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FRANCIS RAMALEY
ARNOLD EMCH
EDITORS

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Smelter and Mill Methods of Analysis

IN USE IN THE WEST

BY

PHILIP H. ARGALL, B. S.

CANDIDATE FOR THE DEGREE M. A.

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CONTENTS

In the preparation of this thesis the following works have been freely consulted:

- Practical Assaying, Furman.
- Assay Notes, Colorado School of Mines.
- The Mineral Industry.
- Journal of the Chemical and Metallurgical Society of South Africa.
- The Engineering and Mining Journal.
- Journal of the American Chemical Society.
- Papers of the Institute of Mining and Metallurgy.

Due credit is given under each note when taken from any of the above-mentioned sources.

In the lead and copper smelting notes, and in some of the cyanide notes, the methods given have been in almost daily use by the author of this thesis for some time. All the methods given under lead and copper smelting have been checked, and are known to be accurate.

My thanks are due to Dr. John B. Ekeley, under whose direction this work was undertaken; Dr. C. S. Palmer, Mr. Philip Argall, Mr. E. M. Johnson and Mr. Barry Hogarty, for valuable help and for my laboratory training.

LEAD SMELTING

I
STANDARD SOLUTIONS

The following are in general use in the lead and copper smelters of the West.

NAME OF SOLUTION	AMOUNT OF SALT IN ONE LITRE		APPROXIMATE STANDARD	USED FOR DETERMINING
	Theoretical	Practical*		
Potassium Bichromate	4.381	4.4	1cc=.005 Fe.	Fe.
Sodium Hyposulphite	19.59	20.0	1cc=.005 Cu.	As, Cu, I, Sb.
Potassium Permanganate	5.643	5.8	1cc=.005 CaO.	Mn. CaO, Fe, Sb.
Potassium Ferro-cyanide	----------	22.5	1cc=.005 Zn.	Zn.
Ammonium Molybdate	----------	4.28	1cc=.005 Pb.	Pb.
Potassium Cyanide	----------	44.5	1cc=.001 Cu.	Cu.
Oxalic Acid	11.25	11.46	1cc=1cc $KMnO_4$ =1cc .01 Fe.	Mn.
Potassium Sulphocyanate	8.981	10.0	1cc=.01 Ag.	Ag, As.
Barium Chloride	76.25	76.25	1cc=.01 S.	S.

From the $KMnO_4$ solution above, 1cc=.005 CaO, the following comparison is deduced:

100 CaO= 253.3 Ammonium Oxalate.
100 CaO= 203.3 Oxalic Acid.
100 Fe.= 700. Ferrous Ammonium Sulphate.

All of these solutions, except KCN, keep well if kept in dark bottles, well stoppered.

*The difference between the theoretical and the practical columns is due to impurities in the chemicals and in the water used.

In actual practice these solutions are made to read 1 cc.=.005, so that the reading will be direct on ½ gram of ore or slag.

Impurities in the chemicals, even in the so-called C.P., as well as dust and organic matter (sometimes in the water, obtained by the condensation of boiler steam, and due to the use of organic boiler compounds), generally affect the solutions more or less, hence it is well to let them stand a few days before using.

In actual practice these solutions are always made up in quantities of not less than four litres, and in duplicate, one bottle being in use while the other is standing.

STANDARDIZING SOLUTIONS.

1. Potassium Bichromate.—Weigh out on the analytical balance a piece of C.P. iron wire, approximately .200 gram; cut into small pieces and place in a flat-bottomed flask; pour about 15 cc. conc. C.P. HCl and 15 cc. boiling distilled water on it, and heat on the hot plate until dissolved. Dilute with 100 cc. H_2O; boil, and add 2 drops of stannous chloride solution, stirring vigorously. Remove from the heat, allow to cool, add 20 cc. of mercuric chloride solution, stir well. The solution should now look white and silky, from the presence of mercurous chloride, and is ready for titration.

Fill the burette to the zero mark with the bichromate solution. Place on a clean, dry spot-plate the solution of potassium ferrocyanide. Transfer the iron solution to the No. 2 beaker, washing out with cold distilled water. Run in the bichromate from the burette, slowly, testing from time to time a drop on the ferrocyanide solution. It will give a dark blue at first, shading off to colorless, this being the end reaction.

Read the number of cc.'s used, divide the weight of iron taken by the number of cc.'s used, and the quotient will represent the amount of iron in the ferrous condition which 1 cc. of the solution is capable of oxidizing.

This should be done in duplicate, and the results should check.

2. Potassium Permanganate.—Three methods are in general use—

(a) By iron wire.
(b) By oxalic acid.
(c) By ferrous ammonium sulphate.

Comparing the following equations—

$$10\ FeSO_4+2\ KMnO_4+8H_2SO_4=5\ Fe_2(SO_4)_3+K_2SO_4+2\ MnSO_4+8H_2O,$$

and

$$5\ (H_2C_2O_4,2H_2O)+2\ KMnO_4+3H_2SO_4=10\ CO_2+2\ MnSO_4+K_2SO_4+18H_2O,$$

it will be seen that two equivalents of iron require the same amount of permanganate solution for oxidation as one equivalent of oxalic acid, or 2/56 Fe, is equal to 126 oxalic acid, i. e., as 8:9. Taking oxalic acid, therefore, we simply multiply the weight taken by 8/9 to find the equivalent in iron.

The composition of ferrous ammonium sulphate is, $Fe(NH_4)_2(SO_4)_2\ 6\ H_2O$, the molecular weight is 392, of which 56, or 1/7, is Fe.

To Standardize the Solution with Fe Wire.—Weigh out approximately .200 gram of wire, cut in small pieces, and place in a flask, as before; add 20 cc. cold water and 5 cc. conc. H_2SO_4, heat slightly until dissolved (the H_2SO_4 often furnishes enough heat of itself). When completely dissolved, add 20 to 30 cc. of boiling water, then add a spoonful of granulated amalgamated zinc; put on the hot plate and boil a few minutes; remove, cool by dipping into cold water, test with KCNS. It should show no pink coloration whatever at first. If such is the case, dilute with 100 cc. cold water; stir with a glass rod; allow the zinc to settle and decant, carefully, into a white porcelain dish, being careful that none of the zinc passes over; wash the zinc three times by decantation with cold water. The solution is now ready for titration with the permanganate solution. Run in rapidly, constantly stirring, until a faint pink appears. The titration is then finished.

To Standardize with Oxalic Acid.—Weigh out about ½ gram of the pure acid, which has been kept in a well-stoppered bottle. Dissolve this in a No. 3 beaker in about 350 cc. of boiling water. In another beaker place 50 cc. cold water, add to it 20 cc. strong sulphuric acid, mix by shaking around gently, then pour this hot acid into the oxalic acid and titrate at once with the volumetric solution.

To Standardize with Ferrous Ammonium Sulphate.—Coarsely powder about 3 grams of the salt in a porcelain mortar, weigh out about 2.1 grams, dissolve in about 250 cc. of cold water in a white dish, add 20 cc. sulphuric acid (1 part acid, 5 parts water). When the salt has completely dissolved, titrate with the volumetric solution.

3. Potassium Ferrocyanide.—Ignite in a porcelain crucible about 1 gram of C.P. zinc oxide. When cold weigh up two portions of .200 grams, place each portion in a No. 2 beaker, add 25 cc. boiling distilled water and 5 cc. HCl, and stir until completely dissolved. In another No. 2 beaker place 7 grams of ammonium chloride, dissolve it in 100 cc. boiling water, add 15 cc. conc. ammonia water to it, carefully, then filter it into the solution of zinc in HCl. Wash with a little water so that the entire bulk of solution fills the beaker two-thirds full. Place on the hot plate, after adding a spoonful of granulated C.P. lead,* and boil.

Fill the burette with the standard solution and have the spot plate ready with uranium acetate indicator. Now take the beaker off the hot plate, add 1 or 2 cc. of a concentrated solution of sodium sulphite (the solution should smell of SO_2), and titrate. The end reaction is a very faint pink.

The writer has found it a good plan to divide the solution before adding the sodium sulphite, leaving 20 to 30 cc. on the lead in one beaker, to this part adding the Na_2SO_3. Titrate the other portion rapidly until a good end reaction is reached, then pour in the other part, lead and all, rinse carefully and complete the titration slowly. This precaution prevents running past the end point.

4. Potassium Cyanide.—Weigh in duplicate a piece of Cu. foil approximately .200 gram, place in an 8-oz. flask and dissolve in 5 cc. strong nitric acid. Boil off the red fumes, cool by dipping in cold water; when cold add 20 cc. cold water, then 10 cc. strong ammonia, then 5 cc. cold water, mix and titrate with the volumetric solution of KCN until colorless. Divide the weight of the Cu. taken by the number of cc. used.

5. Sodium Hyposulphite.—Weigh accurately about .2 grams of Cu. foil and place in an 8-oz. flask, add 5 cc. strong nitric acid, and boil off all the red fumes. (This must be carefully done, otherwise trouble will follow due to nitrous acid liberating iodine.) Remove from the heat and add 15 cc. water and 6 to 7 grams of zinc

*The addition of lead is not necessary here, but since we use it to take care of the Cu when we are testing for zinc in ores (Low's Method), we desire to have the same conditions present in standardizing.

acetate, boil for about a minute, then cool until quite cold and dilute with 50 cc. cold water. Add about three or four grams of KI, and shake about until dissolved. Cuprous iodide will be precipitated and iodine liberated.

$$2\ Cu\ (C_2H_3O_2)_2+4\ KI=Cu_2I_2+4\ KC_2H_3O_2+I_2$$

The free iodine is soluble in KI and colors the solution brown. Titrate at once with the hyposulphite solution until the brown tinge has become weak, then add about 5 cc. of starch solution, or a sufficient amount to produce a good blue color. Continue the titration until the blue solution has entirely disappeared, leaving the solution milky and somewhat yellow.

Calculate the standard as before.

6. Ammonium Molybdate.—Weigh into a No. 2 beaker .200 grams of pure lead foil and dissolve in 5 cc. nitric acid and 5 cc. water by boiling for a few minutes. Remove from the heat and add 20 cc. dilute sulphuric acid, mix well with a stirring rod and allow to settle. Filter through a 9 cm. filter, wash the precipitate into the filter with dilute sulphuric acid, and with two or three washings with water.

Put the filter paper and contents into another clean No. 2 beaker and add 6 grams of ammonium acetate and fill the beaker half-way with boiling water. Heat to boiling and titrate the contents just as they are, using a solution of tannic acid as an indicator on the spot plate, the end reaction being a light orange color. Great care must be used to avoid running over.

II

SLAG ANALYSIS

DAILY WORK. Slag.—The composition of the slag in any given smelting operation has probably a greater influence on the success of the process than any other single factor, regarded either from a technical or financial standpoint.

Smelting may be regarded as the fusion or reduction of an ore or ores, so that the resulting metal or matte, by reason of its greater specific gravity, may sink through the fused gangue, and be collected for further purification freed from the earthy metals which form the slag. In order that this separation may be complete and perfect, the slag must fuse at a temperature as near the fusing point of the metal as possible, and in most cases, the more fluid the slag, and the lower its specific gravity, the better it is. In the lead, copper, and iron industry, the slags are invariably complex silicates; that is, a silicate of numerous bases. The ratio of acid to base has an exceedingly important influence on the perfect separation of the metals from the slag, affecting, as it does, the specific gravity, the fusibility, the influence on the furnace walls, and the influence on the oxide of the metal to be separated.

In general, it has been found that "singulo-silicates" are the most fluid, fuse at the lowest temperature, and are most commonly used where economically possible. (A slag in which the ratio of the oxygen combined in the silica, is to the oxygen combined in the bases, as 1 is to 1, is called a singulo-silicate.)

It has been found that, if a slag be suddenly chilled, either by pouring into water, or upon a cold piece of steel, or even by dipping a cold steel bar into the fluid slag and quickly removing it with its adherent slag, the slag so treated has a vitreous lustre and decomposes rapidly and completely with acids. If, however, it is allowed to cool slowly, as it would under ordinary circumstances, it is no longer decomposed by acids, but requires fusion with alkaline carbonates. With singulo-silicates the decomposition with acids is perfect when the slag is chilled, but as the slags become more acid they become more difficult to decompose, and when slags approach 40% silica, the decomposition is no longer satisfactory.

In all lead smelters at least one sample of slag is analyzed daily, and from the analysis the fluxes are adjusted. This slag analysis is the first thing taken up by the chemist when he arrives at the plant in the morning, and since the results are expected by 10 a. m., very rapid methods are required.

The figures required, generally, are silica, iron, lime, zinc, manganese, magnesium and alumina; lead and silver are determined by fire assay. A separate portion of ½ gram is weighed out for iron, manganese, zinc and alumina; silica and lime are determined on one weighing.

The slag is usually delivered to the chemist ground and screened, so that he may weigh up at once.

DETERMINATIONS.

Iron.—To ½ gram of slag add 20 cc. boiling water and 15 cc. strong HCl. Boil until action ceases. Now add three drops of stannous chloride solution and allow to cool. When cool add 15 cc. $HgCl_2$ to neutralize the excess Sn. *Titrate with Bichromate solution, using Potassium Ferro-cyanide indicator.

Silica and Lime.—Weigh into a No. 3 R.B. casserole ½ gram of slag, moisten with water and add 4 to 5 cc. HCl and stir with a glass rod;† while stirring the silica can not gelatinize. Evaporate to dryness on the hot plate, being careful to avoid "spitting." Take up with 5 cc. HCl and 5 cc. water and boil. Dilute, filter into a beaker containing 10 cc. of nitric acid. Burn filter paper in a porcelain crucible in the muffle, cool, and weigh.

To the filtrate, acid with nitric acid, add ammonia until all the iron is precipitated, redissolve the iron in oxalic acid and boil. Filter off the calcium oxalate and wash two or three times with

*In practice this is the first one out and is not titrated at once, being allowed to cool until the manganese is also ready to titrate. This method of complete solution of the slag in water and HCl is of value in another way, as it gives an indication of incomplete reduction in the furnace—i. e., if the solution has a yellow color it shows that some of the iron is present in the ferric state, and when this is the case it may be necessary to give an increased amount of fuel; such a fact should be noted on your report.

†Keep stirring while adding the acid in order to keep the silica from gelatinizing into lumps.

hot water. Put filter paper containing the calcium oxalate in a beaker, half fill with boiling water and add 10 cc. dilute sulphuric acid, warm and titrate with potassium permanganate.

*The nitric acid is used in the second stage to oxidize any lead or copper sulphides which may be present and which are not decomposed by HCl alone. The amount of lead present will invariably be dissolved by the acids present and pass readily into the solution.

There is invariably a small amount of carbon in the slag which will make the silica look dark before ignition, but burns off in the muffle.

Care must be taken in the evaporation to dryness not to heat too strongly; sometimes the iron when too strongly heated becomes oxidized to Fe_2O_3 and obstinately refuses to dissolve, in which case a new determination is necessary.

This, while a very rapid method for determining the lime, is not free from error. The precipitate is liable to contamination with zinc, manganese, lead and copper oxalates (the latter being completely precipitated), hence the results usually obtained on ordinary lead slags are about $\frac{1}{2}\%$ too high.

The technical term "silica" embraces all that is insoluble in acids.

Manganese.—Weigh out in a No. 2 beaker $\frac{1}{2}$ gram of slag and treat with 20 cc. water and 5 cc. nitric acid and boil well. Dilute with hot water, add enough zinc emulsion to neutralize, titrate with potassium permanganate solution. Since this solution is standardized with iron, we have simply to multiply by $\frac{165}{560} = .2946$ to obtain the value in manganese.

Another method is to add boiling water, then 4 to 5 cc. of HCl, then 4 to 5 cc. of nitric acid, then 4 to 5 cc. of sulphuric and evaporate carefully to dryness. Take up with water and boil 5 to 10 minutes, then add zinc emulsion and proceed as before.

Zinc.—To $\frac{1}{2}$ gram of ore in a No. 3 R.B. casserole add 10 cc. of chlorate mixture (a saturated solution of potassium chlorate in

* It will be observed that no nitric acid is used during the first evaporation; this is to avoid the oxidation of the sulphur which is combined in the slag as a sulphide, and which by treatment with HCl alone is eliminated as H_2S. If the sulphur were oxidized to sulphuric acid, some barium sulphate would be formed, and remaining with the silica, make the result too high.

nitric acid) and evaporate slowly to dryness. Now add 10 grams of ammonium chloride crystals and 20 cc. of ammonia, boil, filter, wash with ammonia and then with water. To the filtrate add a small piece of litmus paper; make acid with HCl, and then add 5 cc. HCl in excess. Now add 2 to 3 grams of test lead and boil. Titrate with potassium ferro-cyanide, using uranium acetate indicator. Add about 3 cc. of the sodium sulphite solution before titrating. (See standardizing the solution.)

Some chemists evaporate to dryness, first, with nitric acid, then take up and boil with nitric acid, adding a small pinch of potassium chlorate, this method giving steady results.

*Sources of error in the ferro-cyanide titration—Losses may result from:

(1). Volatilization of Zn as the chloride.
(2). Recombination of Zn with SiO_2.
(3). Imperfect decomposition by acids.
(4). Occlusion by ferric-hydroxide, etc.
(5). The use of H_2S for separating Cu, Cd, etc.
(6). Failure to make the final titration under the same conditions as in standardization.
(7). Insufficient dilution of the solution.
(8). Too great haste in titrating, especially with cold solutions.

On the other hand, results may be too high, owing to:

(9). The presence, in the solution, of Cd, Cu, Sb, Mn, Al, or some organic acid as tartaric, oxalic, etc.
(10). The decomposition of the ferro-cyanide solution by Cl, Br, nitrous oxides, H_2O_2, etc.
(11). The addition of an inordinate excess of acid to the solution.
(12). The use of an incorrectly standardized solution of ferrocyanide.

Magnesium.—To ½ gram of slag add 15 cc. water, then 10 cc. HCl and 5 cc. nitric acid, boil, precipitate the iron with ammonia and add 5 cc. bromine water (or hydrogen peroxide) and filter off the iron. The iron is then redissolved with 5 cc. of HCl, diluted, and again precipitated with ammonia and bromine, as before. The filtrates from the two precipitates are then combined and boiled. Ammonium oxalate is now added to precipitate the lime, which is

* By Geo. Waring, Jour. Am. Chem. Soc., Vol. XXVI, 1 Jan., 1904.

then filtered off. The filtrate is placed in a flask, corked, and placed under running water to cool. When quite cold add 20 cc. of ammonia and 5 cc. of sodium phosphate solution, shake and let stand alternately until all the magnesium phosphate is precipitated. Filter, wash with cold dilute ammonia, burn, and weigh.

Alumina.—Weigh out in a No. 3 RB casserole ½ gram of slag and treat as in silica, but, on filtering, do not add nitric acid to the filtrate. This will give you a check on your silica determination.

Wash the filter paper carefully with dilute HCl, and then with water before removing. Then, to the filtrate, add ammonia until the solution becomes dark red in color, but contains no precipitate. Now add 3 cc. of HCl and 2 grams of phosphate of sodium (dissolved in water and filtered), constantly stirring, then add 10 grams of hyposulphite of sodium in solution and 15 cc. of acetic acid. Heat to boiling and boil for 15 minutes, filter rapidly, wash with hot water, burn in a porcelain crucible,* and weigh as $AlPO_4$, which, multiplied by .41847, gives the weight of Al_2O_3.

The student should now begin to study how to weigh these all out, start them together, run them along together, and cut the mechanical operations down as much as possible. Try to have all filtrations come at the same time, etc., etc.

The chemist is now ready to make his report to the metallurgist, and since these elements must be reported as oxides, the following table will be useful:

CONVERSION TABLE.

$Fe \times 1.29 = FeO$
$Fe \times 1.43 = Fe_2O_3$
$Mn \times 1.29 = MnO$
$Zn \times 1.25 = ZnO$
$Cu \times 1.25 = CuO$
$Pb \times 1.08 = PbO$
$S \times 2.50 = SO_3$
$As \times 1.32 = As_2O_3$
$Sb \times 1.27 = Sb_2O_4$
$S \times 7.47 = PbS$

* It is necessary, in burning off the ppt., to raise the heat very carefully, until all the carbon is burned off, otherwise the $AlPO_4$ may fuse. (Wöhler 1.)

From this table the computations are made and the report is then turned in.

The next in order of determination will be the sulphurs from the roasters.

III

ORE AND FUEL

Sulphur.*—To ½ gram of ore add 10 cc. chlorate mixture and evaporate to dryness. Take up in 10 cc. HCl and 10 cc. water and boil. Filter off the silica, boil the filtrate, and add solution of barium chloride (½ gram barium chloride to each determination), allow to settle, filter, washing thoroughly with hot water, remove filter, burn in the muffle and weigh—the weight × .13734 = % S.

Ores.—On ores, silica, iron, and lime are generally determined on one weighing, viz.: To ½ gram of ore add 15 cc. HCl and 10 cc. nitric acid and evaporate to dryness, in a beaker. Take up in 10 cc. HCl and 20 cc. water, boil and filter; burn and weigh the silica. To the filtrate add ammonia to ppt. the Fe, boil a few minutes and filter. To the filtrate add ammonium oxalate, boil, and filter off the lime, as calcium oxalate.

The Fe on the filter is now dissolved in HCl, warmed, reduced with $SnCl_2$, etc., and treated as in Fe in slag.

The ammonium oxalate is now proceeded with as in lime in slag.

Zinc.—Zinc in ores is treated essentially as in slag, by a modification of Low's method.†

Manganese.—Essentially as in slags. Often, however, it is only necessary to boil the ore with HCl.

Copper and Lead.—To 1 gram of ore add 15 cc. HCl and boil a few minutes. Now add 15 cc. nitric and 10 cc. sulphuric acids and boil until all SO_3 fumes cease. Cool, take up in 30 cc. water and boil to take up all soluble sulphates. Filter; the lead will then be on the filter and the Cu will be in the filtrate.

Cu.—Place in the filtrate a small piece of aluminum (1¼ inches

* In practice the sulphurs are weighed out and started at the same time as the slag.

† Cadmium may be removed when necessary by passing H_2S through the acid solution before adding the test lead. CdS and CuS are then ppted. together and must be filtered out. The solution is then ready for titration, the addition of test lead being now unnecessary. The H_2S will not interfere.

square, with the diagonal corners bent in opposite directions to prevent the plate from lying flat on the bottom of the beaker) and boil until all the Cu is ppted. on the Al; filter, and test the filtrate for Cu with H_2S. Dissolve the Cu in as little nitric acid as possible, add a few drops of water and evaporate until only a pasty mass remains in the beaker. Cool, add 20 cc. water and 5 cc. ammonia, boil 3 to 4 minutes, add 5 cc. acetic acid, cool and titrate* with sodium hyposulphite, adding a few drops of starch solution.

Before proceeding to titrate add ½ gram KI crystals and shake well. Starch solution is made by placing 1 gram pure starch in a No. 4 casserole and pouring upon it 100 cc. cold water and letting it stand until the lumps of starch have broken down into a fine powder; when this has been accomplished, stir well and bring rapidly to a boil; boil until the solution becomes translucent. When cold the solution is ready for use.

Pb.—Put the filter paper (silica and all) in a beaker, add 20 cc. ammonia and 10 grams of sodium acetate crystals, then half fill the beaker with water and boil slowly. Titrate with ammonium molybdate, using tannic acid indicator.

This scheme works equally well on ores, slags, or mattes.

In such ores as those of Aspen, Colorado, which contain calcium carbonate, lead carbonate and lead sulphide, it is necessary to get rid of the lime, hence the following scheme: To ½ gram of ore add 5 cc. HCl and evaporate to 2 cc. Dilute and filter; filtrate contains the lead. Ppt. the Pb on Al foil. Filter, dissolve the metallic lead in dilute nitric acid, add water, neutralize with ammonia, acidify with acetic acid and titrate with molybdate solution as before.

Sulphur.—On ores, essentially as in slag.

Baryta.—The insoluble residue from the acid treatment is fused with alkaline carbonates, and dissolved in hot water. Boil and ppt. the barium as barium sulphate with sulphuric acid. Or, weigh the residue after burning in a platinum crucible, add a few drops of sulphuric acid and a few drops of HF (Baker & Adamson's), place on the hot bath and evaporate to dryness. Weigh; the difference in the two weights will be the true silica.

---

*If there is any Bi present in the ore, it will interfere with the end point in the Cu titration, bismuth iodide being yellow.

ORE BEDS.*

In order to analyze an ore bed, the chemist makes up a miniature bed from the samples of the ores that formed that particular bed. He is given such a list as follows:

Sample No.	Mine	Weight in Pounds
560	Summit	23800
9500	Hecla	44160
2660	Portland	243342

etc.

The chemist has already analyzed these ores and still has the samples. From these he now makes up the miniature bed, substituting grams for thousand pounds. Hence, on Summit No. 560, above, he would weigh out 23.8 grams, and so on. Since the beds average 1,000 tons, he will have a very large sample, which he will mix thoroughly and quarter down to a sample of about ¼ pound. From this he will make his analysis, saving the remainder of the sample in case it is necessary to repeat the determinations.

Where the bedding system is not carried out, the metallurgist is kept pretty busy figuring his daily charges from the various lots of ores received at the works.

On all beds the following are determined: Total insoluble, true silica, iron, manganese, lime, baryta and sulphur; sometimes zinc, alumina, lead, copper, and other elements are called for.

Silica, iron, manganese, lime, copper, and lead are determined essentially as in ores and slags.

Magnesium in Ores and Bed Mixtures.—Weigh 1 gram into a No. 3 casserole and treat with a mixture of HNO_3 and HCl, using sufficient nitric acid to completely oxidize the sulphides, and about

*The smelter beds vary in size from one thousand tons to several thousand tons, and are built up of the daily ore supplies that reach the works. This ore is spread out in layers, so as to have as even a mixture as possible. When a given bed is about completed, it becomes necessary to determine its exact chemical composition, so that the last layer can be added of ores of such nature as to bring the whole up to the definite composition required for the smelter charges; or the metallurgist can, if he so desires, add the necessary ingredients to each charge. When this is done the furnaces are run continuously on the given bed, receiving, of course, ore of uniform composition and obtaining uniform metallurgical results.

5 cc. of HCl. Evaporate to dryness and dissolve the residue with 10 cc. HCl, boil, add 15 cc. water, boil, allow to settle, filter through 9 cm. filter, treat the residue with 1 cc. HCl, boil, dilute with water and wash into the filter, cleaning out the casserole with a finger cot. The filtrate will contain, generally, Ag, Cu, Pb, Fe, Al, Mn, Zn, Ca, and Mg. Add ammonia until slightly alkaline, then about 8 cc. sulphide of ammonium and 10 cc. carbonate of ammonium, and boil for three minutes. Remove from the heat, allow to settle, filter rapidly into a No. 3 beaker, washing the ppt. three times with boiling water containing a little sulphide of ammonium. To the filtrate add HCl until slightly acid and boil down rapidly to about 50 cc. Filter out the sulphur and add bromine water to the filtrate until it clears, boil out the bromine, then make alkaline with ammonia and add 5 cc. ammonium oxalate to remove the small amount of lime still remaining. Boil, let settle, filter and wash, evaporate the filtrate to 50 cc. and cool by dipping the beaker into cold water. Add Na_2HPO_4 and NH_4OH, and proceed as in magnesium in slag.

Alumina, Etc.—A hydrochloric acid solution of the soluble portion of the ore is obtained, the insoluble residue ignited and weighed in a platinum crucible, fused with alkaline carbonates, extracted with water and HCl, evaporated to dryness to separate silica. Then proceed as in slags, after adding the portion soluble in acid above.

COAL AND COKE.

Proximate Analysis (Heinrichs).—Weigh out in duplicate 1 gram of powdered coal; place in a small beaker, covering with a watch glass, and place on the steam dryer for 24 hours. Take off and weigh; the loss found $\times 100 = \%$ of moisture in the coal.

Weigh 1 gram of the powdered coal into a medium-sized porcelain crucible, put the cover on and place the crucible in a medium hot muffle and allow it to remain until fumes cease to come out around the edge of the cover. Remove, cool, and weigh; the loss, less the moisture previously found, $\times 100 = \%$ volatile combustible matter. This should also be done in duplicate, and results should check.

After weighing the volatile matter, put material back in the crucible, replace the cover and place in the muffle until the ash turns white, showing the carbon to be completely burned off. Remove, cool, and weigh. The difference between this weight and the last $\times 100 =$ % fixed carbon; what remains is ash, which $\times 100 =$ % ash.

Coke.—Essentially the same method as for coal. Coke ash is, however, analyzed for silica, iron, alumina, and lime, as follows:

Burn about 5 grams of coke in the muffle in order to have a sufficient amount of ash. Pulverize about ½ gram finely in an agate mortar, and place in a crucible with about 3 grams of fusion mixture and mix thoroughly; cover with about a gram more of the fusion mixture and fuse in the muffle. Place the crucible, when cool, in a casserole of hot water and boil until the fusion is dissolved. Cover the casserole with a watch glass and add HCl from a pipette until effervescence ceases and the solution is acid. Evaporate to dryness, dissolve the residue in 20 cc. HCl and 50 cc. boiling water. Boil, filter, wash, ignite, and weigh silica.

Boil the filtrate, and while boiling add ammonia in slight excess, boil, and filter out the ppt. of ferric and aluminic hydroxides (containing all the phosphoric acid which, in lead smelters, can usually be neglected), and wash three to four times with boiling water. The filtrate is now boiled, ammonium oxalate is added, the lime thus ppt. being allowed to settle. While the calcium oxalate is settling, the ppt. of ferric and aluminic hydroxides is dissolved in dilute HCl, and poured into a 200 cc. flask and diluted to the mark, then poured into a No. 2 beaker, mixed thoroughly and 100 cc. taken out with a pipette. This is placed in a No. 2 beaker, boiled, reduced with stannous chloride, mercuric chloride is added, and titrated with the bichromate solution for iron. Calculate the iron to ferric oxide and report as such.

Wash the remainder from the 200 cc. flask into another beaker, and rinse the pipette in it. Place this beaker on the hot plate, and, when the contents are boiling, remove from the heat, add a slight excess of ammonia, again boil, allow to settle, filter, wash, ignite, and weigh as $Fe_2O_3+Al_2O_3+P_2O_5$, subtract the weights of $Fe_2O_3+P_2O_5$ previously found, and the remainder is Al_2O_3. It must not be overlooked that these weights represent only one-half the amount of substance originally taken, so that the weights must be doubled to obtain the correct amount. The calcium oxalate, which has settled by this time, is now filtered out and the filtrate at once placed on the hot plate to evaporate down for the determination of the magnesia.

The calcium oxalate is washed carefully (the washings being added to the Mg filtrate), and the lime determined by titration with potassium permanganate.

The filtrate containing the Mg is evaporated down to 25 cc., cooled, 10 cc. sodium phosphate solution added, then 10 cc. ammonia, is well stirred and allowed to stand (preferably over night), filtered, washed with dilute ammonia, ignited, and weighed as $Mg_2P_2O_7$.

ANTIMONY AND ARSENIC.

Antimony and Arsenic.—These determinations are often called for, especially in an analysis of dross or speiss.

Take 1 gram of material, add dilute HCl (50%) and evaporate almost to dryness, take up in 5 to 10 cc. HCl and boil. Add an excess of sodium sulphide and boil well. (In the presence of Cu avoid ammonium sulphide.) Filter and re-treat the black sulphides. Now combine the filtrates, acidify with HCl, boil and filter (avoid an excess of HCl). Wash the sulphides off the filter with water, add $KClO_3$, and boil until free chlorine ceases to come off. Cool, make strongly alkaline with ammonia, add magnesium chloride (in case very little arsenic is present, let stand 5 to 6 hours, agitating), filter and wash with strong ammonia. Dissolve the magnesium arsenate in 50% HCl, add KI and let stand, because the action is slow. Titrate with hyposulphite solution as in copper.

Acidify the filtrate from the magnesium arsenate with HCl, warm and filter, wash the antimony into a flask, washing the filter paper with HCl containing a little potassium chlorate. Now add in the flask a little more chlorate and boil until no chlorine is apparent on iodide starch paper (be careful at this stage not to volatilize the antimony), cool, add KI and 2 cc. of carbon bisulphide and titrate with hyposulphite solution.*

Tin.—When tin is present, run down with 50% HCl, but avoid dryness. Add yellow potassium sulphide, or sodium sulphide, and boil well for an hour. Filter (Sb and Sn are in the filtrate).† Acid-

* This method does not work when tin is present.
† Volumetrically tin does not interfere with As and Sb.

ify with HCl, warm, and filter. Wash the ppt. into a beaker, rinse the filter paper with a hot concentrated solution of oxalic acid (in which stannic sulphides are soluble), boil, and filter. Add nitric acid, boil until red fumes cease (oxalic goes to carbonic acid), evaporate to dryness, take up in yellow ammonium sulphide, reprecipitate with HCl, filter into a Gooch crucible and ignite in the muffle. Weigh as SnO_2.

There are three ways of getting rid of oxalic acid in the above —by permanganate of potassium, by sulphuric acid, by nitric acid. The latter is to be preferred, because nitric acid is a volatile acid, and can be evaporated.

IV

OTHER METHODS OF ANALYSIS

The methods mentioned previously are those in general use, daily. There remain, however, other methods, designed to meet exceptional cases, and these I shall now take up.

Manganese.—Volhard's method, the one previously given, is the best for general use. It is well, however, to have another method to check by.

Pattinson's Method (Modified).*—Weigh into a No. 4 casserole $\frac{1}{2}$ gram of ore, treat with HNO_3, and HCl, according to requirements, i. e., if an oxidized ore, little or no nitric acid will be required; if a sulphide, from 5 to 8 cc. will be required. Evaporate to dryness, dissolve in 15 cc. strong HCl, dilute with 100 cc. boiling water, add an emulsion of oxide of zinc until the solution turns red, then a slight excess; now add from 20 to 50 cc. strong bromine water, according to the amount of manganese present, 50 cc. being sufficient to ppt. about 40% Mn, boil until all the excess Br has been expelled, and filter through a large filter, washing by decantation, until free from chlorides and bromides. Remove the filter and its contents carefully from the funnel, open it against the side of a No. 3 beaker; wash the ppt. into the beaker with boiling water, cleaning the filter paper as thoroughly as possible.

Fill a burette with a volumetric solution of oxalic acid (see table on page 1); from this burette run into the casserole 10 cc. of the solution, add 20 cc. dilute sulphuric acid (1 to 1) and a little boiling water. Dissolve all the MnO_2, etc., adhering to the casserole with this mixture, and then pour it over the filter in the beaker, to remove what still sticks to it; wash the filter with boiling water and remove it from the beaker. Now add to the mixture in the beaker about 30 cc. more of the oxalic acid solution (an excess is required), and 200 cc. boiling water. If everything does not dissolve, heat until it does and the solution becomes clear. Titrate with the volumetric solution of potassium permanganate until just pink.

*Assay Notes, Colorado School of Mines.

Now determine the value of the oxalic acid solution in terms of the permanganate solution, as follows: Into a No. 3 beaker run 40 cc. oxalic acid solution, add 200 cc. boiling water, then 20 cc. dilute sulphuric acid (1 to 1), and titrate with the permanganate (it is best to make the solutions exactly equal in value, so that 1 cc.=1 cc.). Divide the amount of permanganate solution into the amount of oxalic acid solution, to find its value in terms of oxalic acid, multiply the number of cc.'s of permanganate solution used in the titration by this factor, and subtract from the amount of oxalic acid solution used—in the above case 40 cc.'s—this will give the amount of oxalic acid oxidized by the MnO_2 obtained from the ore.

We have previously found (standardizing a solution of potassium permanganate) that the ratio of iron to oxalic acid is as 8 to 9. Hence,

1. Standardize the oxalic acid solution with the permanganate solution and find its equivalent in Fe. Thus, if 1 cc.=1 cc. exactly, then 1 cc. oxalic acid=.01 Fe, or, if 1 cc. oxalic acid=.9 cc. permanganate solution, then 1 cc. oxalic acid solution=.009 grams Fe, etc.

2. Multiply the equivalent in iron by 1.125 to find the value per cc. in oxalic acid, i. e., to find exactly how much $H_2C_2O_4$, 2 H_2O 1 cc. of the oxalic acid solution contains. This amount is then marked on the bottle.

3. Multiply the amount of oxalic acid oxidized by the MnO_2 of the ore by .4365 to find the equivalent in Mn, then calculate the %; or the last two may be combined and the value in iron multiplied by (1.125×.4365)=.49106.

Slags which will not decompose by treatment with acids may be either sintered or fused.

The sintering is performed (see Furman's Manual) in a small platinum dish by mixing ½ gram of the slag with about 1½ (one and one-half) grams sodium carbonate in a small agate mortar; transfer this to the platinum dish, brushing the mixture to a small heap in the center, now place in the muffle and heat until the mass sinters together. Fusion must not take place, since the lead would be reduced and spoil the platinum dish. Remove from the muffle, cool by dipping the bottom of the dish in cold water, then add 2 cc. water and 5 cc. HCl, and proceed as previously directed under silica.

Fusion, when necessary, is conducted as follows: ½ gram of slag is mixed with about 3 times as much fusion mixture, and ½ gram of potassium nitrate (this is added to keep the lead from reducing and spoiling the crucible) and fuse in a platinum crucible in the muffle. Cool the crucible and place in a No. 4 casserole with about 50 cc. boiling water, boil until clean, take out crucible, rinse with hot water, using finger cot if necessary, boil until dissolved. Cover with a watch glass and add through a pipette 10 cc. strong HCl, wash off the cover, remove it, and evaporate to dryness. Treat the dry mass with 50 cc. dilute HCl, boil, dilute with 50 cc. water, filter, wash, ignite, and weigh silica.

Iron.—To the filtrate add ammonia in slight excess to ppt. the iron, filter and wash, dissolve the ppt. in dilute HCl, and proceed in the usual way.

Lime.—To the filtrate from the iron add 10 cc. of a 10% solution of oxalic acid, then make slightly alkaline with ammonia, boil, allow to settle, filter, wash, proceed in the usual manner.

Lead.—The purchase and sale of lead ores is at present based on the fire assay. This method, though inaccurate, appears to meet the commercial requirements.* The titration by ammonium molybdate already given is the method in general use where lead is determined in the wet way, but another way, by titration with potassium permanganate, is also in use.

In this method the lead is separated first as metal, then dissolved and ppted. as oxalate, the acid oxalate being titrated with permanganate of potassium.

Treat ½ gram of ore with 15 cc. strong nitric and 10 cc. strong sulphuric acids, and evaporate to white fumes over a strong heat, cool, add 50 cc. cold water and 2 grams of Rochelle salts, boil, filter, wash with dilute sulphuric acid (1 to 1), and then with water.

Wash the lead sulphate back into the casserole, add 10 grams ammonium chloride, 25 cc. water, and boil until dissolved; filter and wash with a little more solution of ammonium chloride, wash with boiling water. The filtrate should be received in a No. 2 beaker, containing the Al foil, such as was used in the Cu determination. Boil five minutes, when the lead will be completely ppt., and, if in considerable quantity, will usually separate from the foil and unite into a spongy mass. Decant the solution from the lead and aluminum into the casserole and fill the beaker with boil-

* The Colorado Scientific Society are at present gathering information regarding the best method of determining lead.

ing water, discard the solution in the casserole, being careful that no lead has escaped. Now remove the Al foil and, with the finger cot, remove any adhering lead, wash the foil with boiling water, decanting as closely as possible the last time. Pour over the piece of Al foil 6 cc. dilute nitric acid, to dissolve any particles of lead adhering to it, remove the foil with a glass rod, washing it slightly with a stream of water from the wash bottle, heat the acid in the casserole to boiling so as to dissolve the particles of lead, then pour it upon the greater portion of lead in the beaker, heat until dissolved, add a few drops of an acid solution of phenolphthalein, then add a solution of sodium hydroxide until slightly alkaline, then 10 cc. of a solution of oxalic acid (1 in 10), cool, filter, wash with cold water several times until excess of oxalic acid is removed. Remove the filter paper from the funnel, open against the side of a No. 2 beaker, wash the ppt. from the paper into the beaker with hot water, add 5 cc. dilute sulphuric acid and titrate with a solution of potassium permanganate made by diluting 1 volume of the 1% solution with 4 volumes of water, making a solution of which 1 cc.=.002 Fe. Multiply the value of the solution in Fe by 1.85 to obtain its value in Pb.

Comparing the equations,

$$10\ FeSO_4+2KMnO_4+8H_2SO_4=5Fe_2(SO_4)_3+K_2SO_4+2MnSO_4+8H_2O$$

and

$$5\ PbC_2O_4+2KMnO_4+8H_2SO_4=10\ CO_2+2MnSO_4+K_2SO_4+5PbSO_4+8H_2O$$

we see that the same amount of potassium permanganate will oxidize 5 equivalents of Pb oxalate, or 10 equivalents of ferrous sulphate. 5×207, the atomic weight of lead, therefore, are equivalent to 10×56, the atomic weight of Fe. From this we obtain the above factor.

$$\frac{5 \times 207}{560}=1.85.$$

Copper.—Cyanide Method.—Weigh 1 gram into an 8-oz. flask, add from 8 to 15 cc. strong nitric acid (according to the amount of sulphides in the ore), then add 5 cc. strong H_2SO_4, and evaporate to white fumes over a strong heat, eliminating all nitric acid. When the flask is full of white fumes, remove and place on a piece of asbestos to cool; when cold, add 30 cc. cold water and 6 grams of sheet zinc in strips; allow to stand until the evolution of hydrogen has nearly ceased, then add 10 cc. strong commercial H_2SO_4

and 50 cc. water, mix by shaking the flask, and allow it to stand until the zinc has completely dissolved, all action has ceased, and the black or red ppt. of copper has completely settled to the bottom of the flask. Fill up the flask with hot water, shake, and allow to settle completely. Carefully decant off as much of the liquid as possible, leaving all the ppt. in the flask; repeat this washing three times. Dissolve the ppt. Cu in 5 cc. strong nitric acid and boil off the red fumes, cool, add 20 cc. cold water, then 10 cc. strong ammonia, then 50 cc. cold water, mix, titrate with the volumetric solution of KCN until the blue color has become faint, but still indicates Cu. Filter rapidly through a 20 cm. Prat Dumas plaited filter paper, using a funnel with a 2-inch stem, wash with a little water, then finish the titration exactly as in standardizing the solution.

Multiply the number of cc. used by the standard previously found, and the result by 100, gives the % Cu.*

Or, if the assay of the ore is known (since 2Ag=1Cu, or 1% Ag=0.3% Cu), deduct .1% Cu for each 100 oz. Ag present. Zinc and nickel, which interfere with the titration by cyanide, not being ppt. by the zinc, have been removed. Lead has been converted into insoluble sulphate, or subsequently that derived from the sheet Zn used, has been ppt. as hydrate by ammonia.

In both the Iodide method (given previously) and in this method, when the Cu is over 20%, a standard of C.P. Cu should be run at the same time as the ore, and the ore should be run in duplicate, and the results should check.

SPECIMEN SLAG ANALYSIS.

SiO_2	30.0%
FeO	28.7%
MnO	5.4%
CaO	14.2%
MgO	2.3%
ZnO	5.7%
Al_2O_3	5.6%
	91.9%

* Only Ag interferes with this method; it can be removed by adding a few drops of HCl to the nitric acid solution of the copper before adding the ammonia. Shake well to make the silver clot, then filter into another flask and wash well with cold water, add 10 cc. ammonia and proceed as before.

SPECIMEN BED ANALYSIS.

Total Insoluble	42.4%
SiO_2	33.2%
Fe	12.4%
Mn	4.0%
CaO	4.5%
$BaSO_4$	9.2%
MgO	0.7%
Zn	2.2%
Al_2O_3	6.0%
Pb	14.7%
Cu	.3%
S	4.7%

COPPER SMELTING

The determinations called for in the laboratory of a copper smelter do not vary a great deal from those required in lead smelter practice; except for the fact that copper in some form or other, will be found in all samples, solutions, etc., with which we have to deal. Where this element interferes to any extent, the fact will be noted and the remedy suggested.

Slags, ores,* sulphurs, zinc, lead, etc., are analyzed or determined by one of the methods already given in the chapter on Lead Smelting.

Copper.—All samples containing more than 2 or 3% copper, such as mattes, ores, copper cakes, etc., are run for copper by the electrolytic method, as follows:

Weigh out from $\frac{1}{2}$ to 1 gram of ore in a No. 3 beaker; just moisten with a drop or two of water, then add from 10 to 15 cc. of strong nitric acid, and 5 to 8 cc. of sulphuric acid, and heat until white fumes of sulphuric acid are given off. Be sure that all of the ore (which is soluble in acids) has been dissolved, then dilute to about 80 cc. heat again just to boiling, to disintegrate the mass; filter off the residue in which the lead and silica may be determined if necessary. Filter the solution into a No. 2 beaker, add 1 or 2 strips of heavy aluminum foil, boil for 10 or 15 minutes, which is generally sufficient to insure complete precipitation of the copper. Pour off the solution and wash 3 times by decantation with hot water. Then add 3 or 4 cc. of strong nitric acid to the contents of the beaker, allowing the acid to flow over the aluminium. Boil to expel the nitrous fumes, decant into another beaker (a long narrow one) and rinse the alumnium with a few drops of water; just neutralize the solution with ammonia, and add about

*Copper interferes with the determination of Fe by the bi-chromate method. Either precipitate the iron with NH_4OH, filter off, and redissolve or use test lead to reduce the iron after the insoluble residue has been removed. (Furman, page 180B.)

15 cc.'s of 1 to 10 sulphuric acid. Place platinum cylinder into the solution, connecting it with the negative or zinc element of the battery; inside the cylinder place a platinum wire spiral, reaching almost to the bottom of the beaker, being careful not to allow the spiral to touch the cylinder.

A very good battery for this purpose is a Bunsen cell; about eight hours is usually required for a total precipitation of the copper. To determine whether or not all the copper has been ppt., remove a few drops of the solution in a pipette and test it with H_2S water. If the test shows that all copper has been removed, then, without turning off the current, remove the cylinder and place immediately into a beaker of warm water, so as to wash off as quickly as possible all acid from the cylinder. After the cylinder has been thoroughly washed, place it in a beaker of alcohol, which removes the water, then dry as quickly and carefully as possible, avoiding the oxidation of the copper on the cylinder. The ppt. copper should be a bright rose-red color.

In case the ore contains only a trace of arsenic, antimony, or bismuth, the precipitation of the copper on the aluminum foil may be dispensed with. In that case, after the ore has been dissolved and the mass disintegrated, add enough ammonia to just neutralize this solution, add ½ gram NH_4NO_3 and 15 cc. of 1 to 10 H_2SO_4, and place on the battery as before.*

COLORIMETRIC COPPER DETERMINATION.

To make up the standard: One gram of C.P. copper foil is dissolved in just as little HNO_3 as possible, then 10 cc. more of HNO_3 is added. Thoroughly boil off the red fumes, and add distilled water up to 1000 cc. From this solution 1 cc. is used for every 1/10%. Make alkaline with 20 cc. NH_4OH, and add enough distilled water to bring the bulk up to 350 cc. The standards are placed in large salt-mouthed bottles of colorless glass, with glass stoppers. These are kept in a suitable rack, which is lined with white paper, and placed in a well-lighted part of the room.

Slags and Tailings.—Weigh 2 grams of the pulp into a No. 2 beaker, add 5 cc. HCl, and take to dryness on the steam bath. Take up with 5 cc. HNO_3 and boil until copious fumes are driven off. Now add distilled water and remove from the plate. Add 20 cc. NH_4OH, and filter into the glass bottles. Wash twice with boiling water,

* From Chemists' Handbook, Western Chemical Co.

to wash any salts of copper out of the precipitate. Fill the bottle with water to the 350 cc. mark. The bottle is then compared with the standards and the reading divided by 2.

The mill tailings run higher in copper, hence use only 1 gram. Add 5 cc. of a mixture of HNO_3+$KClO_3$, and heat for 15 minutes. Now add 30 cc. water and remove. Proceed as before.

Copper, by KCN.—Weigh 1 gram of the sample into a 500 cc. flask and add 10 cc. of HNO_3; put on a hot plate and heat gently (if heated too rapidly sulphur will collect in globules and retain some copper). When no more NO_2 fumes come off, add 20 cc. cold water, remove, and cool. Add 200 cc. cold water and 20 cc. strong NH_4OH and titrate with standard KCN solution (1 cc. equals 0.005 Cu). Take about one hour for the titration, adding a few cc.'s of the standard solution from time to time, and allowing the ppt. to settle after each addition. When the titration is almost finished, filter the contents of the flask into another flask of the same size and finish the titration.

A standard should be run with each determination, taking .200 grams of copper foil for the standard. Run the standard exactly in the same way as the assay.*

DETERMINATION OF COPPER IN SILVER MUD AND SILVER MILL SLAGS.

SILVER MUD.

Treat ½ gram with 5 cc. HNO_3, and, when action has become quiet, add 3 cc. H_2SO_4, and evaporate to white fumes; cool, add 50 cc. H_2O, and heat to dissolve the soluble sulphates; add NaCl solution in slight excess, heat to boiling, remove and filter off the AgCl. To the filtrate add sodium sulphite and a small excess of NH_4CNS, stir and warm; $Cu_2(CNS)_2$ will precipitate; filter, wash thoroughly, ignite gently in a porcelain crucible. Dissolve the residue in 5 cc. HNO_3, and determine Cu electrolytically.

SLAGS.

Treat 1 gram in a Pt. dish with 6 cc. HNO_3 and 6 cc. HF. Add 4 cc. H_2SO_4, and proceed as before.

*All samples which contain Mn, Zn, As, or any organic matter, require the addition of a little $KClO_3$.

SILVER DETERMINATION ON ANODE COPPER BY FIRE ASSAY.

The silver is ppt. as AgCl, scorified and cupelled.

Weigh 1 A.T. of the sample in duplicate, place in a large beaker, add 200 cc. cold water + 130 cc. HNO_3 and let stand until completely dissolved. Then add 175 cc. of cold water and 8 cc. NaCl sol. (1 cc. equals 18.4 mgs.). Stir the solution well for a few minutes and allow to stand for twelve hours, to allow AgCl to settle. Filter and wash, add a couple of grams of litharge and set the filter paper on a 2½-inch scorifier, place in a muffle and burn off the filter paper at a very low temperature. Take the scorifier from the muffle and add about 35 grams of lead with four grams of borax for a cover. Place the scorifier in the muffle at a cherry red heat and scorify at a low temperature. This gives about an 18-gr. button. Cupel and weigh.

BISMUTH IN METALLIC COPPER.

Dissolve 10 to 50 grams of the copper in HNO_3 and H_2O. If much insoluble matter is present, filter off and fuse it with Na_2CO_3. Dissolve the fusion in HNO_3 and add to main solution. To the solution in HNO_3 add Na_2CO_3 until a slight permanent precipitate is formed. All the Bi will be included in this ppt. Filter it from the main solution, dissolve the ppt. from the filter with warm dilute HCl. Evaporate the HCl solution on a water bath till free acid is driven off, then add five or six drops acid and 2 or 3 cc. of water. The solution should be clear—if not, add a few drops HCl to clarify, then pour into the solution a large volume of water (400 to 500 cc.), and let the ppt. of BiOCl separate over night. Weigh as BiOCl on Gooch crucible.

ARSENIC AND ANTIMONY.*

USED ON COPPER SMELTER FLUE DUSTS.†

To 1 gram of ore in a 3-inch casserole add 10 cc. HNO_3 and warm. After the evolution of red fumes has nearly ceased, add about 10 cc. H_2SO_4 and run down to copious fumes of H_2SO_4. Do

*By Lewis B. Skinner and R. H. Hawley, Colorado Springs, Colorado.

†But works equally well on ores, etc.

not boil too long after dense fumes of H_2SO_4 have started, or some small amounts of arsenic may be volatilized.

Allow the casserole to cool and add 40 cc. of cold water and 10 cc. of HCl. Some tartaric acid should be added, also, if antimony is to be determined. Boil to dissolve all soluble matter.

If much gangue is present, filter; if not, wash into a No. 3 Griffin lipped beaker, using warm water, and reduce to a colorless solution with a mixture of one part of ammonium bi-sulphite and two parts of strong ammonia. The reduction is best made by adding the ammoniacal sulphite solution drop by drop with constant stirring, waiting for the ppt. formed to dissolve after each addition. Do not add any more sulphite than that necessary to reduce to colorless stage. Add a little more HCl in case the hydrates formed do not dissolve. If there is much gold, selenium, or tellurium in the ore, these metals will be ppt. by the excess of sulphurous acid and darken the solution; so, if after the solution is nearly colorless this darkening occurs, no more sulphite need be added.

Boil the solution a few minutes until there is no apparent odor of sulphurous acid, and then while still warm pass in a lively current of H_2S gas for about 15 minutes, or until the precipitate gathers together and the super-natant liquid does not appear murky. It is safer to pass the gas through for a longer period of time; but, in case of hurry, after some experience, the point may be told almost with certainty by inspection.

Filter the ppt. sulphides through an 11 cm. filter paper and wash the sulphides all on to the paper with water. Wash out the iron salts. Test the filtrate with H_2S gas.

Put the paper containing the sulphides into a 4-oz. distillation flask, the arm from the neck of which is bent down at the end, so as to connect with a 12-inch Liebig condenser set vertically. If the sulphides are too bulky to wrap in the paper and put into the flask, pierce the filter and wash most of the ppt. through the funnel into the flask, using a minimum wash of 1 volume of HCl and 1 volume of water, used in a wash bottle with a Bunsen valve.

Remove the paper and put it into the flask, then pour through the funnel, to wash it, 50 cc. of the cupric chloride solution. Always pour the chloride solution in through a funnel reaching below the opening at the side of the neck, so as to avoid getting copper into the distillate.

A thermometer through a rubber stopper is inserted in the neck of the flask reaching to within about ¼ inch from the bottom. The flask is set on a sand bath 4 inches in diameter, so that the naked flame shall not play on the sides of the flask, so avoiding the raising of the temperature at any spot above that desired. Allow the outlet of the condenser to dip about ½ inch into about 40 cc. of cold water in a No. 1 beaker.

Heat the flask gradually until the thermometer reads 115° C., then remove the stopper and add 10 to 25 cc. strong HCl, collecting the second distillate in water as before.

The distillate is poured into a No. 3 beaker, made alkaline with NH_4OH, just acidified with HCl, cooled, about 8 grams of bi-carbonate of soda and some starch solution added, and titrated with standard iodine solution.

Antimony may now be determined after removing the stopper containing the thermometer and inserting another through which is a glass tube reaching nearly to the bottom of the flask and connected with a HCl gas generator. This generator contains HCl, into which H_2SO_4 is allowed to drop from a separatory funnel at the rate of about two drops per second.

The condenser is sealed with cold water as for the arsenic distillation and heat is applied to the flask until the mass in the flask becomes about dry. Do not heat to a much higher point, since copper chloride is liable to come over. Remove the beaker containing the distillate, add a little tartaric acid, almost neutralize with ammonia and pass in H_2S gas. If the orange antimony sulphide ppt. shows up, put under the condenser other beakers of water as seals, keeping up the heating and passing in of the HCl gas until no ppt. is formed with H_2S.

Filter the sulphide of antimony into a tared Gooch crucible, heat in an air bath at 255° C. for one hour and weigh. The weight multiplied by 71.40 will give the amount of antimony.

It takes about 15 minutes each for the arsenic and antimony distillations. In the distillation some uncombined sulphur comes over, but does not affect the results. No sulphurous acid or H_2S will be found with the arsenious chloride distillate. Antimonous chloride can not be titrated, owing to other decompositions from the high temperatures required to distill it.

The solutions required are: Cupric Chloride—Dissolve 300 grams of pure cupric chloride crystals in 1 litre of HCl. This solution is mixed with 1 litre of a solution of zinc chloride, which boils at 180° C. The zinc chloride may be made by adding successively to 1 pound of pure stick zinc 500 cc. of water and 1250 cc. of HCl. After the zinc is in solution, bring to a boil and evaporate a little to bring the boiling point up to 180° C., this making about 1100 cc. of solution.

Standard Iodine Solution.—This is best made so that 1 cc. equals .005 grams of As. Dissolve about 40 grams KI in a minimum of water, and to this add 17 grams of I. After the iodine is all dissolved make up to 1 litre with distilled water.

To standardize, dissolve 300 mgs. of C.P. arsenious acid in a little caustic soda or potash, dilute to about 200 cc., acidify slightly with HCl, add about 2 grams $NaHCO_3$ some starch solution and titrate to a permanent blue. The arsenious acid contains 75.76% arsenic.

MODIFICATION. (THOMSON.)

Treat the ore with HNO_3, and, when violent action ceases, add 5 to 10 cc. HCl and evaporate to dryness. (If the sample contains organic matter, as in the case of flue dusts, treat with HNO_3+ $KClO_3$). Take up with water and HCl, filter off the residue, neutralize with ammonia, make acid with HCl to redissolve the ppt.; then add some sodium sulphide solution, and heat to drive off excess of SO_2. Ppt. with H_2S, and proceed as in above method.

CYANIDE PROCESS

I

DAILY WORK

1. Titration of Cyanide Solutions.—This is invariably made by Liebig's well-known method, depending on the fact that when a solution of nitrate of silver is added, drop by drop, to the solution to be tested, each drop of the silver solution forms a white cloud of silver cyanide, which disappears on agitation so long as the free cyanide is in excess, the reactions being as follows:

(a). $AgNO_3+KCN=AgCN+KNO_3$.

(b). $AgCN+KCN=KAg(CN)_2$.

The completion of the reaction is shown by the permanence of a white turbidity or opalescence. As soon as the whole of the free cyanide has been converted into the double silver salt, a further drop of silver nitrate in excess gives a ppt. of silver cyanide which does not redissolve on agitation.

(c). $AgNO_3+KAg(CN)_2=2AgCN+KNO_3$.

From these reactions it is evident that 169.55 parts of $AgNO_3$ are equivalent to 130.04 parts of KCN.

Standard Solution.—Dissolve 6.519 grams of $AgNO_3$ in 1 litre of water. Every cc. of this solution is equivalent to .01 grams KCN. Hence, if we take 50 cc. of the liquid to be tested, every cc. of the standard $AgNO_3$ added will represent .01% KCN.

From the solution to be tested take, by means of a pipette, 50 cc., place in a beaker, dilute with 50 cc. H_2O; add 5 cc. of a 1% neutral solution of KI,* and titrate with the standard solution.

It is advisable to place about 9 inches of rubber tubing over the end of the pipette, as a safeguard against drawing cyanide solution into the mouth. When the pipette is blown out, fill it with an equal volume of water and add to the cyanide solution in the beaker or flask. The pipette is thus washed out and ready for

* The addition of KI corrects the slight errors due to the presence of caustic alkalies, ammonia, alkaline carbonates, chlorides, ferro-cyanides, thio-cyanates, thio-sulphates, and perhaps some other salts.

the next measurement of cyanide solution. The method of titration for KCN herein given is for solutions, say, over 0.10%. Below this strength it is not advisable to dilute with water.

The practice varies considerably in different mills, both regarding the strength of the silver nitrate solution, and also the amount of the working cyanide solution taken for analysis. In some works but 10 cc. of solution is taken, and the silver nitrate standardized, so that each cc.=0.10 lbs. of cyanide per ton of solution, and in other cases 1.0 lb. per ton.

Liebig's method works admirably with pure cyanide solutions, but gives uncertain and inaccurate results in ordinary working solutions, particularly in the presence of zinc. As, however, it is generally only necessary to obtain relative commercial results, and a knowledge of the real strength of the working solution in actual free KCN or its equivalents is not essential, this method is in general use.

2. Titration of Alkalinity.—KCN and other simple cyanides of the same class are alkaline to ordinary indicators. The whole of the alkali may be determined by titrating with standard acid, using methyl orange as indicator. With phenolphthalein the end point is indefinite, owing to the faint action of HCN on this indicator. The double cyanide of zinc and potassium is likewise alkaline to methyl orange.

For practical purposes it is most important to know the alkalinity exclusive of cyanide, as it is this alkali which is chiefly of use in preventing the unnecessary waste of cyanide by reactions due to base metal compounds, and to the carbonic acid of the air. This may be done (accurately in the absence of zinc) by adding silver nitrate till a slight turbidity is produced, adding phenolphthalein to this turbid solution, and titrating, without filtering, with N/10 acid. The result indicates generally—

Equivalent of hydrates in terms of N/10 acid plus equivalent of half the alkali metal in normal (mono) carbonates, in terms of N/10 acid.

The reactions in a typical case are:

$$KOH+HNO_3=KNO_3+H_2O.$$
$$K_2CO_3+HNO_3=KHCO_3+KNO_3.$$

Bi-carbonates are neutral to phenolphthalein, hence are not determined. They have no protective influence in this case.

When zinc is present add an excess of a solution of $K_4Fe(CN)_6$ before adding the silver nitrate.*

3. Estimation of Free Cyanide:

(a). Differential Method.—Where zinc is the only metal present which is capable of forming easily decomposible double cyanides of the character of $K_2Zn(CN)_4$, a determination of the so-called "total cyanide" by the method given below, together with a determination of the zinc, enables us to calculate the free cyanide, assuming one part of zinc equivalent to 4 parts of KCN converted into $K_2Zn(CN)_4$. In this case:

Free cyanide equals total cyanide minus 4×Zn.

The presence of cyanogen, in the form of ferro-cyanides or thiocyanates, does not affect this result.

4. Estimation of "Total Cyanide."—Strictly speaking, the term "total cyanide" should indicate the equivalent of all the cyanogen contained in the solution. Practically, it is generally taken to mean "the equivalent, in terms of KCN, of all the cyanogen existing in the form of simple cyanides, HCN, and certain readily decomposible double cyanides, such as that of zinc." Some other double cyanides, such as those of silver and copper, are generally excluded, together with ferro and ferri-cyanides, thio-cyanates and similar bodies.

Method Based on Use of Alkaline Iodide Indicator.—An indicator is prepared by dissolving 40 grams of caustic soda and 10 grams of KI in water, and making up to a litre. Fifty cc. of the cyanide solution are taken, and 5 cc. of the above indicator added. The liquid is titrated with standard $AgNO_3$ (6.519 grams per litre) until a distinct yellow coloration is obtained, disregarding any white turbidity. This latter may sometimes be removed by adding NH_4OH, which, in moderate amounts, does not affect the accuracy of the test:

1 cc. of $AgNO_3$ used equals .01% KCN (equivalent to total cyanide).

5. Estimation of HCN.†—Estimation of free HCN in presence of alkaline cyanides and of zinc double cyanides:

(a) The free cyanide is first estimated in the ordinary way without addition of alkali. It is assumed that the presence of free HCN does not affect this result.

*Proc. Inst. Min. and Met., volume X, pages 29 to 37, Green.

† Bettel. Proc. Chem. and Met. Soc. of S. Africa, volume 1, page 165.

(b) Another portion of the liquid is mixed with a solution of potassium or sodium bi-carbonate containing no normal carbonate or free CO_2. The mixture is titrated with $AgNO_3$ as before, the reaction as regards HCN being:

$$2KHCO_3+AgNO_3+2HCN=KAg(CN)_2+KNO_3+2CO_2+2H_2O.$$

The difference of the two titrations gives the equivalent in terms of KCN of the amount of HCN present.

Bi-carbonates do not decompose $K_2Zn(CN)_4$, but, both titrations being subject to some indefiniteness as to the finishing point, the method is not very satisfactory.

6. Estimation of Ferro-cyanides by Means of Potassium Permanganate.—The ferro-cyanide is ppt. as Prussian blue by means of an acidulated solution of ferric chloride. The ppt. is collected and washed thoroughly. It is then decomposed by hot caustic potash, yielding ferric hydrate and potassium ferro-cyanide, filtered, the filtrate acidulated with H_2SO_4, and titrated with standard permanganate. The finishing point is shown by the change from yellow to reddish yellow. When much ferro-cyanide is present the solution must be diluted, otherwise the end-point is not sharp. About 100 cc. of H_2O should be added for every 0.1 grams ferro-cyanide present. The permanganate must be standardized against a solution of pure potassium ferro-cyanide; 3.16 grams KMnO, are equivalent to 42.2 grams of $K_4Fe(CN)_6,3H_2O$, the reaction being:

$$KMnO_4+5K_4Fe(CN)_6+4H_2SO_4=5K_3Fe(CN)_6+3K_2SO_4+MnSO_4+4H_2O.$$

A centi-normal solution (0.316 grams $KMnO_4$ per litre) may be conveniently used.

The chief objection to this method is the difficulty of thoroughly washing the ppt. of Prussian blue. This is absolutely necessary, as other bodies, e. g., thio-cyanates, are almost invariably present, which would likewise reduce permanganate in acid solution.

7. Estimation of Thio-cyanates by Means of Iodine.*—This depends on the fact that the thio-cyanates react with iodine in the presence of alkaline carbonate, thus:

$$KCNS+8I+4H_2O=H_2SO_4+6HI+KI+ICN$$

* Rupp & Schied, J. S. C. I., 1902.

A known quantity of the solution is first boiled for about 15 minutes with ½ gram of tartaric acid in an open flask to get rid of all HCN, cooled and made up to 100 cc. Of this liquid, 10 cc. are then taken for determination of thio-cyanate. A measured amount of N/10 I., more than sufficient for the reaction, is then added, and about one gram of $NaHCO_3$. After standing in a stoppered bottle for ½ hour in the dark, the excess of I is titrated with N/10 thio-sulphate.

Shaking the bottle should be avoided, in order to prevent the evolution of CO_2. It is stated that the presence of cyanogen iodide prevents the use of starch as an indicator. It is advisable to work with such quantities that not more than 20 cc. of iodine solution are required. The end of the reaction is shown by the disappearance of the yellow color.

When zinc compounds or ferro-cyanides are present a white or bluish ppt. occurs on boiling with tartaric acid, which must be filtered off before adding $NaHCO_3$ and I.

8. Estimation of "Total Cyanogen."—The term "total cyanogen" is here taken to imply cyanogen existing in every form, whether as free cyanides, double cyanides, cyanates, thio-cyanates, ferro and ferri-cyanides, etc.

(a). Estimation by precipitation with $AgNO_3$, using chromate indicator. (Based on Vielhaber's method.)

This method involves the separate determination of the various cyanogen compounds, and can only be regarded as a check on the combined results. It is not applicable in presence of chlorides, unless they also be separately determined and allowed for. Protective alkali must first be neutralized.

Standard silver solution is then run in until the reddish color of silver chromate becomes permanent on shaking. The indicator consists of a few drops of a strong solution of neutral (yellow) potassium chromate; it is advisable to insure the absence of chlorides in the indicator by adding silver nitrate to the chromate solution till a red color is produced, and allowing the ppt. to settle. In this process, cyanides (chlorides), thio-cyanates, iso-cyanates and ferro-cyanides are ppt. as silver salts.

(b). Total Cyanogen by boiling with oxide of mercury and removing mercury by alkaline sulphide. (H. Rose, modified.)

In cases where ferro-cyanides and similar compounds are present, the solution is boiled with excess of oxide of mercury until complete decomposition is effected, the liquid nearly neutralized with HNO_3, and filtered. The filtrate is then mixed with $Zn(NO_3)_2$, dissolved in NH_4OH and H_2S added gradually until a perfectly white ppt. begins to appear. The ppt. is then allowed to settle, filtered, washed with very dilute NH_4OH, and the filtrate titrated with $AgNO_3$, with addition of KI as indicator.

9. Estimation of zinc by decomposition with HNO_3 and HCl, and proceeding by Low's method, volumetric.

10. Estimation of Copper.—Volumetrically by iodide titration. Method of A. H. Low. (See chapter on Lead Smelting.)

Qualitatively, the presence of copper may readily be detected, even in very small quantities, by acidulating the liquid with any mineral acid, and adding a few drops of dilute ferro-cyanide solution, which gives the characteristic reddish brown color.

11. Estimation of Gold.—Where the gold or silver are present in quantities sufficient to be easily weighed up from one assay ton of solution, 30 cc. are placed in a lead foil tray 3″x2″x1″, evaporated to dryness, the lead tray rolled up and placed on the hot cupel and the resulting bead parted and weighed in the usual manner. Due care must be exercised to prevent loss from spitting during the last few moments on the sand bath or hot asbestos plate. The following method, while not so rapid, is accurate, and is preferable in all cases where large quantities of solution must be taken for assay: Argall's Method.*—Take 500 cc. of the solution, or, for greater convenience, prepare a pipette to hold 20 A.T. of the solution. Take a tall beaker, add 7 grams of zinc dust and pour in the 20 A.T. of solution; next add 10 cc. of commercial H_2SO_4, stir well with a glass rod and cover with a watch glass. When the action begins to fall off, add another 10 cc. of acid. The precious metals will be completely ppt. in from 10 to 20 minutes, but the solution had best be left in the beaker till the Zn is practically dissolved, usually occupying 30 minutes. A smaller quantity of Zn should not be used, and if the gold and silver is over 0.05 ozs. per ton, 10 grams should be taken.

When action is completed, filter, add 3 grams of SiO_2 to the residue on the filter paper, fold, place in a 10 gram crucible, incinerate in the muffle, remove crucible, and when cool add 10 grams each of flux and litharge, thoroughly mix in the crucible, fuse,

* The Mineral Industry, volume X, page 361.

cupel, weigh, and part in the usual manner. The flux used consisted of 42 parts potash, 84 $NaHCO_3$, 2 borax-glass and 9 of flour. Should copper be present in the solution, a larger proportion of flux will be required, and scorification may be necessary.

Qualitative Detection of Gold.—The presence of gold in quantities less than 0.1 mgr. may be detected in cyanide solution by acidulating, boiling till most of the HCN is expelled, then adding $KClO_3$ and again boiling till most of the chlorous gases are driven off, and finally adding stannous chloride, which gives the well-known Purple of Cassius. The final solution should not be too strongly acid, or the color may not appear. It frequently becomes more marked on allowing to stand for some time.

Estimation of Silver.—In the Argall method for gold we determine the combined weight of gold and silver, from which the silver may be calculated after parting the bead with HNO_3 and weighing the gold. I have not tested this method where large amounts of silver were present in solution, but up to 16 oz. per ton I know it gives correct results and without the formation of silver sulphates. If on richer solutions this was feared, hydrochloric acid could be substituted for the sulphuric.

The following method, recommended by Alfred Chiddey*, has not been tested, though it is claimed to give higher results than the evaporation process in ordinary use. The proportion of silver to gold in the solutions on which Mr. Chiddey used it is 10 to 1, and in case of nearly pure gold solutions the addition of a known quantity of silver nitrate dissolved in cyanide is suggested. Introduce into a porcelain dish 4 assay-tons, or more, of the solution to be assayed, add 10 cc. of a 10% solution of acetate of lead, then 4 grams of zinc shavings; boil a minute, add 20 cc. of hydrochloric acid. When the action has ceased, boil again; wash the spongy lead with distilled water; transfer it with a stirring rod to a piece of filter paper; squeeze into a compact lump and place in a hot cupel. The mouth of the muffle should contain a piece of dry pine wood, so that the muffle is filled with flame at the moment of introducing the spongy lead.

12. Estimation of Alkalies.—Generally only two determinations are attempted: (1) What is known as the "total alkali," which may be defined as the equivalent, in terms of KOH, of all the ingredients which are alkaline to methyl orange. (2) What is

* Engineering and Mining Journal, March 28, 1903, page 473.

known as "protective alkali." This means, in practice, the alkalinity which the solution shows to phenol-phthalein, after sufficient $AgNO_3$ has been added, to convert all the cyanogen of the free cyanides into the double silver salt. (1) Titration of Total Alkalies.—A measured quantity of the liquid is titrated with N/10 acid (any mineral acid may be used, but HNO_3 is preferable), a few drops of a .1% solution of methyl orange being used as indicator. If the addition of acid should cause a ppt. (as when Zn, Cu or Ag salts are present) it is better to add a moderate excess of acid, make up to a definite volume, and titrate an aliquot portion with N/10 caustic alkali. The substances determined are: Cyanides, hydrates, carbonates, bi-carbonates, sulphides, zincates, etc., of the alkali and alkaline earth metals and of ammonium.

The double cyanides of Zn, Ag, Cu, and perhaps some other metals give ppts. which represent a consumption of acid proportional to the amount of such bodies as may be present, e. g.

$$K_2Zn(CN)_4+2HNO_3=Zn(CN)_2+2KNO_3+2HCN$$

HCN and carbonic acid do not affect methyl orange. Ferrocyanides ferri-cyanides, and thio-cyanates of potassium, sodium, etc., are neutral to all indicators. (2) Titration of Protective Alkalies.—This has already been described. (See page No. 36.) All results should be calculated as the equivalent of KOH.

The following method for estimating cyanogen in commercial cyanide is said to be more accurate than Liebig's, and is recommended by Adair.*

The method to be described was originally devised for the estimation of ferro-cyanide in pot-metal (a very impure product). It can be readily adapted for the estimation of cyanogen in commercial cyanide, and is preferable to the silver methods for this purpose, because, although not quite so quick, only the useful cyanide is estimated. Cyanates, sulpho-cyanides, sulphides and chlorides, even in large percentages, do not sensibly affect the result.

The outline of the method is to convert the cyanide as such into ferro-cyanide—next to oxidize with $KMnO_4$, in the presence of H_2SO_4. The ferro-cyanide is oxidized to ferri-cyanide only, whereas cyanates, sulpho-cyanides and other impurities are either distinctively oxidized or converted into substances which do not inter-

*Journal of the Chemical Society of South Africa, January, 1903.

fere with the final steps of reducing the ferri-cyanide to ferro-cyanide, and the titration of the latter with $KMnO_4$ in acid solution.

Estimations can be made in 15 minutes, and concordant results are obtained in different operators' hands.

The solutions required are:

25% caustic alkali.

20% H_2SO_4 pure.

Saturated solution of $KMnO_4$, approximate strength only.

Saturated solution of $FeSO_4$, approximate strength only.

$N/10 KMnO_4$. 1 cc.=.156 grams total CN, or more convenient strength, 1 cc.=.100 total CN.

The solution is standardized with $K_4Fe(CN)_6+3Aq$. 3 grams are dissolved in 300 cc. H_2O and 15 cc. of the 20% acid are added.

$$\frac{880 \times 3}{157.9 \times \text{cc. consumed}} = \text{Value CN in grams per cc.}$$

Method.—Ten grams of the cyanide are weighed into a litre flask and about 200 cc. water used to dissolve it, add 2 cc. of the alkali solution and a quantity of the $FeSO_4$ solution equal to 12 grams $FeSO_4+7Aq$. Add the latter 5 cc. at a time and shake well.

$$6KCN \text{ and } FeSO_4+\text{alkali}=K_4Fe(CN)_6+K_2SO_4+\text{alkali}.$$

The reaction is immediate. Add H_2SO_4 and Prussian blue is formed. Then 15 cc. H_2SO_4 and saturated solution of permanganate until the color remains persistent; the color can be seen through the edges. 1 or 2 cc. or more in excess does not matter. The above quantity of acid is enough for each gram of $KMnO_4$ added, but if more than 1 gram $KMnO_4$ is used acid must be added in the same proportion, viz.: 15 cc. to each gram of $KMnO_4$ used. If much sulpho-cyanide is present, allow to stand 15 minutes, and if necessary, a further addition of $KMnO_4$ may be required. The reaction is:

$$5K_4Fe(CN)_6+4H_2SO_4+KMnO_4=5K_3Fe(CN)_6+3K_2SO_4+MnSO_4+4H_2O$$

Next add $FeSO_4$ solution in quantity equal to 15 grams and immediately 15 cc. alkali solution. The solution must be strongly alkaline. Shake thoroughly and make up to the mark, again mixing thoroughly.

Filter through a large folded filter. The titration is completed by taking 500 cc. or an aliquot portion, adding 20 cc. H_2SO_4 and adding the standard $KMnO_4$.

The influence of the precipitate on the results is small. It may be ascertained by testing a weighed portion of pure $K_4Fe(CN)_6$, $3H_2O$, adding the quantities of solutions as for an impure sample.*

Impurities in commercial cyanide may be detected in the following manner.† Potassium cyanate will dissolve in alcohol of specific gravity 0.849, and this solution, on addition of hydrochloric acid, will evolve carbon dioxide. Or, on adding water to the alcoholic solution, and boiling off the alcohol, the liquid will give a precipitate of calcium carbonate with calcium chloride. Cyanate may also be detected by the following application of Blomstrand's color-reaction: A strong solution of the sample is decomposed by passing carbon dioxide through it until no more hydrocyanic acid is evolved. By these means E. A. Schneider (Journal, Society Chemical Industry, 1895, page 887) found that 3 grams of potassium cyanide were decomposed in 45 minutes. To the resulting liquid Schneider adds sufficient 95% alcohol to precipitate the potassium carbonate formed. The filtrate is then slightly acidified with acetic acid, and some cobalt acetate solution added. An intense blue color, due to the formation of the double cyanate of cobalt and potassium, is produced, which renders easy the detection of as little as 0.35% of cyanate. If present in smaller quantities, more of the cyanide must be taken, dissolved in the smallest possible quantity of water, and the greater part of the cyanide precipitated by the addition of absolute alcohol. The filtrate is then treated with carbon dioxide, and tested as before.

Chlorides may be detected by silver nitrate, added in excess, which throws down silver cyanide as a white curdy precipitate. They may be determined by Siebold's volumetric method.

L. Siebold has shown that chlorides, when present, may be conveniently determined in the same liquid in which the cyanide has been estimated by neutralizing the excess of free alkali (which should not be ammonia) by the cautious addition of dilute nitric

*Quite a number of these methods are taken from a paper, entitled Analytical Work, in connection with the cyanide process, by J. E. Clennell, read before the Inst. of Min. and Met., London, May 21, 1903.

† Allen, Engineering and Mining Journal, August 15, 1903, page 239.

acid, adding a few drops of a solution of neutral potassium chromate, and continuing the addition of the silver solution until the red tint due to the formation of silver chromate remains permanent. If cyanide only be present, the volume of silver solution now required will be exactly equal to that previously employed to obtain a permanent turbidity, whereas any excess over this amount represents the silver solution corresponding to the chlorides present.

Formates, if present, will cause the salt to blacken on ignition. They may be detected more certainly by precipitating the cold dilute solution of the sample with excess of silver nitrate solution, filtering cold and heating the clear liquid. In presence of a formate, metallic silver will be precipitated. The filtrate from the precipitate produced by silver nitrate will also give a red color with ferric nitrate or sulphate if a formate be present.

Carbonates will remain insoluble on treating the sample with hot alcohol of 0.849 specific gravity.

Silicates can be detected and estimated in the ordinary way by evaporation to dryness with hydrochloric acid, the residue insoluble in acidulated water being silica.

Sulphates are detected by the formation of a white precipitate on adding barium chloride to a solution of the sample previously acidulated by hydrochloric acid.

Sulphides will give a black precipitate with mercuric chloride, and a yellow precipitate with a solution of cadmium. They can be separated by agitating the solution with lead carbonate.

Free ammonia can be recognized by the smell, and determined by treating the solution with an alkaline solution of sodium hypobromite and measuring the nitrogen gas evolved.

II

ESTIMATION OF OXYGEN IN WORKING CYANIDE SOLUTIONS

It is a well-known fact that in the cyanide process, as ordinarily used, the solution must contain oxygen in order to dissolve the gold. Realizing the importance of this, about ten years ago the Chemical and Metallurgical Society of South Africa offered a gold medal to anyone who should find a method of actually determining the oxygen in a working cyanide solution. This medal was awarded to Mr. Andrew F. Crosse, in January, 1899.

The following description of his method is adapted and condensed from Mr. Crosse's articles published in Volume 2 of the Transactions of the Chemical and Metallurgical Society of South Africa, pages 396, 419, and 476.

ESTIMATION OF OXYGEN IN WORKING CYANIDE SOLUTIONS.

By A. F. Crosse.

The ordinary working cyanide solution contains substances which prevent the direct application of Thresh's well-known method for the determination of oxygen dissolved in water, as described in Sutton's Volumetric Analysis, pages 277-283. By preliminary treatment, however, these substances can be either removed or neutralized without affecting the oxygen present in the solution, leaving it amenable to Thresh's method. This method is based on the fact that iodine is liberated when potassium nitrite and sulphuric acid are brought together in water containing free O, 16 parts of O liberating 254 parts of I.

Apparatus Necessary:

1 "Winchester quart" white glass bottle, with accurate fitting glass stopper and of known capacity—about 2½ litres.
1 smaller glass bottle—16 oz.
1 50 cc. burette, for $ZnSO_4$ solution.
1 rubber stopper with two holes, to fit large bottle.
2 293 cc. Thresh's separatory tubes, ground glass stoppers.

1 large wide-mouthed bottle, white glass.
1 rubber stopper with 4 holes, to fit same.
1 50 cc. burette for hyposulphite solution.
1 small pipette with stopcock for $NaNO_2$, KI solution.
1 small pipette with stopcock for H_2SO_4 solution.
1 350 cc. flask.
Beakers, glass tubing, rubber tubing etc.

Solutions.

$ZnSO_4,7H_2O$—200 grams made up to 1 litre; 1 cc. soln.=.2 grams $ZnSO_4,7H_2O$.
Phenolphthalein.
$Na_2S_2O_3$—7.75 grams per litre of water.
Bromine water.

KI and sodic nitrite solution / KI and starch	$NaNO_2$	.5 grams
	KI	20 "
	H_2O	100 cc

The method consists in:

First—Adding KOH.
Second—Adding $ZnSO_4.7H_2O$.
Third—Determining hyposulphite required by Thresh's method with clear solution decanted from precipitates formed in the closed bottle.
Fourth—Qualitative tests for nitrites.
Fifth—Correction for nitrites and re-agents used.

The Winchester quart and the 16-oz. bottle are filled with the solution to be tested; the contents of the latter to be used for preliminary work, and the former for the actual analysis.

Take 100 cc. from the small bottle, add a few drops of phenolphthalein and run in the 20% solution of $ZnSO_4$ until the alkaline action has disappeared, which is seen at once by the characteristic magenta color having vanished. It is advisable to filter the solution after the first disappearance of the pink coloration, as the ppt. carries down the coloring matter. The amount required for the Winchester quart, the contents of which are known, can then be calculated.

Add 5 or 6 grams of solid KOH to the Winchester quart, and, when dissolved, add the required amount of solid $ZnSO_4.7H_2O$, taking care not to allow any air to enter the solution. Replace the stopper, shake the bottle well, and let it stand for some time, so that the flocculent ppt. of cyanide of zinc may settle, and obtain a clear supernatant liquid. If possible, let it stand over night. When the ppt. has settled sufficiently, the liquid is siphoned off. Use a two-holed rubber stopper, with a siphon passing through one hole, and a short, bent tube through the other, and start the action by blowing through this bent tube, as one would use a wash bottle. The end of the siphon in the liquid should have a small bag of lint tied over it, to prevent the carrying away of any small particles of ppt. In this way, fill the two 293 cc. separatory tubes and put them aside for the present. Draw off the same quantity —293 cc.—into a beaker, add 1 cc. H_2SO_4 (half acid and half water), and 1 cc. of iodide of potassium and starch. From a burette, add carefully, drop by drop, dilute bromine water (1 bromine water to 2 of water) till a blue color is obtained, and note the number of drops.

Take the tube with the solution to be tested, add 1 cc. $NaNO_2$ and KI solution and 1.0 cc. H_2SO_4 (half acid, half water), and the number of drops of bromine water required, put in the stopper and turn over the tube several times. Iodine is at once set free in proportion to the oxygen in the solution, and is ready to be determined by titration with hyposulphite, according to Thresh's method.

The wide-mouthed glass bottle, having a rubber stopper, pierced with 4 holes, is here used, and coal gas, or CO_2, must be passed through it during the experiment. The CO_2 must be purified by passing through a solution of potassium iodide and freed from oxygen. The tube containing the solution is inserted through the third hole and the hyposulphite burette through the fourth. Coal gas (or CO_2) is passed through the bottle for 15 minutes, and then the KCN solution is allowed to flow into the bottle, and also a few drops of starch solution, which becomes blue at once. The stopcock is turned off, and the free iodine is determined by dropping in hyposulphite solution, slowly, until the blue color disappears; 7.75 grams of hyposulphite, in 1 litre of water, gives a solution 1 cc. of which corresponds to .25 milligrams of O. A correction must be made for the O in the reagents used.

Nitrite of potash (or soda) is oxidized by the addition of bromine water, and liberates iodine. To determine the correction necessary for this iodine, take a 350 cc. extra strong flask, and pour into it the same amount of solution as taken for the analysis.

Add a few drops of KOH, and close the flask with a one-hole rubber stopper, containing a glass tube with stopcock. Boil the solution for several minutes and close the cock. Cool the flask, pour the contents into the tube, add 1 cc. of iodide of potassium and nitrite solution, and 1 cc. dilute H_2SO_4 (half and half). Place the burette in the stopper of the wide-mouthed glass bottle, turn on the gas, and after 10 minutes run the solution into the bottle, add a few drops of starch and titrate, as before. The quantity required will give the correction for the nitrites in the solution, and also for the reagents used, as the same amount of H_2SO_4, and also the same amount of KI, containing potassium nitrite, is used in each case.

CALCULATIONS.

Let

L = capacity of Thresh's tube, minus reagents used, = 293—3 = 290 cc.

X = milligrams of oxygen per litre in the solution under examination.

M = correctiòn for nitrites and oxygen in the reagents used.

N = hyposulphite of soda used in the final determination.

Then,

$$\frac{(N-M) \times .25 \times 1000}{L} = X.$$

In an actual analysis the following results were obtained:

N = 10.2 cc. M = 2.8 cc.

$$X = \frac{(10.2-2.8) \times .25 \times 1000}{290} = 6.3 \text{ mg. O per litre.} = .0063 \text{ grams O per litre.}$$

PRECAUTIONS.

In all stages of the analysis care should be taken to prevent the addition of air to the solution.

The bromine water in the lower part of the burette under the stopcock quickly deteriorates by loss of Br, and should, therefore, be run off before beginning the titration.

III

ORE TESTING BY THE CYANIDE PROCESS

A very important part of the duties of the chemist in a Cyanide Works is to make extraction and consumption tests on the ores received. It is not unusual, in large custom works, to make such tests on each lot of ore received. But of greater importance, perhaps, is the testing and examination of ores for the purpose of determining their adaptability to cyanide treatment.

PRELIMINARY TESTS.

A physical examination of the ore will give a good idea of the screen aperture through which it must be passed in order to obtain a good extraction. For example; if the ore is a porous or cellular oxidized product, perhaps, crushing through 0.44″ screen aperture will suffice; if of dense and solid structure it should be crushed to pass screen apertures varying from 0.024 to 0.018-inch. Flinty material, pyritic and telluric, silver ores, etc., may have to be reduced to impalpable powder to obtain the desired extraction.

Roasting, apart from oxidizing or driving off the volatile metals, also resembles fine crushing in that it makes the ore porous, allowing the solutions to penetrate the individual ore particles, much as if they had been reduced to a very fine state of division.

CONSUMPTION TEST.

These are best made direct with cyanide solutions, and, as lime is invariably used to correct acidity, add it at once and note results. Weigh up 4A.T. of the crushed ore and place in 250 cc. glass stoppered bottle; add fresh slacked, pure lime at the rate of 5, 10, 15 and 20 lbs. to the ton of ore and 30 cc. of cyanide solution; place on the agitator for 30 minutes, filter, and determine cyanide consumption.

The lowest consumption may be found with 10 lbs. of lime (excess of lime will in itself consume cyanide),* indicating that about 10 lbs. of lime should be used per ton of ore.

If a high consumption of cyanide is shown when 15 to 20 lbs. of lime are added, see if soluble cyanicides can be removed by preliminary water washes (use three washes, each double the volume of the ore).

Should the cyanide consumption remain high after water washing, look out for oxidized copper compounds, and, if their presence is proved, treat the ore first to 3 washes of 5% sulphuric acid, followed by an alkaline wash (sodium hydrate preferably).

Organic compounds are often rendered harmless by a preliminary treatment with sulphuric acid.

If the acid wash fails, try concentrating out the heavy minerals previous to cyaniding. Copper, antimony, lead and other sulphides are thus removed, and the tailings are invariably rendered amenable to cyanide treatment.

PRELIMINARY EXTRACTION TESTS.

These are preferably made in the glass stoppered bottles used in the cyanide consumption tests. Should the ore under investigation be a gold ore, containing no appreciable amount of silver, weigh up 10 ½A.T.'s of the pulverized ore, add the amount of lime found necessary to neutralize acidity, and place in the glass stoppered bottles. Make up the following solutions of cyanide from the stock bottle:

0.300%—Put 30 cc. in each of 2 bottles. Duplicate tests.
0.200%—Put 30 cc. in each of 2 bottles. Duplicate tests.
0.100%—Put 30 cc. in each of 2 bottles. Duplicate tests.
0.050%—Put 30 cc. in each of 2 bottles. Duplicate tests.
0.025%—Put 30 cc. in each of 2 bottles. Duplicate tests.

Place on agitator for 8 hours. Allow to stand for 4 hours, so far as one set of bottles are concerned, allowing the duplicates to remain on the agitator 16 hours. Remove, decant on to dry filter paper, take up 10 cc. of the filtrate and titrate for cyanide consumption. Now wash out the bottles and give 2 water washes on the filter, dry and assay the residue for gold in the usual manner.

* The consumption of cyanide in laboratory tests, when pure solutions are used, is 25% higher than mill results with zinciferous solutions. (P. Argall, Mineral Industry, volume 6, page 373.)

From these tests the following are deduced:

(1). The proper strength of the solution to attain the best results on the ore.

(2). The time required for agitation, 8, 16, or more hours.

(3). The cyanide consumption.

These tests are quickly and cheaply made, and can be repeated or modified and concordant results obtained, results which are satisfactory to competent cyanide experts.

It has been found that, for silver ores, solutions from 0.25% to 0.75% are necessary to attack the sulphides, hence the following solution strengths are recommended for silver or for gold-silver ores: 0.25%, 0.30%, 0.40%, 0.50%, 0.75%.

The lime found necessary in bottle tests to neutralize the acidity is about 35% more than is required on a full working scale. Mass action in the latter case probably accounts for this.

Should the extraction on all the series of bottles be low, put on another series, using the percentage of cyanide that promised the better results in the previous case, but have the ore reduced to different degrees of fineness, say to pass a screen aperture of

0.011″ —About	40 apertures to the inch.
0.0087″—About	50 apertures to the inch.
0.0055″—About	100 apertures to the inch.
0.0030″—About	150 apertures to the inch.
0.0020″—About	200 apertures to the inch.

These would show the increased extraction due to fine grinding,* and, should the extraction remain unsatisfactory, add, after 2 hours' agitation, in a new series of bottles, 0.05% to 0.10% of the weight of the ore of cyanogen-bromide. This salt will often give good gold extraction on heavy sulphides or medium-grade gold telluride ores, particularly when the ore is ground fine. Moreover, by the use of cyanogen-bromide, the cost of roasting may be obviated.

Bromo-cyanogen is a very difficult substance to obtain in the West, but, in reference to its use in West Australia, Mr. Alfred James states:† "It is now usually made on the spot, from imported bromo-salts, in view of the difficulty of getting the steamship

* The finer the ore is ground, the easier and quicker the silver sulphides are attacked by weak solutions. Commercial results will thus lie between fine grinding and high cyanide consumption, for, the weaker the solution the lower the cyanide consumption.

† Engineering and Mining Journal, Jan. 7, 1904.

companies to carry the actual bromo-cyanide crystals. The method of preparation is as follows: Bromo salts include potassium bromide and bromate, roughly in quantities required for the reaction. Assuming this to be,

$$2KBr+KBrO_3+3KCN+3H_2SO_4=3BrCN+3K_2SO_4+3H_2O$$
$$238+167+195+294=318+522+54.$$

"Bromo salts imported from Germany are very impure, but contain the correct mixture to satisfy the above reaction. The charge used at Kalgoorlie to generate 100 lbs. of BrCN is:

Mixed bromo salts	125 lbs.
Cyanide (100%)	65 lbs.
Sulphuric acid (70%)	147 lbs.

"The salts are agitated in a wood or lead lined vat of about 200 gallons capacity, securely covered by a lid, through which a revolving stirrer or paddle works. Above this is a small vat, in which is stored the necessary charge of cyanide dissolved in 40 gallons of water. The vat is first ¾ filled with water, the agitator started, and the sulphuric acid added slowly and carefully. The whole charge is now left to stand until cool, say, 1 hour, as the great heat generated by the addition of the acid would destroy the bromo-cyanide. When cool, the mixed bromo-salts are added gradually and the solution of cyanide run in simultaneously with constant stirring. The reaction commences almost immediately, but is not thoroughly completed until after 6 hours' continuous agitation."

This method can be modified for laboratory use where the bromo-salts are not available for testing the ores.

ROASTING.

Should none of the foregoing tests give satisfactory results the ore may be roasted in the muffle, first to a dead roast; second, in case of silver ores, by a chloridizing roast, as plain roasting invariably interferes very seriously with silver extraction, and almost as persistingly greatly increases the extraction of the gold.

In a chloridizing roast the loss of gold by volatilization is often very heavy, and should, in all cases, be determined in the following manner:

Mix the necessary amount of dry salt with the ore, and reduce to pass the desired screen aperture. Assay for gold and silver, then weigh up 50 to 100 grams of the mixed ore and salt, place in a roasting dish and set in a cool muffle.* Gradually raise the temperature to cherry-red. When the fumes cease coming off, remove, cool and weigh. Note the loss of weight, then assay for gold and silver and calculate the loss of precious metals.

In practice the salt is often added toward the end of the roasting furnaces to prevent gold losses in the earlier stages of roasting. Chloridizing roasting is only necessary for silver ores, and, where the amount of the silver is considerable, it may be preferable to leach the roasted ore first with sodium thiosulphate to remove the silver chloride; wash well, and extract the residue of the gold and some of the silver compounds by cyanide solutions. Except for the fact that gold is soluble in thiosulphate solutions, a combination of the former, with the cyanide process, could be used on chloridized ores; the former to remove the silver, the latter the gold. I have found that thiosulphate would extract, in some cases, 50% of the gold present in chloridized ores, while subsequent cyanide treatment extracted not only a large proportion of the remaining gold, but also, in cases, as much as 10% of the remaining silver values. The Patera process is cheaper than cyanide in the treatment of these ores, but it never gives a satisfactory gold extraction. Therefore, when the cyanicides can be removed by preliminary water washes, followed by an alkaline wash, the cyanide process will extract both the gold and silver in one operation, greatly shortening and simplifying the treatment of the ore. In testing ores, as above outlined, the chemist should clearly keep in mind that the solution of his problem is, that process or combination of processes that will give the highest results at the least expense of operation, and, if possible, the smallest investment of capital in a plant.

MODIFICATION OF BOTTLE TEST.

In the foregoing tests it is assumed the ore treated in the bottles is fine enough for assaying. Should this not be the case the extraction can be determined by assaying the solutions by the

* Chloridizing roasts must be started at a very low temperature and gradually raised to cherry-red at the end, moreover, when the sulphur exceeds 4% a preliminary roast is desirable, then cool, add the salt and complete the roast. Gold is easily volatilized as chloride, but is, to a large extent, recoverable from the dust collected in a proper system of condensing flues.

evaporation, or the Argall method (see page 41). The solutions from one bottle would be used for determining cyanide consumption, the duplicate being used for this assay. Apart from this it is always advisable to test an occasional solution assay against the corresponding tailing assay, the one giving the precious metal extraction, the other the amount remaining in the tailings, and they should check within the limits of experimental error.

If the ore experimented with is to be treated by agitation, the bottle tests give all the information required, if, by percolation, it is necessary to establish the ratio of time between agitation and percolation. It is, of course, variable, but approximates 1 for agitation to 4 for percolation.

PERCOLATION TESTS.

These can be made in glass percolators holding about 4 lbs. of ore. The ore, in which is thoroughly incorporated the required amount of lime, should be placed evenly and carefully in the percolator, gently pressed around the sides to prevent channeling, and the solution added on top. The strength of the solution to be used has been previously determined from the results of the bottle tests.

Allow the solution to stand on the ore 4 hours, then allow to percolate through. Allow the ore to drain dry every day; after the second complete day's treatment turn the ore out from the percolator when drained dry, and cut out a sample for assay, to show the extraction, and return the remainder to the percolator. Keep up this sampling, daily, until the final extraction is reached, so far as one percolator is concerned. Allow the duplicate to run on without being disturbed, but it must be drained dry daily.

The percolator tests should follow the usual cyanide practice:

1. Water, or alkaline wash, if required.
2. Weak solution.
3. Strong solution.
4. Weak solution.
5. Water wash. Finish.

If the preliminary wash is unnecessary, add at once the strong solution, followed by No. 4 and No. 5.

Where copper or organic compounds are present, or to obtain details of change in the solutions, several small-sized Working Tests may be made in wooden or steel vats, holding 1,000 or 2,000 lbs. of ore. Proceed as with the percolators, but allow the solution to pass through filiform zinc in two or more glass or porcelain cells. Note the precipitation and analyze the solutions on completion of the tests. Be careful that the solutions are aerated before returning them to the leaching vats, for, as the solutions in percolating through a charge of ore are gradually deprived of their oxygen, it is found that the lowest layers of ore, those nearest the filter, do not extract as well as those layers above. This can be remedied by running on an occasional aerated solution from below. This must be performed slowly, to avoid forming holes or channels in the charge. In this way solutions rich in oxygen are brought in contact with the bottom portions of the charge, and a more even extraction thus obtained.

THE ANALYSIS OF BRONZES AND BEARING METALS*

By H. E. Walters and O. I. Affelder.

Bronzes.—Weigh 1 gram of the sample (½ gram if the lead is over 15%) into a No. 2 beaker, cover with a watch-glass, add 10 cc. nitric acid (Sp. Gr. 1.42) and warm until all is dissolved. When in solution, add 40 cc. hot water and boil five minutes, filter, wash with a 2% nitric acid solution, burn and weigh as SnO_2. To the filtrate add 25 cc. strong ammonia and heat to boiling, then add about 5 grams ammonium per-sulphate and boil from 5 to 10 minutes. Make acid with sulphuric acid, filter and wash with hot water. The lead will remain on the filter as lead peroxide. Transfer the precipitate and lead to a beaker in which the precipitation was made, add water and stir well to disintegrate the filter paper. Dilute to 600 to 700 cc. with cold water, add about 3 grams potassium iodide and some starch solution. When all the iodide is dissolved, add 10 cc. hydrochloric acid, stir well and titrate with 1/20 normal solution sodium thio-sulphate until the solution changes from the dirty and dark yellow solution to a bright lemon yellow; or an excess of sodium thio-sulphate may be added and the excess titrated with 1/20 normal iodide solution until the color changes from the bright yellow of the lead iodide present to the dirty and dark yellow. The number of cc. of sodium thio-sulphate used, multiplied by 0.5175, will give the percentage of lead. Where speed is not desirable the lead may be determined by adding sulphuric acid to the filtrate from the oxide of tin, or the lead and copper may be deposited with the electric current.

Dilute the filtrate from the lead peroxide to 500 cc., heat to boiling and add 50 cc. of a 20% sodium thio-sulphate solution, boil five minutes, filter, wash with hot water, burn and weigh as CuO.

Copper may also be determined as in the following method,

*Journal American Chemical Society, June, 1903.

which is a modification of Low's method: Dissolve ½ gram of the sample in 10 cc. nitric acid. When in solution, dilute with cold water and add sodium carbonate until the solution is alkaline, make acid with acetic acid and add about 3 grams potassium iodide and some starch solution. Titrate with a sodium thio-sulphate solution which has been standardized with pure copper.

Oxidize the filtrate from the copper sulphide thrown down by the thio-sulphate as described above, with nitric acid and potassium chlorate and evaporate until the volume is about 300 cc. Make a basic acetate separation and determine iron or alumina by the well-known methods. Make the filtrate from the iron or alumina strongly alkaline with ammonia, heat to boiling and add ammonium per-sulphate, boil for five minutes, filter, and wash with hot water, burn, and weigh as Mn_3O_4.

To the filtrate from the manganese add ammonium phosphate in excess, heat to boiling and add hydrochloric acid until there is but a slight excess of ammonia, boil for five minutes, filter, and wash with hot water. The ppt. may be dried and weighed as $ZnNH_4PO_4$, or it may be filtered on a Gooch crucible and ignited to $Zn_2P_2O_7$. It may also be titrated with a standard acid and alkali.

Any nickel which may be present will be found in the filtrate from the zinc, and may be ppt. as sulphide and ignited to NiO.

If manganese is present in small quantities, it may be determined in a separate portion by the following method: Weigh 0.2 gram of the sample into a suitable test tube, add 10 cc. nitric acid (Sp. Gr. 1.20), and warm until the sample is dissolved and all nitrous fumes are driven off. Add 15 cc. silver nitrate solution (1.33 grams of the salt to 1 litre of water) and about ½ gram of ammonium per-sulphate, warm until the manganese is oxidized to permanganic acid, cool, transfer to a beaker, dilute to 100 cc. and titrate with standard sodium arsenite or hydrogen peroxide until disappearance of the pink color.

DETERMINATION OF PHOSPHORUS.

To determine phosphorus, dissolve 1 gram of the sample in 5 cc. fuming nitric acid, evaporate to expel most of the free acid, add 10 cc. conc. HCl and water, heat to boiling and ppt. the lead, tin and copper with metallic zinc, filter and wash with hot water. To the filtrate add some iron solution free from phosphorus and 10 cc.

HNO_3, boil a few minutes, and then ppt. with ammonia and filter to separate most of the zinc, dissolve the ppt. in hot HNO_3 and ppt. the phosphorus with molybdate solution. The yellow ppt. may be weighed or titrated.

BEARING METALS.

If the sample is high in tin and low in lead, proceed as outlined for bronzes; but if the sample is high in lead and contains antimony, proceed as suggested by Mr. George Hopkins, chemist to the Carrie Furnaces of the Homestead Steel Works, he having found that the addition of an excess of pure tin will insure the complete separation of the antimony with the oxide of tin. Weigh 0.5 gram of the sample and $\frac{1}{4}$ gram of pure tin into a tall No. 2 beaker, cover with a watch-glass, add 20 cc. HNO_3 (Sp. Gr. 1.33) and boil down to a pastiness, add 40 cc. hot H_2O and boil a few minutes, filter and wash with a 2% HNO_3, burn and weigh as SnO_2+Sb_2O_4. The filtrate is made strongly alkaline with caustic potash and the lead oxidized by adding about 10 grams ammonium per-sulphate. The rest of the analysis is carried out as outlined for bronzes.

To determine the antimony, weigh 1 gram of the sample and 1 gram KI into a No. 2 beaker, add 80 cc. HCl (Sp. Gr. 1.10) and boil gently for one hour, filter on a weighed paper or Gooch crucible and wash with dilute HCl, and then with hot H_2O until free from chlorides. Wash once with alcohol, dry for one hour at 100° C. and weigh. The increase in weight is metallic antimony. Calculate this to Sb_2O_4 and subtract from the weight of the mixed oxides; calculate the tin from the weight of the stannic oxide found and subtract the tin which was added.

Arsenic is determined in a separate portion by any of the well-known distillation methods.

Bismuth, if present, would be found with the copper sulphide, and can be determined by dissolving the copper sulphides in HNO_3, and ppting. the bismuth with ammonia.

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CONTENTS.

RECENT STATE CONSTITUTION-MAKING[1]

By John B. Phillips

Constitutions which determine the form a government shall take are always the result of slow growth. It does not matter whether they are written or consist only of unwritten precedent. In every case they must needs represent the fundamental notions of the people in regard to the proper safeguards necessary to secure them in the enjoyment of their liberties. What these safeguards are can be determined only by the slow changes of time and the processes of evolution. These fundamental notions are constantly changing in order to keep pace with the shifting conditions of opportunity for human endeavor. The growth of opportunities in modern times has made it necessary to embody in the constitutions many things which were not considered by the constitution-makers of one hundred years ago. Intricate and complex have become the industrial relations of our time, and so great the consequent pressure upon the weaknesses of our legislators that it has become necessary to modify greatly the older constitutions in order to cope successfully with this new form of danger to the liberties of a people. Hence the growth of modern constitutions. There is no evidence that this growth will be arrested. On the contrary, it will probably increase for a considerable time to come. It is highly probable that we are now only in the beginning of the new industrial era; and if this is the case, it is clear that with new industrial opportunities it will be necessary further to define the limits of individual rights. It is unlikely that this will be left to the courts alone. On the contrary, it will probably be settled by putting into the constitution something to mark the limits of the individual's sphere of action.

Aside from the variations in their interpretation by the courts the constitutions of the American States can grow in but two ways. They may be changed by amendment, or an entirely new constitution may be

[1] Reprinted from the *Yale Review*, Vol. XII, No. 4 (February, 1904), by permission of the editors.

formed by a constitutional convention. Of these the most common method is that of amendment. The various State constitutions are being constantly changed in this way. The constitutions of the older States have been greatly modified by the number of amendments that have been made to them. Massachusetts has amended her constitution thirty-six times.

In order that the constitution may guarantee what the form of the government shall be and insure it against frequent change, it is necessary that amendments may not be made too easily. In France and Prussia, where it was not intended that the constitution should interfere with the powers of the legislature, it has been provided that amendments may be made by the law-making body. But in each of the forty-five American State constitutions various restrictions have been placed on amendment. It was felt by the framers that changes in the organic law should not be made too frequently. In some States, as Indiana and New York, a proposed constitutional amendment must be adopted by two successive legislatures before it can be submitted to the people for ratification. In others, as Michigan, a proposed amendment must be passed by a majority of the members elected to both houses before its submission to the people. In two States, Mississippi and South Carolina, even after the amendment has been proposed in the legislature and submitted to and adopted by the people, it is not a part of the constitution until inserted in that instrument by a legislative resolution.

The object of the restrictions is, of course, to prevent rapid changes in the organic law. In this way the framers of the constitutions sought to give greater stability to the government. Our constitution-makers have always been filled with distrust of the legislatures. In only one State, Delaware, can the constitution be amended by the legislature alone, without submission to the people. Great as are these restrictions, however, they are not sufficient to prevent radical changes from being constantly made, as the opposite table shows.

From this table it appears that during the eight years from 1895 to 1903 the people of the various States voted on two hundred and eighty-one different amendments to their constitutions, an average of thirty-five a year. Of these one hundred and sixty-eight were adopted and one

State Constitutional Amendments Adopted, Rejected, and Proposed from 1895 to 1903

States	Adopted	Rejected	Proposed	States	Adopted	Rejected	Proposed
Alabama	..	1	..	Nevada	1	..	6
Arkansas	4	1	4	North Carolina .	1	..	1
California.......	20	15	27	North Dakota ..	2	1	13
Colorado	7	3	9	New Hampshire	..	..	..
Connecticut	2	4	7	New Jersey	2	1	..
Delaware	..	1	2	New York......	5	1	12
Florida	12	..	11	Ohio	..	2	4
Georgia	5	2	1	Oregon	1	8	19
Idaho	6	..	5	Pennsylvania ...	2	..	4
Illinois	..	1	2	Rhode Island ...	1	6	4
Indiana	..	3	6	South Carolina..	3	..	3
Iowa	1	2	5	South Dakota...	11	1	13
Kansas	2	2	3	Tennessee	..	..	7
Kentucky	..	1	2	Texas	8	3	6
Louisiana	7	15	17	Utah	4	..	..
Maine	none	none	none	Virginia........	3	1	6
Massachusetts ...	2	2	1	Vermont	..	..	..
Maryland	3	1	3	West Virginia ..	5	..	7
Michigan	7	6	5	Washington	3	2	4
Minnesota	12	4	14	Wisconsin	4	1	14
Mississippi	3	4	2	Wyoming	..	1	..
Missouri	14	7	20				
Montana	5	..	5				
Nebraska	..	10	10	Totals	168	113	284

The sum of the first two columns does not equal the third because some amendments were pending January 1, 1895, and some are still pending. In some States, as Utah and Vermont, proposed amendments are not printed in the session laws, and it is impossible to ascertain without great difficulty how many such have been proposed.

hundred and thirteen rejected Only in Maine, New Hampshire, Vermont and Ohio were no amendments added to the constitutions. The tendency to amendment has been greater during the latter part of this period. In 1900 the forty-five States adopted thirty-nine amendments, rejected twelve, and proposed ten. In 1901, they adopted sixteen, rejected seven, and proposed ninety-three. This is sufficient to show that the constitutions have a very substantial growth by means of amendment. The ninety-three amendments proposed in 1901 are on all sorts of subjects. Two leading causes have largely contributed to this tendency to constitutional amendment. They are the outgrowing of the constitutions by modern industrial society, and the increasing distrust of the legislature by the people.

The complex growth of modern society and the intricate industrial relations which have been developed in the last two decades have clearly demonstrated that the old constitutions are no longer adequate. Contingencies which the most sagacious intellects among the framers of these older State constitutions could not foresee have arisen and must be met by changes in the fundamental law.

One of the more important subjects concerning which it has been found necessary to adopt amendments is the power to create a State highway commission. In a number of States the demand for road-improvement has made itself felt in the form of legislation to enable the State to oversee the building of roads and to appropriate money for this purpose. In the State constitutions this power is frequently denied the legislature, and it has therefore been found necessary to make the amendment.

In the matter of railroad taxation, also, great changes have occurred. The manner of taxing railroads has been prescribed in many of the older State constitutions, and with the growth of modern ideas of reform in the taxation of public-service industries an amendment is necessary or no reform is possible.

Again concerning the question of municipal government, it is found that in most of the older constitutions there is no general rule laid down for the incorporation and government of cities. Amendments must be made to prevent the legislature from abusing the privilege of special legislation, and also to introduce some sort of order into the municipal system.

Even more urgent has been the necessity of changing the qualifications of voters. This has resulted from higher ideas of citizenship and also from the great influx of ignorant foreigners on whom we have indiscriminately conferred the franchise. A number of States have recently sought to protect themselves by adopting an amendment requiring all voters to have a reading knowledge of the English language. Washington adopted such an amendment in 1901 and her example has just been followed by New Hampshire. A similar amendment was adopted in Massachusetts as early as 1857 and may have had a good deal to do with elevating the politics of that State.

These illustrations are sufficient to show that it is not possible to frame a constitution broad enough to cover all the points that must of necessity arise among any progressive people.

The second cause of this growing tendency to change the State constitutions by amendment is the distrust of the legislature. Evidences of the increase of this feeling toward the members of the legislature may be easily found in every State. There is a very general feeling that we have too much legislation. Business men feel that the frequent sessions of the legislature are a constant menace to their prosperity. They feel that any sort of law is liable to be enacted if it appeals to the legislator as a means of getting votes. Changes in the tax laws are perhaps the most common cause of complaint. These are very frequently made, and the vested interests have become greatly alarmed of late at the uncertainty that hovers over each meeting of the legislature. During the past three years the State of New York has been considerably agitated in this way. Capital there has been very apprehensive as to what might be the outcome of the tax reforms which the party in power has been pushing through. Radical changes in the tax laws have been either made or vigorously attempted during each of the last three years. This is especially true of the legislation affecting the banking and insurance interests. It is in consequence of the interference with business in this way by the legislature that the saying has become current: "If the legislature would adjourn for ten years, there would be a period of great prosperity." Idle as this is, it nevertheless shows in a certain way the distrust of the legislature which is not wholly confined to the business world.

There are three prominent reasons for this distrust of the legislature. They are unwise laws, special legislation, and the power of the boss.

It is of course very well known that the legislature does not use the care it should in the preparation of bills. Bills are often prepared by someone who has no special knowledge of law, and are not examined by a lawyer at all, but are hurriedly passed by the legislature and signed by the governor. It is for this reason that so many acts must be declared unconstitutional by the courts. In these days, people are not going to obey a law as long as there is any doubt of its constitutionality. As a consequence, the shrewd lawyers who are now employed by the great private interests are sparing no energy to detect evidences of unconstitutionality in the new laws that are ground out in such quantities almost every year. That the efforts of these lawyers are crowned with a reasonable degree of success is apparent from the statistics of unconstitutional laws that have been enacted by the legislature of the State of New York since 1895. Of the laws enacted since that date, forty-one relating to all sorts of subjects have been declared null and void by the New York courts. This condition of affairs is to be accounted for only on the theory that the bills were not given proper consideration before they were enacted into law. It is unlikely that the members of the legislature were unable to judge whether or not a proposed law was liable to prove unconstitutional or not. Had they given the matter the attention it deserved, they would have asked someone competent to tell them in case they had doubts of their own. The trouble comes about through the haste with which the legislator has to work. Between seven and eight hundred laws are enacted each year by the New York legislature during its sessions of less than four months. It is next to impossible for the members to find out much about all these various measures on which they are obliged to pass. Hence the rush and hurry of the modern legislature. The inevitable result is hasty and unconstitutional legislation, and the consequent confusion in business and distrust of the people.

A second cause of this distrust is in the evil that has been done by special legislation and the current belief that it has been so often secured by bribery. It is well known that many of the large corporations keep what is known as a corruption fund, and they frequently appear before the legislature and ply all the arts of the lobbyist. That they are often successful is beyond dispute. They are quite likely to secure what they want in the shape of a special act. Sometimes it is said the money is spent in the campaign, and then the public believe a promise has been secured from the State boss to secure the legislation the corporation may desire. Mr. Havemeyer, of the American Sugar Refining Company, testified before the Industrial Commission that his company contributed to the campaign funds of both the political parties according to the State.

Another form of this special legislation and bribery which the people desire to curtail is due to the power of the boss in State politics. He is thought by many persons to be the worst source of bribery. In some States he is said to own the legislature. In States where this is the case it is only necessary for those desiring special legislation to deal directly with the boss. The individual member of the legislature may well be ignored. It is in this way that the disappearance of the striker is to be explained. The striker was a member who introduced bills for the purpose of selling out. It was his custom to get up a bill inimical to the interests of some corporation and to draw it in such form that it might have some reasonable assurance of favorable committee consideration. Then he would sell out to the corporation. If they would pay him enough, he would get the committee to throw the bill into the waste-basket. This individual has well-nigh disappeared from the legislatures of those States where there is a powerful State boss, and it seems not unreasonable to assume that the boss has usurped the striker's functions along with those of the legislature generally.

The desire to curb the power of the boss has led to many amendments, such as those restricting the power of the legislature to grant special charters or pass special acts and make exemptions to private persons in the matter of taxation. The last amendment to the constitution of the State of New York forbids the legislature to exempt individuals and corporations from taxation. It is due, therefore, to this distrust that the people insist on getting more and more the power of legislation into their own hands by adding new amendments to the constitution.

The other way in which constitutions have been growing is by revision by a constitutional convention; in short, by framing an entirely new organic law. In most of the State constitutions there is a provision requiring the submission of the question of calling a convention to revise the constitution to the people at specified times. The interval differs in the different States and is usually from seven to sixteen years. Of course, this does not mean that the revision may not be undertaken at any time. It is simply a requirement that the people may have an opportunity to vote on the question of a new constitution at stated periods. The States have not been slow to take advantage of this privilege. Since 1890, Delaware, Kentucky, Louisiana, South Carolina, Alabama, Virginia, New York, Mississippi, and Utah have adopted new constitutions. New constitutions have been framed and rejected by the people in Connecticut and Rhode Island. A convention to revise the constitution was in session in New Hampshire during the past winter. It submitted ten amendments, only four of which were adopted.

The general characteristic of all these constitutions as compared with those they have superseded is their great length. The New York constitution is three and one-half times as long as the old constitution of 1846. The new constitutions of the southern States are about twice as long as the old ones they superseded. The tendency everywhere in constitution-making is to include in the new instruments a great mass of law which has no connection with the framework of government.[1] At present there is no limit to what a convention may put into a constitution except the restrictions on the States to be found in the constitution of the United States. The result is that the members of a constitutional convention take upon themselves to make such laws as they think necessary in addition to making a frame of government. Each member usually has some particular idea that he is especially anxious to have put into the new constitution, and by a process of log-rolling, a bargain to support each other's propositions, many members succeed in getting their ideas incorporated into the fundamental law. The leading cause of so much legislation being put into the constitutions is the prevalent distrust of the legislature. The fear is general that the legislature cannot be trusted, and therefore the constitution-makers feel that the subjects on which legislation is most desired should be attended to by the convention and the matter settled once for all, instead of being left to the uncertainties of the legislature.

This desire to limit the power of the legislature reached the extreme in the new constitution of Alabama, where, besides a great deal of special legislation, the convention substituted quadrennial for biennial

[1] R. H. Whitten, *New York State Library Bulletin*, No. 72, p. 28.

sessions, and even these are limited to fifty days in length. A determined effort was made to insert a similar provision in the constitution of Virginia, but it was defeated. In the new constitutions of these two States the power of the legislature to pass special laws is greatly restricted. The conduct of the legislators is responsible for these restrictions. The great number of special laws on trivial matters was one of the most urgent causes of the new constitution in both Alabama and Virginia. Special legislation, however, is abundant in both these constitutions. As an illustration of the manner in which it gets into the constitution, it is said that in the Alabama convention, when the sections relating to indebtedness were under consideration, "one member after another had an exception to introduce and at last, when a delegate protested against such special provisions, twenty cities or towns had been specially favored in the constitution."[1]

Constitutions which are so crowded with special legislation are in need of frequent amendment. The larger a constitution gets, the more subjects on which it legislates, the more often it must be changed. If the entire body of statute law were in the constitution, it would require constant amendment. In such detailed constitutions needing so frequent change, provision should be made for their amendment by the legislature alone without submission to the people. A two-thirds vote by two successive legislatures would seem to be amply sufficient to secure safety to popular government. Of course, the more vital points in any constitution should always be submitted to popular vote. It is impossible, however, for the people to act wisely on a large number of amendments at each election. They will not and cannot inform themselves on all the difficult questions involved.

It has been pointed out that the distrust of the legislature need be no excuse for filling the constitution with special legislation. There is another way of controlling the legislature, and that is by the initiative and referendum. At present we have in nearly all the States the compulsory referendum on all constitutional amendments. By the introduction of the optional referendum, a salutary check on any evil legis-

[1] *Annals of American Academy*, Vol. XIX, p. 145. Quoted by R. H. Whitten in *New York State Library Bulletin*, No. 72, p. 29.

lation would be established. It is true the frequent use of the referendum would be cumbersome in the extreme, but it is not to be supposed that it would be often necessary to resort to this method of checking bad legislation. If it were possible by petition of a not too large number of names to compel the submission to popular vote of any law passed by the legislature before such law should become operative, it is highly probable that this would act as a most wholesome check on any legislation that did not meet in very great degree the approval of the public sentiment of the State. The possibility of the use of this referendum would serve to keep the legislature within its proper limits.[1]

ADOPTION AND PROMULGATION OF STATE CONSTITUTIONS

After the Declaration of Independence and the opening of the Revolutionary war, royal charters were of no avail as foundations of government. All the colonies save two framed for themselves constitutions, New Hampshire and South Carolina each adopting two. Thirteen constitutions had been adopted in the various States before the federal convention of 1787. Connecticut and Rhode Island still operated under their old charters, as in these instruments it was provided that the governor should be elected by popular vote. None of these constitutions save two in Massachusetts were ever submitted to the people for adoption or rejection. They were proclaimed by the conventions which framed them. In some cases they were framed by the legislature. The first constitution ever submitted to the people in the history of the world was the constitution of Massachusetts in 1778. Its treatment at the hands of the people was enough to dishearten the stoutest champion of democracy. It was rejected by an overwhelming majority. In Boston every vote was cast against it. The chief reason for this rejection was that the new constitution did not contain a bill of rights. Another constitution containing a suitable bill of rights was accordingly prepared and submitted to the people in 1780. It was adopted and is still in force. After that time it became the almost universal practice to submit constitutions to the people for adoption or rejection. Of the constitutions in force at the present time, all have

[1] R. H. Whitten, *New York State Library Bulletin*, No. 72, p. 29.

been adopted by popular vote except those of Vermont, Virginia, South Carolina, Delaware, Kentucky, Louisiana, and Mississippi. Of the nine new constitutions framed since January 1, 1890, only three have been submitted to popular vote. These are the constitutions of New York, Utah, and Alabama. It seems that there has grown up a tendency to adopt constitutions by promulgation merely. This tendency seems to be confined to the southern States, and may be a part of the program to disfranchise the negro.

It is interesting to see how the promulgation of these constitutions came about. Of the seven States that have constitutions that were promulgated, Vermont is the only one that belongs to the old régime. Its constitution was made in the days when the idea of submitting to the people for adoption had not become a part of American political thought. The constitution of this State was promulgated by the convention, July 9, 1793. The authority for promulgating it was in the constitution of 1777.

The constitution of Delaware was promulgated by the convention, June 4, 1897. In the act which called the convention there was no authority for promulgating the instrument. This act states that in the opinion of the legislature the constitution framed by the convention should be submitted to the voters of the State for their adoption or rejection.[1] The convention decided to reject the opinion of the legislature.

In Kentucky the convention was called for the purpose of "readopting, amending, or changing the Constitution of this State." The act required the revised constitution to be ratified by a majority of the qualified voters before taking effect.[2] After the constitution had been ratified by the voters, the convention, which had adjourned to await the result of the vote, met and made many amendments to the instrument and published it as the law of the State, September 28, 1891. The supreme court has held that these amendments are valid and that the legislature had no power to require the constitution to be submitted to the voters for ratification.[3]

The constitution of Louisiana was promulgated May 12, 1898. The

[1] 1895, ch. 183. [2] 1890, p. 124. [3] 92 Kentucky, 589, 605.

authority for promulgation was in the act calling the convention. This act had been submitted to and was adopted by the people, January 11, 1898.[1]

In Mississippi the legislature passed an act calling a convention "to revise and amend the present constitution of the State, or to enact a new constitution."[2] The convention did not submit the new constitution to the people for ratification, but promulgated it as the fundamental law, November 1, 1890. The supreme court has held that this convention represented the sovereignty of the State.[3]

The South Carolina constitution was promulgated December 4, 1895. There was no authority for promulgation in the act which called the convention, but as the old constitution did not require the submission of a revision to the people for ratification, the convention decided that submission was not necessary.[4]

In May, 1900, the people of Virginia voted to hold a convention to revise the constitution. An extra session of the legislature was held in January, 1901, to provide for the election of delegates. The act provided that in case the convention had completed its work before the November election of that year, the new constitution should be submitted to the voters for adoption at that time. If the constitution should not be ready then, the next legislature should provide for its submission.[5] The convention had not completed its labors by November, 1901, and the following legislature did not provide for submission to the people. The convention promulgated the constitution July 10, 1902.

There is considerable danger in this plan of promulgating constitutions. It places too much power in the hands of the constitution-makers. There is hardly any limit to the power of a constitutional convention. In case bad features are put into a new constitution that is to be promulgated, the only recourse the people have is to elect a legislature, and have this legislature call a convention to revise the constitution and submit it to the people for ratification. It is not hard to see how this might prove a tedious and troublesome process.

[1] 1896, ch. 52.

[2] 1890, ch 35.

[3] 69 Mississippi, 898.

[4] 1894, ch. 542.

[5] 1901, ch. 243.

STRUGGLE FOR NEW CONSTITUTION IN CONNECTICUT

The ingenuity of the New Englander has become proverbial. Of the people of this section of the country, none have enjoyed a greater reputation for shrewdness than the Connecticut Yankees. This reputation has been preserved in the tradition of their manufacture and sale of wooden nutmegs. However, ingenious as they are in many ways, they have not as yet been able to frame a constitution suited to the needs of modern times.

The present constitution was adopted in 1818. It provided that each town should have two representatives in the lower house of the legislature. According to the distribution of the population at that time, this apportionment was fairly just. However, with the shifting of population to cities and the consequent decline of the rural towns, representation has become very unequal. Since 1818 two feeble efforts have been made to correct this evil. An amendment adopted in 1874 provided that a new town of 5,000 should have two representatives in the lower house, and another amendment adopted in 1876 required a new town to have at least 2,500 inhabitants to be entitled to one representative. These amendments were wholly inadequate to correct the abuse that had grown up. At present the thirteen cities, which contain over half the population of the State, have only about one-tenth of the representation in the lower house. In the house of representatives there are two hundred and fifty-two members, and the thirteen cities with over half the population have twenty-six of these. The town of Union with four hundred and twenty-eight inhabitants has as many members in the house as New Haven with a population of 108,000.[1]

It is plain that such an arrangement gives the power in the legislature to the delegates from the rural districts. These are jealous of their power and desire to keep it. In recent times, when the injustice of the apportionment of representatives has become fully apparent, there have been vigorous protests on the part of the delegates from the cities. Finally, after a long agitation, the legislature submitted to the electors at a special election in October, 1901, the proposition to hold a convention to frame a new constitution. The proposition was adopted.

[1] R. H. Whitten, *New York State Library Bulletin*, No. 72, p. 27.

Delegates to the convention were elected in November, and the convention met in January, 1902. The rural element in power in the legislature had taken pains to keep their power in the convention by providing for the election of a majority of the delegates from the towns. As this party was unwilling to give up the power it had so long held on account of the inequality of representation, it was impossible to remedy the greatest defect in the old constitution. After a stormy session of more than four months, the convention adjourned, May 15, 1902. It had prepared a new constitution which did not correct the defect of representation in the old instrument, and it was accordingly rejected by the people at an election, June 16, 1902. The fact that the people of Connecticut continue to live peaceably under a government with such inequalities in the representation establishes beyond peradventure the justice of calling that State the "land of steady habits."

RESTRICTIONS ON THE POWER OF THE LEGISLATURE

In all recent constitutional growth there is a distinct tendency to curb the power of the legislature. This has resulted from the great abuse by the legislature of its power to pass local and special legislation. Numerous are the laws that have been enacted for the benefit of individuals. Nor is the justice of many of these very apparent. It is generally felt that there is greater chance for bribery and corruption when the legislature gives so much of its time to the passage of special laws. As illustrations of these laws it may be stated that in many States corporations are still chartered by the legislature. This is true of so advanced a State as New York. In that State some of the greatest assaults on the liberties of the people have come to light in connection with corporations specially chartered by the legislature. The Ramapo Water Company and the New York and New Jersey Bridge Bill are well-known examples. In some states it is common to pass acts to admit certain individuals to the bar. This is frequently the scheme resorted to by the men who have pulls to get their friends to practice law in States where the requirements are high. A number of States still pass special acts in order to change the names of persons. In Virginia many of the counties have separate game laws. Texas has a separate highway law for most of its counties. The law prescribing what constitutes a legal fence is different for many of the counties of Virginia.

Perhaps the greatest evil in this matter of special legislation is in the chartering of cities and villages. In many States it is necessary for a city or village wanting a new charter to apply to the legislature for it. The effect is an opening for all sorts of corruption. This method of chartering cities is condemned by all municipal reformers. The best method is one similar to that in force in Illinois. There all cities and villages are incorporated under one law, and it is not necessary for them to apply to the legislature for charters. A similar law is in force in England, where all cities are organized under it. The success of British municipal government is without a parallel in the world. A system of this kind will tend to prevent the passage of ripper bills for the purpose of legislating the city officers out of office in case they have not obeyed the dictates of the State boss or for other purely political reasons, as was done in Indiana, Michigan, and Pennsylvania in the sessions of 1902.

The result of this power to pass special laws is that the time of the legislature is in great measure given to this kind of work. Laws of general interest to the whole State are not given the consideration that is due them, because so many local and special interests are clamoring for the attention of the law-making body. The spirit of localism in the American States is so strong that by log-rolling with each other the members representing the various local and special interests have little difficulty in securing the enactment of their pet measures. That the work of the legislature is very largely that of special and local law-making is apparent from the following table of acts passed in 1901 in the States where this evil is greatest. In this table general laws are those that apply to the whole state.

	Laws Passed	General
Alabama	1,132	94
North Carolina	1,265	155
Connecticut	750	153
Massachusetts	652	185
New York	737	249
Rhode Island	253	54
Virginia (1900)	1,485	152
Maryland (1900)	758	114

In 1894, the last year of the old constitution in Kentucky, three large volumes were filled with special laws. Since the new constitution was adopted only a thin volume of laws has appeared each year. New constitutions have in large measure taken away the power of the legislature to pass special laws. This is particularly true of the constitutions of the newer States.

There is no reason why the time of the legislature should be taken up in this way. In Illinois this evil was very great under the old constitution. When the new constitution was framed in 1870, the legislature was forbidden to pass special acts save in a few cases. As a result, the statutes of Illinois are very generally such as apply to the whole State. In 1901 there were passed in that State one hundred and ninety-three laws, of which more than one hundred and twenty-five were of general application.

The new constitution-makers have not always been content with taking away the power to pass special laws; they have in many cases tried to curb the power of the legislature further by putting a limit to the number of days of the session. A movement is also on foot to have sessions less often. This movement found expression in the new constitution of Alabama, which provides that the regular sessions of the legislature shall be held once in four years. This seems like a rather doubtful experiment. While it is perhaps desirable that the sessions be not held too often, yet grave evils may be caused by meeting only at long intervals. There are some subjects on which it is necessary to legislate oftener than once in four years. Some reforms must be fought through many sessions of the legislature and when this body meets only at long intervals, the much-needed reform may be greatly delayed. This was well illustrated in Alabama during the recent session. There is in that State a great need of some legislation on the subject of child-labor, as the employment of young children in the cotton mills has recently awakened public sentiment on the question. The persons who are profiting by the exploitation of this labor made a determined effort to prevent any legislation on the subject, knowing full well that if they could prevent it at that session, they would be secure for four more years. The subject of child-labor is not one on which public sentiment can be roused to such a pitch that a special session of the legislature will be called to enact a law forbidding it. In this way the infrequent sessions of the legislature may tend to defeat real progress.

VETO POWER OF THE GOVERNOR

Like the federal government, the governments of the American States are suffering from a lack of the concentration of responsibility. It is difficult to find anybody who is responsible for any legislation. This diffusion of responsibility, combined with the ideas of the members that they must represent—first of all, the particular locality from which they are returned—has led to special and local legislation and laws that are detrimental to the public interest. This tendency was foreseen by the framers of the constitutions, and they endeavored to guard against it by giving the governor the veto power. There are but three States in which this power is not put into the hands of the govarnor. These are Ohio, North Carolina, and Rhode Island. Formerly the governor did not have the veto power in Delaware, but by the new constitution which went into operation in 1897 he is given the usual power to veto all bills. Of course, the influence of the governor in legislation is enormously increased by this power. It is rare that a bill may be passed over his veto. Consequently his power to kill unwise bills and impress upon his constituents the soundness of his judgment and strength of his individuality is afforded by the exercise of this negative of legislation. It has been said that Grover Cleveland's rise to fame and the presidency is due in large measure to his fearless use of the veto power. It is true that he made a great record in the state of New York as a veto governor. If his fame was originally due to the use he made of this power, it is clear that had he been the executive of a State where this power is denied the governor and where that officer is a sort of nonentity as far as law-making is concerned, it is very probable that he would never have been prominent in our national life. Governor Odell of New York first impressed his good judgment and strong individuality upon the people of that State by the use of the veto power.

Now, if there be added to the general veto power of the governor the power to veto separate items in any bill which appropriates money, it is easy to see that this additional power makes the governor one of the greatest forces in State legislation. It has been the custom for many years to place all the appropriations for the support of the government in one bill and, after having passed it through the two houses of the legislature, send it to the governor, who must under the ordinary State constitution either sign or veto the whole bill. In this way the governor was prevented from cutting out any steals which would frequently creep into the bill. In many States the general appropriation bill is loaded with items that will not bear the closest scrutiny. It is usually a bill of some thirty or more pages and carries several millions of dollars. Being of such a nature, it is not difficult for designing politicians to conceal in it certain appropriations that never ought to be made. Accordingly, it is of the highest importance that the governor should be given the power to go through the bill and prune out the items that have been improperly inserted there. Of the general appropriation bill for the State of New York for the year 1901, Governor Odell vetoed more than one hundred items and reduced the amount of the bill by more than $1,000,000. His action was generally praised by the press of the State. This shows that there was a popular feeling that the public money was being improperly spent.

There can be no question that such a provision in the federal constitution would be a great saving to the nation. The way the general appropriation bill is loaded with improper items has long been known to be a national disgrace. The President must either sign or veto the whole bill, and as it is usually not presented to him until in the closing days of the session of Congress or after the adjournment, it is next to impossible for him to stop the wheels of administration by vetoing the bill. Practically he has no choice in the matter and must sign it. This evil was recognized by the men who made the constitution of the Confederate States. In that constitution the president was empowered to veto any item or items of the appropriation bill.

This power to veto separate items is given to the governor in the constitutions of twenty-six States.[1] It has recently been inserted in the new

[1] Alabama, Arkansas, California, Colorado, Delaware, Georgia, Idaho, Illinois, Kentucky, Louisiana, Minnesota, Mississippi, Missouri, Montana, Nebraska, New York, North Dakota, Pennsylvania, South Carolina, South Dakota, Texas, Utah, Virginia, Washington, West Virginia, Wyoming.

constitutions of Alabama and Virginia. In the constitution of Washington it is provided that the governor may veto separate sections or items of any bill. The effect of these provisions is to increase greatly the responsibility of the governor in all legislation. This fact will tend to attract to the office able and conscientious men who will furnish a counterpoise to the vagaries of the legislature.

The most advanced stage of this power to veto separate items has been reached in Pennsylvania. In the constitution of 1873, this provision was inserted: "The governor shall have power to disapprove of any item or items of any bill making appropriations of money, embracing distinct items, and the part or parts of the bill approved shall be the law, and the item or items of appropriation disapproved shall be void, unless repassed according to the rules and limitations prescribed for the passage of other bills over the executive veto."

At different times the governors have construed this section as giving them the right to veto, not only items, but also parts of items, that is, to cut down the amount of money appropriated for any certain purpose. In 1899 Governor Stone vetoed in this way $1,000,000 of an item in the appropriation bill granting $11,000,000 for the public schools. The governor's construction of this clause of the constitution was sustained by the supreme court in a decision on April 22, 1901.[1] This is an interesting decision, and whether or not it will be sustained in the other States having similar clauses in their constitutions will be watched with much interest. If it should become a part of the established constitutional law of the American States, it would place in the hands of the governor the sole authority to determine how much money should be spent and for what purposes. As the general appropriation bill seldom reaches him until after the legislature adjourns, there is no possibility of passing it over his veto. His power is therefore practically absolute. In 1901 Governor Stone of Pennsylvania vetoed forty-seven items and partly vetoed or cut down one hundred and thirty-two other items.[2] A governor of Pennsylvania who is willing to assume the responsibility will have little trouble in making his influence felt in the expenditures of that State.

[1] Commonwealth *v.* Barnett, 48 Atlantic, 976.

[2] R. H. Whitten, *New York State Library Bulletin*, No. 72, p. 38.

Like their statute laws, the constitutions of the American States are developing along broad and healthy lines. Great improvements are manifest in all the newer instruments and there is no reason to fear that our constitution-makers of the future will not be able to meet and handle successfully any difficult problem that may confront them.

THE BOUNDARIES OF COLORADO

By Frederic L. Paxson

The State of Colorado is bounded on the north and south, respectively, by the thirty-seventh and forty-first parallels of north latitude, and on the east and west by the twenty-fifth and thirty-second meridians of longitude west from Washington. The territory inclosed by this rectangle has had a history of remarkable variety and change. It has at various times, in whole or in part, been subject to the jurisdiction of the independent countries, France, Spain, Mexico, Texas, and the United States; and while under the United States it has formed parts of the territorial governments of Utah and New Mexico, Kansas and Nebraska, and of the State of Texas. It is the purpose of this article to trace the external facts in connection with this history of change.[1]

With the acquisition of Louisiana under the convention of April 30, 1803, the territory of Colorado came for the first time within the jurisdiction of the United States. The boundaries of this vast province beyond the Mississippi had never been surveyed, and it is doubtful whether at the time of the transfer they were really known. Certain it is that the terms of the treaty threw no light upon them, for the First Consul was not averse to planting seeds of discord between the United States and Spain. The territory had passed from France to Spain in 1763, from Spain to France in 1800, and now, "with the same extent that it now has,"[2] was delivered by the French Republic to the United States.

The province of Louisiana extended, by all laws of discovery, exploration, and conquest, to the limits of the drainage basin of the Mississippi.[3]

[1] The various boundaries within the United States have been described briefly in *Bulletin of the United States Geological Survey No. 71*, which is a pamphlet by Henry Gannett on the "Boundaries of the United States." This is a second edition, printed in 1900, of *Bulletin No. 13* of 1885. The second edition is fully illustrated with maps; but these are inaccurate in a number of instances and must be used with care. As a whole, the work is extremely useful. All references in this article are to the second edition.

[2] *Treaties and Conventions Concluded between the United States of America and Other Powers*, p. 331.

[3] Hermann, *The Louisiana Purchase* (Washington, 1898), contains an excellent map showing the relations of Colorado to Louisiana and Texas.

Its boundary on the west, had it ever been described, must have followed the summit of the Rocky Mountains from the vicinity of the forty-ninth parallel to the headwaters of the Arkansas River. It is not impossible that the line should have extended even farther south, to the source of the Rio Grande.[1] But, whichever river be accepted as the southern limit of Louisiana, it is certain that by the purchase of this province the eastern half of Colorado became the property of the United States.

By an act of March 26, 1804, Congress provided its first government for the new lands.[2] So much of Louisiana as lay south of the thirty-third parallel became the territory of Orleans, while the remaining portion of the purchase was appended to the territory of Indiana with the name of district of Louisiana.[3] It was not until March 3, 1805, that Congress gave an independent territorial organization to this district, under the same name.[4]

When the territory of Orleans was admitted to the union in 1812, it received for its name Louisiana,[5] and the territory to the north, thus deprived of its name, was called Missouri by the act of June 4, 1812.[6] For a period of seven years this new territory of Missouri stretched from the Mississippi indefinitely to the west. Spain was in no hurry to define the boundaries between her American possessions and those of the United States, and it was not until 1815 that the United States was ready to receive a minister from His Catholic Majesty. The first minister sent by Ferdinand VII after his restoration to the throne of Spain in 1815 was Don Luis De Onis, who entered upon the threefold task of protesting against American intervention in the Floridas, of withstanding the American sympathies for Spain's revolted colonies, and of drawing a line between the respective American territories of Spain and the United States.[7]

The three tasks of De Onis were almost inextricably entangled, and

[1] Hermann, 48, takes this view; and Henry Adams, *History of the United States*, II, 5, shows that France believed this to be the case.

[2] Poore, *Charters and Constitutions*, I, 691; Henry Adams, II, 125.

[3] McMaster, *History of the People of the United States*, III, 23.

[4] Poore, I, 697.

[5] Act of April 8, 1812, Henry Adams, VI, 235; McMaster, III, 375.

[6] Poore, II, 1097; McMaster, V, 570.

[7] Paxson, *Independence of the South American Republics*, p. 114.

it was only after long and patient negotiations with John Quincy Adams, Secretary of State, that a conclusion was reached.[1] While even then the fears of Spain respecting South America were not satisfied. By the treaty of February 22, 1819, Spain, for a consideration, ceded the Floridas to the United States, and a compromise boundary between Louisiana and Mexico was agreed upon. The Louisiana enabling act of February 20, 1811,[2] had fixed for the western boundary of the State the Sabine River up to the thirty-second parallel, and thence due north to the thirty-third parallel. The new treaty started the western boundary of the United States at the same point.[3] Beginning at the mouth of the Sabine River, it followed the western bank of the same to the thirty-second parallel of north latitude; from this point it ran due north to Red River, and followed the course of the river westward to the one hundredth meridian west of London; thence it went due north again to the southern bank of the Arkansas River, followed this bank to the source of the river "in latitude 42 north," and thence ran westward along the forty-second parallel to the Pacific. For the first time a boundary of the United States had been drawn through Colorado.

The territory of Missouri, erected in 1812, lasted until the act of March 6, 1820, to enable the people of Missouri to form a state government, reduced its boundaries to those of the present State of Missouri without the "triangle."[4] The western lands were thus deprived of territorial organization, coming so far as they had government at all under the military rule of the United States army on the frontier. Until the acts of 1850 and 1854, dividing the western lands among Utah, New Mexico, Kansas, and Nebraska, Colorado had no territorial government.

But before 1850 the territory of Colorado was twice extended in its dimensions. By the Spanish treaty its boundaries on west and south were the Arkansas River and the meridian of its source. By the admis-

[1] Morse, *John Quincy Adams*, pp. 111–117; McMaster, IV, 474–83.

[2] Poore, I, 690; Gannett, 110.

[3] *Treaties and Conventions*, p. 1017. After the independence of Mexico had been gained, a treaty was entered into by the United States and Mexico, January 12, 1828, confirming this boundary.—*Ibid.*, 661. The Republic of Texas, by a convention of April 25, 1838, accepted this line and arranged for a joint survey commission with the United States.—*Ibid.*, 1079.

[4] Poore, II, 1102. The State of Missouri was admitted by proclamation, August 10, 1821.—Richardson, II, 96.

sion of Texas to the union on December 29, 1845,[1] the territory between this line and that new line of the Rio Grande and the meridian of its source, which Texas claimed as her western boundary, was added to Colorado, while by the treaty of Guadalupe Hidalgo,[2] February 2, 1848, the remaining portion of the territory embraced in Colorado was acquired by the United States.

The division of the territory conquered during the Mexican war and ceded to the United States at its close led to bitter controversy in Congress, between the representatives of the slave-holding and the anti-slavery interests. And the dispute was ended only by the comprehensive measure of Henry Clay, that has come to be known as the Compromise of 1850. By this settlement, the territory gained from Mexico, including certain territory lying east of the Rio Grande and claimed by Texas, was cut into the two new territories of Utah and New Mexico. And between these territories so much of Colorado as lay south of the treaty line of 1819 was divided.[3]

The act creating the territory of Utah is dated September 9, 1850. The boundaries of this territory, which alone of the new lands had any considerable amount of white population, were the thirty-seventh and forty-second parallels, the eastern boundary of California, and the summit of the Rocky Mountains.[4] All of Colorado west of the Rocky Mountains lay within the territory of Utah.

The New Mexico act was a part of the general compromise scheme and was passed on December 13, 1850.[5] The greater portion of the

[1] H. H. Bancroft, *Works*, XVI, 383; Gannett, 24, 111. This Texan boundary was based on the secret treaties of Santa Anna and various resolutions of the Texan congress. Although the title of Texas to this land was not valid as against Mexico, it has always been considered good as against the United States.—Bancroft, XVI, 270, 399; XVII, 454.

[2] *Treaties and Conventions*, p. 681.

[3] This statement is not literally accurate. That portion of Colorado east of the one hundred and third meridian and north of the thirty-eighth parallel was left without a government. In 1854 a portion of this became a part of Kansas territory.

[4] Poore, II, 1236; Bancroft, XVII, 458; XXVI, 453, 454; Gannett, 131.

[5] Gannett, 131. Utah extended to the summit of the Rocky Mountains on the east, and the western boundary of the New Mexico "panhandle" was the summit of the Sierra Madre mountains. If we are to understand by "Rocky Mountains," as we must in this case, the Continental Divide, and by "Sierra Madre" the Front Range, it is evident that between Utah and New Mexico lay a strip of territory bounded on its other sides by the thirty-seventh and thirty-eighth parallels. This piece of land was too far west to be in the old Missouri territory, and hence never came under territorial government until the passage of the Colorado Act in 1861. But in 1850 the territory had not been accurately surveyed, and it is not likely that Congress realized that it was leaving this fragment of uninhabited waste without a government. The name Sierra Madre is no longer applied to the Front Range. For a good case of the old usage see William Gilpin, *Mission of the North American People* (second edition, Philadelphia, 1874), p. 16.

northern boundary of the territory was the southern boundary of Utah, the thirty-seventh parallel. But in the north-east corner of New Mexico was a "pan-handle" extending into the present limits of Colorado. The one hundred and third meridian, which was the eastern boundary of New Mexico, extended north to the thirty-eighth parallel; the line ran west along this parallel to the summit of the Sierra Madre mountains, and south along the mountains to the thirty-seventh parallel. Thus so much of Colorado as lay between the thirty-seventh and thirty-eighth parallels, the one hundred and third meridian, and the Sierra Madre was part of New Mexico.

That portion of Colorado, bounded on the west by the Rocky Mountains and on the south by New Mexico had been without any government since the passage of the Missouri enabling act, when the Kansas-Nebraska measures were taken up in 1854. Here, as in the measures of 1850, the struggle between the slave and free States dictated the terms of the territorial division. By the final agreement, in the act of May 30, 1854, the territory between Missouri and the Rocky Mountains was divided between two territorial governments. A southern strip,[1] lying between the thirty-seventh and fortieth parallels, and bounded on the west by the Rocky Mountains and the New Mexico "pan-handle," became the territory of Kansas. What was left of the undivided territory north of the fortieth parallel and east of the Rockies[2] was established under the territorial government of Nebraska. And now, for the first time, the whole area of Colorado was covered by territorial governments, by Utah, New Mexico, Kansas, and Nebraska.

The settlement of the western States moved forward with great thoroughness until Kansas and Nebraska were reached. Until this time the wave of population had covered the ground evenly, and had not advanced in one direction much more rapidly than in another. But the discovery of gold in Cherry Creek, on the north fork of the Platte, transformed this even movement, and brought about a rush of settlers

[1] Poore, I, 574; Rhodes, *History of the United States*, I, 439, has failed to notice this irregularity in the southwest corner of Kansas; Gannett, 125. The map in Gannett, facing p. 122, gives the incorrect impression that Kansas extended to 36° 30′ on the south, and on the west *only* to the Arkansas River and the hundredth meridian; while his map facing p. 126 corrects the former blunder and repeats the latter.

[2] Poore, I, 569; Gannett, 126.

into the gold diggings before actual government had been established there and long before the frontier had reached the Rockies. From this sudden emigration in 1858 came the settlement of Colorado.

The earliest suggestion of a new State to be erected at Cherry Creek, where Denver now stands, came in the autumn of 1858, two weeks after the first miners reached Auraria and when there were hardly two hundred settlers in the whole district. Distance from the seat of territorial government, absence of courts, and the lawless character of much of the mining population made some sort of local organization necessary in the gold camp. And the suggestion of 1858 developed in 1859 into the spontaneous territory of Jefferson. At a preliminary convention held in Denver on April 15, 1859,[1] it was determined to erect an independent government there, and the boundaries within which the new State was to claim jurisdiction were the thirty-seventh and forty-third parallels, and the one hundred and second and one hundred and tenth meridians. The movement for statehood failed, but the constitution of the "territory" of Jefferson which was adopted by the people on October 10, 1859, claimed those boundaries.[2]

The "territory" of Jefferson thus constituted lived a precarious existence for almost two years. At no time, however, was its control of the situation in the Arkansas and Platte Valleys complete, It was admittedly an illegitimate organization, existing without federal authority, and in defiance of the laws of Kansas and Nebraska. Its only justification was the need for a government and the absence of any effective authority; and this excuse became better after Kansas had been admitted as a State with boundaries excluding the gold country.

Most of the southern boundary of Colorado was defined in the Utah and New Mexico acts of 1850. The eastern boundary was first drawn by the act of January 29, 1861, under which Kansas was admitted. And this act accepted the boundary provision of the Wyandotte constitution. Through three constitutional conventions, at Topeka,[3] Lecompton,[4] and

[1] The first number of the *Rocky Mountain News*, April 23, 1859, contains the account of the steps in the formation of a State constitution. Compare also J. C. Smiley, *History of Denver*, p. 309, and his map on p. 310.

[2] *Rocky Mountain News*, October 20, 1859; Hollister, *The Mines of Colorado*, 92; Bancroft, XXV, 406; Smiley, 314; Hall, *History of Colorado*, I, 211.

[3] Poore, I, 580. [4] Poore, I, 599.

Mineola,[1] the boundaries claimed for the State of Kansas were those of the territory, extending westward to the mountains and New Mexico. But the Wyandotte constitution[2] substituted for this the twenty-fifth meridian of longitude, west from Washington, and the Kansas act accepted this statement of the case.[3] Colorado was for the second time deprived of even the form of a territorial government.

When Kansas was admitted, the flimsy government of the "territory" of Jefferson had nearly run its course. For two sessions that government had conducted a legislature, and its governor had used every effort to make his administration effective. But the men in the mining camps had evaded the jurisdiction of the "territory," and the support of the Denver inhabitants had never been enthusiastic. When the Kansas act cut off Colorado, there was already before Congress and near to completion a bill that was to bring peace and termination to the "territorial" government.

A bill to erect a new territory west of Kansas and Nebraska, out of lands taken from those territories and New Mexico and Utah, had appeared in Congress in the session of 1859–60. But other and stronger interests had prevented the passage of the act at this time and had delivered the work over to the next session. In 1860–61 the act was taken up again and passed.

The Colorado territorial act became a law on February 28, 1861.[4] It accepted as the southern boundary of the territory the thirty-seventh parallel, which had already been drawn between Utah and New Mexico as far east as the Sierra Madre mountains. For the eastern boundary it made use of the western boundary of Kansas, the twenty-fifth meridian from Washington, and continued it north to the forty-first parallel which became the northern boundary of Colorado. On the west Utah was pushed back from the Rockies to the thirty-second meridian to make way for the western half of the new territory. The extravagant claims

[1] Poore, I, 614. [2] Poore, I, 630. [3] Gannett, 125.

[4] Poore, I, 212; Gannett, 130; Bancroft, XXV, 413; Hall, I, 262; Blaine, *Twenty Years of Congress*, I, 270. It should be noticed that no portion of Kansas was given to Colorado, as the western end of the former territory was cut off before Colorado was created. And the Wyandotte constitution under which Kansas was admitted, and which first fixed the twenty-fifth meridian as its western boundary, was framed in the summer of 1859 before the idea of a new territory for Colorado had developed in Congress. *Cf.* Gannett, 125.

of the "territory" of Jefferson to the forty-third parallel and the one hundred and tenth meridian were calmly disregarded.

The territory of Colorado existed under those boundaries throughout its history. When it framed a constitution and became a State in 1876, it still retained them.

PALEONTOLOGY OF THE BOULDER AREA

By Junius Henderson

This paper deals only with fossil species either known or suspected to exist within a few miles of the University, and is based chiefly upon material in the University Museum, though in its preparation a number of private collections have been examined and much material studied in the field. Most of the formations of the region are not well adapted for the preservation of organic remains, so that many of the fossils are in such condition that identification is difficult or impossible. Dr. T. W. Stanton, of the United States Geological Survey, has rendered valuable assistance in the determination of difficult material, and other friends of the University have made a good collection possible by their contributions. Much remains yet to be done to complete the paleontological collections, and the alumni and other friends of the institution can greatly aid in the work, bearing constantly in mind that the value of fossils depends largely upon the exactness of the data as to the locality and conditions under which they are found. Some good material has been rejected in the preparation of this paper because of the uncertainty as to whether it was found "in place" or lying loose upon the surface, where it may have been carelessly thrown by someone or deposited by some of the natural methods of transportation.

The western American geological column from the Permian upward is as follows, in their order of occurrence, reading the column from the most recent downward:

Cenozoic

- Recent
- Quaternary
- Tertiary

Mesozoic
- Cretaceous
  - Upper Cretaceous
    - Post Laramie
      - Denver Beds
      - Arapahoe Beds
    - Laramie
    - Montana
      - Fox Hills
      - Fort Pierre
    - Colorado
      - Niobrara
      - Fort Benton
    - Dakota
  - Lower Cretaceous
    - Como
    - Kootenay
- Jura-Trias
  - Jurassic
  - Triassic

Paleozoic
- Permian

The Cenozoic is not represented in this area by deposits of any importance, the Tertiary not being found at all. The Lower Cretaceous is also missing, or at least unrecognized. The time interval and enormous erosion between the Laramie and Post-Laramie would indicate that the latter should be assigned to the Tertiary instead of the Cretaceous, but there is paleontological evidence making it advisable to leave the arrangement undisturbed until all the evidence of various kinds is further studied with the idea of harmonizing it, if possible. In any event, the Denver and Arapahoe beds are entirely missing from the Boulder area, though well developed a number of miles to the south. The Permian is not positively known in this region. At Boulder the formations are very nearly vertical, except the Montana, in consequence of which they occupy but a comparatively narrow strip along the edge of the foothills, except the Montana, which, being more nearly horizontal and of enormous thickness, covers a strip several miles in width. Northward all the formations flatten out rapidly, widening the outcrops.

JURA-TRIAS

The lowest sedimentary rocks in the Boulder area are commonly designated Jura-Trias, though the lower part of the supposed Triassic may be in fact Permian. The entire group of stratified rocks below the Cretaceous seems to be devoid of organic evidence in this locality, with the exception of a single specimen, apparently a cast of a rather flat bone, so that their age can at present only be determined by stratigraphic relations and lithologic analogies. The Jura-Trias, up-turned to a high angle, rests upon the granite, which yields to erosion and atmospheric influences more readily than the sandstones and conglomerates at the base of the sedimentaries, thus forming a slight valley west of the Jura-Trias, while the conglomerates and sandstones constitute the second line of "hogbacks" or ridges along the foothills. The Upper Jura-Trias, being also of yielding material, forms another valley east of that ridge, separating it from the first "hogback," or Dakota ridge.

CRETACEOUS

The Cretaceous of this region is divided into three very unequal portions, called respectively the Dakota, the Colorado, and the Montana. The Colorado is subdivided into Fort Benton and Niobrara. The Benton consists chiefly of soft shales, containing thin bands of limestone and capped by a sandy zone. The base of the Niobrara is a hard, thick-bedded limestone overlaid by more or less calcareous shales. The Montana is subdivided into Fort Pierre and Fox Hills, the former being almost entirely soft shales, with some sandstone bands and limestone beds, the Fox Hills being largely friable sandstones.

DAKOTA

This formation, composed chiefly of hard sandstone, forms the first ridge of the foothills and is paleontologically barren ground in this region, though fragments of undetermined leaves and wood are found. Much better preserved leaves are found at Golden, of which a collection recently presented by the State School of Mines is now in the University Museum.

FT. BENTON

Cephalopoda.—Three imperfect casts found five miles north of Boulder in general outline resemble the *Placenticeras* group of *Pseudoceratites*, but, as they are not well enough preserved to show the surface ornamentation or sutures, and it cannot be even definitely ascertained whether the keel which characterizes some other groups is absent, more and better material must be awaited.

Another series, collected north of Left Hand Creek by Professor R. D. George, Professor D. W. Spangler, Mr. F. M. Dille, and the writer, with the surface ornamentation better preserved, appear to be of different species, resembling *Placenticeras* in the row of nodes near the umbilicus, another row near the ventro-lateral angle, another at the ventro-lateral angle, and in the absence of a keel, but apparently differing in other important respects. The specimens are inner volutions, except two large fragments which may be body chambers of the same species, none of them showing traceable sutures. The unidentified specimens of this series include at least two species. Two other fragments seem to answer to the description of *Helicoceras? corrugatum.*

Inoceramus labiatus.—At various points north of the city occurs this species in abundance, quite variable in form, as usual with the genus.

Inoceramus sp.—An undetermined and perhaps undescribed species has been found in this formation at the mouth of Bear Cañon, as well as north of Boulder. The specimens are quite flat, which may possibly be the result of pressure, and are all in a fragmentary condition.

Anisomyon? sp.—Professor Spangler has found one specimen north of Left Hand Creek which seems to be closely related to *Anisomyon.*

Veniella mortoni.—One or two specimens seemingly referable to this species were found north of Left Hand Creek.

Ostrea sp. undescribed.—An oyster pronounced by Dr. Stanton an undescribed species is found in great quantities in a narrow zone in the lower third of the formation, in such fragmentary condition that they cannot be satisfactorily described or figured.

Ostrea sp.—An undetermined species, probably of *Ostrea*, occurs wherever *Inoceramus labiatus* is found in this region, always in the form of poorly preserved rusty casts. This species, with *I. labiatus* and the cephalopods heretofore mentioned, seem to be confined to a very narrow band of limestone, which is continuous through each outcrop, but whether continuous between outcrops is not known. Other similar bands exist at each outcrop, but are not fossiliferous.

Fish.—A few fish scales have been found in the lower part of the formation, in a hard, very black limestone, near an igneous intrusion south of Left Hand Creek.

Fossil sea weeds and a few fossil mollusk or worm borings are found in the sandy zone near the top of the formation.

NIOBRARA

Inoceramus deformis.—This large species is found in abundance at every Niobrara outcrop, being confined chiefly to the upper strata of the basal limestone and the lower part of the superincumbent shales, and often covered with *Ostrea congesta.*

Inoceramus simpsoni.—A fragment from the fold five miles north of Boulder seems to be of this species, but there is not enough of it to make identification certain.

Inoceramus sp.—Fragments of a large undetermined species were found at the lime kiln in the western edge of Boulder, and five miles north of Boulder.

Ostrea congesta.—This small oyster is found in the basal limestone attached to *I. deformis*, and abounds at a higher horizon in the shales, where, with large, flattened, undetermined *Inoceramus*, it forms thin bands—continuous for long distances. This horizon and the *I. deformis* horizon may be recognized at almost every outcrop of the formation.

Fish.—Mr. F. A. Fair has brought in one fish tooth from this formation at Coal Creek, south of Boulder, and Mr. H. F. Watts found fish scales in Upper Niobrara north of Boulder.

FORT PIERRE

This formation consists of about seven or eight thousand feet of shales with a strong easterly dip, differing very little in lithological characters with the exception of a persistent sandstone in the lower half. In the absence of recognizable lithological horizons, the discovery of definite paleontological horizons which may be depended upon would be of great importance, but much of the material on hand is unavailable for such an investigation on account of the lack of exact locality labels. Better records are being kept of all material brought in now, and it is possible that by platting the fossil localities and indicating the faunal associations upon the geologic and topographic maps, when they are published, results of considerable consequence to geological investigations along the plains bordering the foothills of the Front Range may be obtained.

Sphenodiscus sp.—A small fragment showing part of several sutures was found at the brick kiln east of the University Hospital. The sutures, so far as they can be traced, resemble *S. beecheri* more nearly than any other species, but its identity is not certain.

Baculites compressus.—A few specimens have been found near Haystack Butte, on Left Hand Creek, and one specimen having the compressed form, but not showing the sutures, was found at the brick kiln on Boulder Creek near the University. The species is common at Fossil Creek, near Fort Collins.

Baculites ovatus.—Very abundant at both brick kilns south of Boulder Creek and at numerous other points.

Baculites anceps.—One specimen in the collection from Bear Cañon, south of Boulder.

Scaphites nodosus.—Widely distributed, found in this vicinity at the mesa southeast of the Chautauqua Grounds, Four Mile Mesa (four miles north of Boulder), and Haystack Butte.

Heteroceras cochleatum.—Several specimens from Table Mountain, on Left Hand Creek, and from the field west of Haystack Butte, we have referred to this species, described by Meek and Hayden, the type specimen of which was lost before reaching Washington, and is therefore not available for comparison. One small specimen shows slender, somewhat curved spines, but the spines are usually represented by nodes which are interior casts of the hollow bases.

Heteroceras nebrascense.—One fine specimen found by Dr. Stanton is in the Museum. It is described in the *Proceedings of the Colorado Scientific Society*, Vol. II, p. 186, and is of importance because it includes the deflected body whorl characteristic of the genus.

Heteroceras tortum.—One specimen from five miles north of Boulder.

Ptychoceras sp.—Found at Four Mile Mesa, Table Mountain, and west of Haystack Butte. The specimens at hand may include more than one species, but they are not in good condition for determination.

Pteria nebrascana.—A few specimens have been found at the brick kilns near the University.

Anchura haydeni.—A few, poorly preserved, found at the brick kilns above mentioned.

Anisomyon sp.—Found at Four Mile Mesa.

Inoceramus barabini.—Widely distributed, quite variable, found in many localities, particularly in this vicinity at Haystack Butte and Table Mountain, where some puzzling forms referable to this species have been found. Professor R. P. Whitfield, in his report on the fossils of the Black Hills, described a new genus based upon the existence of a posterior sulcus upon casts of specimens which would otherwise have been considered *Inoceramus.* He called the new genus *Endocostea.* Specimens of two species from the above-named localities indicate that the existence of the sulcus and the corresponding internal rib of the shell has neither generic nor specific significance. From an area of only a few square yards specimens have been extracted with and without the sulcus, but otherwise indistinguishable. Typical *I. barabini* have been found, both sulcate and non-sulcate. The same is true of the next species. The same thing has been noticed elsewhere by paleontologists. Dr. Stanton writes, after examining part of this material: "The posterior sulcus is a peculiar feature, but I cannot see that it has any taxonomic value." Other specimens make the worthlessness of this feature as a generic character still more evident.

Inoceramus sublœvis.—The specimens referred to this species, from Haystack Butte and Table Mountain, also include both sulcate and non-sulcate specimens. They are somewhat more gibbous than Meek's figures and description would indicate, and may possibly be distinct.

Inoceramus sagensis.—This species is found on Left Hand Creek and at the brick kilns near the University. Forms heretofore called *I. convexus* are included under this name, as the two are now considered identical. This species is abundant at Fossil Creek.

Inoceramus vanuxemi.—Abundant at Four Mile Mesa, and a few at Haystack Butte and the brick kilns near the University.

Inoceramus proximus.—If this is to be admitted as a species distinct from *vanuxemi* (and it seems better so to consider it for the present), it is found at Haystack Butte.

Inoceramus oblongus.—Some small specimens of this species have been brought in from Left Hand Creek. They are found in enormous quantities at Fossil Creek.

Ostrea inornata.—Specimens answering to the description of this species, except that they are not attached by the whole lower valve (not of specific importance) are found at Haystack Butte and Table Mountain.

Lucina occidentalis.—Common at many places both north and south of Boulder.

Spœriola obliqua.—No specimens are in the collection, but the original description of the species was based upon specimens from Left Hand Creek, about midway between Boulder and Longmont.

Callista ? pellucida.—A few specimens labeled Boulder, answering to Meek and Hayden's description of this species, are in the collection, but the exact locality where they were found is unknown.

Mactra gracilis.—Found in a crowded mass at Haystack Butte.

Fish.—A portion of a vertebral column, unidentified, was found by Mr. Fair on the Mesa south of the Chautauqua Grounds.

Insect.—A single wing, unidentified, was found by Mr. Fair at one of the brick kilns near the University.

Plants.—Fragments of wood, leaves, and sea weeds are occasionally met with in the Pierre shales, but have not been identified.

Dr. T. W. Stanton, in his paper before the Colorado Scientific Society in 1887, reported the following species about five miles north of Boulder, some of which are not represented in the museum:

Inoceramus vanuxemi	Ptychoceras mortoni
Anisomyon borealis	Heteroceras nebrascense
Baculites ovatus	Heteroceras tortum
Placenticeras placenta	Heteroceras cochleatum
Scaphites nodosus	Helicoceras stevensoni
Ancyloceras jenneyi	Helicoceras mortoni

FOX HILLS

The Fox Hills formation is generally so friable that it is difficult to obtain good specimens of most species, though a few, such as *Cardium speciosum*, are found in very good condition. East of the big White Rock fault the following species have been found:

Mactra alta	Tellina scitula
Mactra warrenana	Nucula sp.
Pteria haydeni ?	Dentalium sp.
Cardium speciosum	Cylichna scitula
Pholodomya subventricosa	

Further north a single specimen referred to *Pholodomya subventricosa* has also been found.

A poorly preserved undescribed *Mactra* labeled Marshall is in the collection, but the exact locality is unknown.

At the south end of the Weisenhorn Mesa, south of Weisenhorn or Boulder Lake, the following species are found intermingled:

Mactra formosa	Nucula sp.	Pyrifusus sp.
Mactra warrenana	Ostrea glabra	Melania wyomingensis
Callista sp.	Dentalium sp.	Undetermined gasteropods
Cardium speciosum	Lunatia sp.	

It is worthy of notice that in this list at least two Laramie species, *Ostrea glabra* and *Melania wyomingensis*, are associated with strictly marine Fox Hills species. Dr. Stanton writes: "Similar occurrences of these same Laramie species in Fox Hills beds have been noticed elsewhere, especially on the Coffin Ranch four miles east of Longmont, Colo., and near Point of Rocks, Wyoming."

LARAMIE

The Laramie is the coal-bearing formation. Leaf impressions, fossil wood, and sea-weed casts are common, but we have no determined material on hand from this locality. *Ostrea glabra* occurs in great quantities at various points, particularly near Marshall.

FOSSIL CREEK SPECIES

Two days recently spent at Fossil Creek, near Fort Collins, by Professor D. W. Spangler and the writer, resulted in the collection of the following species, some occurring in abundance, in Fort Pierre beds:

Margarita nebrascensis	Volsella meekii
Anchura haydeni	Pteria linguiformis
Lunatia ? sp.	Lucina occidentalis
Anisomyon 2 sp.	Cardium speciosum
Pinna lakesi	Veniella humilis
Inoceramus barabini	Placenticeras whitfieldi
Inoceramus oblongus	Scaphites nodosus
Inoceramus sagensis	Baculites compressus
Inoceramus vanuxemi	Algae
Ostrea sp.	Fucoids
Anomia sp.	Other undetermined fossils

As the same formations occur in this locality, with some of the same species, and the distance between the points is not great, all these species may be expected in the Boulder field.

Without attempting an exhaustive examination of the literature of the subject, we find scattered through the various reports and proceedings references to the finding of the following additional fossil species of invertebrates on the plains bordering the eastern slope of the mountains in Colorado from Denver northward:

Actæon woosteri	Baroda subelliptica
Actæonina prosocheila	Beaumontia solitaria
Ammonites sp.	Bulinus disjunctus
Anchura americana	Bulinus subelongatus
Anchura bella	Callista deweyi
Anchura nebrascense	Campeloma multistriata
Anisomyon centrale	Cantharus julesburgensis
Anodonta parellela	Caryophyllia egeria
Anomia Gryphorhynchus	Chaetetes ? dimissus
Anomia micronema	Chalmys nebrascensis
Baculites grandis	Corbicula augheyi

Corbicula berthoudi
Corbicula cardiniæformis
Corbicula cleburni
Corbicula obesa
Corbicula macropistha
Corbicula planumbona
Corbicula subelliptica
Corbula crassatelliformis
Corbula subtrigonalis
Corbula tropidophora
Crenella elegantula
Cylichna volvaria
Cyrena holmesi
Dentalium gracile
Discinia sp.
Fasiolaria cheyennensis
Faciolaria culbertsoni
Fusus sp.
Glycimeris berthoudi
Goniobasis gracilenti
Goniobasis nebrascensis
Goniobasis tenuicarinata
Haminea ? occidentalis
Haploscapha capax
Inoceramus pertentuis
Lingula nitida
Liopistha undata
Lunatia subcrassa
Mactra canonensis
Mactra holmesi
Melanopsis americana
Mytilus subarcuatus
Neritina bruneri
Nautilus dekayi
Nucula cancellata
Nucula planimarginata
Ostrea patina
Pachyma ? herseyi
Pecten sp.
Pholodomya sp.
Physa felix
Placenticeras lenticulare
Protocardia rara
Protocardia subquadrata
Pseudobuccinum nebrascense
Pteria fibrosa
Pyrula bairdi
Scaphites cheyennensis
Scaphites conradi
Scaphites mandanensis
Serpula sp.
Spæriola cordata
Spæriola endotrachys
Spæriola obliqua
Solemya bilex
Solemya subplicata
Solen sp.
Tancredia americana
Tancredia coelionotus
Tellina equilateralis
Teredo sp.
Thetis ? circularis
Tulotoma thompsoni
Turritella sp.
Unio sp.
Viviparus leai
Viviparus prudentius
Volsella regularis
Yoldia evansi

The few fossils of the Arapahoe and Denver beds should not be expected here, as those formations do not occur until some distance is reached from the foothills; but inasmuch as nearly all the species listed are from formations which are found in the Boulder area, with few exceptions they may be considered probably or possibly included in the fossil fauna of this vicinity.

The almost complete absence of brachiopods, bryozoans, corals, and other lower forms in the Boulder area cannot escape notice. It is also noticeable that the gasteropods are confined chiefly to the Fox Hills formation. The largest invertebrates of the region are *Baculites ovatus* and some species of *Inoceramus*. It is reported upon good authority that many years ago some large fossil reptiles were taken up in the Laramie formation at White Rock, but their whereabouts is unknown; no definite data are now at hand concerning them, and none are found exposed at the present time, though excavations might reveal some. The only vertebrate material now on hand consists of the few remains of fish mentioned hereinbefore, and the possible cast of a bone from the Jura-Trias. None of the higher vertebrates have been yet found here.

ADDITIONAL LIST OF BOULDER COUNTY BIRDS, WITH COMMENTS THEREON

By Junius Henderson

Since the publication of the preliminary list in Vol. I, No. 3, of University of Colorado Studies, April, 1903, the following species have come to our attention, making a total of 206 species now recorded for the County:

Podilymbus podiceps.—Pied-billed grebe.

Aythya marila.—American scaup duck (Felger).

Aythya affinis.—Lesser scaup duck (Felger, Henderson).

Clangula americana.—American goldeneye (Felger).

Oidemia deglandi.—White-winged scoter (Felger).

Olor columbianus.—Whistling swan.

Porzana carolina.—Carolina or sora rail (Felger, Henderson).

Steganopus tricolor.—Wilson phalarope (Henderson).

Helodromas solitarius.—Solitary sandpiper (Felger).

Accipiter atricapillus.—American goshawk (Sprague).

Buteo swainsonii.—Swainson hawk (Henderson).

Dryobates pubescens homorus.—Batchelder woodpecker (Henderson).

Picoides americanus dorsalis.—Alpine three-toed woodpecker (Felger).

Sphyrapicus thyroideus.—Williamson sapsucker (Sprague, Felger).

Tyrannus verticalis.—Arkansas kingbird (Dille).

Empidonax difficilis.—Western flycatcher (Sprague, Brackett).

Empidonax wrightii.—Wright flycatcher (Henderson).

Aphelocoma woodhousei.—Woodhouse jay (Bragg, Henderson).

Cyanocephalus cyanocephalus.—Piñon jay (Dille).

Dolichonyx oryzivorus.—Bobolink (rare, Brackett, Bragg, Henderson).

Agelaius phoeniceus.—Red-winged blackbird.

Carpodacus cassini.—Cassin purple finch (Sprague, Henderson, Bragg).

Astragalinus psaltria.—Arkansas goldfinch.

Spinus pinus.—Pine siskin (Sprague, Henderson, Bragg).

Poœcetes gramineus confinis.—Western vesper sparrow.

Chondestes grammacus strigatus.—Western lark sparrow.

Zonotrichia leucophrys gambeli.—Gambel sparrow.

Spizella socialis arizonæ.—Western chipping sparrow (Sprague, Henderson).

Spizella breweri.—Brewer sparrow (Henderson, Felger).

Junco hyemalis.—Slate-colored junco.

Junco montanus.—Montana junco.

Amphispiza belli nevadensis.—Sage sparrow (Dille).

Melospiza cinerea montana.—Mountain song sparrow.

Zamelodia ludoviciana.—Rose-breasted grosbeak (Cooke).

Zamelodia melanocephala.—Blackheaded grosbeak.

Guiraca cærulea lazula.—Western blue grosbeak (Felger, Dille).

Spiza americana.—Dickcissel.

Tachycineta thalassina lepida.—Northern violet-green swallow (Felger, Henderson).

Lanius ludovicianus excubitorides.—White-rumped shrike (Dille).

Dendroica coronata.—Myrtle warbler (Bragg, Henderson).

Geothlypis trichas occidentalis.—Western yellow throat (Henderson).

Wilsonia pusilla pileolata.—Pileolated warbler.

Oroscoptes montanus.—Sage thrasher (Dille).

Toxostoma rufum.—Brown thrasher (Henderson).

Certhia familiaris montana.—Rocky Mountain creeper (Sprague, Henderson).

Sitta carolinensis aculeata.—Slender-billed nuthatch (Sprague).

Sitta Canadensis.—Red-breasted nuthatch (Sprague).

Regulus calendula.—Ruby-crowned kinglet (Sprague).

Hylocicla ustulata almae.—Alma thrush (Dille).

The same plan has been followed as in the preliminary list, of placing the name of the person upon whose authority the species is reported in parentheses after the common name, in all cases where Boulder County specimens are not in the University collection. The additional list is gathered from the notes of Dr. J. R. Brackett, Professor A. H.

Felger, F. M. Dille, William A. Sprague, L. C. Bragg, and the writer, except so far as they appear in the collection. A manuscript list received from Mr. Sprague shows eighty-one species noted by him in the county, all of which, however, are included either in this or the one published last April.

The red-winged blackbird was omitted from the former list through inadvertence, not through ignorance of its occurrence here, as so conspicuous and plentiful a species could hardly escape observation. The record of the jaeger should have been parasitic jaeger (*Stercorarius parasiticus*) instead of pomarine jaeger (*S. pomarinus*). The interrogation point after the dwarf thrush in the former list should be removed, Mr. Sprague's identification having been confirmed by Mr. Ridgeway.

The finding of the western blue grosbeak near Left Hand Creek is an important item, as it had heretofore not been reported north of Colorado Springs in this state, so far as the writer is aware, except one specimen taken at Morrison. Professor A. H. Felger has taken one specimen (the first) and F. M. Dille another near Altona, and the latter reports several others at the same place.

The sage sparrow reported by Mr. Dille seems to be the second record east of the Front Range, the first being Mr. Bond's specimen at Cheyenne. The white-winged scoter appears to be the eighth for Colorado, Dr. Bergtold's specimen recorded in the *Auk* as the ninth having been taken on October 11, 1903, while Professor Felger's was taken at Longmont on October 20, 1901. The scaup duck was mentioned in the first list, but the specific identity was in doubt, so that the identification of the two species only adds one to the total number of species for the county. The goldeneye adds nothing to the former list, so far as the number of species known to occur here is concerned. The rose-breasted grosbeak is the one at Longmont mentioned in Professor Cooke's bulletins.

Possibly the Wilson warbler (*Wilsonia pusilla*) should be added to the list, as specimens from Boulder County so labeled are found in at least one collection; but inasmuch as *pileolata* is common in the county and in Colorado generally, while *pusilla* is declared by Ridgeway and others only "occasional during migration in Colorado," it seems best to omit the latter until further investigation clears up the doubt. The specimens in the University collection are *pileolata*, some of them having been identified by the United States Biological Survey. A series of juncos identified at the same time clears up some of the doubts concerning that genus for this county. The most troublesome specimen is declared a hybrid (not a true intergrade)—*J. aikeni* × *J. mearnsi*. This gives us two hybrids, as the supposed species *J. annectens*, heretofore listed, is now considered a hybrid—*J. caniceps* × *J. mearnsi*. This eliminates *J. annectens* from the former list, but we add *J. montanus*, so that the total remains unchanged by that omission. The juncos, eliminating the two hybrid forms, for the county, now stand as follows:

Junco aikeni.—white-winged junco.
Junco oregonus shufeldti.—Shufeldt junco (*J. h. connectens*).
Junco hyemalis.—Slate-colored junco.
Junco montanus.—Montana junco.
Junco mearnsi.—Pink sided junco.
Junco caniceps.—Gray-headed junco.

Professor Felger confirms the occurrence of the ring-necked duck (*Aythya collaris*), lesser scaup duck (*A. affinis*), American scaup duck (*A. marila*), and American goldeneye (*Clangula americana*). The writer confirms the occurrence of McGillivray warbler by a specimen taken above Camp Albion last September. The sora rail was found dead by Professor Felger, in company with the writer, on the surface of the ice near the terminal moraine of Arapahoe Glacier, last September.

One evening during the summer of 1903 a flock of about fifteen crows or ravens passed over Mapleton Hill, Boulder, just after sundown, flying barely over the housetops. The writer was unable to determine the species. If they were crows (*Corvus americanus*) or American ravens (*C. corax sinuatus*), another species would be added to the known Boulder County avifauna; but from the fact that the range of the former in Colorado is confined chiefly to the northeastern part of the state, and the range of the latter chiefly to the mountains and westward, while the range of the white-necked raven (*C. cryptoleucus*) was along the eastern base of the mountains before the species became so rare, it is likely that the birds were of the last-named species, which has been already recorded for Boulder County.

The rapidity with which the white-necked raven has decreased in numbers in the foothill region is an excellent illustration of the effect of civilization upon the fauna of a newly settled country. It is to be regretted that more work was not done in the preservation of natural-history records while the country was in its original condition, in order that the many changes could be determined. It is hoped that much may yet be done along this line in unsettled portions of the state, by trained workers, capable of making accurate observations. The state should establish a natural-history survey under the direction of the University, to carry on this work systematically and effectively, with reliable observers well distributed, working systematically, and co-operating with each other, in order to eliminate the speculation and guess-work which have had so pernicious an influence upon natural history in the past, and even now fill so many of the so-called "nature books" in common use in the graded schools and in American homes.

The listing of species is but a first step in ornithological investigations, to facilitate the solution of numerous other problems, such as local distribution, summer and winter range, breeding habits, migration, food habits, and so on.

It must not be supposed that the list of birds of Boulder County is anywhere near complete. It is likely that at least fifty or sixty species will yet be added. Conditions are so diverse that a large list may be expected. The plains area forming the eastern portion of the county, dotted with lakes and crossed by streams of various size, fertile fields alternating with dry mesas, presents to the ornithologist an avifauna in part peculiar to itself. The foothill region is the home of other species rarely found on the plains or among the higher peaks. The snow-clad peaks furnish abiding places for species not found much below timber line. Other species seem able to adapt themselves to a great variety of conditions and may be found from the plains nearly to the top of the range.

The study of bird migration in this vicinity is complicated by at least one feature not found in more level countries. Many species here, as everywhere, pass through twice a year on their northward and southward journeys, stopping but a few hours, if at all, to eat and rest. Others come from the south, remain through the summer, and return to their winter homes with the first breath of cold weather. Others spend their summers in the north, rear their young there, but come here for winter. Others remain with us throughout the year. In addition to the usual latitudinal migration, however, we have here a pronounced altitudinal migration. To illustrate, grayheaded juncos breed in large numbers in the mountains, up to timber line. In the winter they come down to the valley to join their cousins from the north, so that one not familiar with their summer range might suppose they also came from the north. Severe weather also brings some of the Rocky Mountain jays down to the valley. The long-crested jay may be seen all summer in the foothills, but seldom come into Boulder City until after the first frosts, when they arrive in considerable numbers and remain until spring. There are also reasons for supposing that some species make a sort of altitudinal migration between broods, raising their two broods at different altitudes. Others apparently indulge in erratic movements singly or in flocks after the breeding season and before the southward movement. The erratic movements of such birds as the evening grosbeak are such that it is difficult to connect them with any known change of conditions, though it seems likely that the supply of preferred food would furnish the key to the movements. From this it seems clear that the problems confronting the ornithologist require extensive observations which can only be obtained by scattered observers working in unison. Such work the United States Biological Survey is doing for the country at large, by tabulating the migration records of observers all over the land; but for the local and state problems more minute data are required.

FISHES OF BOULDER COUNTY, COLORADO

By Chancey Juday

The following list of fishes is based on some collections made in Boulder County during the months of September and October, 1903. Collections were made in Boulder Creek about five miles east of the city of Boulder and in St. Vrain Creek in the vicinity of Longmont. Also, through the kindness of Dr. Place, we were enabled to obtain two species of food fishes (*Pomoxis sparoides* and *Micropterus salmoides*) which have been introduced in Culbertson's Lake, a small private lake about five miles east of Boulder.

This list is incomplete, as specimens of the trout that inhabit the mountain courses of the above streams have not been obtained as yet. Indeed, it is not even presumed that all the species inhabiting these streams in the regions where collections were made have yet been obtained. One additional species at least has been reported from these regions by local fishermen. Also there are several other streams and lakes in the county in which collections have not been made.

As far as the author has been able to determine, but a single species of fish, besides a mention of the trout, has been reported from the County before. Jordan (1889, p. 7) states that he found young *Catostomus griseus* in Boulder Creek in the cañon above Boulder.[1] So far, twenty-five species have been found and as stated above, the list is still incomplete. This large number of species alone has been sufficient to make the work very interesting for it was not supposed in the beginning that nearly so many species would be found. This interest has been greatly increased, however, by the fact that one species is new to science.

The writer wishes to acknowledge his indebtedness to Judge Junius Henderson, of Boulder, and Professor D. W. Spangler, of Longmont, for their valuable assistance in making the collections.

In the list, the letter B indicates that the species was found in the vicinity of Boulder, and L in the vicinity of Longmont. The common

[1] *Bulletin*, U. S. Fish Commission, Vol. IX (1889), pp. 1–36.

names as well as the scientific names are given for those species which have them.

Carpiodes velifer Rafinesque.—Quillback; spearfish. L.

Catostomus griseus Girard.—B, L.

Catostomus commersonii Lacépède.—Common or white sucker. B, L.

Campostoma anomalum Rafinesque.—Stone-roller; steel-backed chub. B, L.

Chrosomus erythrogaster Rafinesque.—Red-bellied dace. B, L.

This is much farther west than this species has been noted before. Jordan and Evermann give Iowa as the western limit of its range.[1]

Hybognathus nuchalis Agassiz.—Silvery minnow. B, L.

The members of this species have a dark lateral band.

Pimephales promelas Rafinesque.—Black-head minnow. L.

Only one specimen of this species was obtained.

Semotilus atromaculatus Mitchill.—Horned dace; creek-chub. B, L.

Leuciscus sp. nov. B.

This is apparently a new species of *Leuciscus*, and a description of it is being prepared. So far only three specimens have been obtained.

Notropis cayuga Meek.—L.

Notropis scylla Cope.—B, L.

Notropis piptolepis Cope.—B.

Notropis lutrensis Baird & Girard.—L.

Notropis cornutus Mitchill.—Shiner; red-fin. B, L.

Phenacobius scopifer Cope.—L.

Rhinichthys cataractæ dulcis Girard.—B.

Hybopsis kentuckiensis Rafinesque.—Horny-head; river chub. B, L.

Couesius dissimilis Girard.—B.

Fundulus zebrinus Jordan & Gilbert.—B, L.

Fundulus floripinnis Cope.—B, L.

Pomoxis sparoides Lacépède.—Calico bass; strawberry bass. B.

Apomotis cyanellus Rafinesque.—Blue-spotted sunfish; green sunfish. L.

Micropterus salmoides Lacépède.—Large-mouthed black bass. B.

Boleosoma nigrum Rafinesque.—Johnny darter. B, L.

Etheostoma iowae Jordan & Meek.—L.

This species has not been reported west of Valentine, Nebraska (longitude 100° 30′ W.), before.[2]

[1] *Bulletin 47*, U. S. National Museum, Pt. I, p. 210. [2] *Ibid.*, p. 1084.

ON THE LEARNING OF A MODERN LANGUAGE[1]

By Charles C. Ayer

This country leads the world in popular education. In no other country does the layman have so great a voice in the policy pursued. He is to be found on the board of trustees from the primary grades to the state university. He often boasts no special training for the position he occupies, excepting that of common-sense and the business qualifications for deciding how much the community can afford to pay for in the way of education. At the same time, being a practical person, he deems himself fitted, in a general way, to judge of the practical results of the study of the various subjects put down in the curriculum. It is to his attitude toward the study of a foreign modern language that the following pages are to be devoted. And to be entirely fair, it is not for the layman alone that they are written, but for a rather large proportion of college-bred people, whose work has been along other lines, and who have, therefore, not advanced much beyond the average practical outsider, as far as their real understanding of modern-language study is concerned. To limit the question still further, we will consider only the study of French, that being the language concerning which the writer, after nearly ten years' experience with college classes, feels best fitted to speak. The results, however, would, in his opinion, remain the same with German, Spanish, Italian, or any other modern language which is taught in our colleges.

To the average uninitiated person the ability to speak the modern language in question is regarded as paramount. Not a few of our average citizens are disappointed, and not a little puzzled, when a student leaves college unable to speak the French or German he has been taking courses in. To him it seems that something must be radically wrong. And it is not only the every-day outsider who is puzzled. Not long ago a student of mature years, deficient by nature in all the various qualities of mind which make for ultimate success in French, asked the writer

[1] Read at the Modern Language Conference, Colorado College, February 20, 1904.

if he would probably be able to speak French by the end of the year. These various qualities of mind shall be discussed later. It is first necessary to state in what the study of a modern language consists, as conducted in our modern colleges. To most people the statement of these constituent parts of the study of French will be superfluous and unnecessary. Nevertheless, there are many who do not realize in what proportions they may be profitably studied, or in what relation they stand to one another.

A beginning course in French lasting one year is broken up into the following three divisions: (1) the translation of French into English; (2) the translation of English into French; (3) pronunciation.

The translation of French into English is the easiest division of the study. It is the part which would seem to appeal most readily to the so-called average man. It is, on the whole, rather easy for him, as long as it remains simple and direct, as so much French prose is. If it becomes difficult and involved, and requires a minute syntactical analysis, the average student remains more or less helpless in presence of the passage to be translated. It is a common saying that easy French is very easy, and hard French very hard. Nevertheless, for those who are well grounded in French prose composition, no modern French is really beyond their powers, and this brings us to the second division of the study—the translation of English into French.

This is justly regarded as the most difficult element in the study of French. But, for that matter, it is the most difficult element in the study of any foreign language; and, indeed, prose composition in one's native tongue is not so simple a matter as many imagine. College professors of English will bear witness to this fact. French prose composition is usually a serious stumbling-block to the average man, and his standing suffers severely from the requirements exacted of him. A few students, however, distinguish themselves in French prose composition. They are, I think, without exception those persons who are careful of their own English speech. Those who are slipshod or illiterate in the use of their native tongue—and there is always a considerable number, it would appear, in our higher institutions of learning—can scarcely hope to do more than mediocre work in French prose composition.

The third division of beginning work in French has to do with the pronunciation. This in its way is quite as troublesome as the prose composition. Before the days of methodical, scientific procedure, some would give it up as impossible at the outset and refuse to make an effort; others would pronounce as best they could, badly, without fear, determined at least to indulge in the luxury of uttering a French phrase now and then if they wished. At the present time the study of pronunciation has been reduced to a series of definite rules with phonetic symbols, which, barring an occasional exception, can be applied with almost mathematical precision. With the aid of these rules, applied with infinite pains, every French sound can be attained, and almost perfectly. In some cases, to be sure, perfection is only approximately attained, but the short-coming is by no means offensive. It is not true that the pronunciation of French is so far beyond the powers of Americans that it would be better, as a professor in one of our leading universities is said to have advocated, to abandon all effort toward correctness, and pronounce the words in the most convenient English fashion.

Reading, writing, and pronouncing French are, therefore, the three elements which may profitably enter into a first-year course in French. The taxpayer, the average man, the student in some other department of the university—now wishes to know, and with reason, why training in speaking the foreign tongue is not provided. He is right in rating the ability to speak French correctly and fluently as no mean achievement, and one worth making an endeavor for. It is not easy to give an entirely satisfactory reason for not emphasizing this part of the study. But a little reflection will convince anyone that conversation must be the outcome of favorable psychological conditions, which are absent from the classroom. Fictitious conversations grafted upon the necessarily formal conditions which must obtain in any classroom where the number of students is large, cannot be otherwise than spiritless and dead. In a rather small class, to be sure, the students might perhaps be coaxed to throw off their restraint and to play as they did when they were children, imitating and acting out whatever the conversation might suggest. But this they will not do. The period of play has passed with them; it was left behind when they emerged from childhood; it is very far removed from the adolescent, awkward, self-conscious stage in which students from seventeen to twenty-one find themselves. Conversation in the classroom is, therefore, not worth while. The hour is short at the best. Many other and, contradictory as it may seem, more ultimately practical things require attention. Oral prose composition, necessarily stilted and didactic, has to be the most practicable substitute for what we call "conversation."

Nevertheless, during the past few years I believe I have hit upon a means which will stimulate the student to speak French, after having first been made to think in French. The student has been made to think in French, or at least to think in a Frenchified English, by means of daily themes written in French, preferably in journal form as being the form best adapted to make the person writing think subjectively. Students in the second year of college French begin usually with a few sentences each day of primitive, even puerile, ideas, written evidently with more or less difficulty at the beginning; but within a few months' time, most students in the course can cover a page of fool's-cap with a very readable account of their daily thoughts and doings. After having expressed themselves for a time slowly but surely with short sentences, which have stood the test of the corrector's red-ink revision, they gain confidence, expand, and reveal themselves almost as freely and well in French as they would in English. They write about themselves, and their own genuine psychic state is the impulse which spurs them on to write. It is to a certain extent as if, being in France, they were compelled to do their thinking in French. Having by this means become proficient in the structural handling of the language, and having gradually and imperceptibly acquired a large and practical working vocabulary of French words, the students are not far from understanding spoken French with comparative ease, and yet ostensibly their work has been only for the purpose of learning French composition.

To sum up, then, when the time comes, the faithful student who has learned to read, write, and pronounce French, will be able to help himself in speaking French, and thus justify himself in the eyes of the layman. He will be able to get along at least when the psychological moment arrives. Whether he will be able to do more than that, will depend on certain temperamental conditions, certain mental qualities, which we are now ready to discuss.

The mental make-up of any given class is always a varied composite. One set of students passes on; another comes. In general, the average remains the same. Duplicates are usually found for those who have gone before. Brilliant and dull are both represented, as regularly as the new college year opens. In every new class the brilliant student is eagerly looked for; the dull one, too; for he also is an interesting psychological study. Perhaps his dulness may be in evidence only in the language-room; he may be as brilliant as the brightest in mathematics or in chemistry. But how does it often happen that the best student in French may be the best in some other branch, which is apparently far removed from it? My observations in the past few years on several hundred students who have been in my classes do not enable me to classify them definitely. In looking back over my class records, I find that my best students have come from all departments. It is not only the language students who have distinguished themselves. Students of mathematics, chemistry, engineering, law, and medicine have done excellent work, have demonstrated a special talent for language work. This is apparently a motley array, and yet the individuals in this motley group must possess certain temperamental qualities in common, at least in so far as they show the ability to do exceptionally good work in the study of French. Thus for translating easy French, I should say that no especial amount of ability is necessary. The memory is slightly exercised in recalling the vocabulary; the translation, once begun, goes on of its own accord by a process of reflex motor action, and the English sentence forms itself automatically without difficulty. In translating from English back into French, however, a very different process is necessary. The memory is brought into play at every moment and the powers of reasoning are constantly drawn upon. A student once remarked that her sense of accuracy was as severely tested in a French composition exercise as in a lesson of mathematics.

For success in pronouncing the same qualities are necessary. The careful student with his phonetic system at command will first give an accurate visual transcription of each word or phrase to be uttered, and his own utterance therefrom will be approximately perfect, if his ear be correct. In some cases a student has been known to betray something akin to color-blindness in his attempts to produce a certain sound, and the result is that he pronounces off the key. The better the musical ear, the better the tonal results will be in pronouncing French. In the case of several of my best students, of whom I am able to speak, I would note a well-developed taste for music.

Having attained a high degree of proficiency in translation, prose composition, and pronunciation, the student is at last justified in asking whether he be not on the eve of speaking French. A student returning home from the university with high grades in French is naturally expected by his friends to be able to speak French, if occasion requires. This expectation is especially cherished, if the student goes abroad to a French-speaking country. What is the result? Almost invariably a disappointment for all concerned. The new language does not flow from his lips. He stammers and makes mistakes of which he is painfully conscious, but which, once uttered, it is too late to retrieve. But in the course of a few days the solid work done in college asserts itself and comes to the fore, and in a short time he speaks better in every way than the person who has been vegetating for several years on French soil without working at the language and without a final mental quality—which remains to be spoken of. This final quality is one which everyone must possess, if he would speak a foreign language well. Without it even the most profound student, the most learned professor, will not be able to speak so as to give pleasure to the native whose language he essays. It is the dramatic instinct, the power to imitate a native, the ready sympathy which would seem to project the speaker into a new and foreign personality. Without the dramatic instinct the spoken utterances in French of the average American, for example, are not French. They are a phenomenon far removed from the ideal. One has only to visit a class during the reading, whether in French or English, of a modern French play to see how little able the majority of the class are to enter into the dramatic situation. Some few will show by their reading an appreciation of the emotional value of what they read; others will merely drone the words, and these latter are not necessarily poor students. They may even attain high college grades in French. But they have not the dramatic temperament.

It might seem, from what has just been said, that the accomplishment of speaking French could be achieved only at the expense of sincerity. There is a grain of truth in this. If we are entirely sincere—that is, if we allow our spoken French to sound as nearly as possible like our spoken English—it will cease to sound like French. An element of simulation is necessary; one must be self-conscious to the extent that he be alive constantly to his own shortcomings.

This is especially true of the adult learning to speak a foreign language. It is also equally true of the person who takes up a different dialect of his own language. Many Americans return from a comparatively short residence in England, letter perfect in the English pronunciation, vocabulary, phrasal intonation, and English manner generally. But all this has not been acquired by persons deficient in imitative power. It has been acquired through deliberate, even if sympathetic, imitation by persons of naturally dramatic temperament. The mental process has been one which we could look for only in an adult.

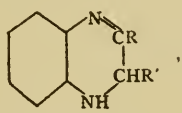
In the case of a child the conditions are different. The child imitates for the most part unconsciously the speech, both good and bad, which he hears about him; and he does this with successful results, which cannot be attained by the adult except at the expense of careful and deliberate imitation and simulation. I have said that the child imitates for the most part unconsciously. At the same time, every child possesses to a greater or less degree the spirit of deliberate imitation. In all the tendency to play is inborn, but the variety of games involving the impersonation of various characters, such as the locomotive engineer, the storekeeper, the schoolmaster, or whatever the game may require, will depend upon the dramatic temperament of the children at play. Some children play one game constantly; others vary their game with every new influence which appeals to their imitative sense. And on this ability to play and to play many and varied parts will depend their aptitude in later years for speaking modern languages.

A final word remains to be said with regard to the professor of modern languages. It goes without saying that he should be competent for his position, that he should be thoroughly grounded in all the departments of his specialty. But it must be remembered that he is, after all, a human being, liable to the failings of a human being. The born teacher will strive intuitively to be helpful to those under his instruction. As far as he is able, he will try to understand the various personalities which go to make up his class. These will necessarily vary according to sex, age, social position, previous experience in life, and as many other conditions, perhaps, as there are individuals in the class. The teacher must learn to understand, if possible, these various personalities, and to deal with them fairly and humanely. If a student fails, the professor is not necessarily to be blamed. If a student makes a brilliant success in after-years, the professor is not necessarily to be praised. The spur which leads a student to ultimate success must have come from within himself. If the professor can feel that he may have been helpful in starting that student on the right path, he has his reward.

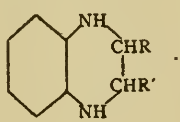
ON A DIHYDRO-QUINOXALINE FROM ORTHO-PHENYLENE-DIAMINE AND MESITYLOXIDE

By John B. Ekeley and Robert J. Wells

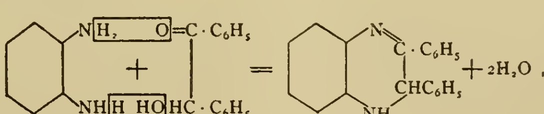
The series of organic bases of which quinoxaline, $C_6H_4\left\langle\begin{matrix}N=CH\\ \quad\ |\\ N=CH\end{matrix}\right.$, is the first member has been shown to be closely related to two series of hydro-compounds, the dihydro, of the general formula

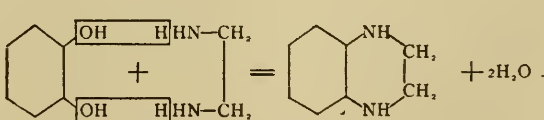


and the tetrahydro, of the general formula



These hydro-compounds may be obtained either by direct reduction of the normal quinoxalines or by condensations. The following are examples of the latter:



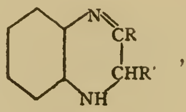


Experience has shown that the addition of two hydrogen atoms to the quinoxaline ring changes the colorless quinoxalines to yellow dihydro-quinoxalines, which in dilute solution show a yellow-green fluorescence.

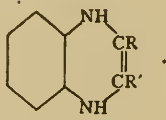
Their mineral acid salts are characterized by an intense, usually red, color. No marked increase in basicity over the normal quinoxalines has been observed in the case of these dihydro-compounds. The hydrogen of the imido group is replaceable by the hydrocarbon, acetyl, and nitroso groups.

The tetrahydroquinoxalines, as far as investigated, do not show fluorescence. They are basic in character.

Besides the above-mentioned dihydro-compounds of the general formula



there is possible, theoretically, another series corresponding to the general formula,



It is the purpose of this paper to describe the first member of this series to be isolated.

GENERAL AND THEORETICAL PART

If orthophenylene-diamine is dissolved in an excess of dry acetone and treated with a current of dry hydrochloric acid gas, a solid substance separates out, which proves to be the hydrochloric acid salt of a new base. The diamine reacts in the same way when mesityloxide is used instead of acetone, proving that the first reaction, in the case of acetone, is a condensation of the ketone to mesityloxide, which then reacts with the diamine. The free base crystallizes in large monoclinic prisms from benzene. It is very slightly soluble in water, easily soluble in ether, alcohol, chloroform, carbon bisulphide, the hydrocarbons, and in acids. It dissolves in benzene, xylene, etc., in the cold to a colorless solution, which turns to a golden yellow on heating. If a saturated benzene solution of the base is allowed to crystallize slowly, the crystals obtained are large, well-defined monoclinic prisms; if, on the other hand, a dilute benzene solution is allowed to evaporate, the crystals obtained are large thin plates. Both melt at 124°, uncorrected.

An elementary analysis of the substance corresponds to a compound having a formula $C_{12}H_{16}N_2$. A cryoscopic molecular weight determination gave 192, whereas, for the above, the calculated molecular weight is 188.

If a stream of dry hydrobromic acid gas is led through a cold solution of the base in benzene, a lemon-yellow crystalline powder is precipitated, which, on analysis, corresponds to a mono-hydrobromic acid salt, $C_{12}H_{16}N_2$,HBr. If, however, the base is dissolved in aqueous hydrobromic acid, and the solution evaporated over calcium chloride, colorless needles separate out, which, on analysis, are shown to have the composition $C_{12}H_{16}N_2$,2 HBr.

If dry hydrochloric acid gas is led into a cold benzene solution of the base, at first a lemon-yellow crystalline powder, similar to that obtained with hydrobromic acid, is precipitated. This, however, begins almost immediately to turn white. Numerous attempts were made to isolate the yellow powder from the solution before it could change, in order to analyze it. Results nearer than 1 per cent. to the calculated amount of hydrochloric acid required for a mono-hydrochloric acid salt could not be obtained. Considering the speed with which the yellow salt changes to the white one, this is not to be wondered at. The white salt on being analyzed always gave too low a value (by about 2 per cent.) of hydrochloric acid for a dihydrochloric acid salt. If, however, the base is dissolved in aqueous hydrochloric acid and is allowed to evaporate over sulphuric acid, long colorless crystals, similar to those obtained with aqueous hydrobromic acid, are obtained. These, on analysis, are shown to be the dihydrochloric acid salt, $C_{12}H_{16}N_2$, 2 HCl.

These salts are extremely soluble in water. The solutions are colorless when concentrated, but change to a bright yellow when diluted, showing that the complex kation $C_{12}H_{17}N_2$ is yellow. The salts were analyzed by titration with standard sodium hydroxide. They can act as their own indicators, because, at the point of neutralization, the change from bright yellow to colorless is very sharp.

Dilute sulphuric acid dissolves the base to the same yellow-colored solution and the concentrated acid to a colorless one, showing that a sulphate is also probably formed. This salt could not be isolated from the solution on account of its extreme solubility, and also because, on standing, it decomposed into mesityloxide and phenylene-diamine sulphate, as shown by the characteristic odor of mesityloxide and an analysis of the crystals which are slowly deposited. These crystals show the characteristic diamido-phenazine reaction with ferric chloride.

If alcohol solutions of the base and picric acid are mixed, bright yellow needles crystallize out, having a composition $C_{12}H_{16}N_2$, $2\,C_6H_2OH(NO_2)_3$.

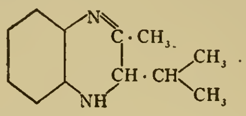
The base also gives a platinum double salt, $(C_{12}H_{16}N_2)_2H_2PtCl_6$.

With potassium nitrite and an acetic acid solution of the base, a dinitroso compound is obtained, as shown by the analysis (corresponding to a compound $C_{12}H_{14}N_2(NO)_2$), and the fact that it shows Liebermann's reaction for nitroso compounds.

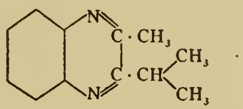
Treated with benzoylchloride, the base immediately dissolves, and the solution suddenly solidifies to a mass of minute yellow crystals. The analysis shows them to be $C_{12}H_{14}N_2(C_6H_5CO)_2$.

If the base is treated with acetic anhydride, it dissolves, but no crystals are formed. Addition of alkali gives the odor of mesityloxide, showing that a decomposition has taken place. No acetyl derivative was obtained by using acetyl-chloride.

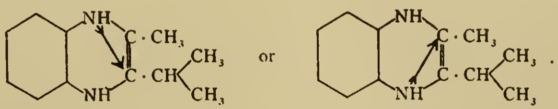
The base seems to be stable toward reducing agents, being unacted upon by sodium and hot alcohol. It is, however, very sensitive to oxidizing agents. Potassium bichromate, potassium permanganate, alkaline potassium ferricyanide, and hydrogen peroxide attack it, forming a quinoxaline, and in some cases another dihydro-quinoxaline. At the same time, there are formed large quantities of a dark substance more or less soluble in most solvents, so that it was not possible to isolate the pure quinoxaline. Its presence is, however, betrayed by the characteristic odor of quinoxalines. If the base is allowed to stand several days with hydrogen peroxide, it dissolves to a yellow solution which gradually turns dark red. If this solution is filtered and shaken with ether, a dihydro-quinoxaline, of the probable formula



goes into solution, as indicated by the beautiful green-yellow fluorescence of the ether solution. The solution also contains a normal quinoxaline, probably of the formula



It was attempted to isolate this from the ether solution, but unsuccessfully. That the normal quinoxaline is really present is shown by the fact that, upon evaporating the ether, a thick oily substance remains, whose odor is almost identical with that of quinoxaline, $C_8H_6N_2$; in fact, it is difficult to distinguish between the two odors. This oily substance shows also the characteristic red color of the salts of ordinary dihydro-quinoxalines on being moistened with mineral acids. It would seem probable, then, that, in the case of hydrogen peroxide (also with ferric chloride), besides an oxidation of the dihydro-quinoxaline to the normal base, there has also been a rearrangement of the hydrogen atoms in the sense,

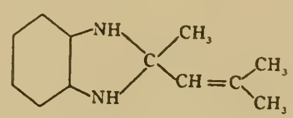


The base gives characteristic precipitates with solutions of several salts, that with mercuric chloride being a beautiful lemon-yellow and that with copper sulphate being light green. In the case of copper sulphate, the solution changes first from blue to green on the addition of a dilute water-alcohol solution of the base.[1]

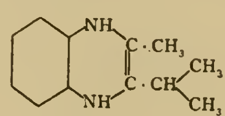
[1] This color change is not obtained when a copper sulphate solution and dilute alcohol of the same concentration as that in the experiment are mixed. The color change is therefore not due to the association of Cu and SO_4 ions.

The compound resulting from a condensation of mesityloxide and orthophenylene-diamine, having the formula $C_{12}H_{16}N_2$, and containing two imido groups, could have any of the following constitutional formulas:

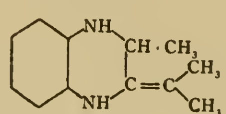
I



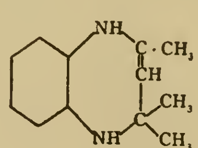
II



III



IV



Formula I represents a dihydro-benzimidazole. Very few compounds of this class are known, and they are very unstable, oftentimes oxidizing to benzimidazoles on crystallizing. Gentle warming with dilute acids is sufficient to decompose them.[1] Since the compound here obtained is a stable diacid base, it seems most unlikely that it should have a constitution corresponding to I. The green fluorescence obtained by oxidizing the base would militate against Formula I.

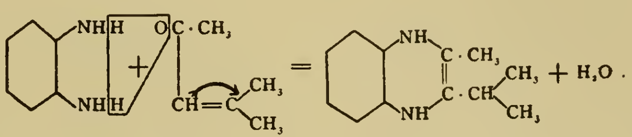
Formula IV represents a compound having a ring of seven atoms. Such compounds containing nitrogen in the ring are exceedingly rare, those known being mostly imids of carboxylic acids.

This leaves for our consideration Formulas II and III. Both of these are dihyhro-quinoxalines, II having a double carbon linkage in the heterocyclic ring, and III having it in the side chain. It seems more probable that II is the correct formula, for in III it would be

[1] Kühling, *Orthocondensationsproducte*, pp. 187, 188.

necessary to assume that, on condensation of the diamine with mesityloxide, a hydrogen atom from the carbon atom of the oxide carrying the double bond passes to the carbon atom holding the methyl group. It would seem more likely that this hydrogen atom would pass to the isopropylene group. The fact that a normal quinoxaline is undoubtedly formed on oxidation of the base would seem to support this view.

The reaction taking place between orthophenylene-diamine and mesityloxide would then be represented by the equation,



EXPERIMENTAL PART

PREPARATION OF THE BASE

Dry hydrochloric acid gas was passed for two hours into a cold concentrated solution of orthophenylene-diamine in dry acetone. A wine-colored solid separated out in a hard compact mass. The container was broken and the mass pressed out on a porous plate. This hydrochloric acid salt was then dissolved in a small amount of water, filtered, and treated with a slight excess of concentrated potassium hydroxide. The impure base, thus precipitated as a sand-colored solid, was filtered off by suction, and pressed out on a porous plate. Bone black took the impurities from a hot benzene solution of the base, from which it crystallized in large, straw-colored monoclinic prisms. M. P. 124°. The yield is almost quantitative.

Similarly the hydrochloric acid salt was prepared by passing the dry acid gas through a warm solution in molecular proportions of the diamine and mesityloxide.

Experiment showed that the base could also be formed by heating a mixture of the diamine and oxide with phosphorus pentoxide on the oil bath at 160°. The yield here, however, is not good.

CARBON AND HYDROGEN DETERMINATION

0.1420 g. of substance gave 0.3970 g. CO_2 and 0.1052 g. H_2O.

$C_{12}H_{16}N_2$

Computed	Found
C=76.59 per cent.	C=76.24 per cent.
H= 8.51 per cent.	H= 8.23 per cent.

NITROGEN DETERMINATION

0.5152 g. substance gave 84.4 c.c. N at a temperature of 22.5° and a pressure of 610.4 mm.

Computed	Found
N=14.87 per cent.	15.18 per cent.

MOLECULAR WEIGHT DETERMINATION

0.2426 g. substance, dissolved in 17.21 g. benzene, lowered the freezing-point 0.36°.

Computed	Found
$C_{12}H_{16}N_2$=188.	192.

HYDROBROMIC ACID SALTS

A

Hydrobromic acid gas was passed through a benzene solution of the base. A canary-yellow crystalline powder was immediately precipitated.

ACID DETERMINATION

0.2041 g. salt required 6.05 c.c. of a 0.12626N. NaOH solution.

$C_{12}H_{16}N_2 \cdot HBr$

Computed	Found
HBr=30.10 per cent.	30.33 per cent.

B

A solution of the base in aqueous hydrobromic acid was allowed to evaporate in a vacuum desiccator over calcium chloride. After several days the salt crystallized in long colorless needles.

ACID DETERMINATION

0.2442 g. of salt required 11.2 c.c. of a .12626N. NaOH solution.

$C_{12}H_{16}N_2 \cdot 2\,HBr$

Computed	Found
2 HBr=46.28 per cent.	46.34 per cent.

HYDROCHLORIC ACID SALTS

A

The salt obtained as a yellow powder by passing hydrochloric acid gas into a benzene solution of the base showed itself upon analysis to be impure. The color and general character would indicate that a monohydrochloric acid salt had been formed.

B

On standing for several days over sulphuric acid in an exhausted desiccator, an aqueous solution of the base gave long needle-shaped crystals similar to those obtained with aqueous hydrobromic acid.

ACID DETERMINATION

0.1818 g. of the salt required 11.83 c.c. of a 0.12626N. NaOH solution.

$$C_{12}H_{16}N_2 \cdot 2\,HCl$$

Computed	Found
$2\,HCl = 27.9$ per cent.	27.72 per cent.

ACTION OF SULPHURIC ACID

No sulphate of the base could be isolated from a solution of the base in dilute sulphuric acid. A sulphate undoubtedly exists in the solution, as shown by the characteristic yellow color due to the complex ion, $C_{12}H_{16}N_2H$. On standing, colorless crystals separate out, which dissolve in water to a colorless solution, give the diamido-phenazine reaction with ferric chloride, and correspond, on analysis, to ortho-phenylene-diamine sulphate. The sulphuric acid solution of the base acquires a distinct odor of mesityloxide after standing.

ANALYSIS OF THE CRYSTALS

0.2933 g. substance required 19.86 c.c. of a .12626N. NaOH solution.

$$C_6H_4(NH_2)_2 \cdot H_2SO_4 \cdot 1\tfrac{1}{2}H_2O$$

Computed	Found
$H_2SO_4 = 42.07$ per cent.	41.85 per cent.

PICRIC ACID SALT

Alcohol solutions of the base and picric acid give canary-yellow needles on being mixed.

NITROGEN DETERMINATION

0.1936 g. substance gave 36.6 c.c. N. at a temperature of 25.8° and a pressure of 612.1 mm.

$$C_{12}H_{16}N_2 \cdot 2\ C_6H_2(OH)(NO_2)_3$$

Computed	Found
N=17.33 per cent.	17.39 per cent.

CHLOR-PLATINIC ACID SALT

Platinum chloride precipitated beautiful yellow needles from a hydrochloric acid solution of the base.

PLATINUM DETERMINATION

0.1897 g. substance, dried at 100°, yielded, on ignition to constant weight, 0.0471 g. platinum.

$$(C_{12}H_{16}N_2)_2 \cdot H_2PtCl_6$$

Computed	Found
Pt=24.8 per cent.	24.83 per cent.

DINITROSO DERIVATIVE

An ice-cold solution of potassium nitrite was poured with constant stirring into a cold solution of the base in acetic acid. A pale-yellow precipitate formed which soon became red and gummy. This was separated from the solution, pressed out upon a porous plate, and washed with xylene. The red gummy matter dissolved, leaving a yellow substance which, on being recrystallized from ether, proved to be a dinitroso compound. It responded beautifully to Liebermann's Reaction. Melting-point 177°.

NITROGEN DETERMINATION

0.1473 g. substance gave 35.35 c.c. N. at a temperature of 18° and a pressure of 614.4 mm.

$$C_{12}H_{14}N_2 \cdot (NO)_2$$

Computed	Found
N=22.76 per cent.	22.86 per cent.

DIBENZOYL DERIVATIVE

The base dissolved in benzoyl chloride, and the solution immediately solidified to a mass of small lemon-yellow needles. These were filtered off and washed with benzene until they no longer had the odor of benzoyl chloride. The substance has no definite melting-point. At 85°–90° it begins to grow soft; this continues to 175°, where the compound decomposes.

NITROGEN DETERMINATION

0.2096 g. substance gave 15.2 c.c. N. at a temperature of 24.9° and a pressure of 614.3 mm.

$$C_{12}H_{14}N_2 \cdot 2\ C_6H_5CO$$

Computed	Found
N=7.07 per cent.	N=6.71 per cent.

$C_{12}H_{15}N_2 \cdot C_6H_5CO$ would require 9.59 per cent. nitrogen.

Since this paper was written, the authors have found that it is much easier to prepare the base by heating a benzene solution in molecular proportions of orthophenylene-diamine and mesityloxide for several hours upon the water bath. On cooling, the base crystallizes out.

THEORY OF COMPOUND CURVES IN FIELD ENGINEERING

By Arnold Emch

In No. 2, Vol. V, pp. 99–108, of the *Kansas University Quarterly*, which appeared in October, 1896, the writer published the first article on "Compound Curves." Previously, in May, 1896, an article on "A Special Complex of the Second Degree and its Relation with the Pencils of Circles" appeared in No. 5, Vol. III, of the *American Mathematical Monthly*. In this the theorems were established which served as a base for the theory of compound curves. To show the efficiency of this theory and its didactic value in mathematical teaching I published a solution of a well-known problem in field engineering in the *Engineering News* of December 31, 1903 (Vol. L, No. 27). To this a number of engineers offered criticisms and other solutions in the same journal of March 10, 1904 (Vol. LI, No. 10). On studying these the reader will find, as pointed out by the author in reply to those critics, that their opinions are contradictory in essential parts. The question, of course, is not whether my solution is correct or not; it is in reference to the practical value of the solution.

Since 1896 I have had many inquiries concerning the theory of compound curves and the articles in which my results were published. In view of this, I find it advisable to present all those results once more in a single article, revised and in a condensed form. The mathematical apparatus employed contains nothing beyond common-place mathematical knowledge.

I. BICIRCULAR QUARTICS PRODUCED BY TWO PROJECTIVE PENCILS OF CIRCLES

The equations of two projective pencils of conics may be written in the form:

$$U_1 + \lambda U_2 = 0, \qquad (1)$$

$$U_3 + \frac{a\lambda + b}{c\lambda + d} U_4 = 0. \qquad (2)$$

For every value of λ we get two conics which generally intersect each other in four points. For all values of λ the locus of these points is in general a curve of the fourth order, whose equation

$$(a U_1 - b U_2) U_4 - (c U_1 - d U_2) U_3 = 0 \tag{3}$$

results from the elimination of λ between (1) and (2).

For the purpose of this paper we assume in the first place two pencils of circles. The first of these shall be determined by two circles through the points A_1 and A_2, with the equations

$$U_1 \equiv x^2 + y^2 - 2a_1 x - 2b_1 y + a_1^2 + b_1^2 - r_1^2 = 0, \tag{4}$$

$$U_2 \equiv x^2 + y^2 - 2a_2 x - 2b_2 y + a_2^2 + b_2^2 - r_2^2 = 0; \tag{5}$$

the second by two circles through the points A_3 and A_4, with the equations

$$U_3 \equiv x^2 + y^2 - 2a_3 x - 2b_3 y + a_3^2 + b_3^2 - r_3^2 = 0, \tag{6}$$

$$U_4 \equiv x^2 + y^2 - 2a_4 x - 2b_4 y + a_4^2 + b_4^2 - r_4^2 = 0. \tag{7}$$

Designating the parameters of the pencils of circles determined by (4) and (5), and (6) and (7), by λ and λ' respectively, we have as equations of these pencils

$$U_1 + \lambda U_2 \equiv x^2 + y^2 - 2\frac{a_1 + \lambda a_2}{1 + \lambda} x - 2\frac{b_1 + \lambda b_2}{1 + \lambda} y + \frac{a_1^2 + \lambda a_2^2 + b_1^2 + \lambda b_2^2 - r_1^2 - \lambda r_2^2}{1 + \lambda} = 0, \tag{8}$$

$$U_3 + \lambda' U_4 \equiv x^2 + y^2 - 2\frac{a_3 + \lambda' a_4}{1 + \lambda'} x - 2\frac{b_3 + \lambda' b_4}{1 + \lambda'} y + \frac{a_3^2 + \lambda' a_4^2 + b_3^2 + \lambda' b_4^2 - r_3^2 + \lambda' r_4^2}{1 + \lambda'} = 0. \tag{9}$$

For certain values of λ and λ' two corresponding circles of these pencils are orthogonal, if the condition holds:

$$\left(\frac{a_1+\lambda a_2}{1+\lambda}-\frac{a_3+\lambda' a_4}{1+\lambda'}\right)^2+\left(\frac{b_1+\lambda b_2}{1+\lambda}-\frac{b_3+\lambda' b_4}{1+\lambda'}\right)^2$$

$$=\left(\frac{a_1+\lambda a_2}{1+\lambda}\right)^2+\left(\frac{b_1+\lambda b_2}{1+\lambda}\right)^2$$

$$-\frac{a_1{}^2+\lambda a_2{}^2+b_1{}^2+\lambda b_2{}^2-r_1{}^2-\lambda r_2{}^2}{1+\lambda}$$

$$+\left(\frac{a_3+\lambda' a_4}{1+\lambda'}\right)^2+\left(\frac{b_3+\lambda' b_4}{1+\lambda'}\right)^2$$

$$-\frac{a_3{}^2+a_4{}^2+b_3{}^2+\lambda' b_4{}^2-r_3{}^2-\lambda' r_4{}^2}{1+\lambda'}.$$

Simplifying and solving for λ', we find

$$\lambda'=\frac{a\lambda+b}{c\lambda+d}, \qquad (10)$$

where

$$\begin{aligned}
-a&=2a_2a_3+2b_2b_3-a_2{}^2-a_3{}^2-b_2{}^2-b_3{}^2+r_2{}^2+r_3{}^2,\\
b&=2a_1a_3+2b_1b_3-a_1{}^2-a_3{}^2-b_1{}^2-b_3{}^2+r_1{}^2+r_3{}^2,\\
c&=2a_2a_4+2b_2b_4-a_2{}^2-a_4{}^2-b_2{}^2-b_4{}^2+r_2{}^2+r_4{}^2,\\
-d&=2a_1a_4+2b_1b_4-a_1{}^2-a_4{}^2-b_1{}^2-b_4{}^2+r_1{}^2+r_4{}^2. \qquad (11)
\end{aligned}$$

Substituting the value for λ' in (10) in (9), then for every value of λ the two corresponding circles with the equations

$$U_1+\lambda U_2=0 \qquad (12)$$

$$U_3+\frac{a\lambda+b}{c\lambda+d}U_4=0 \qquad (13)$$

are orthogonal. But according to (1) and (2) these quations (12, 13) represent two projective pencils and their product is a curve with the equation

$$(aU_1-bU_2)U_4-(cU_1-dU_2)U_3=0. \qquad (14)$$

As this equation is satisfied when simultaneously $U_1=U_2=0$, or $U_3=U_4=0$, and as both pencils (12) and (13) pass through the circular points, the curve passes through A_1, A_2, A_3, A_4, and twice through the circular points. (14) represents therefore a bicircular quartic.

For $b = 0$, $c = 0$, $a = d$, $\lambda' = \lambda$, and (14) reduces to

$$U_1 U_4 - U_2 U_3 = 0,$$

which represents a bicircular cubic. For $\lambda = -1$ the corresponding circles $U_1 - U_2 = 0$ and $U_3 - U_4 = 0$ are the radical axes of the pencils. To sum up, the theorem may be stated:

Two pencils of circles in which each circle of one pencil is orthogonal to a certain circle of the other pencil, and conversely, are projective and their product is a bicircular quartic.

If the radical axes of the two pencils are orthogonal, then the curve degenerates in a bicircular cubic and the line at infinity.

II. BICIRCULAR QUARTICS PRODUCED BY PAIRS OF TANGENT CIRCLES OF TWO PENCILS OF CIRCLES

In view of the application to compound curves, we have to show how the foregoing bicircular quartic may be produced by tangent circles, as indicated in the above title.

Let W be a circle of the pencil through the two fixed points A_1, A_2 Fig. 1. Now, it is known that in general there are always two circles through two other fixed points B_1, B_2 tangent to W. To construct these draw a trial circle K through B_1 and B_2, cutting W in C and D, and let CD produced cut B_1B_2 produced at N. From N draw the tangents NA and NB to W: then A and B are the points of tangency of the required circles V_1 and V_2 with W. AE and BE produced, cut the bisector of B_1B_2 at the centers G and F of V_1 and V_2. If we now construct the circle W', with N as a center and $NA = NB$ as a radius, then W' is orthogonal to W, V_1, and V_2; W' is therefore a circle of the pencil through A_3 and A_4 conjugate to the pencil through B_1, B_2. In Fig. 1 the points A_3 and A_4 are imaginary, since B_1 and B_2 are real. The same holds true for every circle of the pencil through A_1 and A_2. Hence the theorem:

The locus of the points of tangency of pairs of tangent circles belonging to two different pencils of circles is identical with the product of one pencil *and the projective conjugate pencil of the other pencil, and is therefore, in general, a bicircular quartic.*

In the special case where the two fundamental points of each pencil of circles coincide, or where all circles are tangent to a fixed line at a fixed point in each pencil, *the bicircular quartic has also two finite real double points, and degenerates therefore into two circles.* This, however, represents precisely the case of compound curves in railroad engineering.

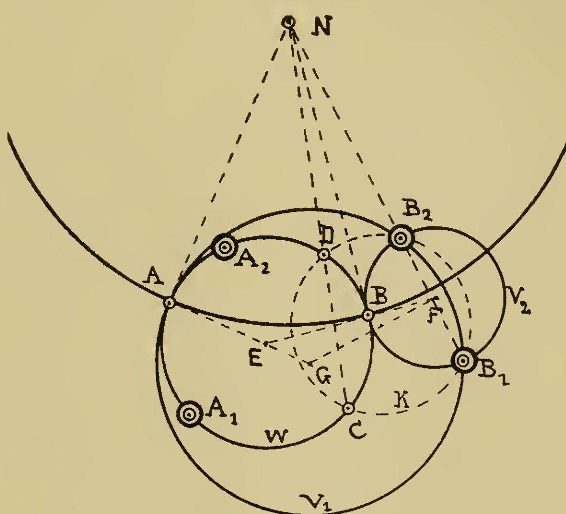


FIG. 1

III. THEORY OF COMPOUND CURVES

Assume the equations of the two special pencils of circles in the form

$$U_1 - 2\lambda U_2 = 0,$$

$$U_3 - 2\lambda' U_3 = 0, \qquad (16)$$

and as the coincident fundamental points of these pencils the points (o, o) and (a, b), Fig. 2. For the sake of convenience we replace the parameters of the pencils (8) and (9) by -2λ and $-2\lambda'$.

A verification of the results obtained in the preceding sections will lead to furmulas applicable to actual field problems.

The circles of the first pencil we assume tangent to the y-axis ($x = 0$), and those of the second tangent to the line.

$$\frac{x-a}{y-b} = k,$$

$$\text{or} \quad x - yk - a + bk = 0 \qquad (17)$$

at the point (a, b).

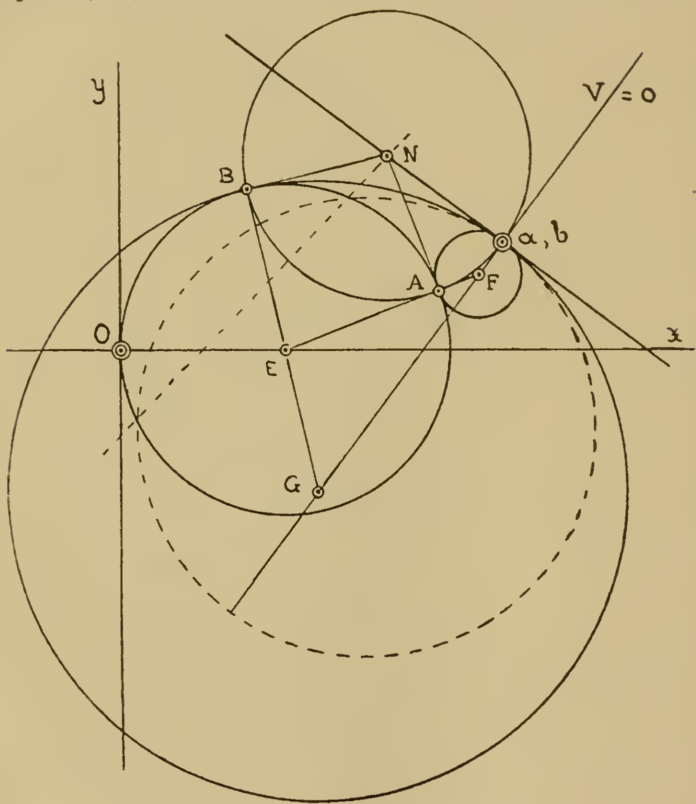


FIG. 2

Now, any two circles of a pencil of circles determine all the other circles of the pencil, as indicated in formula (16). We may also choose special circles of these pencils, for instance, the tangents at their double points and the zero-circles in these points. Thus we have

$$U \equiv x^2 + y^2, \qquad V \equiv x$$
$$U' \equiv (x-a)^2 + (y-b)^2, \; V' \equiv x - yk - a + bk.$$

The equations of our special pencils of circles are therefore

$$x^2 + y^2 - 2\lambda x = 0, \tag{18}$$
$$(x-a)^2 + (y-b)^2 - 2\lambda'(x - yk - a + bk) = 0. \tag{19}$$

Designating the co-ordinates of the centers of any two circles by (α, β) and (α', β') and their radii respectively by ρ and ρ', the condition for the orthogonality of the two circles is

$$(\alpha - \alpha')^2 + (\beta - \beta')^2 = \rho^2 + \rho'^2.$$

Associating the values α, β, ρ for a special value of λ with the corresponding circle of the pencil (18), we have

$$\alpha = \lambda, \; \beta = 0, \; \rho = \lambda.$$

In the same way we associate the values α', β', ρ' with the pencil (19) and have

$$\alpha' = a + \lambda', \; \beta' = b - \lambda' k, \; \rho' = \lambda' \sqrt{(1 + k^2)}.$$

Substituting these values in equation (5), there is

$$(\lambda - a - \lambda')^2 + (\lambda' k - b)^2 = \lambda^2 + \lambda'^2 (1 + k^2),$$

or, simplifying and solving for λ',

$$\lambda' = \frac{2\lambda a - a^2 - b^2}{2a - 2\lambda - 2bk} \; . \tag{20}$$

According to this condition, to each value of λ corresponds one and only one value of λ'; *i. e.*, taking any circle of the pencil (18), there is one and only one circle in the pencil (19) orthogonal to that circle. If we substitute in formula (21) for λ' and λ successively the values

$$\lambda' = \alpha' - a, \; \lambda = \alpha, \text{ and } \lambda' = \frac{b - \beta'}{k}, \qquad \lambda = \alpha,$$

we obtain the two expressions

$$\alpha' - a = \frac{2a\alpha - a^2 - b^2}{2a - 2\alpha - 2bk},$$

and

$$\beta' - b = \frac{k(2a\alpha - a^2 - b^2)}{2a - 2\alpha + 2bk}, \tag{21}$$

or

$$\alpha' = \frac{a^2 - b^2 - 2abk}{2a - 2a - 2bk} \quad ,$$

$$\beta' = \frac{2a(b + ak) - 2ab - a^2k}{2a - 2a + 2bk} \quad .$$

From this is seen that the centers of corresponding orthogonal circles in the two pencils form projective point-ranges. The two pencils are projective and their product is a bi-circular curve of the fourth order. To obtain the equation of this curve we have to eliminate λ and λ' from the following equations:

$$x^2 + y^2 - 2\lambda x = 0 \qquad \text{(I)}$$

$$(x - a)^2 + (y - b)^2 - 2\lambda'(x - yk - a + bk) = 0 \qquad \text{(II)}$$

$$\lambda' = \frac{2\lambda a - a^2 - b^2}{2a - 2\lambda - 2bk} \quad . \qquad \text{(III)}$$

From (I) follows

$$\lambda = \frac{x^2 + y^2}{2x} \quad ,$$

hence

$$\lambda' = \frac{a(x^2 + y^2) - x(a^2 + b^2)}{2x(a - bk) - (x^2 + y^2)} \quad .$$

Substituting this value in II, there is

$$\left[(x - a)^2 + (y - b)^2\right]\left[2x(a - bk) - (x^2 + y^2)\right] -$$
$$2\left[x - yk + bk - a\right]\left[a(x^2 + y^2) - x(a^2 + b^2)\right] = 0.$$

This equation may also be written in the conspicuous form

$$\left[x^2 + y^2 - x(a - bk - b\sqrt{1 + k^2}) - y(b + ak + a\sqrt{1 + k^2})\right] \times$$
$$\qquad (22)$$
$$\left[x^2 + y^2 - x(a - bk + b\sqrt{1 + k^2}) - y(b + ak - a\sqrt{1 + k^2})\right] = 0$$

and represents two circles

$$x^2 + y^2 - x(a - bk - b\sqrt{1 + k^2}) - y(b + ak + a\sqrt{1 + k^2}) = 0, \qquad (23)$$

$$x^2 + y^2 - x(a - bk + b\sqrt{1 + k^2}) - y(b + ak + a\sqrt{1 + k^2}) = 0, \qquad (24)$$

which both pass through the origin and through the point (a, b), the two finite double points. Thus, as established before, in this case the bicircular cubic degenerates into two circles.

The co-ordinates of the center of the first circle are

$$m = \frac{a - bk - b\sqrt{1 + k^2}}{2}, \qquad n = \frac{b + ak + a\sqrt{1 + k^2}}{2}, \tag{25}$$

and of the second

$$m' = \frac{a - bk + b\sqrt{1 + k^2}}{2}, \qquad n' = \frac{b + ak - a\sqrt{1 + k^2}}{2}. \tag{26}$$

The radii of these circles are $\sqrt{m^2 + n^2}$ and $\sqrt{m'^2 + n'^2}$. It is easily verified that

$$(m - m')^2 + (n - n')^2 = m^2 + n^2 + m'^2 + n'^2.$$

This, however, is the condition that two circles are normal to each other. Hence:

The two circles forming the locus intersect each other at right angles.

From this follows that the points P, Q, O, M, T in Fig. 3, all lie on the same circle with the line PQ as a diameter.

The normal pencil of circles of the pencil (18) is obtained by considering the normal to the straight line (17), $\frac{x - a}{y - b} = k$, which is

$$xk + y - ak - b = 0,$$

and the zero-circle at the point (a, b) as two circles of the pencil. The required normal pencil is therefore given by the equation

$$(x - a)^2 + (y - b)^2 - 2\lambda'' (xk + y - ak - b) = 0.$$

For a fixed value of λ'' the co-ordinates of the center of the corresponding circle are

$$\alpha'' = a + \lambda'' k,$$
$$\beta'' = b + \lambda'', \qquad (27)$$
and
$$\rho'' = \lambda'' \sqrt{1 + k^2}.$$

The condition for the tangency of the circle (27) and of the original circle (10) is

$$(\alpha - \alpha'')^2 + (\beta - \beta'')^2 = (\rho \pm \rho'')^2.$$

Substituting the values of α, β, ρ and α'', β'', ρ'' and solving for λ'' we find

$$\lambda'' = \frac{a^2 \times b^2 - 2a\lambda}{2\lambda(k \pm \sqrt{1 + k^2}) - 2(ak + b)},$$

which shows that to each value of λ belong two values of λ'', or that each circle of the pencil

$$x^2 + y^2 - 2\lambda x = 0$$

touches two circles of the pencil

$$(x - a)^2 + (y - b)^2 - 2\lambda''(xk + y - ak - b) = 0.$$

These results are all well known from the theory of pencils of circles, and it is for the present purpose not necessary to develop further details.

We will now show that any circle C' of the pencil

$$(x - a)^2 + (y - b)^2 - 2\lambda'(x - yk - a + bk) = 0$$

which is normal to a certain circle C of the pencil

$$x^2 + y^2 - 2\lambda x = 0$$

cuts the latter circle in two points, A and B, which are precisely the points of tangency of the two possible tangent circles C_1'' and C_2'' out of the normal pencil of circles

$$(x - a)^2 + (y - b)^2 - 2\lambda''(xk + y - ak - b) = 0.$$

In Fig. 3, C_1'' and C_2'' are the two circles tangent to the circle C.

Now the tangent to C or C_2'' at B intersects the tangent V_1 in the point $(\alpha', \beta',)$, or N, so that $NB = NM = NA$. Hence the normal circle of C', C_1'', and C_2'' passes through A and B.

The locus of the points of tangency of the circles of our special pencils of circles is, therefore, the same as the product of projectivity of one of the pencils with the normal pencil of the other, *i. e.*, consists of two circles which both pass through M and O, which also follows as a special case of the theorem under 2.

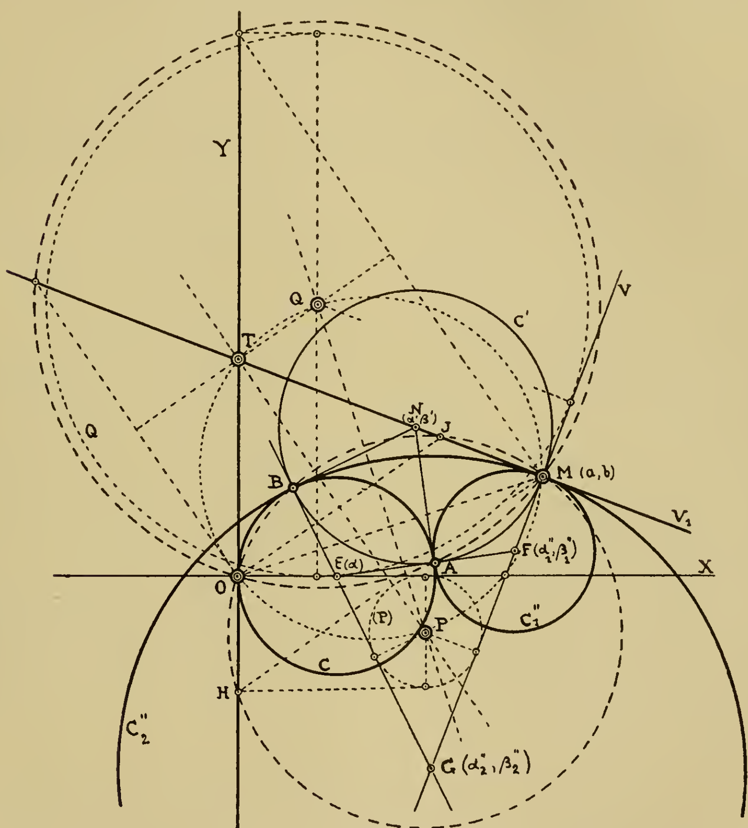


FIG. 3

The equation of the line V_1 is

$$xk + y - ak - b = 0,$$

or

$$\frac{xk}{\sqrt{1+k^2}} + \frac{y}{\sqrt{1+k^2}} - \frac{ak+b}{\sqrt{1+k^2}} = 0,$$

and of the y-axis

$$x = 0.$$

The equations of the inner and outer bi-sector are therefore

$$x(k - \sqrt{1 + k^2}) + y - ak - b = 0,$$

and

$$x(k + \sqrt{1 + k^2}) + y - ak - b = 0.$$

As is easily verified, the co-ordinates (25) which represent the center of one of the circles of the locus satisfy the first of these equations and those of (20) the second.

If we now use the technical terminology, *i. e.*, designate the arcs MB, OB, MA, AO, etc., as arcs of compound curves and their points of tangency as points of compound curves, we may state the theorem:

The locus of all points of compound curves between two given tangents and points of curve consists of two circles which pass through the two given points and whose centers lie on the bi-sectors of the two given tangents.

To construct these centers we may, therefore, connect A with B, erect a perpendicular to AB in the middle of AB, which will intersect the bi-sectors in the required points P and Q.

Any point of compound curve as B lies on the same right line with the centers of the corresponding arcs of compound curves OB and MB. Since O and B lie also on the circle of the locus of points of compound curves with the center P, the perpendicular to the chord OB through E passes through P. Hence

$$\angle PEX = \angle PEG.$$

This means that every ray connecting the centers of two compound curves whose point of tangency, or point of compound curve, lies constantly on one of the circles of the locus, is tangent to a fixed circle which is concentric with the circle of the locus. The same can be proved for the ray EF. The two concentric circles, one with P, the other with Q as a center, in Fig. 3, are designated by (P) and (Q).

The circle of the locus with P as a center intersects the y-axis and the line V_1 in two other points J and H, so that $JM = OH$, and $TM - TO = OH$. Evidently OH is equal to the diameter of the circle

(P). In a similar manner it is proved that the diameter of the circle (Q) is equal to $TM + TO$. To sum up, we may say:

The locus of points of compound curves of all compound curves between two tangents, TM and TO, and two tangent points, M and O, consists of two circles which pass through the points M and O, and whose centers lie on the bi-sectors of the tangents TM and TO.

By this condition, the centers P and Q of these circles and, therefore, the circles themselves are perfectly determined. In all compound curves the radial lines through the points of compound curves belonging to this system are all tangent to either of two fixed circles having as their centers the points P or Q and for their radii the values

$$\frac{TM - TO}{2} \text{ or } \frac{TM + TO}{2}[1],$$

The points, P, Q, O, M, T, in Fig. 3, all lie on the same circle, having the line PQ as a diameter.

Among the great number of special cases we will consider the problem where the two tangents are parallel. The general theorem and construction still hold, so that the solution is simply a matter of reduction for special values. To find the equations of the locus we have to put $k = \infty$ in formulas (23) and (24). Observing that for an infinitely large value of k

$$\lim_{k=\infty} \left(-bk + b\sqrt{1 + k^2}\right) = 0$$

$$\lim_{k=\infty} \left(ak - a\sqrt{1 + k^2}\right) = 0$$

these equations become respectively

$$bx - ay = 0 \tag{28}$$

and

$$x^2 + y^2 - ax - by = 0,$$

or

$$(x - a/2)^2 + (y - b/2)^2 = \frac{a^2 + b^2}{4} \quad . \tag{29}$$

[1] In practical treatises on this subject the conception of compound curves is not given under this general point of view. Thus in Mr. W. H. Searles's treatise on Field Engineering the following restriction is made:

"A compound curve consists of two or more consecutive circular arcs of different radii, having their centers on the same side of the curve; but any two consecutive arcs must have a common tangent at their meeting point, or their radii at this point must coincide in position."

The meaning of equations (30) and (31) is clear: The first represents a straight line through the point (a, b) and the origin; the second a circle with the point $(a/2, b/2)$ as a center, and OM as a diameter, Fig. 4.

This result is also obtained from the expressions (25) and (26). For $k = \infty$ the first indicates that the center of the circle (3) is at an infinite

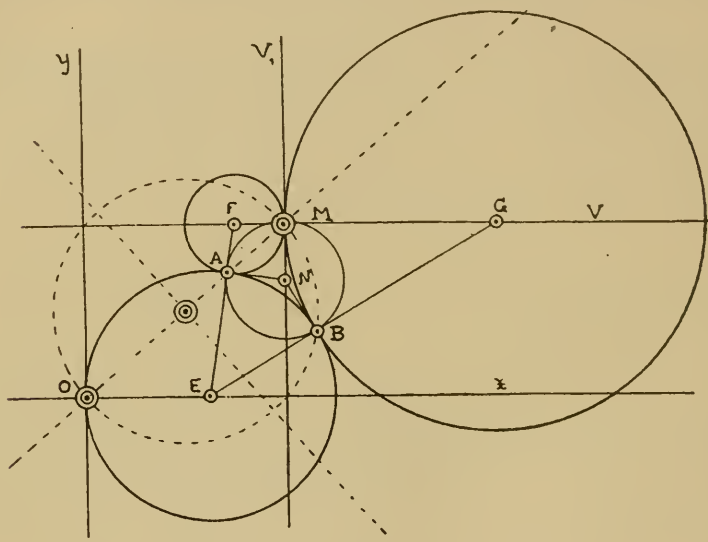


FIG. 4

distance in a direction whose trigonometric tangent is

$$\lim \left\{ \frac{b + ak + a\sqrt{1 + k^2}}{a - bk - b\sqrt{1 + k^2}} \right\}_{k = \infty} = -\frac{a}{b} .$$

The second expression gives for the co-ordinates of the circle (24)

$$x = a/2, y = b/2 .$$

IV. A COMPOUND CURVE PROBLEM

As an application of the preceding theory I shall solve the following well-known problem:

Given two tangents T_1 and T_2 of unequal length, their angle of intersection ϕ, and one radius R_1, to find the length of the radius R_2 of the other branch of a compound curve which will unite the two tangents.

Let the tangent-distance of the other branch of the compound curve be $NT = NP = NR = S$, Fig. 5. Assume the direction of the tangent $T_1 = IC$ as the y-axis, and the perpendicular to it at the point of curve

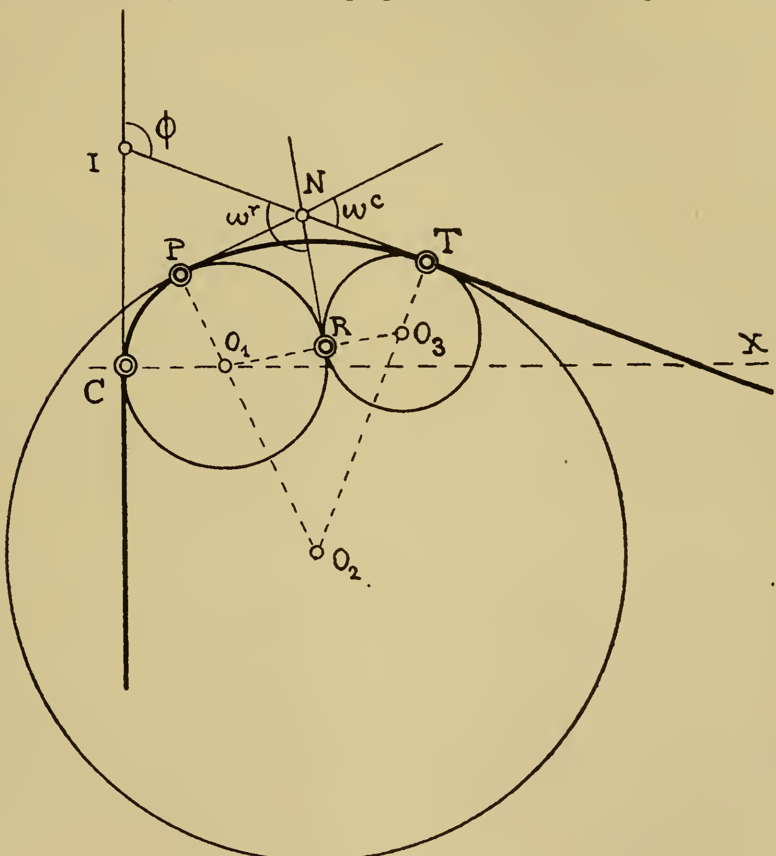


FIG. 5

C as the x-axis. Then for the co-ordinates a and b of T in (17) we have, since $IC = T_1$, $IT = T_2$

$$a = T_2 \sin \phi,$$

$$b = T_1 + T_2 \cos \phi.$$

According to usage, we designate by ϕ the angle supplementary to the angle formed by the tangents and opposite the compound curve.

Designating the co-ordinates of the point of intersection N of the tangents of the second branch of the compound curve by α, β, from the figure

$$NT = S = (\alpha' - \alpha)^2 + (\beta' - b)^2.$$

According to (21)

$$\alpha' - a = \frac{2a\alpha - a^2 - b^2}{2a - 2\alpha - 2bk},$$

$$\beta' - b = \frac{-k(2a\alpha - a^2 - b^2)}{2a - 2\alpha - 2bk},$$

here $k = -\cot\phi$. Substituting these values for $\alpha' - a$ and $\beta' - b$ in the expression for S, and putting $\alpha = R_1 = O_1C_1$, $\beta = 0$, and reducing, we get

$$S = \frac{T_1^2 + T_2^2 - 2T_2(R_1\sin\phi - T_1\cos\phi)}{2T_2 - 2(R_1\sin\phi - T_1\cos\phi)}. \qquad (30)$$

According to formulas (27), the co-ordinates of the center of a part of a compound curve, or reversed curve below tangent V_1, Fig. 3, are

$$\alpha'' = a - \mu k,$$

$$\beta'' = b - \mu, \qquad (31)$$

and the radius $R_2 = \mu\sqrt{1 + k^2}$.

The tangency of the branches of a compound or reversed curve implies the condition:

$$(\alpha - \alpha'')^2 + (\beta - \beta'')^2 = (R_1 \pm R_2)^2, \qquad (32)$$

in which the positive sign on the right side gives a reversed curve, and the negative sign a compound curve.

Substituting the values for α'', β'', R_2 given in (31) in (32), we obtain for μ the expression:

$$\mu = \frac{2R_1a - a^2 - b^2}{2R_1\left(k \mp \sqrt{1 + k^2}\right) - 2(ak + b)},$$

and replacing a, b, k by $T_2\sin\phi$, $T_1 + T_2\cos\phi$, $-\cot\phi$;

$$\mu = \frac{T_1^2 + T_2^2 - 2T_2(R_1\sin\phi - T_1\cos\phi)}{\frac{2}{\sin\phi}\left\{\pm R_1 + T_1\sin\phi + R_1\cos\phi\right\}},$$

where in the denominator the positive and negative signs in front of R_1 stand for reversed and compound curve respectively. Now

$$R_2 = \mu\sqrt{1 + k^2} = \frac{\mu}{\sin\phi} \;;$$

hence the radius $R_2^c = PO_2$ of the required branch of the compound curve (internal tangency)

$$R_2^c = \frac{T_1^2 + T_2^2 - 2\,T_2\,(R_1 \sin\phi - T_1 \cos\phi)}{2\,(T_1 \sin\phi + R_1 \cos\phi - R_1)}\;, \qquad (33)$$

and for the reversed curve, $R_2{}^r = RO_3$ (external tangency)

$$R_2^r = \frac{T_1^2 + T_2^2 - 2\,T_2\,(R_1 \sin\phi - T_1 \cos\phi)}{2\,(T_1 \sin\phi + R_1 \cos\phi + R_1}\;. \qquad (34)$$

To find the trigonometric tangent of the angle of intersection of the two tangents of the second branch of the compound curve, from Fig. 5 it is seen that the tangent of half the supplement w, $\tan\frac{w}{2} = \frac{R_2^c}{S}$, hence for the angle of intersection $w^c = 180 - w$, $\cot\frac{w^c}{2} = \cot\left(90 - \frac{w}{2}\right)$ $= \tan\frac{w}{2} = \frac{R_2^c}{S}$, or

$$\cot\frac{w^c}{2} = \frac{T_2 - R_1 \sin\phi + T_1 \cos\phi}{-R_1 + T_1 \sin\phi + R_1 \cos\phi}\;. \qquad (35)$$

In case of a reversed curve

$$\cot\frac{w^r}{2} = \frac{T_2 - R_1 \sin\phi + T_1 \cos\phi}{R_1 + T_1 \sin\phi + R_1 \cos\phi}\;. \qquad (36)$$

CORRECTIONS TO VOL. I

In Dr. Neikirk's article, "Groups of Order P^m," etc., Vol. I, No. 4, pp. 285–97, the following corrections must be made:

Page 294:

$$R^{z'} Q^{y'} P^{a(y'z''-y''z')} p^{m-3} = R^{z'} Q^{y'} P^{a'xp^{m-3}} \qquad (18)$$

VI. $a(y'z''-y''z') \equiv a'x \pmod p$.

Page 295:

	k	$\propto$	a	$(\beta \equiv 0)$ A	$(\beta \not\equiv 0)$ B
1	$\equiv$	$\equiv$	$\equiv$		
2	$\not\equiv$	$\equiv$	$\equiv$		
3	$\equiv$	$\not\equiv$	$\equiv$	A_2	B_1
4	$\equiv$	$\equiv$	$\not\equiv$		
5	$\not\equiv$	$\not\equiv$	$\equiv$	A_2	B_2
6	$\not\equiv$	$\equiv$	$\not\equiv$	A_4	B_4
7	$\equiv$	$\not\equiv$	$\not\equiv$	A_4	B_4
8	$\not\equiv$	$\not\equiv$	$\not\equiv$	A_4	B_4

Omit:

* B_1 divides into two parts; the part where $a - a\beta \equiv 0$ being simply isomorphic with B_1, while the part where $a - a\beta$ not $\equiv 0$ is simply isomorphic with B_3.

The type groups are

A_1 $k=p$ $\alpha=p$ $a=p$ $\beta=p$, the Abelian group of type $(m-2, 1, 1)$

A_2, $k=1$ $\alpha=p$ $a=p$ $\beta=p$

A_4, $k=p$ $\alpha=p$ $a=1$ $\beta=p$

B_1, $k=p$ $\alpha=p$ $a=p$ $\beta=1$

B_2, $k=1$ $\alpha=p$ $a=p$ $\beta=1$

B_4, $k=p$ $\alpha=p$ $a=1$ $\beta=1$

Page 296: In A_1, A_2, B_1, B_2:

VI. $a' x \equiv 0 \pmod p$

Leave out

Elimination between V and VI gives

$$\alpha' - a' \beta' \equiv 0 \pmod p$$

Page 297: Leave out Case B_3 and insert A_4 and B_4.

A_4

I. $a(yz' - y'z) \equiv k'x \pmod p$

III. $\beta' z' \equiv 0 \pmod p$

IV. $\beta' y' \equiv 0 \pmod p$

V. $a(yz'' - y''z) \equiv \alpha' x \pmod p$

VI. $a(y'z'' - y''z') \equiv a'x \pmod p$

B_4

I. $a\beta x \frac{z'(z'-1)}{2} + a(yz' - y'z) \equiv k'x \pmod p$

II. $\beta x z' \equiv 0 \pmod p$

III. $\beta' z' \equiv 0 \pmod p$

IV. $\beta' y' \equiv \beta + z'' \pmod p$

V. $a\beta x \frac{z''(z''-1)}{2} + a(yz'' - y''z) \equiv \alpha' x + \beta' x' + a\beta' y' z \pmod p$

VI. $a(y'z'' - y''z') \equiv a'x$ mod p)

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CONTENTS.

ORGANIZATION OF EMPLOYERS AND EMPLOYEES[1]

By John Burton Phillips

The strength of organization is in the fact that in this way the influence of a class may make itself felt. Public opinion is influenced by class feeling. The distribution of wealth among the various classes of the population is in considerable measure fixed according to public opinion. The true philosophy of the organization of the laboring class is that they realize that the wage scale is in part set in this way. Wages are in considerable part the result of public opinion as to the standard of living and the amount of income necessary to maintain the degree of comfort which it is thought desirable should be maintained by the various classes of the population. For example, the salaries of government officers are in part fixed at a rate that it is thought will enable them to entertain, as this is considered by their constituents a necessity in their positions. There does not appear to be any great necessity for a government officer to spend large sums in entertaining, but the public think it is necessary and they attempt to fix the salary accordingly. They are dissatisfied if he does not live up to a certain style of life which common consent has fixed upon as proper for such as he.

Just as the public is displeased with the government officer if he does not spend his income in keeping up a certain style of living, so it may be displeased with the wages that different classes of the population receive. There is a feeling that after a man has spent a certain amount of time and money in the preparation for a line of work he should not be paid less than a certain fixed wage or fee. This is fixed by public opinion at such an amount as is thought to be necessary for him to supply the larger needs that are supposed to have resulted from his superior training. This is clearly seen in the amounts that it is believed are proper for a physician to charge for his services. These fees are not fixed by the law of demand and supply; neither are they fixed by charging what

[1] Reprinted from the *Bankers' Magazine*, Vol. LXVIII, No. 5, May, 1904, by permission of the editor.

the traffic will bear. They are in all probability fixed by the opinion of the public as to how much such a man should be paid. Public opinion is thus a great factor in determining what a fair wage shall be.

While this is true of certain classes of the population, it is the case with but a small number of the entire laboring class. It is therefore to the interest of all classes to make their influence felt to as great an extent as possible in the formation of public opinion. If this can be done they will be able to rely on public sentiment to assist them in determining in the distribution of products what their share shall be. This is the principle of social philosophy that is behind the organization of the wage-earning class. They, least of all classes, have as yet had the assistance of public opinion in fixing the amount of wages they shall receive. They know that organization will further the growth of this class feeling which will make itself felt. When a definite public opinion has settled upon what a wage-worker should receive, the number of strikes will very likely tend to diminish. The workers will then be content to take the wage that the public have determined is fair and just, as is the case with the doctors, or they will go into some other employment where the prospect of higher wages is better.

MOVEMENT FOR THE ORGANIZATION OF EMPLOYERS

Recent success in the efforts of the unionists in increasing their numbers, and still more in their disturbance of industry by strikes, has led to the formation of organizations of employers in various parts of the United States. These organizations have been formed largely as a means of self-defense, and also in part, perhaps, to convince the public that in many lines of industry the limit of high wages has almost been reached. At least this is the contention of the employers. Experience has also taught the employers that standing alone one employer is hardly equal to the task of keeping up a winning fight against the odds that the unions are able to wage against him. It was seen that the weaker firms were being crowded to the wall. The result has been a union of employers so that their combined strength may serve as a bulwark to withstand the attacks of the labor unions. The movement for the organization of employers is new. The idea is said to have been originated by Mr.

D. M. Parry, of Indianapolis, and was first pushed by the manufacturers' association of that city. The movement has spread quite rapidly from state to state. All these organizations are combined in a grand national association which is to include, as the *New York Commercial* says, "all the great manufacturers of the country, the railroads, great retail interests, and the majority of banking institutions. Nearly all the existing organizations, local in scope but with the same object in view, will be affiliated with the national body." The competitive interests of the employers are forgotten in their effort to utilize their united strength against what they regard as their common enemy—the unions. They are clear and definite as to their program. "There is to be no single-handed warfare against labor unions, but a concentrated effort. It will be a war in which the employers will stand united." This was the remark of a member of the railroad association. A representative of the manufacturers' association said: "Every time a sympathetic strike is used as a weapon against the employers, the employers will strike back with a sympathetic lockout. Arbitration is a farce. It simply means splitting the difference." The employers have organized into a national association, and their platform demands:

Freedom of contract. No discrimination against non-union labor.
No sympathetic strikes to be tolerated.
Enforcement of law.

DEMAND FOR GOVERNMENT INTERVENTION

In addition to the idea of fighting the unions in such matters as strikes, there is another and somewhat newer feature in the movement. This is the growth of the feeling that some power of the government should interfere in the settlement of strikes. The power of organized labor is beginning to make itself felt in legislation. This was seen in the recent agitation in favor of the anti-injunction and eight-hour bills. The coal strike of 1902 was a strong influence in favor of public ownership of the coal mines. There is no question but that the general effect of that strike was to influence public opinion in favor of the workers as opposed to the capitalists. Recent legislation shows the influence of the laboring class, and it is to counteract this influence in legislation, as well as to resist the demands of the union for higher wages, that the employers have organized. That this is the true situation is evident from the remarks of Mr. Parry. "There is no safe dependence to be placed in the action of the legislators whose political life is dependent in some degree on the labor vote. Even the constitution of the country does not appear to be a sufficient bulwark for our liberties, and while the majority of the judiciary is in the main standing firm, yet our judges are being subjected to such attacks that even they may yield."[1]

It is not at all unlikely that the organization of capital for the purpose of fighting the labor unions will be productive of considerable good. When all employers are perfectly organized, the odds against the workmen will be so great that it will be futile for the men to attempt to carry on a fight. It will be a losing game from the start. This will tend to check the hasty calling of strikes. It is very likely that it will make the unions more ready to submit their disputes to a board of arbitration. In this way the organization of employers is to be looked upon as a good omen. Germany keeps out of war with France and Russia by keeping a large reserve of fighting power. So it may be that the employers by organizing into a fighting power will not need to use this power against the workmen. The knowledge that the sympathetic strike will be followed by the sympathetic lockout will be apt to make the bravest of the walking delegates more thoughtful before he calls a strike. However, the good we hope may come from this organization of employers is not unmixed. It is tempered by the fear of a combination between employers and laborers which is fraught with danger to the public, illustrations of which appear below.

HOSTILE FEELINGS BETWEEN CAPITAL AND LABOR

Perhaps a word should be said on the effect that these combinations are likely to have on the hostile class feeling between laborers and capitalists. It is true that there is a good deal of this feeling now in the country. It is almost certain that anything that tends to separate the working class into a group on one side and the employers into another and opposing group is very certain to intensify any class feeling that may exist. Whenever a man joins a labor union and thereby proclaims that he is a

[1] Quoted in *Wilshire's Magazine*, September, 1903.

manual laborer, he identifies himself with a certain class, and the more that class exerts itself so as to make its influence felt, the more the stratification of society tends to become clearly defined. As class lines become more definite the more difficult it becomes for one to escape from the class in which he is to the higher class where each one desires to be. The strife between the two groups in the case we have been discussing is a cause that is operating to make our society like that in European countries and separate it more and more into classes. There seems to be little escape from this at the present time.

INDIVIDUALISM GIVING WAY TO ORGANIZATION

When all employers are organized into one association and the rules prescribed by which they shall carry on their business, on what terms they shall hire and discharge their men, what shall be the hours of work, what material they shall use and of whom they shall buy it, what prices they shall charge and for whom they shall work, there is almost if not quite an entire loss of that peculiar mark of personality which has often been expressed by the owner and proprietor when conducting his business.

In many ways it is possible for a man to express his individuality in the management of industry. This possibility is tending to disappear. The more closely the business interests of the community are organized, the smaller is the chance of expressing any individual idea, especially if the idea is a little out of the usual line. All business must then be carried on according to set rules. The chance for originality in the treatment of employees, for experimenting with shorter hours, or fixing a different rate of wages, or putting into operation the original and ingenious ideas of individual employers, such as has been characteristic of industrial methods in the past, will be greatly curtailed.

Under the new system, when all employers are thoroughly organized, the method of conducting industrial affairs will be similar to the methods by which ordinary corporate business is now carried on. In the corporate industries the owners or stockholders are far removed from the scene of the actual business. Their responsibility is at a minimum. There is none of their individuality in the conduct of the business, or at most but a very infinitesimal part. In fact, there is very little of anybody's individuality in the management of the business. Some Wall Street individual may make his influence felt in the price of the stocks of the concern, but the business methods are not those of any stockholder. They are the methods of an artificial person—the corporation, and this person has but one sentiment, viz., to make money. The directors select a manager to carry on the business. He is hired to make the business pay; in other words, to earn dividends for the stockholders. This he knows and feels. He dares not undertake any venture that tends in the slightest degree to imperil the earning capacity of the organization that employs him. Under the old system, when the owner was his own manager, it has often happened that he has done things in business that have injured his profits, but he has done these things knowing exactly what the result would be but doing so for the sake of principle. It has seemed to him a duty he owed to society to imperil his profits for the sake of reforms in which he believed.

Here is a good illustration of the case. In the year 1900 Gustavus Meyers wrote a history of Tammany Hall. In this book he exposed, as much as the evidence warranted, the corruption that had been practiced in the long history of this powerful political organization. The book is written with a good deal of care, and the statements are verified by references to the testimony of witnesses in the investigations that have been made by the State of New York to inquire into the workings of this society. The book is a real contribution to political literature, and is proving a good seller. The curious thing about it was the difficulty of its publication. He submitted the manuscript to nine different publishing corporations, but it was declined by the manager in each case. It was not rejected because it was an inferior work or one that would not sell, but as several of these firms replied, it was considered inadvisable to publish such a work. One firm, whose readers recommended the book, said that they did not consider themselves warranted in locking horns with Tammany Hall. The work was finally published by private subscription. It is now on sale at the author's home.

It seems strange that in a great city no publishing house could be found to publish a work of so great interest and one whose statements were not contradicted. But a little reflection will enable us to see that in the city of New York there is a great demand for school textbooks and it may be that the publishing houses which are nearly all in the educational book trade feared that in some way the adoption and use of their books in the schools of the city of New York might be interfered with by their activity in publishing such a work.

This was a case where there was a very good chance for a publisher of strong character to assert his individuality in his business. He might have undertaken the publication of the work for the sake of principle even though he knew it would endanger his profits somewhat. Here was a chance for a person of strong will to deal a blow at what he considered a huge mechanism of corruption. It seems that many a man in managing his own private business would not have hesitated to avail himself of this opportunity. There are some men who will seize the opportunity to do what they think right without thinking of the loss it may cause in their business. But the manager of an organized concern cannot do this. As has been stated, his position depends on the size of the dividends he can make the stock in his corporation earn. He is therefore not going to undertake anything that will jeopardize the earning capacity of his company. When business is carried on in this way, the only object is the making of money. The chance of striking a blow for moral progress by the way in which business is managed is very nearly lost. The only thought of the manager is the increasing of the dividends, and little attention is paid to the moral effect of the conduct of the business.

Now, there cannot be much question that the organization of employers is tending to reduce business management more and more to set rules. It tends constantly to the elimination of the individual element in the management of the business. The responsibility for any questionable methods is scattered among the various members of the organization and lost, just as is the case with the stockholders of corporations. Stockholders seem to feel that they are entirely relieved of responsibility for anything. The manager shifts the responsibility to the directors; the directors shift to the manager. As a result it is knocked back and forth like a tennis ball and has become exceedingly hard to locate.

Now, the men who will organize as an employers' association are the managers of these corporations. It is part of their business to earn more dividends, and if it can be done by a national federation of the employing class, they will of course resort to that. When such an organization is once formed, it will be managed just as the corporations are now managed, and if there is anything to be gained by the use of unscrupulous methods in the management of the federation, there will be a temptation to use them.

The same might be said of the unions. Their officers hold their positions by virtue of the skill they show in securing higher wages for their members. The very conditions in which they must work are such that they cannot be expected to discriminate nicely over the ethical aspects of their action in calling a strike at a time when it is most unfair not only to the employer but to the consuming population, as in the case of a strike of the milk-drivers in a large city.

GAIN THE SOLE OBJECT OF ORGANIZED LABOR AND ORGANIZED CAPITAL

The managers of corporations think of nothing but how to earn for their companies the highest dividends. The officers of labor unions think of nothing but how to get the highest wages for their members. The stockholders of the corporations and the members of the labor unions think of nothing but what they will receive. Both are considerably removed from the scene of the actual bargaining. The result is that there is a chance for the more unscrupulous manager or officer to do a great deal of work in ways which the members alone would not feel that they could approve. In any case the members of the union or the stockholders of the corporation do not hesitate to receive their share of the profits, be they legitimately or otherwise obtained. It has been shown that the members of the New York unions knew that the methods of Sam Parks were not such as to bear the light of day, yet they would say, "Look at the wages! They were $2.50, now they are $4.50! What if he does take out something for himself? He deserves it!"

The members of the trades unions want results, and they want them in the form of higher wages. The stockholders of corporations want results, and they want them in the form of higher dividends. Neither the unionists nor the stockholders are going to ask too closely of the manager or the walking delegate concerning the methods he has employed to secure the returns. It is the size of the return that interests them. This it is and this alone.

This condition of things is very much like that which prevailed before the state had enacted any factory legislation. When the employment of children might be carried on without restriction, the employer who did not hesitate to employ them was able to drive his more scrupulous competitor to the wall. At the present time the corporation manager and the walking delegate are tempted to use unscrupulous methods. It has been said that in certain lines of industry the corporation manager who does not hesitate to bribe the city alderman nor to make a bargain with the walking delegate to call strikes in all jobs except his own, is frequently able to earn large dividends for his stockholders. It has been shown that the managers of some of the construction companies in the city of New York have not hesitated to use all the means of corruption known to the modern lobbyist, in order to secure contracts for the erection of public buildings at a larger sum than was just. In this way the returns to the stockholders have been increased. Such a condition of industry is one which tends to put a premium on the worst traits in the business world.

The same conditions confront the walking delegate. It has been said that as at present managed the union is a thing that makes it possible for the worst of walking delegates to rule and make large sums in a dishonest way. Recent magazine articles claim that it has been customary for some of these delegates to ascertain what contractors are under bonds to complete their work within a certain time and find out if they are in any way behind, and then for some trifling excuse call out their men. In a case of this kind the strike is likely to be a success. It is also said that some of the most successful strikes have been ordered by the worst of walking delegates. This has been illustrated by the career of the notorious Sam Parks in New York.

It is quite clear that, left entirely alone, the organized conditions of modern industry are such that they tend to prevent the managers of corporations and the leaders of the labor unions from considering the ethical effects of the methods they are tempted to employ. This constant tendency to organize is creating an opportunity which unless carefully guarded will enable corrupt men to get control of industry and conduct it so as to put a premium on corrupt methods.

ORGANIZATION NOT VICIOUS IN ITSELF

It is the same with industrial organizations as it is with political parties. There is nothing wrong in either workmen or employers organizing; any organization is apt to fall into the hands of designing men. Organized employers as well as organized workmen are a power that may be corruptly used. The point is that organizations, both political and industrial, must be jealously watched by a patriotic and public-spirited people in order that they may not be used against the public weal.

When two industrial organizations are so well situated that they are able to control by a monopoly the conditions of labor, and though they are antagonistic bodies, it is quite likely that they will follow the methods of other monopolies and form a combination to advance the interests of each. This has been the industrial experience of the large concerns of the United States. It is not likely that any organization will long keep up a fight when it can do better by making peace with its adversary. This is the rule of progress in all directions. It always follows the line of least resistance. In 1870 the railroads found they were wasting their strength in a useless competition, and they hit upon a scheme to combine. By this method they have saved the energy they had been wasting in strife with each other and greatly increased their profits. It seems clear that labor and capital will pass out of the fighting stage, in which they now are, as soon as they learn that it is only necessary for them to combine in order to charge and obtain the monopoly prices they desire.

CAPITAL AND LABOR UNITING TO THE INJURY OF THE PUBLIC

In the last bulletin of the Department of Labor published by the Massachusetts bureau are the agreements in twelve cities between the unions and the employers' associations. The officials of the bureau state that these agreements are fast becoming a most important factor in the industrial life of the present time. In none of these agreements is there evidence of an exclusive contract by which both parties seem to have united for the purpose of getting more than they otherwise could out of the pockets of the public. They are very largely agreements as to the conditions of work, hours, wages, holidays, etc. There is no provision to hire only unionists, nor is there an arrangement by which the unionists agree to work only for the members of the employers' associations. This is all that is lacking to make the monopoly perfect on both sides.

The conditions in Chicago are such as to show that in certain lines of work the fighting stage in the relations of labor and capital is well-nigh over. The result is not so good as the public has hoped for from the union of labor and capital. The success of the combination of labor and capital in Chicago will prove an inducement to organization in other quarters, and the result is likely to be a repetition of the extortion that prevails in that city.

In Chicago everything is unionized, both employers and laborers. Here are some of the results of the employers and laborers getting together.[1] Five years ago a struggle began. It was the Coal-Teamsters' Union fighting for an increase of wages. Finally the Coal-Team-Owners' Association and the Coal-Teamsters' Union entered into an agreement regarding hours, wages, etc. They also made a secret agreement the terms of which are as follows:

> "Party of the first part (the Coal-Team-Owners' Association) agrees to employ none but members of the Coal-Teamsters' Union, local number 4, in good standing and carrying the card of the organization."
>
> "We (the Coal-Teamsters' Union) further agree that we will not work for any firm that does not belong to the Coal-Team-Owners' Association."

The agreement was signed May 21, 1902. For fear of prosecution it was slightly changed. The men agreed that they would use their best endeavors to have all employers of coal teamsters become members of the Coal-Team-Owners' Association. This is the same thing. This agreement means that the Coal-Team-Owners agree to employ only union men. The scab is driven out and competition is killed on the side of labor. The men will work only for the association and the

[1] This account of conditions in Chicago is taken from RAY STANNARD BAKER in *McClure's Magazine*, September, 1903.

independent employer is crushed. The result is an absolute monopoly of industry.

What were the fruits of this combination? The teamsters put up their wages from eleven to fifteen per cent. No teamster can be hired without first notifying the union. He must pay his dues, $15 to join and one dollar a month. Some teamsters earn $25 a week. The union has $25,000 in the treasury. *Dealers raised the price of coal 40 per cent. No citizen can draw his own coal to his own cellar in his own wagon.* The salvation army had to get special permission from the association to haul a few loads for the poor.

Not content with a monopoly of their own industry, the combination decided to use their power to kill another and competing industry. The natural-gas industry was the one selected for destruction. Marshall Field, the Fair, and the Auditorium Hotel used gas to some extent, but had to have coal in the colder weather. The drivers refused to deliver coal in the winter unless they would cease to use natural gas at all. They compelled them to remove all the gas-fixtures. The users of gas were at the mercy of the combination, and they were obliged to surrender. Marshall Field & Co. were the last to yield. For a long time they kept up a vigorous fight, and only yielded when there was not coal enough in their furnaces to run for more than two hours longer. Thomas A. Hall, the manager of a set of apartment buildings would not surrender. His janitors struck. The teamsters struck in sympathy. He was forced to yield. The union has further changes in the industry projected. They intend to stop delivering coal in bags. Then the public will be obliged to hire hustlers to carry the coal from the walk to the cellar. In this way room will be made for the employment of another set of manual laborers.

Perhaps the worst feature of this new form of union between labor and capital is the agreement as to the number of milk deliveries a day in the city. The utter ruthlessness of this extortionate method of organized industry is well exemplified by the decision of the Milk Dealers' Association and the Milk-Wagon Drivers' Union to make but one milk delivery a day in the city. Two deliveries a day had been made for years in most districts. Dr. Reynolds, of the board of health, wrote a letter to the associations and protested in behalf of the suffering babies. They paid no attention to his protest. The cry of the children was as nothing to them. The bulletin of the Board of Health soon showed the effects. The infant death rate began to increase at once and in a few weeks had increased 40 per cent.

The monopoly combination between labor and capital when once adopted tends to strengthen each of the separate organizations. The public will not have an avenue of escape from these conditions till a new legal code is developed and adopted. In some way there is apt to be a means of escape from conditions like these. However, there is no reason to think that it will come about easily and of itself. Such an opinion is nothing but the most blind and unreasoning optimism. None of the great benefits of civilization have come without a severe struggle, and so it will be with the destruction of the new extortion in the shape of these monopoly combinations.

When all trades are well organized, in fact so well organized that they are able to keep up the prices of their services to a point beyond what the community are willing or able to pay for them, it becomes a serious matter as to how the problem may be solved. It is true that in some industries this may be left to the ordinary economic laws, but in many lines of work this is not the case. In the case of the coal-handlers of Chicago, it is not a matter that can be left to competition and the laws of political economy. It is true that new inventions would in that case as in others ultimately secure for us some other means of heating our houses and supplying the power we need in other ways, but we cannot afford to wait, for before we could secure the benefits of the new invention we should probably all be dead.

With the growth of civilization many things with which the public had formerly nothing to do have now become things in which the public has an interest of infinite value as it determines whether the population shall live or die. Before the era of great modern cities it was of no consequence to the public as to how milk was delivered. Most men kept their own cow and in this way were protected from the trouble in Chicago that has already been mentioned. The same may be said of the delivery of coal. It was not then a matter of life or death to vast numbers of the population. When it was first discovered that certain industries were in their nature what have been called quasi-public, it was thought that only a few industries were of this type. These were such as the railroad, water supply, gas-works, and a few others of like nature; industries that all could see that their stoppage resulted in great loss to the whole country. With the course of time the number of these industries is tending constantly to increase. It seems that it may be likely that the list will be so extended as to include all businesses that are concerned with providing for the more necessary wants of modern society. It is becoming quite clear that the delivery of coal in a great city is one of the legitimate functions for the interference of the government. So it is with the case of milk. These are things on which the lives and welfare of the population depend. Any government is justified in interfering in any case where the lives of the people are in danger. This is simply the doctrine of common sense.

In these industries that are becoming more and more quasi-public, the duty of the government to guarantee their operation becomes apparent. There seems to be no reason why the city should not operate its milk supply. It is almost as important as that it should furnish a supply of pure and wholesome drinking water. We are told by medical men that typhoid fever is very often conveyed in milk as well as water. In Glasgow two hundred cases of typhoid fever were traced to a dairy whose cows had been drinking polluted water. It is probable that aside from water the healthfulness of the population is as dependent on the milk supply as on any other one thing. This is especially important in the case of infants. The death rate of infants is much greater than it would be if it were possible for the parents to procure a supply of pure milk for their babies. Many cities attempt to inspect the milk supply, but affairs in Chicago seem to indicate that the delivery also should be guaranteed by the city government.

Bound up with the checking of the infant death rate is a more subtle problem. It has been shown that the death rate of infants, where it is excessive, is a strong factor in causing poverty. The high death rate of infants in the poorer districts tends to keep the people poor. Charles Booth has shown by his studies of the poor in London that the death rate of infants is abnormally high in the poorer sections and that it acts as a cause to keep the population there in a continual state of poverty. He says that the death of one baby is almost invariably followed by the birth of another in a few months thereafter. This continuous succession of births and deaths tends to lay on the population there a heavy burden and greatly interferes with its industrial efficiency. This same truth is very well illustrated in other parts of the world and has, in fact, become a generally accepted truth in the science of biology. Such being the case, it is not difficult for any one to realize that the importance of supplying pure milk to the children of the city and thus reducing the death rate in this class, thereby preventing in some measure the evils that are so intimately connected with the poverty of great centers of population.

What is true of milk is also true of coal. It is now known that coal is an article that the modern world must have. Every one became convinced of this fact during the coal strike of 1902. Modern life is so tied up with the coal industry that in many quarters a strong demand arose for the public ownership and operation of the coal mines. While this may not be needed, it is safe to say that such an arrangement as has been shown to exist in the city of Chicago in regard to the delivery of coal to the consumers there is a problem that calls for governmental solution. There is no doctrine but the doctrine of robbery that will advocate the standing idly by and allowing the population to be plundered so unscrupulously. In such a case no one will hesitate to call in the aid of the government. No one will halt at government operation. It may be that desirable results can be attained by the interference of the government in some other way than by direct ownership and operation. Perhaps some sort of supervisory control may achieve the desired result, but in this country the results of attempts at such supervisory control have been anything but gratifying. The ordinary citizen is beginning to look more and more to the government to help him out of these most serious difficulties.

THE STEREOSCOPE AS A METHOD OF WORKING OUT THE PRINCIPLES OF VISUAL INTERPRETATION

By Joseph Hershey Bair

How we see is a subject, it seems to me, for various reasons, that ought to evoke a greater popular interest. It is a problem that has elicited the attention of the philosophers from the Greeks down. Before any definite method was evolved by which visual facts could be observed and formulated, and a consistent theory advanced, much speculation regarding the factors involved in visual interpretation took place. In the light of modern scientific knowledge many of the points of view found in the history of philosophy on this subject seem ridiculous.

One of the first writers on the right track toward positive knowledge regarding vision was Descartes.[1] According to him both the accommodation of the refractive media of the eye and the convergence of the optic axes contribute to perception of depth. Berkeley[2] was the first to attempt to show how we perceive distance by sight. He pointed out that we all know that when we look at an object, whether it approaches or recedes from us, we alter the disposition of our eyes by lessening or widening the distance between the pupils. This alteration of the eyes is attended by sensations to which experience fixes a value for distance. The mind finds constantly certain relations between strain sensations, or confusion of the image, and the distance of the object; and there arise in the mind connections between the various degrees of confusion, or strain, and the distances which become habitual.

In the development of definite knowledge of visual factors the stereoscope has played an important part. This instrument (see Figs. 5 and 9) was first described in 1834 by Professor Elliott of Edinburgh University, but was not made by him until 1839. In the meantime, 1838,

[1] Cartesius, *Dioptrice*, VI.

[2] Berkeley, *An Essay towards a New Theory of Vision* (1709).

Wheatstone[1] constructed the first stereoscope which superposes two similar images by means of mirrors (see Fig. 5), and produces the illusion of depth. This reflecting form of stereoscope is known as "Wheatstone's Stereoscope." In 1849 Sir David Brewster invented the refracting stereoscope (Fig. 9).

The first real experimenter along the line of visual interpretation was Hueck[2] in 1838, and by him was established the fact that convergence influences our judgment of the position and distance of the object looked at. Meyer[3] between 1848 and 1852 showed a very interesting experiment with the Wheatstone stereoscope. He found that if two figures were inserted in the slides (Fig. 5) at A and B, thus combining them for the observer into a single image, this image appeared to approach or recede in the direction of depth according as the figures in the slides were moved back and forth. By drawings indicating the paths of the reflected rays he showed that the change of apparent distance was, throughout the series, consistent with the changes of convergence of the visual axes of the eyes.

Two views arose with reference to fundamental factors of vision. These were held by the empiricists and nativists. Nearly all those who experimented with the stereoscope were of the former class, and Berkeley is one of the best representatives of this school. The great representatives of the other school were Johannes Müller,[4] Lotze,[5] and Hering.[6] Müller held that the capacity to see space was innate, but that sensations of movement by association become important secondary factors in adult perception of space. Almost everyone is familiar with the Lotzian theory of *Local Signs*. When an object comes into the field of vision, the eyes reflexly turn so as to bring its image upon the two foveæ. The movement accompanying the transference of the image from any peripheral point to the fovea differs in magnitude and direction

[1] Wheatstone, "Contributions to the Physiology of Vision," *Philosophical Transactions* (1838).

[2] A. Hueck, *Die Achsendrehung des Anges* (1838).

[3] Hermann Meyer, "Uber die Schätzung der Grösse und Entfernung." *Poggendorff's Annalen der Physik und Chemie* (1852).

[4] Müller, *Vergleichende physiologie des Gesichtsinnes* (1826).

[5] Lotze, *Medicinische Psychologie* (1852).

[6] Hering, *Die Lehre vom binocularen Sehen* (1868).

for each such point. Every retinal point furnishes in the movement which corresponds to it a cue for the location of its objective stimulus. Dove[1] made experiments with the stereoscope and found that it was possible to get stereographic effects by a flash-light (one ten-millionth of a second duration). This demonstration which was repeated by several, established for some time the nativistic doctrine and its last great exponent was Hering. According to his theory each light ray gives a light sensation, whose character is determined by the objective stimulus; and a space feeling conditioned by the retinal point stimulated. He does not use eye-movements in spacial vision. Each retinal point has its own space value which is a function of the distance and direction of that point from the fovea.

From Wundt[2] down every psychologist has dealt with the principles of vision. And several have gone into very great detail.[3] The most readable and interesting book on the subject is by Le Conte.[4] Wundt made an interesting experiment in monocular and binocular vision and his conclusions have gone far toward establishing the present point of view. His purpose was to ascertain the influence of accommodation and convergence on the perception of depth. His instrument consisted of a long black box with observation tubes at one end and a white background at the other. Two parallel slits were placed one inch apart in the top of the box continuing from one of its ends to the other. From these slits two small weights were suspended by black silk threads reaching almost to the bottom of the box. These threads could be moved backward and forward in the slit. It was found that by looking with the two eyes while one of the threads was moved the sensitivity was 4.5 as great as when but one eye was used. Quite a number of experiments along this same line have subsequently been made, but will not be mentioned here on account of the limited space allotted to this discussion. The above account was given to show that this was by no means a neglected field.

The purpose of this article is to show by means of a stereoscopic demonstration the factors involved in vision. These experiments out-

[1] DOVE, *Berichte der Berliner Akademie* (1841).
[2] WUNDT, *Beiträge.*
[3] HELMHOLTZ, *Physiologisehc Optik.*
[4] LE CONTE, *Sight.*

lined can very easily be made by anyone, as a stereoscope and a few mirrors are always available.

Figs. 1, 2, 3, and 4 show how a stereograph can be made.[1] If you fasten your head in a head-rest and place a lamp-shade with the narrow end toward you, as is represented in Fig. 1, there will be two cones of light entering each of the two eyes (*X* and *Z*) looking at the globe. Every point of the shade (e. g., *A*) will send a ray of light into each of the two eyes. So all the rays of light entering each eye from the large circle *AB* form cones with the apices at *Z* and *X*. The same is true of all the rays passing to the eyes from the circumference of the little end. These cones will be inside the larger cones represented by the rays from circumference *AB*. Now if a plane be passed in front of the eyes so as to intercept the cone-forming rays, those rays will form upon the plane for each eye two circles. In Fig. 3, where the two circles looked at, i. e., *AB* and *CD*, are in the same plane and concentric, the two cones for each eye are concentric and the two circles for each eye on the interposed plane are concentric. In Fig. 1, where the little end *CD* of the lamp-shade looked at, lies in a plane nearer the eyes than the big end *AB*, and in Fig. 2, where the little end *CD* lies in a plane farther away than the plane of the big end; in neither of these two cases are the two cones of rays for each eye, nor the circles formed on the interposed plane, concentric. In Fig. 1, the little circle *cd*, for the right eye, is eccentric in the direction of *a* of the circle *ab*, and in the left eye in the direction of *b* of the circle *ab*. In Fig. 2 the little circles *cd* for each eye are eccentric in just the opposite directions from those in Fig. 1, for the reason that in one of the figures the little end of the shade looked at is toward you and in the other away.

In Fig. 4, the following experiment can be performed to show how the eccentricity changes with reference to the little end *CD* of the object looked at. A ring *AB* can be taken, across which a rubber dam can be stretched and stitched along *AB*. Concentric with *AB* can be sewed on the dam a smaller ring *CD*. By placing this object in the proper position for this experiment, and letting the dam assume the form of

[1] By stereograph is meant the card, with two images upon it, which, looked at through the stereoscope gives the effect of solidity.

FIG. 1

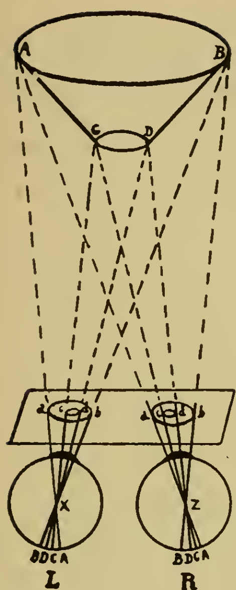


FIG. 2

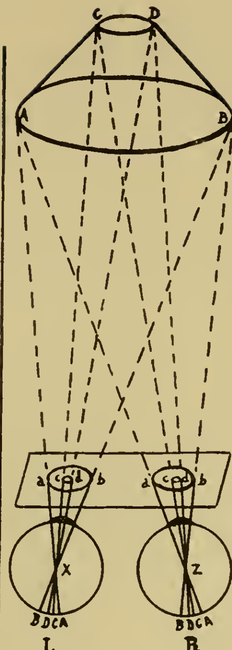


FIG. 3

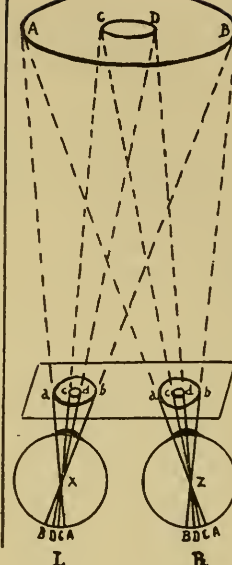


FIG. 4

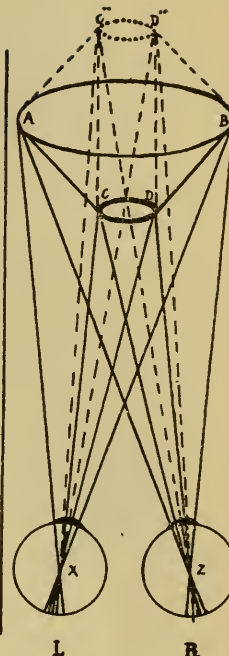


FIG. 5

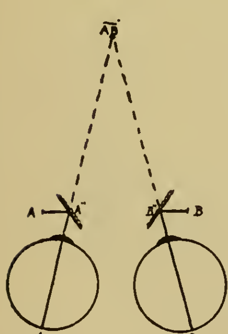


FIG. 6

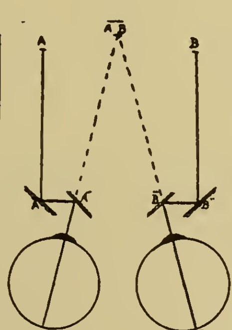


FIG. 7

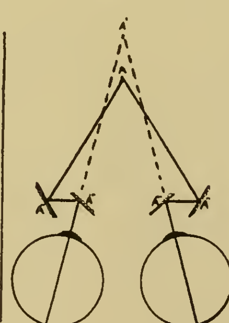


FIG. 8

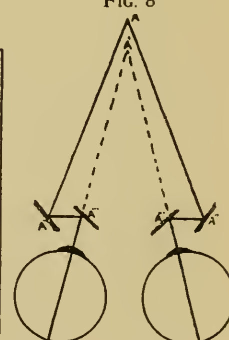


FIG. 9

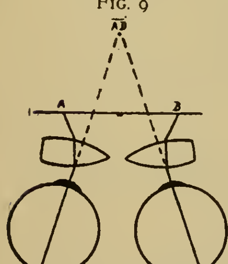


FIG. 10

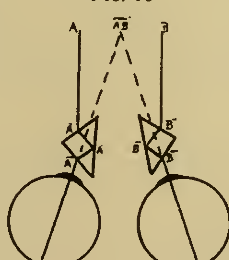


FIG. 11

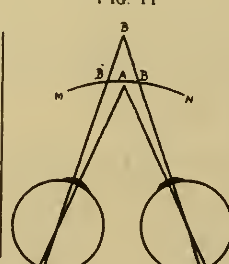
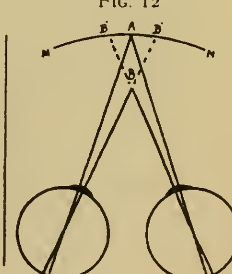


FIG. 12



its own elasticity, the two circles *AB* and *CD* will be concentric and in the same plane, and we will have the two cones of rays for each eye, and its two circles on the interposed plane, concentric, as is shown in Fig. 3. If now the circle *CD* is pulled in toward the eyes the angle *DXB* becomes smaller, and *CXA* larger, for the left eye, and *vice versa* for the right eye; and if *CD* is pulled away from the eyes to the position of *C''D''*, directly the opposite will happen. So it can easily be seen why the inside cones change their position to the right or left according as *CD* is pushed in and out in the direction of depth. The two figures or images (one for each eye) on the interposed plane of each of the above-described figures constitute what we have called above the stereograph.

This stereograph may be produced as follows: Place a piece of celluloid or glass between the eyes and lamp-shade, as in Fig. 1. Now with the head, interposed plane, and shade fixed and with the left eye closed, trace as accurately as possible the image of the right eye on the glass. Then, still in the same position, close the right eye and in a similar manner trace the image of the left eye. By still keeping the head and glass fixed and removing the shade, and by looking through the glass in such a way that the traced image of each eye falls respectively upon that eye it is impossible for you to tell that the globe has been removed, for there it is in the same position and just as distinct as when it was being drawn.

How could the eye know that it is not the globe but the intercepted images? All the factors are the same. The eyes are converged[1] exactly to the same degree. The retinal images are exactly the same size, of the same coloring, and in the same position, yet the object that excites the retina is an entirely different thing and in a different position. In fact each retina has its own image. Hence we have an illusion. Give little Johnny the stereoscope and let him look at an interesting picture—I mean scene. If you ask him to show you where a certain object in the background of the scene is he will not put his finger on the stereograph, but will stretch his arm away beyond it in the direction in which it seems to him to be.

[1] By convergence is meant the bending in of the two eyes (Fig. 5). The farther an object looked at is away the less the convergence, i. e., the more nearly parallel the eyes are.

FIG 13

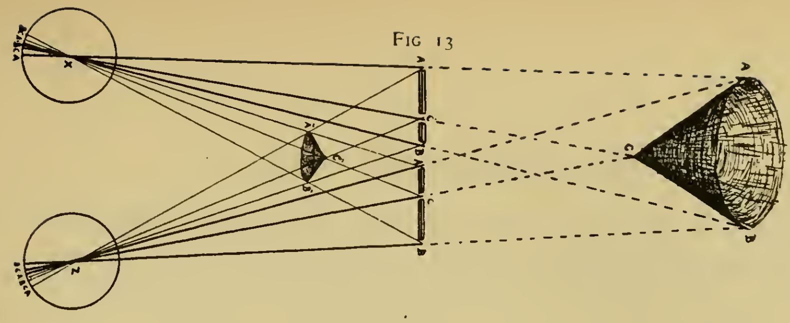


FIG 14

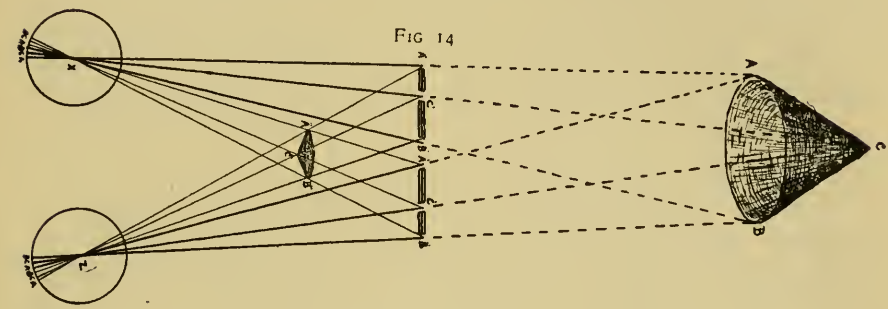


FIG 15

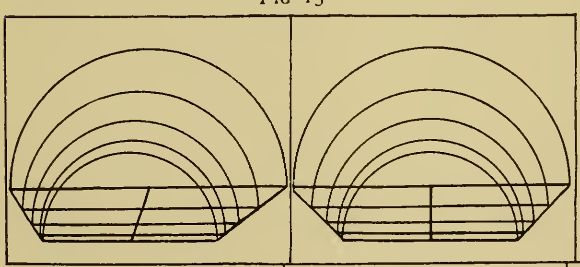


FIG 16

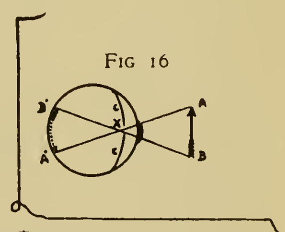


FIG. 17

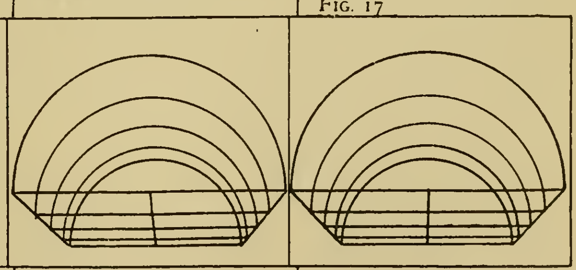


FIG 18

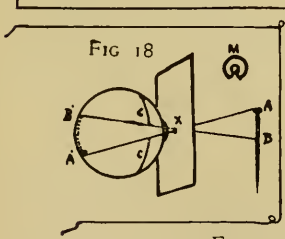


FIG. 20

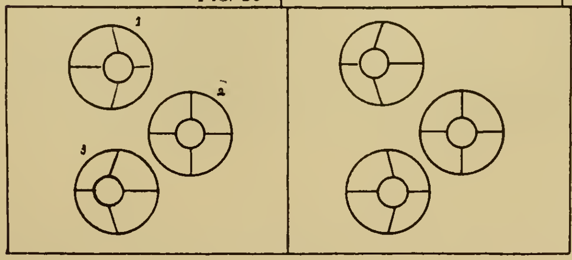
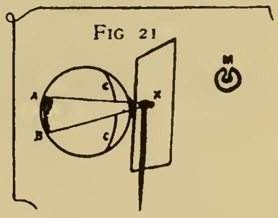


FIG 21



In Fig. 1, if we take the corresponding points *a* on the circles, left-hand *a* stimulates the left eye, and the right-hand one the right eye. The left eye refers the point of stimulus along the line *XaA*, and the right eye along the line *ZaA*. But where those two corresponding lines of reference meet there the point of stimulus seems to be. That point is *A*. (The dash lines in these figures represent lines of reference.) The supposed point of stimulus *C* lies in the two lines of reference. It is in a plane closer to the eye than *A*, or any point in the circle *AB*, consequently the eye interprets it as an extended object with three dimensional values. In Fig. 3, all the points of reference *AB–CD* are in the same plane, consequently the eye interprets the object as having only two dimensional values.

The most conclusive argument in favor of the importance of convergence is found in a study of Figs. 13 and 14. Taking first Fig. 13, where the little circles of the figures on the glass plate are eccentric toward the inside, if the image of the right-hand figure falls on the right eye and that of the left side on the left eye, what seems to be seen is the large cone *AcB*. This will seem far away. If now the eyes are squinted so that the left figure falls on the right eye and the right figure on the left eye, what will be seen is $A''C''B''$, which seems small and close at hand. The apex will also be turned away, whereas in the first case (when it seemed far away) the apex was toward you. How can all this be explained? The size of the retinal images in both cases is the same. The squinting has reversed the figures and this accounts for the change of direction of the apex. In the case of squinting the convergence is very much greater, and consequently the points of reference are brought closer. Fig. 14 is just the opposite from 13, i. e., the images on the glass serving as a stereograph are reversed, and the results can be understood by consulting the diagrams.

The question might be asked: How is it that I can compare the statures of people at a distance with those immediately before me? The retinal image of those close by may be many times as large as of those farther off, and yet I can make as accurate comparisons between close and far-off people as between those of equal distances. If you were to represent by diagram the ocular relations for the two situations, it could be seen, that while, for the far situation, both the retinal image and amount of convergence are small, for the nearer object both would be much greater. So by a process of correlation which becomes established in experience we seldom go wrong in our judgment.

In Fig. 20, by combining[1] the upper two figures the little end comes toward you. The middle one (*2*) remains flat, and the lower one (*3*) projects away from you. Now squint. This can be done by holding up the finger between yourself and the card. Look at the finger and let the lines of sight cross at it. Now *1* will be away from you and *3* toward you, and all three figures will be small because of the increased convergence.

If you superpose the two images in Fig. 15, you will get a beautiful third dimensional effect of bridgework. Fig. 17 is the two images of 15 reversed. So here the squinting is done for you. Now by superposing the two images, you get an extended effect of iron framework, but with the little end toward you; whereas, in 15 all the bends are of the same size, and the sides parallel. Now squint for each of these two figures. The figure which you get from 15 when squinting is the same in design as 17 when not squinting; and 17 when squinting is the same in design as 15 when not squinting. But in each case when squinting the figure is smaller than when not squinting, and this is accounted for as above by increased convergence.

Figs. 5 to 8 represent stereoscopes constructed on the reflecting principle. In Fig. 5, A'' and B'' represent mirrors with the reflecting faces turned toward the eyes at an angle of about 45°. (The faces of all these mirrors are represented by a straight black line and the backs by a lighter corrugated edge.) A and B represent the objects looked at. A represents the right half of the stereograph and B the left. These are superposed by means of the two inclined mirrors. Notice here that A and B are the objects from which the stimulus comes to the eyes; but the point from which it comes to each eye is on the mirrors at A'' and B''. The eyes do not interpret them as coming from these sources, but refer them on along the lines $A''A'$ and $B''B'$, and where those two lines meet there the images are superposed and give third

[1] This can be done with very little practice. Hold up the card and place a finger beyond. Look at the finger. Now move the card back and forth until the images come together and fuse.

dimensional effects, and at about the point of intersection the object seems to be. Suppose A and B were made to recede laterally along the line of incidence, the third dimensional image would nevertheless maintain its position at AB, but would become smaller and smaller. The image would maintain its position because the convergence would remain the same, but the decrease in apparent size would be due to the decrease of size of retinal images. In Fig. 6, where there is another set of mirrors by distancing A and B along the respective incidence lines the position of the referred third dimensional image at AB again does not change, but its size changes with the recession of A and B. Figs. 7 and 8 show two arrangements with double sets of mirrors whereby actual objects in space at A can be made to appear in the position of A'. In the first case it seems more remote than it really is and in the second nearer. Here again the distance is inferred from the amount of convergence, and as in all the other cases, there is an illusion. In Figs. 5 and 6, if A and B could be made to compensate, when receding, by increasing in size so that the size of the retinal image remained unchanged, the eye would not be conscious of any movement or change whatever. In Figs. 7 and 8 this would not be so. If A, the real object, should be made to approach or recede from the observer, and mirrors A'' should be kept turning on their pivots so that the angles on mirrors A''' would be kept constant, no movement of the object could be detected, but it would be observed as changing its form—longer or shorter or inverted. The reasons for this can be seen by manipulating the figures, and verifying by experiment.

So far we have not made any experiments with the refractive stereoscope of Brewster which usually has two double convex (six-inch) lenses. The lenses add nothing essential to the effects, only they serve to concentrate the rays, and consequently there is an advantage, as larger pictures can be used. Fig. 9 shows the function of convex lenses. A and B are corresponding points on the two pictures of the stereograph. Without their aid these points would probably be farther apart than the interocular distance. The lines of reference of the two eyes would never meet, and there could be no superposition of the two images and therefore no third-dimensional effects.

Stereoscopic views are made not entirely by the method above described, but by photography. The stereographic camera has two plates and two bull's eyes the interocular distance apart. Both plates are exposed simultaneously. The picture taken by the right camera is mounted on the right side of the stereographic card, and that by the left on the left side. In this way we get all the advantage of details, which by drawing would be impossible. We see as when looking at the scene directly. There is an appearance of reality which cheats the senses with its seeming truth. Through the stereoscope we do not get a miniature image of the object observed, as is often supposed. The six-inch lens of the stereoscope compensates entirely for the six-inch lens of the camera by which the picture was made. The following experiment was made by the author to ascertain this fact: A picture was made of a scene (Madison Square Garden, New York) with the regular stereographic camera. The left picture of the scene was mounted and placed in the left side of the stereoscope. The lens on the right side of the stereoscope was removed so that the right eye was free to view the scene.[1] When the observer stood in the exact position where the picture was taken and looked at the scene (i. e., looking through the stereoscope with the left eye stimulated with the left stereograph, and the right eye free) the two images exactly superposed and the results were the same as when the two eyes were free.

To show the disparity of the images seen by the two retinæ, I give below the stereograph of the girl stretching forward her hands. Notice the position and size of the hands when just looking at the picture as a photograph. The right hand of the left figure is almost in front of the face, whereas in the other figure it is quite to the side. Where is it when the two figures are superimposed? Notice how much smaller the hands seem when there is stereoscopic effect. By this time the cause of all this will be understood.

The second picture is one of President Roosevelt standing on a high point. It seems almost level behind him toward the falls, but superpose the two images! You can now see thousands of feet down into the rugged gorge of the Yosemite. It is indeed wonderful, and one is almost as

[1] That is, the real scene.

much fascinated by the scene as if he were standing on the spot with Roosevelt and actually beholding the view.

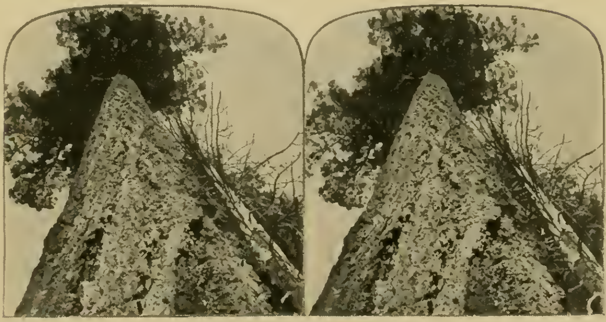
The third picture represents a photograph taken up a tree. This picture, as a photograph, looks like a wigwam, and by many is not recognized at all; but just as soon as the stereograph is held up and the head thrown back as if actually looking up the tree, when the two pictures of the stereograph are superimposed, the effect is exactly the same as if actually standing at the foot of the tree and tooking up into its top. In merely looking at this view, without looking up, you will not get the same interpretation. Throwing back the head is absolutely necessary. Unless you do, all the factors are not present that would be present were you actually beholding the scene.[1]

I hope I have made clear the fact of the valuable aid which the stereoscope lends in working out the factors of vision. Before I close I shall outline just a few more experiments to show that in every case we perceive in terms of normal vision. Fig. 16 shows that in normal vision the rays of light entering the eye cross in the pupil. The pupil *X* is a pinhole in the iris *cc*. When there is strong light the iris contracts and narrows this opening, whereas when it is weak it relaxes and enlarges the pupil. The figure shows that as a consequence of the crossed rays the image is always (in normal vision) inverted. In Fig. 18 we form an artificial pupil at *X*. This is done by looking at a pin through a pinhole in a piece of cardboard held up close before the eye. The pin is not inverted but will appear to be in the hole as in *M*, accompanying this figure. When now the pin is held between the eye and the pinhole, Fig. 21, the image of the pin-head will not be inverted, consequently the eye will interpret as in normal vision and see it as upside down in the pinhole, as in *M* of this figure. In both these last cases there is an illusion due to the fact that interpretation in terms of the factors of normal vision in these selected cases is not valid.

Stratton tried an experiment of tying lenses over the eyes in such a way as to bring the image of the object looked at upright instead of inverted, and for a number of days everything was topsy-turvy. But gradually he became adjusted, and had he continued wearing the lenses,

[1] These last three stereographs are published by permission of Underwood and Underwood, New York.

Plate I



finally everything would have seemed as in normal vision. That is, instead of being inverted would seem in its normal position.

In Fig. 11 is illustrated why, when we hold up two fingers in line before us and look at the nearer one, the farther one seems double. The farther one *B* is seen in the same transverse plane (horopter), and seems at *B′* and *B′*. Fig. 12 shows the nearer finger double when the farther one *A* is looked at. The horopter has shifted its position, and each eye projects its source of stimulus forward upon it. To get the tri-dimensional effects in looking at an object, or objects which do not lie in the same transverse plane the eye makes rapid excursions over the different parts, and as a result of the shifting varies the amount of convergence and gets the full feeling of the relative depth positions of the different parts.

That the convergence and accommodation strains are the cues we have in judging size and distance of objects can be verified by such arrangements as Figs. 5 to 8, where one factor can be kept constant while the other varies and its influence is noted. The size of the retinal image can be kept the same while convergence shifts, or convergence can be kept the same while the size of the retinal image shifts.

All these experiments show that the cues by which we judge position, size, and depth are seized upon by experience, and in cases where we are deceived these cues are not valid, as in the stereoscope, and the result is an illusion.

TABLES FOR THE IDENTIFICATION OF ROCKY MOUNTAIN COCCIDÆ (SCALE INSECTS and MEALY-BUGS)

BY T. D. A. COCKERELL

SUBFAMILIES

Males with compound eyes 1
Males with simple eyes 3
1. Anal ring of female with hairs . . . . ORTHEZIINÆ
   Anal ring of female hairless 2
2. Mouth-parts present in adult female; legs present in all stages MONOPHLEBINÆ
   Mouth-parts absent in adult female; legs absent in intermediate stage of female . . . . MARGARODINÆ
3. Abdomen of female terminating in a compound segment or plate; anal orifice hairless; adult without legs; scale composed partly of the exuviæ . DIASPINÆ
   Abdomen of female not so terminating 4
4. Insects enclosed in a resinous cell with three orifices; adult female apodous, with the terminal segments produced into a tail-like organ, bearing at the extremity the anal orifice; a prominent spine-like organ usually present above the base of the caudal extension . . . . TACHARDIINÆ
   Not so 5
5. Females with the posterior extremity cleft; anal orifice closed above by a pair of triangular plates (these united in *Aclerda*) . . . . . COCCINÆ
   Not so; triangular anal plates absent . . . . . DACTYLOPIINÆ

ORTHEZIINÆ

Female antennæ 8(rarely 7)-jointed . . . . . *Orthezia*, BOSC.

ORTHEZIA, BOSC. (Females)

Secretion dense, not easily removed; a series of three imbricated lamellæ in the middle line of the back; species of the higher mountains, in the Canadian zone (Colorado and New Mexico) . (subg. *Arctorthezia*, CKLL.) *occidentalis*, DOUGLAS.
Secretion less dense, much more easily removed; no imbricated mid-dorsal lamellæ (subg. *Orthezia*, *s. str.*) 1
1. Species found in nests of ants of the genus *Lasius;* color of body orange; antennæ (so far as observed) only 7-jointed (Las Vegas and Gallinas Cañon, N. M.) . . . . *lasiorum*, CKLL.
   Species not, or not normally, occurring in nests of ants; antennæ always 8-jointed 2

2. Body pale pea-green; middle of back with a double crest of long erect white lamellæ; tibia very long (Organ Mts., N. M., on *Garrya*) . . *garryæ*, CKLL.
   Body not so colored 3
3. Back covered by white secretion 4
   Back not wholly covered by white secretion; more or less (often much) of the skin visible 5
4. Legs and antennæ sepia brown, of nearly the same shade throughout; secretion more compact than usual; eighth antennal joint the longest (Organ Mts., N. M., on *Cheilanthes fendleri*) . . . . . *cheilanthi*, TINSLEY.
   Legs and antennæ dark red-brown; third antennal joint the longest (Embudo, N. M., on *Artemisia*) . . . . *artemisiæ*, CKLL.
   Legs and antennæ dark brown, the femora and tarsi normally much darker than the tibiæ (New Mexico and Colorado, usually on *Atriplex*) . . *annæ*, CKLL.
5. Ovisac very long, when well developed 10 mm.; third antennal joint longest, or third and eighth equal (Mesilla Valley, N. M., on grass) . *graminis*, TINSLEY.
   Ovisac much shorter 6
6. Dorsal surface naked, except for a very little mealy powder, and two median rows of small white waxy tufts (Organ Mts., N. M., at roots of grass) *monticola*, CKLL.
   Dorsal secretion not arranged so as to form two separate lines of tufts (New Mexico, on *Gutierrezia*) . . . . *nigrocincta*, CKLL.

MONOPHLEBINÆ

With a long posterior ovisac . . . . . . *Icerya*, SIGNORET
Without any ovisac . . . . *Palæococcus*, CKLL.

ICERYA, SIGNORET.

Southern New Mexico, on *Larrea* and *Prosopis* . . . . *rileyi*, CKLL.

PALÆOCOCCUS, CKLL.

Fossil at Florissant . . . . *simplex* (SCUDDER)
Living species of New Mexico 1
1. Female about 5 mm. long, 4 broad, 3½ high (on *Gutierrezia*, *Hymenoxys*, *Grindelia* and *Bahia*, in the Upper Sonoran zone) . . *townsendi* (CKLL.)
   Female about 6½ mm. long, 5½ broad, 5 high; back with very distinct yellowish-white protuberances (on *Pluchea borealis*, in the Middle Sonoran zone) . . . . *plucheæ* (CKLL.)

MARGARODINÆ

Subterranean; anterior legs of both sexes adapted for digging *Margarodes*, GUILDING

MARGARODES, GUILDING.

Species of the Mesilla Valley, N. M. . . . . . . *hiemalis*, CKLL.

TACHARDIINÆ

Anal ring with numerous bristles . . . . *Tachardia*, BLANCHARD

TACHARDIA, BLANCHARD.

Species on *Parthenium incanum* in Southern New Mexico . . *cornuta*, CKLL.
Species on *Gutierrezia glomerella* in the Mesilla Valley, N. M . *glomerella*, CKLL.[1]

DACTYLOPIINÆ

Tribes.

Female enclosed in a complete sac of waxy or horny texture; skin usually with figure-of-8 glands; legs absent in adult; larva not fringed with spines *Asterolecaniini*
Female globular or reniform, with a hard shell; larva fringed with spines; occurring only on oaks . . . . *Kermesini*
Female not enclosed in a hard shell, or waxy[2] or horny sac, but often in a sac of cottony texture; very rarely in a gall 1
1. Newly hatched larva with rows of dorsal spines . . . . *Eriococcini*
Newly hatched larva without rows of dorsal spines . . . *Pseudococcini*

Asterolecaniini

Antennæ well-developed in adult female . *Lecaniodiaspis*, TARGIONI-TOZZETTI
Antennæ rudimentary or absent in adult female; covering horny in texture; end of abdomen not or hardly chitinous; scale with a caudal process ending with an orifice . . . . *Solenophora*, MASKELL

LECANIODIASPIS, TARGIONI-TOZZETTI

Outline oval; antennæ 8-jointed (on various dicotyledonous shrubs, Colorado and New Mexico) . . . . *rufescens* (CKLL.)
Outline rounder; antennæ 7-jointed (on *Yucca* and *Dasylirion;* New Mexico) . . . . *yuccæ* (TOWNSEND)

SOLENOPHORA, MASKELL

Species having the aspect of a *Lecaniodiaspis;* on *Artemisia* in Northern New Mexico . . . . *artemisiæ* (CKLL.)
A typical *Solenophora;* on *Atriplex canescens* in Colorado . *coloradensis*, CKLL.

Kermesini

Larva of the Eriococcine type . . . . . . *Kermes*, BOITARD

[1] A new species, without the projections of *T. cornuta*, discovered October 6, 1904, by DR. DAVID GRIFFITHS. The detailed description has been sent for publication to *Entomological News.*

[2] An exception is *Eriococcus neglectus*, with a waxy sac, but the insect has all the structure of an *Eriococcus*, and is very different from the *Asterolecaniini.*

KERMES, BOITARD

Large (about 8 mm. long, 7½ broad, 7 high), the dorsum with rounded tuberosities; larva very elongate (Colorado and Northern New Mexico) . . *Gillettei*, CKLL.
Smaller, the dorsum smooth (Colorado and New Mexico) . *arizonensis*, KING.

NOTE.—The species here referred to *arizonensis* has generally been referred to *K. galliformis*, Riley. The insect is a variable one, and it is not yet certain how many species should be recognized in this group, or whether all the Rocky Mountain forms are reall *arizonensis*.

Eriococcini

Living in a gall on oak leaves in Southern New Mexico . . . *Olliffiella*, CKLL.
Not living in a gall 1
1. Anal ring without hairs; living on Cactaceæ . . . *Dactylopius*, COSTA
Anal ring with hairs 2
2. Anal ring with 8 hairs; caudal lobes long . . *Eriococcus*, TARGIONI-TOZZETTI
Anal ring with 6 hairs; caudal lobes rudimentary or absent *Gymnococcus*, DOUGLAS

OLLIFFIELLA, CKLL.

Antennæ of adult female 6-jointed; skin with figure-of-8 glands . *cristicola*, CKLL.

DACTYLOPIUS, COSTA

With much white secretion; insects producing a carmine stain when crushed. (Colo., N. M.) . . . . *confusus*, CKLL.

NOTE.—*D. confusus* occurs on *Opuntia* at Boulder, Colo.

ERIOCOCCUS, TARGIONI-TOZZEETI

Sac covering female waxy; antennæ 6-jointed (on *Atriplex canescens*, New Mexico) . . . . *neglectus*, CKLL.
Sac oval, about 4 mm. long, white, covered with particles of sand; female antennæ 7-jointed; tibia and tarsus almost exactly the same length (on *Psoralea micrantha*, Embudo, N. M.) . . . . *arenosus*, CKLL.
Sac normal,[1] closely felted; tarsus longer than tibia (they may be subequal in *tinsleyi*) 1
1. On *Juniperus virginiana* at Salida, Colorado; female antennæ 7-jointed; sac 2–3 mm. long; caudal lobes not distinctly prolonged . . . *gillettei*, TINSLEY
On *Salix* at Beulah, New Mexico; antennæ 7-jointed, varying to 8; sac 2½ mm. long; caudal lobes distinctly prolonged . . . . *borealis*, CKLL.
On *Atriplex canescens* in New Mexico, and a variety on *Malvastrum coccineum* at Denver, Colo. (Bethel); antennæ 7-jointed, varying to 6; sac 4 mm. long . . . . *tinsleyi*, CKLL.
On roots of *Gutierrezia* in northern New Mexico; antennæ 6-jointed *cryptus* (CKLL.)

[1] Unknown in *E. larreæ*; it is possible that this species does not form a sac, in which case it goes in the genus *Rhizococcus*; it is so closely allied to *E. tinsleyi* in structure, however, that this seems unlikely.

On *Larrea* in the Mesilla Valley, N. M.; antennæ 7-jointed; much less spiny than *tinsleyi*, and with smaller spines . . . . . *larreæ*, PARROTT AND CKLL.

NOTES.—Prof. Tinsley has described the male of *E. tinsleyi* in *Canadian Entomologist*, Dec., 1898, p. 317.

E. kemptoni, Parrott, found on *Andropogon* in Kansas, may be expected in the plains region of Colorado.

E. toumeyi (Ckll.), described as a variety of *E. quercus*, is a form with a very long tibia, found on *Prosopis velutina* in Arizona.

GYMNOCOCCUS, DOUGLAS

More or less pyriform, 6 mm. long and about 4 broad, soft, slightly pruinose, dull terra-cotta red; antennæ 7-jointed (on grass, New Mexico) . . . . *ruber*, PARROTT AND CKLL.

NOTE.—Another species, *G. nativus*, Parrott, occurs on grass in Kansas. It is of the color of *ruber*, but the adult female is only half the size.

Pseudococcini

Adult female without legs . . . . *Antonina*, SIGNORET
Adult female with well-developed legs 1
1. Antennæ 9(rarely 8)-jointed in adult female; claw with a denticle on inner side 2
Antennæ 8(sometimes 7)-jointed; claw simple 3
Antennæ not more than 7-jointed; usually in ants' nests 4
2. Female of the normal "mealy-bug" type, or rarely hemispherical *Phenacoccus*, CKLL.
Female large, with a spiny skin, and usually with *Orthezia*-like waxy lamellæ . . . . *Ceroputo*, SULC.
3. Body oval, usually with cottony tassels . . . . *Pseudococcus*, WESTW.
Body subglobular, enclosed in a cottony sac . . . . . *Erium*, CRAWFORD
4. Antennæ normally placed . . . . *Ripersia*, SIGNORET
Antennæ close together at the extreme anterior part of the head *Ripersiella*, TINSLEY

ANTONINA, SIGNORET

Female in a globular sac, 3 mm. diameter (on grass, northern New Mexico) . . . . *parrotti*, CKLL.

NOTE.—On *Bouteloua* in Kansas, are found two other species; *A. boutelouæ*, Parrott (distinguished by having the anal orifice deeply invaginated, protected on ventral surface by a chitinous plate), and *A. nortoni*, Parrott and Ckll. (having the antennæ with not more than three joints, while those of *parrotti* have four or five). *A. parrotti* occurs on *Eragrostis*, *Bulbilis*, and *Paspalum*.

PHENACOCCUS, CKLL.

On *Cevallia sinuata* in New Mexico; female 4 to 5 mm. long, pale olive green, covered with white secretion, with lateral tassels and two thick caudal ones; second joint of antennæ much the longest . . . . *cevalliæ*, CKLL.
On *Amelanchier* in Colorado; second and third antennal joints equal or subequal in length . . . . *cockerelli*, KING

On *Helianthus*, *Pluchea*, and *Phacelia*, Mesilla Valley, New Mexico; caudal and lateral filaments prominent; a posterior cottony ovisac, about 5 mm. long; second antennal joint longer than third . . . . . . *helianthi* (CKLL.)

In nests of the ant *Solenopsis geminata*, about the roots of *Boerhaavia* and *Kallstrœmia*, also on roots of *Atriplex canescens*, in the Mesilla Valley, N. M.; close to *P. helianthi*, but caudal and lateral filaments not prominent, antennæ a little different, and ovisac much less compact . . . . *solenopsis*, TINSLEY

On *Picea pungens* in Colorado; extremely small, adult female about 1 mm. long; ovisac without definite shape . . . . *minimus*, TINSLEY

With the ant *Lasius niger* at 8,000 ft. in New Mexico; small, female about 2 mm. long, pale salmon-pink, with short marginal cottony tassels *ripersioides*, W. & T. CKLL.

On roots of *Rubus strigosus* at 8,000 ft. in New Mexico; hemispherical, with the form of a half-pea, pale pinkish, with no cottony tassels . . *rubivorus*, CKLL.

On violets in the mountains of New Mexico; about 2½ mm. long, brownish olivaceous, without lateral tassels; remarkable for the very thick hind tibæ; second antennal joint longer than third . . . . *wilmattæ*, CKLL

CEROPUTO, SULC.

Female about 3 mm. long, at least 4 with the secretion; wholly covered by a dense chalk-white secretion, which gives it the appearance of an *Orthezia;* male grey, wings dusky, somewhat iridescent, abdomen with two long white filaments (New Mexico, at 8,000 ft., on grasses, *Koeleria* and *Phleum*) . . *calcitectus* (CKLL.)

Female about 4 mm. long, almost white, with a faint greenish tinge, covered with wool-like white secretion; posterior lamellæ not at all prolonged (in *calcitectus* they form two tails); claw with denticle on inner side (in nests of *Lasius interjectus* under rocks, Las Vegas, N. M.; also found at Boulder, Colo.) . . . . *lasiorum*, CKLL

PSEUDOCOCCUS, WESTWOOD (*Trechocorys*, Curtis)

Introduced species, found only on indoor plants 1

Native species, found on native plants (rarely on plants cultivated in the field) . . 2

1. Wth short cottony tassels all round the body; caudal tassels not long (on various plants) . . . . *citri*, (RISSO.)

   With slender cottony filaments all round the body; caudal filaments long (on various plants, especially ferns) . . . *longispinus*, (TARGIONI-TOZZETTI)

   Small, with dense secretion, forming four dorsal rows of protuberances, and a marginal fringe; antennæ 7-jointed (*citri* and *longispinus* have 8-jointed antennæ and have not the dorsal protuberances); male, yellow (on indoor palms at Las Vegas, N. M.) . . . . *pseudonipæ*, (CKLL.)

2. On *Dasylirion wheeleri* in southern New Mexico, living at the bases of the leaves; about 4 mm. long, dark olivaceous, covered with white meal; no lateral tufts, but sides very mealy; thick caudal tufts, not very long; antennæ 8-jointed . . . . *dasylirii* (CKLL.)

   On *Gutierrezia* in New Mexico; small, slate-color, forming a long, firm, snow-white ovisac, 4 to 6 mm. long and about 1 broad, on the leaves of the plant; antennæ 8-jointed . . . . *gutierreziæ* (CKLL.)

On roots of grass and *Gutierrezia* in New Mexico; 2 to 3 mm. long, pale brown varying to yellowish, pale grey and pale pink; no lateral or caudal filaments; ovisac compact, elliptical, much like that of an *Eriococcus;* antennæ 8-jointed . . . . *neomexicanus* (TINSLEY)

On grass in an alkaline spot at Roswell, N. M., covered with mealy white secretion, and with short thick cottony caudal tassels, and lateral tassels posteriorly; sac thin but dense, covering all but hind end; eggs red *neomexicanus alkalinus*, CKLL.

In nests of *Lasius americanus*, Las Vegas, N. M.; 1⅗mm. long; pink, varying to pale sage green; mealy; no lateral or caudal tufts; no well-defined ovisac . . . . *neomexicanus indecisus* (CKLL.)

On mesquite (*Prosopis*) in the Mesilla Valley, N. M. . . *prosopidis* (CKLL.)

On roots of grass, Romeroville, N. M.; pink, with a slight lateral fringe, and well-developed short caudal tassels, no ovisac observed; antennæ 8-jointed . . . . *roseotinctus*, (T. & W. CKLL.)

On potato and *Solanum rostratum*, underground, Colorado and New Mexico; antennæ 8-jointed, joint 2 much longer than 3 . . . . *solani* (CKLL.)

On *Atriplex canescens* in the Mesilla Valley, N. M., infesting the twigs; joint 2 of antennæ shorter than 3 . . . . *solani atriplicis* (CKLL.)

On *Fouquiera splendens* in the Mesilla Valley, N. M.; about 3 mm. long, covered by a white sac; antennæ 8-jointed, joints 2 and 3 equal . . . *townsendi* (CKLL.)

On *Larrea* in New Mexico; very similar to the last, but differing in details of the antennæ etc. . . . . *steelii* (CKLL. & TOWNSEND)

On sprouts of potato at Fort Collins, Colo., April 1903 (C. P. Gillette); about 2½ mm. long, hind part of body elevated by a copious but short ovisac, in which the yellow eggs are laid; color of insect varying from very pale yellow to pink; antennæ 8-jointed, joints 2 and 3 subequal; immature forms have a very distinct fringe of white filaments, as in *P. citri;* (differs from *solani* by the fringe, rather smaller size, and antennæ) . . . . . . *trifolii* (FORBES)

NOTE.—*P. hymenocleæ* (CKLL.) occurs on *Hymenoclea monogyra* in Arizona; *P. texensis* (Tinsley) occurs on *Acacia farnesiana* in Texas; *P. wheeleri* (King) occurs in nests of the ant *Camponotus maculatus* var. *sansabeanus* in Texas.

ERIUM, CRAWFORD

In a white globular sac on *Artemisia*, New Mexico and Colorado (Boulder, Colorado Springs, etc.) . . . . *lichtensioides* (CKLL.)

NOTE.—*E. irishi* (Ckll.) occurs on *Larrea* in Arizona. The limits of *Erium* are uncertain; perhaps it ought not to be separated from *Pseudococcus*. By the white sac, *P. steelii* and *townsendi* may be considered to belong to *Erium*, but they have not the globular form.

RIPERSIA, SIGNORET

On *Sporobolus depauperatus* above ground; antennæ of female 6-jointed, first three joints subequal (Las Vegas, N. M.) . . . . . *sporoboli*, CKLL.

On roots of plants, usually in nests of *Lasius* 1

1. Female with a definite sac at maturity, the sac closely felted, like that of *Erium lichtensioides*, insect very pale, with a slight pinkish tinge (Las Vegas, N. M.) . . . . *porteræ*, CKLL.
   Female with no such sac 2
2. Female with a definite fringe of lateral white tassels 3
   Female without such a fringe 4
3. Female light yellow, small; antennæ 6-jointed (northern New Mexico; Boulder, Colo., found by W. P. Cockerell, Nov. 1904) . . *fimbriatula*, CKLL. & KING
   Female salmon-pink, larger; antennæ 7-jointed(northern New Mexico and Boulder, Colo.) . . . . *salmonacea*, CKLL.
4. Female very convex, almost hemispherical, bright orange; antennæ 6-jointed (Las Vegas, N. M.) . . . . *aurantia*, CKLL.
   Female of the ordinary shape 5
5. Female pale green; antennæ 7-jointed (Las Vegas, N. M.; and recently found by W. P. Cockerell, at Boulder, Colo.) . . . . *viridula*, CKLL.
   Female pinkish, yellowish, or whitish 6
6. Female dark pink, about 2⅝ mm. long; antennæ normally 7-jointed (Trout Spring, N. M.) . . . . *magna*, T. & W. CKLL.
   Female pale pink or pale yellow 7
7. Antennæ 7-jointed (sometimes 6 in *flaveola* and *cockerellæ*) 8
   Antennæ 6-jointed 9
8. Antennal joints 1 to 6 subequal; legs very slender (Trout Spring, N. M.) *tenuipes*, CKLL.
   Joints 1 to 3 successively a little longer, or 2 and 3 equal, 4 to 6 obviously shorter than 3; legs ordinary; insect yellow (Las Vegas, N. M., with *Lasius interjectus*) . . . . *flaveola*, CKLL.
   Joint 3 conspicuously shorter than 2 or 4; legs ordinary (Beulah, N. M., 8,000 ft.) . . . . *cockerellæ*, KING
9. Longer than usual; caudal bristles very long (165 micromillimeters); bristles of anal ring long (Las Vegas, N. M.) . . . . *trichura*, CKLL.
   Shape ordinary; caudal bristles not especially long 10
10. Female with antennal joints 1 to 3 about equal; head of male seen from above widest in region of eyes, which are black and relatively large (northern New Mexico) . . . . *trivittata*, CKLL.
   Female with the third antennal joint obviously longer than second; male with head seen from above broadest behind the eyes, which are small and dark crimson (northern New Mexico, in nests of *Lasius americanus* and probably this, but young only found, at Boulder, Colo.) . . . . *confusella*, CKLL.

NOTE.—*R. arizonensis*, Ehrhorn, found in Arizona, is light purplish-brown, and makes a waxy sac.

The identity of species of *Ripersia* should be confirmed by measuring the joints of the antennæ of adult females. Of course no two antennæ will measure exactly alike, but with a reasonable allowance for variation the measurements are very helpful. The following measurements are all in micromillimeters:

Antennal Joints	1	2	3	4	5	6	7
R. sporoboli	24–30	27	24–30	18	21–27	45–51	.....
R. porteræ	35–39	39	42–45	24–27	33–36	60–66	.....
R. fimbriatula	40	40	56	20	32	76	.....
R. salmonacea	42	42	30	30	30	35	78–84
R. aurantia	33	39	48	18	30	80	.....
R. viridula	36	33	30	30	18	27	60
R. magna	39	42	27	24–30	21	27–30	63–66
R. magna (6-jointed form)	42	39	51	18	24	60	.....
R. tenuipes	30	24	24	24–25	21–23	24	60–69
R. flaveola	36–39	42	42–45	36	30–33	33–36	75–84
R. flaveola (6-jointed form)	40	40–44	44	32	28–32	72–80	.....
R. cockerellæ	30	30	18	33	21	27	63
R. trichura	39–45	33–36	30–42	25–27	30	60	.....
R. trivittata	30	30	30	18–24	24	72	.....
R. confusella	33	30	45	21	27	60	.....

The measurements of the 6-jointed *R. flaveola* were made by Mr. G. B. King.

RIPERSIELLA, TINSLEY.

Female about 3 mm. long, elongated, perfectly white; antennæ 6-jointed (Las Vegas, N. M., and recently found by W. P. Cockerell, at Boulder, Colo.) . *leucosoma*, CKLL.

COCCINÆ

Tribes

Adult female naked, legless, terminal segments pygidiform, anal operculum of a single undivided plate . . . . *Aclerdini*

Adult female with the posterior extremity cleft; anal orifice closed by a pair of plates, usually triangular in form . . . . *Coccini*

Aclerdini

ACLERDA, SIGNORET

Adult female brown, 2 to 5 mm. long; no antennæ (at the bases of grass-stems, northern New Mexico) . . . . *californica* (EHRHORN)

NOTE.—Another species, *A. obscura* (Parrott) occurs on grass in Kansas. It is distinguished from *californica* "by the absence of the row of thick blunt spines on margin and by the presence of very chitinous spine-like glands on the margin of the posterior segment." (Parrott.)

Coccini

Secretion of female like cotton or felt, forming a white ovisac . . . Series I

Secretion of female like wax or glass, covering the insect, not forming an ovisac Series II

Female naked, or covered only with a film of secretion . . . . Series III

Series I

(All ours have well-developed antennæ and legs)

Ovisac largely covering the insect . . . . . *Lichtensia*, SIGNORET
Ovisac posterior to the insect, not covering it 1
1. Body of female more or less chitinous, becoming hard, and without dorsal patches of secretion . . . . *Pulvinaria*, TARGIONI-TOZZETTI
Body of female soft, not chitinous; dorsum with patches of white secretion . . . . *Philephedra*, CKLL.

LICHTENSIA, SIGNORET

On *Lycium torreyi* in the Mesilla Valley, N. M.; antennæ 8-jointed; margin with spines . . . . *lycii*, CKLL.

PHILEPHEDRA, COCKERELL

On *Ephedra* in the Mesilla Valley, N. M.; body pink in front, greenish on dorsum, with some black specks; antennæ 8-jointed . . . . *ephedræ*, CKLL.

PULVINARIA, TARGIONI-TOZZETTI

Ovisac large, convex, adhering to whatever touches it 1
Ovisac parallel-sided, firmer, not very convex, not adhering to objects touching it, except of course to the twig or leaf on which it rests 3
1. Large; female when mounted on slide 10 mm. long and wide. (On osage-orange, Mesilla Valley, N. M.) . . . . *macluræ* (KENNICOTT)
Smaller; female on slide 5 to 8 mm. long 2
2. Antennæ 7-jointed, joint 3 always the longest, but 4 nearly as long (on *Celtis* in the Pecos Valley, N. M.) . . . . *tinsleyi*, KING
Antennæ 8-jointed (Colorado and New Mexico, on maple, boxelder, tamarisk, etc.) . . . . *innumerabilis* (RATHVON)
Antennæ 8-jointed; similar to the last, but some slight differences in antennæ; hair on first joint much longer than in *innumerabilis* (Colorado, on *Betula*) . . . . *innumerabilis betheli*, KING
3. On peach trees in New Mexico . . . . *amygdali*, CKLL.
On low-growing native Compositae 4
4. On *Chrysothamnus* in Colorado; antennæ 8-jointed . . . *bigeloviæ*, CKLL.
A closely allied form on a plant believed to be *Hymenoxys* in the Organ Mts., N. M.; female marbled with ochreous and black . *bigeloviæ marmorata* (CKLL.)

Series II

Covering of female consisting of wax . . . . . *Ceroplastes*, GRAY
Covering of female glassy, brittle . . . . . . *Ceroplastodes*, CKLL.

CEROPLASTES, GRAY

Wax white or whitish; on *Atriplex canescens* . . . . . *irregularis*, CKLL.
Wax very dark madder red or pinkish-brown, with the short dorsal line of secretion showing up conspicuously white; on the same plant, southern New Mexico . . . . *irregularis rubidus*, CKLL.

CEROPLASTODES, COCKERELL

On *Parosela formosa* in the Mesilla Valley, N. M.; a small species with many little ridges or protuberances . . . . *daleæ*, CKLL.

On *Acacia* in the Mesilla Valley, N. M . . . . *acaciæ*, CKLL.

Series III

Legs and antennæ rudimentary or absent in adult female 1

Legs and antennæ well developed in adult female 2

1. Oval or suboval, not very convex, covered with a more or less distinct glassy film; skin with large glands . . . . *Neolecanium*, PARROTT

   Very convex, subglobular, with distinct pits, and no glassy film *Toumeyella*, CKLL.

   Very convex, subreniform, brown, without pits or a glassy film . . . . *Physokermes*, TARGIONI-TOZZETTI

2. Flat or flattish, never high convex; when moderately convex, then soft . . 3

   High convex or hemispherical, hard when mature; color brown or black . . 4

3. Very flat, distinctly divided into plates, color dark . . *Eucalymnatus*, CKLL.

   More convex, oval, color lighter, pale yellowish or greyish; soft . *Coccus*, LINNÉ.

4. With an H-like mark on back consisting of ridges (absent in adult of one species); skin (seen under the microscope) with very conspicuous cell-like markings . . . . *Saissetia*, DÉPLANCHES

   With no H-like mark at any stage; skin without such markings . . . . *Eulecanium*, COCKERELL

NEOLECANIUM, PARROTT

Female about 4 mm. long, oval, moderately convex, reddish-brown, more or less covered with a thin fragile coat of glassy secretion. (Organ Mts., N. M., on *Mimosa* and allied plants) . . . . *imbricatum* (CKLL.)

TOUMEYELLA, COCKERELL

On mesquite (*Prosopis*) in southern New Mexico . . . . *mirabilis* (CKLL.)

On *Robinia neomexicana* in the Organ Mts., N. M. . . *quadrifasciata* (CKLL.)

PHYSOKERMES, TARGIONI-TOZZETTI

On *Picea* at Manitou, Colorado; 7 mm. diameter . . . . *coloradensis*, CKLL.

EUCALYMNATUS, COCKERELL

On hothouse palms only; antennæ 8-jointed . . . *perforatus* (NEWSTEAD)

COCCUS, LINNÉ

(Our species occur only on hothouse or indoor plants)

Female very small, never over 3 mm. long, light yellow, antennæ 7-jointed (on *Pilea*) . . . . *flaveolus* (CKLL.)

Female larger, 4 mm. long or more 1

1. Female elongate; antennæ 8-jointed (on *Ficus*) . . . *longulus* (DOUGLAS)

   Female oval; antennæ 7-jointed (on various plants) . . *hesperidum*, LINNÉ

SAISSETIA, DÉPLANCHES

(Our species occur only on hothouse or indoor plants)

Adult female nearly always black, marked with a raised H . . *oleæ* (BERNARD)

Adult female smaller, very convex, red-brown, without a raised H . . . . *hemisphærica*, (TARGIONI-TOZZETTI)

EULECANIUM, COCKERELL

Female 4 to 6 mm. long, 3 to 5 wide, very convex, reddish-brown to very dark brown; antennæ 7-jointed; eggs pink (on *Robinia pseudacacia*, Mesilla Valley, N. M.) . . . . *robiniæ* (TOWNSEND)

Female 3 to 5 mm. long, 3 to 4 wide, very convex, brown; antennæ 7-jointed (Colorado and New Mexico, on oak, rose, etc.) . . . . . *quercitronis* (FITCH)

Female 4 mm. or more long, about 2½ high, not so convex as the other species; antennæ 6- or 7-jointed (on fruit trees, introduced.) . . *armeniacum* (CRAW)

NOTE.—In Kansas are found *E. aurantiacum* (Hunter), on osage-orange; *E. canadense* (Ckll.) on elm, etc.; *E. cockerelli* (Hunter) on elm, oak, walnut, etc.; and *E. kansasense* (Hunter), on *Cercis*.

DIASPINÆ

Scale of female circular 1

Scale of female elongated 4

1. Male scale white, elongated, with the exuvia at one end[1] . . . *Diaspis*, COSTA
   Male scale not or not greatly elongated, similar in texture to that of the female though much smaller, usually dark-colored if the female scale is dark . . 2
2. Female with elongated chitinous processes extending inwards from the bases of the caudal lobes . . . . *Chrysomphalus*, ASHMEAD
   Female with chitinous processes or thickenings at the bases of the lobes short or absent 3
3. Circumgenital glands always absent; male scale more elongated *Targionia*, SIGNORET
   Circumgenital glands usually present; male scale oval or circular *Aspidiotus*, BOUCHÉ
4. Scale of male white, parallel-sided, like that of *Diaspis*, and usually longitudinally keeled; scale of female white, except the exuviæ . *Chionaspis*, SIGNORET
   Scale of male similar in texture and color to that of the female, not keeled; scale of female mytiliform . . . . *Lepidosaphes*, SHIMER
   Scale of female brown, not unlike that of a *Lepidosaphes;* but whereas in *Lepidosaphes* there are two exuviæ at the narrow end, there is here only one, the apparent scale consisting of the greatly enlarged second exuvia . . . . *Fiorinia*, TARGIONI-TOZZETTI

DIASPIS, COSTA

On oak trees in southern New Mexico . . . . . *montana* (CKLL.)

On *Opuntia* in New Mexico . . . . . . *echinocacti cacti* (COMSTOCK)

On greenhouse palms at Denver, Colorado . . . *boisduvalii*, SIGNORET

[1] In some forms of *Targionia* the male scale could be taken for that of *Diaspis*, but it has no trace of the longitudinal keel or keels present in the latter genus.

NOTE.—The male scale of *D. echinocacti cacti* is unicarinated; that of *boisduvalii* is tricarinated. In Texas are found *D. celtidis*, Ckll. (on *Celtis*) and *D. texensis* (Ckll.) (on *Sophora*). In Arizona are found *D. arizonica*, Ckll. (on *Prosopis*) and *D. toumeyi*, Ckll. (on *Holacantha*).

CHRYSOMPHALUS, ASHMEAD

Native species, found on oak . . . . *lilacinus* (CKLL.)
Tropical species, found only in hothouses 1
1. Scale black or almost, with a light spot marking the exuviæ . *aonidum* (LINNÉ)
Scale reddish, not dark . . . . *dictyospermi* (MORGAN)

TARGIONIA, SIGNORET

On *Yucca* and *Isocoma* in the Mesilla Valley, N. M.; scale comparatively large; caudal lobes of female truncate; caudal area with very numerous small glands . . . . *yuccarum* (CKLL)[1]
On *Yucca elata* in the Mesilla Valley, N. M.; smaller than the last; female with only one pair of well-defined lobes, these rounded at the end, and notched on each side; spines much larger than in the last . *yuccæ neomexicana* (CKLL. & PARROTT)
On *Gutierrezia glomerella* in the Mesilla Valley, N. M.; female scale $1\frac{1}{3}$ to $1\frac{1}{2}$ mm. diameter, snow white; exuviæ marginal, covered by a delicate film, often rubbed off, exposing the shining straw-yellow first skin *gutierreziæ* (CKLL. & PARROTT)
On leaves of grass at Las Vegas, N. M.; female scale about 1 mm. diameter, white, with pale yellow exuviæ, which are covered, and surmounted by a white boss; female differing from *gutierreziæ* in the rounded, wide-apart median lobes, the much larger blunt second and third lobes, and the dorsal glands, which are few and in rows, instead of being numerous and scattered . *graminella* (CKLL.)

ASPIDIOTUS, BOUCHÉ

Female with neither elongated thickenings of the body wall nor incisions with thickened edges at the bases of the caudal lobes . . . *Aspidiotus*, s. str.
Female with incisions at the bases of the lobes, flanked or margined by chitinous processes, which, however, are never greatly elongated 1
1. Scale quite convex, with the exuviæ marked by a darker spot; anal orifice large; median lobes large, the others hardly or not developed . *Hemiberlesia*, CKLL
Scale flatter, usually (but not always) dark, the exuviæ appearing as a yellowish or reddish spot; anal orifice smaller; second pair of lobes usually distinct . . . . *Diaspidiotus*, BERLESE AND LEONARDI

ASPIDIOTUS, s. str. (*Evaspidiotus*, Leonardi)

Female scale white or whitish; exuviæ exposed, yellow; female with four groups of circumgenital glands; on indoor and hothouse plants, such as oleander, ivy, etc. . . . . *hederæ* (VALLOT)

[1] Besides the *Hymenoxys*, there exists a second rubber-plant in the Rocky Mountains. We have obtained a piece without data, and the only clue to its origin is the occurrence upon it of some specimens of *Targionia yuccarum!*

Subgenus *HEMIBERLESIA*, Cockerell

Female with circumgenital glands; usually on palms . . . *lataniæ*, SIGNORET
Female without crcumgenital glands; on various plants *acuminatus*, TARGIONI-TOZZETTI.

NOTE.—These are exotic species, occurring only on indoor plants. *A. acuminatus* is more generally known as *A. rapax*, Comstock.

Subgenus *DIASPIDIOTUS*, Berlese and Leonardi

Adult female without circumgenital grouped glands 1
Adult female with such glands, at least four groups 2
1. Native species, on *Pinus* in New Mexico; median caudal lobes of female broad and low . . . . *coniferarum*, CKLL.
Introduced species, on fruit trees in the Mesilla Valley, N. M.; median lobes much longer and narrower; scale of female gray, with the exuviæ central, or nearly so, yellowish . . . . *perniciosus*, COMSTOCK.
2. Female scale comparatively large, diameter 3 mm., or nearly; exuviæ when rubbed shining orange or foxy-red 3
Female scale smaller; diameter 2 mm. or less 4
3. Female scale (except the exuviæ) white; New Mexico, usually on fruit trees . . . . *juglans-regiæ albus*, CKLL.
Female scale (except the exuviæ) brown; on plum at Las Cruces, N. M. . . . . *juglans-regiæ pruni*, CKLL.
4. Female scale dull pale orange-brown; on *Chilopsis* in the Mesilla Valley, N. M. . . . . *coloratus* (CKLL.)
Female scale pale greyish, exuviæ dull orange; female similar to *A. ancylus*, but second lobe developed; Colorado and New Mexico, on fruit trees *howardi*, CKLL.
Female scale blackish or dark grey to dull black, the exuviæ when exposed orange-red 5
5. Second lobes of female absent or rudimentary; chitinous process on inner side of first interlobular incision straight; New Mexico and Colorado, on maples and fruit trees . . . . *ancylus* (PUTNAM)
Second lobes of female small but distinct; chitinous process on inner side of first interlobular incision curved; Mesilla, N. M, on apple; Colorado City, Colo., on *Cercocarpus parvifolius* . . . . *forbesi*, JOHNSON

NOTE.—*A. candidulus*, Ckll., occurs on *Prosopis* in Arizona; *A. townsendi*, Ckll., on ash in Arizona; *A. ulmi*, Johnson, on elm in Kansas; and *A. uvæ*, Comstock, on grapevine in Kansas.

CHIONASPIS, SIGNORET

Male scale without longitudinal keels; on willow . . *ortholobis*, COMSTOCK
Male scale with one or more keels 1
1. Median lobes united to form a single lobe in adult female; on oak, Organ Mts., N. M. . . . . *quercus*, COMSTOCK
Median lobes separate in adult female; not found on oak 2
2. Female scale usually narrow; on leaves of conifers, especially *Pinus*, Colorado and New Mexico . . . . *pinifoliæ* (FITCH)

Female scale rather broad; on *Populus* and *Salix;* New Mexico; Colorado Springs, Colorado . . . . *bruneri* (CKLL.)

NOTE.—*C. bruneri* is usually called *C. salicis-nigræ* (Walsh), but Walsh's species cannot be identified from the description, and his type is lost.

C. furfura (Fitch) on fruit-trees, and *C. americana*, Johnson, on elm, occur in Kansas.

LEPIDOSAPHES, SHIMER

Female with "fusi piliformes" between and about the caudal lobes *Mytilaspis*, S. STR.
Female without such "fusi piliformes," but with prominent spines in the region of the lobes . . . . *Aonidomytilus*, LEONARDI

MYTILASPIS s. str.

No species of this group lives within our area, but *M. beckii* (Newman), with a reddish-brown scale, is sometimes found on oranges and lemons exposed for sale.

Subgenus *AONIDOMYTILUS*, Leonardi

Female scale white; on *Atriplex canescens*, Mesilla Valley, N. M., to Colorado Springs, Colo. . . . . *concolor* (CKLL.)
Scales of both sexes emerald green; female insect dark purple, with a bright yellow patch in the anal region, and suffused crimson spots at intervals round the margins of the hind end; on *Atriplex canescens*, Mesilla Park, N. M. . . . . *concolor viridissima*, CKLL. & PARROTT

FIORINIA, TARGIONI-TOZZETTI

Exotic species, found only in hothouses, usually on palms or camellias . . . . *fioriniæ* (TARGIONI-TOZZETTI)

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MODIFICATIONS OF THE JURY SYSTEM[1]

By John Burton Phillips

There has always been considerable agitation against the rule that a jury should be unanimous in the verdict it renders. Emlyn in 1730 argued for the abolition of the rule. Hallam in his *Middle Ages* wrote against it. Bentham and Francis Lieber are also on record in favor of its abolition. But a greater name than any of these in modern jurisprudence is that of Judge Cooley. In his edition of Blackstone, he says of the jury system, as far as its unit rule is concerned, that it is "repugnant to all experience of human conduct, passions, and understandings." He further says that "it could hardly, in any age, have been introduced into practice by a deliberate act of the Legislature." Justice Miller of the United States Supreme Court is also on record against the unit rule. He says, "I am of opinion that the system of trial by jury would be much more valuable, much shorn of many of its evils, and much more entitled to the confidence of the public, as well as of the legal and judicial minds of the country, if some number less than the whole should be authorized to render a verdict."

It is peculiar that the unit rule in regard to the verdict of the jury is a thing that prevails in England and America alone.

In Scotland, before 1815, a verdict could be rendered by two-thirds of the jury. The English system of unanimous verdict was introduced in 1830, but it did not give general satisfaction. In 1854 it was modified by a law which provides that a verdict by nine jurors is sufficient after six hours' deliberation.

In France the jury system was introduced in 1771, and requires only a two-thirds vote for a verdict. In Italy and Germany a majority is sufficient, and in Austria, eight of the twelve are all that are required to agree. In British India, after reasonable deliberation, if six are united in their opinion and the judge agrees with them they may render a verdict. "Reasonable" is interpreted by the judge. In the Bahama Islands, a verdict may be rendered by two-thirds of the twelve.

[1] Reprinted from the *Green Bag*, Vol. XVI, No. 8, August, 1904, by permission of the editor.

This is enough to show that the unit rule has been greatly modified by the countries of the old world. It has also been partly abandoned by the following American States:

STATES IN WHICH VERDICTS NEED NOT BE UNANIMOUS

Arizona—Three-fourths in civil and misdemeanor cases. '91, chap. 5.

California—Three-fourths in civil cases. C. C. P. '97, § 618.

Colorado—Three-fourths in civil cases. '99 chap. 111. Unconstitutional. 28 Col. 129.

Idaho—Three-fourths in civil cases. Five-sixths majority in misdemeanors. Const. art. 1, § 7. '91, p. 165.

Kentucky—Three-fourths in civil cases. Statutes '94, § 2268.

Louisiana—Three-fourths in crimes not capital. Const. § 116.

Montana—Two-thirds in crimes not felonies. P. C. § 2142. Two-thirds in civil actions. C. C. P. § 1084.

Minnesota—Legislature may provide for verdict by five-sixths of jury after six hours' deliberation. Const. art. 1, § 4.

Missouri—Three-fourths in courts of record: two-thirds in other courts. Civil cases. '99, p. 381.

Nevada—Three-fourths in civil cases. C. L. '00, § 3270.

South Dakota—Three-fourths in civil cases. Ann. S. '99, § 6268.

Utah—Three-fourths in civil cases. Const. art. 1, § 10.

Washington—Ten of twelve jurors may render verdict in civil cases. Ballinger's S. § 5011.

Wyoming—Three-fourths in civil cases. R. S. '99. § 3651.

Some of the leading arguments for this reform of the jury system are given below. The principal one is, of course, the claim that the jury as at present constituted gives one man too much power.

Everyone is familiar with instances where one man has been able to set at naught the opinions of eleven by refusing to agree with them in a jury decision. It is difficult for two men to see things alike, and it is still more difficult for twelve men to come to the same conclusion. This is well known to lawyers. They have agents whose business it is to look up jurors and learn their mental characteristics and opinions on various subjects. In this way they are able to know whether or not they want these particular jurymen to sit on their cases. They know that one strongly prejudiced juror is enough to decide the case his way or else bring about a new trial by a disageement. It has been pointed out that persons of certain nationalities are famous for seldom changing their minds. One such person on a jury is enough to make the verdict represent not so much deliberate conviction as the yielding of the others to the member of the obstinate nationality.

It is claimed that the abolition of the unit rule will tend to prevent the fixing of juries. It is rare that anyone attempts to bribe more than one juror, because under the present rule if one juror is bought that is all that is necessary. He will be able to bring about a disagreement. Under a rule that would allow two-thirds or three-fourths of the twelve to render a verdict, the person desiring to fix the jury would have to bribe at least three, a thing which is well nigh impossible. It is not likely that there is very much bribing of juries, but that is no reason why all temptations in that direction should not be reduced to the minimum.

Everyone with experience in courts of justice knows that jury verdicts are very often not the results of the unanimous opinions of the twelve men. The verdicts are very often compromises. This is especially the case in actions for damages. Each juror has a different opinion as to the amount of money that should be paid for the wrong done. They are apt in such cases to strike an average and allow the result to stand as the verdict. It is not the opinion of anybody. Compromises sometimes occur when several persons accused of crime are tried together.

There are many things which induce the jurymen to compromise. Many of the jurors are actively engaged in business, and are anxious to have the court matter settled so that they may return to their homes and affairs. They are very apt, therefore, to yield a few points in order to get their liberty again. Still further, the prospect of remaining all night in the jury room is not inviting to any man. Jurymen, like all other human beings, are fond of the comforts of home and good quarters in which to rest for the night. They like to have their meals at regular times and places. When confronted with the alternatives of sitting up all night in the jury room or yielding a little in what one believes is the right, most individuals, unless endowed with a constitution stronger than the majority of the race, and more firmly set in their principles, are apt to yield a little in what they think is the abstract justice of the case. Says Pope:

> The hungry judges soon a sentence sign,
> And wretches hang that jurymen may dine.

It has also been pointed out that the jury system with its unit rule puts a premium on obstinacy. The narrow-minded, obstinate, and prejudiced man is given an exaggerated importance as soon as he enters the jury room. He has made up his mind, perhaps, before the trial began, and his mental apparatus is of such a character that he cannot be persuaded by the arguments of the majority. He therefore feels his importance, and will have the verdict his way or the jury will have to disagree. Cases are on record where one obstinate juror caused the disagreement and afterward went bragging about his achievement.

Again the jurors are not all of the same vitality. An obstinate person with abounding health and strength will be able to wear out the other members of less physical endowment. In such cases there is a presumption that the stronger man's influence with the jury is not measured by his intellectual capacity, but by other things which are of very little value in weighing the merits and demerits of a case. The brute strength of the jurors becomes an element of great importance in their decisions. If the verdict were rendered by less than twelve, it would perhaps be rendered very soon after the jury entered the room and thus the element of brute strength would be eliminated. So also would be the now exaggerated importance of the narrow-minded and obstinate juror.

It has become a common saying that the best men of the country are not now serving on the juries. It is also a fact that there is such a person as the professional juryman. The men who are the real bulwarks of our society are too busy with their business to think of spending the time wrangling with the narrow-minded and obstinate, as is the present requirement of the jury system. We want the best men in the community in the jury box. If we must go into the courts, as many of us must sometimes do, and through no fault of our own, we want our case tried by the men who have proved by their ability in the actual business world that they have good common sense. We do not want cases of great importance intrusted to a set of men like the professional jurymen of the present time, men who have never shown that they have the ability to make a living except by conniving with court officers and getting drawn as jurors.

Such being the case, it is highly important that the ablest men in the community be made in some way to do jury duty. The exemptions from jury service at the present time are so many that almost anyone can get excused. It is indeed hard for the judge to refuse to excuse a man when he knows that the juryman cannot serve without great personal sacrifice. Even after the evidence is in and the case summed up by counsel, there is still the long wrangle in the jury room. It is possible that the abolition of the unit rule would make it likely that better men would more often consent to serve on juries than they do now. If less than twelve of the jury might render the verdict the time in the jury room would be perhaps much cut down.

No man should be excused from jury duty except for the most urgent reasons. It is a thing each citizen owes to his country to familiarize himself with the working of its administrative machinery. Nothing is so important as human rights, and no one should be excused from assisting in their establishment.

Another argument in favor of the abolition of the unit rule is that it would tend to expedite appeals to the higher courts. In this way, then, the administration of justice would not be delayed. When the jury fails to agree, the only alternative is to have another trial or drop the case. One or the other of these two things is all that is left for the parties who are trying to secure justice. It is quite common for them to resort to both alternatives. After they have exhausted their means in a new trial, they let the case drop and neither party has obtained justice.

In modern practice it is very common for all cases that are of any particular importance to be carried to a higher court than the one which has the original jurisdiction. Before the case was begun both litigants have usually made up their minds not to stop till the matter is finally determined by the court of last resort. As this is the rule of modern litigation, it is of the greatest importance that as little hinderance as possible should interfere with the progress of a cause from the lower to the higher courts. Every time a jury disagrees, it is a checking of the progress of the suit to its final adjudication. It delays the determination of justice by causing a new trial. If two-thirds or three-fourths of the jury were able to render the verdict, it is quite likely that fewer new trials would occur. There would be fewer disagreements and cases would be hastened on their way to their adjudication in the higher court.

In recent years there have been a number of suits growing out of elections or in other ways the result of actions of a political nature. They have been cases in which the actions of a political party were concerned. A verdict for the relator would in some way interfere with the party's prospects of success in the next election. Juries whose members have been of different political parties have often failed to agree when there was a chance that the verdict would result in injury to the success of the party candidate. Such was the outcome of the Laingsburgh election cases in the state of New York. The trial occupied thirty days and 750 witnesses were sworn, but the jury could not agree. They divided on party lines, nine for the defendant and three for the relator. Such has been the case with juries in other parts of the country when considering similar cases. It has become the current opinion that whenever there is a favorable opportunity, a jury will be very apt to divide on party lines. It is clear that the disagreements that are now so common in the trials of a political nature would be greatly reduced if a verdict could be rendered by less than twelve of the jurymen.

Partisans of this reform also urge that it is in no wise inconsistent with the general character of the administration of justice as now carried on. Inconsistencies in the judicial system are pointed out. If a person brings a claim against a board, it is allowed or rejected by a majority of the board. If he is dissatisfied with the award and takes the matter into the courts, there his claim will be decided upon by the unanimous verdict of twelve men. When originally presented to the board, he needed to convince only a majority of its justice; now before the court he must convince twelve men that he is in the right in his demands.

It has been said that the decision of questions of law is as important as the decision of questions of fact. In courts that have more than one judge, questions of law are always decided by a mere majority. The decision is never required to be unanimous. The same thing is true of all the leading governmental actions in countries where there is government by a body of men. The policy of the government as to peace or war is not necessarily determined by more than a mere majority. It is said that unanimity is a requisite of the jury room, but of no other place in the conduct of the government.

No one has advocated the abolition of the unit rule in the trial of criminal cases. It is unlikely that this rule will ever be dispensed with in such trials. In criminal cases the accused is entitled to the presumption that he is innocent till his guilt is proven. The law requires that before he may be declared guilty there must be in the minds of the twelve jurors no reasonable doubt of his innocence. In a civil case on the other hand, the decision is made according to the preponderance of the evidence. There may be a reasonable doubt in the minds of the jurors, but that does not preclude them from rendering their verdict in favor of the litigant on whose side the preponderance of the evidence lies. It is therefore, not so important in the civil case that there should be a unanimous verdict. It is not a matter of the guilt or innocence of anyone, but rather the determination of questions of *meum* and *tuum*. In such questions it is more important that decisions should be reached and the judicial machinery kept in operation than that abstract justice be obtained.

One of the strong arguments for the unanimity rule is that it tends to emphasize the importance of the individual juror, and in this way make him more attentive to the matter in hand than would be the case if his individuality were sunk in the verdict by a majority. This is probably quite true. If the juror knows that unless he consents to agree with the others there can be no verdict, it is very likely that he will be careful in trying to make up his mind according to the evidence and render a just verdict. The inducement for him to do this is all the greater since in case he is the only one who will not agree to the verdict the other eleven wish to render, he must take the responsibility for the entire decision. Not many men care to go before the world with this responsibility unless they are fully persuaded that they are justified in holding to their opinion. Without carefully considering the whole matter they will not feel justified in taking this responsibility. Under a rule by which the majority decides, it is clear that the individual juror would not be likely to give the case so much attention. We are all aware of the comfortable feeling that comes over us as soon as we know that some other person will vote as we do. Our minds are at once relieved from the exertion of finding more arguments in support of our position. On the contrary when standing alone in our opinion, we feel the amount of energy we must spend in finding evidence to convince others that we are in the right. This is precisely what happens in the jury room. While the trial is going on each juror feels the necessity of paying close attention lest he be the one that will have the others against him and thus be compelled to produce the reasons for his position. It seems quite clear that the unit rule in this way tends to emphasize the individual juror's responsibility.

The principal argument against the abolition of the unit rule is that it is not a matter of very much importance. This is the leading argument that was made in the New York constitutional convention of 1894, where the question was discussed somewhat, though not at very great length. It is said that not many disagreements of jurors are such that they would be prevented by the adoption of the unit rule. When a jury disagrees the vote usually stands either six to six, seven to five, eight to four, or nine to three. The cases are not many when one or two men hang the jury.

Again it has been shown that out of the whole number of jury trials the disagreements of the jury are comparatively few. Of 1,104 jury cases tried in the superior court of the City of New York, there were but 35 disagreements. The Supreme Court in the first department of the State of New York, which includes the city, tried from 1889 to 1893, 3,460 jury cases. Of these there were but 22 in which the jury disagreed. It seems as though there is a mistake in the number of disagreements, it is so small. Yet these are the figures given by the clerk of that court, and presented by Mr. Truax to the constitutional convention. From these figures it is clear that the question of the abolition of the unit rule is not as important as it might seem from reading the arguments that have been presented in its favor.

It should still further be added that these cases are not civil cases alone; the number includes the criminal cases as well. It is true that the disagreements of the jury are much more common in cases where a person is charged with crime than in civil cases where the action of the jury is not such as to deprive anyone of life or liberty. This is why jurors decide the cases submitted to them very quickly when nothing but the question of property is concerned. It is not in the cases that are concerned with the determination of line fence troubles that the jurors are kept out all night in the jury room. Only cases that are concerned with the lives and liberties of persons are sufficient to do that.

Such being the case, it is clear that the abolition of the unit rule will not tend greatly to diminish the number of disagreements in civil cases. This proves that there are other reforms in the judicial system that are more urgently demanded than the abolition of the unit jury rule in civil actions.

The best results of the jury system are sometimes lost by the death or disability of one of the jurors. The general rule in such cases is to summon a new jury and have the entire case commenced again at the beginning. This is a serious defect in the judicial system. In important cases it is frequently difficult to get a jury. In one case in the City of New York, weeks were consumed in getting a jury and when the evidence was all in and the jurors were deliberating upon their verdict one became insane. Experts on insanity were called to examine him and testify as to his competency to render a verdict. The result was the usual one when experts are employed. The experts failed to agree. In another case, a criminal case in the same city, one of the jurors became ill just as the evidence was being summed up. The result was a new trial. This cost the City of New York thousands of dollars, and occupied the attention of the court for many weeks. In another case one of the jurors died while waiting to render a verdict. The only thing that can be done in such cases is to begin at the beginning and have a new trial.

In civil cases this difficulty can be avoided if counsel are willing to go on with less than twelve jurors. In a criminal case, however, this cannot be done without express authority in the constitution. The courts have generally held that while the right to jury trial may be waived in civil cases, it cannot be waived in criminal cases, and that by jury means trial by a jury of twelve.

In the following States provision has been made so that death or disability of a juror does not interrupt the trial:

STATES IN WHICH ILLNESS OR DEATH OF JUROR NEED NOT INTERRUPT A TRIAL

Colorado—Civil cases. C. C. P. § 189.
Idaho—Civil cases. R. S. '87, § 4381.
Iowa—Civil cases by consent of parties. Code '97, § 3713.
Michigan—Civil cases if nine jurors remain. Howell's S. § 7622.
Nevada—Civil cases. C. L. '00, § 3261.
North Dakota—Civil cases. R. Codes '99, § 5439.
Oregon—Civil cases by consent of parties. Hill's S. '87, § 199.
South Dakota—Civil cases. Ann. S. '99, § 6262.
Texas—Civil cases if nine jurors remain. R. S. '95, § 3229. Same in misdemeanors in district court. White, Crim. Code, § 745.
Tennessee—Civil cases by consent of parties. Code '96, § 4688.
Utah—Civil cases. R. S. '98, § 3157.
Washington—Civil cases by consent of parties. Ballinger's S. § 5000.

In the interest of economy it has been argued that a jury may safely consist of less than twelve. In the following States provisions for such juries exist:

STATES IN WHICH JURY MAY CONSIST OF LESS THAN TWELVE IN COURTS OF RECORD

Arkansas—By consent of parties in cases less than felony. Statutes '94, § 2121.
California—By consent of parties in civil actions and misdemeanors. C. C. P.'97, § 194.
Colorado—Six to twelve in civil cases on demand and payment of fees. '91, p. 83.
Connecticut—Nine or more in civil cases by written consent of parties. G. S. '88, § 1103.
Florida—Twelve in capital cases, six in others. R. S. '92, § 2854.
Georgia—Not less than five in all except city and superior courts. Const. art. 6 § 18. Code '95, Vol. 2, § 4143.
Idaho—Less than twelve in civil cases by consent of parties. R. S. '87, § 3939.
Illinois—Twelve or six by agreement in trials of right to property in county courts. R. S. '99, p. 1274.
Indiana—Three to twelve by agreement in civil cases. Ann. S. '97, § 521.

Kentucky—Less than twelve by agreement in all cases except felony. Statutes '94, § 2252.

Louisiana—When punishment may be hard labor, jury of five; when must be hard labor, jury of twelve. Const. § 116.

Montana—Less than twelve by consent in civil cases and criminal cases not amounting to felony. Const. art. 3, § 23.

Nevada—Not less than four by consent in civil cases. C. L. § 3256.

Oregon—Less than twelve by consent in civil cases. Ann. L. '87, § 180.

Utah—Eight jurors in all but capital cases. Const. art. 1 § 10.

Washington—Not less than three by consent in civil cases. Ballinger's S. § 4978.

CERTAIN UNSCIENTIFIC ASSUMPTIONS IN MARSHALL'S THEORY OF CORRESPONDENCES

By Melanchthon F. Libby

Every friend of philosophy must regard with pride certain recent efforts to establish dynamic relations between rationalistic idealism and the scientific notation of reality which alone dominates the minds of physicists, biologists and medical men. No one will feel much inclined to put brakes on such a movement before it acquires momentum. At the same time nothing can injure this movement more than a handling of empirical contents which betrays ignorance of the contemporary state of empirical research.

Marshall[1] revives the view of Fechner, and many others, that consciousness may be held to coincide with every kind of transfer of energy, and restates this view *not*, he declares, as a play of fancy, but upon a scientific basis derived from recent biology. He states that modern biologists are teaching us that all protoplasmic matter has powers of interaction, of "conductivity," similar to those observed in nervous tissue. From this he reaches the suggestion that the "social body" is organic in its nature, and that there is a social consciousness corresponding therewith. In other words that the consciousness of a group is something other than the resultant of the individual consciousness, however related, of its members. From this we are led to further interesting surmises regarding a universal consciousness.

Now all this appeals to many of us immensely as a beautiful and imaginative view of the world. It has many supports from analogy and would offer a pleasing and symmetrical offset to certain individualistic facts. But are the facts upon which this view is revived really of a nature to advance it beyond the position where the charming Fechner left it in his *Zend-Avesta?* This is hardly an age for sophisticated Hylozoism, dear as that *-ism* may be to poetic natures. If we say

[1] *Journal of Philosophy, Psychology, and Scientific Methods*, Vol. I, No. 14, and several later numbers.

today that *conduction* is possible (in any sense which will assist Fechnerism) except through the *neurofibrillae* of Apathy, we undertake to decide a question which according to the neurological literature of the present time is perhaps being decided by experts in an opposite sense. Bethe for example (*Allgemeine Anatomie und Physiologie des Nervensystems.* Leipzig 1903), says that "Die Leitung ist nervöser Natur," (p. 108), On page 109, he says, "Nach alledem kann es keinem Zweifel unterliegen, dass bei den Medusen [which particularly favored Marshall's view] die Reizleitung nervös und nicht muskulär ist, und dass die Netze im Epithel diese reizleitende Funktion ausüben." In this work of over 450 pages, perhaps the most authoritative textbook of the *neurofibrillae* school, this view is expressed repeatedly with convincing arguments, and it seems as if we must lean to the opinions of those who declare they have the most perfect scientific grounds for asserting that there is absolutely no protoplasmic conduction, so long at least as expert histologists on all hands are finding these newest and finest conduction threads all through the protoplasm where physiologists had overlooked them. Will physiologists even make a stand against anatomists in this field?

But now where does this doctrine leave the thoroughgoing correspondences of Marshall? Is there one atom of evidence of a scientific nature that the energies of starry systems, or even of much smaller systems, have noetic patterns corresponding to them?

The admirable effort to bring philosophy into some relation to a scientific notation is only hampered by fantastic digressions of this kind. What some of us should like to hear more about than about the alleged modern biological basis for *Nanna* and *Zend-Avesta* (which, as published, were justified by their poetry and absence of over-serious style), is just how the field of inattention itself is limited, and why so much insistence is put upon the reciprocity between the field of attention and the field of inattention *within the human skin*, so to speak, while no attempt is made to show that the air we breathe, and the food we eat, and our whole environment are in "efficient relation" to the conscious experience of the field of attention.

EDUCATION AND MEDICAL ADVANCEMENT AS PRECLUDING ANY FURTHER MENTAL AND PHYSICAL EVOLUTION OF THE HUMAN RACE

By Joseph Hershey Bair

An efficient treatment of almost any aspect of modern thought or method is necessarily opened by a statement of the salient points in its development. This is especially true when the discussion implies some phase of life or mind. The evolutionary spirit is at large, and we cannot escape the air we breathe. It is the modern *Zeitgeist* that everything must be understood in the light of the setting in which it was produced historically. Explanation implies tracing a thing back through a series of causes, as far as possible, toward an ultimate source. From the standpoint of the theory of evolution, thinking, both in content and method, from the view of the empirical data and of the logical processes involved is essentially different from that of any preceding age. This statement seems a truism, and for verification, therefore needs no further argument. Civilization of mankind, like everything in the organic world, has developed in time and under set conditions, and each stage in this development determines the next. Thought is but the conscious concomitant of civilization, and in view of the subject of this theme it cannot be out of place to sketch in a few brief statements the characteristic changes it has undergone during the last two centuries. Such a sketch will itself, without an argument, betray the nature of the evolution process in thought, and thought is but one aspect of the world process.

Heir to all that had passed, the nineteenth century began with high philosophical aspirations, but under the inspiration of such men as the Bacons, Newton, and Rousseau whose watchword was, "Return to Nature; get from her first-hand knowledge!" there was a decided turn toward natural science. There came a notorious revolt against the purely subjective methods of the 16th century. The empirical interest passed to the extreme. This objective enthusiasm, however, was less deleterious to the advancement of science than was the addiction to the purely *a priori* methods from which she reacted.

So thoroughgoing and deep-rooted became this reaction against any form of deduction that by the beginning of the 20th century it was considered a presumption for anyone to attempt theorizing upon the philosophical import of the facts of his subject. Science was completely resigned to the idea that it ought to consist of a mere observation and tabulation of facts. The works of Linnæus and Cuvier betray this ideal. A scientist's status was estimated by the number of specific names and habitats he could remember, as well as facts *per se* he could discover, rather than any evidence he might give of intellectual powers in the way of constructive thinking and of finding general principles under which these facts could be explained and co-ordinated.

Darwin, the great organizer of biological science, deviated from the ideals of his times and constructed hypotheses under which he explained all the facts which were then at hand. To him facts *per se* were not the end of scientific quest, but the means of furnishing legitimate material for the production of theory. The chief value of any fact is that which it acquires in rendering possible the discovery of law. The fact is a legitimate landmark pointing us in the direction in which it goes. Darwin's predecessors were timeservers, and the facts which they had discovered and accumulated were only rendered valuable when he constructed them into systems of explanation. Ever since Darwin his method has been the ideal of investigators and the result has been the wonderful conquest over Nature.

The theory of evolution makes it clear that in order to become highly efficient as an observer one must have a comprehension of the system to which the fact belongs. The system enables the scientist to locate facts, and the facts corroborate or modify the working hypothesis.

When the facts of the material world were thus explained, or in the process of relegation into systems under general principles, the interest of scientists turned more to the immaterial or world of inner experiences, and by the same technique its conquest is sought. There is a general interest among, not only the representative thinkers, but also among the general public, in the subjective world of conscious experience. To distinguish our age from the objective one of Linnæus it might be characterized as the Psychological age. It started in a narrow circle of philosophers, but developed into a general interest wherever mental life is touched. The diffusion of the doctrine of evolution, with its historical implication, is largely responsible for the transition. Or, to be more scrupulous in statement, the same factors that brought to the consciousness of thinkers the principles of evolution are also accountable for the development of this present historico-psychological interest. Darwinism invaded all quarters and mental phenomena were subjected to the methods and the views of natural science.

The psychological interest, at first narrow, began with a study of the senses, and sense mechanisms. The field widened to a simple analysis of the feelings, and developed to an insight into the factors of higher mental life.[1] Today there are at its service many large, and elaborately equipped laboratories of psychology, physiology, and biology where almost every aspect of consciousness, or response may be subjected to analysis. As a result of introspection and the spirit of the times interest was developed in the mental equipment of the species, as well as of children and savages, and the psychological organization of society. The developmental implications according to Darwinian views, created an interest in the genesis of mind as well as of the body.

Since these developmental theories have been advanced history has acquired new meaning and interests and there is a demand for new explanations. Man—the whole physical, mental, and moral man—is looked at as the product of development; and in history are sought the steps of change which he has undergone, and the factors accountable for them. History, literature, art, religion, language, law, and politics all become data for the psychologist. The world is a psychological laboratory in which every living being acts and has acted as a subject. In history the experiments of the past are written up, under the different headings just enumerated, and the facts of mental life and development are recorded. It is in proportion that these facts are co-ordinated and interpreted that we are learning the nature and processes of mind, and its relation to its surroundings.

[1] Münsterberg, *Psychology and Life*, Chap. I.

Everyone is beginning to realize the importance of a comprehension of the relations between ideas, actions, and all other manifestations, on the one hand, and the conditions under which they are produced, on the other. A sound body and a sound mind imply a sound environment. The criminologist seeks just as much the conditions of the transgression in the environment as does the physician that of disease. There is mental as well as physical susceptibility. Any reform is futile that fails to get hold of the conditions. All are seeking the aid of psychological assistance—physicians, teachers, and reformers alike. It is this feeling of the integral relationship between the individual and his environment that characterizes the modern spirit, and that makes for a more efficient system of education. This spirit makes it inevitable, even for the biologist, to mix up psychology with his theories of evolution. It is this last statement and its relation to educational philosophy that I wish to discuss.

As already intimated, evolution imposes on us a dynamical view of the world. And all scientific evidence seems to corroborate the fact that all forms and aspects of life have evolved. No other conception has any standing in the court of science, and no failure is as yet recorded against it. The keynote is a common origin of all life from simple forms. In the light of a common origin many attempts have been made to account for man's ascent over his fellow creatures. Wallace[1] was the first to strike a successful keynote of explanation in applying the principle of Natural Selection to mental as well as physical qualities. He argues that after man had partly acquired those intellectual and moral qualities which distinguish him from the lower animals, he was but little liable to bodily modifications through natural selection, or any other means. He is enabled through his mental faculties to keep with an unchanged body in harmony with the changing universe. With increased intelligence he has greater power of adapting his habits to new conditions of life. He invents weapons, tools, and various stratagems to procure food and to defend himself. When he migrates into colder climes he uses clothes, builds shelter, and makes fire; and by aid of it cooks food otherwise indigestable. He aids his fellows and anticipates future events.

[1] *Anthropological Review*, May, 1864.

To show that natural selection operates in the direction of mental as well as physical qualities it is but necessary to cite a few illustrations. When America was discovered the wild animals were generally tamer than now. This tameness however varied, and when the white man began to hunt them down, those that were tamest and most easily approached were killed and consequently had no offspring. Those that were wary and kept out of sight or range of man, escaped and became the parents of the subsequent stocks which varied around the parents with reference to this mental quality—wildness or wariness. And so by a continuous process of maintaining the wilder ones the type of offspring deviated from the average of the parents for this quality and animals become wilder and wilder. In breeding turkeys the farmer obviously keeps those for the stock that stay about the farmyard, while those that stray he sells.

Romanes[1] in describing a visit to the Falkland Islands and the Land of Terre del Fuego gives some interesting light along this line. In the former, the large land birds were so tame that they could easily be approached by man. A hawk, usually so wary, could not be urged to move from a lower limb until pushed off with the muzzle of a gun. In the Land of Terre del Fuego the same animals were much wilder because harassed for four centuries by man all tame ones were killed by him and the wild remained to perpetuate the type. In the Falkland Islands the alligator was so tame that he could be pulled about by the tail without at all frightening him. But when pushed into the sea he immediately struggled to get out, because selection for long centuries had taken place with reference to sharks. Those alligators that were not wary were devoured and their type became extinct. The goose of certain Pacific islands is not afraid of man who is a recent comer but is very careful of the fox who is an old persecutor. Birds that have instincts which cause them to fly south during winter have greater chances to survive and perpetuate their type, than those that remain behind and are probably starved or frozen.

Consciousness and intelligence are late acquirements of living creatures, and selection before their acquisition must have been mainly with

[1] *Mental Evolution in Man*, appendix.

reference to physical fitness. Loeb in a recent series of physiological experiments[1] has shown definitely that most lower forms have no intelligence, not even consciousness. Some very complex reactions and instincts which were constantly interpreted by physiologists and psychologists as intelligent[2] and giving evidence of power of choice[3] and of power to learn by experience,[4] are merely some form of tropism and can be explained in terms of the chemical constituents of the organism.

He explains, e. g. heliotropism in the moth on exactly the same basis as that of a flower which turns toward the source of light. The stereotropism of the worm, e. g. Nereis, which seeks to bring its body into contact with solid objects is exactly like that of Tubularia whose stolon turns toward and sticks to solid bodies. Certain animals, e. g. actinians, are geotropic and are not satisfied until they burrow into the sand just as the roots of a plant which also possesses this tropism. His experiments are convincing. These reactions are physical in their nature and do not imply consciousness any more than do the reactions of a root or flower. But they are elements which factor in consciousness when it [consciousness] does appear. It may be possible that the wildness reactions and migratory instincts, illustrated above, will be found to be mere tropisms, when we get a more adequate knowledge of comparative psychology.

Hodge, from some experiments on specimens of Vorticella, attributed to them intelligence. He fed them yeast which they voraciously devoured, but after a while spewed out. No attempt to feed them yeast afterward was successful. This was interpreted as a learning by experience. Loeb's experiments make another explanation possible. The yeast effected a chemical change in the organism, and with reference to yeast produced a negative tropism.

These tropisms, essential to the organism are seized upon and maintained. Emotion may be regarded, from the standpoint of the James-Lange theory of the emotions,[5] as a form of tropism, and the following

[1] LOEB, *Physiology of the Brain.*

[2] PFLÜGER, *Die sensorischen Functionen des Rückenmarks.*

[3] BINET, *Psychic Life of Microorganisms.*

[4] HODGE, "Daily Life of a Protozoan," *American Jour. Psychol.*, Vol. VI; JENNINGS, "The Psychology of a Protozoan," ibid; WATKINS, "Psychical Life of Protozoa," ibid., Vol. XI.

[5] JAMES, *Principles of Psychology*, Vol. II, chapter on Emotions.

is an illustration of how natural selection operated in the development of the expression of emotions in all present forms of animal life. It is remarkable how uniform is the expression of the same emotion in all the different animals and this illustration furnishes a rational explanation. All life according to present views began in simple cell forms. Those primordial forms of cells with reference to their responses to stimuli might be conceived of as forming four possible classes. The first group is formed by those cells that contract to all stimuli, whether beneficial or harmful; the second by those cells dilating to all stimuli; the third by those that contract to beneficial and dilate to harmful stimuli; and the fourth by those that dilate to beneficial and contract to harmful. Where consciousness exists the stimuli are referred to as pleasurable and painful instead of beneficial and harmful. If there ever did exist such a distribution of cells with reference to their responses natural selection would immediately have been called into play and the first three types eliminated. In the third type every response is unfavorable to the welfare of the organism, because in relaxing to a harmful stimulus the greatest amount possible of the life tissues must be exposed to the harmful stimulus; whereas in contact with a beneficial stimulus the least possible amount of the bodily tissues would be benefited by contact and hence nutrition would be poor. In the fourth type the responses are all the most favorable, because in dilating to a beneficial stimulus nutrition is favored, and in contracting to a harmful stimulus, thus bringing the least possible amount of the life tissues in contact with the harmful stimulus, the organism is protected from destruction. This is, consequently, the type to survive and to be the perpetuator of life. The second type, providing it never gets in contact with harmful stimuli, would be just as efficient as the fourth. But it is inevitable for an organism in the course of its life to come into contact with the harmful stimuli and this predetermines the fate of this class. In the first type the nutrition is poor and elimination also is certain. There is a remarkable consistency throughout the whole realm of organic life, with which each emotion manifests itself in connection with the fourth type of responses.

Natural selection has factored in the development of the expression of the emotions, yet it cannot be said that expression is any evidence of consciousness. Expression may be entirely instinctive, or more correctly *tropic*. Goltz showed that a dog after having its cerebral hemispheres removed would still growl and snap if teased, and this creature certainly had no consciousness.[1] This fact is thoroughly understood by physiologists and is supported by many experiments on cerebral extirpation.[2]

Nothing originates all at once like a creation by fiat but all things are in a state of continuous growth and development. Not only are tropisms necessary predecessors of consciousness, but so also is a nervous system. An idea of the development of a nervous system in lower organisms will help us to understand it in higher forms. The entrance of a nerve element into a mass of tropic plasma must have proven an advantage to both elements vouchsafing their survival.

From the standpoint of evolution any organism might be regarded as a community of cells each of which performs a function for the whole group. Thus through the economy of the division of labor, and specialization, the group organism, in competition with other cells and groups, in the struggle for existence, is rendered more efficient, and consequently is able to survive. In this division of labor in the group organism the nerves prevent the response impulses from being diffused throughout the mass but transmit them by natural selection to the place where the response yields the most efficiency to the organism. These nerve elements guarantee greater effectiveness and sensitiveness. Loeb[3] has shown that a stimulus is about eight times as effective in the normal ascidians than it is when the nerve ganglia are removed. If the efficiency of the response, and hence the animal's efficiency for life is conditioned by the increase of nerves, and assuming that nerve supply varies in the organism (as it certainly does), then natural selection will favor increase of nerve supply. This multiplication of nervous substance ultimately gives rise to the association memory and consciousness.

[1] *Der Hund ohne Grosshirn*, Pflüger's Archiv., Bd. 51.

[2] EXNER, *Entwurf zu einer physiologischen Erklärung der psychischen Erscheinungen.* Leipsig, 1894; SCHRADER, "*Zur Physiologie des Vogelgehirns*," *Pflüger's Archiv.*, Bd. 44. LOEB, *Physiology of the Brain*, 1900, pp. 268, and 275.

[3] *Physiol. of the Brain*, p. 38.

Whenever a favorable tropism by means of variation accompanies a physical character in an organism that is maintained by natural selection, it is also a step toward the ultimate development of consciousness.

Before consciousness develops, and consequently the power to learn by experience, adaptation of the organism takes place entirely through selection. In ever-changing conditions lower animals must have their bodies constantly modified in order to survive. They must become smaller to escape detection, must have greater teeth and claws for defense, they must have their fur thickened when migrating into a colder climate.

When the stage of learning by experience is reached mind becomes the principal factor of selection, and the advancement of intelligence is comparatively rapid. The bodily form becomes fairly stable and tends to change only where mental and physical characters are correlated. Wallace has pointed out that the faculties in man are variable just as physical characters are and these variations tend to be inherited. They would, therefore, be advanced and perfected by natural selection.

Sagacity, reason, imitation, and sociability are variations which are mental in their character. In rudest society according to Darwin[1] the most sagacious individuals who would, therefore, invent and use the best weapons would be most powerful and also rear the most offspring because of the increased control over Nature and their fellows which they would have. The tribes including the greater number thus endowed would supplant the other tribes. Reason also develops through variation and is seized upon for fitness. Those that cannot be caught in a trap and can devise strategies have an advantage over their fellows. Imitation also is a powerful factor in the selection for intelligence. Those individuals who cannot imitate the strategies in which their most intelligent fellows participate will be eliminated by competition.

Sociability, or rather gregariousness, develops long before there is intelligence. This also may be regarded as a form of tropism. This gregariousness is manifested by many lower forms, and even decapitated they will still in some cases maintain the instinct, this shows the mechanical nature of it. Just as the hydrogen atoms will collect together at the carbon pole in a battery so will these creatures aggregate in local-

[1] *Descent of Man*, Chap. 5.

ities under certain conditions. Gregariousness, though seldom accompanied by intelligence is essential to the survival of the species and consequently is determined by selection.

Flesh-eating animals are solitary. This character, though the very opposite, is also determined by natural selection, because the group is unfavorable to their necessary conditions of life. In the struggle for existence two factors usually operate which make for gregariousness; struggle for food[1] and struggle for possession of the females.[2] Those males that band together in struggling for the possession of food and females will be able to drive away those that do not. Those that do not band together in the struggle will be starved. Those that take possession of the food and females will thrive and also be the parents of the next generation of the species. Gregariousness varies around an average and there will be selection away from that average according to the direction in which variation is favorable. In this case since gregariousness is an advantage there will be a deviation from this average from generation to generation in the direction of it. This law was first stated by Galton,[3] and finds wide application. From generation to generation the struggling groups become larger and larger and selection (all other things equal) favors the larger group. The development of sociability in the human race and the factors responsible can be seen in relation to war. War is the implement by means of which the human race became socialized. The whole story of warfare is one of exploitation by the larger and more aggressive group of the smaller. So sociability is a product of natural selection in the human race after consciousness had advanced far toward her. adult stage.

Since intelligence appeared, it has been the main factor seized upon by selection. But intelligence is not infrequently ignored in favor of a physical character. The "Black Death" which spread all over Europe and Asia during the 14th century is a good illustration of this point. An account of this deadly pestilence is recorded in the Humboldt Library.[4] According to this author London alone lost 100,000 inhabitants. German and other European cities sustained similar enormous losses.

[1] DARWIN, *Origin of Species*, Natural Selection.

[2] DARWIN, *Sexual Selection.*

[3] *Hereditary Genius*, p. 347.

[4] HECKER, *The Black Death.*

Intelligence could make no stand against it. Physicians were impotent in all attempts to check it. Every country lost many of her most intelligent citizens. So long as human intelligence has not advanced to a stage where it can produce, through medical and surgical aid, arbitrary immunity, the disease will run its natural course, when once it takes possession of a race, and will eliminate the susceptible and ultimately produce complete immunity. This will take place no matter how intelligent the race may be providing there is as yet no known means of checking the disease. If there happens to be correlation between intelligence and susceptibility to any definite disease to which a community is exposed the inevitable result is retrogression. This is certainly the case in any tropical country where a new white population and a native population reside. In so far as there is ignorance of artificial immunity the majority infected by the jungle diseases are the new comers and hence those of superior intelligence.

In man and the higher animals the physical character that is best correlated with intelligence is the size of the cerebral cortex. In man the brain is almost the only character changing and developing. And when we reach a stage in medical science when we are able to render every individual immune through surgery and inoculation, and "by means of the sum of human contrivances"[1] advance, independently of heredity, this will be more true. Yet it is doubtful whether even the brain is developing in any degree rapidly enough to account for the progress that is taking place.

In human civilization each generation is working at a higher level and with better tools which their predecessors have devised. The product of this labor is the social environment. The essential thing is that evolution has been transferred from the organism to the environment, and it is the environing social structure which persists. Progess may be expressed, therefore, as a product, rather than the rise of average intellectual capacity. This product is the mould in which mediocrity is cast. Progress and education do not necessarily imply that the level of intelligence is becoming higher but merely the level of acquisition.

As a result of the development of medical science and surgery, by

[1] RITCHIE, *Darwinism and Politics.*

means of which the fit and unfit alike are rendered immune and survive; and as a result of education, by which the mediocre, and even the poor (mentally), as well as the apt, are adapted to their environment and are thus enabled to survive, to make a living, and to bring up a family, natural selection can operate less and less on both the mental and physical side, and man's evolution, so far as body, and mind are concerned tends to a limit. One feature that distinguishes social evolution from merely organic evolution, which we see among lower animals, is the predominant part played by the fittest in raising the level of the less fit. Not a much higher man either physically or intellectually can be produced under the functioning of present conditions. Progress must be along the line of superorganic development, and along the line of cumulative environmental factors.

It can easily be seen how even retrogression in the human species under present conditions can be, and probably is being, brought about. In every country in which a large standing army is kept up, the best young men are enlisted. These are subjected to exposure, to death in war, to temptation in vice, and are prevented from marrying during the prime of life, whereas the feebler men stay at home marry and have large families.[1] The careless, squalid, unaspiring multiply, like rodents, whereas the sagacious, prudent, aspiring, and intelligent struggle for fame and wealth in celibacy. They marry late, if ever, and have small families. Rome can attribute her fall to the drafting away of her aggressive and ambitious elements. From the rural districts, where no adequate means of realization are afforded, the aspiring element of the rising generation is drawn to the city and other places of opportunity, where there is close competition and where the strenuous life is essential and nervous diseases inevitable. The residue left behind composed of a large mass of a helpless, conservative, unaspiring element tends ultimately, if this selective process is long enough continued, to produce a peasant population.

As a result of the complication of the environment and the lack of man's adaptation to it, through the operation of natural selection, civilization is becoming more and more artificial, and many "dishar-

[1] Fick, *Einfluss der Naturwissenschaft auf das Recht.*

monies" are produced which must be adjusted by means of science and surgery. The appendix as well as the large intestines are disharmonies[1] and man were better off if rid of them. Until surgery obtained control over a fatal inflammation of the appendix (a disease now known as appendicitis) natural selection operated toward the elimination of this appendix in the race. The size of this organ like every physical character varies, and the smaller it is the less likely is the affection. Those with a large appendix would be more likely to have the disease and if surgical aid were not rendered, ultimately it would disappear from the race by selection. But since surgery is so successful in operations of removal of this organ, the victims are saved for the race. All survive, and selection ceases, i. e., the appendix will not tend to become smaller in the race. It thus becomes obligatory to remove it—either at birth or when it causes trouble. The same is true with the large intestines. With the production of diets (breakfast foods) which contain the proper proportions of nutrition to sustain the life with the least waste, the large intestine becomes useless and even harmful. The intestines were developed by natural selection, when man had less palatable foods, and consequently in order to maintain good nutrition required a large alimentary canal. Now the latter part of this canal instead of being essential, and instead of being a digestive and assimilative organ is a stagnant cesspool of putrefaction the best possible incubator for all germs that chance to get through the pyloric orifice of the stomach alive. By the aid of medical science we are becoming able, to a considerable degree, to combat the diseases and fevers resulting from this anomaly, and thus here too, natural selection is barred from performing her work of shortening this intestine and thus fails ultimately in bringing the body in consonance with its environing conditions. Surgery may ultimately see fit to extirpate this organ at birth.

By artificial means we are rendering the body immune to many diseases, and thus finally, in order to save the race from becoming exterminated this inoculation must be faithfully administered to every individual who hopes to survive. If one generation should neglect this essential duty of inoculation almost the whole race might be swept away as chaff before the wind.

[1] METCHNIKOFF, *Nature of Man.*

I hope this much by way of illustration has made clear the fact that all progress upward so far as the individual is concerned, in bodily fitness and brain capacity tends to be retarded by means of man's arbitrary arrangements in the form of education and science. It seems time that educators become awake to the destiny, or fate, of the race, and by way of the inculcation of popular opinion ultimately put such factors into operation again that will once more start the curve of physical and mental evolution upward. It seems that some of the factors now operating are inevitable, but still something, if the truth be taught, can be done toward amelioration. We cannot hope to do for the human race what Burbank[1] is doing in the vegetable world, but we can do something toward the development of sentiments and ideals along this line, and no one can tell what will be the fruits of our efforts.

[1] "A True Account of Burbank's Work," *Century Magazine*, Mar. and Apr., 1905.

A FEW EXAMPLES IN THE THEORY OF FUNCTIONS

By Arnold Emch

1. The progress of the student in a first course of the theory of functions is usually retarded by a lack of proper illustrative examples. For a clear understanding of the problems involved in such a study, the beginner must be aided by geometrical representations and models and by exercises fully worked out by the teacher as well as by the student.

In what follows I shall present a few examples which may be considered according to the foregoing suggestions.

2. **Example I.** All rational numbers form an enumerable system.

In other words, with every number of the sequence of natural numbers 1, 2, 3, . . . we can associate a definite rational number, so that to every rational number corresponds conversely a definite natural number. This relation is also designated as a *one-to-one correspondence.* As the analytical reasoning for the establishment of this theorem is sufficiently known,[1] I shall not repeat it here and merely give a geometrical illustration of it which makes its truth intuitively apparent.[2]

Divide the xy-plane into a net of equidistant lines parrallel to the x- and y-axes; let the distance between any two parallel lines be unity and extend the net indefinitely. At every point of the net write its abscissa as a numerator and its ordinate as a demoninator, so that every point of the net is represented by a fraction $\frac{p}{q}$ which may be positive or negative, a proper fraction or an integer. Then, beginning at the origin, describe a spiral-line as indicated in Fig. 1 and continue it indefinitely. As all rational numbers are represented by the points of the net, it is clear that following the spiral-line all rational numbers will be met in a definite

[1] Borel: *Leçons sur la Théorie des Fonctions.*

[2] From Prof. Hurwitz's lectures on analytic functions at the Polytechnic of Zürich.

order. In this counting of the rational numbers all numbers of the form $\frac{mp}{mq}$ where p and q are prime must be left out. According to this arrangement the one-to-one correspondence between the natural numbers and all rational numbers may be indicated by the two rows:

1	2	3	4	5	6	7	8	9	10	11	12	...
$+\infty$	$+1$	0	-1	$-\infty$	-2	$+2$	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{3}{2}$	-3	$+3$	...

FIG. 1

3. **Example II.** EXPANSION OF THE FUNCTION $f(z)=\frac{1}{1-z}$ BY TAYLOR'S SERIES AND ITS ANALYTIC CONTINUATION.

1. According to Taylor's series we have

$$f(z)=f(a)+(z-a)f'(a)+\frac{(z-a)^2}{1.2}f''(a)+\ldots+\frac{(z-a)^n}{n!}f^n(a)+\ldots, \tag{1}$$

where

$$f^n(a)=\frac{n!}{2\pi i}\int_C\frac{f(z)dz}{(z-a)^{n+1}}, \tag{2}$$

an integral taken over the boundary of a circle C having the point a as a center and being entirely within the region of regularity of $f(z)$. In the given example the point a is within the circle of radius 1 and having the origin as a center. We have

$$f^n(a)=\frac{n!}{2\pi i}\int_C\frac{dz}{(1-z)(z-a)^{n+1}} \ . \qquad (3)$$

To integrate this, write $\frac{1}{(1-z)(z-a)^{n+1}}$ in partial fraction form:

$$\frac{1}{(1-z)(z-a)^{n+1}}=\frac{A_{n+1}}{1-z}+\frac{B_{n+1}}{(z-a)}+\frac{C_{n+1}}{(z-a)^2}+\ldots+\frac{K_{n+1}}{(z-a)^{n+1}} \ . \qquad (4)$$

The integrals of these parts along the circle c all disappear with the exception of $\int\frac{B_{n+1}}{z-a}dz$. It is therefore sufficient to determine the coefficient B_{n+1}. For this purpose the following method of recurrence may be used. We have

$$\frac{1}{(1-z)(z-a)^n}=\frac{A_n}{1-z}+\frac{B_n}{z-a}+\frac{C_n}{(z-a)^2}+\ldots+\frac{K_n}{(z-a)^n} \ . \qquad (5)$$

Multiplying (5) by $\frac{1}{z-a}$ we get an expression which must be indentical with (4); i. e., coefficients of equal powers are equal. From this we find

$$\frac{A_n}{(1-z)(z-a)}=\frac{A_{n+1}}{1-z}+\frac{B_{n+1}}{z-a} \ ,$$

or $A_n=A_{n+1}(z-a)+B_{n+1}(1-z)$, and $A_{n+1}=B_{n+1}$; $A_{n+1}=\frac{A_n}{1-a}$.

To determine A_1 assume the case of $n=0$, so that (4) becomes

$$\frac{1}{(1-z)(z-a)}=\frac{A_1}{1-z}+\frac{B_1}{z-a} \ .$$

Here $A_0=1$; hence $A_1=\frac{1}{1-a}$. By recurrence $A_2=\frac{1}{(1-a)^2}$, $A_3=\frac{1}{(1-a)^3}$, ..., $A_{n+1}=B_{n+1}=\frac{1}{(1-a)^{n+1}}$. The value of the required integral is therefore

$$f^n(a)=\frac{n!}{2\pi i}\int_C\frac{dz}{(z-a)(1-a)^{n+1}}=\frac{n!}{(1-a)^{n+1}} \ .$$

The development of $f(z)=\frac{1}{1-z}$ around the point a is therefore

$$\frac{1}{1-z}=\frac{1}{1-a}\left[1+\frac{z-a}{1-a}+\left(\frac{z-a}{1-a}\right)^2+\left(\frac{z-a}{1-a}\right)^3+\ldots\right]. \tag{6}$$

This series is convergent when $|z-a|<|1-a|$; i. e., when z is within a circle having a as a center and the distance from a to 1 as a radius, Fig. 2.

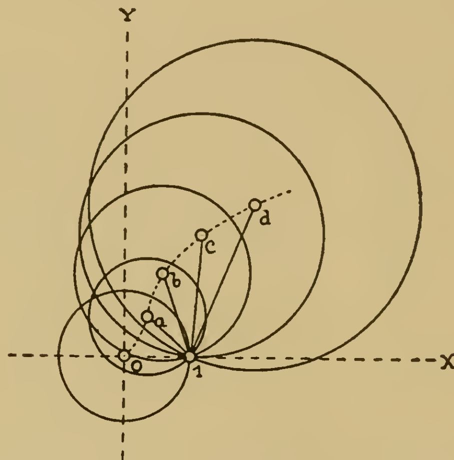


FIG. 2

2. Analytic continuation.

From Fig. 2 it is plainly seen that the series (6) converges at points z outside of the original circle of convergence; in other words, the domain of convergence has been extended; *the function* $\frac{1}{1-z}$ *has been continued.* Designating the expansion of (6) about the point a by $f(z/a)$ we may next take a point b within the circle of convergence of (6) and expand $f(z/a)$ about the point b; designating this last expansion by $f(z/a/b)$ we have

$$f(z/a/b)=f(b/a)+(z-b)f'(b/a)+\frac{(z-b)^2}{1.2}f''(b/a)+\ldots+\frac{(z-b)^n}{n!}f^n(b/a)+\ldots, \tag{7}$$

where

$$f(b/a)=\frac{1}{1-a}\left[1+\frac{b-a}{1-a}+\left(\frac{b-a}{1-a}\right)^2+\ldots\right]=\frac{1}{1-b};$$

$$f'(b/a)=\frac{1}{(1-b)^2}\,;\qquad f''(b/a)=\frac{1\cdot 2}{(1-b)^3}\,;\qquad \ldots f^n(b/a)=\frac{n!}{(1-b)^{n+1}}\,.$$

In the expansion (7) the ratio of a term and the term preceding it is $\frac{z-b}{1-b}$, so that the expansion is convergent for every point z within a circle having b as a center and $|1-b|$ as a radius. Next, any point c within this circle may be chosen and the series (7) be expanded about this point. In this manner an expansion $f(z/a/b/c)$ is obtained which converges within a circle having c as a center and $|1-c|$ as a radius. As is indicated in Fig. 2, this process of continuing the given function beyond its original region of convergence may be carried on indefinitely, so that ultimately the whole plane has been covered. All these continuations, together represent the analytic function. $\frac{1}{1-z}$.

4. **Example III.**[1] THE MANY-VALUED FUNCTION w DETERMINED BY THE EQUATION $w^3-w+z=0$.

In the ELEMENTS OF THE THEORY OF FUNCTIONS OF A COMPLEX VARIABLE by DURÈGE (English translation) the function w of z defined by the equation $w^3-w+z=0$, as an example of a multiform function is studied (p. 38 and p. 76). The treatment however does not seem to be very clear and I shall therefore attempt to analyze the various parts of the problem with the necessary details.

(a) ALGEBRAIC PART.

Putting

$$p=\sqrt[3]{\frac{1}{2}\left(-z-\sqrt{z^2-\frac{4}{27}}\right)}\,,$$

$$q=\sqrt[3]{\frac{1}{2}\left(-z+\sqrt{z^2-\frac{4}{27}}\right)}\,,$$

$$\alpha=\frac{1}{2}(-1+i\sqrt{3})\,,$$

[1] For similar and other examples see HARKNESS and MORLEY, *A Treatise on the Theory of Functions*, pp. 127–159; HARKNESS and MORLEY, *Introduction to the Theory of Analytic Functions*, pp. 284–286; PICARD *Traité d'Analyse*, Vol. II, pp. 348–388 (1 ed.); APPELL & GOURSAT, *Théorie des Fonctions Algébriques*; FRICKE, *Analytisch-Funktionentheoretische Vorlesungen*, pp. 75–172; LANDFRIEDT, *Theorie der algebraischen Funktionen und ihrer Integrale;* BIANCHI, *Lezioni sulla Teoria delle Funzioni di Variabile Complessa*, pp. 217–246.

$$\alpha^2 = \frac{1}{2}(-1 - i\sqrt{3}) \ ,$$

$$(1 + \alpha + \alpha^2 = 0) \ ,$$

the roots of the given equation $w^3 - w + z = 0$, according to TARTAGLIA'S formula, are

$$\begin{cases} w_1 = p + q \ , \\ w_2 = \alpha p + \alpha^2 q \ , \\ w_3 = \alpha^2 p + \alpha q \ . \end{cases} \qquad (1)$$

For $z = 0$, $p = -i\sqrt{\frac{1}{3}}$, $q = +i\sqrt{\frac{1}{3}}$, and the values of the three roots are

$$w_1 = 0 \ ,$$
$$w_2 = q(\alpha^2 - \alpha) = +1 \ ,$$
$$w_3 = q(\alpha - \alpha^2) = -1 \ .$$

For $z = \pm\frac{2}{\sqrt{27}}$, $p = q$, so that at each of these points the two roots w_2 and w_3 become equal. When z is real and $> \frac{2}{\sqrt{27}}$ or $< -\frac{2}{\sqrt{27}}$, p and q are real, so that w_1 is real, while w_2 and w_3 are conjugate complex. When z is real and $|z| < \frac{2}{\sqrt{27}}$, then we have the *casus irreducibilis* and we can get the real solutions of the cubic by introducing an auxiliary angle ϕ by the substitution $z = -\frac{2}{\sqrt{27}}\cos\phi$. In this case, as $|z < \frac{2}{\sqrt{27}}$, $\cos\phi$ is real and

$$p = \sqrt{\frac{1}{3}}\left(\cos\frac{\phi}{3} - i\sin\frac{\phi}{3}\right) \ ,$$

$$q = \sqrt{\frac{1}{3}}\left(\cos\frac{\phi}{3} + i\sin\frac{\phi}{3}\right) \ .$$

The three solutions of the cubic become

$$\begin{cases} w_1 = 2\sqrt{\frac{1}{3}} \cdot \cos\frac{\phi}{3} \ , \\ w_2 = \sqrt{\frac{1}{3}}\left(-\cos\frac{\phi}{3} + \sqrt{3}\sin\frac{\phi}{3}\right) \ , \\ w_3 = \sqrt{\frac{1}{3}}\left(-\cos\frac{\phi}{3} - \sqrt{3}\sin\frac{\phi}{3}\right) \ . \end{cases} \qquad (2)$$

It is important to observe that the expressions (1), in the same order, do not correspond to the expressions in (2). For instance, for $z=0$; *i. e.*, $\phi=\frac{\pi}{2}$, the values in (2) become

$$w_1=+1\ ,$$
$$w_2=\ 0\ ,$$
$$w_3=-1\ .$$

The seeming contradiction can be explained by the fact, that in (2) the cube-roots are explicitly extracted, while in (1) p and q simply indicate cube-roots and each may just as well be replaced by either ap or or a^2p and a^2q or aq, respectively. Formulas (2) are therefore the proper determinations of the function w within the region $-\frac{2}{\sqrt{27}}<z<\frac{2}{\sqrt{27}}$ (z real). When $z=\frac{2}{\sqrt{27}}$; *i. e.*, $\phi=\pi$,

$$w_1=\sqrt{\frac{1}{3}}\ ,$$
$$w_2=\sqrt{\frac{1}{3}}\ ,$$
$$w_3=-2\sqrt{\frac{1}{3}}\ .$$

When $z=-\frac{2}{\sqrt{27}}$; *i. e.*, $\phi=0$,

$$w_1=2\sqrt{\frac{1}{3}}\ ,$$
$$w_2=-\sqrt{\frac{1}{3}}\ ,$$
$$w_3=-\sqrt{\frac{1}{3}}\ .$$

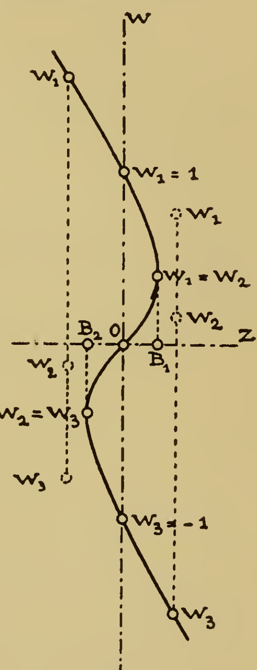


FIG. 3

Hence, for $z=+\frac{2}{\sqrt{27}}$, the roots w_1 and w_2 become equal, while for $z=-\frac{2}{\sqrt{27}}$ the roots w_2 and w_3 become equal.

This again seems contradictory to the equivalent result from (1), where $w_2 = w_3$, for $z = \pm\frac{2}{\sqrt{27}}$, was found, and can be explained as above.

To illustrate the values of the function w, for real values of z draw the graph of the cubic $w^3 - w + z = 0$ in a Cartesian plane zw, Fig. 3, which clearly shows the results obtained by the discussion of the roots.

(b) BRANCH POINTS.

Considering in TARTAGLIA'S formula the expression

$$\sqrt[3]{\frac{1}{2}\left(-z \mp \sqrt{z^2 - \frac{4}{27}}\right)}$$

and representing the roots in a complex plane w, let z describe a circle of radius ρ around the point $\frac{2}{\sqrt{27}}$ as a center and not including the origin. By this assumption $z - \frac{2}{\sqrt{27}} = \rho . e^{i\theta}$ and $z + \frac{2}{\sqrt{27}} = \frac{4}{\sqrt{27}} + \rho . e^{i\theta}$, so that

$$\sqrt[3]{\frac{1}{2}\left(-z \mp \sqrt{z^2 - \frac{4}{27}}\right)} = \sqrt{\frac{1}{2}\left(-\frac{2}{\sqrt{27}} - \rho e^{i\theta}\right) \mp \sqrt{\rho e^{i\theta}\left(\frac{4}{\sqrt{27}} + \rho e^{i\theta}\right)}}$$

$$= \sqrt{\frac{1}{2}\left(-\frac{2}{\sqrt{27}} - \rho e^{i\theta} \mp \sqrt{\rho} . e^{i\frac{\theta}{2}} . \sqrt{\frac{4}{\sqrt{27}} + \rho e^{i\theta}}\right)} .$$

If now z describes the complete circle; *i. e.*, when θ increases by 2π, nothing is changed in this expression except $e^{i\frac{\theta}{2}}$ which goes over into $e^{i\left(\frac{\theta}{2}+\pi\right)} = -e^{i\frac{\theta}{2}}$. Hence after one complete revolution of z about the point $\frac{2}{\sqrt{27}}$, the expression becomes

$$\sqrt[3]{\frac{1}{2}\left(-z \pm \sqrt{z^2 - \frac{4}{27}}\right)} ;$$

in other words p and q are interchanged. The same can be proved for the point $-\frac{2}{\sqrt{27}}$. From (1) it appears that at these points the roots w_2 and w_3 as given in (1) are equal. While z in the z-plane moves as indicated, w_2 and w_3 in the w-plane move in such a manner that w_2 changes to w_3 and w_3 into w_2. Those roots which at one of the points $\pm\frac{2}{\sqrt{27}}$ become equal are permuted if z describes a complete circle around this one point. From (2) it is apparent that when z moves around $\frac{2}{\sqrt{27}}$ the roots w_1 and w_2 in (2) are permuted, while when z moves around $-\frac{2}{\sqrt{27}}$ the roots w_2 and w_3 are permuted.

Designating these points by B_1 and B_2, we may let z describe a path passing through one of these points, say B_1, around which the roots w_1 and w_2 are permuted. These two points w_1 and w_2 describe paths in the w-plane which pass through the point $\sqrt{\frac{1}{3}}$ in the w-plane corresponding to B_1 in the z-plane. But as for any point z, w can have either value w_1 or w_2, it is clear that each of the points in the w-plane representing w_1 and w_2 can move on either of the two branches. Such a point B_1, and similarly B_2, is called a *branch-point* of the function w.

(c) CONSTRUCTION OF THE PATHS DESCRIBED BY Z AND W.

To trace the curves which w describes when z describes given curves, write $z=x+iy$ and $w=u+iv$, so that the original equation becomes

$$(u+iv)^3-(u+iv)+x+iy=0 .$$

Separating real and imaginary parts, we get

$$u^3-3uv^2-u=-x , \tag{3}$$

$$3u^2v-v^3-v=-y . \tag{4}$$

It now z describes the curve $f(x, y)=0$, then w describes the curve

$$f\Big[(-u^3+3uv^2+u) , (-3u^2v+v^3+v)\Big]=0 .$$

If the curve in the z-plane is $x=+\frac{2}{\sqrt{27}}$ (y=arbitrary), then w in the w-plane moves on the curve

$$u^3-3uv^2-u+\frac{2}{\sqrt{27}}=0 , \tag{5}$$

a cubic which has a double-point at $u=\sqrt{\frac{1}{3}}$, corresponding to the branch-point $B_1=\frac{2}{\sqrt{27}}$ in the z-plane. The easiest way to plot this curve is to give u different values and then solve for v. In order to follow the motion of the w's, when z describes the line $x=\frac{2}{\sqrt{27}}$, $(bcd\,B_1\,fgh)$, Fig. 4,[1] or conversely, the motion of z when w describes the curve

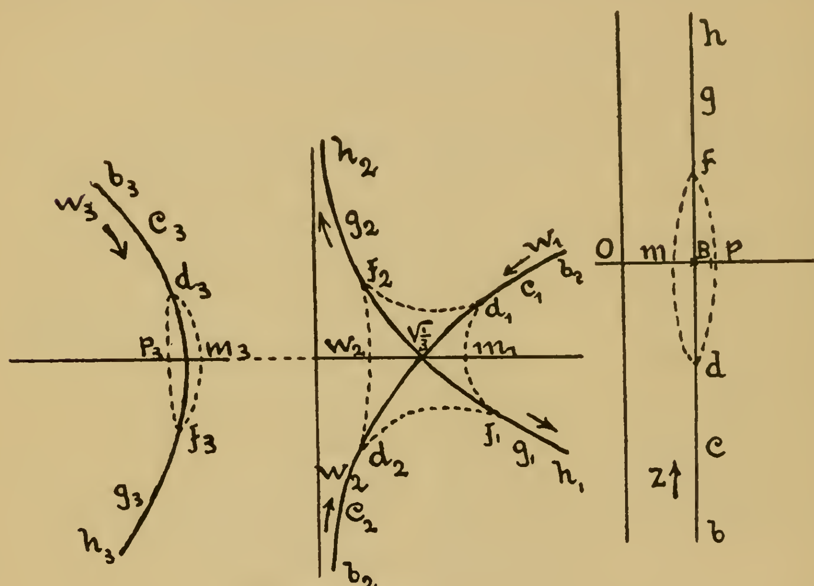


FIG. 4

(5), assume, in accordance with (5), a set of values u, v (assume the u's and calculate the v's according to the formula.

$$v=\pm\sqrt{\frac{u^3-u+\frac{2}{\sqrt{27}}}{3u}}.$$

Putting $u=\frac{m}{\sqrt{3}}$, where m denotes an integer,

$$v=\pm\frac{1}{3}\sqrt{m^2+\frac{2}{m}-3},$$

[1] Taken from Durège, loc. cit.

and substituting these values for u and v in (4), we get

$$y=\mp\frac{1}{27}\sqrt{m^2+\frac{2}{m}-3}\cdot\left(8m^2-6m-\frac{2}{m}\right). \qquad (6)$$

When z moves from b to c to d to B_1, y is negative and increases, so that m and consequently u decrease. With the negative sign of y goes the positive sign of v, so that also v decreases. Hence, while z moves from b over c and d to B_1, w_1 moves from b_1 over c_1 and d_1 to the point $\sqrt{\frac{1}{3}}$. After z has crossed B_1, y becomes positive and increases; hence m increases, u increases and v decreases, w_2 moves from $\sqrt{\frac{1}{3}}$ over f_1 and g_1 to h_1. If we take for m a proper fraction $\frac{1}{n}$, then

$$y=\mp\frac{1}{27}\sqrt{\frac{1}{n^2}+2n-3}\cdot\left(\frac{8}{n^2}-\frac{6}{n}-2n\right). \qquad (7)$$

When y is negative and increases, n must decrease; m and hence u increase. In (7) the positive sign must be taken and hence for v the negative. Consequently as z describes the path $bcdB_1$, the second determination, w_2, describes the path $b_2c_2d_2\sqrt{\frac{1}{3}}$. Similarly, it can be shown that w_2 describes the path $\sqrt{\frac{1}{3}}f_2g_2h_2$ when z describes B_1fgh, and that the third determination w_3 describes the path $b_3c_3d_3\left(-2\sqrt{\frac{1}{3}}\right)$ $f_3g_3h_3$, when z describes the line $x=\frac{2}{\sqrt{27}}$ from below upwardly. The paths corresponding to dmf and dpf can easily be sketched by computing the points m_1, m_2, m_3, and p_1, p_2, p_3 by formulas (2) and (1), respectively. For further details the reader is referred to Durège's treatise, loc. cit.

(d) RIEMANN SURFACE OF THE FUNCTION.

To construct the RIEMANN SURFACE for the function w, superpose three parallel z-planes at equal distances and mark in each the branch-points and the origin perpendicularly above each other. We stipulate that to the values of z in the first plane shall correspond in the w-plane only the values w_1 of the first determination, to the second plane those of w_2, and to the third plane those of w_3. These planes or sheets must now be so cut and connected that by turning around B_1 once, one must be led to a point in the second sheet vertically below the starting-point in the first, because around B_1, w_1, and w_2 are permuted. Similarly, as around B_2, w_2 and w_3 are permuted, by turning once around B_2,

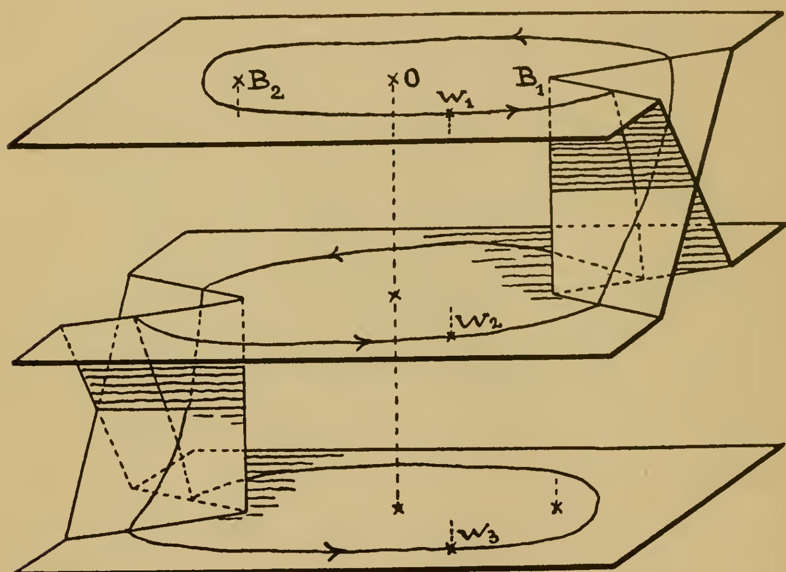


FIG. 5

one must be led from the second to the third sheet. The three sheets may be appropriately designated as w_1-, w_2-, and w_3-sheets, Fig. 5.

Passing in the z-plane a circle with the origin as a center around all branch-points and other singular points which are finite and then making an inversion with respect to this circle $z = \frac{1}{z}$, a function $f(z')$ is obtained which within the inverted circles has no branch-points or other singularities except possibly the origin. Describing now a closed circle, say the circle of inversion, it is possible to decide whether the roots of

$f(z')$ are permuted; i. e., whether the zero point of $f(z')$ or the point at infinity for the original function is a branch-point. In the Riemann surface this is equivalent with describing a closed path including both branch-points, in our example, and in all three sheets. Thus, starting out with one determination of w, for instance w_1, then after one complete revolution of z in the surface, w_1 is permuted with w_3, after a second revolution w_3 is permuted with w_2 and after another revolution w_2 returns with the original value w_1. This path has been drawn in the surface and appears in Fig. 5.

From this it follows that $z=\infty$ is a branch-point of the function w for all roots.

(e) CONSTRUCTION OF MODELS FOR u AND v IN THE FUNCTION
$w=u+iv$

Eliminating in turn v and u from (3) and (4) we obtain

$$y=\pm\frac{8u^3-2u-x}{3u}\sqrt{\frac{u^3-u+x}{3u}}\,, \tag{8}$$

$$x=\pm\frac{-8v^3-2v-y}{3v}\sqrt{\frac{v^3+v-y}{3v}}\,. \tag{9}$$

We can now consider u and v, in turn, each as constants and for every value of u and v construct the curves (8) and (9) in two separate xy-planes. If at the same time we give these curves distances vertically above and below the xy-planes corresponding to the values of u and v, two surfaces are obtained which for every value of $z=x+iy$ give the corresponding values of u and v of the function w as the perpendiculars erected at z to the z-plane and bounded by the surfaces represented by (8) and (9).

These surfaces which are of the ninth order have not yet been modeled. A number of models of this kind have been constructed by A. WILDBRET, H. BURKHARDT, J. KLEIBER, under the direction of Professor W. DYCK, and are sold by MARTIN SCHILLING in Halle a/S, Germany.

(f) EXPANSION INTO SERIES

When z turns twice around a branch-point, say B_1, and the function starts out with the determination w_1, it will return with the same value.

For, by the first revolution w_1 is changed into w_2 and by the second revolution w_2 is changed back to w_1. Hence, putting $z-\frac{2}{\sqrt{27}}=z'^2$, the function w determined by the equation

$$w^3-w+\frac{2}{\sqrt{27}}+z'^2=0$$

will return with its original value after z' has described one revolution in the z'-plane. Hence, setting $w=f(z')$, around $z'=0$ we have the expansion

$$w=f(0)+z'f'(0)+\frac{z'^2}{2!}f''(0)+\ldots \quad .$$

At

$$z'=0\ , \qquad \text{or } z=\frac{2}{\sqrt{27}}\ , \qquad w_1=w_2=\sqrt{\frac{1}{3}}$$

By differentiation we find $(f'(z')=w')$ $3w^2.w'-w'+2z'=0$; $w'=\frac{2z'}{1-3w^2}$, which for $z'=0$ and $w=\sqrt{\frac{1}{3}}$ assumes the form $\frac{0}{0}$. By the usual evaluation we find $f'(0)=\pm i\sqrt{\frac{1}{3}}$, hence

$$w_1=\sqrt{\frac{1}{3}}+i\sqrt{\frac{1}{3}}\cdot\left(z-\frac{2}{\sqrt{27}}\right)^{\frac{1}{2}}+\ldots \quad ,$$

$$w_2=\sqrt{\frac{1}{3}}-i\sqrt{\frac{1}{3}}\left(z-\frac{2}{\sqrt{27}}\right)^{\frac{1}{2}}+\ldots \quad ,$$

$$w_3=-(w_1+w_2)=-2\sqrt{\frac{1}{3}}+\ldots \quad .$$

Around B_2 we have

$$w_1=-\sqrt{\frac{1}{3}}+\sqrt{\frac{1}{3}}\left(z+\frac{2}{\sqrt{27}}\right)^{\frac{1}{2}}+\ldots \quad ,$$

$$w_2=-\sqrt{\frac{1}{3}}-\sqrt{\frac{1}{3}}\left(z+\frac{2}{\sqrt{27}}\right)^{\frac{1}{2}}+\ldots \quad ,$$

$$w_3=-(w_1+w_2)=2\sqrt{\frac{1}{3}}+\ldots \quad .$$

From the Riemann surface it appears that when z turns three times about both branch-points the function will return with its original determination. Such a path of z, in this example, is also equivalent with a path about the point ∞, and around this point the three determinations of the function are permuted. To prove this analytically, we expand the function in the neighborhood of $z=\infty$; or $z'=0$, when $z'=\frac{1}{z}$. w becomes infinite when $z=\infty$, but $\frac{w}{\sqrt[3]{z}}$ is finite for $z=\infty$. Indeed,

$$\lim_{z=\infty}\left(\frac{w}{\sqrt[3]{z}}\right)=\lim_{z=\infty}\left(\sqrt[3]{\frac{1}{2}\left(-1+\sqrt{1-\frac{4}{27z^2}}\right)}+\sqrt[3]{\frac{1}{2}\left(-1-\sqrt{1-\frac{4}{27z^2}}\right)}\right)=-1 .$$

Thus, it is possible to expand the function $w_1{}^{(1)}=\frac{w}{\sqrt[3]{z}}$ about $z=\infty$, or $w_1=w.z'^{\frac{1}{3}}$ about $z'=0$. Substituting $w=w_1.z'^{-\frac{1}{3}}$ in $w^3-w+z=0$, we get $w_1{}^3-w_1.z'^{\frac{2}{3}}+1=0$. If z' turns three times about the origin, w_1 and hence w will return with its original determination. Hence, putting $z'=z_1{}^3$, w will return with its original determination when z_1 turns once about the origin and consequently w_1 in the equation

$$w_1{}^3-w_1.z_1{}^2+1=0$$

can be expanded like a uniform function. Writing $w_1=f(z_1)$ we have

$$w_1=f(0)+z_1.f'(0)+\frac{z_1{}^2}{1.2}f''(0)+\ldots .$$

Now $f(0)=-1$, and from $w_1{}^3-w_1.z_1{}^2+1=0$ we find $w_1{}'=\frac{2z_1.w_1}{3w_1{}^2-z_1{}^2}$. For $z_1=0$, $w_1=-1$, and $w_1{}'=0\big(f'(0)=0\big)$.

$$w_1{}''=f''(z_1)=\frac{6w_1{}^2+2w_1z_1{}^2-6w_1{}^2w_1{}'z_1-2z_1{}^3w_1}{(3w_1{}^2-2z_1{}^2)^2},$$

which for $z_1=0$ becomes $\frac{2}{3}$. Hence

$$w_1=-1+\frac{1}{3}z_1{}^2+\ldots, \quad \text{or}$$

$$w_1=-1+\frac{1}{3}z'^{\frac{2}{3}}+\ldots, \quad \text{or}$$

$$w_1=-1+\frac{1}{3}z^{-\frac{2}{3}}+\ldots .$$

[1] Here w_1 does, of course, not mean the first determination.

But $w_1 = w . z^{-\frac{1}{3}}$, and $w = w_1 . z^{\frac{1}{3}}$; hence

$$w = -z^{\frac{1}{3}} + \frac{1}{3} z^{-\frac{1}{3}} + \ldots \quad .$$

This series represents the function w in the neighborhood of $z = \infty$ and clearly exhibits the permutability of its three determinations when z describes a path around this point.

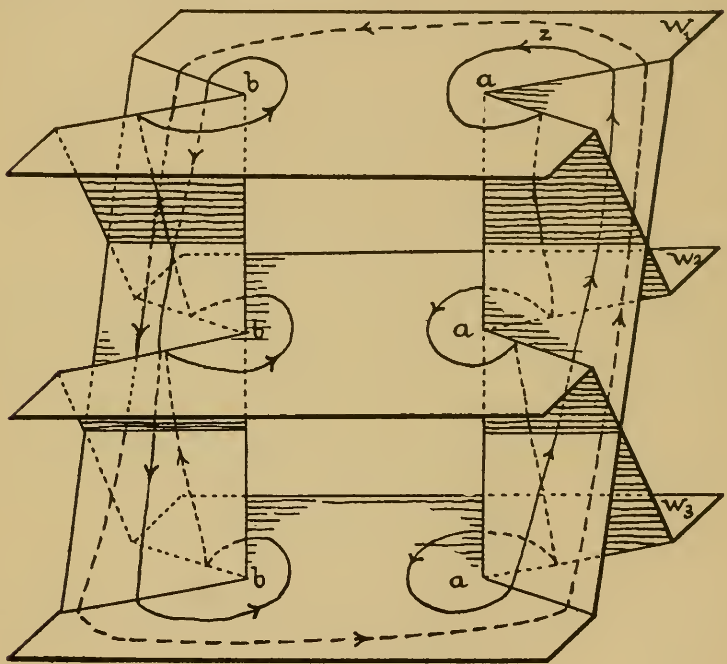


FIG. 6

5. **Example IV.** RIEMANN SURFACE FOR THE FUNCTION

$$w = \sqrt[3]{\frac{z-a}{z-b}} \; .$$

This example is explained in DURÈGE'S treatise, loc. cit., p. 50.

After one, two, three turns of z around a (not including b) w_1, w_2, w_3 are changed into

1. w_2, w_3, w_1 ;
2. w_3, w_1, w_2 ;
3. w_1, w_2, w_3 .

Similarly, turning around b, w_1, w_2, w_3 are changed into

1. w_3, w_1, w_2 ;
2. w_2, w_3, w_1 ;
3. w_1, w_2, w_3 .

According to this the Riemann surface for this function may be represented by Fig. 6.

If z describes a closed contour around both branch-points *once*, then each determination arrives at the starting-point with the same value. Consequently, $z = \infty$ is not a branch-point. In the figure the paths around the branch-points on which the three determinations are permuted are shown in solid lines. The complete path around both branch-points is represented by a dash-line.

A STUDY OF CERTAIN FOLIACEOUS COTYLEDONS

By Francis Ramaley

Introductory.—Little attention has been given by botanists to cotyledon structure. In the standard works of reference I have found nothing on the subject. Every botanist knows the appearance of the cotyledons of the pea, bean, morning glory, and castor oil plant but I think that few have examined cotyledons microscopically. As is well known, the cotyledons of a plant are seldom of the same shape as the leaves. Occasionally they are of similar shape but this is in cases where the leaves are of simple form, as ovate or oblong. Even in these cases the venation of the cotyledon is nearly always different from that of the leaf. If then the cotyledon and leaf be different in gross structure it will be of interest to compare the internal anatomy.

Scope of the paper.—The present paper is intended as a very small contribution to the subject. It is a record of observations on a few plants with foliaceous cotyledons. A "foliaceous" cotyledon is not necessarily a cotyledon resembling the leaf of the species but one which is thin and which looks externally as if it were a leaf. In the following pages are given detailed accounts of the species examined. The separate accounts are all arranged in the same way so that comparison is easy. I have thought it best to illustrate everything with diagrams and figures because, as cotyledon structure is generally unfamiliar, inaccurate conclusions might be drawn if only a few figures were given. When making drawings of the epidermis I have chosen parts of the leaf surface which would show the typical structure and have avoided portions in the vicinity of the large vascular bundles or near the leaf margin. My drawings of leaf cross sections are slightly diagrammatic.

Material.—The plants were grown at the royal Botanical Garden, Peradeniya, Ceylon during the months April to July, 1904. I wish to express my appreciation of the facilities offered me for study at Peradeniya and to thank Mr. J. C. Willis, the director, and Mr. J. B.

Carruthers, the assistant director, for their uniform courtesy. While at the gardens I secured a large amount of other material which I hope to study in the not far-distant future.

Jatropha curcas *Linn.*

General.—Most of the *Euphorbiaceae* have foliaceous cotyledons but the leaf-like appearance of the cotyledons in this species is particularly well marked. A large lamina is developed which is broadly ovate with heart-shaped base. It reaches a length of 60 mm. and a width of 50 mm. The cotyledons do not resemble the leaves in form or in venation but the texture is much the same. The foliage leaves are palmately veined and somewhat the shape of a maple leaf. The sinuses are shallow. *Jatropha curcas* is a shrub or small tree. A full account of the external features of the seedling is given by Lubbock.[1]

Epidermis as seen in surface view.—The cotyledons and leaves have a similar epidermis, the cells only slightly wavy in outline. In both structures the cells of the upper surface are larger than those of the lower surface. Both faces of the cotyledon have stomata. In the leaf, stomata are very few on the upper surface but numerous below.

Internal structure.—Very little difference is to be seen in vertical sections of expanded portions of cotyledon and leaf. A well-developed palisade occurs in both, but the cells of this are larger in the leaf than in the cotyledon.

Cotyledon stalk and leaf petiole.—Here very marked differences occur. The vascular tissue of the cotyledon stalk is in the form of an interrupted arc composed of about seven bundles. In the leaf petiole, on the other hand, the vascular tissue forms a hollow cylinder just as in a stem, and even in a very young petiole a large number of bundles may be counted, arranged in an interrupted circle.

Manihot glaziovii *Mull. Arg.*

General.—This *Euphorbiaceous* tree furnishes "Ceara rubber." The cotyledons are distinctly foliaceous but very different from the leaves in shape and venation. The lamina is oblong and notched at the base instead of being palmately lobed as is the case with the leaf.

[1] Lubbock, *Seedlings.* 2:484. 1892.

In the seed the blade of the cotyledon is 12 mm. long; it grows to be 45 mm.

Epidermis as seen in surface view.—So far as my observations go it seems that there is no essential difference in the epidermis of the cotyledon and leaf. All the cells have a somewhat wavy outline. Both surfaces of the leaf and cotyledon are provided with stomata.

Internal structure.—Here, again, the two organs are much alike. In fact, save for the somewhat larger size of cells in the cotyledon they can hardly be distinguished in cross section unless attention be paid to the vascular tissue. Both are quite thin. They have a single layer of palisade and about five layers of cells forming the spongy parenchyma.

Cotyledon stalk and leaf petiole.—In these there are marked differences. The cotyledon stalk is flattened and there are but two vascular bundles. A well-developed endodermis extends around the outer, or under, surface, forming about three quarters of an ellipse. Parallel to this is a layer of cells with dark brown contents. Five vascular bundles are found in the leaf petiole, which is nearly cylindrical and the endodermis extends the whole way around accompanied by the layer of cells with dark contents.

Eriodendron anfractuosum *D.C.*

General.—This species is known as the "white cotton tree" or "silk cotton tree." It belongs to *Bombacaceae.* The cotyledons are strikingly leaf-like in appearance. They increase in size after opening and carry on all the assimilatory work of the plant for some time. The foliage leaves are slow in appearing. These are palmate and the leaflets are very different from the cotyledons. I give no drawing of this seedling as a good figure is printed by Lubbock.[1]

Epidermis as seen in surface view.—Stomata are found only on the lower surfaces of both cotyledon and leaf; they are far more numerous on the leaf. Distinct reticulate thickenings of the outer epidermal walls are present on the lower leaf surface but absent from the corresponding area of the cotyledon. The upper surfaces of both structures have slightly thickened wavy lines.

[1] Lubbock, *Seedlings.* 1:261. 1892.

Internal structure.—Vertical sections show some difference in the palisade. This consists of a single row of rather short cells in the cotyledon, while in the leaf there is one row of long cells next the epidermis and another row of short cells below the first. The cells composing the upper epidermis of both leaf and cotyledon are of relatively enormous size, being nearly as deep as the palisade cells. In the leaf the epidermis becomes two-layered. A similar epidermis has been recorded[1] for certain other *Bombacaceae*, but apparently this particular plant has not been previously examined.

Cotyledon stalk and leaf petiole.—A marked difference is seen in these structures. The former is flattened, channeled above and rounded below, while the latter is nearly cylindrical. There is a single broad, flat, bow-shaped vascular bundle in the cotyledon stalk and about eight bundles, arranged in a circle, in the leaf petiole. Eventually these eight bundles cannot be distinguished in the complete vascular cylinder produced.

Bombax malabaricum *D.C.*

General.—This plant is known as the "red cotton tree," the name serving to distinguish it from the species just described. The cotyledons are distinctly leaf-like in appearance and texture resembling strongly those of *Eriodendron anfractuosum.* There are, however, certain constant differences in the venation. The first foliage leaf of *Bombax* is palmately three-parted. The later leaves are five-parted.

Epidermis as seen in surface view.—None of the cells have a very wavy outline. Stomata occur an the under surface of the leaves and cotyledons but not on the upper surface of either. In this species, as other species which I have examined, the stomata are more abundant on a given area of the leaf than on a like area of the cotyledon. Numerous bulbous, multicellular trichomes are placed on the lower surface of the leaf and a few of these occur on the cotyledon. There are fine ridges on the surfaces of the epidermal cells of the leaf but these were not observed on the cotyledon.

Internal structure.—The upper epidermis of the leaf becomes two-layered as the leaf reaches its full size. Whether a like tangential divi-

[1] Solereder. *Syst. Anat. der Dicotyledonen.* 167. 1899.

sion of the epidermal cells of the cotyledon ever occurs, I do not know. Such division does not appear in any of my sections. The upper epidermis is relatively thicker in the leaf than in the cotyledon. Both structures have a one-layered palisade; but in the leaf the cells below this are somewhat elongated vertically so that one might almost call this a two-layered palisade. The spongy parenchyma of the cotyledon consists of about five layers of cells while in the leaf there are only about three.

Cotyledon stalk and leaf petiole.—Four large vascular bundles are found in the leaf petiole. They are arranged with phloem outside in a continuous ring. In transverse section the xylem area has the form of a Maltese cross. Only a single broad, flat vascular bundle is found in the cotyledon stalk and the stalk is much flattened dorso-ventrally, being concave above and convex below.

COUROUPITA GUIANENSIS *Aubl.*

General.—This is the "cannon ball tree," cultivated in the tropics, and well known for its wealth of dark red flowers, produced on small branches of the main trunk and followed by the large, smooth, spherical fruits. It belongs to the family *Lecythidaceae.* The cotyledons resemble the leaves very closely in shape and venation. In fact, this plant affords the only example I know in which the cotyledons really are closely like the leaves.

Epidermis as seen in surface view.—The epidermal cells of both leaf and cotyledon are wavy in outline. Apparently no stomata occur on the upper surface of either, although present on the lower surface in both. A given area of leaf has a greater number of stomata than the same area of cotyledon. The nuclei of the epidermal cells of the cotyledon are very prominent.

Internal structure.—The leaf palisade is well marked and consists of a single layer of cells. About five layers of cells go to make up the spongy parenchyma. The cotyledon has what looks like an incipient palisade above a large-celled spongy parenchyma. The palisade layer has somewhat the appearance of that in young leaves, but the cells are of different shape, peing pointed below. Hence, the palisade of the cotyledon cannot be said to show a mere case of arrested development. Here, as in most cotyledons, the spongy parenchyma consists of rather regular cells not bulged out variously as in the leaf. A few multicellular trichomes are present toward the base of the leaf lamina and are continued in greater number along the petiole.

Cotyledon stalk and leaf petiole.—As the cotyledons are practically sessile perhaps no useful comparison can be made with the leaf petiole. However, sections of the extreme narrowed basal part of the cotyledon were made. These show the vascular bundles entering the cotyledon in the form of a flat interrupted arc. In the leaf petiole a similar arc of bundles is found but in addition there are also other bundles above. These, in the first few leaves of the seedling, are not numerous but in leaves taken from old trees they form two or more arcs parallel to the main one.

Ipomoea coccinea *Linn.*

General.—The cotyledons of this species are broadly trapezoidal with the base rounded and slightly heart-shaped while the apex has a broad, shallow sinus. The first leaf is somewhat cordate with sagittate base. Later leaves are narrower and more markedly sagittate.

Epidermis as seen in surface view.—Both surfaces of the leaves and cotyledons have stomata and the cells are wavy in outline. As usual, stomata are very abundant on the lower surface of the leaf, less so on the upper surface and on the cotyledon. The guard cells are flanked by narrow cells which usually differ considerably in size. While the the cotyledons are glabrous the leaves have scattered pubescence.

Internal structure.—A comewhat irregular three-layered palisade is found in the cotyledon, which is thicker than the leaf and evidently modified as a storage organ. There is only one layer of palisade cells in the leaf and these cells are quite long. No special differences are to be noted on the spongy parenchyma of the two structures.

Cotyledon stalk and leaf petiole.—Both are channeled above and rounded below. Neither one is greatly flattened. In the cotyledon stalk there are two principal vascular bundles placed close together and in some specimens almost fused. A well-defined endodermis with starch grains lies below these bundles. In addition to these principal bundles there are two very small ones, one on each side, running close to the upper surface of the leaf stalk. Five bundles may be usually recognized in the leaf petiole, the three lower ones being sometimes closely approximated. Here, as in the cotyledon stalk, the endodermis may be recognized extending below the larger bundles. The structure of this cotyledon stalk has been described by Dangeard.[1]

SOLANUM QUITOENSE *Lam.*

General.—The cotyledons of this species are distinctly foliaceous; they are ovate in shape with acute apex. The leaves are rather broadly obovate with truncate apex. Scattered glandular hairs are present throughout. A description of the seedling of this plant is given by Lubbock. My plants correspond to his description[2] except that all my measurements are about 50 per cent. greater.

Epidermis as seen in surface view.—Very little difference is to be recognized between the epidermis of the leaf and that of the cotyledon. Stomata are present on the upper and lower surfaces of both structures but fewest on the upper surface of the leaf. The epidermal cells have a wavy outline, this waviness being more pronounced in the case of the leaf.

Internal structure.—Both leaf and cotyledon show "shade plant" characters. The palisade is poorly developed and the intercellular spaces large. As my plants were grown in a somewhat shaded situation their structure may be slightly different from the usual. The leaf is much thinner than the cotyledon, the difference being due to the size of the cells. A greater proportion of the total thickness of the leaf is formed by the palisade than is the case in the cotyledon.

Cotyledon stalk and leaf petiole.—These are of similar form, both being channeled above and rounded below. A single vascular bundle extends through the central part of each. This is somewhat more massive in the leaf petiole. Of all the plants examined this species shows the greatest similarity in leaf petiole and cotyledon stalk.

COSMOS BIPINNATUS *Cav.*

General.—In this species the cotyledons are linear while the early leaves are ovate and deeply cleft. The cotyledons increase greatly

[1] DANGEARD, *Le Botaniste*, 1:104, 1899. [2] LUBBOCK, *Seedlings*. 2:295. 1892.

in size after coming above ground and function as leaves for a long time. Although thicker than the leaves they may be described as foliaceous.

Epidermis as seen in surface view.—The epidermis is composed of cells with a very wavy outline. On the whole, they are about alike in cotyledon and leaf. Stomata are, however, absent from the upper face of the leaf. A row of multicellular hairs occurs along the margin of the leaf. No such hairs were seen on the cotyledon.

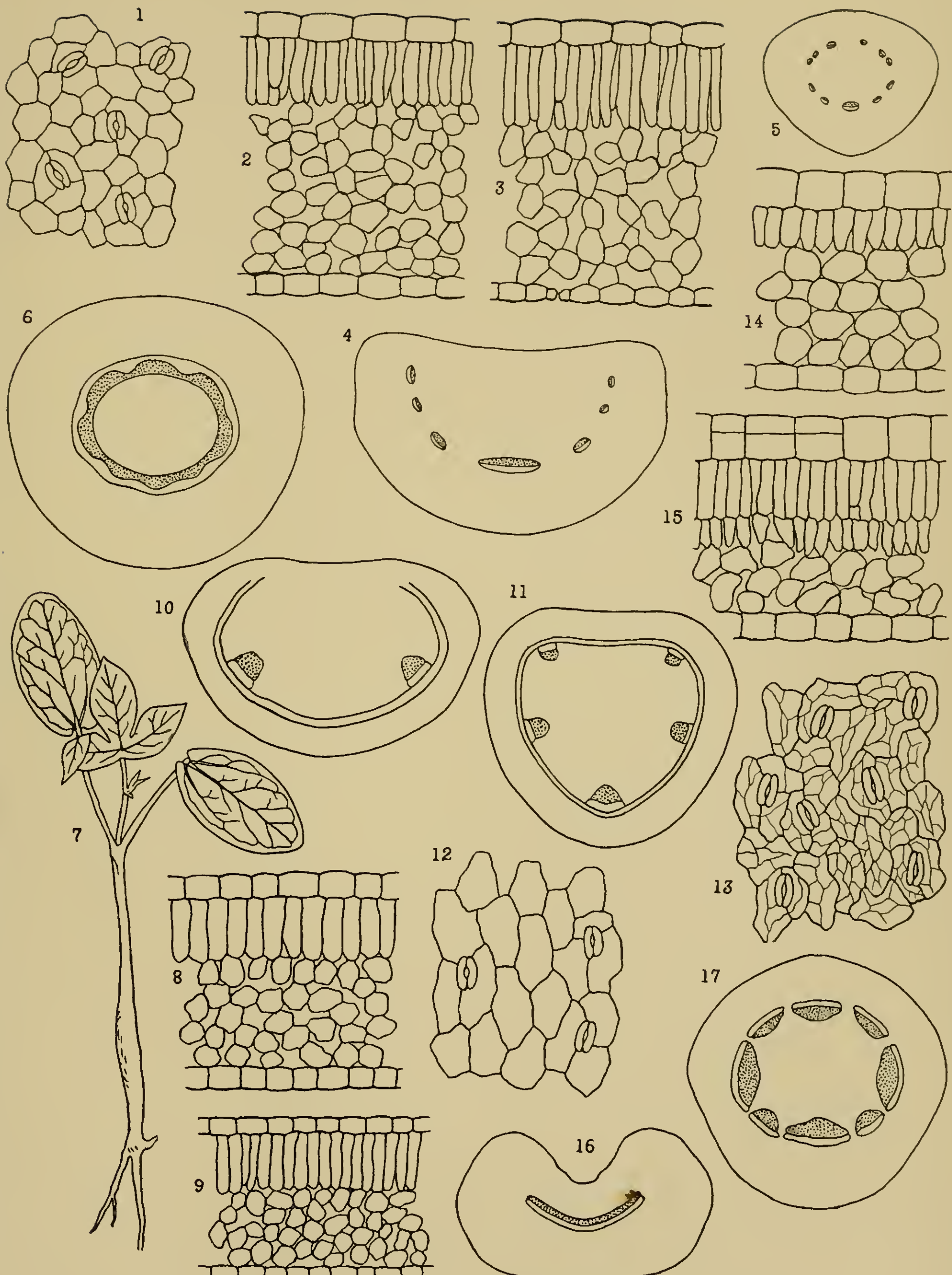
Internal structure.—The palisade cells of the leaf are narrow and placed close together. In the spongy parenchyma there are about four rows of cells. The cotyledon has a loose palisade with many large intercellular spaces. All the cells of the cotyledon are large.

Cotyledon stalk and leaf petiole.—Neither the cotyledon or leaf has a well-defined stalk, but the basal part of the foliage leaf might well be called a winged petiole. So also, the cotyledon is very much narrowed at the base. Sections were made of these narrowed bases. Two well-developed median vascular bundles were found in the cotyledon and, in addition, a small bundle on each side at the margin. In the leaf base there is a single median bundle and two lateral ones not far away.

Summary

The foregoing account refers to seedlings of eight different species of tropical plants, for the most part trees and shrubs. It may be considered as a report of progress. Very little is known concerning cotyledon structure and it was thought that a fully illustrated account of a few species would be of interest. The species were selected because of their foliaceous cotyledons; and both cotyledons and foliage leaves were studied. If the cotyledon be a leaf, as has been generally supposed, we should expect its anatomy to agree with that of the leaf except where modified for storage purposes. A comparative study should throw some light on the nature of the cotyledon. The observed differences in structure of cotyledon and leaf, as shown in the present and in former papers[1] by the author, tend to confirm the view that these two members of the plant body are not really of the same nature.

[1] Published in the *Botanical Gazette* and in the *University of Colorado Studies*.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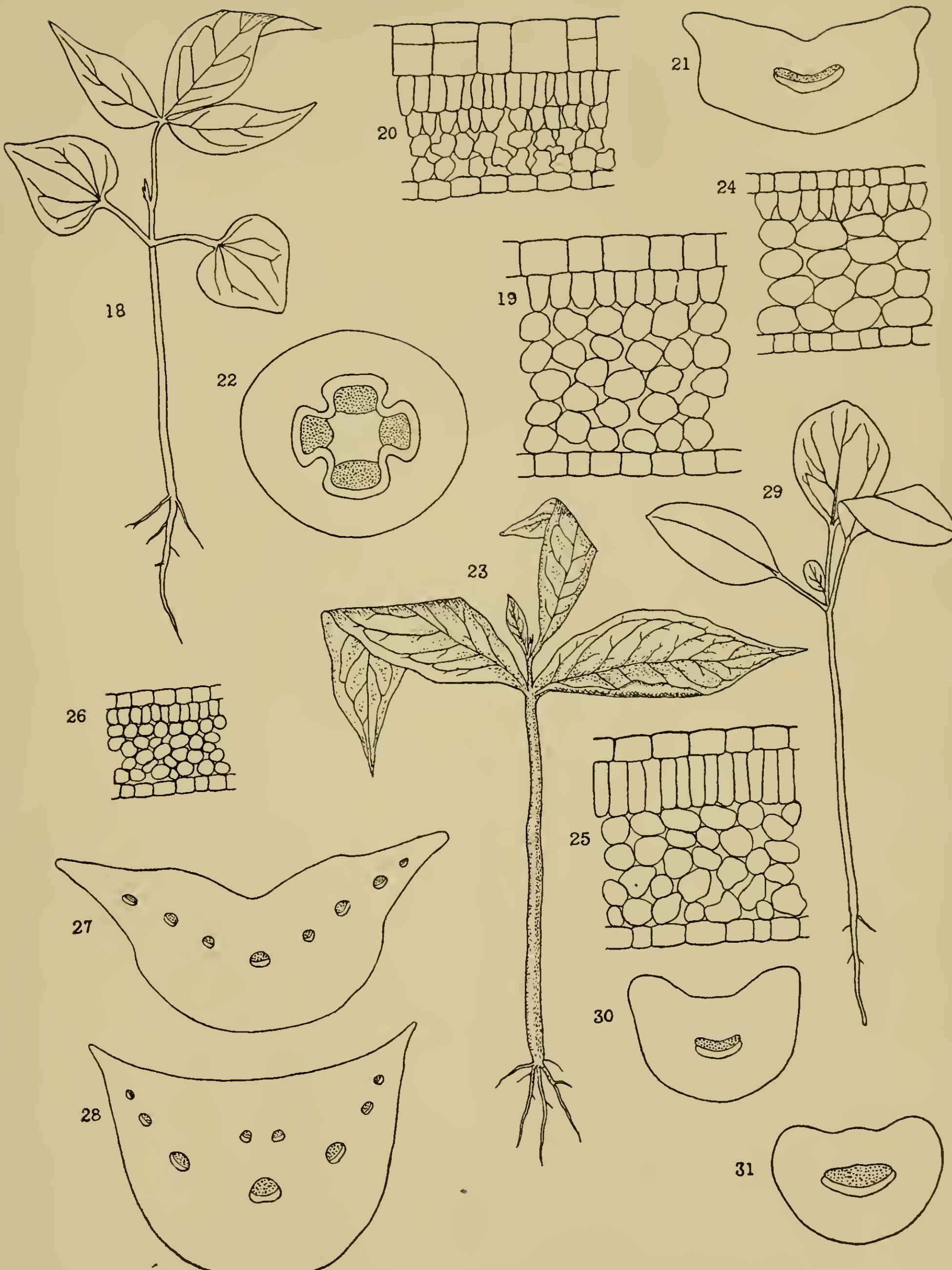
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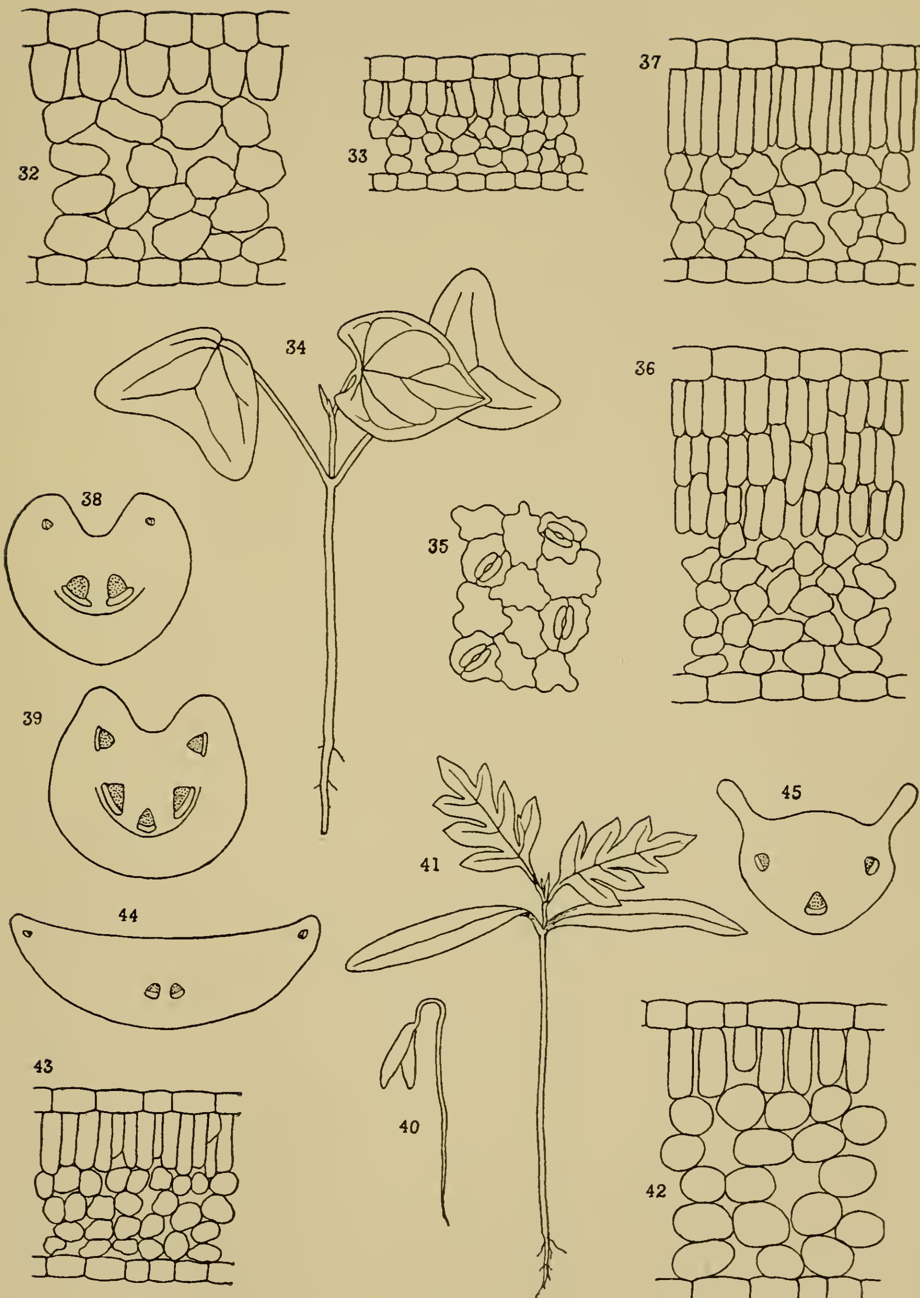
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EXPLANATION OF FIGURES

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All drawings were made by the author from his own preparations. The drawings of epidermis and of vertical sections of leaves and cotyledons represent a magnification of about two hundred and fifty diameters.

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