some remained in B, and a large quantity was left in C.

Experiment II.—In the next experiment the proceedings were identical, except that just double the quantity of white of egg was taken in each case. In A all the albumen has disappeared in $4\frac{3}{4}$ hours; in B some remained even after 6 hours; while in C most of the albumen apparently remained.

Experiment III.—Being desirous of expressing the results in a more quantitative manner, the following proceedings were adopted: four portions of coagulated white of egg, each weighing 1 grm., were taken, and the first portion was dried at 100° C. and the residue weighed; it amounted to ·1312 grm., so that ·8688 grm. of the albumen consisted of water which was lost during the drying. The other portions of albumen were treated as before, and kept in an oven at 38° C. during $3\frac{3}{4}$ hours, after which the mixtures were filtered through tared papers, and the undissolved portions of white of egg were thus collected and weighed after drying at 100° C.

| | Undried albumen at start. | Undried albumen at end. | Quantity dissolved. | Percentage dissolved. |
|---|---|---|---|---|
| A. | 1·000 grm. | 0·114 | 0·886 | 88·6 |
| B. | 1·000 „ | 0·166 | 0·834 | 83·4 |
| C. | 1·000 „ | 0·722 | 0·278 | 27·8 |

or, taking the albumen dry at 100° C., the following were the results:

| | Dry albumen at the start. | Amount undissolved. | Quantity dissolved. |
|---|---|---|---|
| A. | ·1312 | 0·0150 | 0·1162 |
| B. | ·1312 | 0·0218 | 0·1094 |
| C. | ·1312 | 0·0948 | 0·0364 |

Experiment IV.—This experiment was made exactly after the same manner as the last, upon a specimen of coagulated white of egg containing 87·06 per cent. water, and yielding 12·94 per cent. of albumen dry at 100° C.

In the case of A, 50 cc. water, acidulated with pure hydrochloric acid, was employed, and of such a strength that 59·75 cc. N/10 NaHO was required to neutralise the whole quantity. In the case of B, there was used a mixture of 25 cc. water acidulated with the same percentage of acid as A, with 25 cc. 'Sanitas' fluid, to which a corresponding amount of acid had been added, although its acidity was practically double by virtue of its own acid character (25 cc. = 58 cc. N/10 NaHO solution). Mixture C consisted of 50 cc. 'Sanitas' fluid to which had been added 1 per cent. of pure hydrochloric acid, and the total acidity of the solution was therefore equivalent to 116 cc. N/10 NaHO solution.

After the mixtures, containing each 1 grm. of the white of egg, had stood over night, there was added to each 0·05 grm. pepsin, and they were all placed in a water-oven maintained at 38° C., during three hours and fifty minutes. The mixtures were then thrown upon previously tared filters, and the undissolved portions were washed, dried, and weighed.

| | Dry albumen left | = Original albumen. | Quantity digested | = Percentage. |
|---|---|---|---|---|
| A. | 0·0166 | 0·128 | 0·872 | 87·2 |
| B. | 0·0372 | 0·286 | 0·714 | 71·4 |
| C. | 0·1146 | 0·885 | 0·115 | 11·5 |

EXPERIMENT V.—Although, from the results which have been described, it is obvious that 'Sanitas' fluid when present in large amount, seriously interferes with the action of pepsin upon albumen in an acid medium, there is a loss in weight of the original albumen employed in the experiments, and to ascertain the nature of this loss a further investigation became necessary.

In this experiment, therefore, using similar quantities of albumen (containing 14·08 per cent. albumen dry at 100° C. and 85·92 per cent. water) different solutions were used.

A. consisted of 50 cc. dilute acetic acid; total acidity = 57·5 cc. N/10 NaHO.
B. consisted of 50 cc. dilute acetic acid; total acidity = 57·5 cc. N/10 NaHO.
C. consisted of 50 cc. 'Sanitas' fluid unmixed; total acidity the same.
D. „ „ 50 cc. „ „ „ „

The portions of albumen were allowed, as before, to stand in the several solutions over-night, and the next morning 0·05 grm. pepsin was added to A and C only. Then all four mixtures were digested at 38° C. during 5½ hours, after which the undissolved quantities of albumen were ascertained as before.

| | Dry albumen left. | = Original albumen. | Quantity dissolved. | = Percentage dissolved. |
|---|---|---|---|---|
| A. | 0·1310 | 0·9304 | 0·0696 | 6·96 |
| B. | 0·1160 | 0·8238 | 0·1762 | 17·62 |
| C. | 0·2040 | — | — | — |
| D. | 0·1828 | — | — | — |

These results were unexpected, and are remarkable as affording proof that in the presence of dilute acetic acid, pepsin is robbed of its digestive function almost entirely. The loss of 17·62 per cent. in B is entirely due to the solvent action of the fluid in contradistinction to digestive action of the pepsin, and is nearly three times as great as the loss experienced in A, where pepsin was present. It almost looks as if the dilute acetic acid in A had precipitated the pepsin into an insoluble condition. The same precipitation apparently occurred in C, but here, as also in D, the albumen evidently entered into combination with some constituent of the 'Sanitas' fluid, thus leading to results which did not lend themselves to the object of the inquiry.

I dwell upon two matters, however, which are proved by these results, viz., the interference of acetic acid with the digestive action of pepsin, and the observation that albumen when digested in an acid solution in which no pepsin is present, loses weight by being partly dissolved.

Experiment VI.—As hydrochloric acid had been employed in the earlier experiments the results of which required complete elucidation, I now reverted to the use of that acid, using a fresh specimen of white of egg. It contained 86·32 per cent. water, and yielded 13·68 per cent. albumen dry at 100° C.

A. consisted of 50 cc. dilute HCl (1 per cent. in strength).
B. „ 50 cc. „ „ (1 „ „ ).
C. „ 50 cc. 'Sanitas' fluid (contg. added HCl as above).
D. „ 50 cc. „ ( „ „ „ ).

After standing all night with the albumen in the several solutions, 0·05 grm. of pepsin was added to A and C only, and all four mixtures were then digested at 38° C. during 3 hours.

The undissolved albumen was determined in the usual manner :

| | Dry albumen left. = | Original albumen. | Loss. = | Percentage. |
|---|---|---|---|---|
| A. | 0·0100 | 0·0730 | 0·9270 | 92·70 |
| B. | 0·1112 | 0·8128 | 0·1872 | 18·72 |
| C. | 0·0874 | 0·6530 | 0·3470 | 34·70 |
| D. | 0·2024 | — | — | — |

The loss of weight in albumen shown in B proves that of the total loss in weight experienced in A, viz., ·9270 grm., the proportion due to mere solution in the dilute acid is 0·1872 grm., the difference of 0·7398 grm. (73·98 per cent. upon original white of egg used) alone, is due to the true digestive action of the pepsin.

The loss in weight of albumen in C shows that pepsin loses most of its digestive capacity when present in a solution of 'Sanitas' fluid, but not entirely.

The gain in weight of undissolved matter in D proves that white of egg is insoluble in 'Sanitas' fluid even when that solution is acidulated with hydrochloric acid, and that the albumen enters into combination with some constituent of the 'Sanitas' fluid, forming an insoluble compound.

The same result was obtained in Experiment V., by which it was also proved that in pure 'Sanitas' fluid (containing, that is to say, no added hydrochloric acid) pepsin is entirely without action upon white of egg. The addition of hydrochloric acid to 'Sanitas,' as proved by the result of mixture C in Experiment VI., permits of the limited action of the pepsin.

'Sanitas' fluid, then, in its pure state, prevents the fermentative change which pepsin can work upon albumen in its absence, and this anti-zymotic power is probably distributed over any acetic acid that may be present, the soluble camphor ($C_{10}H_{16}O_3$), the thymol and other substances which are present in the fluid.

Reviewing the results of this investigation, it has been proved experimentally that *yeast* is destroyed by 'Sanitas' fluid, and is prevented thereby from exercising its ordinary functions when contained either in a solution of glucose, or starch, or gum. Similarly, it has been experimentally demonstrated, in a strictly quantitative manner, that 'Sanitas' fluid destroys and prevents the functions of other micro-organisms, including the *Bacterium lactis*, the *torulaceous* ferment which changes urea into ammonium carbonate, the *Bacterium termo* and the collective microscopic agencies of the putrefactive process.

I have, also, experimentally and quantitatively proved that 'Sanitas' fluid, when present in sufficient quantity, prohibits the action of soluble ferments or zymases such as ptyalin (in saliva) and pepsin.

These experiments will, I hope, suffice to induce any surgeons who may hitherto have hesitated to avail themselves freely of 'Sanitas' fluid in the practice of antiseptic surgery, to take up its unrestricted use in future, for it is pre-eminently qualified above all other chemical reagents for use in that field of science, and is perfectly innocuous in itself.

Weighing these facts with the results now widely known to attend the use of 'Sanitas' fluid and oil in the treatment of wounds and as disinfectants generally by medical men, I do not hesitate to say that all the claims which I originally made, some years ago, in respect of these agents, have been fully justified, and that by their discovery and introduction I provided for a long-felt want. They are typically excellent disinfectants, destructive alike of micro-organisms and of the soluble zymases to which they give rise. Moreover, they alone, of all substances available for use, possess those other properties which the highest authorities admit to be necessary for the general use of a disinfectant. In the Thirteenth Annual Report of the Local Government Board, 1883 to 1884, Professor Burdon Sanderson writes as follows:

'Nor must it be forgotten that, even after the labour of discovery has been got through, and we have joyfully cried Ευρηκα, what are called practical difficulties are sure to come in of such a kind as to render our achievements in a utilitarian sense fruitless. *For an antidote against infection to be of real value, it must be readily procurable, free from poisonous action, and have such physiological relations to the organism that it is capable of remaining* *in it sufficiently long to exercise its restraining influence on the process which it is intended to counteract. To discover such an agent is indeed a problem of difficulty.'*

I have italicised Professor Burdon Sanderson's words as specially worthy of attention, but I venture to assert that the discovery for which he was then looking had been already made. Not only is 'Sanitas' fluid a natural disinfectant and a mild oxidising agent capable of readily giving off oxygen when and where required, but it is also as well qualified by its non-poisonous nature for internal administration as for external application, and so it can be used for the treatment of all infectious diseases which are located in the human body, such as cholera, typhoid fever, dysentery, ulcerated bowels, and throat complaints, as also for the other contagious diseases which affect more particularly the outside surfaces of the body.

With further reference to the internal use of 'Sanitas' fluid, it may be pointed out that, although, by the experiments described in this chapter, it has been proved that 'Sanitas' interferes to some extent with the action of pepsin and presumably other digestive ferments, yet the quantity required to wholly arrest their action is considerable, and much greater than that which is sufficient to arrest the action of micro-organisms. That is to say, the amount of 'Sanitas' fluid which could be given in doses for the treatment of such diseases as cholera and enteric fever would not suffice to cause serious interference with the digestive processes.

As to the germicidal action of the 'Sanitas' preparations, the following passages are taken from a report recently made by Dr. A. B. Griffiths :*

### 'FIRST SERIES OF EXPERIMENTS.

'(*a*) Silk threads were impregnated with certain microbes, which were then immersed in "Sanitas" oil. The results were as follows :

*Bacillus tuberculosis* (microbe of consumption)
was destroyed in exposure of 25 seconds.
*Micrococcus scarlatinæ* (microbe of scarlet fever)
was destroyed in exposure of 10 „
*Bacillus typhosus* (microbe of typhoid fever)
was destroyed in exposure of 30 „
*Spirillum choleræ Asiaticæ* (microbe of cholera)
was destroyed in exposure of 43 „
*Bacillus diphtheriæ* (microbe of diphtheria)
was destroyed in exposure of 28 „
*Bacillus mallei* (microbe of glanders)
was destroyed in exposure of 25 „

The destruction in each case was proved by inoculating tubes containing various nourishing media, but no growths made their appearance in any of the tubes after the lapse of several weeks' incubation at

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* 'A Report on certain Experiments undertaken to ascertain the Disinfecting and Germicidal Power of "Sanitas" Preparations and Appliances,' by A. B. Griffiths, Ph.D., F.R.S. (Edin.), F.C.S. (Member of the Chemical Societies of Paris and St. Petersburg, Author of 'A Manual of Bacteriology,' 'Researches on Micro-Organisms,' 'The Physiology of the Invertebrata,' etc.), published by The 'Sanitas' Co., Lim., Bethnal Green, London, E.

the temperatures most suitable for the growth of each of the above-mentioned microbes. Besides, several of the silk threads after the exposures, were washed with a small quantity of sterilized water, and a few drops of each fluid were used in inoculating suitable animals, but with negative results; that is to say, the respective diseases were not produced in these animals. These experiments prove that "Sanitas" oil is a powerful germicide.

'(*b*) Silk threads were impregnated with the same microbes, which were then immersed in "Sanitas" fluid. The results were as follows:

| | | | | | |
|---|---|---|---|---|---|
| *Bacillus tuberculosis* | was destroyed | in exposure | of | 5 | minutes. |
| *Micrococcus scarlatinæ* | ,, | ,, | ,, | 2½ | ,, |
| *Bacillus typhosus* | ,, | ,, | ,, | 5½ | ,, |
| *Spirillum choleræ Asiaticæ* | ,, | ,, | ,, | 6 | ,, |
| *Bacillus diphtheriæ* | ,, | ,, | ,, | 4½ | ,, |
| *Bacillus mallei* | ,, | ,, | ,, | 4 | ,, |

'The following results were obtained with "Sanitas" fluid of 50 per cent. strength:

| | | | | | |
|---|---|---|---|---|---|
| *Bacillus tuberculosis* | was destroyed | in exposure | of | 9 | minutes. |
| *Micrococcus scarlatinæ* | ,, | ,, | ,, | 6 | ,, |
| *Spirillum choleræ Asiaticæ* | ,, | ,, | ,, | 16 | ,, |
| *Bacillus typhosus* | ,, | ,, | ,, | 12 | ,, |
| *Bacillus diphtheriæ* | ,, | ,, | ,, | 10 | ,, |
| *Bacillus mallei* | ,, | ,, | ,, | 9 | ,, |

And with "Sanitas" fluid of 25 per cent. strength the following results were obtained:

| | | | | | |
|---|---|---|---|---|---|
| *Bacillus tuberculosis* | was destroyed | in exposure | of | 22 | minutes. |
| *Micrococcus scarlatinæ* | ,, | ,, | ,, | 20 | ,, |
| *Bacillus typhosus* | ,, | ,, | ,, | 30 | ,, |
| *Spirillum choleræ Asiaticæ* | ,, | ,, | ,, | 40 | ,, |
| *Bacillus diphtheriæ* | ,, | ,, | ,, | 25 | ,, |
| *Bacillus mallei* | ,, | ,, | ,, | 25 | ,, |

'(*c*) Silk threads were impregnated with the same microbes as in the previous experiments, which were then immersed in "Sanitas" emulsion mixed with an equal bulk of water (= 25 per cent. "Sanitas" oil). and the following results obtained :

| | | | | | |
|---|---|---|---|---|---|
| *Bacillus tuberculosis* | was destroyed | in exposure | of | 4 | minutes. |
| *Micrococcus scarlatinæ* | ,, | ,, | ,, | 2 | ,, |
| *Bacillus typhosus* | ,, | ,, | ,, | 7 | ,, |
| *Spirillum choleræ Asiaticæ* | ,, | ,, | ,, | 8 | ,, |
| *Bacillus diphtheriæ* | ,, | ,, | ,, | 2¾ | ,, |
| *Bacillus mallei* | ,, | ,, | ,, | 3 | ,, |

'The destruction of the microbes in each case was proved by the methods already described in this report.

'These experiments undoubtedly prove that the "Sanitas" preparations are germicides of great power, as they readily destroy some of the most deadly microbes which attack men and animals.

### 'SECOND SERIES OF EXPERIMENTS.

'In the second series of experiments "Sanitas" oil and "Sanitas" fluid were added to various tubes containing pure cultivations of the six pathogenic microbes already mentioned in this report.

### '(*a*) *With "Sanitas" Oil.*

'*Diphtheria.*—Eight tubes, each containing 100 cc. of nutrient gelatine, were inoculated with *Bacillus diphtheriæ* from pure subcultures of the microbe; and after three weeks' incubation at 20° C. ½ cc. of "Sanitas" oil was added to each tube, and the incubation continued for four days. It was proved that the "Sanitas" oil had destroyed the microbes in each of the tubes, because no further growths could be obtained by inoculating a large number of tubes containing sterilized nutrient gelatine, with the contents of the tubes in question. Moreover, a few inoculation experiments were made on animals susceptible to diphtheria with the contents of the said tubes, but with negative results.

'Four tubes, each containing 100 cc. of alkaline bouillon (*i.e.*, a fluid medium), were inoculated with *Bacillus diphtheriæ* from pure subcultures of the microbe, and after three days' incubation ½ cc. of "Sanitas" oil was added to each tube, and the incubation continued for two days. It was subsequently proved that the "Sanitas" oil had destroyed the microbes in each tube.

'*Tuberculosis.*—Four tubes, each containing 100 cc. of solid blood serum, were inoculated with *Bacillus tuberculosis* from pure subcultures of the microbe; and after twelve days' incubation at 37° C. 1 cc. of "Sanitas" oil was added to each tube, and the incubation continued for six days. But in each tube the tubercle bacilli were completely destroyed.

'*Glanders.*—Six tubes, each containing 100 cc. of solid blood serum, were inoculated with *Bacillus mallei* from pure subcultures of the microbe; and after three days' incubation at 38° C. ½ cc. of "Sanitas" oil was added to each tube, and the incubation continued for a week. But in each tube the bacilli were destroyed.

'*Cholera.*—Ten tubes, each containing 100 cc. of bouillon (slightly alkaline), were inoculated with *Spirillum choleræ Asiaticæ* (Koch's microbe) from pure subcultures of the microbe; and after four days' incubation 1 cc. of "Sanitas" oil was added to each tube, and the incubation continued for five days. But in each case the microbes had succumbed to the action of the germicide. It was further demonstrated that it is quite impossible to inoculate gelatine plates (*i.e.*, plate cultivations) containing 1 per cent. of "Sanitas" oil with the microbe of cholera; although when the "Sanitas" oil was absent, the microbes gave rise to colonies on the surface of the gelatine.

'*Typhoid Fever.*—Four tubes, each containing 100 cc. of nutrient gelatine, were inoculated with *Bacillus typhosus* from pure subcultures of the microbe; and after three days' incubation 1 cc. of "Sanitas" oil was added to each tube, and the incubation continued for six days. But in each tube the microbes were completely destroyed.

'The $\frac{1}{10}$ cc. of "Sanitas" oil in 100 cc. of bouillon was, however, incapable of destroying the microbe of typhoid fever; but 1 cc. of the oil in 100 cc. of bouillon prevented the development of the microbe, or, in other words, destroyed its vitality.

'*Scarlet Fever.*—Six tubes, each containing 100 cc. of nutrient gelatine, were inoculated with *Micrococcus scarlatinæ* from pure subcultures of the microbe; and after ten days' incubation at 18° C. $\frac{1}{2}$ cc. of "Sanitas" oil was added to each tube, and the incubation continued for a week. But in each tube the microbes were completely destroyed. The same result was obtained when $\frac{1}{2}$ cc. of "Sanitas" oil was added to pure cultivations of the microbe of scarlet fever in alkaline bouillon and milk (100 cc. of each).

### '(b) *With "Sanitas" Fluid.*

'*Diphtheria.*—Three tubes, each containing 90 cc. of alkaline bouillon; three tubes, each containing 95 cc. of alkaline bouillon; and three tubes, each containing 98 cc. of alkaline bouillon, were inoculated with *Bacillus diphtheriæ,* and after five days' incubation, 10 cc. of "Sanitas" fluid were added to each of the first three tubes, 5 cc. of "Sanitas" fluid to each of the second three tubes, and 2 cc. of "Sanitas" fluid were added to each of the third three tubes. In each case the incubation was continued for three weeks. In the tubes containing 10 per cent. of "Sanitas" fluid the microbes were completely destroyed. In two out of the three tubes containing 5 per cent. of "Sanitas" fluid the microbes succumbed to the action of the fluid; but in the third tube the vitality of the microbes was impaired but not destroyed, because, after inoculating various nourishing media with the contents of the said tube, growths of *Bacillus diphtheriæ* made their appearance. In the tubes containing only 2 per cent. of "Sanitas" fluid the microbes resisted the action of the fluid—in other words, they were not destroyed.

'Similar experiments were performed on the microbes of tuberculosis, glanders, typhoid fever, cholera and scarlet fever, and in each case 10 cc. of "Sanitas" fluid added to the nourishing media (90 cc. in each case) completely destroyed the said microbes. In the experiments with only 5 per cent. of "Sanitas" fluid all the microbes resisted its action except the microbe of scarlet fever (*Micrococcus scarlatinæ*), which succumbed; and finally, in the experiments with 2 per cent., only, of "Sanitas" fluid, all the microbes, without exception, resisted the action of the fluid.

'The destruction of the microbes in each case (in both series of experiments) was proved by experiments upon animals. These experiments were performed abroad.

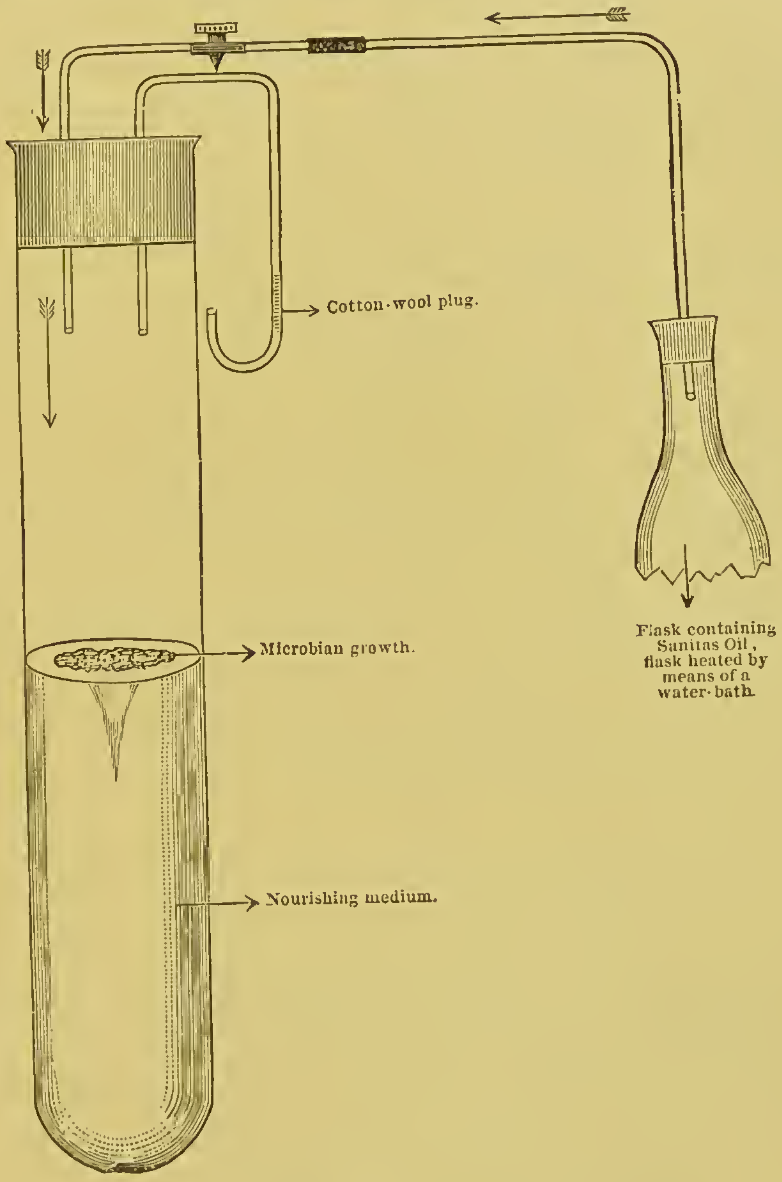
### 'THIRD SERIES OF EXPERIMENTS.

'The *vapour* of "Sanitas" oil has a most destructive action on pathogenic microbes. A flask containing the oil was placed in a water-bath heated to 100° C., and the vapour passed into cultivation tubes containing various microbes (the figure on p. 445 illustrates the apparatus used).

'By using this apparatus, the vapour of "Sanitas" oil destroyed:

| | | | |
|---|---|---|---|
| A. *Bacillus tuberculosis* . . . | in from 7 | to 10 | minutes. |
| B. *Bacillus diphtheriæ* . . . | ,, 5 | ,, 8 | ,, |
| C. *Bacillus typhosus* . . . . | ,, 6 | ,, 8 | ,, |
| D. *Bacillus mallei* . . . . . | ,, 7 | ,, 10 | ,, |
| E. *Spirillum choleræ Asiaticæ* . | ,, 10 | ,, 15 | ,, |
| F. *Micrococcus scarlatinæ* . . . | ,, 4 | ,, 6 | ,, |

'There is no doubt that the vapour of "Sanitas" oil is a powerful germicide, and the inhalation of the vapour of the oil would be most beneficial in the treatment of diphtheria, phthisis, and other diseases of the throat and lungs.



### ‘Fourth Series of Experiments.

‘These experiments were performed in order to ascertain the *fumigating* power of the vapour of

"Sanitas" oil in ordinary dwelling-rooms. The number of microbes present in three gallons (fifteen litres) of air was ascertained by Hesse's well-known method. The figures in the following table represent the average number of microbes (colonies) in three gallons of air, *before* and *after* fumigating with the vapour of "Sanitas" oil:

| Number of Experiment. | Before Fumigating. | After Fumigating | | |
|---|---|---|---|---|
| | | 5 Minutes. | 12 Minutes. | 30 Minutes. |
| I. | 125 | 71 | 12 | 0 |
| II. | 110 | 68 | 10 | 0 |
| III. | 118 | 60 | 9 | 3 |
| IV. | 106 | 58 | 14 | 0 |

'The fumigator recommended by the Sanitas Company was used in the experiments. It is a most efficient apparatus, and should be used in every hospital and in all sick-rooms.

## 'FIFTH SERIES OF EXPERIMENTS.

'The object of these experiments was to ascertain the germicidal power of "Sanitas" fluid when *sprayed* into ordinary dwelling-rooms. As in the previous experiments, the number of microbes present in three gallons of air was ascertained by Hesse's method (see Griffiths' "Manual of Bacteriology," pp. 265-267). The figures in the following table represent the average number of microbes (colonies) in three gallons of air, *before* and *after* spraying with "Sanitas" fluid :

| Number of Experiment. | Before Spraying. | After Spraying | | |
|---|---|---|---|---|
| | | 15 Minutes. | 30 Minutes. | 55 Minutes. |
| I. | 152 | 89 | 31 | 0 |
| II. | 140 | 92 | 29 | 3 |
| III. | 110 | 78 | 20 | 2 |
| IV. | 169 | 85 | 18 | 0 |
| V. | 122 | 83 | 30 | 0 |
| VI. | 109 | 63 | 27 | 0 |

'The spray-producers sold by the Sanitas Company were used in the experiments. These experiments prove the high value of "Sanitas" fluid as a disinfectant or germicide.

## 'SIXTH SERIES OF EXPERIMENTS.

'These experiments were performed in order to ascertain the action of "Sanitas" emulsion ( = 50 per cent. of "Sanitas" oil) on the microbes in certain waters. The "Sanitas" emulsion was mixed with an equal volume of sterilised water ; consequently the mixture contained 25 per cent. of oil. The number of microbes present in 1 cc. of the sample of water was ascertained by Koch's method, or the plate-cultivation process. The figures in the following table represent the average number of microbes (colonies) in each cc. of the sample of water *before* and *after* adding the "Sanitas" emulsion (strength = 25 per cent.):

| Water from | Before. | After adding | |
|---|---|---|---|
| | | 0·5 cc. of Emulsion. | 1 cc. of Emulsion. |
| River Thames . . . . . . . . | 11,200 | 60 | 0 |
| „ Lea . . . . . . . . . . | 7,892 | 41 | 0 |
| „ Seine . . . . . . . . . | 15,630 | 79 | 2 |

'These experiments prove the high disinfecting power of the "Sanitas" emulsion.

### 'SEVENTH SERIES OF EXPERIMENTS.

'I have extracted a number of highly poisonous ptomaines, animal alkaloids, or toxines, from urine in certain infectious diseases (see Griffiths' papers in the *Comptes Rendus de l'Académie des Sciences*, Paris, tomes 113-115); and several of these ptomaines have also been obtained from pure cultivations of the microbes which give rise to certain diseases.

'This series of experiments was undertaken to ascertain the action of "Sanitas" oil and "Sanitas" fluid on these poisonous ptomaines. It is essential in the treatment of infectious diseases, as pointed out in the opening remarks, that not only the pathogenic microbes should be destroyed, but also the poisonous substances (ptomaines) which they indirectly produce.

'*Scarlatinine* ($C_5H_{12}NO_4$) is the poisonous ptomaine of scarlet fever, as it is always present in the urine of patients suffering from that disease; and it is also produced in pure cultivations of *Micrococcus scarlatinæ.* One tenth of a cubic centimetre of "Sanitas" oil completely destroyed 0·76 grm. of scarlatinine; the products of oxidation, being non-poisonous, may readily be taken into the system with impunity.

'*Diphtherine* ($C_{14}H_{17}N_2O_6$) is the ptomaine of diphtheria. It is present in the urine of patients suffering from that disease, and is also produced in pure cultivations of *Bacillus diphtheriæ.* It is very poisonous, but is completely destroyed and rendered inert by the action of "Sanitas" oil and "Sanitas" fluid.

'*Propylglycocyamine* ($C_6H_{13}N_3O_2$) is the ptomaine of parotitis (mumps). It is very poisonous, and when administered to a cat it produced nervous excitement, cessation of the salivary flow, convulsions, and death. But the action of "Sanitas" oil and "Sanitas" fluid rendered it inert.

'*Glycocyamidine* ($C_3H_5N_3O$) is the ptomaine of measles. It is poisonous, and when administered to animals it causes death in from twenty-four to thirty-six hours. "Sanitas" oil and "Sanitas" fluid both destroy this ptomaine, and the products formed, due to the action of these powerful oxidising agents, are perfectly harmless.

'*Glanders.*—The ptomaine ($C_{15}H_{10}N_2O_6$) of this disease is very poisonous. A solution of it injected under the skin of a rabbit produced an abscess at the point of the injection, nodules in the lungs and other organs, and finally death. But this ptomaine (which is also produced by the microbe of glanders in pure cultivations) is destroyed or oxidised by "Sanitas" oil and "Sanitas" fluid. There is no doubt that "Sanitas" preparations would be of the highest value in the treatment of glanders and other infectious diseases.

'*Pneumonia.*—The poisonous ptomaine ($C_{20}H_{26}N_2O_3$) of pneumonia is also destroyed and rendered inert by the action of "Sanitas" oil and "Sanitas" fluid.

'*Erysipeline* ($C_{11}H_{13}NO_3$).—This ptomaine of erysipelas is very poisonous, producing high fever and death within eighteen hours. It is readily destroyed by the "Sanitas" preparations.

'*Puerperaline* ($C_{22}H_{19}NO_2$) is the poisonous ptomaine of puerperal fever. "Sanitas" oil and "Sanitas" fluid completely destroy this ptomaine. Pasteur states that "the antiseptic treatment ought to be infallible in preventing puerperal fever from declaring itself. The employment of carbolic acid may be of great service, but its odour, and often the melancholy association of ideas which it awakens, might render it unsuitable for women in labour." There is, however, not the same objection to "Sanitas" fluid, which I can conscientiously recommend for the purpose. It not only destroys the microbes of disease, but also the poisonous ptomaines, which are so readily absorbed into the system.

'In each of the above cases the innoxious nature of the products formed by the action of the "Sanitas" preparations on the ptomaines was proved by experiments on animals; such experiments were performed abroad.

'My investigations prove that the "Sanitas" preparations are most valuable disinfectants or germicides.'

Later, Dr. Griffiths made a similar investigation concerning the microbe believed to be associated with the production of influenza, and has reported as follows :*

'It may be mentioned that Drs. Pfeiffer, Kitasato, and Canon discovered the influenza bacillus. It was in the saliva and the bronchial discharges characteristic of influenza. In the saliva of influenza patients, the bacilli were found in large numbers ; they may penetrate from the pus cells into the tissue of the lungs, and even pass as far as the surface of the pleura. This fact explains the rapidity and fatality of lung complications in influenza. The same bacillus was also found in the blood of patients suffering from the disease. The knowledge that a bacillus residing in the saliva, etc., causes influenza, will not stop an epidemic ; but the prompt and practical application of this knowledge by complete disinfection of all bronchial and nasal secretions, and the isolation of influenza patients, will arrest the plague.

'In addition to the microbe of influenza, it may be stated that Mr. R. S. Ladell and myself have recently isolated the poisonous ptomaine of influenza (see *Comptes Rendus de l'Académie des Sciences*, Paris, tome 117, and *Chemical News*, vol. lxviii., p. 294).

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* 'A Report on certain Experiments undertaken to ascertain the Action of "Sanitas" Preparations on the Microbe and Ptomaine of Influenza,' by A. B. Griffiths, Ph.D., F.R.S. (Edin.), F.C.S., Member of the Chemical Societies of Paris and St. Petersburg, Author of 'A Manual of Bacteriology,' 'Researches on Micro-Organisms,' etc. Published by the Sanitas Co., Limited, Bethnal Green, London, E.

### ‘FIRST SERIES OF EXPERIMENTS.

‘(*a*) Silk threads were impregnated with the microbe of influenza, which were then immersed in “Sanitas” oil, with the result that the microbe was destroyed in twenty seconds.

‘(*b*) Silk threads were impregnated with the same microbe, which were then immersed in “Sanitas” fluid, with the result that the microbe was destroyed in six minutes. With “Sanitas” fluid of 50 per cent. strength, the microbe was destroyed in fifteen minutes, and with “Sanitas” fluid of 10 per cent. strength, the microbe was destroyed in fifty-six minutes.

‘(*c*) Silk threads were impregnated with the microbe of influenza, which were then immersed in “Sanitas” eucalyptus oil, with the result that the microbe was destroyed in sixteen minutes.

### ‘SECOND SERIES OF EXPERIMENTS.

‘2 cc. of “Sanitas” oil, “Sanitas” fluid (of 100, 50, and 10 per cent. strength), and “Sanitas” eucalyptus oil respectively, were separately added to a number of tubes containing pure cultivations (90 cc.) of the influenza microbe; and in each case the tubes were rendered sterile, or, in other words, the microbe was destroyed.

‘The destruction of the microbes in both series of experiments was proved by no growths making their appearance in nourishing media, as well as by other well-known bacteriological methods.

### 'THIRD SERIES OF EXPERIMENTS.

'The *vapours* of "Sanitas" oil and "Sanitas" eucalyptus oil were proved to have a most destructive action on the microbe of influenza, the microbe being destroyed in from six to ten minutes. There can be no doubt that the inhalation of the vapours of "Sanitas" oil and "Sanitas" eucalyptus oil would be most beneficial in the treatment of influenza.

### 'FOURTH SERIES OF EXPERIMENTS.

'The poisonous ptomaine ($C_9H_9NO_4$) which occurs in the urine of patients suffering from influenza, was readily destroyed by "Sanitas" oil, "Sanitas" fluid (even when diluted to the extent of one part in 250 parts of water), and "Sanitas" eucalyptus oil. After the action of each fluid, the characteristic tests failed to prove the presence of the smallest trace of the ptomaine; and products of oxidation, being non-poisonous, were taken into the system with impunity.

'*Remarks.*—From the above results, it is evident that the "Sanitas" preparations will prove useful in the prevention and treatment, etc., of influenza, as they readily destroy both the microbe and ptomaine of this disease.'

Some observations respecting the germicidal powers of the 'Sanitas' disinfecting fluids have also been published* by J. E. Weeks, M.D. (late instructor in

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* See *New York Medical Record*, August 3rd, 1889.

bacteriology at the New York Post-graduate School). He experimented with the *Staphylococcus pyogenes aureus* and the typhoid bacillus, and found that

| | | | | | |
|---|---|---|---|---|---|
| 'Sanitas' oil | destroyed | their vitality in | exposures of | 20 | seconds |
| 'Sanitas' crude fluid | ,, | ,, | ,, | 1½ | minutes |
| 'Sanitas' fluid | ,, | ,, | ,, | 4 | ,, |
| 'Sanitas' fluid of 50 % strength | | ,, | ,, | 10 | ,, |

and he classes these liquids very high among the most effective germicides.

Summarising the evidence concerning the properties of the 'Sanitas' preparations which has been adduced in this chapter, it has been shown (1) that these products were the outcome of a strictly scientific investigation, and really embody the healthful principles which are generated naturally by pine and eucalyptus forests; (2) that their individual constituents are all possessed of antiseptic or oxidising properties; (3) that their collective constituents have well-marked characters as chemical antiseptics, thereby inhibiting the processes which bacteria are otherwise capable of initiating; and (4) that they are powerful germicides, and therefore act destructively on micro-organisms generally.

# CHAPTER XV.

## EUCALYPTUS, PINE, AND CAMPHOR FORESTS; THEIR EXTENT, DISTRIBUTION, AND HYGIENIC INFLUENCES, AND AN ACCOUNT OF THE INDUSTRIES CONNECTED WITH THEM.

I HAVE shown that for all practical purposes, most of the so-called essential oils, of which there are a great number, may be considered as identical in chemical composition. So that what has been demonstrated to be true regarding the changes induced by bringing air into contact with oil of turpentine and water, is also true of oil of eucalyptus, and, as I have more lately ascertained, of camphor oil too.* This is not merely a matter of inference, but one of fact, for I have not only examined the absorptive power of these oils for oxygen, but also determined the fact that peroxide of hydrogen and soluble camphor ($C_{10}H_{16}O_3$) appear as products of the reaction when it is conducted in the presence of water.

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* Messrs. Faust and Homeyer (*Deut. Chem. Ges. Ber.*, vii., pp. 63-66, and pp. 1429-1430) have shown oil of eucalyptus to consist mainly of terpene ($C_{10}H_{16}$) and cymene ($C_{10}H_{14}$). The oil of eucalyptus also contains an oxidised body, $C_{10}H_{14}O$, or $C_{10}H_{16}O$.

It has also been shown that the sanitary properties of pine, eucalyptus, and camphor forests are undoubtedly due, chiefly, at any rate, to the production in and around them of the products of the atmospheric oxidation of their essential oils conducted in the presence of moisture. The intensity of the process is materially enhanced by the aid of direct sunlight.

In addition to the facts already brought forward in support of this view, and of the further elucidation which follows hereafter, there is a fair amount of what may be called negative evidence. In the first place, other fast-growing trees do not possess, so far as is known, the power of freeing vast tracts of country from malarial fever ; hence, this property cannot be due to the mere drainage of the soil. Then, again, both pine woods and eucalyptus groves are to be found in abundance upon hilly slopes and in mountainous districts, where there can be no waterlogging of the soil ; and there the hygienic influence of these trees is felt just as much as in other places. The positive evidence is no doubt, however, the most important ; and having already made ourselves acquainted with its nature, we may now proceed to study its extent.

In a lecture* on the *Eucalyptus globulus*, the late Professor Bentley, who made a special study of this tree, and the other members of the same genus, said :

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* *Pharm. Journ.*, May 4th, 1878. Professor Bentley's former lecture was delivered on March 14th, 1874, and printed by order. (Taylor and Francis, 1874.)

'Four years ago, I stated my reasons for believing that the emanations from the leaves of groves of eucalyptus had some influence in destroying marshy miasms, and thus improving the healthiness of the district. Since then the very interesting researches of Kingzett have proved that under the influence of air and moisture, both peroxide of hydrogen and camphoric acid* are formed from volatile oils—the former a powerful disinfectant, and the latter an antiseptic ; and hence I think there can now be no doubt that the healthy influence of eucalyptus-trees is, to some extent at least, and probably more than we imagine, due to the volatile emanations from the leaves under the influence of air and moisture, possessing direct disinfectant and antiseptic properties, and thus destroying the injurious effects of paludal miasms.'

In view of the proofs that have been adduced in previous chapters, we may now go even further than this, and say that if not entirely, then at least mainly, the hygienic influences of eucalyptus, pine, and camphor trees are to be attributed to the products of the air-oxidation of their naturally-generated essential oils.

## *The Eucalyptus.*

The word 'eucalyptus' is derived from *eu*, 'well,' and *kalypto*, 'to cover,' and is aptly chosen.

The *Eucalyptus globulus* belongs to the order

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* This should be read as 'soluble camphor' ($C_{10}H_{16}O_3$), not as camphoric acid.

*Myrtaceæ*, which furnishes clove, oil of cajeput, and the pimento. The oil smells like oil of cajeput, and has a mint-like taste. It boils at 144°—177° C., and its Sp. Gr. is 0·917.

*Eucalyptus amygdalina.* The oil from this species is pale yellow, and has a camphoraceous lemon-like odour of a pungent nature. It boils at 165° C., and resinifies on exposure to the air. Sp. Gr. 0·881.

*Eucalyptus oleosa.* The oil has a camphoraceous odour, reminding at once of mint and turpentine. It boils at 161°—177° C. Sp. Gr. 0·911.

*Eucalyptus sideroxylon.* The oil boils at 161°—177° C. Sp. Gr. 0·923.

*Eucalyptus goniocalyx.* The oil boils at 152°—175° C., and has a very penetrating odour and pungent bitter taste.

*Eucalyptus obliqua.* Its oil boils at 171°—185° C. Sp. Gr. 0·899.

*Eucalyptus odorata.* The oil has a very aromatic odour. It boils at 157°—199° C. Sp. Gr. 899—922.

*Eucalyptus rostrata.* The oil is very much like *odorata* oil in odour and taste. It boils at 131°—181° C. Sp. Gr. 0·918.

*Eucalyptus citriodora.* The oil has a variable boiling-point and a Sp. Gr. 0·868.

*Eucalyptus corymboza.* The oil boils at 174°—199° C., and its Sp. Gr. is 0·880.

*Eucalyptus dumoso.* The boiling-point of this oil is also said to be variable. Its Sp. Gr. is 0·931.

*Eucalyptus fissilis.* Sp. Gr. of oil 0·936.

*Eucalyptus longifolia.* The oil boils at 195°—214° C., and its Sp. Gr. is 0·942.

*Eucalyptus viminalis.* The oil boils at 167°—178° C., and its Sp. Gr. is 0·925.

*Eucalyptus mannifera* yields the peculiar sweet exudation known as Australian manna.[*]

Writing of the foliage of the *Eucalyptus globulus*, Mr. H. N. Draper says[†] it is unlike anything seen in these islands. 'It is pendulous, quivering, and evergreen; and the peculiar whitish appearance of one side of the leaves—due to a fatty or resinous secretion—is very characteristic. Till the tree is from three to five years old, the leaves grow horizontally, but afterwards they assume a pendent position. Instead of having one of their surfaces towards the sky and the other towards the earth, they are often placed with their edges in these directions, so that each side is equally exposed to the light.' It has also been suggested that this arrangement of the leaves may have something to do with the large amount of water which these trees exhale into the atmosphere. M. Vallée has shown that a square yard of the leaves of the *Eucalyptus globulus*, weighing about 2¾ lbs., gives off four pints (5 lbs.) in twelve hours. This rapid evaporation of water is greatly assisted by the very numerous *stomata* or breathing spores that exist on the under surface of the leaves. Each leaf possesses 350 of these *stomata*.

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[*] See paper in *Zeitschr. des œsterr. Apoth. Ver.*, 1878, 402; and *Pharm. Zeitung*, 1879, 220.

[†] *Chambers' Journal*, March 26th, 1881.

The flowers resemble those of the myrtle. As for the seeds of the tree, which are contained in the fruit, they are very minute, and it is said that 160,000 plants can be raised from a single pound weight of them.

The eucalyptus sheds its bark annually, but as this does not take place at one given time of the year, the trunks always present a rough and ragged appearance.

In Australia, the *Eucalyptus globulus* commonly attains a girth of 16 to 80 feet, and a height of from 160 to 200 feet, and there are records of trees even 420 feet in height. Such gigantic members are often found without a branch, the tops being capped with radiating branches full of foliage.*

The oils of eucalyptus, as obtained from the different species, of which there are more than 135, are, to a large extent, of the same composition, although the odour, which is generally rich and camphoraceous, varies a good deal. The oil is chiefly stored in the pellucid glands which spread throughout the leaves, and which may readily be seen by holding up the leaves to the light. It is, however, to be found more or less throughout the tree.

The following table expresses the results of an examination of some twenty-four samples made by R. H. Davies, F.I.C., and T. H. Pearmain :†

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* *Pharm. Journ.*, vol. xvii., p. 13.

† Communicated to the British Pharmaceutical Conference in 1891. See *Chemist and Druggist*, August 22nd, 1891, p. 293; also *Pharm. Journ.*, vol. xxii., p. 235, and vol. xxiii., p. 205.

|  | Specific Gravity. | Specific Rotation. | Solubility of Salicylic Acid. | Phellandrene Reaction. | Solubility in Rectified Spirit. | Acidity as Acetic Acid. |
|---|---|---|---|---|---|---|
|  |  |  | Acid. Oil. |  | Oil. Spirit. | % |
| Average of all the samples | ·9015 | −12°·15 | 1 to 7·6 | — | — | 0·09 |
| Lowest ,, ,, ,, | ·8575 | −64°·72 | 1 ,, 3·0 | — | 5 in 1 | 0·02 |
| Highest ,, ,, ,, | ·927 | +18°·09 | 1 ,, 17·6 | — | 5 ,, 50+ | 0·23 |
| Average of 'heavy' class . | ·9125 | +2°·65 | 1 ,, 4·65 | Phellandrene absent | 3·3 ,, 1 | 0·11 |
| Lowest ,, ,, ,, . | ·8994 | −19°·23 | 1 ,, 3·0 |  | 5 ,, 1 | 0·02 |
| Highest ,, ,, ,, . | ·927 | +18°·09 | 1 ,, 8·3 |  | 2 ,, 1 | 0·23 |
| Average of 'light' class . | ·8721 | −53°·26 | 1 ,, 12·8 | Phellandrene present | — | 0·06 |
| Lowest ,, ,, ,, . | ·8575 | −64°·72 | 1 ,, 7·6 |  | 2 ,, 1 | 0·02 |
| Highest ,, ,, ,, . | ·8848 | −40°·20 | 1 ,, 17·6 |  | 4 ,, 50+ | 0·09 |

These results give support to the general conclusions of MacEwan, Squire, and others, that there are two more or less distinct classes of commercial eucalyptus oils, which may be termed respectively the 'heavy' and 'light.' The authors concluded, from their examination, that the oil of *Eucalyptus amygdalina* is the only commercial one that contains phellandrene.

When sodium nitrite is added to a solution of oil of eucalyptus in glacial acetic acid, a solid nitrite is formed if phellandrene be present, and of the samples with which they experimented, the *amygdalina* oil was the only one that gave this reaction. The authors also examined their samples with the view of determining approximately the amount of eucalyptol present in each. That substance (which is said to be identical with cineol and cajuputol) boils at 176° C. to 177° C., is without optical activity, and solidifies when cooled in a freezing mixture.

The amount of the fractions coming over in the distillation of seven oils selected by the authors at from 170° to 175°, and from 175° to 180°, are given in the next table :

| | E. globulus. | | | E. odorata. | E. oleosa. | E. amygdalina. | E. dumosa. |
|---|---|---|---|---|---|---|---|
| Percentage of fraction 170°—175° . | 38·2 | 28·8 | 20·0 | 29·6 | 38·0 | 33·0 | 41·4 |
| Rotation (100 mm.) | +17°·63 | —2°·36 | +4°·70 | +16°·96 | +1°·56 | —43°·5 | +7°·05 |
| Percentage of fraction 175°—180° . | 21·0 | 9·8 | 18·0 | 26·6 | 27·4 | 22·6 | 22·4 |
| Rotation (100 mm.) | +16°·76 | —1°·70 | +2°·66 | +17°·0 | +2°·01 | −43°·06 | +4°·5 |

These results can only be regarded as approximate, because the authors did not actually isolate and weigh the eucalyptol from each sample of oil, but only measured the fraction in which it should be contained if present.

It is frequently assumed that the medicinal value of the oils of eucalyptus depends upon the amount of eucalyptol which is contained therein, but there is absolutely no acceptable evidence of the correctness of this view, and I regard it as incorrect. Eucalyptol may be a valuable constituent, but I see no reason why the hydrocarbon portion of the oils and the other oxidised constituents should not be equally, or even more, valuable. It is far better to regard the matter as quite undecided, and to keep an open view of the subject. In any case, I am sure that the sanitary properties, and, therefore, probably the medicinal virtues, of these oils are, to a considerable extent, dependent upon the hydrocarbon (terpene) constituents, because it is from their oxidation in the presence of moisture that the peroxide of hydrogen which results from that process is derived.

In a further contribution* to the chemistry of eucalyptus oils, Davies and Pearmain obtained eucalyptol from the oils of *E. oleosa*, *E. dumosa*, and *E. globulus.* This substance was found to have a boiling-point of 174·5° C., and a melting-point of 0° C. to 0·5° C.; its specific gravity at 16° C. was determined at 0·927, which is the same as that of cineol.

M. Cloez found† that ten kilos of fresh leaves, taken from the branches of a eucalyptus (species not named) which was killed by frost at the end of 1867, furnished by distillation with water 275 grms., or 2·5 per cent. by weight of oil. In another experiment (species again not named) eight kilos of dry leaves, gathered at Hyères, gave, after keeping them one month, 489 grms., or 6 per cent.† From completely dry leaves, which had been kept five years, he obtained only 1·5 per cent. of oil.

The percentages given in the following table,‡ representing the amount of oil contained in the foliage of different species of the eucalyptus, were, for the most part, determined by Mr. Bosisto for the exhibition of 1862:

| | |
|---|---|
| Eucalyptus amygdalina (or narrow-leaved peppermint tree) | 3·313 |
| ,, oleosa | 1·250 |
| ,, leucoxylon | 1·060 |
| ,, goniocalyx | 0·914 |
| ,, globulus (or blue gum-tree) | 0·719 |
| ,, obliqua (or stringy bark-tree) | 0·500 |

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* *Chem. News*, vol. xxvi., p. 63.

† Probably from *Eucalyptus amygdalina*, judging from the quantity.

‡ See *Chem. News*, vol. xxxix., p. 169.

The next table is compiled from the paper of M. Raveret-Wattel,[*] quoted in a previous chapter :

| | |
|---|---|
| Eucalyptus amygdalina | 5·75 |
| ,, oleosa | 1·25 |
| ,, sideroxylon | 1·00 |
| ,, goniocalyx | 1·00 |
| ,, fabrorum | 0·50 |
| ,, woolsii | 0·18 |
| ,, rostrata (or red gum-tree) | 0·06 |

It is thus seen that, although the *Eucalyptus globulus* is the best-known species, being a favourite on account of the rapidity of its growth and the luxuriance of its foliage, it is by no means one of the richest oil-yielding trees ; and as Baron Ferdinand von Mueller (Director of the Victorian Botanical Department, Melbourne) therefore thinks, this species is not so important from a sanitary point of view as some of the others. Indeed, Mr. R. D. Adams, who obtained his information from Baron von Mueller, writes : 'The respective hygienic value of various eucalypts may, to some extent, be judged from the percentage of oil in their foliage,' which latter also varies in quantity and quality as much as the oil.[†] Even in the same species the amount of oil varies somewhat, according to the locality and season.

*Eucalyptus rostrata,* one of the poorest in oils, grows well in periodically inundated places, and even in stagnant water which is not saline, and thus it is important for planting in malarious districts.

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[*] *Pharm. Journ.*, New Series, vol. iii., pp. 22 and 43.

[†] *Chem. News*, vol. xxxix., p. 169.

The eucalyptus is indigenous to the temperate parts of Australia and Tasmania, where the temperature ranges from 52° to 72° F. Indeed, as Mr. Bosisto has said, 'it ranges over the greater portions' of those countries, but is entirely absent from the other islands of the South, excepting a few species in New Guinea.

It is said that some species grow well in hot and others in cold climates, and thus there are eucalypts to suit the tropics of India and the more temperate regions in England. It must, however, be admitted that the English climate is, generally speaking, much too rigorous during the winter months for the young plants. Old trees could withstand these climatic influences, but the trees cannot grow old in England.

Mr. Draper had at one time twenty-five healthy saplings of the *globulus*, five years of age, of from ten to sixteen feet high, growing near Dublin, and one which was twenty-five feet high, with a stem twenty-two inches in circumference; but though he kept them during four ordinary winters, they were all killed by the very cold weather experienced in the winter of 1878-79.

At Tre Fontane, Mr. Draper, who has personally visited the place, says there are cultivated at least eleven varieties, some of which, such as the *E. viminalis* and *E. botryoïdes*, do best in humid ground, whereas *E. resinifera* and *E. meliodora* flourish best in a dry soil; the *globulus*, however, will adapt itself well to all sorts of conditions.

In a lecture on 'Forest Culture,'[*] Baron von Mueller stated that Mr. Bosisto, a citizen of Melbourne, was then largely exporting the oil of eucalyptus, and was producing about 700 lbs. a month. Since then, Mr. Bosisto, who has most industriously pursued this business, has given much further attention to the hygienic value of the eucalyptus. He became convinced that its properties have some connection with the essential oil, and set himself to ascertain what he could about the quantity of oil and its probable sanitary effects, supposing it gets into the atmosphere through evaporation aided by warm winds. He writes:[†] 'The evidence of oil evaporation might thus be stated—that the desert scrub gums, after a winter of average rainfall, supplied the air with a continuous and even quantity of aromatic vapour, and kept up a rigorous vitality throughout the summer, and that a short season of rain and a long dry summer diminished the formation of oil, and so lessened the exhalation; but, on the other hand, the species tending seaward increased their quantity after a short winter.'

It is said that sometimes the aroma of the volatile oil can be detected in the atmosphere even when travelling in the bush.

It was in the year 1854 that Mr. Joseph Bosisto set up the first still for the preparation of oil of eucalyptus, since which time the industry has attained large dimensions, the factories now comprising,

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[*] *Pharm. Journ.*, New Series, vol. ii., p. 628.

[†] *Ibid.*, vol. v., p. 270.

among many others, two stills each of 5,000 gallons working capacity, and two others of 3,500 gallons. One factory is situate about thirty to forty miles east-south-east from Melbourne at a place known as 'Emerald,' where twenty-two tons of leaves are subjected to distillation every week. Another factory is between Lake Hindmarsh and the town of Dimboola, where about twenty-five tons of twigs and leaves are treated each week for the extraction of the essential oil. The stills are made of wood, duly lined, and are fitted with copper heads.

The production of eucalyptus oil as an article of commerce has become so extensive since the last edition of this work was published, that the product has almost become a mere 'drug in the market,' and its price has fallen to a comparatively low figure.

'Scrub' covers millions of acres, averaging in height not more than eight feet, and is so dense that it almost shuts out sun and sky. It is of interest to note that in one kind of scrub there is lodged in the stem about half a pint of almost pure water. Mr. Bosisto reduces the whole tribe of eucalypti to some eight types, namely :

The Viminalis, or manna-yielding eucalyptus.
The Odorata, or sweet-smelling.
The Rostrata, or red gum-tree.
The Obliqua, or stringy-bark.
The Leucoxylon, or iron-bark.
The Globulus, or blue-gum.
The Dumosa, or mallee.
The Amygdalina, or peppermint-scented eucalyptus.

These types supply from the maximum to the minimum amount of essential oil, viz., 500 fluid ounces or 25 Imperial pints to 7 fluid ounces of essence per 1,000 lbs. of fresh leaves.

As regards the wood of the eucalyptus, a test mentioned by Mr. Bosisto showed that the blue gum-tree wood carried 14 lbs. more than English oak, and 17½ lbs. more than Indian teak, to the square inch.

Now, in a previous chapter, attention has been called to the report of Mr. Skene, setting forth the distribution of eucalyptus forestry over Australia, and using these figures, Mr. Bosisto calculated that the mallee scrub in the colony of Victoria would retain in the leaves at one time no less than 4,843,873,000 gallons of oil, and the seaward species 280,891,000 gallons. In another calculation applying to the whole of New South Wales and South Australia, he showed that 96,877,440,000 gallons of oil is held continually at one and the same moment in the leaves of trees massed together, and occupying a belt of country over which the hot winds blow. In the face of these figures, few could hesitate to come to the conclusion that forced itself upon Mr. Bosisto, viz., that the eucalyptus as a fever-destroying tree owes this power to the oil which finds its way into the atmosphere.

As already stated, and as proved again and again, the oil has, of itself, certain antiseptic powers. These, however, are enormously intensified, and also become disinfectant and oxidant in character, so soon as the oil is oxidised by the atmospheric oxygen in contact with moisture. This has been explained in preceding chapters. From what is there described, it is probable that every molecule of oil of turpentine, or oil of eucalyptus, or camphor oil, gives rise in this process of oxidation to a molecule of peroxide of hydrogen, and one of the soluble camphor which has the approximate formula of $C_{10}H_{16}O_3$. Now, if this be so, then I have calculated that 96,897,440,000 gallons of eucalyptus oil can and must produce in the atmosphere surrounding the forests no less than 92,785,023 tons of peroxide of hydrogen, and about 507,587,945 tons of the soluble camphor, not to mention the other products of oxidation.

This quantity of peroxide of hydrogen is capable of oxidising a correspondingly large amount of organic vegetable matter, rendering it harmless. In this way the peroxide of hydrogen could part with nearly half its weight of nascent oxygen.

Then, again, the antiseptic powers of such an immense quantity of soluble camphor can be conceived, if we reflect that a solution containing only a few grams to the litre is sufficiently strong to preserve animal matter, almost indefinitely, free from decomposition, as demonstrated by my experiments.

I have not met with any figures showing the weight of foliage to the individual trees from which the sanitary value of a single tree could be estimated ; but there can be no doubt that the sanitary value of even a single tree must be considerable.

In view of these facts as bearing on the climate of Australia, which is stated to be the finest in the world, it is not surprising to learn* that the death-rate from phthisis there, is less than one-half that of the mother country, even including the cases of death of persons visiting that continent for the benefit of their health.

### *The Pine-tree.*

Now, what is true about the eucalyptus and its oil, is true also of the pine-tree and its turpentine, and on even a much more extensive scale. That this is so, is evident from the very great quantity of turpentine which finds its way into commerce ; and even this amount, great as it is, represents but a mere fraction of that produced in nature.

Oil of turpentine is contained in the wood, bark, leaves, and other parts of the members of the *Coniferæ*, and the method by which it is distilled from the exudations of pines and firs will be referred to hereafter.

According to Planchon,† the French oil of turpentine is produced particularly by the *Pinus maritima* and *Pinus pinaster ;* the German oil is yielded by *Pinus sylvestris*, L., *Abies pectinata*, and *A. excelsa*, DC. ; the Venetian oil is extracted from *Larix Europæa;* and the English oil is a product yielded from the American turpentines produced by *Pinus tæda*, L., and *P. Australis*, Mich.

Dr. R. Godeffroy‡ has also recorded a similar

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* *Brit. Med. Journ.*, September 24th, 1887, p. 676.

† See paper by Dr. Julius Morel, *Pharm. Journ.*, New Series, January 12th, 1878.

‡ *Pharm. Zeitung*, 1877, No. 81.

statement, and furthermore adds that the German oil is also obtained from *Pinus vulgaris*, *P. picea*, and *P. rotunda.* He says that pine cone oil (*oleum abietis pini*) is obtained by distilling with water the cones of *Abies pectinata;* dwarf pine oil by similarly distilling the young tops and cones of *Pinus pumilio*, and pine leaf oil from the leaves of *Pinus sylvestris* or *P. abies.*

The Swedish oil of turpentine (according to Morel) is obtained by distilling the wood itself; it is characterised by its odour, and by the presence of certain empyreumatic substances.

All these different oils are classified as oil of turpentine; they differ, to some extent, in their boiling-points (average 160° C.), their specific gravity and their action on polarised light, but in a more ultimate chemical sense they are identical, and merely represent so many different isomeric forms of terpene ($C_{10}H_{16}$). As produced in nature, they are accompanied with certain oxidised products, and doubtless the natural resins and gums are formed by the action of atmospheric oxygen upon the terpenes existing in the trees.

The process by which the turpentine is generally obtained from the trees consists in tapping them at regular intervals, and collecting the 'crude' or 'brute' turpentine, which constitutes a thick resinous mass, and is afterwards subjected to distillation, either with water, or steam, or otherwise.

It is certain that the hygienic influence of the pine is much greater than that of the eucalyptus, since it has a much wider and more extensive distribution in nature. Thus, Russia alone has 500,000,000 acres of forestry largely consisting of pine-trees; while, as is well known, a large industry is carried on in turpentine products yielded by the pines and firs of not only Russia, but also France, Switzerland, Germany, Sweden, and Austria. The European trade, however, is not so large as the American one, which now furnishes most of the turpentine met with in commerce.

In illustration of the extent of pine forestry in America, it is interesting to notice a remarkable shower of pollen grains which fell in the north-eastern part of Pennsylvania on the morning of March 17th, 1879, and covered an area of more than 2,500 square miles. The pollen was that of *Pinus Australis* from the Southern States, and it was believed to have been carried a distance of over 500 miles.*

Curiously enough, a similar occurrence was recorded† some years since as having been noticed at Windsor, Slough, and in that neighbourhood generally. The pollen, which was probably derived from *Pinus sylvestris,* and blown from Windsor Forest, was at first thought by the people residing in the district to be sulphur.

Even in our own country pine woods abound, not merely in Scotland, but scattered over the entire

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* *Hardwicke's Science Gossip*, June 2nd, 1879.

† See *Nature,* June, 1878.

area. They are to be found so near to London as Bournemouth, Upton, and Weybridge.

From this vast extent of pine forestry distributed all over the world, an incalculable quantity of oil of turpentine finds its way into the atmosphere, just in the same manner as does the volatile oil of the eucalyptus. Of course this process of oil evaporation proceeds far more rapidly in warmer climates, and is much more noticeable in summer than in winter. All who have visited Arcachon, or our own woods at St. George's Hills (Weybridge), in the summer, must have remarked the delicious aromatic perfume of the atmosphere. On a warm day the air is balmy with the odour of the oil which is being incessantly poured into it, and that of the products which result from its oxidation.

That persons suffering from throat and lung diseases derive distinct benefit from residence in such places, is beyond cavil. By the natural atmospheric oxidation of the oils of eucalyptus and turpentine there is produced an almost illimitable amount of peroxide of hydrogen and camphoraceous matters which must, perforce, act, according to their chemical natures, upon the pestilence that may be floating in the air, and upon the animal and vegetable matters that may be rotting in the soil, as also upon the poison which constitutes the virus of pulmonary disease.

What is done by pine and eucalyptus forests on this grand scale, is carried out in miniature by every plant or flower which owes its perfume to the essential oil which it secretes. The importance of essential oils as hygienic agents is well set forth by a report of Dr. Schomburgk* on the progress and condition of the Botanic Garden and Government plantations at Adelaide, Australia. In this report it is stated that British India and Europe consume about 150,000 gallons of handkerchief perfume yearly, and the English revenue from eau-de-Cologne alone is about £8,000 a year, while the total annual revenue from imported perfumes is estimated at £40,000. One perfume distillery at Cannes uses no less than 100,000 lbs. of acacia flowers, 140,000 lbs. of rose petals, 32,000 lbs. of jasmine blossoms, 20,000 lbs. of tube-rose, besides other fragrant flowers.

Dr. Schomburgk points out that in Australia, mignonette, sweet verbena, jasmine, rose, lavender, *Acacia famesiana*, heliotrope, rosemary, peppermint, violets, wallflower, laurel, orange, and the sweet-scented geranium, all grow exceedingly well—indeed, with greater perfection than elsewhere. Australia, then, promises fair to produce commercially vast quantities of essential oils, which by their distribution and use produce hygienic results no less effectually than the eucalyptus, the chemical history of which is studied in this treatise.

Governing bodies and the public alike should never lose sight of the value of eucalyptus and pine plantations. Valleys and swamps may, by their agency, be freed from malarial fever ; and in the

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* *Soc. of Arts Journal*, Aug. 22nd, 1879.

place of a poisonous atmosphere, they substitute a state of balminess and purity, at once luxurious and health-giving.

There is no necessity to dwell further on this theme, but I hope that enough has been said and sufficient evidence brought forward to conclusively prove that among the processes of Nature's Hygiene there are few more extensive, or more important, than that we have been considering.*

In conclusion, it will be of some interest to glance at the industries that are carried on in a turpentine farm and in connection therewith. It has been well said that the pine of the South Atlantic States is to the dwellers therein what the palm is to the South American, and the bamboo to the Chinaman. They build their houses with it, and construct their rude furniture, fences, carts, and farming implements with it. They also use it for heating and lighting purposes, and live upon the profits resulting from the extraction of turpentine, resin, pitch, and tar from it.

The turpentine industry has gradually extended from the pine forests of North Carolina, southwards from Wilmington, through South Carolina and into Georgia, where it now centres, but it also extends to Florida, where State convicts are employed in 'turpentining.'

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* For further evidence concerning the relation of plants, generally, to hygiene, I may refer readers to an interesting article by J. M. Anders, *Pharm. Journ.*, October 18th and 25th, 1884. The author of that paper, however, has fallen into the mistake of calling ozone that which has been proved to be peroxide of hydrogen.

Savannah is the principal port in the United States for the exportation of turpentine. In 1885, the quantity exported was 2,800,838 gallons, of the value of £183,402, and in 1886 the quantity was 3,498,244 gallons, worth £229,302. From Wilmington there was shipped during 1886 only £145,714 worth of spirit of turpentine, illustrating the above-made remark as to the shifting of the centre of this industry.

The extraction of turpentine does not unfit the trees for lumbering, so that large saw-mills are often found in close proximity to turpentine orchards.

The lands are almost worthless, and 'boxing' of the pitch-pine trees for the gum, constitutes the only industry of these districts.

There are several kinds of pine, including the white, spruce, yellow, Roumany, and pitch pine, which latter differs a little from the yellow, and is the only valuable one for 'boxing.'

It is said that the owners of these lands generally lease the 'privilege' for the business, and receive about 125 dollars for each crop of 10,000 boxes. These boxes are cavities, of which there may be from one to four, cut into each tree near the ground, and hold about a quart each. Each crop of 10,000 boxes requires the service of one man only in the season, which lasts from March to September. If the bark of the tree above each box be hacked away a little every fortnight, then about three quarts of pitch or gum is obtained from each box during the season. After successive seasons of hacking, all the bark that can be reached becomes removed, and the quality of the gum gradually depreciates in the sense that it yields less turpentine oil.

A 'still' load of sixteen barrels of this crude gum yields about eighty gallons of turpentine, which fetches 40 cents per gallon, and ten barrels of residual resin, which sells at from one and a half to five dollars per barrel, according to quality. The money produce of the turpentine is said to represent the profit of the industry.

Trees that are unfit for further boxing (which happens in five or six years), and are not suitable for timber, are sometimes used in the manufacture of tar. In that case they are cut up and piled in a large hole in the ground, then covered with earth, and burned in the manner that charcoal-burning is conducted. The gum which is 'sweated' out, flows off with the smoke through a channel provided for that purpose. Each 'cord' of wood makes two barrels of tar, which fetches 1·5 dollars per barrel, and costs 37½ cents to make. The charcoal is sold for fuel.

It is reported that Mr. E. Koch, of New Orleans, is now extracting turpentine from pine wood by the following process: The richest pine knots are selected, and charged into iron retorts holding about 2½ 'cords' of wood, which are then fired from below, and at the same time subjected to the passage of superheated steam. After some six hours of this treatment, gas is evolved from the retorts, and it is utilized as fuel. At the same time, crude turpentine and tar is separated from the wood, and these are discharged through appropriate openings; subsequently, the turpentine is refined by distillation. The heating of the wood is continued until only charcoal remains in the retorts. A cord of wood thus treated yields from thirty-five to forty gallons (American measure) of turpentine, about two barrels of tar, and from twenty to twenty-five bushels of charcoal.

Experiments were conducted some time since in Georgia for sweating the sawdust from the mills in the same way as the 'boxed out' trees, and it is said that each ton yields fourteen gallons of turpentine, three or four barrels of resin, and a quantity of tar.

The annual average yield of the State is put down at 175,000 barrels of resin and 35,000 barrels of turpentine, and all this finds a market in the United States.

The distillation of the crude turpentine is carried on in copper stills, and is continued until the proportion of turpentine to water in the distillate sinks to one to nine parts.

The resin left in the still is drawn off and passed through a strainer, to separate it from twigs and other foreign substances.

Virgin dip—that is, the first exudation from a newly boxed tree—yields about five gallons turpentine to the barrel of 280 lbs., about 20 per cent. being left in the resin, in order to keep it of a good colour and value. 'Yellow dip,' or that obtained in after-years, yields about four gallons to the barrel.

From North Carolina, the turpentine annually exported amounts to about 5,300,000 gallons, and the resin to 550,000 barrels.

Another account, which I believe refers to the industry as practised in France, is given in a paper by Dr. Julius Morel,* from which I have derived some of the following information :

The tapping of turpentine may continue over one hundred and fifty years, and more profitably if, while the tree is young, it is allowed an occasional period of rest. The process of 'hacking' is carried on during the months from May to September. A vigorous pine standing alone will yield annually twenty to forty kilogrammes (44 lbs. to 88 lbs.) of 'crude turpentine'; but if the trees be massed together, the individual yield amounts only to about five or six kilogrammes. As already stated, the product thus obtained is called crude or brute turpentine. A sample which had been obtained from the Silver and Spanish fir-trees (Strasburg turpentine) was analysed by Caillot in 1830, with the following results :

| | | |
|---|---|---|
| Volatile oil - - - - - - | 33·50 | per cent. |
| Resin insoluble in alcohol - - | 6·20 | ,, |
| Abietine (a kind of resin) - - | 10·85 | ,, |
| Abietic acid (resin acid) - - - | 46·39 | ,, |
| Aqueous extract containing succinic acid - - - - - - | 0·85 | ,, |
| Loss - - - - - - | 2·21 | ,, |
| | 100·00 | ,, |

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* *Pharm. Journ.*, sec. 3, vol. viii.

During the flow of the crude turpentine, there forms upon the bark a concrete mass, consisting of crude turpentine from which the volatile oil has been evaporated by atmospheric influences. This concreted substance is known as 'gum thus,' or 'galipot.' A yet cruder product of the same nature is known as 'barras.'

The pure oil of turpentine is obtained from the crude turpentine containing it, together with certain hydrated and oxidised substances (resins, etc.), by various processes of distillation. The distillation may be conducted in the presence of water, or in a current of steam, or in the dry state. The yield of oil amounts to from 15 to 30 per cent. of the crude product and averages about 25 per cent.

Strasburg turpentine is very siccative, and is furnished by the Pectinate fir-tree, Silver and Spanish fir-trees. This tree inhabits almost all the mountains of Central Europe, the Alps, Pyrenees, etc., and is common on the Vosges and in the Black Forest, where it constitutes high and dense forests.

Venice turpentine is not very siccative, and is yielded by *Larix Europæa*, or common larch. This tree will grow upon almost any soil, but prospers best in a clear, dry atmosphere, or a cold-bottomed soil. It thrives at 1,800 feet above the sea-level, and attains a higher level even than the Scotch pine. A tree of fifty or sixty years of age can yield from three to five kilos of crude turpentine annually, for five or six years.

Canada balsam, or Canadian turpentine, is siccative, and is obtained from *Abies balsamea.* Burgundy pitch is obtained from *Abies excelsa,* DC., and contains a large quantity of resinous matter.

Chian turpentine acquired some reputation a few years ago as a cure for cancer, but conflicting testimony as to its value soon followed, and now again it is rarely met with.

Another branch of chemical industry is carried on with the resin which is produced as already described. By further destructive distillation it is made to yield resin spirit, resin oils, and pitch, which latter substance is left behind in the retorts.

Oil of turpentine is chiefly used in commerce in the manufacture of varnishes, which may be described as solutions of gums or resins, made by dissolving them in volatile solvents. When a varnish is spread over the surface of any object, the solvent evaporates and leaves behind a thin layer of the gums previously held in solution. The gums and other substances employed in varnish-making are very numerous, and include copal, shellac, dammar, sandarach, mastic, elemi, benzoin, animi, resin, asphalt, etc. Among the most important varnishes are those made from copal gums. In order to dissolve these in turpentine, they have to be powdered and subjected to dry distillation at a temperature of about 360° C., until a loss of from 20 to 25 per cent. by weight is effected. The residual product can then be dissolved in oil of turpentine and linseed oil, and the product is copal varnish. While, however, the hard gums are quite insoluble in turpentine, I have found that copal, sierra leone, and kowrie gums readily dissolve in 'Sanitas' oil without previous distillation, and that product is now used to some extent for this purpose.

The use of 'Sanitas' oil in varnish-making is important, because not only does it avoid the waste of 25 per cent. by weight of the expensive copal gums, but it increases the body of the resulting varnish by the oxidised substances which it contains, and it also avoids the objectionable darkening in colour which results from the distillation of copal. 'Sanitas' oil, which is now manufactured by my process on a large scale, also dissolves shellac, mastic, dammar, and resin very readily, and it is said to be of commercial value for bleaching wax and feathers. Its chief employment, however, is as a disinfecting fumigant and for reproducing (by volatilisation over water) an artificial atmosphere resembling in composition that of pine forests.

Mention may here be made of an industry now carried on at Humboldtsan (in Upper Silesia), Remda (Thüringen-Wald), Jonköping (in Sweden), Wageningen (in Holland), and elsewhere, in connection with the acicular leaves of pines, firs, and conifers in general. These are exhausted of their oil and then boiled with an alkali (strong solution of carbonate of soda), in order to remove the resinous substances contained in them; after which the leaves are converted into a kind of cotton or wool, termed pine or forest wool. This product is used as a wadding for upholstery purposes, and for stuffing mattresses, etc. It is also used to some extent as an absorbent dressing in surgery. It is said to have the pleasant smell of fir wood and to be repulsive to vermin, but its hygienic value as a pine product is insignificant, seeing that the substances which would give it a value are removed by the process of manufacture.*

We now come to the study of another but allied subject.

### *The Camphor Tree.*

The crystalline substance, *camphor* ($C_{10}H_{16}O$), and its properties are so well known as hardly to require description. It exists ready formed in the *Laurus camphora* (a plant indigenous in Japan, Java, Sumatra, and Borneo), and other trees, and is known to chemists to possess three several modifications which are distinguished by their action on polarised light.

Laurel or dextro-camphor ($C_{10}H_{16}O$) exists in the wood and bark of several Lauraceous plants, and can also be produced artificially by the action of nitric acids upon Borneol or Borneo Camphor ($C_{10}H_{18}O$). Camphor is very volatile, and crystallises upon sublimation.

Every one is familiar with the fact that camphor is more or less volatile according to the circumstances to which it is exposed ; but I am only aware of one

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* Mr. Thomas Greenish has shown, by a carefully conducted investigation, that several articles now being sold in this country under the names of pine wool, fir-tree wool, pine foliage forest wool or flannel, etc., etc., are nothing more or less than stained cotton or sheep's wool, or a combination of the two materials.—*Pharm. Journ.*, November 15th, 1884.

effort* to ascertain the amount of loss which it experiences when exposed to the air. Mr. J. C. Folger has ascertained that the percentage of loss in different samples is wide, and varied in his observations during ten weeks from 11½ to above 84 per cent., according to the solidity of the substance, the amount of surface which is exposed, and the condition of the atmosphere. During the ten weeks of his observations the temperature ranged from 61° to 80° F.

Camphor is soluble in alcohol, ether, and a number of other liquids, but water only dissolves $\frac{1}{1000}$ part of the substance, acquiring thereby its distinctive taste and odour. It melts at 175° C., and boils at 204° C. Its specific gravity ranges from 0·986 to 0·996. It burns in the air with a smoky flame.

The striking rotations which are exhibited by small pieces of camphor when thrown on to the surface of water are supposed to be caused by the movement of the vapour of the substance which is gradually given off therefrom, but the phenomenon is really ill-understood.

According to Proust, a substance resembling camphor may be obtained from the essential oils of rosemary, marjoram, lavender, and sage by deposition; and by the action of nitric acid on the essential oils of pansy, semen-contra, valerian, and sage, other substances supposed to be modifications of camphor have also been obtained.

The manufacture of camphor is quite an important

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* See the *Druggist's Circular* (America), July, 1885, or *Pharm. Journ.*, July 18th, 1885.

industry in the Island of Kio Shui (Kew Shew), there having been exported from the Port of Nagasaki, in 1882, no less than 15186·18 piculs of 133⅓ lbs. each, valued at 227,792 dollars,* in addition to that sent from other ports not accessible to foreign trade. It is said that the annual export of camphor from Japan amounts to about 5,000,000 lbs., of which quantity three-fourths come to Europe.

The camphor-tree, or *Kusonoki*, as it is called in Japan, grows most abundantly in those provinces of the Islands of Shikoko and Kinshin which have the southern sea-coast, being found alike on high elevations and in low valleys ; it also grows abundantly in the province of Kishu. It is a hardy, vigorous, slow-growing, but long-lived tree, which flourishes in all situations, and often attains an enormous size, many in the vicinity of Nagasaki measuring ten to twelve feet in diameter, while at other places there are said to be some as much as twenty feet in diameter. The ancient temple of Osuwa at Nagasaki is situated in a magnificent grove of camphor-trees of great age and size. They usually run up twenty and thirty feet without limbs, and then branch out in all directions, forming well-proportioned beautiful trees, evergreen, and very ornamental. Many are said to live for more than three centuries.

The leaf is small, elliptical in shape, slightly serrated, and of a vivid dark-green colour, except in the early spring, when for a few weeks the young

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* From a report by Consul Jones of Nagasaki, printed in the *St. Louis Druggist*, August 18th, 1883.

leaves are of a delicate tender green. They bear seeds or berries, which grow in clusters, resembling black currants in appearance. The wood is valuable for many purposes, such as shipbuilding, the roots being also used for making ship's *knees,* while the fine grain of the wood makes it specially suitable for cabinet work.

According to H. Oishi,* the amount of contained camphor varies according to the age of the tree, that of one hundred years old being tolerably rich in the substance. To extract the camphor, the tree has to be cut down, and by a stringent law of the land, Mr. Jones reports that another tree is planted in its stead.

The trunk and large stems of the selected trees are cut into small pieces, and by means of a simple apparatus are then subjected to distillation with steam. A metal pot is charged with water and placed over a slow fire, and a wooden tub having a perforated bottom is placed over the pot. In this the broken camphor wood is placed, and a clean light cover is then placed over the tub, from which a bamboo pipe leads into another tub, through which the steam, camphor, and generated oil flow. The second tub is connected with a third, which is divided by a floor into two compartments, one above the other; the oil and water pass on to the lower floor, while the upper one is provided with a layer of straw, which catches and holds the crystals of camphor as they are deposited by cooling. The camphor is after-

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* *Journ. Soc. Chem. Industry,* vol. iii. (1884), p. 353.

wards packed in tubs of one picul, or 133⅓ lbs., ready for the market.

The water is afterwards separated from the oil by means of a faucet, and the oil is said to be used by the natives partly for illuminating purposes, while the exhausted wood is dried and used as fuel. The yield of camphor and oil varies greatly with the season, much more solid being obtained in winter than in summer, while the reverse holds good of the oil. In summer from 120 kilos of wood, 2·4 kilos, or 2 per cent., of camphor is obtained in one day, whilst in winter 3 kilos, or 2·5 per cent., is obtainable in the same time.

The amount of oil obtained in ten days, *i.e.*, from ten charges of 120 kilos each, is in summer about 18 litres (4 gallons), and in winter it amounts to about 5 to 7 litres (1 to 2 gallons). Mr. Oishi reported the then price of camphor to be 1s. 1d. per kilo (1,000 grammes or 2·2 lbs.). The camphor oil contains a considerable quantity of camphor, and by means of distillation and cooling about 20 per cent. of it can be removed.

By the fractional distillation of some original oil Mr. Oishi obtained between 180° and 185° C. a distillate which, after a number of re-distillations, was analysed and found to have the composition of camphor. Another fraction which came over between 178° and 180° C. after three distillations, was analysed, and gave 86·95 per cent. carbon and 12·28 per cent. hydrogen = 99·23 per cent. This substance was, therefore, in the main a hydrocarbon, probably of the terpene series. The original camphor oil may therefore be described as a solution of camphor dissolved in this hydrocarbon and an oxidised modification of it.

The probability of the hydrocarbon being a terpene, thus bringing it into distinct family relationship with turpentine and oil of eucalyptus, I have since established by proving that when exposed to oxidation by air or oxygen in the presence of water, it yields in common with those essential oils, and all others which contain terpenes, a large amount of peroxide of hydrogen and soluble camphor ($C_{10}H_{16}O_3$) in the manner explained in previous chapters. Indeed, I have conducted this process on a manufacturing scale.

Japanese camphor oil has been studied with some care by Mr. K. Yoshida,* who also observed that it has the property of absorbing oxygen. By subjecting a sample of the oil to fractional distillation he finally separated it into five portions, of which the chief ones were as follows:

(1) Terebenthene ($C_{10}H_{16}$) boiling at 156° C.; a hydrocarbon, probably isomeric with ordinary turpentine, of specific gravity ·8641, and forming 7 per cent. of the oil which was distilled.

(2) A terpene of pleasant lemon odour, said to be probably identical with the citrene of lemon oil, and like hesperidene of the orange. When oxidised with chromic acid it yielded a camphor-like substance. It formed some 20 per cent. of the oil. Its boiling-point was 172° C.

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* *Journ. Chem. Soc. Trans.*, 1885, p. 779.

(3) Camphor, boiling-point 205° C., forming some 23 per cent. of the total oil.

(4) An oxygenated oil boiling at 212° to 213°, and forming 50 per cent. of the whole.

This last-named constituent is of the greater interest, as Mr. Yoshida considers it to be connected with the formation of camphor, since by repeated distillations he obtained from this portion a quantity of camphor. This was supposed to be formed during boiling (a temperature of 100° C. was insufficient to produce any camphor) from a substance which he has named camphorogenol, with the assumed formula $C_{10}H_{16}O, H_2O$. That is to say, he regards the substance as a hydrate of camphor, which upon continued boiling is resolved into ordinary camphor and a dark coloured oil supposed to be polymerised camphorogenol.

This so-called camphorogenol is a colourless heavy oil of sp. gr. 0·9794 at 20° C., and has a pleasant camphoraceous odour, milder, however, than that of pure camphor. Mr. Yoshida supposes that the camphor which is believed to be produced in camphor oil by the process of ageing (oxidation) is likewise formed by the agency of this peculiar camphor hydrate. Probably this substance has but a hypothetical existence, and the camphor which he obtained in the way described was pre-existent. I have lately ascertained that when camphor is dissolved in oxidised camphor oil, even to the (added) extent of 20 per cent., none of it can be removed therefrom by freezing; thus rendering it probable that the camphor which

Yoshida obtained from his oxidised oil (which had been previously subjected to freezing) was pre-existent, and resulted merely from the concentration which ensued upon repeated distillations.

I have shown that the active principles obtained by oxidising the oils of turpentine, eucalyptus, and camphor are identical, and that they give rise to the production of peroxide of hydrogen in the same way.

Like turpentine, camphor oil dissolves many resins, and is therefore suitable for varnish and paint making.

The following report by Mr. Oishi shows the annual production of camphor in the province of Tosa up to 1880:

1877—504,000 kins (of $1\frac{1}{3}$ lbs. each) of total cost 65,520 yen (2s. 9d.)
1878—519,000 ,, ,, ,, 72,660 ,,
1879—292,890 ,, ,, ,, 74,481 ,,
1880—192,837 ,, ,, ,, 58,302 ,,

As distinct from the statement of Mr. Consul Jones, respecting the replacement of trees cut down, Mr. Consul Hall, reporting on the trade of Nagasaki, states that the destruction of the camphor forests still goes on, and that no effort is made to replace the trees, for the reason that the tree is so slow-growing that none but large capitalists can afford to wait during the many years that would have to elapse before a new plantation could become a source of profit. He adds that seven-eighths of the camphor exported from Japan goes into the Hong Kong market, where it has to compete with the supply from the Island of Formosa (China).

According to Flückiger and Hanbury, camphor oil is used by the Chinese in the treatment of rheumatism. Japanese camphor oil as it comes to this country is not of constant quality, for while some tins of it contain a mass of deposited camphor crystals, I have bought many barrels quite free from any crystalline deposit, although smelling strongly of camphor, and containing a large percentage of terpenes.

The camphor trade in Formosa, which had almost become extinct, is said to have been recently taken under the protection of the Chinese authorities as a Government monopoly. Hitherto, the collection has been too scattered to make the trade very remunerative, but now the Government has undertaken the establishment of fixed depots for receiving the scattered supplies, which are paid for at a certain rate, and resold for exportation at a profit.

Borneo camphor, or *Borneol* (as it is also known to chemists), is somewhat different from ordinary camphor, its formula being $C_{10}H_{18}O$, and it yields the ordinary variety when subjected to the action of nitric acid. It can also be produced artificially from common camphor. In odour and many properties it resembles the ordinary article.

The substance in question is extracted from the *Dryabalanops camphora* or *aromatica*, being found in cavities in the trunks of old trees. It is also present in small quantity in moist oil of valerian.

I have gathered some useful notes respecting Borneol from a paper written by Mr. Peter MacEwan.* He

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* *Pharm. Journ.*, vol. xv., p. 793.

points out that from an early date it has been sought after by the inhabitants of the Malay archipelago, and that the tree which furnishes it is found in Johore as well as in Borneo, while in the state of Perak there is known to be a vast forest of camphor-trees. This tree is known by the natives as the 'Kayo Kapur,' and its product as 'Kapur baroos.' The wood of the tree is of the colour of cinnamon, and is as durable as, and stronger than, oak, and weighs 48 lbs. per cubic foot. It is a handsome tree, frequently running up to 150 feet in height, with a diameter of six or seven feet at five feet from the ground.

The Labuan export in 1863 was valued at 5,168 dollars; in 1864, at 11,156 dollars; and in 1865, at 2,587 dollars.

The wood of the *Dryabalanops camphora* yields, upon distillation, an oil much resembling that obtained from the Laurel camphor previously described.

Borneol camphor oil is said to consist chiefly of Borneene (an isomer of turpentine), holding in solution a quantity of Borneo camphor. It varies in specific gravity (averaging ·882) according to the amount of oxidised matters contained therein. The oil undergoes oxidation when exposed to the air, just as the Japanese camphor-oil and ordinary turpentine do, and, as in those cases, an organic peroxide is formed which produces peroxide of hydrogen when placed in contact with water.

In conclusion, it may be remarked that the natural history of camphor forests affords another and remarkable illustration of Nature's Hygiene. In these forests, as in those of pine and eucalyptus trees, which we have previously considered, atmospheric oxygen is constantly being absorbed by the essential oils that are continuously evolved into the air, and this simple process gives rise to the production of a number of active chemical principles, including peroxide of hydrogen, a thymol-like substance, and soluble camphor, all of which purify the air and enhance the healthful influences of the climate. Thus Nature may be said to dispense with the efforts which have to be made by man, in densely populated cities and districts, to maintain the health of the public.

In this connection it may fairly be argued that there can be no better disinfectants than those which are styled 'Sanitas' fluid and oil, for they are Nature's own products, and embody all the healthful principles that are generated naturally in pine, eucalyptus, and camphor forests.

# INDEX.

THE END.

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