Transactions of the Wisconsin Academy of Sciences, Arts and Letters. volume XII, Part II 1899

Madison, Wis.: Wisconsin Academy of Sciences, Arts and Letters, 1899

https://digital.library.wisc.edu/1711.dl/B44YAM2CN6YXH8B

TRANSACTIONS

OF THE

WISCONSIN ACADEMY

OF

SCIENCES, ARTS, AND LETTERS

VOL. XII, PART II

1899

WITH TWELVE PLATES

EDITED BY THE SECRETARY

Published by Authority of Law

MADISON
Democrat Printing Company, State Printer
1900

TRANSACTIONS

OF THE

WISCONSIN ACADEMY

OF

SCIENCES, ARTS, AND LETTERS

VOL. XII, PART II

1899

WITH TWELVE PLATES

EDITED BY THE SECRETARY

Published by Authority of Law

MADISON
DEMOCRAT PRINTING COMPANY, STATE PRINTER
1900

LIST OF PLATES.

TABLE OF CONTENTS.

ORIGINAL PAPERS.

MEMORIAL ADDRESSES.

THE WISCONSIN ACADEMY OF SCIENCES, ARTS, AND LETTERS.

PROCEEDINGS OF THE ACADEMY.

Report of the Secretary —

CORRECTIONS.

VOL. XI.

PAGE.
564, Line 2. For "1898" read "1897."

VOL. XII.

78, Line 6. Following "1815" for "in" read "it."
78, Line 32. For "paid are" read "were."
203, Line 4. For "Barbie" read "Barbier."
502, Line 2 from foot. For "three" read "five."
508, Omit triangle No. 20.
402, Table following. Read "Table I."

THE ELECTRICAL CONDUCTIVITY OF NON-AQUEOUS SOLUTIONS.[1]

AZARIAH THOMAS LINCOLN, PH. D.
University of Wisconsin.

WITH PLATES II TO VII.

INTRODUCTION.

Van't Hoff formulated his modern theory of solutions from the results of Pfeffer's[2] classic experiments on the osmotic pressure of a few substances in aqueous solutions, and from the work of de Vries[3] who pointed out that equimolecular quantities of dissolved substances produce the same osmotic pressure. Van't Hoff[4] stated that the condition of a substance in the gaseous state is analogous to the condition in which a substance exists in dilute solutions wherein the osmotic pressure of the dissolved substance corresponds to the pressure of the gaseous particles. It was soon observed, however, that many substances did not give normal values for the osmotic pressure, the rise of the boiling, or lowering of the freezing point; and thus that the laws of gases would not hold for solutions of these substances.

Arrhenius pointed out that those substances which yield solutions in water that conduct electricity are acids, bases, and salts (called electrolytes); and that they are the same class of compounds as give abnormal values for the osmotic pressure, the rise of the boiling point, and the lowering of the freezing point in aqueous solutions. In order to explain these anom-

---

[1] A thesis submitted for the degree of Doctor of Philosophy, University of Wisconsin, 1899.

[2] *Osmotische Untersuchungen*, Leipzig, 1877.

[3] *Zeit. phys. Chem.* **2**, 414; 1888.

[4] *Zeit. phys. Chem.* **1**, 481; 1887.

alous results, Arrhenius[1] promulgated his well known theory of electrolytic dissociation, which has been very widely accepted. The theory has, however, met with very strong opposition particularly from the English chemists. Some English scientists contend that the supposition that the molecules of the dissolved substance are electrolytically dissociated is not necessary to explain the facts, and that in many cases it is not adequate. However, the dissociation theory has stimulated the investigation of aqueous solutions and particularly as to their electrical conductivity. Attention has also been directed to the study of mixtures of water with other solvents, and more recently the attention of scientists has been directed towards the character of solutions other than aqueous. The investigation of non-aqueous solutions is replete with interest, and many lines of research, both theoretical and practical, offer themselves, the interdependence of which is very apparent. But the present research is confined chiefly to the electrical conductivity of non-aqueous solutions.

The degree of dissociation in aqueous solutions is calculated from determinations of the electrical conductivity and also from the rise of the boiling point and the lowering of the freezing point of the solutions; and the results show very close agreement. Hence in connection with the conductivity measurements of non-aqueous solutions, it is desirable to have boiling point and cryscopic determinations to aid in ascertaining the molecular condition of the dissolved substance. Since these methods are employed to determine to what extent the dissociation has taken place in aqueous solutions, one would naturally be inclined to apply them to solutions other than aqueous; for it is reasonable to suppose that the methods are as applicable to one solvent as to another. The advocates of the electrolytic dissociation theory state that whenever any solvent conducts electricity the dissolved substance is dissociated electrolytically, and consequently the solvent possesses dissociative power. This meaning of the term, dissociative power, will be retained throughout this paper. The agreement between the values for the degree of dissociation in non-aqueous solutions

---

[1] *Zeit. phys. Chem.* **1**, 631; 1887.

as calculated from the boiling point or the cryscopic, and from the conductivity determinations, is not nearly as close as in the case of aqueous solutions. In many cases the boiling point determinations show practically no dissociation, while the solution conducts well. It must be remembered, however, that a slight amount of dissociation cannot be detected by the boiling point method; and where the conductivity is slight, the dissociation might be sufficient to account for it. However, this difficulty would not be experienced in solutions that conduct well. Since these methods are used to determine the degree of dissociation and the results show so slight an agreement in non-aqueous solutions, it seems but proper to ask which of these methods shows the correct degree of dissociation; and one might further ask which of the methods is a measure of the dissociative power of the solvent.

A number of auxiliary theories have been advanced to explain many of the facts observed in relation to the conductivity of non-aqueous solutions. Nernst[1] calls attention to the fact that solvents which conduct electricity have a high specific inductive capacity. Brühl[2] concludes that the dissociative power of solvents is dependent upon spare valences; that is, the solvents that yield solutions which conduct, are unsaturated compounds. Dutoit and Aston[3] claim that only those solvents the molecules of which are polymerized, yield conducting solutions. Abegg points out that even these theories are not sufficient to explain satisfactorily the phenomenon of the electrical conductivity of non-aqueous solutions. These theories will be discussed more fully subsequently.

In face of the data that have been collected, and in view of the fact that such a large number of chemists to-day do not accept the electrolytic dissociation theory as applied to aqueous solutions, one may well hesitate to apply this theory to non-aqueous solutions, until there is a sufficiently firm experimental basis to justify it. The chief object of this investigation is

---

[1] *Zeit. phys. Chem.* **14**, 622; 1894.

[2] *Zeit. phys. Chem.* **18**, 514; 1895; **27**, 317; 1898; *Ber. Chem. Ges.*, Berlin **30**, 162; 1897.

[3] *Comptes rendus*, **125**, 240; 1897.

therefore, to determine to what extent Arrhenius' theory, which is based upon the behavior of electrolytes in aqueous solutions, can be applied to the solutions that are non-aqueous. In presenting the results of this investigation, an inquiry will also be made as to whether there is any relation existing between the dissociative power of solvents and their other general properties.

EXPERIMENTAL PART.

Qualitative Determinations.

In an investigation of the electrical conductivity of non-aqueous solutions, the chief requirement is that both the solvents and the dissolved substances be absolutely free from water. To accomplish this is not an easy task. Then, too, the question arises as to what anhydrous salts are soluble in the various solvents. In many cases this could only be answered by experiment. The work of other investigators on the conductivity of non-aqueous solutions has been confined almost exclusively to the salts of the alkalies, ammonium and the substituted ammonias. It was soon learned by direct experiment that the chlorides of many of the heavy metals are soluble in a number of organic solvents and that the solutions formed conduct electricity. Therefore the investigation was confined chiefly to the conductivity of the solutions of the salts (mostly chlorides) of the heavy metals. Even when the salts were readily soluble, conducting solutions were not always obtained. In order to determine what solutions conduct and to estimate roughly, at least, the relative magnitude of the conductivity, it was necessary to perform an elaborate series of qualitative experiments to ascertain what solvents yield solutions having a conductivity sufficient to justify quantitative measurements.

The method employed in making the qualitative determinations was as follows: Into a resistance cell of the Arrhenius pattern, the electrodes of which were about three millimeters apart, was introduced the solution to be tested. This cell, a rheostat, and a delicate galvanometer were placed in the circuit of a Leclanché element. The circuit was then completed and the deflection of the galvanometer needle noted. It was very seldom that any resistence had to be introduced by means of the rheostat. A hundredth normal solution of sulphuric acid gave a deflection of about twenty divisions when 500 ohms resistance was introduced. By means of a direct current thus employed polarization of course could not be avoided. The circuit was only closed for a few seconds. The sole object of these experiments being to ascertain whether the solution conducted, and to determine only very roughly the relative magnitude, the slight amount of polarization could be entirely neglected.

The solvents were all of the C. P. variety of standard makes: Kahlbaum, Merck, Schuchardt, or Trommsdorff. Professor Kremers of the pharmacy department of this university kindly furnished several compounds from his collection and Professor Hillyer kindly placed at my disposal a number of solvents in his possession. For thus furthering the experimental work, I desire to extend to these gentlemen my thanks. The methods employed in rectifying and dehydrating these solvents will be found under the head of the particular solvent in the record of the quantitative determinations.

The salts employed were absolutely anhydrous and the method employed in their preparation and dehydration will now be given.

Ferric chloride was prepared by passing anhydrous chlorine over heated iron wire contained in a hard glass tube. The chlorine was prepared in the usual manner from manganese dioxide and hydrochloric acid. The gas was conducted through a wash bottle containing water to free it from hydrochloric acid, then through sulphuric acid, then through a cylinder containing fused calcium chloride, and finally through another wash bottle containing sulphuric acid. From this it was conducted into the long hard glass tube containing the fine iron wire. This tube was gently warmed, and by increased heat the chloride was sublimed along the tube. This resublimation was repeated several times, and then the tube was sealed off and the product preserved in these sealed tubes. Before using, the tube was opened and allowed to remain under a bell jar containing concentrated sulphuric acid for several days, when not the least trace of free chlorine could be detected in the salt.

The trichloride of antimony was obtained by passing anhydrous chlorine over metallic antimony contained in a retort which was gently warmed. The chlorine was dried in the manner described above. The product was then distilled and this distillate redistilled, during which process all necessary precautions to exclude the moisture of the air were observed.

The cupric chloride was prepared in a manner analogous to that employed in the preparation of the chloride of iron.

Stannous and aluminium chlorides were prepared by passing dry hydrochloric acid gas over the respective metals which were contained in hard glass tubes. The hydrochloric acid gas was prepared by dropping concentrated hydrochloric acid into concentrated sulphuric acid, and then drying it by passing the gas through a train consisting of three bottles containing concentrated sulphuric acid and a cylinder filled with fused calcium chloride.

The trichloride of bismuth was prepared by Professor Kahlenberg by treating the hydroxide of bismuth with concentrated hydrochloric acid, evaporating the solution to a thick paste and thus volatilizing a large portion of the excess of the hydrochloric acid. The residue after cooling was finally broken up and tranferred to a Berlin porcelain retort and purified by distillation.

These chlorides were all pure and perfectly anhydrous; and every precaution necessary to keep them so was employed.

Arsenic trichloride was prepared by treating arsenious acid with dry hydrochloric acid gas in a retort and then distilling the product. This distillate was redistilled, and had a very constant boiling point.

The stannic chloride used was an anhydrous product from Schuchardt. The phosphorus trichloride from Kahlbaum was redistilled and that portion taken that gave a constant boiling point.

A C. P. sample of manganous chloride from Merck was recrystallized several times and then heated for several days in an air bath at a temperature of about 100° C. It was then thoroughly pulverized in a mortar and returned to the bath, where it remained for about two days longer. C. P.

samples of the chlorides of nickel and cadmium from Schuchardt were dehydrated in a similar manner. The C. P. sample of cobaltic chloride from Trommsdorff was treated in the manner just described; but the temperature was raised to about 120° C. for several hours. The C. P. samples of lead nitrate and mercuric iodide from Merck, mercuric cyanide from Trommsdorff, and zinc chloride from Kahlbaum were dehydrated, in the manner described above, at a temperature not exceeding 100° C. The silver cyanide was prepared from potassium cyanide and silver nitrate by Professor Kahlenberg, who dehydrated it and upon subsequent analysis found it to be pure.

During the course of the qualitative experiments a great many interesting facts relative to the solubility, color of solutions, etc., were brought out, to most of which it will not be possible to call attention at the present time. It was soon observed that if ferric chloride did not yield solutions that conducted electricity, it was not worth while to make tests with certain other salts; and for this reason many blank spaces occur in the following table. In each case the conductivity of the solvent was tested and the deflection of the galvanometer needle noted. In nearly all cases it was found that the solvents were excellent insulators, giving no deflection of the needle whatever. In the case of acetic aldehyde, furfurol, and ethylene glycol, the deflection was several divisions. When the salts were found to be quite soluble, the solutions were prepared in the resistance cell; but they were usually made up in small test tubes and frequently by the aid of heat. The strength of the solutions was not determined accurately; but it varied, being as high as five per cent. in some cases.

The electrolytic dissociative power of a solvent is believed by the supporters of the dissociation theory to be measured by the conductivity of its solutions. Since the qualitative determinations throw some light upon the dissociative power of solvents, the results are given in Table I. In the first two columns are given the names and formulæ of the solvent. In the next twenty-two columns is indicated whether the solutions of the several salts whose formulæ head the respective columns conduct electricity. Where the solution conducted so poorly that no deflection of the galvanometer needle was observed, the fact is indicated by the minus sign (—). The plus sign (+) indicates that the solution did conduct. The addition of the interrogative sign to the plus sign (+ ?) indicates that a very slight movement of the needle was detected; and when the plus sign is followed by the exclamation mark (+ !), this indicates that the solution conducts sufficiently well to make a quantitative determination desirable. The magnitude of the conductivity can be learned from the quantitative results given subsequently. Blank spaces indicate that determinations were not made, and the letter *i* indicates that the salt was insoluble in the solvent or very difficultly soluble. In the last two columns respectively, are given the dielectric constants and the coefficients of association of the solvents. The data in these two columns are as complete as could be obtained from the literature.[1]

The letters R & S refer to the article by Ramsay and Shields as authority;[2] R & A to the work of Ramsay and Aston;[3] and D & F to that of Dutoit and Friderich.[4] The letter V designates determinations by Vollmer, C by Carrara, D & A by Dutoit and Aston, and S by Schlamp.

From Table I it will be observed that ferric chloride dissolves in the hydrocarbons and their halogen substitution products, but the resulting solutions do not conduct. This is in harmony with what other investigators[5] have found concerning solutions of other salts in these solvents. It will be noted that both the dielectric constants and the coefficients of association (as far as they were available) are very low. The acid chlorides, acetyl and benzoyl chlorides, yield solutions of ferric chloride and antimony trichloride that do conduct. The coefficient of association in the case of acetyl chloride is about unity, thus showing no polymerization and the dielectric constant (the results of Drude and Thwing differ greatly) is much

---

[1] (1) Thwing, *Zeit. phys. Chem.* **14**, 286; 1894.
(2) Drude, *Zeit. phys. Chem.* **23**, 308; 1897.

[2] Ramsay and Shields, *Jour. Chem. Soc.* **63**, 1089; 1893.

[3] Ramsay and Aston, *Jour. Chem. Soc.* **65**, 168; 1894.

[4] Dutoit and Friderich, *Bull. Chim. Soc. Paris* (3) **19**, 321; 1898.

[5] Kablukoff, *Jour. Russ. Chem. Soc.* **23**, 391; 1893. (Ref.) *Jour. Chem. Soc.* **64**, ii. 151; 1893.

Solvent.	Formula.	$FeCl_3$	$AlCl_3$	$CrCl_2$	$MnCl_2$	$ZnCl_2$	$CoCl_2$	$NiCl_2$	$CuSO_4$	$CuCl_2$	$CdCl_2$	$BiCl_3$	$AsCl_3$	$SbCl_3$	$SnCl_2$	$Pb(NO_3)_2$	$HgCl_2$	$Hg(CN)_2$	HgI_2	$AgNO_3$	$AgCN$	KCl	$LiCl$	Dielectric constant (air = 1)		Coefficient of association.	
1 Heptane	C_7H_{16}	—																									1
2 Amylene	C_5H_{10}	—																						2.30	Landolt & Jahn	0.96 R & S (Schiff)	2
3 Benzene	C_6H_6	—										i		—										2.3377	Palaz	1.01 R & S	3
4 Toluene	C_7H_8	—										i		—										2.3648	"		4
5 Xylene	C_8H_{10}	—										i		—										2.2758	Negreano		5
6 Cymene	$C_{10}H_{14}$	—												—										2.47	"		6
7 Menthene	$C_{10}H_{18}$	—												i													7
8 Chloroform	$CHCl_3$	-																						3.95	Thwing	0.94 R & S (Eötvös	8
9 Carbon tetrachloride	CCl_4	—																						2.2	Tereschin	1.01 R & S	9
10 Methylene iodide	CH_2I_2	—																									10
11 Ethylene chloride	$C_2H_4Cl_2$	—																									11
12 Ethylene bromide	$C_2H_4Br_2$	—																								0.95 R & S (Eötvös)	12
13 Monobrom benzene	C_6H_5Br	—																									13
14 Benzyl chloride	$C_6H_5CH_2Cl$	—										i		—			—										14
15 Benzal chloride	$C_6H_5CHCl_2$	—										i		—			—										15
16 Benzotrichloride	$C_6H_5.CCl_3$	—																									16
17 Acetyl chloride	$CH_3.COCl$	+!										i		+			i							25.3 15.4	Thwing Drude	1.06 R & S	17
18 Benzoyl chloride	C_6H_5COCl	+!										i		+			+(?)										18
19 Methyl alcohol	CH_3OH	+!												+!									V	32.65	Tereschin	3.43 R & S	19
20 Ethyl alcohol	C_2H_5OH	+!								+!	i			+!						V			V	25.7	Rosa	2.74 R & S	20
21 Propyl alcohol	$CH_3(CH_2)_2OH$																						S	20.8	Thwing	2.25 R & S	21
22 Allyl alcohol	C_3H_5OH	+!																		+!			+!	21.6	Thwing	1.88 R & S	22
23 Benzyl alcohol	$C_6H_5CH_2OH$	+!	i	—		—				—		+		+!			+!			—			+!	10.6	Drude		23
24 Ethylene glycol	$C_6H_4(OH)_2$	+!										+!		+!			+									2.92 R & S	24
25 Glycerol	$C_3H_5(OH)_3$	+!										+!		+!			+							16.5	Drude	1.80 D & F	25
26 Epichlorhydrine	$C_3H_5O.Cl$	+										+		+			+										26
27 Phenol	C_6H_5OH	+										+		+			+							9.68	Drude	1.42 R & A	27
28 Meta-cresol	$C_6H_4.CH_3OH$	+										—		—			+(?)										28
29 Ethyl ether	$(C_2H_5)_2O$	—																						4.373	Donle	0.99 R & S	29
30 Phenyl-methyl ether	$C_6H_5.O.CH_3$	+										i		—			—										30
31 Acetic anhydride .	$(CH_3CO)_2O$	+										+(?)	—(?)	+(?)												0.99 R & S	31
32 Acetic aldehyde	CH_3COH	+!										+		+!			+							18.55	Thwing		32
33 Chloral anhydride	$CCl_3.COH$	—												—										5.47	"	1 02 R & S	33
34 Paraldehyde	$C_6H_{12}O_3$	+!										+		+			+									0.85 R & S	34
35 Benzaldehyde	$C_6H_5.COH$	+!												+			+			i				14.48	"	0.97 R & S	35
36 Cinnamic aldehyde	$C_6H_5.C_2H_2COH$	+!										i		+			+										36
37 Salicylic aldehyde	$C_6H_4CHO.OH$	+!	—		—	i	i	—		—				—		i	—	i	—	i			+!	19.21	"		37
38 Furfurol	$C_5H_4O_2$	+!			i	+	—	—	i		i	+		+!		—	+		+	+			+!	39.4	Drude		38
39 Acetone	$(CH_3)_2CO$	+!								+!				+!	+								C	21.85	Thwing	1.26 R & S	39
40 Methyl-propyl ketone	$CH_3C_3H_7.CO$	+!	+			+	—			+		+!		+!			+!		+	i			i	16.75	"	1.11 R & S	40
41 Methyl-ethyl ketone	$CH_3C_2H_5.CO$																DA									1.15 D & F	41
42 Acetophnone	$CH_3COC_6H_5$	+!	+		i	+	—	i	i	i	i	+		+!		i	+!	—	—	—			+(?)	16.4	"	1.10 R & S	42
43 Ethyl acetate	$CH_3COOC_2H_5$	+!								+		+		+	+									6.5	Tereschin	0.99 R & S	43
44 Ethyl monochloracetate	$CH_2ClCOOC_2H_5$	+!	—		i	+	—	i	—	+	i	+		+		i	+	i	—	—		i	+(?)				44
45 Ethyl cyanacetate	$CH_2CN.COOC_2H_5$	+!	+		i	+(?)	—	i	i	+!	i	+		+		i	+	—	—	+!		i	i	26.7	Drude		45
46 Ethyl acetoacetate	$CH_3CO.CH_2COOC_2H_5$	+!			i	+	+	i		+		+	+	+		i	+		—	i			+!	15.7	"	0.96 R & S	46
47 Propyl acetate	$CH_3COOC_3H_7$	+																						6.3	Tereschin		47
48 Butyl acetate	$CH_3COOC_4H_9$	+																						5.0	Drude		48
49 Propyl propionate	$C_2H_5COOC_3H_7$	+																									49
50 Amyl butyrate	$C_3H_7COOC_5H_{11}$	+(?)																									50
51 Amyl valerianate	$C_4H_9COOC_5H_{11}$	+(?)																									51
52 Ethyl benzoate	$C_6H_5COOC_2H_5$	+		i		+(?)				i				+(?)			+(?)			i			i	6.5	Tereschin		52
53 Ethyl oxalate	$(COO.C_2H_5)_2$	+!		—	i	+	—	i	i	—	i	+		+		i	+	—	—	i			+(?)				53
54 Ethyl carbonate	$CO.(OC_2H_5)_2$	—										—															54
55 Ethyl chlorcarbonate	$COCl.OC_2H_5$	+!										+		+!			+!										55
56 Ethyl nitrate	$C_2H_5NO_3$	+!	+	i	i	i	i	i		i	i	i		+		i	i	i	i				i	17.72	Thwing		56
57 Amyl nitrite	$C_5H_{11}NO_2$	+!			i	+(?)	—	i	i	i	i	i		+		i	+	i	—	i		i	—				57
58 Nitrobenzene	$C_6H_5NO_2$	+!	+	i		i				i		+	+	+			+			i		i		32.19	"	0.93 R & S 1.13 R & S	58
59 o-Nitrotoluene	$C_6H_4.CH_3NO_2$	+!			i		i	i	i	+(?)	i	+		+		i	+		—	i			i	26.58	"		59
60 m- " "	$C_6H_4.CH_3NO_2$	+!																									60
61 Aniline	$C_6H_5NH_2$	+										i		+(?)			+(?)			+!				7.5 7.15	Tereschin Drude	1.05 R & S	61
62 Methyl aniline	$C_6H_5NHCH_3$	+(?)										i		i			+										62
63 Dimethyl aniline	$C_6H_5N(CH_3)_2$	+(?)										i		i			i										63
64 Benzylamine	$C_6H_5.CH_2NH_2$	+										i		i			+										64
65 Toluidine (ortho)	$C_6H_4.CH_3NH_2$	+(?)										+(?)		+(?)			i										65
66 Toluidine (meta)	$C_6H_4.CH_3NH_2$	+(?)										+(?)		+(?)			i										66
67 Xylidine (meta asym)	$C_6H_3(CH_3)_2.NH_2$	i										i		i			i			+!							67
68 Phenylhydrazine	$C_6H_5NH.NH_2$	—										i		i			i										68
69 Aceto-nitrile	$CH_3.CN$																									1.58 1.67 D & F	69
70 Propio-nitrile	$C_2H_5.CN$																									1.77 R & S 1.37 D & F	70
71 Butyro-nitrile	$C_3H_7.CN$																									1.19 1.22 D & F	71
72 Benzo-nitrile	C_6H_5CN	+!										+		+!			+			+!				26.0	Drude	0.97 R & S 1.00 Traube	72
73 Pyridine	C_5H_5N	+	+	+	i	+	+	i	i	+	i	i		i		+	+	+	+	+!	+		+!			0.93 R & S	73
74 Piperidine	$C_5H_{11}N$	i			—	—	—	—	—		i	i		i		i	—		—	+			—			1.08 R & S	74
75 Quinoline	C_9H_7N	+			i	+	—	—	+		i	i		i		i	+		—	+			—			0.81 R & S	75
76 Carbon disulphide	CS_2	—																						2.61	Palaz	1.07 R & S	76
77 Phosphorus trichloride	PCl_3	i										i		—			—	i				i				1.02 R & S	77
78 Arsenic trichloride	$AsCl_3$	+!										+(?)		+			+										78
79 Tin tetrachloride	$SnCl_4$	i										i	i	i			i					i					79

higher than that of the halogen substitution products, — of chloroform for example. The alcoholic solutions, including glycol and glycerol, conduct very well. As many quantitative determinations of the conductivity have been made in methyl and ethyl alcoholic solutions, it was unnecessary to make qualitative tests in this connection. The dielectric constants are relatively high; and the high values of the coefficients of association show that the molecules of these solvents are highly polymerized. The viscosity of glycol and glycerol[1] no doubt diminishes their conductivity. The conductivity of phenol and meta-cresol solutions is not as great as that of the alcoholic solutions, neither is the dielectric constant nor the coefficient of association as great as in the case of the alcohols. The dissociative power of the ethers and even of acetic anhydride is virtually nil. From the dielectric constant of acetic aldehyde one would expect solutions of this solvent to conduct. Such is the case; and the fact that solutions of chloral do not conduct is in keeping with its low dielectric constant. The molecules of chloral are not polymerized. The coefficient of association of acetic aldehyde has not been determined to our knowledge. Notwithstanding the fact that the molecules of paraldehyde are not polymerized, its solutions conduct. Benzaldehye solutions conduct sufficiently to justify quantitative measurements; and this would be expected from the value of its dielectric constant. It will also be noted that according to determinations, by Ramsay and Shields, the molecules of this solvent are not polymerized. Solutions in cinnamic and salicylic aldehydes conduct very well. The specific inductive capacity of furfurol would indicate that this solvent would yield conducting solutions; and such is the case. The ketones tested yield solutions that conduct; and this is in keeping with what other investigators[2] have found.

The esters with few exceptions yield solutions that conduct. Notwithstanding the very low dielectric constant of ethyl acetate,

---

[1] Cattaneo, *Real. Accad. Lincei.* II, 112; 1893. (Ref.) *Jour. Chem. Soc.* **70**, ii, 231; 1896.

[2] Dutoit and Aston (loc. cit.).
Dutoit and Friderich (loc. cit.).

its solutions conduct slightly — compare with chloral. The mono chloracetate, the cyanacetate and the acetoacetate of ethyl all yield solutions that conduct well. The high dielectric constant of the last two will be noted as well as the coefficient of association of the last, which indicates that its molecules are not polymerized. In ethyl monochloracetate $AgNO_3$ is not soluble, while in the cyanacetate it dissolves readily, and the resulting solution conducts well. The electical conductivity of solutions in propyl acetate, butyl acetate and ethyl benzoate is very slight, and it will be noticed that the dielectric constants of these solvents are also low. Propyl propionate solutions conducted very little and in the case of amyl butyrate and amyl valerianate only slight deflections of the galvanometer needle were observed. It is probable that the dielectric constants of these esters are very low. Ethyl oxalate solutions conduct; but those of ethyl carbonate do not, notwithstanding the high oxygen content of this solvent, while ethyl chlorcarbonate yields solutions that conduct very well.

The class of organic solvents containing nitrogen are of particular interest. It will be noticed that ethyl nitrate, amyl nitrite, nitrobenzene, nitrotoluene, benzonitrile and pyridine yield solutions that conduct fairly well (See quantitative determinations). The dielectric constants of these solvents that have been determined would tend to indicate that their solutions would conduct. According to the association coefficients as determined by Ramsay and Shields the molecules of nitrobenzene, benzonitrile and pyridine are not polymerized. The solutions of ferric chloride in aniline, methylaniline and dimethylaniline conduct very poorly, whereas benzylamine appears to conduct slightly better.

In the toluidines ferric chloride is difficultly soluble and only a very slight movement of the galvanometer needle was observed. In xylidine most of the salts were insoluble; but silver nitrate dissolved quite readily and conducted fairly well, and the same was found to be the case in aniline. The dielectric constant for aniline is low, and the coefficient of association shows very slight polymerization. Phenylhydrazine dissolves ferric chloride readily, but not the slightest movement of the needle could be detected. Dutoit and Friderich[1] have shown that the nitriles conduct and the results given in this table shows that benzonitrile is not an exception. The dielectric constant would indicate this; and according to the determinations of Ramsay and Shields, as well as according to those of Traube, the molecules of this solvent are not polymerized. The solubility of the salts tested in piperidine is very slight except mercuric chloride and silver nitrate, and even these do not yield solutions that conduct very well. Quinoline yields solutions that conduct, but its molecules are not polymerized. The solution of ferric chloride in carbon disulphide did not conduct, nor should we expect it to do so from its low dielectric constant. Phosphorus trichloride does not yield solutions that conduct. Arsenic trichloride and mercuric chloride are very soluble in it, yet there was not the least movement of the needle. The solutions of ferric chloride and mercuric chloride in arsenic trichloride conduct very well.

In addition to the results tabulated in Table I it was found that stannic chloride dissolved in arsenic trichloride does not conduct, and the same was true of phosphorus trichloride. When phosphorus trichloride was added to a solution of mercuric chloride in arsenic trichloride, the conductivity was decreased to such an extent that the galvanometer needle did not even move. Further, a large number of other tests were made which were too detailed and numerous to include in these tabulated results. Suffice it to say, however, that of the very large number of tests made, both of organic and inorganic substances in these numerous solvents, there was not one instance where the solution conducted electricity, that the dissolved substance was not an acid, a base, or a salt.

Quantitative Determinations.

The method of Kohlrausch was employed in measuring the electrical conductivity — the resistance cell of the Arrhenius pattern being used. This cell was provided with a tightly fitting cover and the electrodes were about three millimeters apart. The determinations were made at 25° C. unless other-

---

[1] Loc. cit.

wise indicated, and the results are expressed in reciprocal mercury units. The higher temperature at which the conductivity was measured was obtained by heating the resistance cell and its contents in a paraffin bath. Owing to the small quantity of the solvents available in most cases it was not possible to make the dilutions in the ordinary manner. Five or ten cubic centimeters of the solvent were introduced into the resistance cell by means of a carefully calibrated burette, the conductivity was determined, and then weighed portions of the salt were successively introduced and the conductivity determinations made after each addition.

In the following tables of the electrical conductivity v represents the volume in liters in which one gram-molecule is contained and μ the molecular conductivity. Although the conductivity of the solvent has been determined in each case, it has not been deducted.

METHYL ALCOHOL.

The sample of methyl alcohol employed was dehydrated several times with anhydrous copper sulphate, over which it remained several days and from which it was decanted and distilled each time. The distillate was then treated with metallic sodium and again distilled. This distillate was fractionated twice, when a product with a very constant boiling point was obtained. The resistance was so great that the conductivity of the alcohol could be practically neglected. After standing for nine months the specific conductivity had decreased to only 5.7×10^{-6}.

TABLE II.

Solvent: methyl alcohol.

Ferric Chloride, $FeCl_3$. v	μ	Antimony Trichloride, $SbCl_3$. v	μ
3.20	20.81	8.15	15.68
6.41	25.26	16.31	18.94
12.81	31.09	32.62	28.52
25.62	40.90	65.24	43.32
51.24	49.00	130.48	63.33
102.48	60.55	260.96	89.47
204.96	72.61	521.91	118.34
409.91	89.11	1,043.83	156.32
819.83	111.08		
1,639.66	147.08		

ETHYL ALCOHOL.

A sample of absolute alcohol was treated with anhydrous copper sulphate, over which it remained for several days. From this sulphate it was distilled, and the distillate was treated in the same manner as the original portion. The distillate from this was then treated with metallic sodium and then distilled. The distillate was redistilled twice; it boiled constantly at 76.8° at 749 mm. pressure. The specific conductivity was 7.7×10^{-7}.

TABLE III.

Solvent: ethyl alcohol.

Ferric chloride, $FeCl_3$. v	μ	Antimony Trichloride, $SbCl_3$. v	μ
2.89	9.91	8.11	4.18
5.79	13.06	16.23	5.68
11.57	13.70	32.45	7.94
23.14	14.50	64.91	12.30
46.28	15.51	129.81	18.23
92.56	16.69	259.62	29.43
195.12	19.33		
390.24	21.20		

ALLYL ALCOHOL.

A C. P. sample of allyl alcohol from Merck was treated with K_2CO_3, over which it stood for several days. From this it was distilled and the distillate treated with fused potassium hydroxide. The distillate from this was again treated with caustic potash in contact with which it stood several days and then distilled. This distillate was redistilled twice and the conductivity determinations made as soon as possible. The specific conductivity was 6.5×10^{-6}.

TABLE IV.

Solvent: allyl alcohol.

Ferric Chloride, $FeCl_3$. v	μ
20.02	17.42
53.71	23.03
115.60	32.15

Ferric Chloride, (v = 20.02 at 25° C.) t	μ
25°	17.42
50	34.62
73	43.63
80	45.65

BENZYL ALCOHOL.

The sample of benzyl alcohol employed was from Merck and was rectified by distillation. The portion used had a very constant boiling point. Owing to the difficult solubility of the salts and the slight conductivity of solutions of this solvent very few determinations were made. The specific conductivity was 1.76×10^{-6}.

TABLE V.

Solvent: benzyl alcohol.

Ferric Chloride, $FeCl_3$. v	μ
88.06	2.62
895.22	6.31

Ferric Chloride, (v = 88.06 at 25° C.) t	μ
25°	2.62
54	5.08
85	6.46
100	7.19

PARALDEHYDE.

The sample of paraldehyde from Kahlbaum was redistilled and the portion coming over at a very constant temperature was employed. The specific conductivity was less than 3.4×10^{-7}.

TABLE VI.

Solvent: paraldehyde.

Ferric Chloride, $Fe\,Cl_3$.

v	μ
4.37	9.81
21.32	16.91
42.52	18 76
81.88	19.16
183.11	16.51
575.50	16.91

Antimony Trichloride, $Sb\,Cl_3$.

v	μ
5.57	0.202
20.76	0.356
61.16	0.532

Antimony Trichloride, (v = 5.57 at 25° C.)

t	μ
25.2°	0.295
26.6	0.299
29.0	0.298
32.0	0.295

BENZALDEHYDE.

The sample of benzaldehyde employed was from Schuchardt. It was purified by redistillation, and the portion boiling between 177° and 178° C. at 741.5 mm. pressure was used in the following determinations. The specific conductivity was less than 4.5×10^{-7}.

TABLE VII.

Solvent: benzaldehyde.

Ferric Chloride, $Fe\,Cl_3$.

v	μ
25.58	14.32
51.65	14.58
117.91	13.05
157.80	12.14
237.14	10.50

Antimony Trichloride, $Sb\,Cl_3$.

v	μ
1.96	0.12
2.42	0.14
3.51	0.18
5.80	0.24
14.89	0.48
33.10	0.86
62.52	1.24
155.22	1.68
523.39	2.62

Ferric Chloride,
(v=25.58 at 25° C.)

t	μ
25°	14.3
52	20.5
55	20.9
60	22.1
65	23.1
70	24.3
75	25.1
80	25.9
85	26.4
90	26.4
95	24.5
102	24.1
105	24.1
111	24.0
125	24.0

Mercuric Chloride,
$HgCl_2$.

v	μ
0.48	0.0031
1.15	0.0063
32.79	0.0490

SALICYLIC ALDEHYDE.

he sample of salicylic aldehyde from Schuchardt was rectified by redistillation. The portion taken had a constant boiling point and the specific conductivity was 5.98×10^{-6}.

TABLE VIII.

Solvent: salicylic aldehyde.

Ferric Chloride,[1]
$FeCl_3$.

v	μ
20.39	3.76
81.38	4.71
220.74	5.60

Ferric Chloride,
(v = 20.39 at 25° C.)

t	μ
25°	3.76
45	6.30
50	6.73
109	6.46

FURFUROL.

The sample of furfurol from Merck was treated with fused calcium chloride over which it stood for several weeks. It was then distilled and the distillate again distilled. The portion coming over between 156° and 158° at 744 mm. pressure was collected and its specific conductivity was 2.4×10^{-5}.

---

[1] Apparently not quite all dissolved. After cooling became a very viscous mass.

TABLE IX.

Solvent: furfurol.

Ferric Chloride, $Fe\,Cl_3$.

v	μ
45.60	20.78
80.98	22.20
149.21	26.42

Ferric Chloride, (v = 45.60 at 25° C.)

t	μ
25°	20.78
45	37.83
55	40.98
65	44.06
75	47.96
85	51.41
95	56.07
105	60.02

ACETONE.

The acetone employed was treated with fused calcium chloride, over which it stood for several days and was then distilled. The distillate was again treated with calcium chloride and the distillate from this was redistilled twice and the portion having a boiling point at 56° C. at 744 mm. pressure was taken. The specific conductivity was less than 7.7×10^{-7}.

TABLE X.

Solvent: acetone.

Ferric Chloride, $Fe\,Cl_3$.

v	μ
14.65	51.70
29.30	59.90
58.60	64.65
117.19	68.68
234.39	70.67
468.77	77.28
937.54	83.76
1,875.08	91.22

Antimony Trichloride, $Sb\,Cl_3$.

v	μ
7.07	1.23
14.14	1.55
28.27	1.83
56.55	2.13
113.10	3.34

Stannous Chloride, $Sn\,Cl_2$.

v	μ
37.78	8.77
75.56	8.09
113.33	6.87

Cupric Chloride, $Cu\,Cl_2$.

v	μ
45.87	25.72
91.74	27.10
183.48	28.71
366.96	28.94
733.91	29.18

METHYL–PROPYL KETONE.

The sample of methyl-propyl ketone employed was from Schuchardt and gave a specific conductivity of 9.5×10^{-7}.

TABLE XI.

Solvent: methyl-propyl ketone.

Ferric Chloride, $Fe Cl_3$. v	μ
13.64	28.25
22.83	31.07
53.36	36.98
100.71	42.76
111.13	41.59
164.43	46.15
358.09	50.28
1,074.27	59.52

Ferric Chloride, (v = 13.64 at 25° C.) t	μ
25°	28.25
49	33.47
50	33.66
55	33.79
60	34.07
70	35.60
75	35.89
80	36.17

$CuCl_2$ in less than 460.28 liters gave $\lambda = 5.22 \times 10^{-6}$. A resistance of 6000 ohms was introduced in the measuring.

ACETOPHENONE.

A sample of acetophenone from Schuchardt was treated with barium oxide, over which it stood for several days and then distilled. The distillate was redistilled and the portion coming over between 194° and 195° C. at 745 mm. pressure was taken. The specific conductivity of this portion was 1.8×10^{-7}.

TABLE XII.

Solvent: acetophenone.

Ferric Chloride, $Fe Cl_3$. v	μ
23.46	10.28
46.71	11.03
65.77	11.59
124.91	12.03
292.98	13.08

Ferric Chloride, (v = 23.46 at 25° C.) t	μ
25°	10.28
50	15.17
65	17.52
80	20.52
100	23.90
114	27.49
125	28.74
135	28.85
150	28.16

ETHYL ACETATE.

The sample of ethyl acetate was treated several times with anhydrous copper sulphate, over which it stood for several days and then distilled each time. This last distillate was redistilled and the portion coming over between 76° and 77° C. at 738 mm. pressure was collected. The specific conductivity was 7.0×10^{-7}.

TABLE XIII.

Solvent: ethyl acetate.

Ferric Chloride, $Fe\,Cl_3$.

v	μ
16.89	0.87
33.78	1.12
67.56	1.25

Antimony Trichloride, $Sb\,Cl_3$.

v	μ
10.92	0.013
21.84	0.019

Stannous Chloride, $Sn\,Cl_2$.

v	μ
68.05	0.042

Bismuth Trichloride, $Bi\,Cl_3$.

v	μ
112.12	0.034

ETHYL MONOCHLORACETATE.

This solvent was a C. P. sample from Schuchardt, the boiling point of which was 143.5° C. The specific conductivity was less than 1.7×10^{-6}.

TABLE XIV.

Solvent: ethyl monochloracetate.

Ferric Chloride, $Fe\,Cl_3$.

v	μ
7.76	12.45
14.96	13.14
19.18	13.49
22.09	13.75
45.63	14.78
92.05	16.38
152.55	17.88

Ferric Chloride, (v = 7.76 at 25° C.)

t	μ
25°	12.45
50	15.21
55	15.77
67	16.28
80	16.28
92	15.61
100	14.73
110	13.11

Antimony Trichloride,
$SbCl_3$.

v	μ
4.25	0.174
11.49	0.201
44.73	0.337

Cupric Chloride,
$CuCl_2$.

v	μ
13.32	1.24

Did not all dissolve;
so $\lambda = 1.33 \times 10^{-5}$.

ETHYL CYANACETATE.

This solvent was a C. P. sample from Schuchardt and **was** rectified by redistillation. The boiling point was very constant, and the portion collected came over between 203° and 203.5° C. at 744 mm. pressure. The specific conducting was 3.7×10^{-7}.

TABLE XV.

Solvent: ethyl cyanacetate.

Ferric Chloride,
$FeCl_3$.

v	μ
15.30	8.88
19.72	8.99
27.08	9.29
44.64	9.80
185.22	11.57

Silver Nitrate,
Ag No_3.

v	μ
10.62	4.19
19.00	4.78
28.30	5.29
58.57	6.46
110.97	7.66

Ferric Chloride,
(v = 15.30 at 25° C.)

t	μ
25° C	8.88
49	13.40
60	15.85
75	20.14
87	22.44
100	24.83
125	29.49
150	38.70

Cupric Chloride.
$CuCl_2$.

v	μ
29.85	7.00
41.67	7.50
59.40	8.08
97.77	12.80

ETHYL ACETOACETATE.

The solvent employed was from Schuchardt, and was rectified be distillation. The portion which boiled between 174° and 176° C. at 736 mm. pressure was used. The specific conductivity was 4×10^{-7}.

Table XVI.

Solvent: ethyl acetoacetate.

Ferric Chloride,
$Fe\,Cl_3$.

v	μ
5.46	10.82
15.04	14.04
16.31	14.08
22.14	14.62
24.12	14.63
27.59	15.04
31.90	15.25
44.64	15.94
157.98	19.79
240.51	20.65
503.56	23.43

Antimony Trichloride,
$Sb\,Cl_3$.

v	μ
0.75	0.031
0.94	0.034
1.34	0.041
2.76	0.044
4.34	0.050
8.18	0.059
17.02	0.076
33.69	0.108
59.86	0.132
511.50	0.529

Mercuric Chloride,
$Hg\,Cl_2$.

v	μ
0.91	0.012
1.35	0.013
2.91	0.017
36.33	0.072

Phosphorus Trichloride,
$P\,Cl_3$.

v	μ
1.80	0.026
4.48	0.097

Stannic Chloride,
$SnCl_4$.

v	μ
2.02	1.08
4.13	1.71
8.76	2.37

Ferric Chloride,
($v = 5.46$ at 25° C.
Solution two weeks old.)

t	μ
25° C	12.0
50	16.8
56	17.5
60	18.2
65	19.2
70	19.9
75	20.7
81	21.2
86	21.7
90	21.7
95	21.8
100	21.7

(Gases disengaged
at higher temperatures.)

Bismuth Trichloride,
$BiCl_3$.

v	μ
5.65	0.059
11.30	0.053
27.09	0.098
48.20	0.137
83.00	0.164
288.96	0.472

Arsenic Trichloride,
$As\,Cl_3$.

v	μ
0.47	0.087
0.65	0.071
0.84	0.068
1.13	0.067
1.37	0.067
2.49	0.084
3.50	0.070
10.20	0.085
31.13	0.114

ETHYL OXALATE.

This solvent was a C. P. sample from Merck, and its specific conductivity was 7.12×10^{-7}.

TABLE XVII.

Solvent: ethyl oxalate.

Ferric Chloride,
$Fe\,Cl_3$.

v	μ
13.15	5.88
22.07	5.89
42.29	5.92
94.79	6.25
342.85	7.70

Ferric Chloride,
(v = 13.15 at 25° C.)

t	μ
25° C	5.88
50	8.11
62	9.21
75	10.15
100	11.14
125	9.58

(At 148° solution began to boil.)

ETHYL BENZOATE.

This solvent was a C. P. sample from Trommsdorff, and its specific conductivity was 1.8×10^{-7}.

TABLE XVIII.

Solvent: ethyl benzoate.

Ferric Chloride,
$Fe\,Cl_3$.

v	μ
29.54	1.55
174.28	1.61
517.21	1.91

Ferric Chloride,
(v = 29.54 at 25° C.)

t	μ
25° C	1.55
56	1.16
75	0.82
100	0.48

AMYL NITRITE.

This solvent was a C. P. sample from Schuchardt, and its specific conductivity was 1.8×10^{-7}.

TABLE XIX.

Solvent: amyl nitrite.

Ferric Chloride,
$Fe\,Cl_3$.

v	μ
21.34	1.54
29.03	1.63
38.74	1.74
69.46	2.02
104.64	2.29
264.16	3.00
644.56	3.73

Ferric Chloride,
(v = 21.34 at 25° C.)

t	μ
25° C.	1.54
50	1.13
55	1.08
64	1.21

(At about 70° the solution began to boil.)

NITROBENZENE.

The sample of nitrobenzene employed was from Kahlbaum and was prepared from crystallizable benzene. The specific conductivity was less than 3.5×10^{-7}.

Table XX.

Solvent: nitrobenzene.

Ferric Chloride,
Fe Cl_3.

v	μ
2.84	3.76
5.67	4.79
11.34	6.58
22.68	13.70
45.37	16.25
90.74	17.61
181.49	18.86
362.98	20.02
725.96	20.51
1,451.93	20.82
2,903.86	20.45

Phosphorus Trichloride,
P Cl_3.

v	μ
8.43	0.026
16.86	0.042

Ferric Chloride,
(v = 7.185 at 25° C.)

t	μ
25° C	5.2
52	7.2
56	7.6
61	8.1
67	8.8
70	9.2
75	9.8
80	10.3
85	11.0
90	11.6
95	12.5
100	13.3
110	14.6
122	15.7
125	15.9
130	16.4
135	16.7
140	16.8
145	16.9
150	16.9

Antimony Trichloride,
Sb Cl_3.

v	μ
1.83	0.033
3.65	0.048
7.31	0.122
14.60	0.225
29.21	0.390
58.41	0.706
116.83	1.276

Bismuth Trichloride,
Bi Cl_3.

v	μ
8.50	0.80
17.01	0.91
34.02	0.96
68.04	1.03
136.07	1.07
272.14	1.11

Arsenic Trichloride,
As Cl_3.

v	μ
1.338	0.016
2.676	0.021
4.014	0.028

Aluminum Trichloride,
Al Cl_3.[1]

v	μ
4.692	3.67
9.384	4.51

---

[1] Dissolved with slight evolution of heat. When the dilutions were made the evolution of hydrochloric acid gas was very perceptible, and for this reason no further determinations were made. For the same reason the cryoscopic determinations do not appear among the results in Table XXI.

The following cryoscopic results will be of interest in connection with the conductivity measurements. The molecular weight determinations were made with a Bechmann's apparatus, and all of the usual precautions necessary to insure accurate results were observed. The solvent was the same as that employed in the conductivity measurements, but it was further purified by being recrystallized several times. The molecular lowering of the freezing point used in these calculations was 70.70 (see Ostwald's *Grundriss der allgemeinen Chemie*). The constant for nitrobenzene has been lately redetermined by Ampola and Carlinfanti[1] who give 69 as the new value, while from their calculation according to van't Hoff's formula they found it to be 68.6. The following results were not recalculated; for while the correction throughout would be the same and rather small, the relative values would remain practically the same.

TABLE XXI.

Solvent: nitrobenzene.
Ferric chloride, $FeCl_3$,
Mol. Wt. = 161.14.

Substance in 100 g solvent.	Lowering.	Mol. wt.
1.4792	0.330°	316.9
1.6510	0.433	269.6
1.9661	0.575	241.7
2.3582	0.728	229.2
3.0566	1.065	203.0
3.4823	1.255	196.2
4.0097	1.501	188.9
4.7389	1.756	190.8

Antimony Trichloride, $SbCl_3$,
Mol. Wt. = 225.06.

Substance in 100 g solvent.	Lowering.	Mol. wt.
2.5811	0.714°	255.6
3.1528	0.910	245.5
5.2983	1.585	236.3
6.3113	1.928	231.4
7.2706	2.248	228.7
8.3095	2.655	223.3
10.6533	3.555	211.9

---

[1] Gazz, *Chem. Ital.*, **26**, II, 76; 1896. (Ref.) *Jour. Chem. Soc.*, **72** ii, 12; 1897.

Stannic Chloride, $Sn Cl_4$.

Mol. Wt. = 258.87

Substance in 100 g solvent.	Lowering.	Mol. wt.
2.1259	0.337°	445.9
3.4059	0.742	332.1
5.3896	1.242	306.8
6.8268	1.662	290.4

Arsenic Trichloride, $As Cl_3$.

Mol. Wt. = 179.98.

0.3997	0.223°	126.7
0.9756	0.493	139.9
1.2298	0.568	153.1
1.7010	0.763	157.6
2.7756	1.189	156.1
3.7299	1.554	169.7
4.5366	1.857	172.7
5.2582	2.138	174.3
6.4207	2.613	173.7
7.8651	3.179	174.9
10.4642	4.207	175.7

Bismuth Trichloride, $Bi Cl_3$.

Mol. Wt. = 312.08.

0.6833	0.230°	203.9
0.9190	0.250	258.1
1.1268	0 280	282.6
1.4927	0.340	301.8
1.8563	0.410	317.9
3.0829	0.662	326.9

Phosphorus Trichloride, PCl_3.

Mol. Wt. = 136.33.

0.9339	0.530°	124.6
1.3482	0.758	125.8

ORTHO NITROTOLUENE.

The C. P. sample of this solvent employed was from Kahlbaum, and the specific conductivity was less than 1.8×10^{-7}.

TABLE XXII.

Solvent: ortho nitrotoluene.

Ferric Chloride,
$Fe\,Cl_3$.

v	μ
10.94	8.37
16.38	9.44
25.99	10.74
74.28	13.32
201.43	15.24

Ferric Chloride,[1]
($v = 10.94$ at 25° C.)

t	μ
25° C	9.39
46	11.98
60	12.77
70	12.92
80	12.67
90	12.12
100	11.46

Antimony Trichloride,
$Sb\,Cl_3$.

v	μ
3.40	0.056
6.55	0.088
19.82	0.244
34.10	0.389

Murcuric Chloride,
$Hg\,Cl_2$.

v	μ
105.43	0.628

META NITROTOLUENE.

The C. P. sample of this solvent was from Kahlbaum, and the specific conductivity was less than 1.8×10^{-7}.

TABLE XXIII.

Solvent: meta nitrotoluene.

Ferric Chloride,
$Fe\,Cl_3$.

v	μ
10.86	6.86
46.93	11.10
84.77	12.55
448.14	19.00
814.81	18.20

Ferric Chloride,
($v = 10.86$ at 25° C.)

t	μ
25°	6.86
50	12.28
60	13.05
70	13.82
80	15.66
90	17.35
100	18.20
125	16.80

---

[1] This solution remained in the resistance cell for two hours before the determinations were made.

BENZONITRILE.

The C. P. sample of this solvent employed was from Trommsdorff, and the specific conductivity was 1.9×10^{-6}.

TABLE XXIV.

Solvent: benzonitrile.

Silver Nitrate, $AgNO_3$.		Silver Nitrate, (v = 2.09 at 25° C.)	
v	μ	t	μ
2.09	3.37	25° C.	5.55 (?)
9.43	5.18	50	6.75
16.33	6.37	56	7.05
24.06	7.66	65	7.59
44.62	10.12	77	8.11
58.98	11.19	87	8.75
83.92	13.41	95	9.26
151.96	16.38	105	9.65
301.21	18.20	114	10.09
803.24	21.64	125	10.69
		135	11.20
		150	11.70

PYRIDINE.

The sample of pyridine from König was fractionated, and the portion distilling over between 106° and 117° was treated with fused caustic potash from which it was distilled. The distillate was again treated with caustic potash, over which it stood for several days and was then distilled. The distillate was redistilled and the portion coming over between 113° and 114° at 742 mm. pressure was employed in some of the following determinations. The specific conductivity was 7.6×10^{-7}. For other determinations a C. P. sample of the solvent from Kahlbaum was employed and its specific conductivity was about 7.5×10^{-7}.

TABLE XXV.

Solvent: pyridene.

Ferric Chloride,
Fe Cl_3.

v	μ
6.06	7.96
15.02	7.52
24.56	6.85
42.18	6.82
95.35	6.41

Ferric Chloride,
Fe Cl_3.
(New series.)
(λ of solvent $= 1.74 \times 10^{-6}$)

v	μ
45.52	6.32
93.69	5.91
159.55	5.57

Ferric Chloride,
($v = 6.06$ at 25° C.)

t	μ
25° C.	7.96
54	16.50
59	17.24
65	18.23
70	19.59
75	20.40
80	21.16
85	22.71
90	23.36
95	24.12
100	24.80
105	25.61
110	25.61

Silver Nitrate,
Ag NO_3.
First series.

v	μ
7.55	24.07
10.71	24.87
17.70	25.79
25.52	26.91
27.43	27.29
37.32	27.96
51.43	29.49
60.90	30.17
93.71	30.83
140.57	36.21
Second series.	
392.28	40.16
588.42	43.13
784.56	45.21

Lead Nitrate,
Pb $(NO_3)_2$.

v	μ
21.10	0.81
55.96	1.57
168.47	3.25

Cupric Chloride,
Cu Cl_2.

v	μ
45.10	0.98
57.04	1.16

Mercuric cyanide,
Hg $(CN)_2$.

v	
5.35	0.012
13.09	0.014
357.42	0.153

Mercuric Iodide,
Hg I_2.

v	μ
21.78	0.35
93.61	1.39
200.12	2.70

Silver cyanide,
$Ag\,CN$.

v	μ
14.64	4.78
24.52	5.04
38.40	5.42
100.47	6.16
393.01	6.47

Silver Tartrate,
$C_6\,H_4\,O_6\,Ag_2$.

v	μ
340.74	14.64
1,505.91	35.29

Cobaltic Chloride,
$Co\,Cl_2$.

v	μ
74.06	0.20
805.31	1.45

A solution of cobaltic chloride becomes deep blue at a temperature between 40° and 50° C. The following specific conductivity determinations were made in order to ascertain whether the two differently colored solutions had the same conductivity.

	λ at 25°.	λ at 55°.
Solvent - - - - - - - -	7.5×10^{-7}	1.4×10^{-6}
Saturated solution of $Co\,Cl_2$ at 25° C. -	2.9×10^{-6}	5.5×10^{-6}

PIPERIDINE.

A C. P. sample of this solvent from Kahlbaum was employed, and its specific conductivity was less than 1.8×10^{-7}.

TABLE XXVI.

Solvent: piperidine.

Silver Nitrate,
$Ag\,NO_3$.

v	μ
4.24	0.368
5.25	0.277
7.88	0.154
10.50	0.091
15.62	0.043

Silver Nitrate,
(v = 4.24 at 25° C.)

v	μ
25°	0.368
30.5	0.391
35	0.432
40	0.453
45	0.478
50	0.508

QUINOLINE.

The sample of this solvent employed was from Merck, and its specific conductivity was 3.7×10^{-7}.

TABLE XXVII.

Solvent: quinoline.

Silver Nitrate, $AgNO_3$.		Silver Nitrate, ($v = 4.80$ at 25° C.).	
v	μ	t	μ
4.80	2.45	25° C.	2.45
9.60	2.79	50	4.67
34.92	2.80	62	5.20
129.83	3.62	70	5.52
		85	5.89
		104	5.75
		124	5.77
		136	5.52

GENERAL DISCUSSION OF RESULTS.

THE ALCOHOLS.

The non-aqueous solvents that yield solutions which conduct the best are in general the alcohols. Through the labors of Carrara,[1] Cattaneo,[2] Cohen,[3] Fitzpatrick,[4] Holland,[5] Kablukoff,[6] Pfeiffer,[7] Schall,[8] Schlamp,[9] Vollmer,[10] Zelinsky and Krapiwin,[11]

---

[1] (1) Gazz, *Chem. Ital.*, **24**, II, 504. (Ref.) *Jour. Chem. Soc.*, **68**, ii, 302; 1895. (2) Ibid., **26**, I, 119. (Ref.) *Jour. Chem. Soc.*, **70**, ii, 511; 1896. (3) Ibid., **27**, I, 422. (Ref.) *Jour. Chem. Soc.*, **72**, ii, 473; 1897.

[2] *Rend. Accad. Linc.*, II, 63 and 73; 1895. (Ref.) *Jour. Chem. Soc.*, **72**, ii, 537; 1897.

[3] *Zeit. phys. Chem.*, **25**, 1; 1898.

[4] *Phil. Mag.* (5), **24**, 322; 1887.

[5] *Wied. Ann.*, **50**, 261; 1893.

[6] *J. Russ. Chem. Soc.*, **23**, 391. (Ref.) *Jour. Chem. Soc.*, **64**, ii, 151; 1893.

[7] *Wied. Ann.*, **26**, 31; 1885.

[8] *Zeit. phys. Chem.*, **14**, 701; 1894.

[9] *Zeit. phys. Chem.*, **14**, 273; 1894.

[10] *Wied. Ann.*, **52**, 328; 1894.

[11] *Zeit. phys. Chem.*, **21**, 35; 1896.

and others, considerable knowledge concerning the conductivity of alcoholic solutions has been gained. Raoult,[1] Beckmann,[2] Woelfer,[3] Jones and King,[4] Salvadori,[5] and others from their boiling point determinations have likewise contributed a large number of facts that throw some light on the molecular condition of substances dissolved in alcoholic solutions.

Electrical conductivity determinations of many solutions of both organic and inorganic compounds in the following alcohols have been made: methyl, ethyl, propyl, isopropyl, butyl, isobutyl, amyl, isoamyl, allyl, and benzyl. In most cases but few determinations have been made, and the conductivity is slight except in the case of the first three. In the methyl, ethyl, and propyl alcoholic solutions the value of μ approximates to, and in some cases exceeds, the value found in aqueous solutions; but in general it is much less. A few examples will illustrate this more fully. Lithium chloride in an aqueous solution gives a value of 95 for μ_∞ at 18° C.; while in propyl alcohol, in a volume of about 3,000 liters, the value of μ at 15° is given as 128.9. In fact, most of the values of μ in dilute solutions of propyl alcohol are, according to Schlamp, greater than the values of μ_∞ in water. In methyl alcohol the value of μ_∞ for $N(C_2H_5)_4I$ is 113.8, while in water it is only 104.2; for $S(C_2H_5)_3I$ μ_∞ is 112.5, while in water it is 107.6; in the case of $N(CH_3)_4I$ the values of μ_∞ in both solvents are virtually the same (115.3). According to the determinations in the other alcoholic solutions the values of μ do not even approximate those in aqueous solutions.

In order to calculate the degree of electrolytic dissociation of the dissolved substance, it is necessary to know the value of μ_∞. In non-aqueous solutions this value is more difficult to obtain, owing to the high resistance of the solutions employed. In alcoholic solutions these values have been usually obtained

---

[1] *Compt. rend.*, **107**, 442; 1888; *Ann. de chim. et phys.*, **6**, 346; 1890

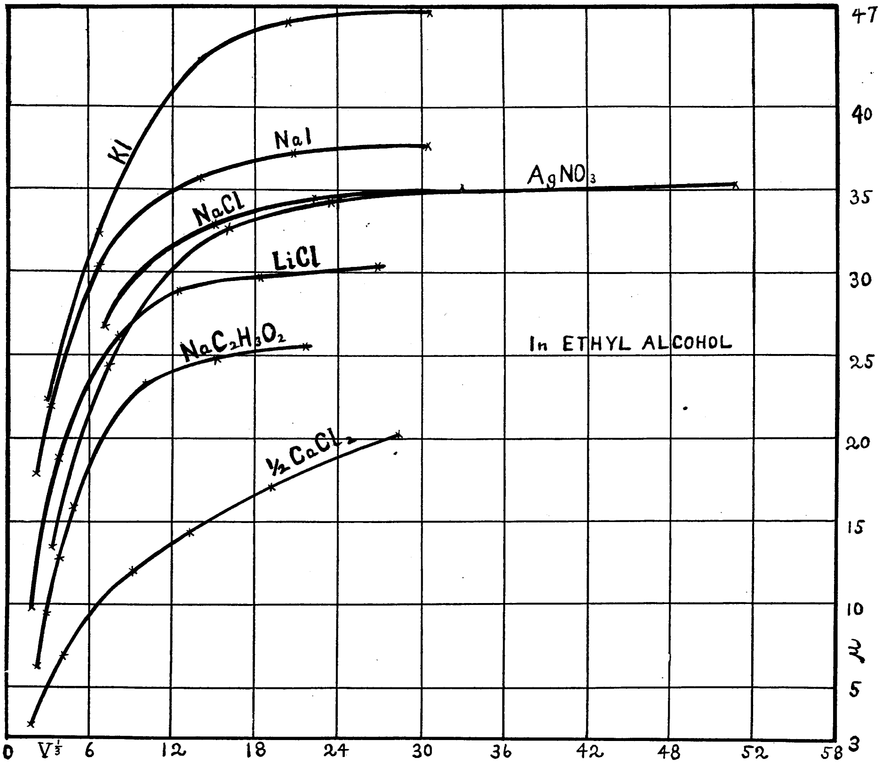
[2] *Zeit. phys. Chem.*, **6**, 437; 1890.

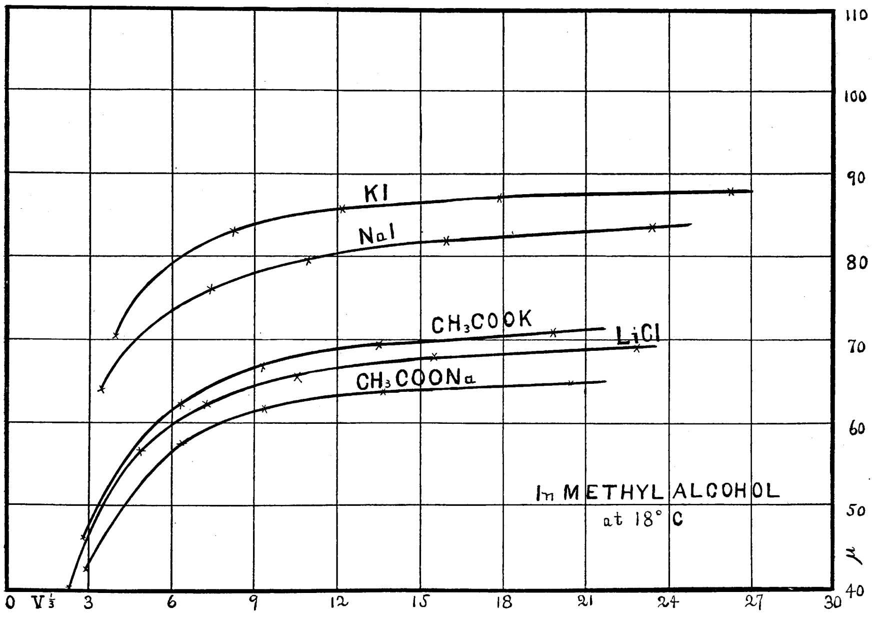
[3] *Wied. Ann.*, **57**, 91; 1896.

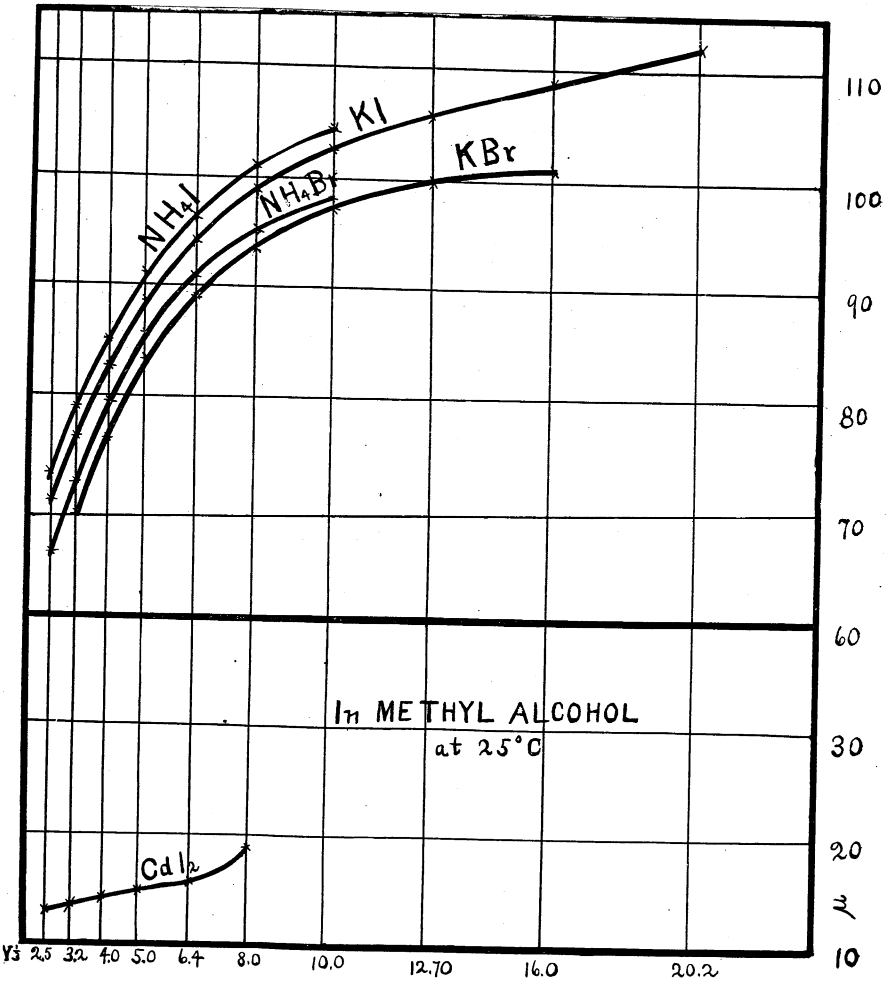
[4] *Am. Chem. Jour.*, **19**, 753; 1897.

[5] Gazz. *Chem. Ital.*, **26**, I, 237; 1896. (Ref.) *Jour. Chem. Soc.*, **70**, ii, 712; 1896.

Plate II.


KI
NaI
AgNO3
NaCl
LiCl
NaC2H3O2
½ CaCl2
In ETHYL ALCOHOL
47
40
35
30
25
20
15
10
λ
5
3
0
V⅓
6
12
18
24
30
36
42
48
52
58


KI
NaI
CH₃COOK
LiCl
CH₃COONa
In METHYL ALCOHOL
at 18° C
0
V⅓
3
6
9
12
15
18
21
24
27
30
110
100
90
80
70
60
50
μ
40


KI
KBr
NH4I
NH4Br
CdI2
In METHYL ALCOHOL
at 25°C
110
100
90
80
70
60
30
20
3
10
V⅓ 2.5
3.2
4.0
5.0
6.4
8.0
10.0
12.70
16.0
20.2

by experiment, while in other cases they have been extrapolated. This will subsequently be shown to be unjustifiable.

In Plate II is platted the molecular conductivity of various salts in ethyl alcoholic solutions, from the determinations of Vollmer at 18°. The molecular conductivity is represented by ordinates, and the cube root of the volume, in which one gram-molecule of the substance was dissolved, is represented by abscissas. The cube root of the volumes was employed in order to represent the values for the more dilute solutions in the figure.

It will be noticed that the salts of the alkalies yield limiting values for μ, while in the case of $CaCl_2$ there seems to be no tendency for the curve to become asymptotic. The same is true for $Ca(No_3)_2$, and from my determinations for $FeCl_3$ and $SbCl_3$.

In Plate III is represented the molecular conductivity of salts in methyl alcohol from Vollmer's determinations at 18° C. and in Plate IV the results of Zelinsky and Krapiwin determined at 25° C.

In most cases it will be seen limiting values are reached, CdI_2 being, however, an exception. Zelinsky and Krapiwin's determination for KI indicates that the curve would not become asymptotic, and therefore no limiting value for μ would be reached. Nevertheless, Carrara assigns 97 as the value of μ_∞, and Cohen[1] has pointed out that the difference in the determinations of Carrara and of Zelinsky and Krapiwin may be attributed to the effect of the platinum black electrodes, which they used, on the alcohol.

Carrara calculated the values of μ_∞ for a number of salts in methylic alcohol solutions and found them to agree very closely with his own experimental results. In the following table are given these results and also the value of μ_∞ in water.

---

[1] Loc. cit.

TABLE XXVIII.

Values of μ_∞.

	IN METHYL ALCOHOL.				IN WATER.			
	Cl	Br	I	OH	Cl	Br	I	OH
H	133.80	....	134.5	....	395.2	398.	397.	....
Li	77.30	....	....	....	110.0	....	....	....
Na	86.80	87.58	89.77	71.83	119.4	122.2	121.4	216.2
K	95.57	96.52	97.63	75.75	140.8	143.6	142.6	237.6
NH_4	96.24	99.93	105.25	(82.0)	140.6	143.4	142.6	230.0
$N(CH_3)_4$	....	....	115.30	....	....	....	115.6	....
$N(C_2H_5)_4$	95.76	96.62	113.76	91.13	102.4	105.2	104.2	199.2
$S(CH_8)_3$	100.09	102.5	116.38	97.34	117.8	120.3	119.3	214.0

Carrara's calculations of μ_∞ were based upon Campetti's[1] determinations of the transference figures of the halogens in methylic alcohol solutions. From these values Carrara also calculated the rate of migration of the ions and the results are given in the following table which is taken from the *Jahrbuch der Electrochemie* **3,** 13, 1896:

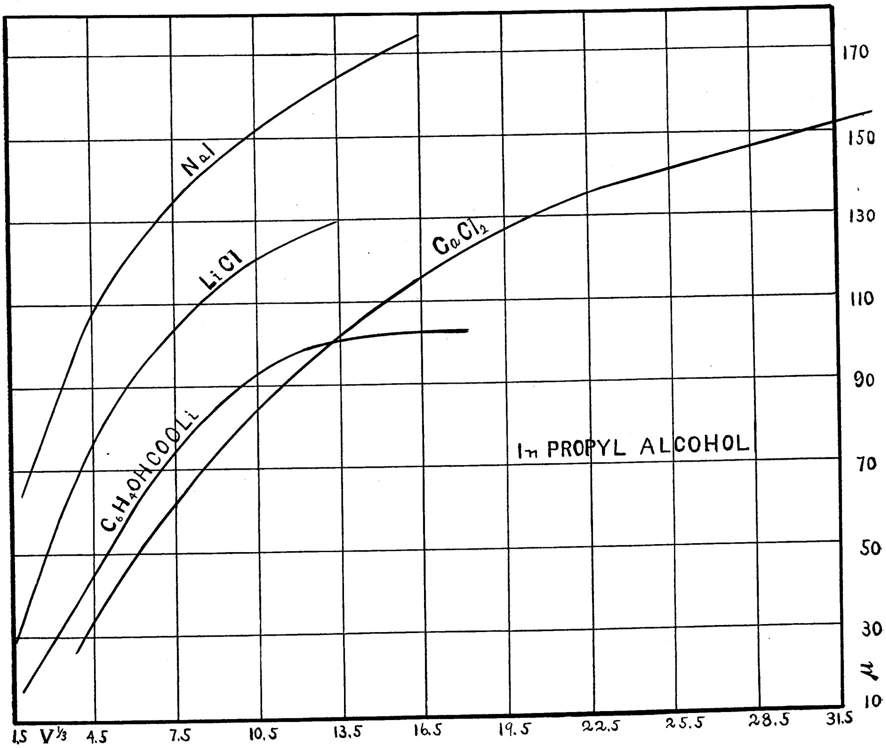
TABLE XXIX.

Speed of Migration.

	IN METHYL ALCOHOL.			IN WATER.
	Cl	Br	I	
Li	27.83	.....	.....	39.8
Na	37.33	37.33	37.33	49.2
K	46.10	46.26	45.19	70.6
NH_4	46.77	49.49	53.81	70.4
$N (CH_3)_4$	.....	.....	63.08	43.6
$N (C_2 H_5)_4$	46.29	46.36	61.34	32.2
$S (C H_8)_3$	51.43	49.85	63.94	47.6
H	85.53	.....	82.50	325.0
OH		32.00		170.0
Cl		49.47		70.2
Br		50.24		73.0
I		52.44		72.0
CH_8 COO		32.99		38.4
C Cl_8 COO		35.95		32.8

---

[1] *Nuovo Cimento* [3] **35**, 225; (Ref.) *Jahr. der Electrochemie*, **1**, 22; 1894.


NaI
LiCl
CaCl₂
C₆H₄OHCOOLi
1n PROPYL ALCOHOL
170
150
130
110
90
70
50
30
μ
10
1.5 V⅓
4.5
7.5
10.5
13.5
16.5
19.5
22.5
25.5
28.5
31.5

Kawalki[1] found that the diffusion coefficient of a number of substances in ethyl alcohol is 0.34 times as great as in water. Vollmer[2] from his work observed that the conductivity in ethyl alcoholic solutions at 18° C. is approximately 0.34 times as great as in aqueous solutions, while his empirical factor for methyl alcohol is 0.73. In general, then, limiting values can be obtained for μ in methyl and ethyl alcoholic solutions.

In other alcoholic solutions no such uniformity seems to exist. This is perhaps best illustrated in the case of solutions in propyl alcohol. The molecular conductivity of solutions in this solvent are represented in Plate V. The determinations are from Schlamp's[3] work with this solvent.

It will be noted that lithium salicylate is the only salt the conductivity of which appears to approach a limiting value. Schlamp does not hesitate, however, to assign values for μ_∞ in all cases and from the platted results this seems hardly justifiable.

The conductivity has been found to increase with the temperature. In my determinations with both allyl alcohol and benzyl alcohol this was also found to be the case. (See quantitative results—Tables IV and V.)

Raoult found that the vapor pressure of alcohols is very slightly lowered by the addition of the dissolved substance. The subject has been further investigated by Woelfer, who finds a considerable rise in the boiling point of methyl and ethyl alcohol when various substances are added. The calculated values are usually lower than the theoretical values for the molecular weights of the dissolved substances. In methylic alcohol solutions the degrees of dissociation as calculated from the boiling point determinations, show closer agreement with those obtained by the conductivity method than in the case of the other alcoholic solutions. In the following table from Woelfer are given the values of the degree of dissociation, a, as calculated from the boiling point determinations of Woelfer and the conductivity measurements of Vollmer.

---

[1] *Wied. Ann.*, **52**, 300; 1894.

[2] Ibid., **52**, 328; 1894.

[3] *Zeit. phys. Chem.*, **14**, 272; 1894.

TABLE XXX.

Values of α.

Salt.	Per cent.	From boiling point.	From conductivity.
LiCl	0.45	0.63	0.57
KI	0.36	0.61	0.79
NaI	0.44	0.87	0.74
$CH_3COO K$	0.48	0.48	0.63
CH_3COONa	0.40	0.49	0.63

Salvadori[1] found $HgCl_2$ to be more highly dissociated in methyl alcohol according to the boiling point method than in aqueous solutions. Beckmann[2] found the reverse to be true in ethyl alcoholic solutions. Jones and King[3] calculated the dissociation of KI from their boiling point determinations, to be 25.4 per cent. in a 2 per cent. solution and 27.2 per cent. in a 3 per cent. solution of ethyl alcohol, i. e., the dissociation increases with the concentration. Cohen,[4] from conductivity determinations at 18° C., found the degree of dissociation to increase with the dilution, the dissociation being about 80 per cent. at a dilution of about 1000 liters. This disagreement of the dissociation values obtained by these two methods will be made more apparent, perhaps, by Table XXXI. The table is copied from Woelfer's paper. The results by the boiling point method were obtained by himself, those by the conductivity method by Vollmer.

---

[1], [2], [3], [4] Loc. cit.

TABLE XXXI.

Values of α.

Salt.	Per cent. in ethyl alcohol.	From boiling point.	From conductivity.
LiCl	0.9	0.35	0.32
CH_3COOK	1.07	0.18	0.27
KI	0.78	0.29	0.49
$AgNO_3$	0.533	0.65	0.38
NaI	2.14	0.27	0.45
NaI	0.68	0.51	0.56
CH_3COONa	0.97	0.01	0.24

It is to be remembered that these two sets of values are calculated from results obtained at different temperatures; in the case of the conductivity measurements at 18° C., where the viscosity factor is about 0.01211, and in the other case at 78° when that factor had decreased (at 70° to 0.00521). Yet it will be seen that there is no regularity of the results and that the degree of dissociation according to the boiling point determinations is not invariably higher than that obtained by the conductivity method. It is no doubt but proper to ask, which of these methods gives the correct measure of the amount of dissociation of the dissolved substance.

In propyl alcoholic solutions the boiling point method gives nearly normal values for the molecular weights of the dissolved substances. In the case of lithium salicylate, however, a double molecular is indicated; and it is only in the case of solutions of this salt, that the values for μ appear to approach a limiting value. (See Plate V.) The results of a few of the molecular weight determinations made by Schlamp are given in the following tables:

TABLE XXXII.

Salicylate of Lithium. Mol. Wt. = 144.		Sodium Iodide. Mol. Wt. = 150.		Lithium Chloride. Mol. Wt. = 42.5.	
Per cent. Content.	Mol. Wt.	Per cent. Content.	Mol. Wt.	Per cent. Content.	Mol. Wt.
1.97	260	3.09	144.8	0.182	36.19
2.16	273.3	5.09	146.1	4.05	48.95
4.86	252.5	7.60	140.1	4.57	45.40
10.30	273.4	14.02	150.5	5.0	42.3
15.45	288.9				

From the analogy of the electrolytic dissociation of substances in aqueous solutions to the dissociation of gases, Ostwald has formulated a law of dilution for binary electrolytes which is as follows:—

$$K = \frac{\alpha^2}{(1-\alpha)V}; \qquad \alpha = \frac{\mu_v}{\mu_\infty}$$

and V is the volume in which one gram molecule of the dissolved substance is contained. In aqueous solutions of weak electrolytes this generally holds fairly well, and many attempts have been made to determine whether it holds for non-aqueous solutions. Most investigators, Vollmer, Woelfer, Cattaneo, and others, have found that Ostwald's dilution law does not hold in the case of methyl and ethyl alcoholic solutions. Cohen[1] has considered this subject at considerable length, and comes to the same conclusion.

The following table compiled from the work of Vollmer and of Woelfer shows more clearly in the case of ethyl alcoholic solutions that the K in the above formula is not constant.

TABLE XXXIII.

From Vollmer's conductivity determinations.

Potassium Acetate.			Lithium Chloride.			Sodium Iodide.		
v	α	100K	v	α	100K	v	α	100K
11.4	0.264	0.83	5.9	0.328	2.70	8.7	0.474	4.92
113.0	0.549	0.59	60.5	0.621	1.68	27.4	0.580	2.92
1120.0	0.862	0.48	605.0	0.858	0.86	280.	0.805	1.19
3520.0	0.934	0.36	1912.0	0.934	0.69	2800.	0.934	0.47

From Woelfer's boiling point determinations.

Potassium Acetate.			Lithium Chloride.			Sodium Iodide.		
v	α	100K	v	α	100K	v	α	100K
6.0	0.077	0.11	2.6	0.178	1.5	9.1	0.289	1.3
6.9	0.100	0.16	3.0	0.205	1.8	10.4	0.317	1.4
8.0	0.126	0.22	3.5	0.240	2.2	12.2	0.353	1.6
9.7	0.160	0.31	4.2	0.277	2.5	14.7	0.391	1.7
12.2	0.195	0.39	5.3	0.325	2.9	18.4	0.438	1.8
16.2	0.249	0.50	7.0	0.381	3.4	24.6	0.495	1.9
24.4	0.324	0.64	10.6	0.472	4.0	37.0	0.574	2.1
48.4	0.441	0.71	21.1	0.600	4.3	74.0	0.718	2.4

---

[1] Loc. cit.

Rudolphi's formula, which differs from Ostwald's in having $\sqrt{V}$ for V, has been shown to hold no better than Ostwald's. The values of the constant as calculated by these two formulæ from the conductivity determination of potassium acetate, are given in the following table for comparison. K with the subscript r indicates that those values were obtained by using Rudolphi's formula, while K with the subscript o indicates that Ostwald's formula was employed.

TABLE XXXIV.

V	μ	$100\,K_r$	$100\,K_o$
11.4	8.28	0.82	0.242
113	17.18	0.59	0.055
1,120	27.0	0.49	0.014
3,520	29.2	0.36	0.006

It will be observed that Rudolphi's formula does not yield a constant.

From the preceding it therefore appears that neither the dilution law of Ostwald nor that of Rudolphi holds for alcoholic solutions.

It has been shown from Schlamp's work that the assumption of values for μ_∞ is not justified; therefore, since these values are wanting, the validity of the law of Ostwald and of that of Rudolphi cannot be tested in regard to this solvent. The data available are not sufficient to draw any conclusions concerning the applicability of these laws of dilution to other alcoholic solutions.

Nernst[1] has called attention to the fact that solvents which have a high dielectric constant yield solutions that conduct electricity. This is true in the case of alcoholic solutions, but those solvents that have the highest dielectric constant do not always yield solutions that conduct the best; but in general this is the case. Propyl alcohol, the dielectric constant of which is only about four-fifths that of ethyl alcohol, generally yields solutions that conduct better; the reverse is the case, however, when hydrochloric acid is the dissolved substance. Further, methyl

---

[1] *Zeit. phys. Chem.*, **14**, 622; 1894.

alcohol, the dielectric constant of which is about 32, yields dilute solutions of $S(C_2H_5)_3I$ that conduct better than those in water, the dielectric constant of which is about 80. The reverse is the case in concentrated solutions. (See Table XXVIII.)

The coefficients of association of the alcohols show that their molecules are polymerized, but the conductivity is not proportional to the degree of polymerization. The illustrations given above in regard to the dielectric constants are applicable here as well.

The conductivity increases with the temperature for the determinations that have been made, and no exception has as yet been found. There are not sufficient data to determine accurately the temperature coefficient of all alcoholic solutions; but it can be stated that, in general, the conductivity does not increase proportionately with the temperature. It has been pointed out by Holland and by Zelinsky and Krapiwin — and later it has been confirmed by Cohen as well as by Walker and Humbly[1] — that the temperature coefficient seems to be but slightly influenced by the addition of a non-electrolyte or even of a small quantity of water.

The investigation that has been carried on with mixtures of water and alcohol is of considerable magnitude; but as it has very little bearing upon the subject in hand, not much attention has been paid to it, and consequently very little reference will be found to it in this discussion. But it might be within the compass of this work to mention the investigations of Cohen[2] and perhaps those of Zelinsky and Krapiwin.[3] The following table of comparative conductivities is taken from the work of Zelinsky and Krapiwin. In the column headed A is given the conductivity in aqueous solutions, under B in methyl alcoholic solutions, and under C is given the conductivity in a 50 per cent. solution of methyl alcohol and water.

---

[1] *Jour. Chem. Soc.*, **71**, i, 66; 1897.

[2], [3] Loc. cit.

TABLE XXXV.

V	KBr			NH_4Br			KI			NH_4I		
	A	B	C	A	B	C	A	B	C	A	B	C
16	123.1		59.82	127.2	65.43	61.16	124.5	69.20	62.13	125.4	72.24	62.63
32	127.5	69.02	62.46	131.8	72.73	63.81	128.2	76.35	64.37	129.6	78.74	65.04
64	130.5	76.70	65.36	135.3	79.56	66.04	130.5	82.52	66.01	133.4	85.0	67.48
128	132.9	83.60	67.11	138.6	85.80	67.45	133.0	88.69	67.45	135.9	91.14	69.28
256	136.4	88.96	69.26	141.2	90.88	68.32	135.8	93.85	68.28	138.7	96.20	70.34
512	140.2	93.26	70.53	143.5	94.99	69.10	137.9	98.19	69.65	141.3	100.6	71.12
1024	143.4	97.25		145.6	98.24	70.11	140.9	102.2	70.55	143.7	104.7	71.57

It will be noticed that the conductivity of the halogen salts of the alkalies in methyl alcohol (B) is considerably less than in aqueous solutions (A). When water is added to the extent of 50 per cent. even (C), the conductivity is somewhat less than it is in absolute methyl alcohol. Cohen and others have pointed out the same fact; that is, at 18° C. the conductivity of a mixture consisting of water and methyl alcohol, and containing more than 60 per. cent of alcohol, is less in dilute solutions than it is in absolute alcohol. This fact seems to be rather difficult to reconcile with the electrolytic dissociation theory, for here we have two solvents that possess dissociative power in a high degree, and yet a salt dissolved in a mixture of equal parts of these yields a solution the conductivity of which is less than that of the solutions formed when dissolved in either.

Carrara[1] has shown that the electrolytic dissociation of water in methyl alcohol is greater than it is in aqueous solutions, while the reverse is the case in ethyl alcohol. It is also of interest to note that KOH and NaOH in methyl alcohol show the same conductivity as CH_3OK and CH_3ONa.

---

[1] Gazz., *Chem. Ital.*, **27**, I, 422; 1897. (Ref.) *Jour. Chem. Soc.*, **72**, ii, 473; 1897.

THE ALDEHYDES.

From the quantitative measurements of the electrical conductivity of solutions in aldehydes, the results of which are given in Tables VI, VII, VIII and IX, it will be observed that furfurol yields the largest values of μ for solutions of ferric chloride. The dielectric constant of this solvent is larger than that of any of the other aldehydes. Owing to the great volatility of acetic aldehyde, satisfactory quantitative measurements at 18° C. were not made; but from the qualitative results it will be seen that this solvent yields solutions that conduct fairly well.

The magnitude of the molecular conductivity can be readily seen from the results. The value of μ increases with the dilution in all cases except for the solution of ferric chloride in benzaldehyde. The conductivity increases with the temperature, except in the case of the solution of the trichloride of antimony in paraldehyde, in which instance the conductivity appears to remain virtually constant. In the solution of ferric chloride in salicylic aldehyde the conductivity becomes practically constant at about 45° C.

The coefficents of association of the aldehydes, as far as these could be found in the literature of the subject, indicate that their molecules are not polymerized.

THE KETONES.

The ketones were found to yield solutions that conduct electricity fairly well. Considerable work has been done with these solvents. The conductivity of the solutions of a number of salts, both organic and inorganic, has been measured by Laszczynski,[1] Carrara,[2] Dutoit and Aston[3] and some boiling point determinations in acetone have been made by Dutoit and Friderich.[4]

Acetone yields solutions the conductivity of which is in gen-

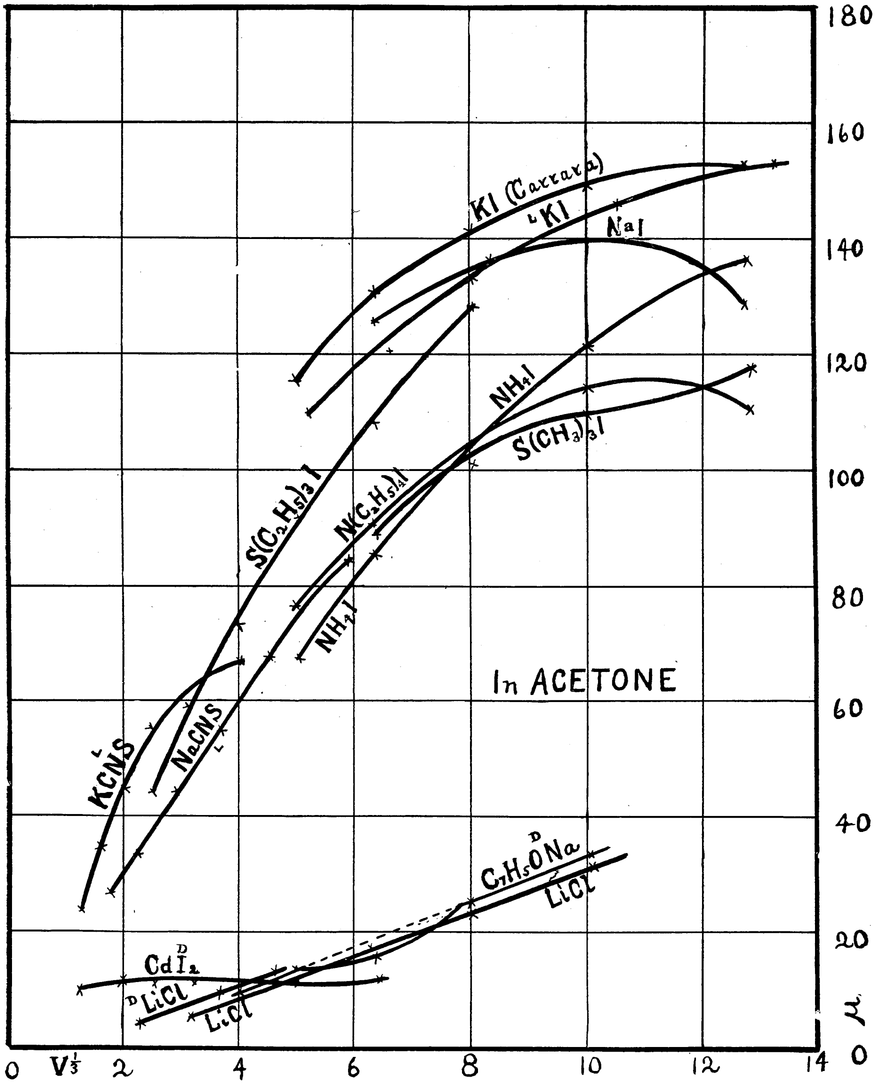
---

[1] *Zeit, Electrochemie*, **2**, 55; 1895.

[2] Gazz, *Chem. Ital.*, **27**, I, 207; (Ref.) *Jahr. der Electrochemie*, **4**, 48; 1897.

[3] *Comptes rendus*, **125**, 240; 1897.

[4] *Bull. Soc. Chim. Paris* (3) **19**, 321; 1898.


In ACETONE
KI (Carrara)
L KI
NaI
NH₄I
S(CH₃)₃I
S(C₂H₅)₃I
N(C₂H₅)₄I
NH₄I
KCNS L
NaCNS L
C₇H₅ONa D
LiCl
CdI₂ D
D LiCl
LiCl
μ
180
160
140
120
100
80
60
40
20
0
0
V^⅓
2
4
6
8
10
12
14

eral better than in the case of many of the other ketones; and on Plate VI is represented the conductivity of a number of salts in this solvent. The results platted are from the determinations of Carrara principally, those designated L from Laszczynski, and those with D are from Dutoit and Aston.

It will be observed, that the molecular conductivity of the solutions of all the salts increases with the dilution except that of cadmium iodide, which remains virtually constant. Dutoit and Friderich found the same to be true for cadmium iodide in acetophenone. In the case of solutions of this salt in both methyl-ethyl ketone and methyl-propyl ketone, the conductivity decreases with the dilution and the same was found to be the case for stannous chloride in acetone. (See Table X.)

In general the conductivity of solutions in ketones is much less than that of aqueous solutions, but there are a few noticeable exceptions. The molecular conductivity of NaI, NH_4I, $N(C_2H_5)_4I$ and of $S(C_2H_5)_3I$ in acetone, according to Carrara, is greater in dilute solutions than the values assigned μ_∞ for aqueous solutions. The value of μ for most of these salts is greater in acetone than in methyl alcohol. Carrara finds that HCl, LiCl and other hygroscopic substances that are highly dissociated in water, yield very low values for the molecular conductivity when dissolved in ketones. The value of μ for $SCN.NH_4$, CdJ_2, and $C_7H_5O_3.Na$ in methyl-propyl ketone as well as those for most salts in acetophenone are not of great magnitude.

It will be seen from Plate VI that very few of the salts yield solutions in acetone that have limiting values for μ. There are two curves, for NaI and $N(C_2H_5)_4I$, that appear to indicate a decrease in the conductivity after certain dilutions are reached. The two curves, platted for KI, one from the determinations of Laszczynski and the other from those of Carrara, apparently intersect at about $\mu = 153$. Laszczynski thinks the value of μ_∞ lies between 160 and 170. Assuming the value of 160 for μ_∞, according to Kohlrausch's law of the additive property of the conductivity of aqueous solutions, Laszczynski calculates the factor k in the formula, $\mu_\infty = k\,(u + v)$, where $(u + v)$ is the conductivity at infinite dilution in water and k is a constant. The value of k he finds to be 1.3 for acetone. If this method be applied to salts other than KI, the one he employed—to CdI_2 for instance—, it will be found that new values for k will be obtained. There is no such agreement between the limiting values of μ in acetone and water as Vollmer found to hold in the case of ethyl alcohol and water. The two curves for LiCl are alike; but the values of μ differ slightly, neither, however, showing any tendency to approach a limiting value. The small conductivity Carrara[1] ascribes to the combination of salt and solvent which forms $LiCl + C_3H_6O$.

There have been too few molecular weight determinations of salts in ketones made by the boiling point method. This method, according to Dutoit and Friderich,[2] yields normal molecular weights for the compounds of the formula $CNS.NH_4$, $HgCl_2$, NaI, LiCl, and CdI_2 when dissolved in acetone. In conjunction with the electrical conductivity of these solvents, this seems to argue against the electrolytic dissociation theory, if the methods employed are trustworthy means for measuring the amount of dissociation in non-aqueous solutions. But Dutoit and Friderich expect soon to show that this is not incompatible with the dissociation theory.

From the magnitude of the dielectric constants, one would expect the ketones to yield solutions that conduct. According to Ramsay and Shields, their molecules are polymerized. As far as measurements have been made, the conductivity has been found to increase with the temperature, except in the case of CdI_2 where it remained the same at 50° C as at 25°; but it must also be remembered that the molecular conductivity of solutions of this salt does not change with the dilution.

THE ESTERS.

In esters the dissociative power is slight, and decreases with an increase in the carbon content. The substitution of Cl, CN or CH_3CO for the hydrogen of the methyl group does not cause a decrease in the dissociative power of the solvent. Ethyl car-

---

[1] Loc. cit.

[2] Loc. cit.

bonate does not conduct, but if one of the ethoxy groups be replaced by Cl, the resulting compound possesses dissociative power to a considerable degree. Ethyl monochloracetate yields solutions that conduct fairly well, while the substitution of the CN group, (thus forming ethyl cyanacetate) yields solutions of ferric chloride that do not conduct as well as those of ethyl monochloracetate; but the reverse is true in the case of solutions of $CuCl_2$. By comparison of Tables XIV, XV, and XVI, it will be seen that neither of these solvents yields solutions that conduct as well as the solutions of ethyl acetoacetate, as far as examined. The esters with the highest dielectric constants usually yield solutions that conduct the best, but there are a few exceptions to this. From Tables XVI and XV it will be seen that ethyl acetoacetate yields solutions of ferric chloride that conduct better than those in ethyl cyanacetate, the dielectric constant of the latter being 26.7, while that of the former solvent is only 15.7. Then, too, those esters whose dielectric constants are very low yield solutions that conduct electricity slightly—for example, ethyl acetate and ethyl benzoate.

The coefficients of association that have been determined, show that the molecules of these esters are not polymerized; yet it will be noted that ethyl acetoacetate yields solutions that conduct very well. In all determinations made, it was observed that the conductivity increases with both the dilution and the temperature.

COMPOUNDS CONTAINING NITROGEN.

The nitro compounds of benzene and toluene yield solutions that conduct fairly well. The conductivity increases with the dilution, and in the ferric chloride solution μ approaches a limiting value. The conductivity of other salts in nitrobenzene is rather low. (See Table XX.) The results of a number of cryoscopic determinations are given in Table XXI. From these it will be observed that the values obtained seem to indicate normal molecular weights for the dissolved substances. These determinations indicate that the molecular weight of ferric chloride is uniformly higher than the theoretical, and decreases with increased concentration of the solution. The same is true in the case of the trichloride of antimony, but the variation is relatively less than in the case of the ferric chloride; and the more concentrated solutions show a molecular weight slightly less than the theoretical. In the case of stannic chloride the same general facts appear. The trichlorides of bismuth and phosphorus yield molecular weights that increase with the concentration. In the more dilute solutions these values are lower than the theoretical. These results are of particular interest in connection with the high values of μ obtained in this solvent for solutions of ferric chloride. The conductivity is in keeping with the high dielectric constant of nitrobenzene; and according to Ramsay and Shields this solvent is classified among those whose molecules are not polymerized. The conductivity increases with the temperature, and reaches a limiting value. (See Table XX.)

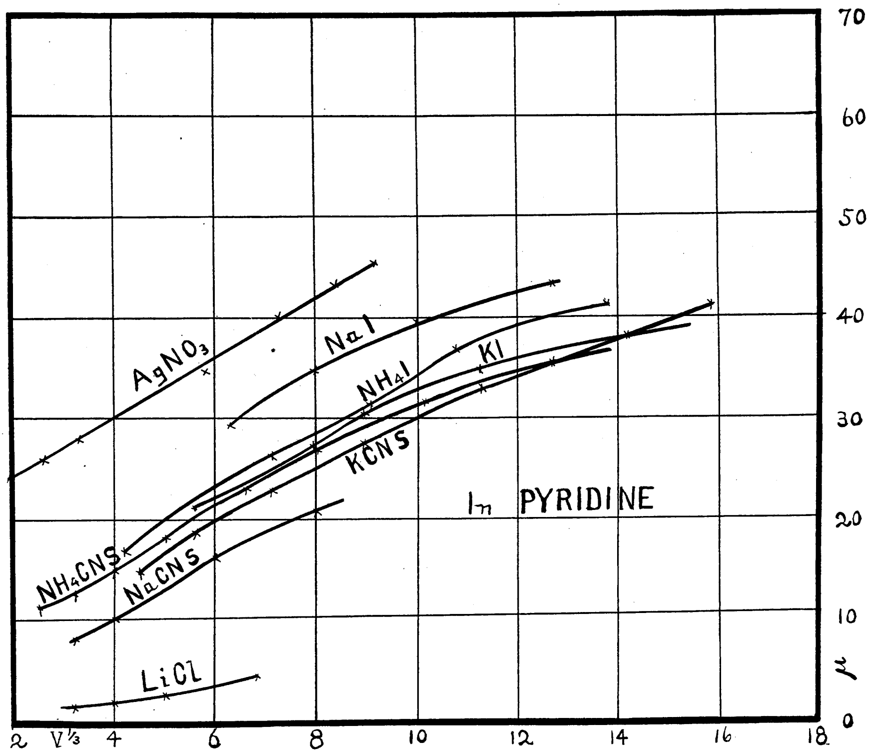
Dutoit and Aston have determined the conductivity of a number of salts in propionitrile. The conductivity of various salts in solutions of acetonitrile and butyronitrile has been measured by Dutoit and Friderich. They find that nitriles yield solutions that conduct, and the same is true of benzonitrile. (See Table XXIV.) Owing to the small quantity of this solvent available, only a few quantitative determinations could be made; but from the qualitative results it will be seen that benzonitrile solutions conduct fairly well. The values of μ for acetonitrile solutions approximate closely those obtained for aqueous solutions, while for $CNS.NH_4$ and NaI, μ is about the same magnitude as for $AgNO_3$ in benzonitrile. The conductivity of the other salts in these solvents is rather low. The conductivity increases with the dilution, but in the case of NaI in butyronitrile it appears to be about constant. The conductivity increases with the temperature except in the case of solutions of CdI_2 in acetonitrile, the value of μ being virtually the same at 0.2° C. as at 37.2° C.

According to Werner,[1] boiling point determinations indicate normal molecular weights of $AgNO_3$ in benzonitrile. The average of his determinations is 176, while the theory requires 170. His values for mercuric iodide are a little above the

---

[1] *Zeit. Anorg. Chem.*, **15**, 1; 1897.

Plate VII.


AgNO$_3$
NaI
NH$_4$I
KI
KCNS
NH$_4$CNS
NaCNS
LiCl
In PYRIDINE
70
60
50
40
30
20
10
0
μ
2
V$^{1/3}$
4
6
8
10
12
14
16
18

normal, while the average of two series shows normal values for $HgCl_2$. The qualitative results given above show that solutions of $HgCl_2$ conduct electricity.

The coefficients of association of the nitriles show that their molecules are polymerized, with the exception of benzonitrile. This solvent shows a high value for its dielectric constant; but no values for the other nitriles could be found in the literature.

ORGANIC BASES.

Of the organic bases investigated, pyridine and quinoline were found to yield solutions that conduct electricity much better than piperidine. Laszczynski and Gorski[1] have determined the conductivity of a number of salts in pyridine, and their results are platted on Plate VII.

Lithium chloride, it will be noticed, yields solutions that conduct very poorly; and the authors attribute this fact, as Carrara did in the case of this salt in acetone, to the combination of the solvent with the dissolved substance forming $LiCl + 2\,C_5H_5N$. They assign limiting values to μ in the case of $NH_4.CNS$, NH_4I, KI and NaI. From Plate VII it appears that the curves representing the conductivity would become asymptotic. The values for $AgNO_3$ are my own determinations, and these do not appear to approximate a limiting value for μ at least in the dilutions at which the measurements were made. A glance at Table XXV will show that the silver salts give larger values for μ than even the salts of the alkalies, according to Laszczynski and Gorski.

Werner's[2] boiling point determinations show about normal molecular weights for the salts of the heavy metals in pyridine. The average of his determinations for $AgNO_3$ is 165.4, — theory 169.55; for $Hg(CN)_2$, 216.68, — theory 251.76; for HgI_2, 308.0, — theory 452.88; and for $Pb(NO_3)_2$, 352.07, — theory requires 330.35. In most cases he obtained values a little under the theoretical. The greatest discrepancy occurs in the case of HgI_2, and it will be observed that the solution of this salt yields small values for μ.

---

[1] *Zeit, Electrochemie*, 4, 290; 1897.

[2] Loc. cit.

The dielectric constants of these solvents have not been determined to my knowledge. The coefficients of association of pyridine and quinoline do not indicate polymerization of their molecules, while that of piperidine indicates a slight polymerization. It will also be noted that this last named solvent yields solutions that conduct very much more poorly than either of the others. Werner's molecular weight determinations in piperidine give values somewhat higher than the theoretical: for example, the average of three determinations for $AgNO_3$ is 188.88 whereas the theory requires 169.55.

THEORETICAL PART.

Through the efforts of various investigators of non-aqueous solutions, a large number of facts have been accumulated which have been rather difficult to explain satisfactorily by means of the generally accepted theory of electrolytic dissociation. From time to time additional theories have been promulgated to explain these facts; until, at the present time, many have been advanced by means of which explanations have been attempted and from which generalizations have been drawn — in some cases apparently without sufficient experimental data to warrant them. A brief survey of the explanations offered will now be given, and an effort will be made to show wherein these are not reconcilable with the experimental results herein presented.

From a consideration of the optical properties of solvents, Brühl[1] comes to the conclusion that oxygen is generally tetravalent. He attributes the polymerization of the molecules of water and of other oxygenated liquids, their high specific inductive capacity, as well as the dissociative power exerted upon the dissolved substance, to their being unsaturated compounds. It is true that a great many oxygenated solvents do yield solutions that conduct electricity; but it has been pointed out by Dutoit and Friderich that the ethers and the ether salts are not polymerized solvents and that they yield solutions that do not conduct, or the conductivity of which is very slight; as

---

[1] *Zeit. phys. Chem.*, **18**, 514; 1895; Ibid, **27**, 317; 1898; *Ber. chem. Ges. Berlin*, **30**, 163; 1897.

in the case of ferric chloride solutions in phenyl-methyl ether. Ethyl carbonate does not yield solutions that conduct. The same is true for chloral solutions, and the esters of high carbon content yield solutions the conductivity of which is very slight. In the case of the substitution of chlorine for the ethoxy group in ethyl carbonate the number of spare valences is undoubtedly reduced, yet this product, ethyl chlorcarbonate, yields solutions that conduct well.

In compounds containing nitrogen, Brühl holds that the conductivity of their solutions is due to the extra valences of the nitrogen. He predicts that hydrazine will prove to yield solutions that conduct. It has been seen that phenylhydrazine does not yield solutions of the salts tested that conduct electricity; however, it still remains to be seen what hydrazine will do. He states that, in general, the dissociative power in the case of nitrogen compounds will vary with the nitrogen content, without being proportional to it, however; just as he claims it varies with the oxygen content of oxygen compounds. He further predicts that the anhydrous hydrocyanic acid, diazo compounds, and even unsaturated compounds of the elements other than oxygen, namely, PCl_3, $AsCl_3$, mercaptans and sulphur ethers, will possess dissociation power. Attention has been called to the fact, that when the CN group is substituted for hydrogen in ethyl acetate, the conductivity is materially increased. Nitriles do yield solutions that conduct very well. Contrary to Brühl's prediction, PCl_3 does not yield solutions that conduct; but in the case of $AsCl_3$ his prediction is confirmed. Werner found that solutions of cuprous chloride in methyl sulphide conduct very poorly. From the evidence we have at present it seems that the theory that the dissociative power of solvents is due to the unsaturated valences, that is, that the only solvents that yield solutions that conduct electricity, are unsaturated compounds, is not substantiated by the facts in many cases. Therefore the theory as promulgated by Brühl is untenable.

It is quite noticeable that a large number of the investigators of the properties of non-aqueous solutions, express the thought that there is manifested considerable influence between the dissolved substance and the solvent. This factor of the influence of the solvent upon the dissolved substance, is one that is no doubt of very great importance; and in the development of the electrolytic dissociation theory (which is based upon the behavior of aqueous solutions) the action of the solvent upon the dissolved substance has been entirely neglected. The opponents of the dissociation theory present this fact in a rather forcible manner.[1]

Fitzpatrick concludes from his investigation on the conductivity of alcoholic solutions that the action of the solvent upon the dissolved substance is a chemical one. He conceives the dissolved salt as decomposing and forming molecular groups in the solvent. Owing to the large excess of the solvent there will be a continual decomposition and recombination of these molecular groups. He cautions one against regarding the solvent as a medium in which the salt particles are suspended or as a dissociating agent. Wildermann[2], on the other hand, recognizes two kinds of dissociation — one, the electrolytic dissociation of the dissolved substance, and, the other, the dissociation of the larger molecular aggregates into smaller ones. For example, in a solution of KCl in water the following aggregates are assumed to exist: K_2Cl_2, KCl, $\overset{+}{K}_2Cl$, $K\overset{-}{Cl}_2$, $\overset{+}{K}$ and $\overset{-}{Cl}$. He further maintains that solutions of all substances, whatever the solvent or concentration, undergo electrolytic dissociation.

Cattaneo[3] was impressed with the fact that the molecular conductivity is greatly influenced by the nature of the solvent employed. He was not able, however, to point out any direct relation existing between the various properties of the solvents which yield solutions that conduct. Konovaloff,[4] from his work on the amines, concludes that only those solvents that react chemically with the dissolved substance yield solutions that conduct. It is true

---

[1] Fitzgerald's "Helmholtz' Memorial Lecture," *Jour. Chem. Soc.* **69**, i, 885; 1896.

[2] *Ber. chem. Ges. Berlin* **26** 1773 and 1881; 1893.

[3] *Rend. Accad. Linc.*, II, 63 and 73; 1895. (Ref.) *Jour. Chem. Soc.* **72**, ii, 537; 1897.

[4] *Wied. Ann.*, **49**, 733; 1893.

that there are many solvents of this nature which do react with the dissolved substance, and yet which do not yield solutions that conduct electricity. Picric acid reacts with benzene but the resulting solution does not conduct electricity. Hence chemical combination of the dissolved substance with the solvent may take place and yet the solutions need not necessarily conduct. Werner has isolated and analyzed a large number of products of pyridine and piperidine, among those of other organic solvents, with salts of the heavy metals. From the boiling point determinations, the molecular weights of these salts seem to be very slightly influenced by their union with the solvent. This is analogous to the fact, that salts which crystallize from an aqueous solution with water of crystallization, yield the same molecular weights whether dissolved in the anhydrous form or with their water of crystallization. Werner perhaps sums up his idea best in the following manner: "Da nicht bezweifelt werden kann, dass in bestimmten organischen Lösungen hydratähnliche Additions-producte von Lösungsmittel und Metallsalz als beständige Verbindungen gelöst sind, so muss auch angenommen werden, dass bestimmte Hydrate in den wässerigen Lösungen enthalten sein können; wenn im letzterem Fall eine elektrolytische Dissoziation eintritt, so entstehen nicht Metallionen, sondern an deren Stelle treten ionisierte Metallwasserradikale." Carrara thinks that the union of solvent and dissolved substance accounts for the slight conductivity in certain cases. The low values for μ in the case of acetone solutions of HCl and LiCl he attributes to this fact.

It has been pointed out by Ciamician[1] that the dissociative power of a solvent depends principally upon its chemical strucure. That is, compounds of the same chemical type, for example, of the HOH type, yield solutions that conduct well. This is true in the case of alcoholic solutions, which are not the only class of compounds that possess dissociative power; as has already been pointed out. In general, however, if one member of a particular type of compounds (e. g. nitriles), yields solutions that conduct, it has been found that other members also possess this property; and if a member of some

---

[1] *Zeit. phys. Chem.*, **6**, 403; 1890.

other type (e. g. hydrocarbons), is found not to yield solutions that conduct, other members do not possess dissociative power.

The data collected are as yet insufficient to show what the relation between solvent and dissolved substance must be in order to yield solutions that conduct electricity. Enough facts have been presented, however, to make it apparent that any theory that aims to explain the electrical conductivity of solutions in general, must take into consideration the influence of the solvent upon the dissolved substance. This subject is replete with interest; for closely connected with it is the true cause of the solubility of substances.

Carrara[1] states that the electrical conductivity of a solution depends upon (a) the dissociative power of the solvent and (b) on the electrical friction or friction between the solvent and the ions. This factor of electrolytic friction he obtains from Kohlrausch's formula $\mu_\infty = k\ (u + v)$, where k is a constant. This formula is based upon the fact that the conductivity in aqueous solutions is an additive property. Carrara himself has pointed out in the case of methyl alcoholic solutions, that the end value does not represent a condition of complete dissociation, but corresponds to an equilibrium between the dissociated, the undissociated and complex molecules. As evidence of this he points to the disagreement between the degree of dissociation when calculated from the boiling point and from the conductivity determinations. From the work of Dutoit and Friderich on the boiling point of acetone solutions, it appears that the degree of dissociation is very slight, since normal molecular weights were obtained; hence it would seem that the other factor, electrolytic friction, was the one remaining, according to Carrara, upon which the large conductivity of acetone solutions depends. It therefore appears evident that Carrara's idea cannot be accepted as the *sole* cause of electrolytic conductivity.

Dutoit and Friderich,[2] from the results of other investigators and from their own researches on the ketones and nitriles, conclude that; "la conductibilité des électrolytes dissous dans un dissolvant

---

[1] Gazz. *Chem. Ital.*, I, 207-222; 1897; (Ref.) *Jour. Chem. Soc.*, **72**, ii, 471; 1897.

[2] Loc. cit.

non polymérisé est null." The accuracy of this statement will become manifest when the following table is examined. In Table XXXVI are arranged the names of a number of solvents in the order of increasing coefficients of association. The names appear in the first column, the coefficient of association in the second. These values were mostly determined by Ramsay and Shields. (See Table I.) The third column contains the dielectric constants taken from Table I; and the fourth column contains the viscosity factors, η, as far as they could be obtained from the tables of Dutoit and Friderich and of Landolt and Börnstein. The last three columns contain the salts, the volume in liters in which our gram-molecule was dissolved, and the molecular conductivity at this particular concentration. That salt was usually chosen that gave the largest value for μ.

TABLE XXXVI.

Solvent.	Coefficient of Association.	Dielectric constant. (Air = 1)	η	Salt.	v	μ
Quinoline	0.81			$Ag\ NO_3$	129.8	3.62
Paraldehyde	0.85			$Fe\ Cl_3$	575.5	17.00
Pyridine	0.93			NH_4I	2528.6	41.00
Nitrobenzene	0.93	32.19		$Fe\ Cl_3$	1451.9	20.80
Ethyl acetoaceate	0.96	15.70		$Fe\ Cl_3$	503.5	23.40
Benzonitrile	0.97	26.00		$Ag\ NO_3$	803.0	21.64
Benzaldehyde	0.97	14.48		$Fe\ Cl_3$	25.6	14.30
Phosphorus trichloride	1.02					
Aniline	1.05	7.50				
Acetophenone	1.05	16.40		$Fe\ Cl_3$	293.0	13.0
Carbon disulphide	1.07	2.61	0.00357			
Piperidine	1.08			$Ag\ NO_3$	4.24	0.37
Methyl-propyl ketone	1.11	16.75	0.0044	$Ag\ NO_3$	1074.0	59.5
Methyl-ethyl ketone	1.15	18.44	0.0041	$CNS.\ NH_4$	94.8	19.7
Butyronitrile	1.22		0.0056	$Ag\ NO_3$	150.4	32.1
Acetone	1.26	21.85	0.0031	KI	2315.2	153.2
Propionitrile	1.40		0.0040	$Ag\ NO_3$	256.0	38.86
Acetonitrile	1.60		0.0033	$Ag\ NO_3$	1141.4	159.3
Allyl alcohol	1.88	21.60	0.0130	$Fe\ Cl_3$	115.6	32.2
Propyl alcohol	2.25	20.45	0.0200	NaI	4495.5	174.7
Ethyl alcohol	2.74	25.70	0.0109	KI	∞	46.0
Methyl alcohol	3.43	32.65	0.0055	KI	∞	89.6
Water	3.60	78.00	0.0089	KI	∞	142.6

It will be observed that those solvents on the list down to and including benzaldehyde, are not polymerized liquids, according to their coefficients of association; and they all produce solutions that conduct electricity. Among these are benzaldehyde and paraldehyde, both of which yield solutions that conduct well. Benzonitrile, the coefficient of which, even according to Traube, shows virtually no polymerization, yields solutions that conduct very well; and according to Werner gives normal molecular weights by the boiling point method. Further, ethyl acetoacetate yields solutions that conduct very well; yet its molecules are not polymerized. It will also be noted that all of these solvents have relatively high dielectric constants. Solutions in nitrobenzene conduct; but according to Ramsay and Shields its molecules are not polymerized. Traube, however, gives a value of 1.47 for the coefficient of association of this substance. Of the organic bases quinoline yields solutions that conduct and shows the lowest degree of association of any of the solvents. Pyridine dissolves a large number of salts, and yields solutions that conduct; yet its molecules are not polymerized. It will be seen that the group of solvents whose coefficients of association are between 1 and 1.08 inclusive, thus indicating a slight degree of polymerization, yield solutions that conduct slightly, and Ramsay and Shields regard most of these as non-polymerized liquids. Aniline yields solutions that conduct, particularly solutions of $AgNO_3$. Acetophenone solutions do not conduct very well; and those in piperidine conduct poorly; while phosphorus trichloride and carbon disulphide, whose molecules are slightly polymerized, do not yield solutions that conduct. The molecular conductivity of solutions of different solvents is not commensurate with the degree of polymerization of their molecules. This has already been pointed out in the case of methyl alcohol and water as well as propyl and methyl alcohols. The value of μ depends, however, to a great extent upon the salts chosen:—for example, the molecular conductivity of CdI_2 is virtually constant (11.7) in acetone, and in propionitrile it is 19.2, at dilution 512; while the conductivity of $AgNO_3$ is 30 in ethyl alcohol at dilution 41,000 liters, and 159 in acetonitrile at 1,141 liters.

The coefficients of association as determined by Ramsay and Shields have been employed in preference to those by Traube[1] because the method of the former has a better theoretical basis, and the results are more in accord with those of other investigators. Traube gives for the value of the coefficient of association for benzene 1.18, for toluene 1.08, ethylene chloride 1.46; and not any of these solvents yield solutions that conduct. Then he gives values for the esters that are very much in excess of the determinations of other investigators, whereas the values for the alcohols are very much less. For example, for methyl alcohol he gives as the coefficient of association 1.79; for ethyl alcohol 1.67; for propyl alcohol 1.55; for allyl alcohol 1.53, and for water 3.06. (Compare with the values given in Table I.)

Many compounds, whose molecules are polymerized, yield solutions that conduct, and there are solvents whose molecules are supposed to be polymerized that do not yield solutions that conduct; and if Traube's results be taken, a large number of examples could be given in addition to those cited above. It has also been pointed out that there are a considerable number of solvents, whose molecules are apparently not polymerized, yet whose solutions conduct well, — for example, benzonitile ethyl acetoacetate, etc.

From the considerations presented in the preceding, it appears that the theory as promulgated by Dutoit and Friderich, that only polymerized solvents yield solutions that conduct, is untenable.

Sometime before Dutoit and Friderich published their conclusions, Crompton[2] assigned a wider rôle to the associative property of liquids. He presents the view, that by means of this theory of association the anomalous results obtained, in the case of certain dissolved substances, electrolytes, by the boiling point, freezing point, and osmotic pressure determinations, can be easily explained; and aims to show that the electrolytic dissociation theory is not only unnecessary but in many respects

---

[1] *Ber. chem. Ges. Berlin*, **30**, 273–4; 1897.

[2] *Jour. Chem. Soc.*, **71**, ii, 925; 1897.

inadequate. As has been previously noticed, Nernst[1] calls attention to the fact that solvents which have a high specific inductive capacity yield solutions that conduct; and he argues that the greater the dielectric constant, the greater is its power of dissociation. It has been pointed out above that no proportionality exists between the values of the dielectric constants of solvents and the molecular conductivity of their solutions. Crompton calls attention to the connection between the specific inductive capacity and the degree of association of solvents. This parallelism has also been pointed out by Abegg[2] who further observes that nitrobenzene, ethyl nitrate, and benzonitrile all have high dielectric constants; yet their association factor is unity. This, he thinks, fulfills the primary conditions of a self-dissociating substance. Crompton further states: "It is almost impossible to doubt that association plays an all-important part in determining the value of the specific inductive capacity of a liquid, and that if there is any connection between the specific inductive capacity and the power of forming electrolytes, it may be looked for rather in the fact that electrolytes are solutions of approximately monomolecular salts in an associated solvent, than in there being any peculiar 'dissociative power' attached to the solvent." From the experimental results given above it appears that it is a *fact*, that *all* solvents that yield solutions which conduct are *not associated* liquids.

Crompton further aims to explain the conductivity of fused salts upon the dissociation of the associated molecules of the fused salt, wherein a small proportion of the salt is in the monomolecular condition. Abegg, however, shows that in many cases the melted salt has a higher dielectric constant than its "ice,"— for example water 78, ice 2.85;[3] and that in these fused salts the self-ionization or self-dissociation is very slight. He states that in about 100 liters of fused AgCl there is about one gram-molecule of AgCl completely dissociated. Kohlrausch[4] has shown that in about eleven million liters of water there is one

---

[1] Loc. cit.

[2] *Zeit. Electrochemie*, **5**, 48; 1899.

[3] Thwing.

[4] *Wied. Ann.*, **53**, 209; 1894.

gram of hydrogen ions; while in methyl alcohol Carrara[1] found one gram-molecule of methyl alcohol dissociated in about five and a half million liters. If water and methyl alcohol manifest such great dissociative power upon salts dissolved in them, why is it that they do not dissociate their own molecules to a greater extent?

CONCLUSION.

From the foregoing the following general statements may be made:

1. In methyl and ethyl alcoholic solutions limiting values for μ can usually be obtained. The salts of the heavy metals are apparently exceptions. In other solvents a limiting value is very seldom obtained.

2. Neither the dilution law of Ostwald nor that of Rudolphi holds in the case of alcoholic solutions. In other solvents (since the conductivity remains virtually constant in some cases with the increased dilution, while in other cases it decreases), it is very apparent that the above named laws do not hold. Then, too, since the value of μ_∞ cannot be obtained in the case of so many solvents, the validity of the dilution laws could not be tested.

3. The degrees of dissociation of the dissolved substances in non-aqueous solutions, as calculated from the boiling point or cryscopic determinations and from the conductivity measurements, show very great disagreement. No such agreement is manifest as is observed in the case of aqueous solutions.

4. Solvents that have a high dielectric constant, yield solutions that conduct the best. Some solvents, the dielectric constants of which are very low, give poorly conducting solutions. The molecular conductivity is not, however, proportional to the dielectric constant of the solvent.

5. Some associated solvents yield solutions that conduct electricity, whereas others do not. Some solvents whose molecules are not polymerized yield conducting solutions. The

---

[1] Gazz, *Chem. Ital.*, **27**, I, 422; 1897; (Ref.) *Jour. Chem. Soc.*, **72**. ii, 473; 1897.

value of μ in those solutions that conduct, is not commensurate with the degree of association of the solvent.

6. The molecular conductivity, in general, increases with the dilution; but in several cases the conductivity decreases with the successive dilutions.

7. The molecular conductivity usually increases with the temperature; but not proportionately. In some cases it remains virtually constant with increase of temperature, while in others it decreases. The changes in viscosity accompanying a varying temperature have not been determined.

8. The conductivity of electrolytes depends very much upon the nature of the solvent employed. No rigid classification can be made; but, in general, solutions in the hydrocarbons and their halogen substitution products do not conduct. Alcoholic solutions conduct well and the conductivity, in general, decreases with the increase of the carbon content. Solutions in esters conduct, but those of high carbon content usually yield solutions that conduct very poorly. The ketones and the aldehydes yield solutions that conduct well. Of the nitrogen compounds ammonium and ammonia substitution products, or amines, conduct The nitriles of both the aliphatic and aromatic series yield conducting solutions; and of the organic bases, pyridine and quinoline come under this same category.

9. The dissociation theory as promulgated for the explanation of the electrical conductivity of aqueous solutions, apparently cannot be applied in its present form to explain the conductivity in non-aqueous solutions. It further appears that the auxiliary theories, which are based upon the specific inductive capacity, the polymerization of the molecules, and the self-ionization of the solvent, are not sufficient to explain satisfactorily the facts that have been accumulated. Notwithstanding the work that has been done, the data at hand are as yet insufficient for the formulation of a theory by means of which a satisfactory explanation can be given of the phenomenon of electrical conductivity of solutions in general.

This investigation was made in the Laboratory of Physical Chemistry of the University of Wisconsin. It was undertaken at the suggestion of Professor Kahlenberg and carried on under his supervision. I am under many obligations to him for his valuable suggestions and assistance and I take this means of acknowledging the same.

A portion of the results of the earlier part of the work has previously been published by Professor Kahlenberg and myself jointly in a preliminary paper in the *Journal of Physical Chemistry* **3**, 12, 1899. For the sake of completeness the results have also been incorporated in the present article.

Madison, Wis., April, 1899.

THE INFLUENCE OF THE PRESENCE OF PURE METALS UPON PLANTS.[1]

EDWIN BINGHAM COPELAND AND LOUIS KAHLENBERG.

Ever since investigators began to grow plants in aqueous solutions, it has been a frequent observation that the distilled water used was in itself more or less injurious. For instance, Asehoff (13. 1890; 115), declares "pure" distilled water to be poisonous for *Phaseolus vulgaris;* and Frank (13. **17**, 535), finds the water he uses to be injurious to *Lupinus*, though not to corn and beans. These statements have called forth replies from Loew (14), and Schulze (13. **20**, 1891; 236), (the latter without experimental proof), who maintained that really pure water is harmless, and that contrary appearances are due to impurities, such as salts of copper, lead, and zinc, absorbed during or after distillation.

Nägeli's (17) careful study of the subject was edited by Cramer and published by Schwendener twelve years after the author's death. Nägeli proved conclusively that water in itself is harmless, but that various metals in solution in infinitesimal quantities are deadly. The presence of "insoluble" substances, such as carbon and platinum, is without effect. The most destructive of all the metals that he tried was copper, one part of which in a thousand million parts of water was ultimately fatal to *Spirogyra*. This dilution was so much greater than that of ordinary toxic solutions as to convince Nägeli that

---

[1] A list of the authorities referred to in this paper, together with their reference numbers, is given at p. 472 following. Each reference is indicated in the text by a reference number; and where a particular page of the authority is referred to, the number of the page is also given in the text, following the reference number.

the injury done the plant was of a different nature from ordinary poisoning, and he proposed for the new phenomena the name of "Oligodynamic effects". His idea seemed to be, that from metallic copper minutest particles pass into solution, and that these particles kill the plants by a different action from that of toxic copper salts — perhaps by physical rather than chemical means.[1] The phenomena of death of *Spirogyra* by oligodynamic action are, as should be expected, different from those when death is caused by much more concentrated copper, introduced as a salt.

The facts in Nägeli's paper are final. But his theoretical explanation appears to us improbable and unnecessary, and this paper is a partial explanation of our disbelief.

Every metal in contact with water and air is subject to some change. It reacts with the oxygen and carbonic acid dissolved in the water, or with the water itself, to form oxides, hydroxides, carbonates, basic carbonates, or acids, which in greater or less degree pass into solution. When this chemical action is sufficient for the effect to become visible, the metal is tarnished or corroded; and even gold and platinum lose their lustre. From common observation and scientific research it is known that many of the salts which form under such conditions are poisonous. Now, since the conditions are present under which salts form, and since the salts are known to be toxic, and since any kind of solutions of metals in the metallic state is unknown to the chemist, it is *à priori* reasonable to suppose that the injury which a plant suffers in water in the presence of a metal, is due to the salts of the metal, just as much as if the salts, and not the metal, were introduced directly into the water.

The injury to the plant will depend largely upon two factors:

1. The tendency of the metal to get into solution as a component of chemical compounds — which we shall designate loosely as salts.

---

[1] This seems to us to be a fair statement of the tenor of Nägeli's work, and is the conclusion commonly drawn from him. Cf. Frank and Krüger (5), though Nägeli does express the belief that the metals dissolve as hydroxides, or carbonates. The presence at some time of the metal itself is repeatedly emphasized as necessary to produce oligodynamic effects.

2. The specific toxicity of the metal when in solution in form of such salts.

There is another possible factor — (3) the nature of the combination formed. But it is not probable that this has made any difference in any of our experiments, except in the case of magnesium, which decomposes water and makes a solution so alkaline that the concentration of OH ions must be fatal. The rapidity of diffusion of the solution is still another factor when the plants and the metals are separated in the water, and the solution is not disturbed: in the cases of iodine, arsenic, and copper (Table IV, copper wire) this was apparent.

Preliminary experiments were made upon *Lupinus luteus* and *Zea Mais*, without equal areas of metal or equal volumes of water. As more accurate work was afterward done with *Lupinus albus*, the experiment with *L. luteus* is not reported. The remaining experiments were performed in uniform glass beakers of 200 c.c. capacity, which were coated with paraffine to remove even the suspicion that the glass had influenced the results. As many of the metals as were available in the form of foil, or as could be rolled, were used in that form; and pieces were cut out for use 57 by 34 mm., exposing an area of 3,876 sq. mm. These pieces were bent so as to stand on edge on the bottom of the beaker. Zinc wire was rolled flat and bent into a coil having the same area as the other metals, and reaching about the same height from the bottom of the beaker. A magnesium coil was used in the same way. Antimony and bismuth were used as sticks, of which enough were used to have the desired area; and these were tied so as to stand about as high as the other metals in the water. All of these metals then offered equal surfaces to the action of the water at practically the same distance from the roots. Roll sulphur and carbon (in the form of a plate cut from conducting carbon such as is used in batteries), though not metals, were experimented with under the same conditions. Mercury could not be employed except as a layer on the bottom of the beaker, whose surface exposed to the water was about 2,000 sq. mm. Arsenic and iodine were used as a coat of flakes over the bottom of the beaker, but the surface actually exposed to the water was of course much greater than the area of glass that was covered. The last nine elements in the tables were available only as samples, of various size, and were put into smaller beakers, each receiving only one plant.

The metals we used were all of them of the best C. P. varieties of standard makes. Any impurity would not only invalidate the results directly, but might also create a miniature battery, which, even if the current itself did not influence the plants, would certainly, by so-called local action, hasten the corrosion of the metals. Before using, the metals were scoured with emery cloth or sea sand and washed clean, and then introduced into the beakers without being touched with the hands.

The water used was distilled from tap water, and may have contained carbonic acid and a trace of ammonia. The entire distilling apparatus was of glass, and the water obtained the first few hours was thrown away, as likely to contain the most of whatever could be dissolved from the glass.

The seedlings used were average plants, selected in every case from a large number; and, except in the second experiment with *Lupinus albus*, they were very uniform in all respects. At the beginning of the experiment a mark was made with India ink 10 mm. from the apex of the root. The numbers in the columns headed "Growth" in the tables, express the excess in length of these apical zones over the original 10 mm. The last change observed in the length of the roots was sometimes a contraction, which showed that the growing region, previously stretched by the turgor, was dead. When the tables do not show this contraction, it may be because the measurements were not timed right; or possibly because the plants as they died grew up to the limit of their stretching. The plants were kept in approximate darkness, but not in an excessively damp atmosphere.

Table I.

Preliminary experiment.

Zeo Mais. Nov. 15, 5 P. M. Radicles 1.5-2 cm. long.

GROWTH IN MM.

METAL.	AREA.	Nov. 17.	Nov. 19.	Nov. 22.
		5 P. M.	2 P. M.	11 A. M.
Cu	550 sq. cm.	0	Tip green; shrunken,	brown above.
Ni............	550	0	Tip greenish; some	what shrunken above.
Sn............	550	25	50.	70.
Ag............	200	0	Dirty.	Brownish.
Pt............	75	10	20.	Curled up.
Au	98	18	25.	40.
Hg	19	6	9.	Coiled tight.
Sb............	92	20	30.	40, dirty.
Bi	114	5	5.	Brownish.
Co............	69	0	Collapsed, flaccid,	tawny.
Cd............	33	0	Tip reddish-brown.	
Fe............	195	5	5.	Rust-brown.
Zn............	40	0	Brown, with purplish	tinge.
Al	160	10	20.	35.
Pb	47	0	Dirty and glassy look	ing.
Control	....	20	40.	70.

The silver and platinum were probably impure, and such a growth in the presence of antimony was not found again in any later experiment.

TABLE II.

Lupinus albus. Nov. 26, 3 P. M. Roots 3–4 cm. long. Two plants in each beaker.

GROWTH IN MM.

METAL.	Nov. 26.	Nov. 27.		Nov. 28.		Nov. 29.	Nov. 30.	Dec. 3.	Dec. 7.
	10 P. M.	9:30 A. M.	4 P. M.	9:40 A. M.	4 P. M.	9:30 A. M.	9:30 A. M.	9:30 A. M.	9:30 A. M.
Au..............	9	14	17.5	26	29	41	51*	70.5	78
Pt..............	9.5	16	21	30.5	36	50	67.5*	87.5	94
Pd..............	8	15	18.5	25	26.5	36	50.5*	74	79
Ag..............	9	17	20	26	30	40	53*	81	88.5
Al..............	9.5	17	20	23.5	25	32	42*	61.5	71
Cu..............	6	6.5	6.7	6.0	....	....	....	....	....
Ni..............	7	13.5	15.5	24	26.5	32	33	33	....
Co..............	5	7.5	7.5	6.0	....	....	....	....	....
Sn..............	8	14.5	16.5	23.5	28	38.5	52*	69	75.5
Fe..............	5.5	9	9	12.5	13.5	16	16.5	16.5	....
Cd..............	6	7	7	6	....	....	....	....	....
Tl..............	5	5.5	5.7	5.7	....	....	....	....	....
Pb..............	6.5	9	10	9.5	....	....	....	....	....
Zn..............	7	11	13	12.5	....	....	....	....	....
Mg..............	6.5	11	12	16	17	16.2	....	....	....
Sb..............	6.5	8	8.5	9.3	9.5	9.3	....	....	....
Bi..............	6	12	13	19	20.5	31.5	57*	104	123
S..............	5.5	10	11.5	17.5	19.5	28.5	44.5*	58.5	66.5
C..............	5	9.5	11	19.5	22.5	39	60.5*	83.5	98
Control, H_2O...	7.5	10	12.5	18	19.5	26*	35	49.5	53
Hg..............	8.5	16	18	25	27	29.5	31.5*	40	42.5
As..............	5.5	6.3	7	7	....	....	....	....	....
I..............	7	13	16	22.5	24.5	31.5	33.5	33.5	....
Started at 5 p. m.									
Ru (Powder)....	5	7	7.7	10.3	12	20	29	40	42
Mn (Lumps)....	4	7	8	10	11	12.7	13.5	17	18.2
Cr (Lumps).....	4.5	10	13	21	24.5	40	55	71	76
In (Lumps).....	4.5	11	14	23	27.5	43.5	65*	94	98
W (Powder).....	2.7	4	4.5	4.5	....	....	....	....	....
Te (Sticks)......	5.5	11.5	15	24.5	29	46	57	61	61
Se (Sticks)	4.5	11	15	23	34	57	82*	121	122.5
B (Powder)......	5	12	15	21.5	24.5	30	37*	59	Broken
Rh (Lumps)....	6	15	17.5	26	28.5	45	65*	86	92

The asterisk * marks the time when the development of lateral roots first seemed likely to affect the growth of the tap root.

The appearance of the dead roots, exposed to various metals, November 30, was as follows:

Cu—the dark *greenish*-brown of Rookwood pottery.

Ni—white.

Co—brown, reddish or bluish in spots.

Fe—not very dark brown. Stubby lateral roots appeared after the main root tip died; these, too, were short lived. The root was covered early in the experiment with a brownish coat of "iron rust."

Cd—brown; entirely collapsed above.

Tl—light brownish; flaccid.

Zn—slightly discolored; lateral roots as with Fe.

Sb—brownish-yellow.

Mg—irregular brown blotches nearly covering light colored field; flaccid.

As—slightly discolored, flaccid; immersed hypocotyl-like root.

I—tip red-brown; little discolored above, and inclined to form stunted lateral roots there. The tip became almost blue as the iodine diffused upward, and killed the rest of the root and stained it red.

W—drab, flaccid; hypocotyl brown.

Hg—one plant dead, with root white.

There were seven control plants in four beakers, and only one of these showed any considerable divergence (an excess) from the average given in the table. They were the first to develop lateral roots, which depressed the growth of the tap root a little; but the platinum, carbon, and gold cultures soon passed them in this respect. A very long tap root does not necessarily indicate thrifty growth and is frequently a symptom of disease. The lower part of the tap roots of the bismuth, chromium, indium, selenium, tellurium, and surviving mercury plants shot out as long, branchless whips, which for a time furnished formidable figures for the table, but were obviously abnormal and likely to result in death. The plant grown with tellurium died abruptly at the end of such a growth, and the selenium plant had probably reached its limit by the last measurement. On the other hand, the tap root of the ruthenium plant became stunted and at the end of the experiment was being passed by two very slender lateral branches. The root of the manganese plant was stained pale yellow and cracked to let out numerous lateral roots, which grew just enough to show their tips, after the fashion of the iron plant.

As to the condition of the metals themselves at the end of the experiment, there was no visible change in the gold, platinum, palladium, silver, nickel, tin, antimony, (sulphur, carbon), rhodium, chromium, indium, tellurium, (selenium), and ruthenium, tungsten, and boron,— the last three being in form of powder. The aluminum was not quite as bright as at first; the copper, of a little darker hue; the cobalt, tarnished olive green. The solution containing iron was brownish yellow, and contained a yellow precipitate — in part probably basic carbonate of iron,— with which the metal was thickly coated. The cadmium was badly corroded, the discoloration being very likely due to basic carbonate. Thallium was also corroded, of a blurred grayish appearance; the solution acquired a very pale lavender tint, but contained no precipitate. Zinc was badly discolored, by its basic carbonate. Magnesium was much discolored; there were hydrogen bubbles on the metal, and the sides of the beaker, and the alkalinity of the water was equal to 0.0075 Normal. According to Kahlenberg and True (9. p. 95) a concentration of 0.005 N. of hydroxyl ions is about sufficient to kill in twenty-four hours. The water in which lead had been placed contained a very copious precipitate of basic carbonate of lead, which covered the bottom of the beaker and coated the metal. The change in the sticks of bismuth was slight, the lustre having acquired an olive tint. The mercury surface was somewhat tarnished. The water containing sulphur showed a trace of sulphuric acid with the barium chloride test, but the free acid was only equal to 0.15 c.c. N. per liter. Iodine colored the water the characteristic shade, and diffused upward slowly, staining the paraffine on the wall of the beaker as it went. Manganese became covered with a brown precipitate — probably oxyhydrate of manganese,— which was also deposited on the bottom of the beaker. After a time white flakes on the arsenic betrayed the formation of arsenious oxide.

TABLE III.

Lupinus albus. Dec. 22, 3 P. M. Same conditions, except that the control plants, four in number, were selected seedlings, likely to exceed the average growth, under the same conditions.

GROWTH IN MM.

METALS.	Dec. 23.	Dec. 24.	Dec. 26.	Dec. 29.	Dec. 31.
Control	6.5	15.5	37*	52	54
Au	7	15	34	48.5*	49
Pt	11	18	34	39.5*	42
Pt Cl_4-trace	5	10	29*	41	42.5
Pt Cl_4-faint trace	6.5	10	30.5	48*	51
Pd	9.5	13.5	32	41.5*	42.5
Pd $(NO_3)_4$-trace	1	1	....	....	....
Ag	10	13	29*	44.5	48
Al	7	11.5	34.5	60*	66
Cu	11	11	....	....	....
Cu wire, 5 cm	0-10	0-17	0-20	0-20	....
Cu wire, 1 cm	5-6	10-12	33-35	38-55	38-56.5
Ni	5.5	10	19 (dead)	29.5*	30.5
Co	8.5	8.5	....	....	....
Sn	3	7 (dead)	15	22*	25
Fe	3	4.5	40	....	....
Cd	4	3.8	....	....	....
Tl	2	2	ivory white	except at tip	....
Pb	2	7 (dead)	15.5	15	....
Pb CO_3	2	2	....	....	....
Zn	6	6	....	....	....
Mg	2.5	2.5	....	....	....
Sb	7	10	11.5	11.5 yellow	....
Bi	3.5	9	14.5	40*	42.5
C	14	22	46*	79	85
Hg	7	10	22	32	32.5
Ru	6	16.5	44	59*	59.5
Mn	6	8	11	15	14.7
Rh	5	11	24*	34	37
Cr	8	14	29	38.5*	38.5
In	4	9	38	59	64
W	5	18	40	42*	42
Te	7	15	31	35	35
Se	5	13.5	31	46*	50.5
B	9	23	77	139*	14

The asterisk * marks the time when the development of lateral roots first seemed likely to affect the growth of the tap root.

The most interesting point shown by this table is the growth of the copper and cobalt cultures during the first day, before the solution reached a fatal concentration. Platinic chloride and palladium nitrate were put into the water in unmeasured traces, to see if they would act as stimulants; but no such effects resulted. One of the plants in the presence of metallic lead was too vigorous to be killed by the concentration of lead ions present during the first three days, and grew in the whip-like form observed before in some toxic but not fatal solutions. A spoonful of carbonate of lead in a beaker of water dissolved enough to be deadly during the first day. Tungsten induced a similar brief growth in length, without branches unless at the very base, in this experiment; as did also selenium, indium, and boron; the last one (boron) produced a monstrosity. It would be needless to repeat here the observations on the roots and metals already given under experiment II.

The influence of the area of exposed metal upon the time required for a solution to become deadly, is shown by coating with paraffin all but certain a measured length of submerged copper wire. The first figure in each couple in the table represents a root near the wire, the other being relatively far from it. The influence of the area of exposed metal was tested at another time with similar results shown in the following table, the plant being the same, *Lupinus albus*, beginning December 6.

GROWTH IN MM.

	Dec. 7.	Dec. 8.	Dec. 9.	Dec. 10.	Dec. 15.	Dec. 17.
Control	6.7 mm.	13	24	26*	49.5	51
1 cm. cu. wire.....	4.7	10.5	19.5	28.5	57.5	57
5 cm. cu. wire.....	4.5	7.7	9	8.7	Brown.	....

The plants in pure water were distinguished from those grown with 1 cm. of wire exposed, by their copious development of lateral roots more than by the slight difference in color.

TABLE IV.

Avena sativa. Dec. 8, 3 P. M. Conditions as in Table II. Not more than three roots on a seedling: the longest root — between 30 and 35 mm. in length, — used for the measurements.

GROWTH IN MM.

METAL.	Dec. 9.	Dec. 10.	Dec. 11.	Dec. 13.		Dec. 15.	Dec. 19.	
				Root.	Shoot.		Root.	Shoot.
Control	8	17	29	47	81	61	64	120
Au	12	20	31	52	82	70	73	130
Pt	11	29	37.5	59	95 —	one pla	nt lost.	....
Pd	12.5	21.5	29	42	77	47.5	48.5	120
Ag	4	6.5	7.5	10.5	50 (1 dead.)	11.5	11.5	52
Al	6	15.5	15.7	19.5	70	21.5	21	90
Cu	1	1 —	Nearly	white;	after	ward gr	eenish.	....
Ni	14.5	27	40.5	67	65 — 1	plant	lost.	....
Co	3	3	....	Pale brown.	50	....	....	80
Sn	14	27.5	36	65	82	68	69	115
Fe	3	3.5	4	5	73	5	....	95
Cd	1.5	1.5	....	....	48	....	....	85
Tl	2.3	2.0	....	....	25	....	....	....
Pb	2.8	4	4	....	30	....	....	30
Zn	1	1	....	....	65	....	....	85
Mg	1.5	1.5	....	Dis-col'red.	65	....	....	80
Sb	4.5	8	9.7	11.5	55	12	12	70
Bi	11	16	18.5	22	41	22.5	22.5	55
S	17	27.5	36.5	39	95	39.5	39	125
C	15	26	36	55.5	97	68.5	73	135
Hg	8.5	16.5	26	49	65	63	72	120
As	1	1	....	....	20	....	....	....
I	1	1	....	....	37	....	....	....
Ru	10	11.5	14	14.5	40	14.5	....	80
Mn	10	17	18	19.7	55	20	20	80
Rh	5.5	10.5	14	37	90	46.3	46.5	110
Cr	7	10	11.5	13	67	13.3	13.3	100
In	15	30	36.5	41	90	41	40.5	120
W	5.5	6.3	6.3	60	45	....	....	....
Te	15	30	38	40	70	40	....	100
Se	8	15	20	35	70	62	88	110
B	6.5	18	22	35	90	54	62	160

The shoot was measured to the tip of the longest leaf. The roots of the oat were less inclined to become discolored than those of the lupine. Roots dead under the influence of silver, thallium, zinc, lead, antimony, and bismuth were white; and cobalt and cadmium only gave them a dirty appearance. Manganese colored them yellowish, and tellurium pale brown. The alkalinity caused by magnesium was equal to 4.2 c.c. N. per liter; by zinc, to 0.05 c. c. N. per liter. In its general and most striking features, this table is like those given for *Lupinus.*

TABLE V.

Soja hispida. Dec. 19, 2 P. M. Part of same vessels and metals as in experiment II.

GROWTH IN MM.

METALS.	Dec. 20.	Dec. 21.	
Control	9.5	14	
Au	9	13	
Pt	6	9	
Ag	5	5	Brownish.
Al	6	10	
Cu	0.5	0.5	Greenish-brown.
Ni	11	16	
Co	0.5	0.5	Discolored, flaccid.
Fe	1.5	4.5	
Cd	0.5	0.5	Flaccid, tip yellowish.
Tl	0.5	0.5	Glassy.
Pb	1.5	1.5	
Zn	0.5	0.5	Yellowish.
Hg	5.0	5.0	

The seedlings were not as uniform nor robust as was desirable, and the experiment is reported only to show that the same metals that killed *Lupinus* kill *Soja:* in addition to these, silver and mercury seem to have been deadly.

The elements whose presence in the water where plants grow has been shown to be always fatal, are thallium, cadmium, copper, cobalt, zinc, lead, iron, antimony, magnesium, arsenic, iodine, tungsten, and tellurium. Mercury and silver seem to kill the *Soja* bean. It is not necessary, and might not be possible, to demonstrate by chemical tests the presence of all of these substances in the roots they have killed. They *had* to be in the roots, where they could attack the protoplasm of each cell, before they could kill it. And in some instances the dead root's appearance shows the presence of salts of the metal that killed it. Thus, roots killed by copper or nickel, or iron or cobalt show colors characteristic of salts of these metals, while those killed by zinc, lead, thallium, and arsenic are at the darkest not more discolored than they would be if killed by heat. The appearance of the root or of the metal, or of both, betrayed the presence of salts of every metal that was uniformly harmful.

What literature there is bearing upon this question harmonizes with our results as to the comparative toxicity of the different elements: and as all other determinations, while agreeing with ours, have been made with the salts of the metals, we have in them still further support for the idea, that it is in ordinary compounds, and not in any modification of the metallic form, that the metals in our experiments attack the roots. And this being so, we see absolutely no difference between this and any other ordinary case of poisoning.

On the first factor in determining the injury a metal can do — its tendency to get into solution —, we introduce from a table by Neumann (18. p. 229) the following sequence of basic elements, arranged according to their solution tensions, as determined by the differences in potential existing between the metals and normal solutions of their salts: magnesium, aluminum, manganese, zinc, cadmium, thallium, iron, cobalt, nickel, lead, hydrogen, bismuth, arsenic, antimony, tin, copper, mercury, silver, palladium, platinum, gold. Down to mercury, all of these elements except aluminum and tin and possibly magnesium, are injurious, and, excepting further manganese and bismuth, fatal during the time of experiment. Mercury and silver were sometimes injurious; palladium, platinum, and gold, apparently never so. The salts of the elements standing high in the above series which did not kill our plants are, so far as known, comparatively harmless. On the whole, this series is strikingly similar to the one we would make from the effects upon plants.

On the second factor — the toxicity of the salts of the several elements — there is considerable more or less instructive but scattered literature. On platinum and gold the only information we have found, is a statement by Knop (10. Ref.) that $PtCl_4$ and $AuCl_3$ are injurious to plants, without being demonstrable in the ash; which indicates that they are extremely poisonous. The same statement is made with regard to Ag_2O. Kahlenberg and True (9. P. 104) find the salts of silver to be the deadliest they used, $\frac{N}{409,600}$ being about a sufficient concentration to kill lupines in one day. According to Paul and Krœnig (20), $\frac{N}{200}$ of silver salts is necessary to kill nearly all bacteria in a culture in 10 h. 30 m. The same authors find gold more toxic than copper, but do not call platinum very injurious. Kahlenberg and True state that lupines will just live in $\frac{N}{12,800}$ $HgCl_2$: but Heald (8) places the limit of endurance for *Pisum sativum* at $\frac{N}{204,800}$; and Paul and Krœnig for bacteria, and Stevens (27) for fungus spores, agree that mercuric salts are among the most poisonous known. Other experiments with palladium are not known, but our own merely qualitative one (Table III) showed that its salts are very poisonous. Among these first five metals of our tables, then, are those whose salts are the most deadly known; and yet, because of their resistance to corrosion, their presence in the free, native state caused little or no injury.

From the appearance of the metal and from its position in Neumann's table, it is probable that considerable aluminum went into solution; and from its not hurting the plants, we conclude that it is not very poisonous. This conclusion is confirmed by Molisch (16) who applied alumium sulphate in considerable quantities to pots of *Hortensia* without very great injury, and found alum entirely harmless. Aluminum is nearly always present in *Lycopodium*, and is an occasional constituent of many flowering plants: according to Gaze (6), Al_2O_3 makes up 0.3259 per cent. of the dry weight of *Hydrastis* roots.

The poisonous character of salts of copper is universally recognized, and makes itself apparent whenever any salt which dissociates to form copper ions, enters the plant through the leaves (when it is used as a fungicide) or from the ground. Molisch (16) finds the sulphates of nickel, cobalt, zinc, and copper to be poisonous. Tschirch (29) holds that copper is not a poison, but that its salts are corrosive and therefore injurious; if his view is correct, it must be the salts that are effective in our experiments, but we would not like to rely upon this proof. According to Günther (7. Ref.) copper acts upon fungi as a stimulant when very dilute; when not so dilute, as a poison. The concentration of copper salts (dissociated) necessary to kill Lupinus in twenty-four hours according to Kahlenberg and True (9. P. 96), is $\frac{N}{25,600}$. On the same authority nickel salts are fatal at a concentration of $\frac{N}{25,600}$, and cobalt salts at the same point. Phillips (23) quotes Freytag to the effect that nickel has about three-fifths of the toxic power of cobalt. Other authority makes the difference greater; thus Heald gives $\frac{N}{6,400}$ $CoSO_4$ and $\frac{N}{51,200}$ $NiSO_4$ as solutions just permitting the growth of *Zea Mais*, and Richards (25. P. 686) finds the most favorable concentration for the vegetable development of *Aspergillus niger* to be 0.002 per cent. $CoSO_4$ or 0.033 per cent. $NiSO_4$; their toxicity is probably in the same proportion, and the per cent. data are comparable because nickel and cobalt have about the same atomic weight. Our results agree with those of Richards, that cobalt is decidedly more poisonous than nickel.

The influence of iron upon plants depends upon whether it occurs in solution as a crystalloid or as a colloid substance. In our experiments enough iron dissolved to discolor the solution, but it was probably in large part colloidal. That it did not diffuse readily into the interior of the roots, is shown by their staying alive and attempting to form lateral branches; as was noticed again in the case of manganese. In minute quantities iron is a necessary plant food. Ferrous salts may be injurious chiefly by their reducing action. Richards finds $Fe SO_4$ in appropriate dilution to act as a stimulant upon *aspergillus.* Kahlenberg and True place the concentration at which Fe ions exert a fatal influence at less than $\frac{N}{51,200}$.

The same authors give the greatest concentration at which lupines can endure cadmium salts as $\frac{N}{204,800}$ showing that these salts are exceedingly toxic. Guenther finds cadmium more poisonous than zinc for fungi. Blake (1) from experiments upon animals cites cadmium and thallium as typical elements of high atomic weight and intense physiological action. Knop finds thallium, like gold and silver, deadly without being demonstrable in the ash. Both thallium and cadmium made short work of our plants.

The literature upon zinc as a poison is very extensive, but wanting in quantitative data. Knop (11) attempted to substitute it for calcium, and found it injurious when present as a trace in the roots. Molisch and Günther agree that it is poisonous. Nobbe, Baeseler, and Will (19) find it more poisonous than lead but less so than arsenic (as arsenite). Kranch (12. P. 282) finds it injurious in minute quantity in water cultures, but less so in the ground, which experiment would undoubtedly show to be true of other poisons. At a sufficient dilution it acts as a stimulant. The toxicity of lead is likewise generally recognized, but without there having been any quantitative determinations it is probably less intense than that of many other metals.

We know no previous work upon the effect of antimony upon plants, but its salts have a more intense action in animal physiology than do those of bismuth. Bismuthyl phosphate is not immediately fatal to corn (10. Ref.).

While magnesium is a necessary food of all plants, it is not improbable that it may under some conditions act as a poison.

In our experiments, however, the injury to the roots was more likely to be due to the alkalinity than directly to the magnesium. The action of sulphur upon plants depends entirely upon the chemical combination in which it is present: sulphates are essential food, while sulphites and sulphides (usually, at least) are poisonous.

According to Remsen, arsenic is not poisonous in the elementary state, but becomes so when oxidized. And the violence of the toxicity depends further upon the degree of oxidation. Working with arsenites, Phillips (23) concludes that arsenic is more toxic than copper, and Nobbe, Baeseler, and Will (19), find that it surpasses zinc. On the other hand, working with arsenates Blake (1) finds that the toxicity depends upon the basic ion. Low (15) states that algae grow in 1 per cent. potassium arsenate: and Bouilhac (3) goes so far as to maintain that arsenates may replace phosphates in the nutrition of various green and blue-green algae. This is denied by Stocklasa (28. Ref.) who places the concentration injurious to plants at $\frac{N.}{100,000}$ As_2O_3 and $\frac{N.}{1,000}$ As_2O_5. Knop (10. Ref.) pronounces arsenates harmless toward mature phanerogams.

Manganese is injurious in the concentration used by Molisch (16) but it has been detected in the ash of a great number of plants. According to Spampani (26) while not a substitute for iron, it will postpone chlorosis. It is difficult to draw conclusions from Stevens' work (27) since in one table (p. 399) he rates the toxicity of $KMnO_4$ above that of potassium cyanide, sulphuric acid, or caustic potash, and in another (p. 401), declares that it is not poisonous. Stevens finds potassium chromate somewhat injurious to fungus spores, and potassium bichromate very much so. Knop (10. Ref.) agrees that chromic acid is injurious, but says that chromium oxide is without effect. The only statement with regard to tungsten is Knop's, that "Phosphorwolframsäure" is fatal without being demonstrable in the ash. Cameron (4) regarded selenium as to some extent a substitute for sulphur: but Knop (10. Ref.) and Bokorny (2) agree that, while telluric acid is harmless, the salts of both selenic and selenious acids are poisonous. Knop places boric acid among the poisons, and Peligot (21) agrees with him. Paul and Krœnig do not find it extremely toxic. Traces of boron have been found in the ash of numerous plants.

It is likely that iodine alone among the substances we have tested injures plants directly, acting in the elementary state as the elementary halogens have been found before to attack plants more violently than do their acids. But iodine is so distinct from the metals in all respects that its behavior throws no doubt on our views as to the mode of their action.

With the exception, because of their extreme resistance to corrosion, of the first four or five metals in our table, we find that just those metals poison plants when present in water whose salts are already known to be toxic; which is the final evidence in favor of our original view, that in our experiments — and presumably in Nägeli's too—it is still strictly the salts acting in their ordinary, characteristic ways, which kill the plants.

It is a well recognized fact in animal physiology that the phenomena of stimulation and of poisoning are very intimately related, and the applicability of the same principle in plant toxicology has been constantly forced upon us. The same thing has been observed to apply to certain fungi by Raulin (24), Pfeffer (22. Foot note, p. 238), and Richards (25) for manganese, zinc, iron, cobalt and so on; and a statement of Risse in Sach's *Experimental Plant-Physiology* indicates that zinc sometimes exerts a similar influence on phanergams. Frank and Krueger (5) find that by proper application of copper a potato plant can be stimulated to the production of sturdier leaves and more chlorophyll, and to more active transpiration and assimilation, and longer life. In our own experiments we have seen copper and cobalt certainly, and boron, lead, and tungsten probably, exert a stimulating influence in individual instances. And we have found that, except when the control plants were selected as especially thrifty, those that grew in the presence of gold and platinum, which can have entered into solution only in the most infinitisimal amounts, were uniformly of more vigorous growth. The subject of chemical stimulants is a most inviting one for further study.

University of Wisconsin, Madison, Wis., December, 1899.

LIST OF REFERENCES IN THE FOREGOING PAPER.

1. **Blake (J.).** Relation of the chemical constitution of inorganic compounds to their physiological action.
Chemical News. **55**, 1887; 110-111.

2. **Bokorny (Th.).** Ueber die physiologische Wirkung der tellurigen Säure.
Chem. Zeitung, 1893; p. 17. (Ref.) Just's Bot. Jahresber, 1893, I; 289.

3. **Bouilhac (R.).** Influence de l' acide arsénique sur la végétation des algues.
Comptes Rendus, **119**, 1894; 929.

4. **Cameron (C.).** Preliminary note on the absorption of selenium by plants.
R. Dublin Soc. Sc. Proc., 1879; p. 221. (Ref.) Just's Bot. Jahresber, 1880, I; 324.

5. **Frank (B.)** and **Krueger (F.).** Ueber den Reiz welchen die Behandlung mit Kupfer auf die Kartoffelpflanze hervorbringt.—Vorl. Mittheilung.
Ber. d. d. Bot. Ges., **12**, 1894; 8.

6. **Gaze (R.)** Ueber den Aluminiumgehalt der Wurzel von Hydrastis Canadensis.
Apoth. Zeitung, **5**, 1890; 9. (Ref.) Just's Bot. Jahresber., 1890, I; 51.

7. **Guenther (E.)** Beitrag zur mineralischen Nahrung der Pilze.
Inaug. Diss., Erlangen., 1897. (Ref.) Bot. Centralb., **74**; 194.

8. **Heald (F. de F.)** On the toxic effect of dilute solutions of acids and salts upon plants.
Bot. Gaz. **22**, 1896; 125.

9. **Kahlenberg** (L.) and **True** (R. H.) On the toxic action of dissolved salts and their electrolytic dissociation.
Bot. Gaz. 22, 1896; 81.

10. **Knop** (W.) Ueber die Aufnahme verschiedener Substanzen durch die Pflanze, welche nicht zu den Nährstoffen gehören.
Ber. d. K. Sächs. Gesells. d. Wissens. zu Leipzig. Math.-Phys. Klasse, **37**, 1885; 39. Known only from Ref.—Just's Bot. Jahresber., 1886, I; 80.

11. **Knop** (W.) Agricultur-chemische Versuche, ausgeführt auf der Versuchs-Station zu Möckern.
Landw. Versuchsst., **1**, 1859; 3.

12. **Krauch** (C.) Ueber Pflanzenvergiftungen.
Journal f. Landw., **30**, 1882; 271.

13. Landwirthschaftliches Jahrbuch.

14. **Loew** (O.) Ueber die Giftwirkung de s llirte n Wassers.
Landw. Jahrb. **20**, 1891; 235.

15. **Loew** (O.) Sind Arsenverbindungen Gift für pflanzlichen Protoplasma?
Archiv f. d. ges. Physiologie, **32**, 111–113. (Ref.) Just's Bot. Jahresber., 1883, I; 42.

16. **Molisch** (H.) Der Einfluss des Bodens auf die Blüthenfarbe der Hortensien.
Bot. Zeitung, **55**, 1897; I, 49.

17. **Naegeli** (C.) Oligodynamische Wirkungen in lebenden Zellen.
Denksch. d. schweizerischen Naturf.-Gesellschaft, Bd. 33, 1893. (Ref.) Bot. Centralb. **55**, 31, and Bot. Zeitung, 1893; p. 337.

18. **Neumann.** Ueber das Potential des Wasserstoffs und einiger Metalle.
Zeits. f. physik. Chemie, **14**, 1894; 193.

19. **Nobbe** (F.), **Baeseler** (P.), u. **Will** (H.) Untersuchungen über die Giftwirkung des Arsen, Blei, und Zink im pflanzlichen Organismus.
Landw. Versuchsst., **30**, 1884; 381–423.

20. **Paul** (Th.) und **Kroenig** (B.) Ueber das Verhalten der Bakterien zu chemischen Reagentien.
Zeits. f. physik. Chemie, **21**, 1896; 414.

21. **Peligot** (E.) De l'action que l'acide borique et les borates exercent sur les végétaux.
Comptes Rendus, **83**, 1836; 688. (Ref.) Just's Bot. Jahresber. 1876; p. 903.

22. **Pfeffer** (W.) Ueber Election organischer Nährstoffe.
Jahrb. f. wiss. Bot., **28**, 1895; 205. Foot-note, p. 238.

23. **Phillips** (F. C.) The absorption of metallic oxides by plants.
Chemical News, **46**, 1882; 224.

24. **Raulin** (J.) Etudes chimiques sur la végétation.
Ann. des Sc. Nat. Bot., sér. V, **11**, 1869; 93. See pp. 238, 252.

25. **Richards** (H. M.) Die Beeinflussung des Wachsthums einiger Pilze durch chemische Reize.
Jahrb. f. wiss. Bot., **30**, 1897; 665.

26. **Spampani** (G.) Seil manganese posso sostituire il ferro nella nutrizione delle piante. Pisa, 1891.
(Ref.) Just's Bot. Jahresber., 1891, I.; 27.

27. **Stevens** (F. L.) The effect of aqueous solutions upon the germination of fungus spores.
Bot. Gaz., **26**, 1898; 377.

28. **Stoklasa** (von.) Ueber die physiologische Bedeutung des Arsens im Pflanzenorganismus.
Zeits. f. d. landw. Versuchswesen in Oesterreich, 1898; p. 154. From (Ref.) Bot. Centralb., **75**, 304.

29. **Tschirch** (A.) Weitere Mittheilungen über das Kupfer vom Standpunkte der Toxicologie.
Schweiz. Wochenbl. f. Chem. u. Pharm., 1895, No. 13. (Ref.) Just's Bot. Jahresber., 1895, I.; 294.

NUCLEAR PHENOMENA IN CERTAIN STAGES IN THE DEVELOPMENT OF THE SMUTS.

WITH PLATES VIII AND IX.

ROBERT A. HARPER,

Professor of Botany, University of Wisconsin.

The economic significance of the smuts, together with the uncertainty as to their relationships, has made them almost constantly objects of investigation both from the practical and the more purely theoretical standpoint. The older literature is cited fully in papers by Tulasne[1] and DeBary.[2] The germination of the smut spores of various species in water was first accurately observed and figured by Tulasne, DeBary, and the latter's pupil, Fischer von Waldheim,[3] whose excellent paper developed the knowledge of the spore formation and germination for a considerable series of forms into practically the condition in which it remains today. Brefeld[4] has continued and extended our knowledge of the germination of the spores in artificial media. His work is practically exhaustive so far as the external morphology of the forms is concerned, and his vast series of plates illustrating the stages in germination and the saprophytic growth of all the principal genera and species are models of completeness.

All the authors mentioned and many others have observed and

---

[1] Tulasne, "Memoire sur les Ustilaginées comparées aux Uredinées," *Ann. d. Sc. Nat.*, Ser. 3, VII, 1847; and "Memoire sur les Uredinées et les Ustilaginées." *Ann. d. Sc. Nat.*, Ser. 4, II.

[2] DeBary, *Untersuchungen über d. Brandpilze.* (Berlin, 1853.)

[3] Fischer von Waldheim, "Beiträge zur Biol. u. Entw. d. Ustilagineen." *Jahrbücher für Wiss. Botanik*, VII, 1869.

[4] Brefeld, *Botanische Untersuchungen über Hefenpilze.* (Leipzig, 1883); and *Untersuchungen aus dem Gesammtgebiete d. Mykologie*, XII, Heft, "Hemibasidii." (Münster, 1895.)

described the so-called copulation of the sporida, in which two cells become connected by a tube which joins them in pairs very much as are the conjugating cells of *Spirogyra.* DeBary[1] first pointed out the analogy between this union and the sexual fusions in the Conjugatae, and later[2] he presented the evidence more fully as to whether such fusions are sexual. As favoring this view he points out: First, the almost invariable occurrence of the pairing under the normal conditions of germination, i. e., germination in water. Second, the fusions are usually between two, and only two, sporidia. In the case of *Tilletia*, *Entyloma*, and *Urocystis*, when an odd number of sporidia are borne on the promycelium, the sporidia almost without exception fuse in pairs, and the odd one is left out and does not fuse with either of the adjacent pairs, although such a union would be very easy. This shows that a change has taken place in the fused pairs which makes a second union difficult or impossible. Most authors since DeBary's earlier paper appeared, have accepted the view that the sporidial fusions are sexual unions.

Brefeld[3] opposes this view and maintains that such fusing of cells is mere cell *fusion* in the sense in which Unger used the term. According to Brefeld the essential character in a sexual union of cells lies in the fact, that the conjugating gametes are incapable of further vegetative growth by division, but become capable of further development as a result of their union. He finds that the smut sporidia are capable of unlimited development without fusing so long as appropriate nutriment is supplied, and hence concludes that the fusions are purely vegetative phenomena accompanying, perhaps resulting from, the starvation of the sporidia. Such fusions are to be compared to the unions formed between the germ tubes of various spores or the hyphae of mycelia, such as will be described more fully below.

Dangeard[4] has more recently studied the nuclear phenomena

---

[1] *Beitr.* Ser. V, pp. 126-127, and *Morph. Phys., und Biol. d. Pilze, Mycetozoa, u. Bacteria*, pp. 181-184.

[2] DeBary, *Beitr. z. Morph. der Pilze*, I, Ser., "Protomyces and Physoderma."

[3] *Bot. Untersuchungen über Hefenpilze*, Hft. V. pp. 33, 49-50, 175.

[4] Dangeard, "Recherches histol. sur la famille des Ustilaginées." *Le Botaniste*, Ser. III., pp. 240, 268; and *Le Botaniste*, Ser. 4, p. 12.

in a number of forms and has come to some very interesting conclusions as to the sexual reproduction of the group. He finds that in the genera investigated, *Entyloma*, *Ustilago*, and *Urocystis*, the young spore contains two nuclei which later fuse so that the ripe spore contains a single nucleus. This fusion is considered as the equivalent of the conjugation of male and female pronuclei and the smut spore as really an oöspore formed in an oögone. On this ground Dangeard contends that the doctrine of DeBary as to the sexual nature of the conidial fusions which occur later must be abandoned. In the germination of *Ustilago* in water the oöspore nucleus passes into the germ tube and divides, cross partitions are formed, and a two, three or four celled promycelium results. In *Urocystis* and *Tilletia* eight nuclei are regularly formed in the promycelium and pass into the sporidia which are apical in these forms. The nuclei show a membrane with double contour, a nucleole which is very large, and between the two a hyaloplasm more or less charged with chromatin. In the promycelia of *Tilletia caries* some figures were seen which suggested stages in the indirect division of the nuclei. Each sporidium contains normally one nucleus. The secondary sporidia contain two nuclei in *Tilletia*, indicating in them, as the author considers, a return to the condition of ordinary vegetative cells. Dangeard observed the fusion of the sporidia of *Tilletia* in pairs and offers the suggestion, that in the passage of the nuclei from the promycelium to the sporidia an unequal distribution of nuclei may occur, by which one sporidium may obtain two nuclei and another none at all. The fusion tubes then permit a re-establishment of equilibrium by the wandering of nuclei from the sporidia that have two nuclei into those that have none. He finds nuclei in the fusion tubes under conditions which suggest this view.

DeBary proposed the term *promycelium* for the germ tube pushed out by the germinating smut spores, and I shall retain the term although Brefeld has introduced the word *hemibasidium* for the same structure in the effort to show a relationship between the Ustilagineae and the true Basidiomycetes. DeBary proposed also the term sporidium for the spores born on the promycelia. Brefeld very justly, however, points out that these spores differ in no essential particular from other conidia produced by abstriction, and I shall use this latter term.

While working with Prof. Brefeld at Münster in the summer of 1896, I began some studies on methods of fixing and staining the nuclei of the smuts. Prof. Brefeld's experience in growing these organisms in culture media was of the greatest value to me in enabling me to obtain abundant material in all stages of development. Aside from the work of Dangeard the nuclear phenomena in the smuts have been very little studied and further contributions along this line are certainly very much needed.

I have used especially as types material of *U. antherarum* (Fries), *U. scabiosa*, *Sow. U. maydis* (D. C.), and *U. carbo* (Tul.). Material of the first was obtained from *Lychnis alba*, the commoner form on *Saponaria* being found less favorable for the study of the conidial fusions, since its conidia do not unite so readily as do those coming from the other host. The earlier stages of the spore formation were studied however in sections of the Saponaria anthers. It is easy to determine that Dangeard is right in claiming the presence regularly of two nuclei in the young spores.

In considerably older spores but a single nucleus is to be found, and the ripe spores just prior to germination are also uninucleated. Whether this spore nucleus is really formed by fusion of the two nuclei present in the young spore is a difficult question.

Material fixed in Flemming's chrom-osmium-acetic solution, weaker formula, and stained with the triple stain, shows the nuclei as very minute deeply stained bodies. At this stage it is difficult to make out nuclear structures; but later in the promycelia it is easy to recognize in successful preparations a red stained nucleole and blue chromatin net. Dangeard's description of these nuclei as consisting of a nucleole with a surrounding hyaloplasm more or less charged with chromatin and the whole enclosed in a vesicle with double contour should not be taken as indicating any essential difference between the structure of these nuclei and those of the higher plants, since nucleole, chromatin, and membrane are perfectly distinct in practically all cases. The main difference between my observations and Dangeard's lies in his failure to observe in all cases a chromatin net between the nucleole and membrane. The point is of importance since it has been and still is in some quarters[1] the tendency to either deny the existence of nuclei in the fungi or ascribe to them a structure simpler than that of the nuclei of the higher plants and animals. These nuclei of the smuts on the contrary show the same essential differentiations in structure which are found throughout the higher plants. The simplicity of form and life history of these plants is in no degree paralleled by a corresponding condition in their visible protoplasmic structure.

For the study of the germinating spores and conidia cultures were made in beerwort on the slide or in watch crystals. For fixing and staining the following method was worked out by Mr. D. G. Fairchild and myself and has proved applicable and advantageous for the preparation of a variety of one-celled or few-celled organisms which can be had in great abundance. The spores are sown in the beerwort in sufficient abundance so as to form a thick precipitate on the cover glass when conidia are formed. If the later stages of conidial budding and fusion are desired it is necessary to sow relatively few spores, since they multiply with great rapidity. If the germination stages of the spores themselves are desired a sufficient number of spores should be sown to render the drop turbid at once, since in this case there will be no increase in numbers. When the culture has reached the desired age or stage in development, a drop turbid with spores or conidia is drawn up into a fine capillary tube and is then blown gently out into a larger drop of the fixing solution on a fresh slide.

The fixing solution is in this fashion considerably diluted, but owing to the extreme delicacy of the promycelia and conidia they require only very dilute fixing solutions. In case of more resistant bodies the solution would have to be made proportionately stronger to allow of dilution in the manner indicated. The

---

[1] Holtermann, *Mykologische Untersuchungen aus den Tropen.* (Berlin, 1897.)

anther smut is perfectly killed and fixed by using the weaker Flemming solution with an exposure of from fifteen minutes to an hour. Longer exposures produce no apparent effect. The most delicate cells are neither shrunken nor plasmolyzed by this treatment and are hardly visibly different than in the living condition.

A slide is now covered with a film of albumen fixative as is customary in attaching serial sections. A drop of the fixed material without any washing is drawn up into a capillary tube, touched lightly and quickly to the surface of the prepared slide, and a minute droplet of the fixing solution with the contained cells is thus deposited on the albumen film. The spores settle on the albumen which is at the same time at least partially coagulated by the action of the fixing solution. They are thus held fast, and in the same fashion a series of droplets may be distributed over an area which can be conveniently enclosed by the cover glass. From the appearance of the slide when it is successful the process may be compared to stippling and may be known by that name. The slide should be left exposed for a few moments to remove excess of moisture by evaporation, though it should by no means be allowed to become dry. The preparation can then be passed rapidly through the graded alcohols, whereby the albumen is still more firmly set.

After this treatment the preparation is ready for any desired method of staining on the slide and can be treated in all respects as a slide with attached ribbons of sections. Flemming's triple stain was used in making the preparations of smuts to be described below. The point for care in the above process is in depositing the droplets on the albumen. If the droplets are too large the albumen is washed away and the spores are not attached. The finer the droplets the more evenly the spores can be spread on the slide and the more certain it is that each will be attached. Still it is inevitable that many are lost, and the method is only to be recommended in cases where an abundance of material in every desired stage is obtainable. I have used it in making preparations of yeast and swarm spores with great success. It is also far superior to the ordinary method for attaching bacteria to the slide by drying or heat coagulation, especially when it is desired to preserve the interior structure of the bacterial cells. As Fisher[1] has recently pointed out, bacteria mounted according to current methods are likely to be plasmolyzed and frequently distorted.

The disadvantage of the presence of the albumen film in staining is very slight. If it has not been made too thick it is always decolorized in washing out stains before the cells are. In the case of heavy coarse spores I have sometimes found it necessary to drop 80 per cent. alcohol on the slide at once after stippling it with the spore containing droplets, in order to complete at once the coagulation of the albumen and prevent the possibility of the spores being washed away in the weaker grades of alcohol. This latter modification can of course be resorted to only in cases where the cells are not injured by the comparatively sudden transition from an aqueous solution to 80 per cent. alcohol. I find, however, that spores while still in such fixing solutions as Flemming's, are much more resistant and rigid than after washing in water, and will generally stand rapid transitions into alcohol with no change.

Washing out the acid fixing solution, which is such an important feature in fixing blocks of tissue, can here be entirely omitted. The cells are so small that they are sufficiently washed in passing through the grade alcohols.

If we turn now to the nuclear phenomena in the germinating spore, we find that in the case of *U. scabiosa* the promycelium pushes out without nuclear divisions having yet taken place in the spore. The nucleus wanders out of the spore and is to be found in the promycelium when it has reached one-third its mature length (Fig. 1).

When the promycelium is full grown the nucleus lies near its middle. It can be very easily studied at this stage and, when prepared with Flemming's triple stain, shows a sharply differentiated, blue stained chromatin net lying in a clear nuclear sap, a red stained nucleole, and a bounding membrane. The nucleus now divides. The figure is too minute for study of the process

---

[1] "Die Plasmolyse der Bakterien," *Sitzb. d. kgl. Sächs. Ges.-Wiss., Math. Nat. Cl.*, 1891, and "Unters. ü. Bakt.," *Jahrb. f. Wiss. Bot.*, XXVII.

of spindle formation, etc.; but the equatorial plate stage is very distinct and shows a sharply pointed bipolar spindle, whose fibres end in deep staining granules at the poles (Fig. 2). No polar radiations at this stage have been observed. The chromosomes are rather densely massed at the equator and are probably eight or ten in number. Frequently in the neighborhood of the spindle the nucleole can be seen, generally somewhat reduced in size but still a dense red staining granule.

In the dispirem stage the daughter nuclei appear merely as dense flattened disks of chromatin still connected by the old spindle fibres (Fig. 3); as is the case at this stage in the division of the ascus nuclei, as I have already described it for *Peziza Stevensoniana.*[1] The daughter nuclei become free from each other and wander to the opposite ends of the promycelium before they have fully completed the reconstruction stages (Fig. 4). Here they soon divide again, and the four nuclei become distributed at equal intervals in the promycelium, and three cross walls are built forming a typical four-celled promycelium. Budding then begins (Figs. 6 and 7); the conidia drop off and enter on a yeast-like period of growth, as has already been fully described by Brefeld.

The above account of *U. scabiosa* represents a case where a typical four-celled promycelium is formed, such as Brefeld regards as a typical hemibasidium. The spores produce regularly only a single promycelium and all subsequent conidial growth originates from this one conidiophore.

In some species however a series of promycelia are budded off from a single spore and these may be two or three or one celled. A type which produces series of three celled promycelia is *U. antherarum* (Fr.), growing in the anthers of many Caryophyllaceae, and for which the nuclear phenomena in spore formation have been referred to above. This is the fungus which develops its spores in the anthers of the host plant, thereby emasculating them and apparently availing itself of the means for the scattering of its spores which the host plant intended for pollen distribution.

---

[1] *Ber. d. deutsch. Bot. Ges.*, XII, 1895.

The germination of the spores and fusion of the conidia of the anther smut have been very fully described by Brefeld.[1] The spores germinate in a few hours in beerwort. The single spore nucleus divides and one of the two daughter nuclei wanders into the germ tube (Figs. 8 and 9). The other remains in the spore and develops no further during the formation of the first promycelium. For demonstrating the nuclei in the thick walled spores at this stage, a methyl green stain was found preferable to the triple stain of Flemming. A one per cent. solution was used with exposure for a few minutes. Brefeld reports that the spores when germinated in water produce series of promycelia; but that when grown in nutrient solutions they produce but one promycelium, which, however, produces a very large number of conidia. In the most of my cultures, however, which were made in rather dilute beerwort, series of promycelia were thrown off, all of which produced abundant conidial buds.

When the promycelium has reached about two-thirds of its adult length its nucleus divides, and a cross wall is at once built between the two daughter nuclei (Fig. 10). As the promycelium continues to develop the nucleus of the distal cell again divides, and a cell wall is built between the two nuclei, the apical cell so cut off being generally smaller than the one below it (Fig. 11). Conidia are now budded off in abundance from all three cells, and the promycelium itself soon drops off from the spore which immediately produces a second promycelium at the same spot. This may be followed by a third, and so on. How many such promycelia can be formed from a single spore, I have not attempted to determine. Doubtless the spore nourishes itself from the beerwort as do the promycelia in producing the conidia. Each so produced promycelium continues to bud off conidia indefinitely or as long as the medium contains sufficient nutriment.

After falling off from the promycelium the conidia bud like yeast cells, forming small colonies (Figs. 11, 12, and 13), as do the conidia of most of the smuts. By transferring the conidia and promycelia to fresh beerwort the process can be kept up indefinitely. Each conidium is uninucleate and this nucleus di-

---

[1] Loc. cit., pp. 36–54.

vides to furnish nuclei for the daughter buds. The resting nuclei here also show the characteristic elements, nucleole, chromatin mass, and nuclear membrane.

The division is a typical karyokinetic division, although the conditions of size, etc., make a study of the details of the process very difficult. The equatorial plate stage is well defined (Fig. 14). The spindle is sharply bipolar though no polar asters can be made out. The nucleole can frequently be seen as a bright red granule somewhere in the neighborhood of the spindle (Figs. 14, 16). The separation of the chromosomes and their withdrawal to the poles is shown in Fig. 15, and the young daughter nuclei appearing as dense lumps of chromatin connected by the fibres of the old spindle, in Fig. 16. It is interesting that even in such minute nuclei the typical stages of nuclear division as found in other plants are all readily to be identified. The similarity of the nuclear divisions in these simpler plants with those seen in the higher forms is in striking contrast with the relative simplicity of their external morphology and life histories.

It is quite possible that these parasitic fungi are degenerate in their vegetative structure as a result of their parasitic mode of life. In that case, however, the nuclear divisions being entirely reproductive processes would have naturally remained at least at the stage of development they had reached at the time the plant began its parasitic habit, since reproduction is quite as important for the parasite as for the independent organism, though it can dispense to a considerable degree with complexity of vegetative development.

If such conidial cultures of the anther smut be continued for several days and are then allowed to starve by failure to transfer them to fresh culture media, a very large per cent. of the spores will fuse in pairs by means of tubes pushed out and growing together at their tips. This fusion is accompanied by a very considerable increase in volume, as seen by comparing Figs. 12 and 17. The tubes grow out from adjacent cells and are apparently directed by chemotactic stimuli, so that their ends meet exactly. The end walls are dissolved, and the tubes fuse firmly and evenly together so that the points of union cannot be distinguished when the process is complete, except for a slight enlargement of the tube diameter. The tubes may be long or short according as the conidia are more or less widely separated in the culture. They may be either straight or curved as in Fig. 18. Cells that do not become connected thus in pairs remain small, and their protoplasm frequently undergoes changes which cause it to stain as a homogeneous mass. The behavior of the promycelia which have been carried along in the cultures and have continued to bud is also noteworthy. The distal of the three cells of the promycelium is generally the smaller. When starvation intervenes the proximal larger pair of cells put out tubes from their adjacent ends which fuse and connect the two in the same fashion as the conidial pairs are connected. The fused pair now also enlarge greatly and their adjacent ends become rounded out by increased turgor. The cell wall splits and the two cells become free from each other except for the fusion tube (Fig. 19). In this condition they frequently become inclined at an angle to each other. Whether this change in their relative positions is due to special tensions in the walls of the fusion tube itself, or merely to chance as they float in the culture medium, is not easy to say. The distal cell is thus left unpaired, and much more generally than is the case with the similarly situated conidia, it undergoes a speedy disorganization. Its protoplasmic contents are aggregated in deep staining masses (Fig. 19), and ultimately the wall collapses. In some cases, however, where a conidium is lying near such a promycelium the distal promycelial cell forms a fusion tube with the conidium, and thus provided the pair enlarge and continue in as thriving a condition as the two lower cells (Fig. 20).

The resemblance of this whole process of cell fusion to a sexual conjugation is apparent. Externally it is like what happens in the formation of a zygospore from the contents of two Spirogyra cells. There is, however, here no migration of protoplasm from one cell to the other, and what is still more significant, no fusion of nuclei. The nuclei remain in their respective cells throughout the entire process without division or visible interchange of nuclear substance. It appears like sexual fusion but no fertilized egg in the ordinary sense of the term is formed. In this particular it is similar to the conjugation of such infusorians as *Paramoecium*, where the two conjugating individuals both maintain their individuality and continue to divide after the fusion as before. In *Paramoecium*, however, a complicated system of nuclear changes has taken place, resulting in the loss by disintegration of certain daughter nuclei and the providing of each *Paramoecium* with a new micro- and macronucleus to which both individuals have contributed. The occurrence of the fusion after a prolonged period of vegetative activity in the yeast budding and the reduced vitality of individuals which do not succeed in fusing, is another point of resemblance between the process here and in the infusorians, where Maupas has shown that after a number of ordinary vegetative divisions, somewhat definite for each species, the individuals die unless conjugation takes place. Maupas[1] also finds that the conjugation can only occur when starvation threatens, just as is the case with the smut conidia. In the case of the latter, however, fusion is at the most only necessary to render the individuals a little more resistant to a period of reduced nutrition, and as long as the food supply is abundant they show no diminution of vitality; while the infusorians, in spite of abundant food, inevitably die of "senile degeneration" unless conjugation occurs after a certain number of generations.

When fresh beerwort is supplied to the cultures containing fused pairs they begin budding off conidia as before. (Fig. 22.) The process begins frequently by the formation of a rudimentary germ tube as if a mycelium were to be formed. Each spore pushes out in a short tube of practically the same diameter as itself. Cross walls are then put in, cutting off one or two cells from the end of this tube, and these cells then produce conidia by budding. This budding is well figured by Brefeld.[2] In making fixed and stained preparations the conidia are generally broken off, leaving the spore pairs with the germ tubes alone.

Sometimes only one of the two spores germinates (Fig. 21), though as a rule both do. When only one germinates the nucleus

---

[1] E. Maupas, "Le rejeunissement karyogamique chez les cilies." *Arch. de Zool. Exper. et génér.* 2e. Ser., Vol. VII.

[2] Loc. cit., Tafel.

of the other remains quiescent, as seen in Fig. 21, thus indicating clearly its independent individuality. In the case figured the sterile spore is somewhat smaller than the other and its nucleus is also smaller. In the germinating spore the nucleus divides to furnish nuclei for the cells cut off from the germ tube. One nucleus always remains in the spore itself. Brefeld reports[1] that he finds no difference between the fused and unfused conidia in their ability to live through a starvation period. In my own cultures, however, a marked difference was always noticeable in the per cent. of paired and unpaired cells which survived after a period of two or three days of starvation.

There is no evidence that a thicker wall is formed about the conidia after fusing in pairs. So far as they show greater ability to live through unfavorable conditions it is apparently due to some change in the protoplasm. Exceptionally germination occurs from the fusion tube. In this case nuclei are seen still present in the two spores, and it is uncertain which of them divided to form the nucleus for the conidium. The whole fusion process may be summarized as follows:

1. In cultures several days old when starvation threatens, the conidia put out tubes which fuse end to end, thus establishing protoplasmic continuity between the two cells.
2. No nuclear fusions or visible interchange of nuclear substance accompanies this cell fusion.
3. The cells enlarge rapidly in size and show increased protoplasmic content, indicating a stimulation of anabolic processes as a result of the fusion.
4. Fusion also regularly occurs between the basal cells of the promycelia under the same conditions.
5. Conidia which have not fused in pairs and the end cells of promycelia which have not fused with adjacent conidia, are somewhat less resistant to prolonged starvation than are the fused pairs.
6. The germination of the fused pairs is directly by budding, or a short one to three celled germ tube is produced which buds out in conidia.

---

[1] Loc. cit., pp. 48–49.

Before discussing further the significance of such fusions, it will be interesting to bring together other facts regarding cell fusions where no fertilization in the ordinary sense of the term can be assumed to exist. Observations of this sort are recorded quite abundantly in the literature, and it is of interest to bring them together for purposes of comparison and the determination of their significance in the light of modern theories of sexuality.

One of the familiar cases is that of fusion of the germ tubes of spores so that several spores combine at once in forming a mycelium. Reinke's figure,[1] in which the germinating conidia of Nectria solani are shown uniting their germ tubes in a common system, is a familiar example. The behavior of the nuclei here is unknown and should be investigated, but there is certainly no reason for supposing that this is a sexual union. The fusion results in a larger germ tube than could be produced by any one of the spores singly, and hence the chances that the young mycelium may reach a favorable substratum for its development may be supposed to be increased. It is evident that in this case the fusion was accomplished without especial reduction in volume of the units which combine and indicates clearly the possibility of this sort of aggregation on the part of independent cell units. They are, though each is capable of producing an entire mycelium independently, able to combine, giving up their independent individuality in order to produce a single larger mycelium, which may have a better chance of reaching a substratum favorable for further development. Whether this fusion is customary in the development of germinating spores, or whether it only occurs when the nutrient medium in which germination occurs is poor in nutriment for the fungus, should be investigated more fully. It is also unknown whether the mature mycelium produced from such a series of spores is larger and stronger than that produced from a single spore, the conditions of nutrition being the same. We can simply say that the process seems to show clearly the possibility of a combination of cells for the sake of the advantage of size in reaching a source of food.

---

[1] DeBary *Morph., Phys., und Biol. d. Pilze, Mycetozoa, u. Bacteria,* p. 2.

The case described by Osterhout[1] of the combination of the four tetraspores of *Rhabdonia* in their germination to form a single vegetative body may perhaps be placed in this same category, although the tetraspores do not actually fuse.

A much more striking case of fusion of germ tubes where no strictly sexual significance in the phenomenon is possible, has been worked but by Woronin and Nawaschin.[2] The case is that of *Sclerotinia heteroica*, which is a heteroecious ascomycete producing conidia on *Vaccinium uliginosum* and *sclerotia* in the fruits of *Ledum palustre.* The ascospores of the fungus infect the leaves of *Vaccinium uliginosum* and produce a mycelium which develops a rich, conidial fructification. The conidia from the leaves of the Vaccinium fall on the stigmas of the flowers of *Ledum palustre* at the time of anthesis, the germ tube penetrates the whole length of the style and develops a mycelium in the ovary. As the latter grows, it is mummified by the mycelium and becomes a sclerotium, which passes the winter in a resting condition and in the following May germinates and produces a long stalked peziza cup. The asci of this peziza discharge their spores in the air and they are carried to the young leaves of *V. uliginosum*, infecting them and producing again the conidial fructification. The peculiar fusions referred to occur in the infection of the ovary by the conidia through the stigma. The authors find that a number of the conidia which have fallen on the stigma combine their germ tubes by fusion in order to penetrate through the style to the ovary with its abundant food material below. The conidia lie on the stigma like pollen grains and several, as many as five or six, push out germ tubes which, instead of growing independently downward into the subtratum, converge towards each other, probably by means of mutual chemotactic stimulation, and become fused into a single larger tube which then proceeds downward through the style. Here we have very plainly a fusion of individual cells with loss of their independence for the sake of producing a larger body, a larger germ tube, for traversing the

---

[1] Osterhout (W. J. V.), *Annals of Botany*, 1896.

[2] Sclerotinia heteroica *Zeitschr. f. Pflanzenkrankheiten*, Hft. 3 u. 4, 1896.

relatively considerable distance before it reaches the appropriate subtratum for its further development. Whether the tube of a single spore would be incapable of reaching the ovary and producing the infection has not been determined experimentally, but it is plain that the certainty of infection taking place when once the spores are on the stigma is enhanced by the fusion process described. It would be interesting also to know whether the germ tubes are capable of drawing nutrition from the tissues of the style. The nuclear phenomena in connection with this fusion have not been studied, but in any case it cannot be considered as sexual in any sense of the word. It is a case of protoplasmic fusion where the advantage to be gained is simply the increased size of the resulting body. It belongs in the same category with the case of Nectria, and here the object of the fusion is much more clearly indicated by the conditions under which it occurs.

In two other related species of Sclerotinia the same process had been still earlier described by Woronin,[1] namely, in *S. padi*, whose spores fall on the stigma of *Prunus padus* and penetrate the host plant by means of a similar compound germ tube; and also in *S. aucupariae* parasitic on the mountain ash, which infects the berries of the latter by a compound germ tube from the stigma through the style. On the other hand, in *S. megalospora* which produces sclerotia in the fruits of *V. uliginosum* a single spore on the stigma can produce a germ tube long enough to reach the ovary and fusions of germ tubes in this species have not been observed.[2] The spores of this species of *Sclerotinia* are larger than those of the other three mentioned, but it would be hasty to assume that this visible difference in size is the direct cause of the difference in behavior of the species in germination. The length of the germ tube is not directly proportional to the visible size of the spores as can be shown in many cases.

There are numerous accounts in the literature of the anastomosing of adjacent branches of a mycelium by means of

---

[1] Woronin, "Die Sclerotienkrankheit der gemeinen Traubenkirsche und der Eberesche." *Mem. de l'Acad. imp. des Sci. de St. Petersbourg.* 1895; pp. 11–12, 17.

[2] Woronin u. Nawaschin, loc. cit., p. 11.

tubes which grow out from one branch and fuse at their ends with an adjacent branch. Such fusions are not to be considered as simply due to contact of two filaments that happen to cross each other's path of growth. I have had abundant opportunity of observing the phenomenon in mycelia of *Rhyparobius* grown in a decoction of dung on the slide, and it is plain that many filaments cross and are in contact without fusing, while in other cases a branch will grow out in the shortest path possible to an adjacent branch and fuse with it. Sometimes two tubes grow out and meet and fuse at their tips just like the conjugating tubes of Spirogyra cells. The anastomosing is most common in the peripheral parts of a mycelium and may serve to secure an even distribution of food materials through the whole by a shorter route than would be otherwise possible. Certainly the mycelium is made a more definite unity by means of such anastomosing, but its advantage is by no means clear.

Further examples are given by Woronin[1] and by Woronin and Nawaschin[2] of anastomosing in hyphae developed from the germinating conidia of the above mentioned Sclerotinia species when grown in plum juice. The young germ tubes, the older mycelial branches, and the germinating spores themselves may all become connected by fusion tubes which are developed in the greatest profusion without reference to the food supply or other noticeable external factors.

Very recently the spore fusions in *Protomyces macrosporus* have been described and figured by C. M. L. Popta.[3] The spores fuse in this case soon after they have been expelled from the spore case and the formation of the fusion tube and the appearance of the fused pairs is very much the same as in the anther smut. In stained preparations of the spores before fusion four to seven nuclei are found, and after fusion also each cell of the pair shows from four to seven nuclei. The author concludes that there is no evidence that nuclear fusions follow the cell fusion and is apparently inclined to the opposite view. In living material highly refractive bodies were observed in

---

[1] Woronin, loc. cit., p. 11.

[2] Woronin u. Nawaschin, loc. cit., p. 10.

[3] "Beiträge zur Kenntniss der Hemiasci," *Flora*, Hft. 1, 1899.

the fused spores which the author suspects might be the nuclei. In two cases one of these refractive bodies was seen in the fusion tube but prolonged observation revealed no change in its position. Popta says nothing of changes in the spore pairs which follow fusion. De Bary[1], however, has recorded that after fusion the pairs enlarge very considerably as is the case in the anther smut. According to De Bary also when the fused pairs germinate but a single tube is pushed out and the entire protoplasmic content of the pair passes out into the young mycelium thus formed. The germination regularly occurs on the surface of a host plant and the germ tube at once penetrates the tissues of the host plant and continues its vegetative existence there.

The nuclear phenomena during these germination stages should be investigated before we can be entirely certain that a sexual fusion of nuclei does not occur at any stage of the process; though the phenomena are very similar to those in Sclerotinia, where the number of spores which combine is so large and variable as to practically exclude the assumption of sexuality.

Further in this connection should be mentioned Hoffman's[2] clamp connections between adjacent cells of the mycelia of the *Basidiomycetes.* The more exact investigation of these structures is to be credited to Prof. Brefeld.[3] He finds that in the mycelium of *Coprinus* a tube grows out from the end of one cell and curves in toward the lateral wall of the next adjacent cell, with which it comes in contact and finally fuses, forming thus an open passage between the two cells. Later a transverse wall is built at the base of the fusion tube, so that the continuous passage way formed between the two cells is again interrupted. Brefeld thinks the structure has something to do with circulation of food materials in the mycelium. Its resemblance to the fusion of the cells of the promycelia in the smuts has already been pointed out.

---

[1] *Beitr. zur Morph. u. Phys. der Pilze*, I.

[2] Hoffman, *Bot. Zeitung*, 1856; p. 156. Also De Bary, *Morph., Phys., u. Biol. der Pilze, Bakt., und Mycetozoa*, pp. 2–3.

[3] Brefeld, *Unters. über Schimmelpilze*, III, p. 17.

All the cases of union so far discussed are between cells which are either themselves coenocytic or belong to organisms which in some stages of their development form coenocytic cells. The fusing conidia of the smuts are uninucleate. The fusing spores o *Protomyces* contain each several nuclei. The tendency among the fungi to form multinucleated cells may be another expression of some fundamental quality of their protoplasm which also leads to the cell fusions which have been described. How a binucleated or several nucleated cell arising by fusion would differ from a binucleated or several nucleated cell which became so by internal nuclear divisions, is not certain, especially when the fusing cells are separated in descent by only one or a few cell divisions.

Oltmanns' recent researches on the nuclear phenomena in the sexual reproduction of the red algae, have furnished a very interesting case of cell fusions without nuclear fusions. They are the cell fusions which Schmitz regarded as secondary fertilizations. According to Oltmanns, in the forms where these secondary fusions occur, Dudresnaya purpurifera for example, the sexual fusion of energides — spermatium and egg with their nuclei — takes place in the carpogon. From the carpogon grow out typically three branches ("oöblastema threads" of Schmitz, "carpogenous filaments" of Oltmanns). The fertilized egg nucleus divides, and daughter nuclei are carried along in the carpogenous filaments. The carpogenous filaments fuse with ordinary vegetative auxiliary cells of the branch which bears the carpogon, but no nuclear fusions occur. The sporogenous energide simply uses the material of the cells with which it fuses for its own further vegetative development. After these fusions the carpogenous filament proceeds still further to fuse with special auxiliary cells on the ends of branches in the various parts of the plant. Here again no nuclear fusions occur. The nuclei of the carpogenous and auxiliary cells repel rather than attract each other. In the fusion cell thus formed the sporogenous nucleus divides; one daughter nucleus passes on with the further growth of the sporogenous filament, and the other remains in the fusion cell, appropriates its protoplasm, and by subsequent

---

[1] "Zur Entwicklungsgeschichte der Florideen," *Flora*, 1898.

divisions accompanied by cell divisions forms the mass of carpospores. The original nucleus of the auxiliary cell gradually becomes disorganized and disappears. The whole process consists in the parasitic development of the nuclei derived from the fertilized egg in the auxiliary cells of the mother plant. It is analogous to the parasitic development of the sporophyte on the gametophyte in the mosses. The fusions of sporogenous (oöblastema) filaments with the auxiliary cells is purely a nutritive process, and adds thus a most interesting further type of cell fusion to those already enumerated. The whole process of the presumably chemotactic attraction of the cells for each other, the breaking down of the cell walls, and the union of the cytoplasmic masses, is carried out solely for the purpose of supplying the sexually produced energide with material for the production of a mass of carpospores. It is a case of parasitism in a sense; and yet the cell fusion is in no respect like the penetration of a host plant cell by a haustorium or a swarm spore, as it occurs in the case of the parasitic fungi. The haustorium maintains its own bounding membrane and simply devours the killed and liquefied substance of the host cell by absorption. The unions of the sporogenous and auxiliary cells is a real fusion. The fused cells have a common plasma membrane. The cell wall also, which encloses the fusion cell, as Oltmanns points out, is in part the wall of the auxiliary cell and in part the wall of the sporogenous filament.

These investigations of Oltmanns must be considered as of the greatest importance, not only in bringing clearness out of the chaos which has hitherto existed in our notions of sexuality in the red algae, but also because they bring into sharp contrast the sexual fusion of cells and nuclei and cell fusions which have a purely vegetative and still well defined significance. The independence of the phenomena of nuclear and cell fusions is clearly brought out and the suggestion given, that while each may be of great importance to the organism, their significance may well be quite distinct. These secondary cell fusions have at least a nutritive function and may have others.

In this connection the view of Iwanzoff[1] that normal conju-

---

[1] N. Iwanzoff, "Physiologische Bedeutung u. s. w." *Bull. Soc. Imp.*, 1898.

gation is a mutual devouring of each other by egg and sperm is interesting and perhaps gains an added element of probability. That this does not, however, afford a complete explanation of cell fusions is shown by the case of the conidial fusions of the anther smut, where neither cell devours the other but each maintains its individuality and germinates independently. In this case we must assume that the fusion produces some change in the condition of the protoplasm whereby its metabolism is increased; and, perhaps also, it becomes more resistant to unfavorable external conditions.

For completeness may be mentioned the fusion of cells end to end to form the vessels, tracheae, of the higher plants and the fusion to form laticiferous ducts in certain cases. These cases are however quite different from the others mentioned, in that they occur in cells not destined to further development by division, and in the first case at least are accompanied by the death of the cells.

In still a further and quite interesting category may be mentioned the union of the swarms spores of slime moulds to form plasmodia. Here the union consists in the formation of a larger amoeboid mass with a common plasma membrane by the union of numbers of smaller amoeboid cells. It is in its origin, doubtless, a preparation for spore formation and has been developed from the habit of the Acrasieae to come together to form stalked spore fruits, although in these latter forms the swarm spores pass through their entire vegetative existence as distinct bodies. Plasmodium formation would then be an occurrence at an earlier stage and more completely of the aggregation of cells which in *Dictyostelium*, for example, occurs at the time of uiting. What the advantage of this union is cannot be pointed out with certainty, except that it brings and keeps the cells together so as to prevent their becoming too widely scattered before the time of fruiting. It perhaps also secures a more even distribution of food among all the cells that are later to combine to a single fruit body.

If we look now for the significance of these various types of cell fusions, it seems plain that in none of them do we have anything that is comparable to sexual fusions. The nuclear fusion which Hertwig and Strasburger have pronounced the essential feature in sexual fusions in both plants and animals is lacking. None the less we have, at least in the pairing of the conidia of the anther smut, a phenomenon which shows some of the physiological results which accompany a true sexual fusion, namely, increased metabolism and increased capacity to resist unfavorable external conditions. And in all the cases mentioned an improved physiological condition may be fairly assumed as a result of merely cytoplasmic fusions. How it is that a cell finds itself in better condition as a result of increasing its mass by fusion with a second cell, is not clear except where the increased size is a necessity in order to reach a certain position necessary for the further development of the organism, as in the case of the germ tubes of *Nectria* or *Sclerotinia* described above. Such an advantage is not, however, present, in the fusions of the anther smut. If reduction of volume and consequently of exposed surface for osmosis followed the fusion, as is the case in so many true fertilizations, an advantage might be assumed to exist in this diminution of surface contact with unfavorable surroundings and the greater density of the protoplasmic mass; but in the anther smut fusion is followed by a very notable increase in the size of the fused cells. It is impossible at present to say wherein the significance of this fusion consists. It may be that the phenomena are to be interpreted as a primitive type of sexual union, where the process of fusion has not yet gone so far as to include a union of the nuclei and a loss of individuality of the gametes; or it may be a degenerate form of sexuality in which the nuclear union has been lost and the cytoplasmic union retained.

There can be no doubt, however, that such cases show clearly that there is an advantage to the one celled organism in a cytoplasmic union, even without nuclear fusion. The importance of this cytoplasmic union in the cases of true fertilization where the male cell consists of little but the nucleus, as in the mosses and ferns, may be much reduced. The existence of such cases, however, whether primitive or degenerate, is strongly in favor of the view that sexual reproduction may have originated in fusions of a simpler type than are found in most plants and animals today, and in which neither nuclear fusions nor loss of individuality of the fusing gametes was present. Such cases would furnish an interesting connecting link between ordinary asexual reproduction by division and the sexual fusion of nuclei, with the resulting necessity of chromosome reduction and so forth.

On the much discussed question as to whether the cytoplasm is concerned in the transmission of hereditary characters in true sexual fusions, such cases of cell fusions, showing that merely cytoplasmic unions have a distinct value for the organism, make it probable that that advantage is a prominent feature in the results of fusion of equal gametes in *Spirogyra* and other cases where large amounts of cytoplasm unite in the process of fertilization. In higher organisms, as already noted, where the amount of cytoplasm present in the male gamete has been reduced to a minimum, the significance of the non-nuclear elements in the fusing cells may be correspondingly diminished.

Summarizing the types and apparent effects of cell fusions where no nuclear fusions occur, we can note the following:—

1. Cases where fusion results in increased size thus enabling a germ tube to reach the substratum most favorable for its further development: *Sclerotinia;* possibly *Nectria.*
2. Cases where fusion provides for more ready and equal distribution of food materials in a mycelium: *Rhyparobius* and many others; also possibly the clamp fusions of *Basidiomycetes.*
3. Cases where fusion leads to growth in size of the fused cells, perhaps also making them more resistant to unfavorable external conditions: Anther smut, *Protomyces.*
4. Cases where the fusion is largely at least a nutritive phenomenon, the protoplasm of one energide passing entirely under the control of the other, and results in the disorganization of the nucleus of the former: Secondary fusions in the red algae according to Oltmanns.

Madison, Wis., December, 1898.

EXPLANATION OF FIGURES.

All figures drawn with aid of Abbe camera lucida and with Zeiss apochromatic objective 2 m.m., aperture 1.40. Figs. 1–10, 12, and 17–22 with compensating ocular 12, the others with compensating ocular 18.

PLATE VIII.

Figures 1–7, *Ustilago scabiosae.*

Fig. 1. Promycelium with resting nucleus.

Fig. 2. —— with nucleus in equatorial plate stage of division, nucleole lying near one end of spindle.

Fig. 3. —— with daughter nuclei in dispirem stage, connected by spindle fibres.

Fig. 4. —— with two daughter nuclei not fully developed but widely separated.

Fig. 5. —— with four resting nuclei.

Fig. 6. Four celled promycelium with conidia.

Fig. 7. Upper cell of four celled promycelium. Nucleus in equatorial plate stage.

Figures 8–22, *Ustilago antherarum.*

Fig. 8. Germinating spore uninucleate.

Fig. 9. Germinating spore after first nuclear division.

Fig. 10. Promycelium with first septum.

Fig. 11. Conidium budding like yeast.

PLATE IX.

Fig. 12. Three-celled yeast-like colony.

Fig. 13. Four-celled yeast-like colony.

Fig. 14. Conidium with nucleus in equatorial plate stage.

Fig. 15. Conidium with nucleus in metaphase.

Fig. 16. Conidium with nucleus in dispirem stage, spindle still present.

Fig. 17. Conidia fused in pairs and swollen.

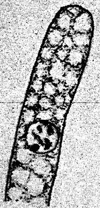
Fig. 18. Conidia fused in pairs, curved fusion tube.

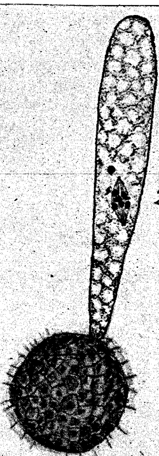
Fig. 19. Promycelium cells with fusion tube. Apical cell in process of disorganization.

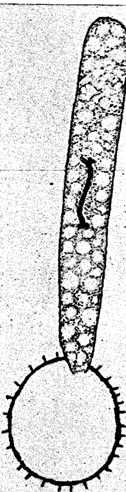
Fig. 20. Promycelium with apical cell fused with adjacent conidium; fusion tube of lower pair lies behind them.

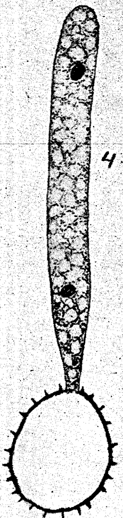
Fig. 21. Fused pair with one germinating in tube.

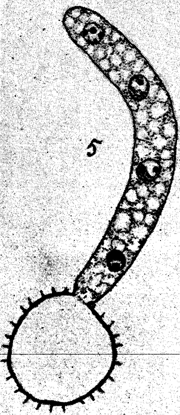
Fig. 22. Fused pair with conidial buds.

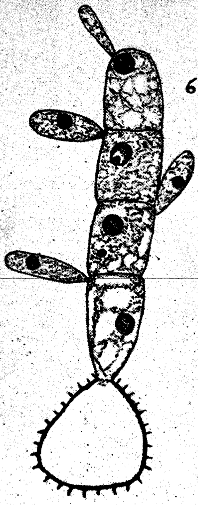

1

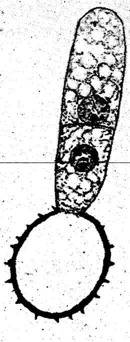

2


3

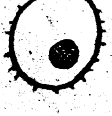

4


5

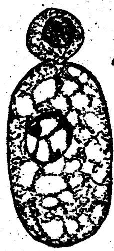

6

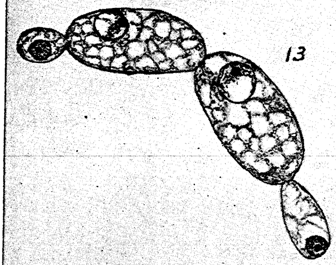

10


9

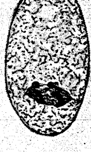

8


7

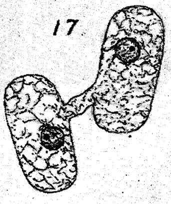

11

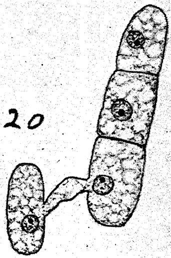

13


14

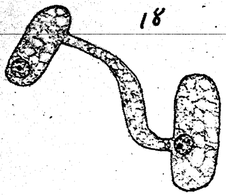

15

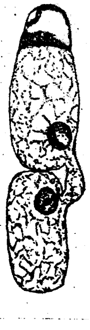

12

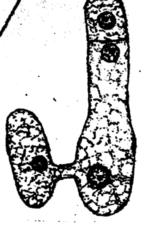

17

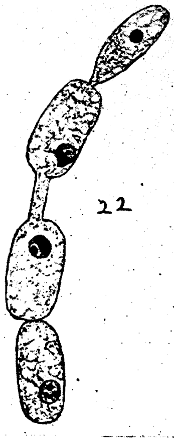

20


16


18


19


21


22

THE INTER-GENERATION PERIOD.

WITH PLATES X AND XI.

CHARLES H. CHANDLER.

The question here considered is whether the popularly received idea that the average interval between successive generations is one-third of a century, has a sufficient foundation in fact. The result of an examination of nearly sixteen thousand dates of births and the computation of mean dates is presented in the accompanying tables and diagrams.

As all the records involved in this examination have been those of New England families, it is evident that it is an entirely pertinent question whether the resulting inferences are applicable to other sections of country. Especially may it appear that in regions where marriages are contracted at an earlier age the interval certainly will be considerably shortened. But on the other hand it must be considered that in those regions families are larger, and marriages in which the woman is very much younger than the man are more frequent, both of which conditions tend to lengthen the inter-generation period; so that without careful investigation it is by no means safe to assume that the generations follow in more rapid succession than under what at first seem to be the more deliberate conditions of New England.

Each of the four tables here given represents the descendants of a common ancestor; the first column giving the numbers of the generations from that ancestor, the second column the number of recorded dates of births in each generation, the third the mean date of those births, the fourth the interval between each generation (after the first) and the one preceding it, and the last column the sum of the three preceding intervals.

A

I	1	1637	..	...
II	5	1677	40	...
III	24	1712	35	...
IV	40	1741	29	104
V	105	1774	33	97
VI	236	1810	36	98
VII	460	1844	34	103
VIII	397	1870	26	96
	1268			

Mean period, 33.3

Omitting generation VIII, 34.5

B

I	2	1616	..	...
II	13	1651	35	...
III	24	1696	45	...
IV	52	1720	24	104
V	150	1757	37	106
VI	231	1798	41	102
VII	387	1829	31	109
VIII	534	1856	27	99
	1393			

Mean period, 34.3

Omitting generation VIII, 35.5

C

I	1	1635	..	...
II	8	1667	32	...
III	44	1700	33	...
IV	81	1743	43	108
V	257	1782	39	115
VI	770	1813	31	113
VII	1575	1841	28	98
VIII	1572	1864	23	82
	4308			

Mean period, 32.7

Omitting generation VIII, 34.3

D

I	5	1632	..	...
II	44	1665	33	...
III	147	1702	37	...
IV	467	1737	35	105
V	783	1771	34	106
VI	1676	1806	35	104
VII	3044	1834	28	97
VIII	2367	1853	19	82
	8533			

Mean period, 31.6

Omitting generation VIII, 33.7

The first family, denoted by A, is also presented in Diagram 1, which graphically represents the dates of birth and the lines of descent of nearly 1,300 descendants of the ancestor placed at the top upon the line of the year 1637, although a few of the lines marking descent are omitted in the later generations on account of insufficient space. But all the known dates of birth in each generation are located upon the heavy lines, the mean date of birth for each generation being shown by a light horizontal line.

In this family the successive inter-generation periods are shown to be 40, 35, 29, 33, 36, 34, 26, together amounting to 233, and giving a mean period of 33.3 years. The exceptional brevity of the last period, however, suggests that the eighth

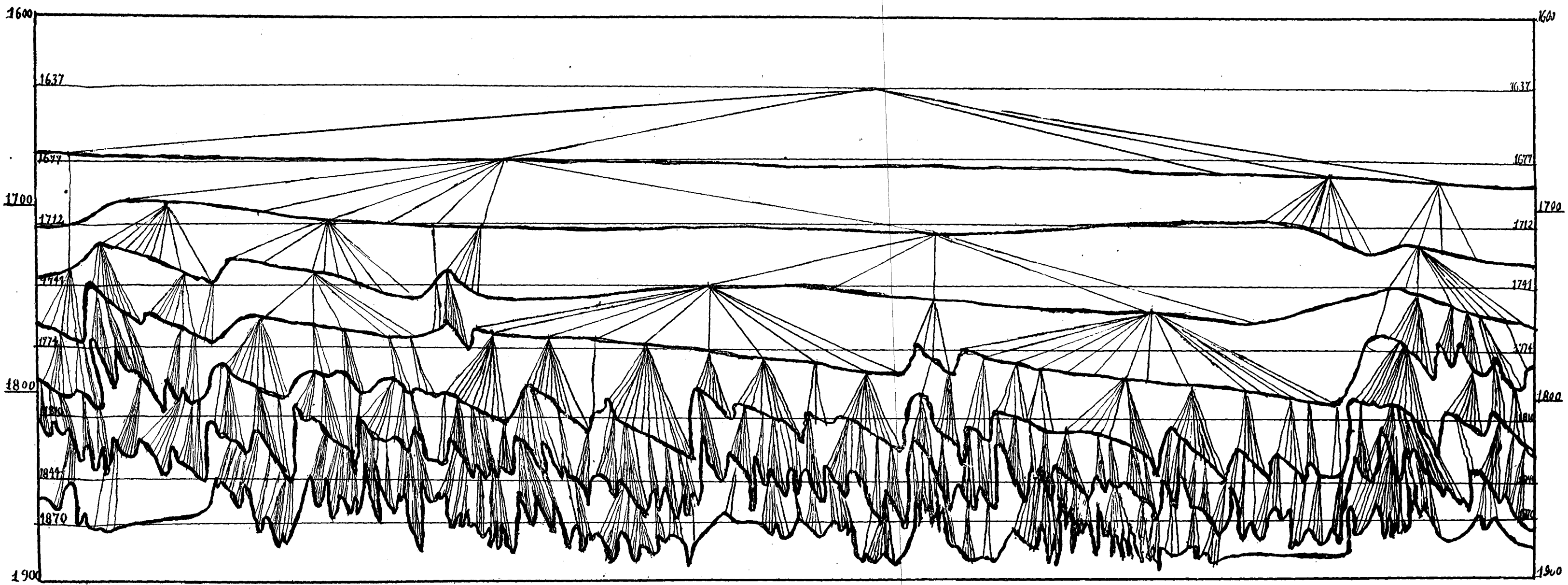


DIAGRAM 1. DESCENDANTS.

generation was by no means complete when the records were compiled, a presumption supported by the observed fact that its numbers, instead of being more than those of the seventh generation, are considerably less. But a compensation for this deficiency is made by the unusual length of the first period, due to the fact that there is no place for a mean when but one person is considered, and that the condition of this one, a pioneer in the unsettled wilderness, seems to have been such as made it by no means easy for him to find a wife, and he remained unmarried until the age of thirty-four. It is also worthy of attention that the sums of these periods, when taken in successive groups of three, are each near an exact century, the largest excess, of only four years, being in the sum containing the effect of the pioneer's isolation, and the equal deficit where it is caused by the generation still incomplete. It is further evident that the greatest irregularities in the generation lines are in those places where the data are imperfect; as, for example, at the extreme left of the diagram, where the only line of descent is that of a member of the third generation who was born twenty-one years after the marriage of his parents. If the data for the older branches of that family had been available, the generation line must have been elevated to a marked extent. The records of the branch presenting such unusual irregularities at the extreme right of the diagram are likewise very imperfect.

The families denoted B, C, and D are not presented graphically; but the tabular exhibits of the dates of birth show less nearly uniform inter-generation periods than those of family A; yet in no case does the mean of the seven periods differ from the third of a century by more than 1.6 years. The sums of three successive periods, however, present much greater irregularities, rising in one case to 115 years. It may be noticed, also, in B, C, and D, as in A, that the intervals between the seventh and eighth generations are very short, and the same evidence of incompleteness in the eighth generation is shown in each case by the small number of births recorded. Therefore it may be well to neglect the eighth generation and find the mean of the six preceding periods; which modification increases the length of the mean period in A from 33.3 to 34.5, in B from 34.3 to 35.5, in C from 32.7 to 34.3, and in D, in which the eighth generation is evidently exceptionally incomplete, from 31.6 to 33.7.

These corrections seem to be in the direction of greater accuracy, and at first they indicate a strong probability that the correct period is somewhat greater than one-third of a century. But, on the other hand, it is necessary to recognize an uncertainty exceedingly difficult to estimate, but presenting a strong probability that the error in mean periods, derived like these from family records and printed histories, is in the opposite direction, and that the true period is shorter than the one thus obtained. For in all such histories the lines of descendants from sons are likely to be recorded far more fully than those from daughters, which are generally widely scattered in the records of the families into which they had married; and, since daughters are likely to marry at an earlier age than sons, the probable resulting error is as stated.

If investigations in the opposite direction could be made with equal ease, that is, if a person's ancestry could be traced as easily as the descendants of a common ancestor, not only would this difficulty be avoided, but there would also be eliminated from the computation the effect of the dates of birth of children dying unmarried or without offspring, and who therefore should not be considered in determining the period of successive generations. But such an investigation requires far greater labor and patience than the search in the opposite direction, since the facts are so widely scattered in different books of record.

Table E, however, shows a tolerably complete record, also represented graphically by Diagram 2, of the ancestry of two children, the mean date of whose births was 1876, extending back to include 11 of the 512 ancestors of the tenth generation. The mean of these nine periods is 32.2. But it is evident that the earlier of these generations are represented by too small a part of their members to furnish a reliable basis for a conclusion. There are, however, no vacancies in the last five generations, only three of the thirty-two members of the sixth are missing, and more than half of the seventh generation have been

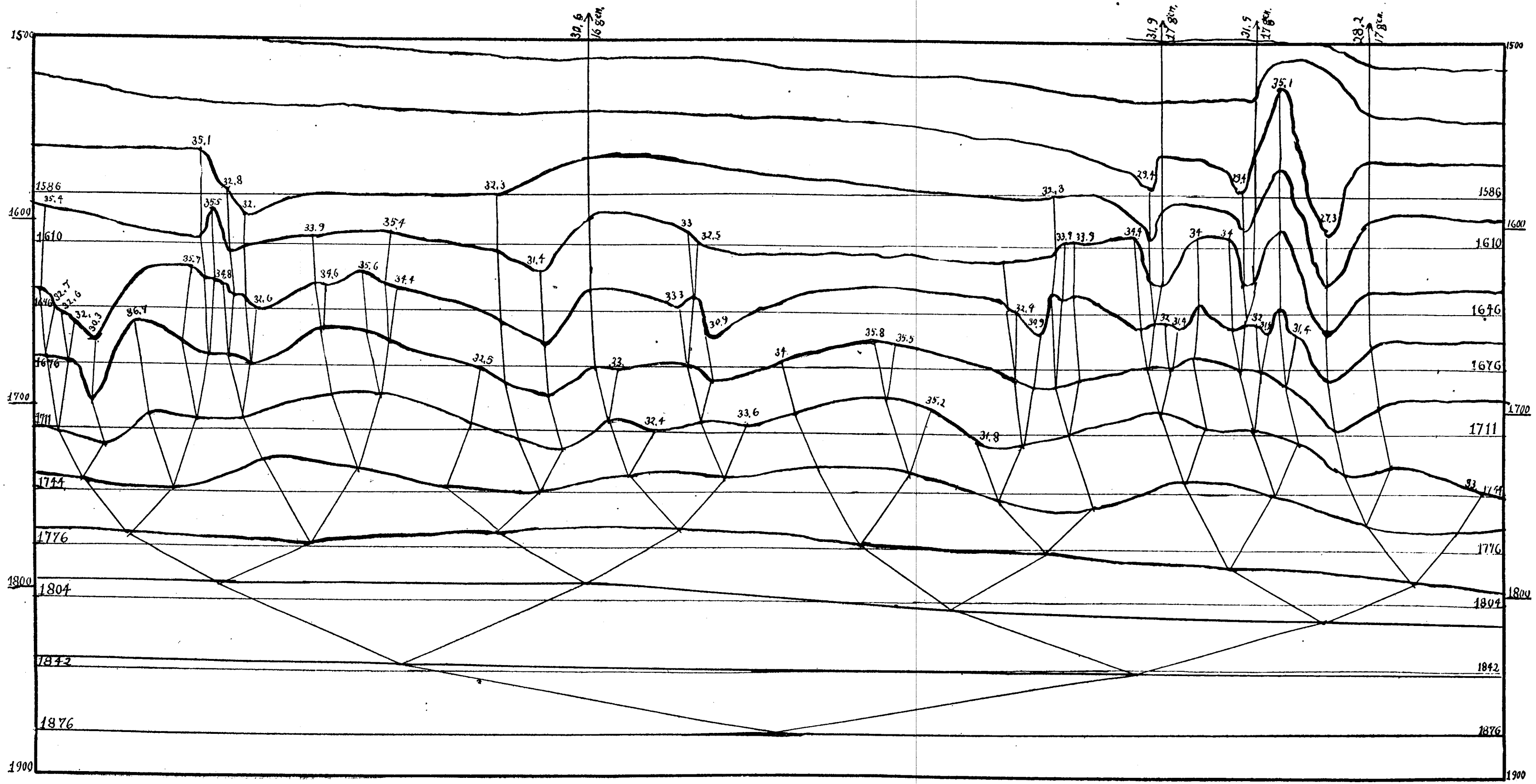


DIAGRAM 2. ANCESTORS.

located. Neglecting, then, the first three generations presented, the mean of the remaining periods is 33.3.

E

X	11	1586	24	90
IX	21	1610	36	101
VIII	40	1646	30	98
VII	33	1676	35	100
VI	27	1711	33	93
V	16	1744	32	98
IV	8	1776	28	100
III	4	1804	38	..
II	2	1842	34	..
I	2	1876	..	..
	164			

Mean period.............. 32.2

Omitting generations VIII, IX and X................ 33.3

F

VI	9	1602	28	94
V	14	1630	31	103
IV	13	1661	35	95
III	7	1696	37	..
II	3	1733	23	..
I	2	1756	..	..
II	11	1790	34	..
III	64	1822	32	..
IV	113	1855	33	99
V	167	1880	25	90
	403			

Mean period.............. 30.9

Omitting first and last generations................. 32.1

The graphic representation of this family may be examined from a somewhat different point of view. Opposite the place of the earliest ancestor of each name is given the mean period computed on the line from that ancestor to the common descendants in which all the lines unite. These fifty-seven periods lie between the extremes 27.3 and 36.7, and they give a mean value of 33, if the line from each ancestor is allowed the same weight, a course which perhaps is hardly correct, since some of these lines include many more generations than others. But it is largely true that these long lines have become known not merely by favoring accident, but because a tendency to early marriages brought more generations within the time and conditions limiting the research, which gives these families an undue influence in the determination. It may, therefore, be just to allow these two considerations to balance. But, if each line be given a weight proportional to the number of generations included, the corrected mean becomes 31.5.

Table F presents five generations of the ancestors and four generations of the descendants of the couple represented by generation I, and gives a mean inter-generation period of 30.9. But it is evidnet that the first and the last of the ten generations are sadly incomplete; and, if these be omitted, the mean period rises to 32.1.

In the preparation of this paper considerable search has been made for lines extending through a larger number of generations than any that are here shown, but it has had very indifferent success. Such lines of descent, when claimed for families of the commonalty, usually present doubtful points of connection, and rest .under suspicion of being due to more or less of ingenious fabrication; and, while royal and noble lines are to be found, such lines of course are generally along the older branches of the family, and so give a period much shorter than the true one, although the tendency in such lines to follow descent through sons counteracts this in part. The line from William the Conqueror to Queen Victoria offers an illustration. It covers twenty-five or twenty-seven periods, according to the ancestral line which is followed, and gives a mean period of 31.7 or 29.3 years.

Perhaps a fair summary of the results of the work presented in this paper may be thus stated. The more nearly complete the record of births in each generation and the greater the number of generations included in the examination, apparently the greater is the tendency to a mean period of one-third of a century.

Ripon, Wis., December, 1898.

COMBINATIONS OF PYTHAGOREAN TRIANGLES AS GIVING EXERCISES IN COMPUTATION.

BY TRUMAN HENRY SAFFORD.

It has been the author's habit to practice his pupils in computation, in order to test and increase their numerical skill, by teaching them to form and calculate triangles whose sides are expressed in whole numbers and whose areas are also so expressed. The simplest way to obtain such triangles is to combine Pythagorean triangles after the example of Hero of Alexandria, eminent as an engineer as well as a mathematician. Hero was the inventor of the Dioptra, an instrument containing the germ of the theodolite. He was also the inventor of the Aeolopile, a precursor of the steam engine, and in all probability also the inventor of the well known formula for the area of a triangle whose sides are given.

Among his works is found the remarkable triangle whose sides are 13, 14, and 15, and whose area is 84. Hero put together this triangle by combining the two Pythagorean triangles whose sides are 5, 12, and 13 and 9, 12, and 15 respectively. The area of the combined triangle 84 is the sum of 30 and 54, the areas of the two Pythagoreans. A combination of the same two Pythagoreans can be made in another way, giving the triangle whose sides are 4, 13, and 15 and whose area is 24, the difference of the areas 30 and 54. These methods can be employed with any pair of Pythagorean triangles which have a common leg; in the case of Hero's pair 12 is the common leg.

We may apply Hero's method to the two Pythagorean triangles whose sides are 10, 8, and 6 and 17, 15, and 8 respectively. We thus get the triangles whose sides are 10, 17, and 21 and 9, 10, and 17 respectively. The areas by Hero's formula are 84 and 36, the sum and difference of the two areas of the right angled triangles 60 and 24 respectively.

This series of processes can be extended to as many pairs of Pythagorean triangles as we please, provided always that the common leg required be brought about by multiplying the parts of one triangle by a whole number.

In Table I, I give a series of Pythagorean triangles, computed by Sir George B. Airy, the late astronomer royal at Greenwich, (*Nature*, 33, 532.) This table seems to me to give a sufficient selection of Pythagorean triangles for practical purposes. It can be extended by the formulae

$$x = 2fab$$
$$y = f(a^2 - b^2)$$
$$z = f(a^2 + b^2)$$

in which a and b are two numbers relatively prime, and f is any whole number or, if both a and b are odd, is the half of any whole number. Thus if $a=7$, $b=1$, $f=\frac{3}{2}$ we shall have

$$x = 21$$
$$y = 72$$
$$z = 75$$

In Table II, I give a selection of triangles whose areas are whole numbers derived from the combination of those given in Table I.

They can be readily tested, and to indicate the method I give the calculation of Triangle No. 14, whose sides are 41, 51, and 58.

$a = 41$	$(s-a) = 34$	$\tan \frac{1}{2} A = \frac{2}{5}$	$\frac{1}{2} A = 21° 48' 5''$
$b = 51$	$(s-b) = 24$	$\tan \frac{1}{2} B = \frac{17}{30}$	$\frac{1}{2} B = 29 \quad 32 \quad 19$
$c = 58$	$(s-c) = 17$	$\tan \frac{1}{2} C = \frac{4}{5}$	$\frac{1}{2} C = 38 \quad 29 \quad 35$
$s = 75$			Sum of half angles, 89° 59′ 59″

Hence $r = \sqrt{\frac{34.24.17}{75}} = \frac{68}{5}$

In computing the angles I used a five figure table of natural tangents, which is usually sufficient to give the sum of the half angles 90° within a second; tenths of seconds can be obtained with six figure logarithms as a usual thing.

After the tangents of the half angles have been computed as whole numbers or vulgar fractions, I need not say that they can readily be checked by the ordinary trigonometric, or more properly goniometric, formulae, which will show that the sums of the half angles are 90° in each case. Thus in our example

$$\tan \tfrac{1}{2}(A + C) = \tfrac{6}{5} \div \tfrac{17}{25} = \tfrac{30}{17}$$

The writer regards it as an orderly method of teaching Trigonometry to deal with the functions without logarithms before the pupils are required to learn the trigonometric artificialities. In the method which the writer prefers Trigonometry becomes the first mathematical subject of Freshman year, and the extension of Algebra is deferred till Trigonometry is pretty well understood, at least in its elements.

I must defer till another occasion some suggestions relating to the construction of tables of the natural trigonometric functions.

TABLE I.—*Sides of Pythagorean Triangles.*

x	y	z	x	y	z
3	4	5	33	56	65
5	12	13	16	63	65
8	15	17	48	55	73
7	24	25	36	77	85
20	21	29	13	84	85
12	35	37	39	80	89
9	40	41	65	72	97
28	45	53	15	112	113
11	60	61	17	144	145

TABLE II.—*Sides of Triangles whose Areas also are expressed by Whole Numbers.*

No. of triangle.	*a*	*b*	*c*
1	13	14	15
2	4	13	15
3	10	17	21
4	9	10	17
5	51	52	53
6	4	51	53
7	29	75	92
8	29	52	75
9	13	37	40
10	13	30	37
11	15	41	52
12	15	28	41
13	43	61	68
14	41	51	58
15	33	41	58
16	25	74	77
17	25	63	74
18	61	74	87
19	52	61	87
20	23	61	68
21	21	61	68
22	53	100	141
23	51	53	100
24	53	339	364
25	53	308	339
26	143	339	350
27	77	145	156
28	145	147	194
29	113	145	194
30	53	117	136
31	53	80	117
32	73	143	180
33	73	84	143
34	45	89	116
35	89	116	123
36	73	148	195
37	73	85	148

Williams College, December 24, 1898.

CHARTISM—A CHAPTER IN ENGLISH INDUSTRIAL HISTORY.[1]

EDWARD D. JONES, PH. D.

Instructor in Economics and Statistics, University of Wisconsin.

Chartism stands for an important though somewhat indefinite part of the great industrial revolution of England. It had its roots in economics, its manifestations in politics. It was an agitation of the masses. To understand chartism we must first look into the causes which set the masses in motion.

GENERAL CONDITIONS.

At the opening of the nineteenth century England was changing from an agricultural to a manufacturing nation. The transitional period was one of suffering and uncertainty and of ill-directed attempts at reform. One of the most important facts of England's condition was perhaps the high price of food. Living expenses were high compared with what they had previously been. This was due to the war with France and to a gradual increase of the population above what the agricultural resources of the country would support. These high prices were but one symptom of the fundamental industrial change which was taking place.

The growth of the factory system had already stranded many hand producers and antiquated the skill of many artisans. It

---

[1] General references: File of the Northern Star, of Cooper's Journal, and of Politics for the People; Martineau, History of the Peace, Vol. IV.; Knight, History of England, Vol. VII.; Tooke, History of Prices; Hodder, Life and Works of the Seventh Earl of Shaftesbury; Engel, Condition of the Working Classes in England in 1844; McCarthy, History of Our Own Times; Carlyle, Chartism; Kingsley, Alton Locke and Yeast; Besant, All Sorts and Conditions of Men; Reade, Put Yourself in His Place. Articles: Frazer's Magazine, Vol. 37, May, 1848; Eclectic Review, Vol. 23; Blackwood's Magazine, Vol. 63, June, 1848; Century Magazine, Vol. I.

developed the power of masses of capital before labor learned to mass itself wisely for resistance. The ethical and social aspects of the new method of production, as it built itself upon the ruins of the old order, were anything but encouraging.

The gathering of workmen together in factory towns, made up of one class of population, took them away from the villages and country districts where there had been some sort of friendly social intercourse between themselves and the middle classes and the local landlords. In the "Deserted Village," which Goldsmith mourned, they had known and respected the personal life of the village parson, and they had themselves been considered as friends and neighbors and not merely as one of the costs of production. When the wage-earners passed into the factories their dwellings were huddled together in separate quarters of large cities. Lord John Russell said in a speech in Parliament, describing the great manufacturing and mining districts of England: "The mass of the people there were constituted of one great working class and of the few individuals by whom they were employed, and who had but little connection with them of the sort calculated to produce that species of subordination which prevailed in other communities. In those districts of the country there were not those means of religious and moral instruction which were required for knitting men together in society." There was great promiscuity both as to living and sleeping rooms. The overpopulation of certain city districts resulted in dirty streets and imperfect sewerage. There was a lack of parks and playgrounds for children. There was little opportunity for recreation of any sort except such as could be made to support vicious institutions. Prices of edibles rose so high that huxters were known to have done a thriving business in selling putrid meats and decayed vegetables. Such articles even found their way into city markets, for the inspection was not as rigid as it is at present. Cheap clothing of rotten shoddy fibre took the place of the warm and durable homespuns.[1] The

---

[1] Carlyle described the clothing of the poorer classes thus: "They wear a suit of tatters, the getting on or off which is said to be a difficult operation, transacted only at festivals and the high tides of the calendar."

large agglomerations of poor and ignorant persons in manufacturing towns furnished the prey for dishonest production and pettifogging trade. Lack of shrewdness and ready money kept the laborer a victim of the tradesman. Physical ailments, unpleasant homes, and ignorance gave the liquor traffic a disastrous hold upon those who were least able to squander their earnings. For an English laborer, the years of life, beyond those of self-supporting activity, were almost certain to be spent in an almshouse. The end was a pauper's grave. The conditions of the agricultural districts were not so bad though the scenes presented in Chas. Kingsley's *Alton Locke* and *Yeast* are anything but pleasing. "There was not so much to complain at in the laws," wrote one farmer to a people's paper, "except perhaps the poor laws, but at certain customs which had outlived their time and which bore down with crushing weight upon the laborers."

Before the close of the war with France, bread was at famine rates and wages at their lowest. The working classes were forced down into a position of destitution from which it later took the most determined efforts to raise them. The landed aristocracy were strongly intrenched in the government and were grasping enough to desire to continue war prices, for agricultural products, after the war was over. For a time the corn laws were manipulated to produce this effect.

In addition to what has been mentioned there were other discouraging features in the situation of England at the opening of the century. The evil possibilities of unwise laws were fully exhibited in the workings of the English poor law. The statute upon which this rested, the 43d Elizabeth of 1601, has achieved a really historic notoriety. The intention of this law was a commendable one, namely, to furnish work for the poor. But in the early part of this century the administration of the law, in the hands of ignorant and selfish local officials, was utterly incompetent. Work was not provided as the act originally contemplated, but money was given to the poor and that without due investigation. Too large an allowance was given to parents to support children, and more was given to support illegitimate than legitimate children. Thus poverty became an engine to break down prudence and virtue. Notwithstanding that money was unwisely given, the system set one parish against another and put each on the watch to shift its burdens as far as possible upon other parishes. This, together with strict laws of settlement, for a time prevented the free movement of labor. But by 1795 the strictness of the laws of settlement was relaxed and the England of the period we are considering was characterized by migrations of the lower strata of society. The English poor laws were not reconstructed until 1834. During that year the total poor rate of England was £6,317,254, while in 1836, under the new system, it was only £4,717,629. The old law took away some of the most necessary restraints upon the increase of population and was the instrument in building up an industrially superfluous class, composed of improvident persons, brought up with the utmost negligence, and left to prey upon society through one of two alternatives; pauperism or crime.

It must be remembered in connection with these things that there seemed to be little or no hope of obtaining relief through government. Parliament was dominated by the landed aristocracy, which was not concerned with the troubles of the manufacturing population. At this time Parliament was probably more often thought of as a council to assist the King than as a body to represent and act for the people. The political situation abroad was also calculated to arouse uneasiness. The people of Europe were demanding constitutions on all sides and monarchs were constrained to protect themselves through the union which the Holy Alliance afforded.

As to the church, "Parson Lot" (Chas. Kingsley) and, somewhat later, many others admitted that the Bible had been used "as a mere opium-dose for keeping beasts of burden patient while they were being overloaded." The sufferings of England awakened Shelley, beyond the Alps, and impelled him to write in 1819, a most vigorous protest, though in rather poor verse, entitled "The Masque of Anarchy." The poet demands that there shall be a great assemblage where the poor and their oppressors shall meet and the former shall triumph by the force of the majesty of their presence and the justice of their claims. This poetic picture often served as an inspiration to chartist meetings later on. This, then, was the soil in which Chartism grew.

CHARTISM AND THE REFORM BILL.

The Chartists were always deeply concerned with the movement toward popular representation in parliament and the enfranchisement of the masses. Agitation along these lines was early begun in England. This movement passed through many stages of its evolution before Chartism became an influence in it. As early as 1783 a committee, of which Chas. J. Fox was chairman, was selected by the electors of Westminster to draw up a statement of desired political reforms. This committee, in their report, produced a truly noteworthy document. They recommended annual parliaments, universal suffrage (by this term was meant manhood suffrage), equal voting districts, no property qualifications for seat in the Commons, voting by ballot, and the payment of the members of parliament. This was not only progressive for its time but it anticipated the points of the "People's Charter" from which Chartism was named. In 1792 there was founded a "Society of Friends of the People" which was active in pushing the reform bills and which sympathized with the wage earning classes in their sufferings. To this society belonged Chas. (later Earl) Grey, James Mackintosh, and others equally prominent.

As a result of distressing economic conditions and political appeals to the masses, in connection with the suffrage, a general ferment began to work in the lower orders of society. The first evidence of this was a general increase in crime. There were frequent explosions in factories. The property of employers was burned and assaults were made upon disliked persons. General depredations became of annoying frequence in the manufacturing centers of the country. The "Henry Hunt Movement," at this time prominent, was characterized by frequent outbreaks of violence. Associations sprang up amongst workmen all over England. Their methods were in most cases secret and must be admitted to have been frequently unlawful. It is known that prices were sometimes set on the head of "knobsticks," as workmen who took the place of strikers were called. Arrangements were made for preventing the use of machinery and persecuting employers in numerous ways.[1] But all this was hardly more than mere ruffianism though the causes of it were serious enough.

The economic distress of the time stirred up the lower elements of society to revolt. The direction which their first definite movement took was determined by the prevailing ideas of the time. Political reform was in the wind and they threw themselves in line with it. The first stage of Chartism was involved in the passage of the Reform Bill of 1832. The discussion of this question occupied the arena of public thought when suffering drove the factory and farm hands of England to take up their own cause. To draw these ignorant classes into their campaign was an easy matter for the Whig defenders of the Reform Bill. In this way they severed Chartism from the issues we should have expected it to represent and made out of it a sort of tail-piece to the Whig reforms of the early thirties. The Whigs were frequently accused of filling their political sails with the rising storm of popular impatience and, when later it passed out of their control, they were roundly denounced by the conservatives for having, as they thought, conjured it up.

The puzzle of Chartism lies in the fact that though the grievances of the average Chartist sympathizers were economic, the movement they supported was persistently devoted to the extension of the suffrage. The causal connection between economic injustice and the indifference and aristocracy of government was not doubted by Chartists. They expected through government to set economic matters right. We have evidence here how little serious influence *laissez-faire* ever existed with the English workmen. The politics of the Chartists were, as Adolf Held said, purely a "magenfrage."[2] Rev. Stevens, one of the Chartist leaders, when addressing a vast crowd of men at Kersall Moor, near Manchester, said: "Chartism, my friends, is no political movement, where the main point is your getting

---

[1] Chas. Reade, *Put Yourself in His Place.*

[2] *Sozialismus und Sozialdemokratie*, p. 87.

the ballot. Chartism is a knife and fork question: the Charter means a good house, good food and drink, prosperity, and short working hours."

The first Reform Bill was introduced into Parliament in 1831. It contemplated three great changes: I. Abolition of rotten boroughs, II. Representation for large towns, III. A wider and more equal distribution of the franchise. It was opposed by the lords, the clergy, the army and navy, the Inns of court, and the universities. It was favored by the press, the manufacturing interests, and the masses generally. The struggle in Parliament was intense. When the bill was carried in the Commons by a small plurality the issue was taken to the people. The new Parliament, largely reform in its sympathies, took up the matter in a new bill. This was discussed until just before the coronation of King William IV., when it was carried by the House of Commons and rejected by the lords. Excitement at this time was very high. Parliament was prorogued for a month. Peers were frequently attacked on the streets. Sixty thousand persons petitioned the King in behalf of the bill. Conspiracies were so numerous that it was found necessary to prohibit political associations by proclamation. Riots occurred all over the country. Extreme doctrines of every sort were readily listened to. Every shade of socialism and anarchism appeared.[1] The more ignorant classes resorted to violence as usual. When Parliament met under the new reign a third bill was introduced. This being amended by the Lords, the King was asked to authorize the creation of new peers. When he hesitated the ministry resigned. The opposition was, however, not able to form a government. Grey was summoned to return and the creation of new peers was authorized. The lords immediately withdrew their opposition and the bill was finally passed in June of 1832.

---

[1] R. Pauli *Staatengeschichte der Neusten Zeit*, II, 80. In 1831 the red flag of anarchism was carried in English riots. Chartist papers long urged that the land of England should be made public property and that various industries should be socially managed when the government should become sufficiently democratic.

PERIOD OF SUSPENSE.

So long as the Whigs pushed the Reform Bills vigorously the forces of Chartism were content to remain an unorganized element in their following. But the time came when the leaders of the party thought they had gone far enough. The majority of their constituencies abided by their decision, but the unenfranchised classes, an element untutored in the art of party compromise and never before dealt with by English politicians, were not so docile. However, they stayed action for a time to see what the effects of the new measures would be. The Parliaments returned under the new franchise law were liberal in their tendencies and accomplished many things in the next few years, though they were such things as did not bring immediate and tangible results to the wage-earning classes. Some abuses connected with the church were corrected; the privileges of the East India Company were removed, and slavery was abolished in the British Empire. Liberal grants were made for educational purposes; the poor laws were amended and many industrial restrictions were removed. The agitation for the freedom of the press was at this time fought through. The people waited for the material results of these reforms. There was a short breathing spell. But they were at no time entirely satisfied with what had been done and they waited in distrust. It was still complained that but one man in seven had the right of suffrage. The Whig leaders were pressed to carry forward the work begun. The cry of "traitor!" was raised when they declared that they would go no further. A writer in *Blackwood's Magazine*, discussing the discontent of the period said: " What is the prevailing cry of the Chartists and universal suffrage men? It is that they have not obtained the fruits of reform; that they have been misled and deceived by their Whig leaders; that all the real and practical grievances of which they formerly complained are still in existence; that wages are as low, provisions as high, taxes as heavy as ever, that the sway of the middle classes has proved more oppressive than ever that of the old borough-mongers; and that the new poor-law has deprived them of their rights of birthright inheritance in a way which would never have been attempted by the ancient guardians of the realm." The reforms inaugurated did not affect the economic life of the masses to their satisfaction. The Chartists had only to look about at home to see that the "knife and fork" question had not been solved. Agitation and violence soon began again.

FIRST PERIOD OF INDEPENDENT CHARTIST ACTIVITY.

After the Whigs completed in 1832 what they had to do in regard to the suffrage, Chartism for the first time became a distinct movement. Chartists were dissatified with what had been done but, peculiarly enough, continued along precisely the same lines of agitation. They even refused to be drawn into combination with the Whigs for the repeal of the Corn Laws or to help push through the bill for a ten hour day.

Throughout this whole history there can be distinguished two elements. There are two distinct sources of discontent, two classes of people, and two types of policy. On the one side was a movement for more liberal government, begun as a theory, developed as a political movement in the hands of the Whigs, continued as an unsatisfied agitation for universal suffrage, and ending in a gradual and natural evolution. On the other side the economic conditions aroused the massess to a revolt which was amorphic and spasmodic and attended with much violence. Its history embraces the activity of many mobs and rioters, of secret organizations of workingmen, and of a few radical clubs and societies. Partaking of the nature of each of these was the "Henry Hunt Movement" which was active for fifteen years before it became a part of Chartism in 1837. It is easy to see that there would be a lack of harmony between these two elements. To one class political reform was an end, to the other a means. These factions worried along together for several years; but the differences in spirit and aim became too evident to ignore. A separation was inevitable. It came over the question of the means proper to employ in carrying on agitation. The Universal Suffragists desired a law abiding agitation of a political character and became "Moral Force" chartists.

The Huntists were for fair words only so long as they would prevail and they became "Physical Force" chartists. The first element was the brains, the second the body of the movement.

Let us first follow the Moral Force chartists. The Universal Suffragists formulated their demands at once upon the passage of the Reform Bill and they pursued a steady consistent policy in advocating their ideas. There were many semi-political societies existing among the unenfranchised. One of the most prominent of these was the National Union of the Working Classes at London. In this Union was Henry Hetherington who was in a sense its leader. He has been credited with being the pioneer of the outspoken part of Chartism. He, with William Lovett, James Watson, and others, was for an educational campaign only and decried the use of violence. A set of principles was drawn up by Hetherington and his followers in the National Union. It was used by the framers of the "People's Charter" and contained the following points:

The right to all honestly acquired property is sacred.

The recognition of the equality of men and of certain natural rights is the only just foundation upon which government can rest.

All hereditary destinctious are unjust.

The suffrage should include every law-abiding adult male of sound mind.

In order to secure proper representatives voting should be by ballot.

Parliaments should be elected for but one year.

These principles were declared to be essential to the protection of the workingmen and no reforms were to be considered satisfactory which did not embody them.

In 1837 the same Union drew up a petition to be presented to Parliament. It was prepared by Mr. Hetherington and was signed by 3,000 persons. Later in the year a conference was held with some of the liberal members of the House of Commons. At this conference twelve persons were selected to draw up a bill which was to be introduced in Parliament. On the committee were six members of Parliament, among whom were Daniel O'Connell and John A. Roebuck. As deputies of the workingmen there were Henry Hetherington, John Cleave, James Watson, Richard Moore, William Lovett, and John Vincent. Lovett wrote the document and Roebuck, who introduced it in Parliament, advised on legal points. The draft of the bill was endorsed far and wide by labor and other organizations and became the famous "People's Charter." The principal points of this bill were the same as those embodied in the report of Chas. Fox to the electors of Westminster in 1780. They were:

I. Manhood suffrage.
II. Annual parliaments.
III. Vote by ballot.
IV. Abolition of property qualification for seats in Parliament.
V. Payment of members of Parliament.
VI. Division of the country into equal electoral districts.

Three of these six points have since been practically realized, namely: manhood suffrage, vote by ballot, and abolition of property qualification. The division of the country into equal electoral districts has been practically realized. The remaining two demands, one for annual parliaments, the other for payment of members, do not seem to be vital points under the present system.[1] This petition, composed of as reasonable a series of demands as it was, and backed by a lively popular sentiment, was almost entirely ignored by the statesmen and prominent thinkers of the day. Leigh Hunt, Carlyle, Kingsley, and a few others only seemed to realize its significance and to understand the meaning of the struggles of the time.

The next move after drawing up the bill was to bring pressure to bear upon Parliament to consider it. A petition was accordingly set on foot. A national convention of Chartists was called to meet at London in 1838. Delegates to the number of fifty-three assembled. The convention was composed of Moral Force Chartists and proved to be a temperate and sensible body. A public statement of principles was made and arrangements completed for presenting their petition to the House of Commons.

---

[1] In 1892 (March 25) a resolution looking toward payment of members was lost in the House of Commons by 272 to 162 votes. This demand is a plank in the platform of the English Socialistic Labor Party.

In this all classes of Chartists joined. When the huge mass of paper was rolled into the House, Mr. Atwood, who acted as the delegate of the Chartists, was allowed, contrary to precedent to make a speech in presenting it. But all this produced no appreciable effect. The Commons scarcely noticed the bill or the petition. A move to consider them was defeated by a majority of 189 in a House of 281 members. The Chartists became discouraged. Meanwhile the actions of the Physical Force wing of the agitation so disgusted the better classes of society that the entire movement was discredited. Universal suffragists refrained henceforth from taking active part in any kind of demonstrations.

The Physical Force wing was always unable to pursue any systematic campaign. Its fortunes rose and fell with the increase and decrease of misery. So when in 1836 English trade began to show signs of distress, the effect was soon appreciated by agitators and demagogues. The scant harvests of 1836 and the extreme severity of the winter of 1836–37, followed as it was by unheard of frost and snow in the middle of summer, caused great distress. Strikes became numerous and through them the workmen's associations took occasion to thrust their political grievances into notice. Meetings were held at which the most inflammatory language was used. Often Chartists came together after sunset, with torches, and were addressed by such leaders as Feargus O'Connor, Earnest Jones, John Frost, and Stevens. These meetings were more than once followed by barn and hay-rick burnings and by attacks upon the local police. In the summer of 1839 there were almost constant outbreaks at Birmingham, Sheffield, and other manufacturing centers. Of the condition of popular sentiment in England at this time Carlyle said: "Sullen, revengeful humor of revolt against the upper classes, decreasing respect for what their temporal superiors command, decreasing faith in what their spiritual superiors teach, is more and more the universal spirit of the lower classes." The period lying between the years 1838 and 1840 has often been designated "The Dark Times."

The leader of Physical Force Chartism was Feargus O'Connor, a gigantic Irishman, of outspoken manner and great enterprise and activity. He was an enthusiastic speaker and was possessed of a disposition that made him the natural leader of the more boisterous element. He was the proprietor and editor of the *Northern Star* and the originator and director of the National Land Co., a scheme for home colonization, which got no further than to use for campaign purposes the subscriptions paid in to it by workingmen. O'Connor was elected to Parliament for Nottingham in 1847 and he kept up a vigorous attack in the House of Commons and addressed mass-meetings all over England.

One method of the Chartists of this period was to attend city churches in large numbers, marching in ranks to and from the services. They often wore badges and usually sat as nearly in a body as possible, their aim being to attract attention to themselves and their condition. Upon one occasion a body of Chartists in Manchester ventured to send directions to the pastor of the Old Church, from what text he should preach. On the following Sunday the church was packed by Chartists but, when the text was announced, they arose in a body and left. The preacher had not taken their text but chose the passage "My house is the house of prayer, but ye have made it a den of thieves."

When the year 1840 was passed the most dangerous years of Chartism were over. Plentiful harvests came again. The distress passed from trade. The government which had been waiting for excitement to subside, in order that juries might be gotten to convict, asserted itself and many Chartist leaders were imprisoned. Others left the country.

THE PARADE OF 1848.

Throughout the first few years of the forties the forces of Chartism worked only in a quiet way. The evolution was a silent one molding men's minds and preparing them for the reforms which were to come after the turbulence of 1848 should have passed away. The withdrawal of the Moral Force element from Chartism was the decapitation of the movement; yet the corpse was, by a mighty effort, galvanized into a state of apparent life and activity. The demonstration of 1848 belongs to the history of Physical Force Chartism.

At a time when there was in England a seeming lull in affairs and when there was no great question before the country, the fall of the monarchy of Louis Philippe in France was announced. The frantic republicanism of the victors spread like a contagion all over Europe. The year 1848 is known as the year of revolutions. There were insurrections in Sicily (as usual) and in Italy. There was fighting in Austria and anarchism and socialism in Berlin. The Irish revolted and serious conflicts took place between the Orangemen and Roman Catholics.[1] It was but natural that a certain class of Chartists should feel a quickening of the pulse. Many looked upon the actions of the French Republicans as an example which, as they often hinted, circumstances might compel them to follow. It was planned to hold a great conference in London in March of 1848. Arrangements were there made for gathering the signatures to a monster petition which should eclipse all former ones and should be presented to Parliament calling for the passage of the People's Charter. While this petition was circulating excitement was kept up by meetings, many of which were riotous. Over-heated speakers were continually making threats that England would see trouble if the petition was ignored. The government took warning from the disturbances on the Continent and was on the alert. As early as the middle of March the practice had become general, in the largest cities, to swear in special constables. Large bodies of men were provided for London, Manchester, and Glasgow. *Punch* said the government of England consisted of the special constabulary. Succeeding the March convention an assembly of Chartist delegates, forty-nine in number, came together in London on the first of April. This convention decided upon a grand spectacular movement. All Chartists were summoned to come to London, on the tenth of April, and assemble on Kennington Common. From there, in vast array, they were to carry their petition to the House of Commons and urge its acceptance, as Shelley would have said, "by the majesty of their presence." Chartist leaders made themselves believe that their

---

[1] At Dolly's Bray, Ireland.

cause could not fail of success. They thought that the people were on their side and hence the English government would either be peacefully reconstructed according to their demands or else that, after a short and ineffectual resistance, it would pass entirely into their hands. They even discussed in convention what they should do when they came into control. They determined, among other things, that they would "divide the land into small farms and give every man an opportunity to get his living by the sweat of his brow." The Chartists alleged that they had secured the signatures of 5,706,000 persons to their petition. The proceedings of the convention verged upon open conspiracy. The sentiment was, that if peaceful means would not prevail the time had come for drastic measures. The plan of action formulated by the convention was, that if Parliament ignored the petition that was to be sent to it, the Queen should be commanded (to use their phrase) to prorogue Parliament and call to her aid such ministers as would make the "People's Charter" a cabinet measure. Whether this command was obeyed by Her Royal Highness or not, on Good Friday, April twenty-first, elections should be held throughout England to choose delegates to a National Assembly. This should convene in London, Monday, April twenty-fourth and remain sitting until the "People's Charter" should be made the law of the land. In other words, if necessary, this assembly should constitute a revolutionary government and constitutional convention.

On the sixth of April the government issued a proclamation forbidding the Chartist procession which was announced for the tenth following and also forbidding any meeting to be held by the Chartists. For the authority of the latter part of their proclamation they went back to an obsolete but unrepealed statute of Charles II., passed in 1661, immediately after the Restoration, and which was for the temporary purpose of crushing the numerous conspiracies of that time. The government was criticised, even by conservatives, for resurrecting this antiquated bit of legislation; no serious attempt was made to enforce it. On the seventh, the public offices of London were supplied with arms in anticipation of a chartist outbreak.

Special constables to the number of about 150,000 were sworn in. The parapets of the Bank of England were fortified with sand bags, and detachments of the regular army were placed behind them.

When the fated tenth arrived the Chartist leaders met at nine o'clock in the morning, in the rooms of the Literary and Scientific Institute, Fitzroy Square. Many wore in their hats cockades of red, white, and green ribbon, the Chartist colors. The crowd that naturally assembled in Fitzroy Square, before proceeding to the appointed meeting place, was addressed by Chartist speakers. O'Connor, the acknowledged head of the movement and the one always depended upon for fire and enthusiasm, was loudly called for. On this occasion, to the surprise of everybody, he took up much of his time explaining that he was really unwell, and had a doctor's certificate which would entitle him to stay at home. He urged the Chartists not to come into conflict with the authorities, who were armed to the teeth and who, he said, were thirsting for their blood. Finally he asked them to forbear for his sake, as he had received many warning letters to the effect, that the authorities would first of all fire upon him.[1] Earnest Jones, of more fiery temper, followed with a speech in which he expressed much surprise that at the last minute they should be counseled to back down. The crowd was divided in opinion. Thus, through hesitancy and disagreement, what might have ended in a revolution did not even produce an effective mob.

The officers of the organization repaired to the place of meeting riding in a highly decorated car. Kennington Common is south of the Parliament Houses and across the river from them. They crossed the river, probably by the Vauxhall Bridge, and carried with them the petition which comprised five huge bales or bundles of paper. The hundreds of thousands of people who were summoned from all parts of England did not appear. Reliable estimates made by army officers placed the number at from fifteen to twenty thousand. Upon attempting to form for the procession the leaders were stopped by the police and the

---

[1] He promised to worry the government into accepting the charter by constantly asking questions about it in the House of Commons.

crowd was thrown into confusion. It was found furthermore that the police were in posession of all the city bridges and that they were thus shut off from the north side of the river and from the Parliament buildings.[1] They cursed their stupidity in choosing so unfortunate a location. The leaders being humiliated desired nothing so much as to get out of sight and court retirement. The crowd gradually dispersed and sought consolation, for the remainder of the day, in the ale houses. There was no procession and after everthing had settled down, the bales of petition were quietly carted to the Parliament Houses. On the north side of the river, in the city, all was orderly. No soldiers appeared in public. The special police paraded up and down all day through nearly deserted streets. The city was more than usually quiet.

The petition was examined by government clerks and found to contain 1,975,496 signatures. Many sheets of these were utterly worthless, either showing the same handwriting or filled with preposterous names. Such signatures as "The Queen," "The Prince of Wales" were found among "Harry the Tar" and the names of favorite characters of fiction. The *Illustrated London News* in the first issue after April tenth said: "Mr. Feargus O'Connor has shown that quality which was as good as valor in Sir John Falstaff and which was still better than valor in him — discretion. . . . Three hundred thousand Chartists summoned to Kennington Common have dwindled down to fifteen thousand. The mountain has laboured, the mouse has been born."

The ridiculous character of this demonstration killed Chartism as an organized power. It did not however alter the main movement of reform in which Chartism has a place. The impulses which so long found expression through Chartism ultimately passed into other lines and gave constituency to various reforms. The Earl of Shaftesbury wrote in his private diary under the entry bearing the date April 13, 1848: "Men are talking, they know not why, and they do not reflect *how*, of *this* slight concession and *that;* of an 'enlargement of the franchise,'

---

[1] From twelve o'clock noon, until four o'clock in the afternoon no one was allowed to cross the bridges from the Surrey side of London.

and other vagaries. No one, except the Chartists, has asked for it, and they will rest satisfied with nothing short of the whole. The middle classes are content, and so are nineteen-twentieths of the working people; but this will be of no avail against indistinct terrors, ignorant uneasiness, and speculative, not social, policy. A sanitary bill would, in five years, confer more blessing and obliterate more Chartism than universal suffrage in half a century; but the world, when ill at ease, flies always to politics, and omits the statistics of the chimney-corner, where all a man's comfort or discomfort lies."[1] There is a good deal of wisdom in this comment but no one now thinks of calling the movement for the "enlargement of the franchise" which so fundamentally reconstructed English government, a "vagary." To the argument of this extract it is only fair to append the Chartists' answer which might assume the form of a question: What chance of success would a sanitation bill or any other radical measure of reform have had in the old aristocratic Parliament supported by a restricted suffrage?

The violence of the French Revolution ended Chartism by opening the eyes of the more conservative and reasonable classes of England to the dangers toward which extremists were leading agitation. It precipitated the division of society into two classes; on the one hand, those who felt they had more to gain than to lose by the maintenance of the existing order, and, on the other, such as believed they could improve their fortunes by revolution. As soon as this destinction was clearly drawn Chartism was at an end.

Chartism introduced the masses to the larger issues of social and political life, and it is not to be wondered at if they blundered after the fashion of a player learning a new game. It must not be forgotton also that many criminal and violent men and many demagogues preyed upon the Chartist movement. We should discriminate their acts from the acts and opinions of the majority. A few turbulent Physical Force leaders engineered the farce of 1848; the majority staid quietly at home. A view of Chartism to some degree sympathetic, is necessary to enable

---

[1] Hodder, "Life, etc." p. 393.

us to understand the sympathy and support which the cause received from a few of the choicest spirits of the age in which it occurred.

INFLUENCE OF CHARTISM.

When Chartism passed away the Liberal Party fell heir to much of its constituency. The effect of this was noticeable in the progressive policy soon adopted by that party. It is impossible to consider that the influence of Chartism ceased entirely with the year 1848. It fallowed the ground, so to speak, for subsequent reforms. One evidence of this is the luxuriant growth of newspapers and periodicals and debating clubs of all sorts that sprang up for a time advocating every sort of reform. Most of these were short-lived, it is true, but they evinced the breaking up of traditional lines of thought. There was, for example, the penny periodical entitled "Politics for the People" advocating sanitary reform, extension of parks and general municipal reform, education and socialized religion. The weekly entitled "The People" advertised itself as the advocate of reform in general, seeking to promote the free and full development of the whole human being. To this end it advocated teetotalism, dietetics, and the healing art, phonography, phrenology, and reform in theology. As may be seen from such an announcement, pretty much every line of thought was shaken up at this time. It could scarcely be but that progress would result in some of the many directions which inquiry took. Those supporters of Chartism who passed into the Liberal Party turned the government to the serious consideration of economic problems. Another portion aided in the regeneration of the English clergy. The Tractarian movement displayed as a central thought the yearning to recover for the church its leadership and to make it worthy to revive the idea of the fatherhood of the church toward its members. The people had shown themselves to be like sheep without a shepherd while the church primates had, from the seats of the scornful, exercised only a negative influence. Another closely allied line of reform, the Young England Movement, was toward re-establishing intimate relations between the aristocracy and the common people.

It aimed to reinstate that ancient condition in which the nobility were the friends, advisors, and leaders of the people. The agitation for universal suffrage was carried on with moderation by two influential societies formed after 1848; The People's League for Manhood Suffrage and The People's Party of Parliamentary Reform. The great hobby proposed as a counter influence by the opponents of Chartism, during its later stages, was foreign colonization. The London *Times*, the Glasgow *Daily Mail*, *Blackwood's Magazine*, and other influential publications urged the colonization of Canada and other English possessions. When the government was making arrests in the latter part of 1848, some of the Physical Force leaders personally took up with this idea with amazing alacrity.

Chartism shows us that movements for reform which begin in the lower orders of society, are often born of physical misery, and progress or recede as that fluctuates. The things agitated for in campaigns so begun have often little connection with the causes of the afflicting evils. Chartism shows us, as does many another popular agitation, the results which always follow from a lack of competent leadership. Several of the leaders of Physical Force Chartism were suspicioned, on good grounds, to have been insane. When the intelligent classes are arrayed upon one side and the ignorant upon the other, even though the latter may be numerically very strong, they cannot hope for permanent success. Popular movements often make the mistake of defying rather than attempting to educate and conciliate their non-sympathisers. Narrow minds proverbially overestimate the differences that exist between individuals and classes because of a failure to grasp fully enough the idea of a common human nature. Chartism opened the eyes of England to the fact that the upper classes owe a duty of intelligent leadership and assistance to those among whom they live. Any criticism of the Chartists for confounding liberty and license strikes back against the classes who failed to see that power and rank and wealth imply duty. Chartism demonstrated the solidarity existing between social reforms. An advance in politics, economics, education, or religion depends in a measure upon the status of each of the others, and each feels an impulse from an advance in any other. Especially is the close connection between political and ethical progress pointed out; for the one irreconcilable contradiction of Chartism was, that through violence the people were not showing themselves capable of taking a part in government but quite the contrary.

Madison, Wis., December, 1898.

A STUDY OF THE GREENBACK MOVEMENT, 1876-84.

ORIN G. LIBBY, PH. D.
Instructor in History, University of Wisconsin.

The economic interpretation of history is one of the most fruitful contributions of modern historical criticism. It is peculiarly valuable for its concreteness, furnishing a ready means for comparison with results already reached in other lines, and for speedily ascertaining the relative value of the new and the old. The abstract proposition, with its finespun logic, its carefully drawn deductions, and its infallible conclusions, is thus relegated to the limbo of mediaeval rubbish. Its place is now filled by a really scientific laboratory method.

It is not a new idea in history or political economy, that environment modifies man and finds expression in his institutions, his laws, and his daily economic life. The detailed statistical proof of this in an actual case is not so common, nor is it easy to demonstrate the rigid working of cause and effect upon a given community in so narrow a field. What can be shown to be true for a series of centuries, is not so readily discernible for a single generation. Yet the tendencies of human life should be susceptible of concrete expression for any period of time, however imperceptible their movement, if only the proper cross section be made and a sufficiently high magnifying power be applied. Such a favorable time for the study of the economic causes of political action may be found in some great upheaval of public opinion, which re-arranges for a moment a considerable portion of certain most susceptible communities along the magnetic lines of self interest. The old and steadily conservative forces of tradition are for the time paralyzed in some favorable localities and the elemental human desires reassert themselves irresistibly. Not all of these disturbances are economic, many of them are intellectual, social, or religious, or more likely still a combination of two or more of these in varying proportions. For the student of history they are among most interesting chapters in the life of our race.

The object of the present paper is to discuss the economic side of a question which in one way or another has agitated us at intervals from the foundation of our government to the present time. Among the various occasions at which this question was uppermost, may be mentioned the paper money issues of 1786; the struggle over state and national banks in 1816, 1830, and 1840; relief legislation in Kentucky in 1826; repudiation of state debts in 1845–54; and the Greenback and Populist movements of recent years.

The early supporters of a paper money policy in 1786–88 were quite largely found with the Anti-Federalists. The sparsely settled districts, largely agricultural, with but few or no cities were the Anti-Federal regions and also the paper money strongholds at this period. The question of debt, too, was an important factor thus early in our history; and in Massachusetts we have the best illustration of the union of these two elements for a common purpose, the interior farmer with his primitive, frontier notions of life and the unfortunate debtor who had come within the power of the law. These two classes, often represented in the same individual, furnished the basis for that formidable uprising known as Shay's Rebellion, which so seriously threatened the Massachusetts government in 1786. It is of course impossible, in the absence of reliable statistics and detailed records for this early period, to do more than point out the approximate location and character of this paper money movement. For that reason it is proposed to speak of a similar movement, occurring about a hundred years later, when it is possible to consider minutely the economic life of the regions affected. With this done, we can study the same problem anew under the less favorable conditions of early history and reach more permanent results.

The Greenback party seems to have attained its maximum strength in 1880, for that year it polled its highest vote and this vote was most widely distributed. By a study of the different counties where this vote was important we can obtain a fair conception of the economic environment which produced it. For this purpose the tenth census affords abundant material, and this forms the ground work for the conclusions here offered. The inquiry has been limited to those counties whose Greenback vote is 10 per cent. of the total vote. This furnishes us for the year 1880 with 306 counties, distributed over fifteen states.

TABLE I.

Groups of States.	Total Number of Counties.	Greenback Counties.	Per cent. of Greenback Vote in State.	Per cent. of Vote in Greenback counties.
Group I	638	224	8.1	22.9
Iowa	99	33	10.3	19.1
Kansas	113	39	9.8	16.3
Michigan	82	26	9.8	17.4
Missouri	117	45	8.8	20.3
Texas	227	81	1.8	31.0
Group II	348	53	5.3	17.1
Illinois	102	12	4.2	12.7
Kentucky	117	19	4.3	18.1
Mississippi	75	9	4.9	20.4
West Virginia	54	13	8.0	17.8
Group III	430	29	2.8	14.6
Colorado	32	3	2.6	14.7
Indiana	94	5	2.5	12.4
Nebraska	80	5	4.5	14.6
Pennsylvania	67	6	2.3	16.6
Tennessee	94	7	2.4	14.8
Wisconsin	63	3	2.5	14.3

As will be seen from Table I, there are three well defined groups of these states. The first comprises Iowa, Kansas, Michigan, Missouri, and Texas, and has an average vote of 22.9 per cent. in 224 counties, nearly two-thirds of the whole The second group, Illinois, Kentucky, Mississippi, and West Virginia, has a smaller but on the whole quite compact vote averaging 17.1 per cent. in 53 counties. The third group, comprising Colorado, Indiana, Nebraska, Pennsylvania, Tennessee, and Wisconsin, has a small and usually a much scattered vote of 14.6 per cent. in 29 counties. The facts concerning the Greenback counties in all these states will be presented for each group as a whole, in order to avoid confusion and to bring out forcibly the characteristics of the typical Greenback county, if such there exists.

TABLE II.

Groups of States.	Manufactures. Value per capita.	Farm Produce. Value per capita.	Total value manufactures and farm produce per capita.	Total valuation per capita.	Farm values per acre.
Group I—					
Average for 5 states................	51.1	55.3	106.4	233.9	16.9
Average for 224 Greenback Counties	21.6	51.3	72.9	194.4	12.7
Group II—					
Average for 4 states................	55.9	47.9	83.1	197.8	16.2
Average for 53 Greenback Counties	17.9	48.9	65.6	168.4	13.4
Group III—					
Average for 6 states................	78.5	46.5	125.1	302.5	23.2
Average for 29 Greenback Counties	33.7	55.1	88.8	227.8	17.9

If the large vote polled by the Greenback party is to any considerable degree the result of the environment of the voter, it ought to appear from an investigation, first, of the peculiar economic life in each of these counties under consideration and, second, of any evidence as to unusual financial burdens upon the property owner. An examination of Table II will afford us some glimpse into the particular economic features that characterize the Greenback counties. It will be seen in the first place that they are, in general, all agricultural communities, with a much less developed manufacturing industry than the average of the group; this is the most striking feature of the showing. It is next to be observed that though these groups are predominantly agricultural, in even this particular they do not rank very high. In the last group, only, does the average considerably exceed that of the state and in the first group it falls below.

The total value per capita of the products from the two greatest sources of wealth in the country, manufactures and agriculture, is seen by the table to be far below that of the groups of states as it is also in each of the separate states except Colorado and Texas. The total valuation per capita is likewise much less than the average, and this is true also for each of the states except Colorado, Illinois, Indiana, and Iowa. Lastly, the value per acre of the farm lands is much lower than that of any of the groups of states, a ratio which obtains in every one of the states except Colorado, Texas, and West Virginia. It should further be noted in this connection that in every one of the cases above given, those counties having on the average the largest Greenback vote show a still more decided tendency in the same direction, as already pointed out.

TABLE III.

Groups of States.	Per cent. of farms rented.	Local debt per capita.	Total taxation per capita.	Per cent. of mortgages to farm values per acre.
Group I—				
Average for 5 states......................	23.6	9.71	4.72	40.5
Average for 224 Greenback Counties....	25.0	5.04	3.58	50.4
Group II—				
Average for 4 states......................	29.2	6.75	3.70	56.0
Average for 53 Greenback Counties.....	29.4	4.06	2.71	61.0
Group III—				
Average for 6 states......................	20.5	12.54	5.93	52.4
Average for 29 Greenback Counties.....	21.4	5.98	4.70	43.9

We may next consider the special burdens, if any, which are borne by the property owners in the Greenback districts. Table III well illustrates the negative as well as the positive side of the evidence in this investigation. It is clearly seen that the ownership or rent of farms has nothing whatever to do with the question we are discussing. The variation from the average is so trifling as not to amount to anything, and we may at once eliminate the rent grievance from our problem. The averages for local debt and taxation in these counties reveal facts of importance but not in the direction of financial pressure upon the property owner. Not only do the Greenback counties pay a smaller average tax per capita and have a smaller per capita debt, but the ratio of this debt and tax to their total valuation is less than the average for the several state groups. This shows conclusively that these districts have not yet attained the complex economic life of older communities in the same states — they form, as it were, a frontier belt, not yet fully developed. The evidence as to the ratio of mortgages to farm values per acre is full of significance. As shown by Table III the two most important groups of states show averages that indicate a heavier per acre burden upon farms in the Greenback areas. The third group gives just the opposite result. The separate states, also, whose Greenback counties do not show a greater per cent. of mortgages to farm values are six in number and represent 104 counties, a little over one-third of the whole number of these counties.

To sum up our results thus far, it has been shown that the most important part of the Greenback vote of 1880 was distributed through 15 states and 306 counties, and comprised those districts largely agricultural in interest. These communities, moreover, were on the average poorer than the remainder of the state in which they were located, and their economic life was more undeveloped. This latter appears from their lower per capita manufactures, total valuation, and local debt and taxation; while their poverty is indicated by the low value of farms and the smaller total value of manufactures and farm produce. And, further, these conditions were aggravated by a higher average value of mortgages upon the farms.

We may next turn our inquiry toward ascertaining the location and character of the more or less compact Greenback districts in the separate states, with a view to testing the conclusions already reached. In selecting these districts for separate study, the effort has been made in each case to choose only those counties which are contiguous, or nearly so, and which seem to form a natural group. In one instance, in southeastern Kansas and southwestern Missouri, two separate groups are made of one large district because of essential physiographic differences.

Again, the counties of Michigan are grouped in two divisions, the agricultural and the manufacturing, on the ground of their differences in the per capita value of agricultural and manufacturing products respectively.

In Table IV is seen tabulated results for ten groups in seven states. The average Greenback vote for these groups is nearly three times as great as that of the states represented, being 21.1 per cent. of the total vote, and hence they may be taken as typical districts. The first group, that of southern Iowa and northern Missouri, consists of about the same number of counties in each state. The Iowa portion lies mostly southwest of the Des Moines river, the heaviest Greenback counties not touching this river, and is drained by rivers flowing south through Missouri into the Missouri river. The Missouri portion lies north of the Missouri river, and is massed largely in a north and south belt just west of the Mississippi river, from which it is separated by a considerable space. It will be seen from an examination of the table that these counties possess most of the Greenback characteristics already pointed out as typical, namely small per capita value of manufactures and total per capita value of farm produce and manufactures; a lower average total valuation as well as farm value per acre; and a less developed economic life, shown by a smaller local debt and total tax per capita. In the case of the proportion of mortgage value to farm value per acre, there is an exception to the general rule, it being the same as the average for the two states. For Iowa alone, however, the state average is 35 per cent. and that of its Greenback counties is 39.2 per cent. All of the southern states except Texas show the same general tendency toward exceedingly high ratios of mortgages to farm values, without doubt owing to the burdens and losses of the late war.

TABLE IV.

States and State Groups.	Per cent. of Greenback vote.	Manufactures; Value per capita.	Farm Produce; Value per capita.	Total value manufactures and farm produce per capita.	Total valuation per capita.	Value of farms per acre.	Per cent. of Mortgages to farm values per acre.	Per cent. of farms rented.	Local debt per capita.	Total tax per capita.
Iowa and Missouri (average)	9.5	59.9	63.9	123 9	245.5	18.1	42.	27.0	11.73	5.52
South Iowa and North Missouri Group	18.3	17 9	74.1	91.9	230.5	17.8	42.	26.8	4.50	4.80
Kansas	9.8	30.9	52 4	83.3	161.5	10.9	38.	17.0	14.97	4.43
Northwest Kansas Group	18.9	4.0	30.1	34.1	44.3	4.0	59.	3.8	3.00	1 15
Southeast Kansas Group	16.0	14.7	50.3	65.0	154.5	11.1	39.1	18.8	13.00	3.94
Kentucky	4.3	45.7	38.1	83.8	212.6	13.9	69.	27 0	8.42	3.15
Green River Group	19.1	8.0	43.3	51.3	136.7	9.2	50.	27.0	4.70	1.61
Texas	1.8	13.0	40.9	53.9	201.2	4.6	49.	38.0	3.78	2.87
Central Group	39.6	8.6	41.0	49.6	174.8	5.6	57.	40.0	1.28	2.20
Michigan	9.8	92.0	55.6	147.6	316.2	33.0	31.	11.0	5.37	5.27
Agricultural Group	16.3	43.2	79.8	123.0	336.8	38.8	32.	10 5	2.27	4.22
Manufacturing Group	20.6	108.9	34.9	143.8	201.6	27.7	32.	7.8	6.40	5.61
West Virginia	8.0	36.9	31.3	68.2	225.7	13.0	47.	12.0	2.44	3.32
First Group	14.4	19.2	31.8	51.0	226.6	19.1	46.	14.3	.32	2.74
Second Group	23.9	5.6	25.9	31.5	129.1	8.0	44.	35.5	.65	2.71
Missouri	8.8	76.2	44.2	120.4	245.7	13.4	49.	28.0	18.79	4.73
S. W. Missouri Group	24.1	10.2	37.1	47.3	112.3	7.4	49.	21.7	5.33	2.30

Kansas supplies two typical Greenback groups, with all the characteristics strongly marked. It is worthy of notice, also, that the northwestern group has the larger vote and shows most strikingly the statistical evidence of poverty, simple economic life, predominantly agricultural in character, and heavily burdened farm lands, 59 per cent. of the value of each acre being covered by mortgage, and in one county the ratio is 95 per cent. The Green river group of Kentucky, situated mainly in this river valley, belongs in rank with that of northwestern Kansas, which it resembles in the main features of its economic life. Its per cent. of mortgage value to farm value, while very large, is less, however, than that of the state.

The Texas group contains twenty-nine counties, six of which polled a Greenback majority vote. This most important of all the groups lies in central Texas, one hundred miles from the coast, in the river valleys of the Colorado, the Brazos, and the Trinity. It is for the most part a compact mass of counties, but four prolongations extend this group up these three river valleys and connect it on the northeast with the valley of the Sabine. In every particular but farm values this group shows decided marks of a purely agricultural section, poorer and less developed than the average county in the state. In particular its very large ratio of mortgages to farm values proves that it is no exception in this feature of its economic life. It should also be added in this connection that no other occupations have as great an importance as agriculture and manufacturing,—cattle raising at this time, at least for the counties under consideration, being of slight importance.

The West Virginia groups are found respectively between the waters of the upper Monongahela and those of the Little Kanawha, and along the middle course of the Great Kanawha. The northern group touches the Ohio river slightly, but both may be considered interior groups, practically out of reach of this great waterway. As has already been pointed out for the Kansas groups, the larger vote of the second group shows itself in a general intensifying of the typical economic features of these counties, the only exceptions being those of the local debt and the mortgage values. This group is also seen to be very closely assimilated to the two Kansas groups and that of Kentucky, especially in its averages for the resources of the state. In the tabulated results for the first group several exceptions may be noted but as their entire number in the whole table is small, they do not vitiate the general conclusions so far reached.

The southwest Missouri group is of interest from the fact that it lies in a section of the state which was Federal during the Rebellion. It occupies the region of the Ozark mountains, is drained by the Osage river, and is separated by a considerable space from both the Missouri and the Mississippi rivers. In the early growth of the state, it offered little to tempt the slave-holding planter and hence its anti-southern tendencies. Its lands are poor and its population contains a considerable proportion of miners. In a state whose manufactures have the same ratio to farm produce as in Michigan, about 7:4, this section has a per capita value in manufactures hardly one-fourth that of its farm produce. In all other respects, also, it reveals a simple, undeveloped economic life.

Michigan contains two groups of Greenback counties, so distinct from all the others as to merit separate discussion at some future time. The second of these, the Manufacturing group, is the only one of the ten groups in which the per capita value of manufactures is in excess of the farm produce,—indeed it is greater than the average for the state. In Michigan both groups show averages which cannot be reconciled with those of the other states. The Agricultural group has a per capita value of manufactures twice as large as that of any group in the other states; its total valuation is greatly in excess of its state average, as is also its farm value per acre. The Manufacturing group, in its great excess of manufactures over farm produce and its greater tax and local debt per capita as compared with that of its state, partakes of this same exceptional character. Without means of comparison it is not now profitable to discuss the significance of this wide difference in economic life. It will have important bearing, however, upon the relation of the Greenback party of 1880 to the Populist party of 1892. The location of the Manufacturing group is quite as significant as its other features. Its counties are ranged chiefly along the western shore of the southern peninsula, including the lower courses of the Manistee, Muskegon, and Grand rivers, while two of the counties extend partly around Saginaw Bay on the eastern shore. The Agricultural group lies in the southwestern part of the state, south of Saginaw Bay, only two counties touching the western shore, while a wide interval separates it from the eastern shore.

If we select from the ten groups of the foregoing table the five having the largest per cent. of Greenback vote (except Michigan) we shall find a fairly typical set of conditions. These five groups, including 76 counties, are: northwestern Kansas, Kentucky, southwestern Missouri, Texas, and West Virginia second group. Their average vote is 25.1 per cent. larger than that of the 224 counties (Group I) in Table II. Carrying this comparison still further we find that these 76 counties have a per capita value of manufactures about one-third as great as the first group in Table II, and for farm produce, total value of manufactures and farm produce, total valuation and farm values per acre, the averages are much lower. In respect to total taxation and local debt the per capita averages are also much less, while the ratio of mortgages to farm values is greater. The conditions found to prevail in the typical Greenback county of the larger group are thus seen to be present in the smaller and more compact groups, and in a decidedly intensified degree.

So far, we have considered the Greenback vote for 1880 only. There are two other presidential elections, those of 1876 and 1884, in which this vote appeared as a factor in the contest; and it is of some interest to know whether the voter partook of the same general character as in 1880. In Table V is shown the averages for those counties which had a Greenback vote of 10 per cent. or over in at least one of the other presidential elections. It will be seen here that the average vote is large and bears about the same ratio to that of the state as in 1880.

Presidential Elections of 1876, 1880, 1884 —States and Counties. (Data from census of 1880.)	Per cent. of Greenback vote.	Manufactures; Value per capita.	Farm Produce; Value per capita.	Total value manufactures and farm produce per capita.	Total valuation per capita.	Value of farms per acre.	Per cent. of Mortgages to farm values per acre.	Per cent. of farms rented.	Local debt per capita.	Total tax per capita.
Illinois	4.2	134.7	66.2	200.9	255.5	32.1	46.	34.	14.60	6.26
Two counties	22.1	16.2	86.9	103.1	197.2	20.4	50.	36.	10.63	3.72
1876 and 1880	13.4	....	....	....	....	....	....	....	....	....
Indiana	2.5	74.8	57.9	132.7	367.8	30.6	43.	24.	6.75	5.48
Two counties	12.4	34.8	59.4	94.2	327.4	31.0	38.	26.	.35	3.52
1876, 1880, and 1884	....	....	....	....	....	....	....	....	....	....
Iowa	10.3	43.7	83.7	127.4	245.3	22.9	35.	24.	4.67	6.31
Nine counties	20.4	15.8	77.0	92.8	229.6	19.6	35.	27.	1.94	6.08
1876 and 1880	21.4	....	....	....	....	....	....	....	....	....
Kansas	9.8	30.9	52.4	82.3	161.5	10.9	38.	17.	14.97	4.43
Nineteen counties	14.7	11.1	49.6	60.7	140.2	10.1	42.	16.1	10.86	3.69
	17.1	....	....	....	....	....	....	....	....	....
1876, 1880, and 1884	13.7	....	....	....	....	....	....	....	....	....
Michigan	9.8	92.0	55.6	147.6	316.2	33.0	31.	11.	5.37	5.27
Twelve counties	19.5	94.0	52.3	146.3	241.6	28.0	37.	9.	4.63	5.09
1880 and 1884	14.1	....	....	....	....	....	....	....	....	....
Pennsylvania	2.3	173.9	30.2	204.1	393.0	44.2	....	22.	21.78	6.67
Two counties	23.4	22.4	32.5	54.9	276.5	22.2	....	20.	3.02	5.52
1880 and 1884	17.3	....	....	....	....	....	....	....	....	....
Texas	1.8	13.0	40.9	53.9	201.2	4.6	49.	38.	3.78	2.87
One county	14.8	9.3	41.8	51.1	192.2	7.7	54.	29.	....	2.44

The value of the manufactures in these counties is very much less, as compared with the average, than in any case yet found, varying from one-eighth to one-half in all the states except Texas (where it is somewhat smaller), and Michigan (where it is slightly greater). In comparing the per capita value of farm produce of these counties with that of their state, it will be discovered that, while there is no uniformity in their relative values, in every case the average is greater than that for the per capita value of manufactures, except in the case of Michigan. The most decisive showing of all appears in the figures for the total valuation and the total value of manufactures and farm produce; in every state except Michigan, the Greenback counties have a much lower relative value than the state. This is true, also, though in a less degree, for the value of farms per acre except in the states of Indiana and Texas. As in the other tables, the rent question is seen to be of little relative importance. The debt feature, as revealed in the mortgage values per acre, proves to be fully as important here as in 1880, with the exception of the counties in Indiana and Iowa. In all the states, the counties under consideration have a less complex economic life as seen from their low per capita tax and local debt. Thus the steadily persistent Greenback counties have shown the same general characteristics as those in the groups for the election of 1880.

The Greenback movement, then, of 1876–84, has a two-fold character, and drew its support from two entirely distinct and separate regions. First, the bulk of the supporters of the party came from what may be termed the inland regions of the states, districts lacking in natural communications with the rest of the state, and, but for the railroads, commercially isolated from the outside world. The counties in these regions, whether studied as a mass, in groups of contigious counties, or considered for three consecutive elections, display certain well defined characteristics, which distinguish them from all others. Predominantly agricultural in occupation and having a comparatively simple economic life, they were also poorer than the average county of their state and more heavily burdened with debt. Second, a less important, but none the less distinct Greenback region, is to be found in Michigan, situated largely on the lake shore and in a region distinctively manufacturing in character. This is the more striking from the fact that it has an even greater per capita value of manufactures than that of the large state average. The greater per capita local debt and total tax, coupled with the foregoing, indicates also a more complex economic life than that of the first regions already discussed.

This later paper money movement thus had not only the support of the poor farmer as in 1786, but also that of the city artisan as well, a new class of supporters for cheap money and repudiation of debts. It now remains to show the development of this latter class into the ardent populist of 1892 and the union of the two elements for free silver in the elections of 1892–1896. The cycle of economic development is thus complete when the representatives of an undeveloped, almost primitive life join hands with their brethren of the cities, whose lives have been embittered and whose vision has been distorted by their fierce struggle for daily bread in our great centers of modern industrial activity.

Madison, Wis., December, 1898.

ON SOME POINTS IN THE STRUCTURE OF THE LARVA OF EPISCHURA LACUSTRIS Forbes.

BY C. DWIGHT MARSH,
Professor of Biology in Ripon College.

WITH PLATES XII AND XIII.

Epischura is a genus of copepods found only in America, its nearest European relative being *Heterocope*, and is remarkable for the very pronounced asymmetry of the abdomen. This is especially noticeable in the male of *Epischura lacustris* Forbes, in which not only is the abdomen twisted to the right, but certain of the segments have marked lateral projections which together form a complicated grasping organ.

Inasmuch as *Epischura* is a form peculiar to America, and yet with no nearly allied forms in this country, its larval history is a matter of considerable interest as being likely to throw some light on its relationship to other copepods.

Forbes ('91, " On some Lake Superior Entomostraca ") says, " among the many hundreds of specimens which I have examined from the Great Lakes and from several of the smaller lakes of Illinois, Michigan, and Wisconsin, I have rarely seen an immature form." It is true that during the summer months, when one is most likely to make collections of entomostraca, larval forms of *Epischura* are very rare, although I have found them in certain localities in May and even in August. It is in the winter months, however, that they are found in the greatest numbers, especially in the month of March. I have collected from Green Lake a large amount of material illustrating the larval stages, and I hope, later, to make a fairly complete description of its development. The publication of the results will necessarily be long delayed because of the time consuming labor involved in making the extremely delicate dissections of these minute forms. It has seemed best to me, on this account, to publish certain facts which have already been worked out, although this paper must be considered as a communication preliminary to a more extended paper.

The peculiar armature of the furca, which can be recognized quite easily in all except the earliest stages, makes it possible to distinguish quite readily between the larval forms of *Epischura* and those of other copepods. The characteristic form of the first maxillipede is developed very early, and by this feature alone one can frequently pick out *Epischura* larvae with a considerable degree of accuracy.

In this paper I will treat of only two structures, the male abdomen, and the male fifth feet.

The dissections on which the following facts are based were made by Mr. E. E. Hemingway, under my direction, and much credit is due him for the skill which he acquired in distinguishing the larvae of *Epischura* from those of other copepods, and for the patience which he exercised in making the difficult dissections.

THE MALE ABDOMEN.

In the abdomen of the mature male the second and third segments are produced to the right, and from the fifth segment there are two projections to the right, one spatulate, and the other dentate. (Plate XII, Fig. 5.)

In the larval abdomen the segments of the abdomen retain their symmetry until the animal has reached very nearly the mature form. In plate XII, Figs. 1, 2, 3, and 4, are shown the 1, 3, 4, and 5 segment stages,— the last having the same number of segments as the mature animal. Up to and including the four segment stage there is nothing in the form of the segments to distinguish these larvae from the larvae of other copepods, as they are entirely symmetrical. In the last stage, however, the bend to the right is very marked: the projection on the second segment is much like that in the mature animal, and the same thing is true of the projections on the fifth segment: the third segment has a pronounced swelling on the right side, but is quite different from the form in the mature animal. The specimen from which this figure was drawn could hardly be distinguished, in most respects, from one which had reached complete maturity. The asymmetry, then, seems to come in quite suddenly, and in the last stages of the development.

The furca of the mature *Epischura* is armed with three broad setae, an external spine, and a weak and inconspicuous internal seta. In the one segment stage, the three setae are much weaker, the internal seta is considerably longer, and there is, in addition, a lateral seta about midway of the length of the furca. The furca of *Epischura* in this stage differs very little from that of *Diaptomus* at the same degree of development. *Diaptomus* also has a lateral seta, but it is longer than that of *Epischura*, and is situated nearer the end of the furca. The lateral seta does not appear in the succeeding stages of *Epischura*, the armature in the three segment stage differing very little from that in the mature animal. In *Diaptomus* the six setae develop to nearly the same length and size, the lateral seta having moved down nearly to the end of the furca. In *Limnocalanus* the lateral seta remains upon the side of the furca, and the sixth, or internal seta is very weak. In *Epischura* the lateral seta disappears, the third, fourth, and fifth are largely developed, the second becomes a broad spine, and the sixth a short and weak seta. In *Cyclops* it is the third and fourth setae which are commonly the most highly developed, the second and fifth sometimes nearly equalling them, but in most cases being reduced to weak and short setae or spines.

DEVELOPMENT OF THE MALE FIFTH FOOT.

The fifth foot of *Epischura lacustris* consists of two parts, in which there is no clear evidence of the division into exopodite and endopodite. (Plate XIII, Fig. 5.) The right foot consists of two segments — the outer is triangular in shape, with a somewhat spatulate tip, and is always flexed upon the first segment. The left foot consists of three segments: the first has a long horn-shaped lateral process, which is as long as the other two segments; the second and third segments are concave on their inner margins; and the apical segment is armed with fine hairs upon the concave margin and with small spines at the tip.

The youngest specimen in which we have been able to obtain a male fifth foot was the one from which the abdomen was drawn for Fig. 2, Plate XII. This was in the three segment stage. The fifth feet are shown in Plate XIII, Fig. 1. In this figure as in Fig. 4, the feet were drawn from the side opposite to that from which the other figures were drawn, so that the relative position of the feet is reversed. In this figure it will be noticed that the left foot consists of a basal segment, and both an exopodite and an endopodite, each consisting of a single segment. The right foot consists of a basal segment, a one-segmented exopodite, and a process on the basal segment which apparently represents an endopodite. The fifth feet shown in Plate XIII, Fig. 2, represent practically the same stage of development as that in the first figure, but in this the right foot has an evident endopodite.

Figure 3 represents the fifth feet of an individual in which the abdomen had reached the four segmented stage. The exopodite of the left foot in this specimen is composed of two segments, the outer segment having three spines, while only one was found in the lower stages. The endopodite is still of a single segment, but has grown long and slender. In the right foot the exopodite is divided into two segments, and the endopodite has disappeared.

In figure 4 is shown the fifth feet of the individual from which the abdomen in Plate XII, Fig. 4, was drawn. In the right foot the exopodite is reduced from two segments to one, has become triangular or conical in shape, and is strongly reflexed. In the left foot the exopodite has the concave inner margins seen in the mature animal, and the terminal segment is armed with spines and hairs much as in the last stage. The endopodite has become greatly curved and is clearly to become the "curved process" of the basal segment as described in the mature form.

It is evident, then, that the fifth feet of *Epischura lacustris* are to be explained morphologically in this way. Of the two segments of the right foot, the first is the basal segment, and the second is the reduced exopodite, the endopdite having disappeared, although existing in lower stages. In the left foot the exopodite is represented by the two outer segments, while the curved process of the basal segment is the endopodite.

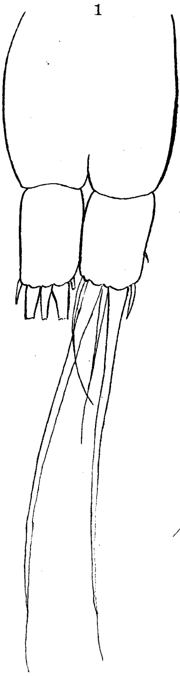
The fifth feet of *Temora* and *Heterocope* are in their structure very similar to *Epischura*, and it is probable that they should be explained in the same way.

In regard to the inferences to be drawn from the structure of the abdomen and fifth feet as to the family history of *Epischura*, it is, perhaps, not safe to say much until the other parts of the body have been more thoroughly worked over. There seems to be nothing especially significant in the structure of the fifth feet. it is true that that there is a marked resemblance between the larval fifth feet of *Epischura* and those of *Diaptomus*, but it is no more than one would expect if they conform to the general type of structure in the copepod appendage.

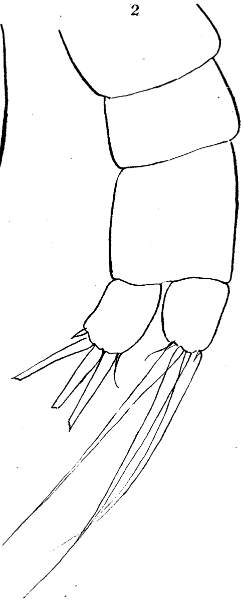
The persistence of the three large furcal setae, even in the earlier stages, would seem to indicate a rather remote connection with *Diaptomus*. On the other hand, the fact that the asymmetry of the abdomen and the lateral processes of the abdominal segments appear only in the very last stages point very strongly to the probability that this most marked peculiarity of *Epischura* is a recent development, and that *Epischura* may be quite closely connected with forms having symmetrical abdomens.

Ripon, Wis., October, 1899.

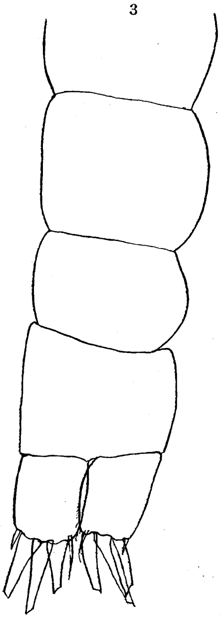
1



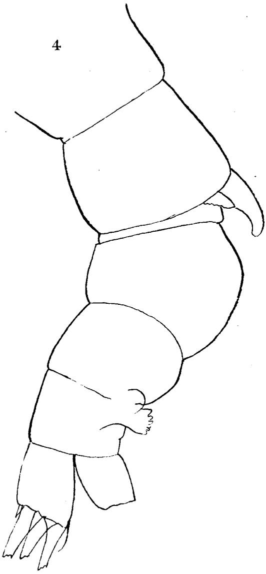
2



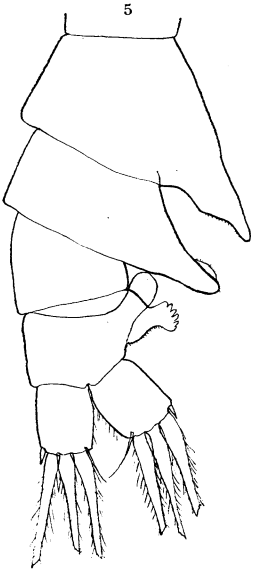
3



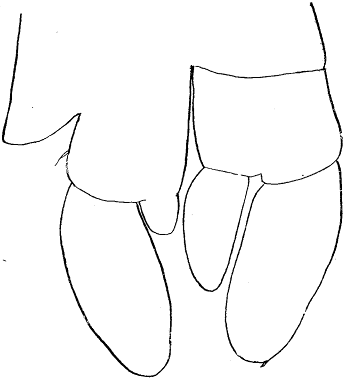
4



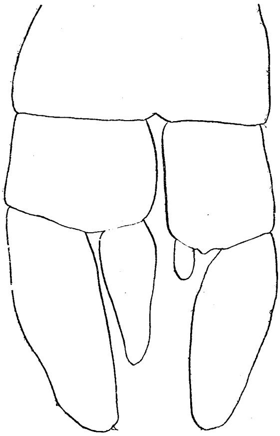
5



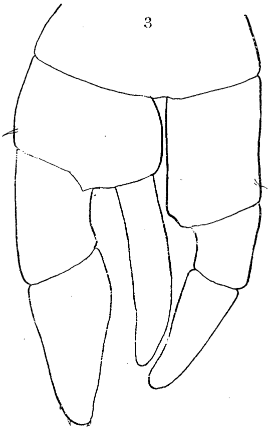
1



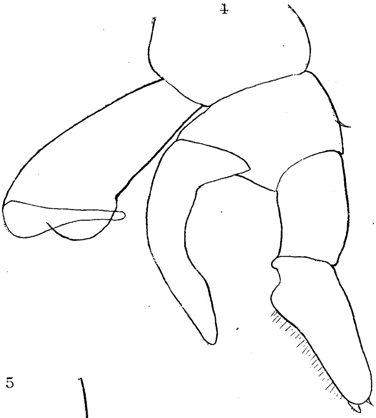
2



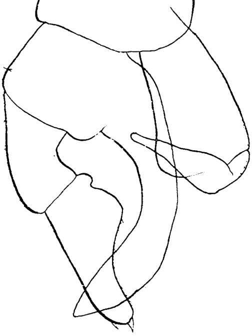
3



4



5



EXPLANATION OF PLATES.

MARSH. *Epischura Lacustris.*

PLATE XII.

Fig. 1—Abdomen of larva of male *Epischura Lacustris*, × 304.
Fig. 2—Abdomen of larva of male *Epischura Lacustris*, × 155.
Fig. 3—Abdomen of larva of male *Epischura Lacustris*, × 155.
Fig. 4—Abdomen of larva of male *Epischura Lacustris*, × 112.
Fig. 5—Abdomen of mature male *Epischura Lacustris*, × 112.

PLATE XIII.

Fig. 1—Fifth feet of larva of male *Epischura Lacustris*, × 375.
Fig. 2—Fifth feet of larva of male *Epischura Lacustris*, × 375.
Fig. 3—Fifth feet of larva of male *Epischura Lacustris*, × 225.
Fig. 4—Fifth feet of larva of male *Epischura Lacustris*, × 140.
Fig. 5—Fifth feet of mature male *Epischura Lacustris*, × 140.

THE UNSTEADY MOTION OF VISCOUS LIQUIDS IN CAPILLARY TUBES.

HENRY CHARLES WOLFF.

When a clean glass tube is dipped into water, the liquid will rise in it to a certain height, where it will come to rest with a concave surface. The amount of the liquid which is raised above the general level depends, as is well known upon the angle of contact of this surface, or meniscus, with the walls of the tube, and also upon the strength of the surface film. The exact form of the meniscus when the liquid is in motion is unknown. Not only is its form different from that which it assumes while at rest, but its shape probably varies with different velocities of the liquid. Under these conditions it seems likely that the pull due to surface tension varies with different velocities of the liquid as it ascends a vertical or flows along a horizontal tube. In the following work I shall attempt to obtain an expression for the velocity of the meniscus along a horizontal tube, supposing that the liquid is forced into one end of the tube under a constant head.

When a liquid is allowed to flow from one reservoir into another through a horizontal capillary tube, we know that the discharge per unit of time, Q, is given by the equation,

$$Q = \tfrac{1}{8} . \frac{\pi a^4 p}{\mu \rho l}, \tag{1}$$

in which a is the radius of the tube, l is its length, μ is the coefficient of viscosity, ρ is the density of the liquid, and p is the difference between the pressures at the two ends of the tube. From this we obtain for the velocity,

$$v = \tfrac{1}{8} . \frac{a^2 p}{\mu \rho l}. \tag{2}$$

Hence we derive

$$p = \frac{8\,\mu\,\rho\,l\,v}{a^2}. \tag{3}$$

These equations are only true, however, for steady motion; that is to say, these equations only hold when the flow has taken place for a length of time sufficient to permit the velocity to have become constant.

In case the motion in the capillary tube begins from a condition of rest and is allowed to increase under the influence of a constant difference in pressure between the ends of the tube, we must consider v as a variable defined by the differential equation

$$p = \frac{8\,v\,\rho\,\mu\,l}{a^2} + \frac{dv}{dt}.\ \rho\,\pi\,a^2\,l. \tag{4}$$

Solving this linear equation we obtain

$$v = \frac{a^2\,p}{8\,\rho\,\mu\,l}\left(1 - e^{-\frac{8\,\mu\,t}{\pi\,a^4}}\right). \tag{5}$$

This gives the velocity at any instant after the commencement of the motion. This equation is analogous to Helmholz's equation of self-induction in the theory of electric currents, as is readily seen from the following form of Helmholz's equation:

$$C = \frac{E}{R}\left(1 - e^{-\frac{Rt}{L}}\right), \tag{6}$$

in which L is the coefficient of self-induction.

If instead of the liquid flowing from one reservoir into another through a capillary tube, the liquid is permitted to flow from a single reservoir into an empty capillary tube, l will no longer be a constant but will be a variable. The equation (4) above must be replaced by

$$l\,v\,\frac{dv}{dl} + \frac{8\,\mu}{\pi\,a^4}\,l\,v - \frac{p}{\rho\pi a^2} = 0. \tag{7}$$

Solving this equation* and determining the constants on the supposition that $l=1$ when $v=0$, we get,

$$\frac{1}{l}\,e^{\left(\frac{v+Al}{F}\right)^2}-e^{\frac{A^2}{F}}-\frac{2A\,(v+Al)}{F}\left(1+\tfrac{1}{3}\,\frac{(v+Al)^2}{F}+\frac{1}{5\,L^2}\,\frac{(v+Al)^4}{F^2}+\ldots\right)+\frac{2A^2}{F}\left(1+\tfrac{1}{3}\,\frac{A^2}{F}+\frac{1}{5\,L^2}\,\frac{A^4}{F^2}+\ldots\right)=0, \quad (8)$$

$$\text{where } A=\frac{8\,\mu}{\pi\,a^4} \text{ and } F=\frac{2\,p}{\pi\,a^2\,\rho}$$

This last equation would give the actual velocity were it not for two things. First, it takes into account the hydrostatic pressure only, to which must be added the influence of the meniscus. This acts as a negative pressure, and probably as a variable one. The variation is probably so small that no difficulty would be experienced in taking proper account of this element of the problem. Second, the equation (7) was derived from expressions which require the velocity in the tube to be a function of the distance from the wall of the tube. But the meniscus acts as a wall or diaphragm, preventing the liquid immediately behind it from moving more rapidly along the axis of the tube than along the walls of the tube. This retarding influence is very important, and equation (8) furnishes the basis for an experimental determination of its amount. Equation (8) must first be plotted, using v and l as the coördinates. Similar graphs must then be constructed from experimental data. The discrepancies between the two curves will indicate the retarding influence due to the meniscus.

If as before the tube should connect two reservoirs, and a bubble of air should be admitted at one end and allowed to flow along, the effect due to the pull of the meniscus would be eliminated, because there would be one pulling in one direction and one in the other.

---

* The type of this equation may be found in W. Heymann's *Studien über die Transformation und Integration der Differential und Differenzengleichungen;* Leipsic, 1891, p. 28.

If we take the equation

$$v = \frac{a^2 p}{8 \rho \mu l}\left(1 - e^{-\frac{8\mu}{\pi a^4} t}\right), \tag{5}$$

and let l equal L, where L is the whole length of the tube, and let l' be the distance the bubble has moved from the end of the tube, we shall obtain

$$l' = \frac{a^2 p}{8 \rho \mu L}\left(1 - \frac{a^4}{8 \mu} e^{-\frac{8\mu}{\pi a^4} t}\right) + C, \tag{9}$$

in which C can readily be determined, depending as it does on the position of the bubble at the beginning of the flow. The different values of t can be compared with those found from experiment, constituting a second method for determining the retarding influence of the meniscus.

A knowledge of the retarding influence of the meniscus would have important applications to problems in the seepage of water through soils or other porous media.

West Superior, Wis., December, 1898.

MEMORIAL ADDRESSES.

HARLOW S. ORTON.

1817-1895.

Judge Orton's name was on the membership roll of the Academy in 1876, and no doubt his influence had aided in the outset as to securing its liberal legislative charter. Harlow S. Orton's birth was in Niagara county, New York, November 23, 1817. Twenty years afterward his course was finished in the Madison University in Madison county of the same state. In the same year he became a law student in Kentucky, but soon came north and became associated with his brother Myron, who was already in legal practice a little southeast of Chicago, at La Porte, Indiana. In 1847, the year before Wisconsin became a state, he removed to Milwaukee and opened a law office there. In 1852 he became the private secretary of Gov. Farwell,— the second governor of the state. Thenceforth his residence was in Madison till his death, July 4, 1895.

He represented Madison in the legislature, was mayor of the city, failed by very few votes of election to congress, and was early, for six years, a circuit judge.

But he was chiefly eminent as an advocate. Many lawyers were more deeply read, but very few could make so ingenious use of their knowledge, or present a case so winningly before a jury. For five years he was dean of the law faculty of the university, and at that time became LL. D. He also served as one of the commissioners who compiled the Revised Statutes of the state.

His longest and largest service was, however, as a justice of the supreme court. He sat on that highest bench of the judiciary seventeen years — a longer period than any other judges have except Cole, Lyon, and Cassoday — and was for five years chief justice. His opinions are embraced in forty-seven volumes of Wisconsin Reports. Surpassed perhaps in learning by some, one need not shrink from comparing them with any in acumen, mastery of legal principles, and felicity of expression.

The labors of Judge Orton for the Historical Society in public and private stations, as well as with pen and voice, attest what he would have done for the Academy had he not been too soon pre-occupied with other duties which demanded all his time and strength till he sank beneath the judicial burden which he bore to the last.

JAMES D. BUTLER.

Madison, Wis.

JOHN GOLDESBOROUGH MEACHEM.

John Goldesborough Meachem, M. D., was born in Somersetshire, England, May 27, 1823. His father, Mr. Thomas Meachem, a teacher and conductor of a boys' school, brought his family to this country in 1831. In the Diocese of New York he was ordained to the ministry of the Episcopal church by Bishop Onderdonk. John, the third son, studied medicine in the office of Harvey Jewitt, M. D., with lectures at Hobart College and at the Medical College in Castleton, Vermont, where he was graduated M. D. in the fall of 1843. In 1862 he reviewed his medical studies at Bellevue Medical College, New York City, from which he received their *ad eundem* degree. He practiced unremittingly till 1895 — fifty-two years, when a neuritic inflammation of the heart was suddenly developed which ended his life February 1, 1896. Dr. Meachem was naturally endowed with superb health, a fine physical presence, an active, enthusiastic temperament, and an untiring purpose to do thoroughly whatever he was engaged in. His habit was to read and study the literature of his profession, standard and current, to which he added many interesting papers from his large experience, determined to learn all that was known of the art and science of medicine as applied to diseased humanity.

His skill in detecting the point where an antidote became an irritant, or in other words to carry the effect of a remedial agent to the point where its full benefit is obtained and then to cease its administration, was remarkable; and to this facility in applied science his wonderful success as a physician may in great measure be attributed. He gave much attention to sanitation for the public health and both by addresses and through the daily papers advocated pure water supply and reforms.

Although primarily devoted to his large practice and promptly responsive to its daily exigencies, he found time along the way for social, religious, and political duties, and civic economics. He was elected mayor of Racine three successive terms, and definitely refused another nomination. During three years he occupied the chair at every session of the council except one. The city improved in many directions under his guidance and administration. "No Racine Mayor ever gave so much of his personal attention and labor to perfect the municipal machinery of city government." His second election "was simply a tribute to the man for his untiring energy in reconstructing the city machinery and he was entitled to the endorsement." "A call on Dr. Meachem, who has just been re-elected mayor of Racine, afforded an opportunity of meeting the man who is entitled to recognition as one who devotes time, labor, and money to the welfare of his fellow men."

He was always an avowed Democrat, outspoken for the "inalienable right" of every individual, and gave his ballot at every election from 1844 to 1894.

All his life a member of the Episcopal church, he was known of all men as a Christian gentleman, and was for forty years a careful, watchful trustee of the finances of the parish and a liberal contributor to its current funds; while he gave professional skill and personal attention without thought of remuneration, as well as money from his purse, to help on any good work for the betterment of society.

His manner was courteous to strangers, cordial and happy to his friends, kind, helpful, and encouraging towards any one who needed assistance. "He was deservedly popular with his patients; his charity was proverbial."

John G. Meacham, M. D., became an annual member of the Academy of Sciences, Arts, and Letters in 1877.

JOHN G. MEACHAM, JR.

Racine, Wis.

CHRISTIAN PREUSSER.

(Compiled by the Secretary from the Milwaukee *Sentinel* of June 7, 8, and 9, 1899.)

Christian Preusser was born at Idstein, dukedom of Nassau, Germany, in 1826. He left school at fifteen years of age in order to learn the trade of watchmaker and jeweler. He came to Milwaukee in 1844 and opened a small jewelry store on East Water street. His business increased steadily until, in 1855, the brick building at East Water and Mason streets, which is still occupied by the firm, was erected for its accommodation. Mr. Preusser's brother, Gustav, had become a partner with him, but the firm name was changed some years ago to the C. Preusser Jewelry company, which to-day is one of the largest jewelry firms in the Northwest. Mr. Christian Preusser was president of the company.

Mr. Preusser devoted much of his energy also to the fire insurance business. He was elected a director of the Milwaukee Mechanics' Insurance company in 1853; and in 1854, when the company had struggled for existence through two years and was on the verge of going out of business, Mr. Preusser was elected president. He had great confidence in the ultimate success of the company, devoted much time to its business, and for the next few years more than once employed his private means to meet its losses. Gradually the company prospered until now it is reputed to be one of the soundest fire insurance companies in the country. A year ago a new company was organized, the Milwaukee Fire Insurance company, of which also Mr. Preusser was made president.

He always took an active part in early public affairs. He was a member of the Volunteer Fire department when S. S. Daggett was chief, and Gen. Rufus King, E. P. Allis and John

Nazro were among the members. He acted as treasurer of the department until the paid department was inaugurated. He always took a keen interest in the educational progress of the state and city and was always ready to foster new enterprises intended for the public welfare. He was one of the founders and for twenty years president of the Natural History society of the state, and an active and influential friend of the society for over forty years. When in 1882 its collection was presented to the city he was appointed a trustee of the Public museum, of which he was one of the originators. Later he was active in securing for the museum the valuable collection of Prof. H. A. Ward of Rochester, N. Y. He was one of the founders of the German-English academy and from the time it was founded until 1886 served as treasurer, which position he also held in the National German-American Teachers' seminary. He was the strongest supporter of the latter institution during its years of struggle for a secure existence, and recently gave a large donation towards establishing it upon an enduring financial foundation.

While a staunch Republican Mr. Preusser never catered for office, though often asked to accept political honors. He was a member of the Deutscher club and one of its active workers.

Mr. Preusser was married in 1851 to Miss Louise Hermann of Diets, dukedom of Nassau, Germany. They had four children, but only two survive.

In accordance with his general interest in educational affairs, Mr. Preusser became an active member of this Academy in 1894.

He continued in active life until within a few days of his end, which came on June 6, 1899.

Madison, Wis.

ALICE MARIAN (AIKENS) BREMER.

(From article in the *Evening Wisconsin*, September 10, 1898.)

Alice Marian Aikens was born at Milwaukee, October 3, 1858. She was the eldest child of Andrew J. and Amanda S. Aikens. She was educated in Milwaukee at the Wheelock school for girls until the age of eighteen when she went to Paris with her mother and a sister and studied modern languages, art, and literature, six months of the time at the Academy of Design. After her return to this country she worked at water color painting with George Smilie of New York, with notable results, but she finally devoted herself especially to the study of astronomy and biology. She was married in 1884 to Hugo Bremer, of Milwaukee, and had one child, who died in infancy.

Mrs. Bremer was a woman of high ambition in her chosen line, and of a sensitive, sympathetic spirit towards the objects of nature, so that the flowers of garden and field were to her as cherished pets. She was an earnest member of the Milwaukee Woman's club, and showed unusual aptitude for original investigation and devotion to its pursuit in connection with her work in the study classes. She also conducted a class in astronomy in the College Endowment association. She read all the good publications relating to her special lines of interest and became an expert herseif in the use of the microscope and collected a considerable private museum of biological specimens. Later she gave special attention to algae and spent six months in Woods Holl in the study of that class, and when she went to California in January, 1898, primarily for the sake of her health, it was also that she might study the algae of that coast. But her physical strength was not equal to her ambition, and her life ended at San Diego, August 25, 1898.

In her will Mrs. Bremer provided that her collection of algae and other specimens be presented to the Milwaukee public museum, and that her microscope and other scientific apparatus be presented to some scientific worker unable himself to procure such aids.

JAMES CLARK FOYE.

James Clark Foye was born in Great Falls, New Hampshire, March 1, 1841, and graduated from Williams College in 1863. The next year he was Professor of Natural Sciences in the Cincinnati Wesleyan College, and for twenty-six years Professor of Chemistry and Physics in Lawrence University, Appleton, Wis. During twelve years of his stay at the latter institution he acted also as vice-president and fiscal agent. During these years, having already earned the degree of Master of Arts, from Williams College, he received the degrees of Doctor of Philosophy from De Pauw University and that of Doctor of Laws from Lawrence University.

Being always a student as well as instructor, he published the results of his study and practical investigations in three volumes: Chemical Problems; Table for the Determination and Classification of Minerals; Handbook of Mineralogy. These books were afterward revised and enlarged. In 1892 the fourth edition of the last named work was issued. He left Lawrence in 1893 when the Armour Institute of Technology was opened in Chicago and accepted the position of Director of the Department of Chemistry in the latter institution. He continued in active service until the day of his death, which was very sudden, July 3, 1896.

Chicago, Ill. JANETTE W. FOYE.

WAYLAND SAMUEL AXTELL.

Wayland Samuel Axtell was born in Union, Rock Co., Wis., June 18, 1862. He was a member of the first graduating class of the Evansville High School. For two years after graduation he was engaged in teaching, his chosen work for life, and then entered Beloit College, from which he graduated with high honors.

After spending two years as principal of the high school in Burlington, Wis., he was called to the principalship of the Beloit high school, where he remained two years. During these four years of teaching he became convinced that it was a grave mistake not to allow the use of the Bible in the public schools. He tried in every way to have such use restored, but to no avail; and he decided to go out of the public school work. He then accepted a position in Beloit Academy as assistant principal, at a greatly reduced salary; but at the close of the first year's work there, he accepted the chair of mathematics and physics in Yankton College, South Dakota. He remained there two years until his health began to fail, when he returned to Wisconsin, where he was prevailed upon to establish Rochester Academy at Rochester.

For three years he put his whole life into this new school; and at the close of that time he was obliged to seek a warmer climate as he feared the cold winters of Wisconsin. Very regretfully he accepted the chair of physics and astronomy in Salt Lake College, Utah.

He went to Utah intending to make that his future home; and he found a vast field there for the work which he loved so well. But the climate was not beneficial, and at the close of the first year he was obliged to leave Utah, and went to Denver, Colorado. His disease, consumption, had by this time so fastened itself upon him, that he was obliged to give up all work, and, after nine months of lingering illness he was seized with pneumonia, which ended his life, April 6, 1899.

Mr. Axtell had a peculiar love for his chosen profession of teaching and labored unceasingly in it. He was also a strong man intellectually and held promise of a much greater work than his strength and years allowed him to accomplish. His life was one of daily Christian practice and was a model to hundreds of students in whose lives the influence of his own noble character will continue to live.

Rochester, Wis. LUTA AXTELL.

THE WISCONSIN ACADEMY OF SCIENCES, ARTS, AND LETTERS.

OFFICERS.

President,
C. DWIGHT MARSH,
Ripon College, Ripon.

Vice-President of Sciences,
HARRIET B. MERRILL,
Milwaukee–Downer College, Milwaukee.

Vice-President of Arts,
EDWARD D. EATON,
Beloit College, Beloit.

Vice-President of Letters,
FREDERICK J. TURNER,
University of Wisconsin, Madison.

Secretary,
ALBERT S. FLINT,
University of Wisconsin, Madison.

Treasurer,
LELLEN S. CHENEY,
University of Wisconsin, Madison.

Librarian,
WILLIAM S. MARSHALL,
University of Wisconsin, Madison.

Curator,
HERMAN F. LUEDERS,
Sauk City.

COUNCIL.

The President, Vice-Presidents, Secretary, Treasurer, and Past Presidents retaining their residence in Wisconsin.

COMMITTEE ON PUBLICATION.

C. DWIGHT MARSH, Ripon, President.
ALBERT S. FLINT, Madison, Secretary.
CHARLES S. SLICHTER, Madison.
JOHN G. GREGORY, Milwaukee.

COMMITTEE ON LIBRARY.

WILLIAM S. MARSHALL, Madison, Librarian.
REUBEN G. THWAITES, Madison.
CHARLES H. CHANDLER, Ripon.

COMMITTEE ON MEMBERSHIP.

ALBERT S. FLINT, Madison, Secretary.
ANDREW S. MITCHELL, Milwaukee.
DEXTER P. NICHOLSON, Appleton.
ADDISON L. EWING, River Falls.
JOHN J. DAVIS, Racine.

PAST PRESIDENTS.

HONORABLE JOHN W. HOYT, M. D., LL. D., Washington, D. C., 1870-75.
PROFESSOR P. R. HOY, M. D.,* 1876-78.
PRESIDENT A. L. CHAPIN, D. D.,* 1879-81.
PROFESSOR ROLAND D. IRVING, PH. D.,* 1882-84.
PROFESSOR THOMAS C. CHAMBERLIN, PH. D., LL. D., Chicago, Ill,, 1885-87.
PROFESSOR WILLIAM F. ALLEN, A. M.,** 1888-89.
PROFESSOR EDWARD A. BIRGE, PH. D., Madison, 1889-90.

LIBRARIAN GEORGE W. PECKHAM, LL. D., Milwaukee, 1891-93.
PROFESSOR CHARLES R. VAN HISE, PH. D., Madison, 1894-96.

---

* Deceased. ** Deceased December 9, 1889. Professor Birge elected to fill unexpired term.

HONORARY MEMBERS.

Agassiz, Alexander, Cambridge, Mass.

A. B., S. B., LL. D. (Harvard) Director of the Museum of Comparative Zoölogy, Emeritus, Harvard University.

Chamberlin, Thomas Chrowder, Hyde Park Hotel, Chicago, Ill.

A. B. (Beloit); Ph. D. (Wisconsin, Michigan); LL. D. (Michigan, Beloit, Columbian). Head of Geological Department and Director of Walker Museum, University of Chicago.

Gilman, Daniel Coit, 614 Park Av., Baltimore, Md.

A. B., A. M. (Yale); LL. D. (Yale, Harvard, Princeton, St. Johns, Columbia, North Carolina). President of Johns Hopkins University.

Harris, William Torrey, 1303 P. St., N. W., Washington, D. C.

A. M. (Yale); Ph. D. (Brown, Jena); LL. D. (Missouri, Yale, Princeton, Pennsylvania). United States Commissioner of Education; Officer d'Instruction Publique of France.

Shaler, Nathaniel Southgate, 25 Quincy St., Cambridge, Mass.

S. B., S. D. (Harvard). Professor of Geology, Harvard University; Dean of the Lawrence Scientific School.

Whitman, Charles Otis, University of Chicago, Chicago, Ill.

A. B., A. M. (Bowdoin); Ph. D. (Leipzig); LL. D. (Nebraska). Head Professor of Zoölogy, University of Chicago; Director of Marine Biological Laboratory, Woods Holl, Mass.

LIFE MEMBERS.

Barnes, Charles Reid, University of Chicago, Chicago, Ill.

A. B., A. M., Ph. D. (Hanover). Professor of Plant Physiology, University of Chicago.

Birge, Edward Asahel, 744 Langdon St., Madison.

A. B., A. M. (Williams); Ph. D. (Harvard); Sc. D., Honorary (Western University of Pennsylvania). Professor of Zoölogy and Dean of the College of Letters and Science, University of Wisconsin; Member of Board of Commissioners of Fisheries, Wisconsin; Director and Superintendent of Wisconsin Geological and Natural History Survey.

Davies, John Eugene, 523 N. Carroll St., Madison.

A. B., A. M. (Lawrence); M. D. (Chicago Medical); LL. D. (Northwestern). Professor of Electricity and Magnetism, and Mathematical Physics, University of Wisconsin.

Hastings, Samuel Dexter, 827 S. Monroe St., Green Bay.

Ex-Treasurer of State of Wisconsin; Ex-Secretary of State Board of Charities and Reform.

Hobbs, William Herbert, 223 N. Carroll St., Madison.

B. S. (Worcester Polytechnic Institute); A. M., Ph. D. (Johns Hopkins). Professor of Mineralogy and Petrology, University of Wisconsin; Assistant Geologist, U. S. Geological Survey.

Hoyt, John Wesley, The Victoria, Washington, D. C.

A. M. (Ohio Wesleyan); M. D., LL. D. (Missouri). Chairman of the National Committee to Promote the Establishment of the University of the United States.

Mitchell. John Lendrum, Milwaukee.

Ex-U. S. Senator from Wisconsin; Vice-President of Board of Managers of National Home for Disabled Volunteer Soldiers, Milwaukee.

Peckham, George Williams, 646 Marshall St., Milwaukee.

LL. D. (Wisconsin). Librarian Public Library.

Van Cleef, Frank Louis, 39 Fort Greene Pl., Brooklyn, N. Y.

A. B. (Oberlin, Harvard); Ph. D. (Bonn). Expert in Office of Commissioner of Records, Kings Co.

Van Hise, Charles Richard, 630 Francis St., Madison.

B. Met. E., B. S., M. S., Ph. D. (Wisconsin). Geologist in charge of Lake Superior Division, U. S. Geological Survey; Non-Resident Professor of Structural Geology, University of Chicago; Professor of Geology, University of Wisconsin; Consulting Geologist, Wisconsin Geological and Natural History Survey.

ACTIVE MEMBERS.

Adams, Charles Kendall, 772 Langdon St., Madison.

A. B., A. M. (Michigan); LL. D. (Harvard). President of the University of Wisconsin; Member *Exofficio* of Board of Commissioners, Wisconsin Geogical and Natural History Survey, and President of Board.

Anderson, Mrs. W. E., 134 Twentieth St., Milwaukee.

Austin, Louis Winslow, 22 Mendota Court, Madison.

A. B. (Middlebury); Ph. D. (Strassburg). Assistant Professor of Physics, University of Wisconsin.

Baetz, Henry, 2820 Highland Boulevard, Milwaukee.

Ex-Treasurer, State of Wisconsin. Purchasing Agent of Pabst Brewing Company.

Balg, Gerhard Hubert, 704 Walnut St., Milwaukee.

A. B. (Wisconsin); A. M., Ph. D. (Heidelberg). Philologist and Teacher.

Bille, John, River Falls.

Teacher.

Blackstone, Dodge Pierce, 921 Wisconsin St., Berlin.

A. B., A. M., C. E. (Union).

Blake, William Phipps, Tucson, Arizona.
A. M., Hon. (Dartmouth); Ph. B. (Yale); Professor of Geology and Mining, University of Arizona; Director, Arizona School of Mines.

Brown, Eugene Anson, 152 E. Johnson St., Madison.
M. D. (Hahnemann Medical). Physician and Surgeon; Secretary of Board of Federal Pension Examiners for Madison District.

Browne, George Merwin, Oshkosh.

Bruncken, Ernest, 269 Seventeenth St., Milwaukee.
Attorney at Law, Room 18, Mack Block.

Buckley, Ernest Robertson, 302 Lake St., Madison.
B. S., Ph. D. (Wisconsin). Geologist in Charge of Economic Geology, Wisconsin Geological and Natural History Survey; University Extension Lecturer, Wisconsin.

Buell, Charles E., University Heights, Madison.
B. S., LL. B. (Wisconsin). Attorney (Buell and Hanks); Assistant Attorney General of Wisconsin.

Burgess, Arthur Joseph, 1102 Grand Av., Milwaukee.
M. D. (Harvard).

Burke, John F., 904 Pabst Building, Milwaukee.

Butler, James Davie, 518 Wisconsin Av., Madison.
A. B., A. M., LL. D. (Middlebury). Minister and Teacher.

Chandler, Charles Henry, 308 Thorne St., Ripon.
A. B., A. M. (Dartmouth). Professor of Mathematics and Astronomy, Ripon College.

Chandler, Elwyn Francis,
University of North Dakota, Grand Forks, N. D.
A. B., A. M. (Ripon). Instructor in Mathematics, University of North Dakota.

Chandler, Willard Harris, Madison.
State Inspector of High Schools.

Chapin, Robert Coit, 709 College St., Beloit.
A. B., A. M. (Beloit); D. B. (Yale). Professor of Political Economy, Beloit College.

Cheney, Lellen Sterling, 318 Bruen St., Madison.
B. S., M. S. (Wisconsin). Assistant Professor of Pharmaceutical Botany, University of Wisconsin.

Clas, Alfred Charles, 628 Jackson St., Milwaukee.
Architect (Ferry and Clas), 419 Broadway, Milwaukee.

Clements, Julius Morgan, 609 Lake St., Madison.
A. B., A. M. (Alabama); Ph. D. (Leipzig). Assistant Professor of Geology, University of Wisconsin; Assistant Geologist, U. S. Geological Survey.

Comstock, Elting Houghtaling, 311 Brooks St., Madison.
B. S. (Wisconsin). Honorary Fellow in Mathematics, University of Wisconsin.

Comstock, George Cary, Observatory Hill, Madison.
Ph. B. (Michigan); LL. B. (Wisconsin). Professor of Astronomy and Director of Washburn Observatory, University of Wisconsin; Secretary of the Astronomical and Astrophysical Society of America.

Conrath, Adam, 630 Chestnut St., Milwaukee.
Ph. G. (Philadelphia College of Pharmacy). Pharmacist.

Copeland, Edwin Bingham, Morgantown, W. Va.
A. B. (Leland Stanford, Jr.); A. M., Ph. D. (Halle-Wittenberg). Assistant Professor of Botany, West Virginia University.

Culver, Garry Eugene, 1103 Main St., Stevens Point.
A. M. (Denison). Professor of Physical Science, State Normal School.

Daniells, William Willard, 515 N. Carroll St., Madison.
M. S., Sc. D. (Michigan Agricultural). Professor of Chemistry, University of Wisconsin.

Dapprich, Emil, 558–568 Broadway, Milwaukee.
Director National German-American Teachers' Seminary.

Davis, John Jefferson, 504 Monument Sq., Racine.
B. S. (Illinois); M. D. (Hahnemann). Physician.

Densmore, Hiram Delos, 718 Clary St., Beloit.
A. B., A. M. (Beloit). Professor of Botany, Beloit College.

Desmond, Humphrey J., 375 E. Water St., Milwaukee.
B. L. (Wisconsin). A. M. (Notre Dame). Lawyer.

Dietrich, Otto, 805 Grand Av., Milwaukee.
Ph. D. (Halle, Germany). Principal of Milwaukee Latin School.

Dowling, Linnãeus Wayland, University Heights, Madison.
Ph. D. (Clark). Assistant Professor of Mathematics, University of Wisconsin.

Dudley, William H. Platteville
Instructor in Biology, State Normal School.

Eaton, Edward Dwight, 847 College Av., Beloit.
A. B., A. M. (Beloit); B. D. (Yale); LL. D. (Wisconsin); D. D. (Northwestern). President and Professor of Ethics and History, Beloit College.

Ely, Richard Theodore, University Heights, Madison.
A. B., A. M. (Columbia); Ph. D. (Heidelberg); LL. D. (Hobart). Professor of Political Economy, and Director of the School of Economics, Political Science, and History, University of Wisconsin.

Estee, Mrs. James B., 1422 Wells St., Milwaukee

Ewing, Addison Luther, River Falls.

B. S., M. S. (Cornell). Professor of Natural Science, State Normal School.

Ferry, George Bowman, 19 Woodland Court, Milwaukee.

Architect (Ferry and Clas).

Fischer, Richard, Madison.

Ph. G., B. S. (Michigan) Student, University of Marburg, 1899-1900.

Flagg, Rufus Cushman, Ripon.

A. B., D. D. (Middlebury). President of Ripon College.

Flint, Albert Stowell, 420 Charter St., Madison.

A. B. (Harvard), A. M. (Cincinnati). Assistant Astronomer, Washburn Observatory, University of Wisconsin.

Folkmar, Daniel, (temporary) 3 Rue de Savoie, Bruxelles, Belgium; (forwarding address) care of Mr. George Cuddeback, Whitewater.

A. B., A. M. (Western).

Frankenburger, David Bower, 115 W. Gilman St., Madison.

Ph. B., LL. B., A. M. (Wisconsin). Professor of Rhetoric and Oratory, University of Wisconsin.

Frost, William Dodge, 311 Charter St., Madison.

B. S., M. S. (Minnesota). Instructor in Bacteriology, University of Wisconsin.

Gibbs, George, 1811 Walnut St., Philadelphia, Pa.

M. E. (Stevens Institute). Consulting Engineer of Baldwin Locomotive Works, Philadelphia, and of Westinghouse Electric and Manufacturing Company, Pittsburg.

Giese, William Frederick, 426 Bruen St., Madison.

A. B., A. M. (Harvard). Assistant Professor of Romance Languages, University of Wisconsin.

Goodhue, William Fletcher, 45 and 204 Grand Av., Milwaukee.

Civil Engineer.

Gordon, Mrs. George, 1144 Humboldt Av., Milwaukee.

Grant, Fanny, 817 Newhall St., Milwaukee.

Author, Musical Critic for the New York *Musical Courier.*

Gregory, John Goadby, 717 Jefferson St., Milwaukee.

Associate Editor, The Evening Wisconsin.

Haessler, Luise, 443 Madison St., Milwaukee.

Teacher of Modern Languages, South Division High School.

Hancock, Edward See, Shullsburg.

B. S. (Wisconsin). Principal, Shullsburg High School.

Harrison, Caleb Notbohm, 422 N. Henry St., Madison.
B. C. E. (Wisconsin); Ph. D. (Johns Hopkins). Acting Professor of Machine Design, University of Wisconsin.

Harvey, Nathan Albert, West Superior.
Teacher of Natural Science, State Normal School.

Harwood, Mary Corinthia, Bartlett Cottage, Ripon.
L. B., L. M. (Lawrence). Preceptress and Instructor in French and German, Ripon College.

Haskins, Charles Homer, 629 Francis St., Madison.
A. B., Ph. D. (Johns Hopkins). Professor of Institutional History, University of Wisconsin.

Heald, Fred de Forest, 309 E. Kirkwood St., Fairfield, Ia.
B. S., M. S. (Wisconsin); Ph. D. (Leipzig). Professor of Biology, Parsons College.

Henry, William Arnon, University Farm, Madison.
B. Agr. (Cornell). Dean of the College of Agriculture and Director of the Agricultural Experiment Station, University of Wisconsin.

Hillyer, Homer Winthrop, University Heights, Madison.
B. S. (Wisconsin); Ph. D. (Johns Hopkins); Assistant Professor of Organic Chemistry, University of Wisconsin.

Hodge, Willard Addison, Madison.
A. B., A. M. (Ripon).

Hollister, Albert Henry, 17 Langdon St., Madison.
Pharmacist; Colonel and Aide-de-Camp to the Commander-in-Chief, Wisconsin National Guard.

Hooper, Sanford Adelbert, Los Angeles, Cal.
A. B., A. M. (Beloit).

Hubbard, Frank Gaylord, 227 Langdon St., Madison.
A. B. (Williams); Ph. D. (Johns Hopkins). Professor of the English Language, University of Wisconsin.

Huntington, Ellsworth, Harpoot, Turkey in Asia; (forwarding Address) care of Mrs. H. S. Huntington, Milton, Mass.
A. B. (Beloit). Teacher, Euphrates College, Harpoot.

Jastrow, Joseph, 237 Langdon St., Madison.
A. B., A. M. (Pennsylvania); Ph. D. (Johns Hopkins). Professor of Psychology, University of Wisconsin.

Jegi, John I., 322 Twentieth St., Milwaukee.
B. S. (Chicago); M. S. (Normal College, Dixon, Ill.). Professor of Physiology and Psychology, State Normal School.

Johnson, Warren Seymour, 120 Sycamore St., Milwaukee.
Mechanical Engineer.

Jones, Edward David, Capitol Building, Albany, N. Y.

B. S. (Ohio Wesleyan); Ph. D. (Wisconsin). Instructor in Economics and Statistics, University of Wisconsin (on leave of absence); Special Agent in Education and Social Economy with the United States Commission to the Paris Exposition of 1900.

Kahlenberg, Louis, 306 Lake St., Madison.

B. S., M. S. (Wisconsin); Ph. D. (Leipzig). Assistant Professor of Physical Chemistry, University of Wisconsin.

Kimball, Mather Dean, 742 Cass St., Milwaukee.

B. A. (Northwestern).

King, Franklin Hiram, 1540 University Av., Madison.

Professor of Agricultural Physics, University of Wisconsin.

Knowlton, Amos Arnold, University Heights, Madison.

A. B., A. M. (Bowdoin); Assistant Professor of English, University of Wisconsin.

Kremers, Edward, 320 Jackson St., Wingra Park, Madison.

Ph. G., B. S. (Wisconsin); Ph. D (Göttingen). Professor of Pharmaceutical Chemistry, University of Wisconsin.

Krueger, Henry, 376 Twenty-seventh Av., Milwaukee.

Principal Tenth District School, No. 2.

Kuhn, Harry, 312 Reservoir Av., Milwaukee.

Clerk, Milwaukee Gas Light Co.

Ladoff, Isidor, Milwaukee.

Analytical Chemist.

Laird, Arthur Gordon, 609 Lake St., Madison.

Assistant Professor of Ancient Languages, University of Wisconsin.

Lamb, Francis Jones, 212 N. Carroll St., Madison.

Attorney at Law.

Lane, George Frederick, Ripon.

Director of Conservatory of Music, Ripon College.

Legler, Henry E., City Hall, Milwaukee.

Secretary of School Board.

Libby, Orin Grant, 426 Bruen St., Madison.

B. L., M. L., Ph. D. (Wisconsin). Instructor in History, University of Wisconsin.

Lincoln, Azariah Thomas, 710 E. State St., Ithaca, N. Y.

B. S., M. S., Ph. D. (Wisconsin). Research Assistant in Physical Chemistry, Cornell University.

Lueders, Herman Frederick, Sauk City.

B. S. (Wisconsin.)

Mallory, Mrs. R. B., 909 Cambridge Av., Milwaukee.

MARKS, Solon, 6 Prospect Av., Milwaukee.

M. D. (Rush). Professor of Fractures and Dislocations and Military Surgery, Wisconsin College of Physicans and Surgeons.

MARSH, Charles Dwight, Ripon.

A. B., A. M. (Amherst). Professor of Biology, Ripon College; Member *Ex officio* of Board of Commissioners of Wisconsin Geological and Natural History Survey and Secretary of the Board.

MARSHALL, Ruth, 221 Langdon St., Madison.

B. S. (Wisconsin). Teacher of Science, High School.

MARSHALL, William Stanley, 324 N. Carroll St., Madison.

B. S. (Swarthmore); Ph. D. (Leipzig). Assistant Professor of Zoölogy, University of Wisconsin.

MAURER, Edward Rose, University Heights, Madison.

B. C. E. (Wisconsin). Assistant Professor of Pure and Applied Mechanics, University of Wisconsin.

McKENNA, Maurice, 78 Third St., Fond du Lac.

Attorney at Law; President of the Bar Association and Chairman of the Board of Supervisors, Fond du Lac County.

McMINN, Amelia, 144 Twenty-seventh St., Milwaukee.

B. S. (Wisconsin). Instructor in Biology, West Side High School.

MEACHEM, John Goldsborough, Jr., 745 College Av., Racine.

M. D. (Rush). Physician.

MERRELL, Edward Huntington, Ripon.

A. B., A. M. (Oberlin); D. D. (Lawrence); LL. D. (Middlebury). Professor of Moral Philosophy, Ripon College.

MERRILL, Harriet Bell, Milwaukee.

B. S., M. S. (Wisconsin). Professor of Biology, Milwaukee-Downer College.

MERRILL, Mary Ellen, (Mrs. S. S.), 3355 Grand Av., Milwaukee.

MEYER, Balthasar Henry, 311 Brooks St., Madison.

B. L., Ph. D. (Wisconsin). Assistant Professor of Sociology, Secretary of the University Extension Department and of the Committee on Accredited Schools, University of Wisconsin.

MILLER, William Snow, 615 Lake St., Madison.

M. D. (Yale). Assistant Professor of Vertebrate Anatomy, University of Wisconsin.

MITCHELL, Andrew Stuart, 220 Greenbush St., Milwaukee.

Ph. C. (Michigan). Analyst and Teacher of Chemistry; Chemist, Wisconsin State Dairy and Food Commission, Madison.

MOOREHOUSE, George Wilton, (until February 28, 1900) Lakeside Hospital, Cleveland, Ohio.

B. L., M. L. (Wisconsin); M. D. (Harvard).

MORRIS, William Augustus Pringle, 240 Langdon St., Madison.
A. B. (Hamilton). Attorney at Law.

NADER, John, 302 W. Main St., Madison.
Architect and Civil Engineer.

NEHRLING, Henry, 254 Twenty-first St., Milwaukee.
Curator Public Museum.

NICHOLSON, Dexter Putnam, 504 John St., Appleton.
B. S., M. S. (Lawrence). Professor of Natural History, Lawrence University.

NORTON, Richard Greenleaf, 22 N. Carroll St., Madison.
Mechanician.

NOYES, George Henry, 204 Prospect Av., Milwaukee.
A. B., LL. B. (Wisconsin). Attorney; Ex-Judge Superior Court; President of Board of Regents, University of Wisconsin.

O'CONNOR, Charles James, 1242 E. Dayton St., Madison.
A. B. (Wisconsin). Fellow in Latin, University of Wisconsin.

O'SHEA, M. Vincent, 140 Langdon St., Madison.
B. L. (Cornell). Professor of the Science and Art of Education, University of Wisconsin.

OWEN, Edward Thomas, 614 State St., Madison.
A. B. (Yale). Professor of the French Language and Literature, University of Wisconsin.

PABST, Fred, Milwaukee.

PARKER, Fletcher Andrew, 14 W. Gilman St., Madison.
Professor of Music and Director of School of Music, University of Wisconsin; Musical Director, Madison Choral Union.

PERELES, James M , 529 Astor St., Milwaukee.
LL.B. Lawyer. Ex-President Public School Board; President Public Library; County Judge, Milwaukee Co.

PERELES, Jennie W. (Mrs. J. M.), 529 Astor St., Milwaukee.
Treasurer Wisconsin Training School for Nurses; Secretary Milwaukee Flower Mission and Mission Kindergarten.

PERELES, Nellie W. (Mrs. T. J.), 535 Astor St., Milwaukee.

PERELES, Thomas Jefferson, 535 Astor St., Milwaukee.
LL. B. (Wisconsin). Attorney at Law (Nathl. Pereles and Sons).

PLANTZ, Samuel, Appleton.
A. M. (Lawrence); Ph. D. (Boston); D. D. (Albion). President of Lawrence University.

PORTER, William, 735 College St., Beloit.
A. B., A. M., D. D. (Williams). Professor of Latin and Dean, Beloit College.

Post, Harriet L., 1182 Humboldt Av., Milwaukee.
M. D. (Woman's Medical College of New York Infirmary). Instructor in Biology, East Side High School.

Pretts, William Walter, 2246 Michigan Av., Chicago, Ill.
B. S. (Wisconsin).

Puls, Arthur John, 116 Mason St., Milwaukee.
B. L. (Wisconsin); M. D. (Heidelberg). Physician.

Putney, Frank Howell, 105 Park Av., Waukesha.
Attorney at Law.

Rankin, Walter L., 201 East Av., Waukesha.
A. M., Ph. D. (Princeton). President, Carroll College.

Reul, Miss Matilda E., Baraboo.
B. S., M. S. (Wisconsin). Teacher, Baraboo High School.

Richter, Arthur William, 426 Murray St., Madison.
B.M.E., M. E. (Wisconsin); M.M.E. (Cornell). Assistant Professor of Experimental Engineering, University of Wisconsin.

Rohde, Hugo W., 319 Park St., Madison.

Roeseler, John Samuel, 1616 N. Seventh St., Sheboygan.
B. L. (Wisconsin). Principal of High School.

Rogers, Augustus J., 318 Ogden Av., Milwaukee.
Ph. B. (Cornell). Principal of East Side High School.

Ruenzel, Henry Gottlieb, 753 Third St., Milwaukee.
Ph. G. (Wisconsin). Pharmacist.

Russell, Harry Luman, 1532 Univ. Av., Madison.
B. S., M. S. (Wisconsin); Ph. D. (Johns Hopkins). Professor of Bacteriology, University of Wisconsin.

Salmon, Edward Payson, 618 Church St., Beloit.
A. M. (Beloit). Congregational Minister; Second Vice-President of Board of Trustees, Beloit College.

Sanborn, John Bell, 215 W. Tenth Av., Columbus, O.
B. L., M. L., Ph. D. (Wisconsin). Assistant in American History, Ohio State University.

Sanford, Albert Hart, 1052 Clark St., Stevens Point.
B. L. (Wiscomsin); A. B. (Harvard). Instructor in History and Civics, State Normal School.

Saunderson, George William, Ripon.
A. B., A. M. (Dartmouth); LL. B. (Boston). Professor of English Literature and Oratory, Ripon College.

Schlundt, Herman, 144 Twenty-seventh St., Milwaukee;
(temporary) Universitäts Str. 26, Leipzig, Germany.
B. S., M. S. (Wisconsin). Student, University of Leipzig.

Scott, William Amasa, 619 Langdon St., Madison.

A. B., A. M. (Rochester); Ph. D. (Johns Hopkins). Professor of Economic History and Theory, University of Wisconsin.

Sharp, Frank Chapman, 27 Mendota Court, Madison.

A. B. (Amherst); Ph. D. (Berlin). Assistant Professor of Philosophy, University of Wisconsin.

Skinner, Ernest Brown, Madison;
(until May 1, 1900) 5738 Jackson Av., Chicago, Ill.

A. B. (Ohio University at Athens). Assistant Professor of Mathematics, University of Wisconsin (on leave of absence); Graduate Student, University of Chicago.

Slaughter, Moses Stephen, 633 Francis St., Madison.

A. B , A. M. (De Pauw); Ph. D. (Johns Hopkins). Professor of Latin, University of Wisconsin.

Slichter, Charles Sumner, 636 Francis St., Madison.

B. S., M. S. (Northwestern). Professor of Applied Mathematics, University of Wisconsin.

Smith, Erastus Gilbert, Beloit.

A. B., A. M. (Amherst); A. M., Ph. D. (Göttingen). Professor of Chemistry, Beloit College.

Smith, Leonard Sewell, 939 University Av., Madison.

B. C. E., C. E. (Wisconsin). Assistant Professor of Topographic and Geodetic Engineering, University of Wisconsin.

Starr, William J., 135 Marston Av., Eau Claire.

LL. B. (Columbia). Member, Board of Commissioners of Fisheries, Wisconsin; President of the Eau Claire Public Library.

Tawney, Guy Allan, Beloit.

A. B., A. M. (Princeton); Ph.D. (Leipzig). Squier Professor of Mental Science and Philosophy, Beloit College.

Teller, Edgar E., 3303 Cedar St., Milwaukee.

Director of Geology and Palaeontology, Wisconsin Natural History Society.

Thwaites, Reuben Gold, 260 Langdon St., Madison.

Secretary and Superintendent, State Historical Society of Wisconsin.

True, Rodney Howard, (temporary), 54 Concord Av.,
Cambridge, Mass.

B. S. (Wisconsin); Ph. D. (Leipzig).

Turner, Frederick Jackson, 629 Francis St., Madison.

A. B., A. M. (Wisconsin); Ph. D. (Johns Hopkins). Professor of American History, University of Wisconsin.

Uihlein, August, Milwaukee.

Updike, Eugene Grover, 148 Langdon St., Madison.
B. S., M. S., D. D. (Lawrence). Pastor, First Congregational Church.

Upham, Arthur Aquila, 106 Conger St., Whitewater.
Professor of Natural Sciences, State Normal School.

Urban, Leopold Charles, 647 Third St., Milwaukee.
Ph. G., Ph. M. (Wisconsin). Pharmaceutical Chemist, Kremers and Urban Co.

Walker, Milo S., 1551 Lill Av., Chicago, Ill.
Ph. B., Ph. M. (Wooster); Ph. D. (Johns Hopkins). Instructor in Chemistry, West Division High School, Chicago.

Van Velzer, Charles Ambrose, 134 W. Gorham St., Madison.
B. S. (Cornell); Ph. D. (Hillsdale). Professor of Mathematics, University of Wisconsin.

Viebahn, Charles Frederick, 703 Western Av., Watertown.
Superintendent of Schools and Principal of High School.

Weidman, Samuel, 115 W. Johnson St., Madison.
B. S., Ph. D. (Wisconsin). Geologist, Wisconsin Geological and Natural History Survey.

Whitcomb, Annabell Cook (Mrs. Henry F.),
721 Franklin St., Milwaukee.

Wingate, Uranus O. B., 204 Biddle St., Milwaukee.
M. D. (Dartmouth). Professor of Diseases of the Mind and Nervous System, Wisconsin College of Physicians and Surgeons; Secretary of State Board of Health.

Wolff, Henry C., 1508 Belknap St., West Superior.
B. S., M. S. (Wisconsin). Instructor of Mathematics in High School.

Woll, Fritz Wilhelm, 424 Charter St., Madison.
B. S., Ph. B. (Christiania); M. S. (Wisconsin). Assistant Professor of Agricultural Chemistry and Chemist to the Agricultural Experiment Station, University of Wisconsin.

Zimmermann, Charles Frederick A., 622 Otjen St., Milwaukee.
Ph. B. (Illinois Wesleyan); A. M. (Charles City). Principal Seventeenth District School.

Zimmermann, Oliver Brunner, 2414½ Cold Spring Av., Milwaukee.
B. Mec. E. (Wisconsin). Director of Manual Training, West Side High School.

CORRESPONDING MEMBERS.

ABBOTT, Charles Conrad, Trenton, N. J.

M. D. (Pennsylvania).

ANDREWS, Edmund, 65 Randolph St., Chicago, Ill.

A. B., A. M., M. D., LL. D. (Michigan). Professor of Clinical Surgery, Northwestern University; Surgeon, Mercy Hospital; Consulting Surgeon, Michael Reese Hospital and Illinois Hospital for Women and Children.

ARMSBY, Henry Prentiss, State College, Pa.

B. S. (Worcester Polytechnic); Ph. B., Ph. D. (Yale). Director of Experiment Station.

BACON, George Preston, Elgin Academy, Elgin, Ill.

BASCOM, John, ark St., Williamstown, Mass.

A. B., A. M. (Williams); D. D ; LL. D. (Amherst, Williams). Professor of Political cience, Williams College.

BENNETT, Charles Edwin, 1 Grove Place, Ithaca, N. Y

A. B. (Brown). Professor of Latin Languages and Literature, Cornell University.

BRIDGE, Norman, 217 S. Broadway, Los Angeles, Calif.; Oct. and Nov. each year, Rush Medical College, Chicago, Ill.

A. M. (Lake Forest); M. D. (Northwestern, Rush). Professor of Medicine, Rush Medical College.

CAVERNO, Charles, Lombard, Ill.

A. M. (Dartmouth); LL. D. (Colorado). Clergyman, retired.

COULTER, John Merle, Chicago, Ill.

A. B., A. M., Ph. D. (Hanover); Ph. D. (Indiana). Head Professor of Botany, University of Chicago.

CROOKER, Joseph Henry, 110 N. State St., Ann Arbor, Mich.

Minister, Unitarian Church.

DAVIS, Floyd, 317 Iowa Loan and Trust Bldg., Des Moines, Ia.

Ph. B., C. E., E. M. (Missouri); Ph. D. (Miami). Analytical and Consulting Chemist.

ECKLES, William Alexander, Oxford, Ohio.

A. B., A. M. (Dickinson); Ph. D. (Johns Hopkins). Professor of Greek, Miami University.

FALLOWS, Samuel, 967 W. Monroe st., Chicago, Ill.

A. B., A. M., LL. D. (Wisconsin); D. D. (Lawrence). Presiding Bishop of the Reformed Episcopal Church; Chancellor of the University Association; President of Board of Managers, Illinois State Reformatory.

HENDRICKSON, George Lincoln, 5730 Woodlawn Av., Chicago, Ill.
A. B. (Johns Hopkins). Professor of Latin, University of Chicago.

HIGLEY, William Kerr, Lincoln Park, Chicago, Ill.
Ph. M. (Michigan). Secretary, Chicago Academy of Sciences.

HODGE, Clifton Fremont, 3 Charlotte St., Worcester, Mass.
A. B. (Ripon); Ph. D. (Johns Hopkins). Assistant Professor of Physiology and Neurology, Clark University.

HOLDEN, Edward Singleton,
Smithsonian Institution, Washington, D. C.
B. S., A. M. (Washington); S. D. (Pacific); LL. D. (Wisconsin and Columbia). Astronomer.

HOLLAND, FREDERIC MAY, Main St., Concord, Mass.
A. B. (Harvard).

HOSKINS, Leander Miller, Stanford University, Calif.
B. S., M. S., B. C. E., C. E. (Wisconsin). Professor of Applied Mathematics, Leland Stanford Jr. University.

IDDINGS, Joseph Paxson, 5730 Woodlawn Av., Chicago, Ill.
Ph. B. (Yale). Professor of Petrology, University of Chicago.

KINLEY, David, Urbana, Ill.
A. B. (Yale); Ph. D. (Wisconsin). Dean of the College of Literature and Arts, and Professor of Economics, University of Illinois.

LEVERETT, Frank, Denmark, Iowa.
B. Sc. (Iowa Agricultural). Assistant Geologist, U. S. Geological Survey.

LURTON, Freeman Ellsworth, Monticello, Minn.
B. S., M. S. (Carleton); Ph. D. (Gale). Superintendent of Public Schools.

LUTHER, George Elmer,
266 S. College Av., Grand Rapids, Mich.
Chief Mortgage Clerk, Michigan Trust Co.; Treasurer of the Historical Society of Grand Rapids.

MARX, Charles David, Stanford University, Calif.
B. C. E. (Cornell); C. E. (Carlsruhe). Professor of Civil Engineering, Leland Stanford Jr. University.

MCCLUMPHA, Charles Flint, Minneapolis, Minn.
A. B., A. M. (Princeton); Ph. D. (Leipzig). Professor of English Language and Literature, University of Minnesota.

ORTON, Edward, 100 Twentieth St., Columbus Ohio.
A. B., A. M., Ph. D. (Hamilton); LL. D. (Ohio). Professor of Geology, Ohio State University; State Geologist of Ohio.

PEET, Stephen Denison, 5327 Madison Av., Chicago.
A. M., Ph. D. (Beloit). Clergyman; Editor American Antiquarian.

Potter, William Bleecker, 1225 Spruce St., St. Louis, Mo.

A. B., A. M., M. E. (Columbia). Mining Engineer and Metallurgist.

Power, Frederick Belding, 535 Warren St., Hudson, N. Y.

Ph. G. (Phila. Coll. of Pharm.); Ph. D. (Strassburg). Director of Wellcome Chemical Research Laboratories, London, Eng.

Raymond, Jerome Hall, Morgantown, W. Va.

A. B., A. M. (Northwestern); Ph. D. (Chicago). President of West Virginia University.

Safford Truman Henry, Williamstown, Mass.

A. B. (Harvard); Ph. D. (Williams). Field Memorial Professor of Astronomy, Williams College.

Salisbury, Rollin D., Chicago University, Chicago, Ill.

A. M. (Beloit). Professor of Geographic Geology, University of Chicago; Geologist, U. S. Geological Survey, State Geological Survey, New Jersey.

Sawyer, Wesley Caleb, 2840 Russ St., Berkeley, Calif.

A. B., A. M. (Harvard); A. M., Ph. D. (Göttingen).

Shipman, Stephen Vaughn, 269 Warren Av., Chicago, Ill.

Architect.

Steele, George McKendrae, 19 Chalmer Place, Chicago, Ill.

A. B., A. M. (Wesleyan); D. D. (Northwestern); LL. D. (Lawrence).

Tatlock, John, Jr., 32 Nassau St., New York, N. Y.

A. B., A. M. (Williams). Assistant Actuary, Mutual Life Insurance Co.

Tolman, Albert Harris, 5750 Woodlawn Av., Chicago, Ill.

A. B. (Williams); Ph. D. (Strassburg). Assistant Professor of English Literature and Dean, University of Chicago.

Tolman, Herbert Cushing, Nashville, Tenn.

A. B., Ph. D. (Yale). Professor of Greek, Vanderbilt University.

Townley, Sidney Dean, 2023 Bancroft Way, Berkeley, Cal.

B. S., M. S. (Wisconsin); S. D. (Michigan). Instructor in Practical Astronomy, University of California.

Trelease, William, Botanical Garden, St. Louis, Mo.

B. S. (Cornell); S. D. (Harvard). Director of Missouri Botanical Garden and Henry Shaw School of Botany, Engelmann Professor of Botany, Washington University.

Van de Warker, Ely, 404 Fayette Park, Syracuse, N. Y.

M. D. (Albany Medical and Union). Surgeon Central New York Hospital for Women; Consulting Physician St. Ann's Maternity Hospital; Senior Surgeon Women's and Children's Hospital; Commissioner of Education, Syracuse.

Van Vleck, Edward Burr, Middletown, Ct.

A. B., A. M. (Wesleyan); Ph. D. (Göttingen). Professor of Mathematics, Wesleyan University.

VERRILL, Addison Emory, 86 Whalley Av., New Haven, Ct.
S. B. (Harvard); A. M. (Yale). Professor of Zoölogy, Yale University.

WINCHELL, N. H., 120 State St., Minneapolis, Minn.
A. M. (Michigan). State Geologist of Minnesota.

YOUNG, Albert Adams, 531 S. Claremont Av., Chicago, Ill.
A. B., A. M. (Dartmouth). D. B. (Andover). Clergyman.

MEMBERS DECEASED.

INFORMATION OF WHOSE DECEASE HAS BEEN RECEIVED SINCE THE ISSUE OF VOLUME XI.

AXTELL, Wayland S. Principal of Rochester Academy, Rochester, April 6, 1899.

BREMER, Mrs. Hugo (Alice Aikens), Milwaukee, August 25, 1898.

DE VERE, Maximillian F. S., Professor of Modern Languages, University of Virginia, Charlottesville, Va., March 12, 1898.

FOYE, James C., Professor of Chemistry, Armour Institute, Chicago, July 3, 1896.

HORR, Asa, M. D., Chief of Staff, Mercy Hospital, Dubuque, Iowa, June, 1896.

HUBBELL, Herbert P., Winona, Minn., January 25, 1899.

*MARCY, Oliver, Professor of Geology, Northwestern University, Evanston, Ill.

STUMP, I. W., Oswego, N. Y.

---

*An account of the life of Dr. Marcy will be found in the Northwestern *Christian Advocate*, March 22 and March 29, 1899.

EXTRACTS FROM THE CHARTER.

AN ACT to incorporate the Wisconsin Academy of Sciences, Arts, and Letters.

The people of the state of Wisconsin, represented in senate and assembly, do enact as follows:

SECTION 1. Lucius Fairchild, Nelson Dewey, John W. Hoyt, Increase A. Lapham, * * * *[1] at present being members and officers of an association known as "The Wisconsin Academy of Sciences, Arts, and Letters," located at the city of Madison, together with their future associates and successors forever, are hereby created a body corporate by the name and style of the "Wisconsin Academy of Sciences, Arts, and Letters," and by that name shall have perpetual succession; shall be capable in law of contracting and being contracted with, of suing and being sued, of pleading and being impleaded in all courts of competent jurisdiction; and may do and perform such acts as are usually performed by like corporate bodies.

SECTION 2. The general objects of the Academy shall be to encourage investigation and disseminate correct views in the various departments of science, literature, and the arts. Among the specific objects of the Academy shall be embraced the following:

1. Researches and investigations in the various departments of the material, metaphysical, ethical, ethnological, and social sciences.
2. A progressive and thorough scientific survey of the state with a view of determining its mineral, agricultural, and other resources.
3. The advancement of the useful arts, through the applications of science, and by the encouragement of original invention.
4. The encouragement of the fine arts, by means of honors and prizes awarded to artists for original works of superior merit.
5. The formation of scientific, economic, and art museums.
6. The encouragement of philological and historical research, the collection and preservation of historic records, and the formation of a general library.
7. The diffusion of knowledge by the publication of original contributions to science, literature, and the arts.

---

[1] Here follow the names of forty others. Sections 5, 6, 8, and 9 are omitted here as of no present interest. For the charter in full see *Transactions*, vol. viii, p. xi, or earlier volumes.

SECTION 3. Said Academy may have a common seal and alter the same at pleasure; may ordain and enforce such constitution, regulations, and by-laws as may be necessary, and alter the same at pleasure; may receive and hold real and personal property, and may use and dispose of the same at pleasure; *provided*, that it shall not divert any donation or bequest from the uses and objects proposed by the donor, and that none of the property acquired by it shall, in any manner, be alienated other than in the way of exchange of duplicate specimens, books, and other effects, with similar institutions and in the manner specified in the next section of this act, without the consent of the legislature.

SECTION 4. It shall be the duty of the said Academy, so far as the same may be done without detriment to its own collections, to furnish, at the discretion of its officers, duplicate typical specimens of objects in natural history to the University of Wisconsin, and to the other schools and colleges of the state.

SECTION 7. Any existing society or institution having like objects embraced by said Academy, may be constituted a department thereof, or be otherwise connected therewith, on terms mutually satisfactory to the governing bodies of the said Academy and such other society or institution.

Approved March 16, 1870.

EXTRACTS FROM THE WISCONSIN STATUTES OF 1898.

TRANSACTIONS OF THE ACADEMY.

Section 341. There shall be printed by the state printer biennially in pamphlet form two thousand copies of the transactions of the Wisconsin Academy of Sciences, Arts, and Letters, uniform in style with the volumes heretofore printed for said society.

CHAPTER 22.

OF THE DISTRIBUTION OF PUBLIC DOCUMENTS.

Section 365. The transactions of the Wisconsin Academy of Sciences, Arts, and Letters shall be distributed as follows: One copy to each member of the legislature, one copy to the librarian of each state institution; one hundred copies to the State Agricultural Society; one hundred copies to the State Historical Society; one hundred copies to the State University, and the remainder to said Academy.

Section 366. In the distribution of books or other packages, if such packages are too large or would cost too much to be sent by mail, they shall be sent by express or freight, and the accounts for such express or freight charges, properly certified to, shall be paid out of the state treasury.

Note.—The Academy allows each author one hundred separates of his paper from the Transactions without expense to the author, except a small charge for printed covers when desired.—Editor.

CONSTITUTION OF THE WISCONSIN ACADEMY OF SCIENCES, ARTS, AND LETTERS.

[As amended in Articles V and IX at the regular meeting of December, 1899.]

ARTICLE I.—*Name and Location.*

This association shall be known as the Wisconsin Academy of Sciences, Arts, and Letters, and shall be located at the city of Madison.

ARTICLE II.—*Object.*

The object of the Academy shall be the promotion of sciences, arts, and letters in the state of Wisconsin. Among the special objects shall be the publication of the results of investigation and the formation of a library.

ARTICLE III.—*Membership.*

The Academy shall include four classes of members, viz.: life members, honorary members, corresponding members, and active members, to be elected by ballot.

1. Life members shall be elected on account of special services rendered the Academy. Life membership in the Academy may also be obtained by the payment of one hundred dollars and election by the Academy. Life members shall be allowed to vote and to hold office.

2. Honorary members shall be elected by the Academy and shall be men who have rendered conspicuous services to science, arts, or letters.

3. Corresponding members shall be elected from those who have been active members of the Academy, but have removed from the state. By special vote of the Academy men of attainments in science or letters may be elected corresponding members. They shall have no vote in the meetings of the Academy.

4. Active members shall be elected by the Academy and shall enter upon membership on the payment of an initiation fee of two dollars which shall include the first annual assessment of one dollar. The annual assessment shall be omitted for the president, secretary, treasurer, and librarian during their term of office.

ARTICLE IV.—*Officers.*

The officers of the Academy shall be a president, a vice-president for each of the three departments, sciences, arts, and letters, a secretary, a librarian, a treasurer, and a custodian. These officers shall be chosen by ballot, on recommendation of the committee on nomination of officers, by the Academy at an annual meeting and shall hold office for three years. Their duties shall be those usually performed by officers thus named in scientific societies. It shall be one of the duties of the president to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

ARTICLE V.—*Council.*

The council of the Academy shall be entrusted with the management of its affairs during the intervals between regular meetings, and shall consist of the president, the three vice-presidents, the secretary, the treasurer, the librarian, and the past presidents who retain their residence in Wisconsin. Three members of the council shall constitute a quorum for the transaction of business, provided the secretary and one of the presiding officers be included in the number.

ARTICLE VI.—*Committees.*

The standing committees of the Academy shall be a committee on publication, a library committee, and a committee on the nomination of members. These committees shall be elected at the annual meeting of the Academy in the same manner as the other officers of the Academy, and shall hold office for the same term.

1. The committee on publication shall consist of the president and secretary and a third member elected by the Academy. They shall determine the matter which shall be printed in the publications of the Academy. They may at their discretion refer papers of a doubtful character to specialists for their opinion as to scientific value and relevancy.

2. The library committee shall consist of three members and shall include the librarian.

3. The committee on nomination of members shall consist of five members, one of whom shall be the secretary of the Academy.

ARTICLE VII.—*Meetings.*

The annual meetings of the Academy shall be held between Christmas and New Year, at such place as the council may designate; but all regular meetings for the election of the board of officers shall be held at Madison. Summer field meetings shall be held at such times and places as the Academy or the council may decide. Special meetings may be called by the council.

Article VIII.—*Publications.*

The regular publication of the Academy shall be known as its Transactions, and shall include suitable papers, a record of its proceedings, and any other matter pertaining to the Academy. This shall be printed by the state as provided in the statutes of Wisconsin. All members of the Academy shall receive gratis the current issues of its Transactions.

Article IX.—*Amendments.*

Amendments to this constitution may be made at any annual meeting by a vote of three-fourths of all the members present; *provided*, that the amendment has been proposed by five members, and that notice has been sent to all the members at least one month before the meeting.

RESOLUTIONS REGULATIVE OF THE PROCEEDINGS OF THE ACADEMY.

THE TRANSACTIONS OF THE ACADEMY.

[*By the Academy, December 28, 1882. Transactions, Vol. VI, p. 350.*]

2. The secretary of the Academy shall be charged with the special duty of overseeing and editing the publication of future volumes of the Transactions.

3. The Transactions of the Academy hereafter published shall contain: (a) a list of officers and members of the Academy; (b) the charter, by-laws and constitution of the Academy as amended to date; (c) the proceedings of the meetings; and (d) such papers as are duly certified in writing to the secretary as accepted for publication in accordance with the following regulations, and no other.

6. In deciding as to the papers to be selected for publication, the committee shall have special regard to their value as genuine, original contributions to the knowledge of the subject discussed.

9. The Sub-Committee on Publication shall be charged with insisting upon the correction of errors in grammar, phraseology, etc., on the part of authors, and shall call the attention of authors to any other points in their papers, which in their judgment appear to need revision.

[*By the Academy, June 2, 1892, Vol. IX, p. ii.*]

The secretary was given authority to allow as much as ten dollars for the illustrations of a paper when the contribution was of sufficient value to warrant it. A larger amount than this might be allowed by the Committee on Publication.

[*By the Academy, December 29, 1896, Vol. XI, p. 558.*]

The secretary was directed to add to the date of publication as printed on the outside of author's separates the words, "Issued in advance of general publication."

LOCAL AND AFFILIATED SOCIETIES.

[*By the Academy, December 28, 1881, Vol. VI, p. 346.*]

Resolved, That the Academy favors and will foster to the best of its ability the establishment of local literary and scientific societies throughout the state.

[*By the Academy, December 30, 1884, Vol. VII, p. 261.*]

Any local scientific or literary society may apply for affiliation with the Academy, submitting its constitution, etc., to the inspection and approval of the Academy. If affiliated, it may propose for membership in the Academy such of its members as it shall select. These persons shall be considered as nominated for membership in the Academy, and if elected, shall be entitled to all privileges of regular members. The society shall pay to the Academy one-half of the regular annual dues of the Academy for each person so elected, and shall be entitled to as many copies of future volumes of the transactions of the Academy as it contains members of the Academy. In case of the discontinuance of a local society, these persons may continue as members of the Academy on payment of the regular dues.

A list of the officers, and the names of the members, and a copy of the minutes of the meetings of affiliated societies shall be forwarded to the Academy, and the whole or such portion as the council shall think best shall be published in the report of the transactions of the Academy.

COLLECTION OF FOSSILS.

[*By the Academy, December 29, 1892, Vol. IX, p. vii.*]

Resolved, That the general collection of fossils which were given to the Academy by the Wisconsin Geological Survey in 1879 may be distributed with the collections of the University of Wisconsin, but so labeled as to indicate that they are the property of the Academy; but that the collection of type specimens is to be kept separate from the others, and not to be included in the general University collection.

FEES OF LIFE MEMBERS.

[*By the Academy, July 19, 1870, Vol. I, p. 187.*]

Resolved, That the fees from members for life be set apart as a permanent endowment fund to be invested in Wisconsin state bonds, or other equally safe securities, and that the proceeds of said fund, only, be used for the general purposes of the Academy.

ANNUAL DUES.

[*By the Academy, December 29, 1892, Vol. IX, p. vi.*]

Resolved, That the secretary and treasurer be instructed to strike from the list of active members of the Academy the names of all who are in arrears in the payment of annual dues, except in those cases where, in their judgment, it is desirable to retain such members for a longer time.

ARREARS OF ANNUAL DUES.

[*By the Council, December 29, 1897.*]

Resolved, That the treasurer be requested to send out the notices of annual dues as soon as possible after each annual meeting and to extend the notice to the second or third time within a period of four months where required.

NOTE.—The Printing Commissioners of the State of Wisconsin now require all copy to be at hand ready for the printer before the permit for printing shall be issued by the Secretary of State. But, under a ruling of the Commissioners, made in response to a presentation by the Committee of the Academy appointed December 29, 1897, each volume of the Transactions may be issued in two consecutive parts; so that a publication may thus be issued each year covering the papers accepted after the previous annual meeting.

LIST OF EXCHANGES.

BY WILLIAM S. MARSHALL,

Librarian.

CONTENTS.

he arrangement of the list is in alphabetical order by continents, countries, and cities.

Page.

AFRICA:

NORTH AMERICA:

SOUTH AMERICA:

ASIA:

Page

AUSTRALASIA:

EUROPE:

AFRICA.

ALGERIA.

Bone.

1. Académie d'Hippone. Société de Recherche Scientifique et d'Acclimatation.

CAPE COLONY.

Cape Town.

1. South African Philosophical Society.

EGYPT.

Cairo.

1. Institut Egyptien.

NORTH AMERICA.

CANADA.

Halifax.

1. Nova Scotian Institute of Science.

Hamilton.

1. Hamilton Association.

Kingston.

1. Queen's University.

Montreal.

1. Canadian Record of Science.
2. McGill University Library.
3. Natural History Society.

Ottawa.

1. Literary and Scientific Society.
2. Ottawa Field Naturalist Club.
3. Ottawa Naturalist.
4. The Royal Society of Canada.

Quebec.

1. Geographical Society of Quebec.

St. John.

1. Natural History Society of New Brunswick.

St. Johns.

1. Geological Survey of Newfoundland.

Toronto.

1. Astronomical and Physical Society.
2. Canadian Institute.

Winnipeg.

1. Manitoba Historical and Scientific Society.

CUBA.

Habana.

1. Real Universadad de la Habana.

MEXICO.

Mexico.

1. Museo Nacional.
2. Secretaria de Fomento, Colonizacion, e Industria.
3. Sociedad Cientifica "Antonio Alzate."
4. Sociedad Farmaceutica Mexicana.
5. Sociedad Mexicana de Geografia y Estadistica.
6. Sociedad Mexicana de Historia Natural.

Tacubaya.

1. Observatorio Astronomico Nacional.

Toluca.

1. Instituto Cientifico y Literario.

UNITED STATES.

Albany, N. Y.

1. University of the State of New York.
2. New York State Library.
3. Museum of Natural History.

Ames, Iowa.

1. Iowa State College of Agriculture.

Ann Arbor, Mich.

1. Engineering Society of Ann Arbor.

Auburn, Ala.

1. Agricultural Experiment Station.

Austin, Tex.

1. Texas Academy of Science.

Baltimore, Md.
1. Johns Hopkins University.

Beloit, Wis.
1. Library of Beloit College.

Berkeley, Cal.
1. University of California Agricultural Experiment Station.

Boston, Mass.
1. Boston Society of Natural History.
2. American Academy of Arts and Sciences.
3. Massachusetts Institute of Technology.

Brooklyn, N. Y.
1. Brooklyn Institute of Arts and Sciences.

Brookville, Ind.
1. Indiana Academy of Science.

Buffalo, N. Y.
1. Buffalo Society of Natural Sciences.

Burlington, Vt.
1. Vermont Agricultural Experiment Station.

Cambridge, Mass.
1. Library of Harvard University.
2. Museum of Comparative Zoology, Harvard University.
3. Nuttall Ornithological Club.

Champaign, Ill.
1. Illinois State Laboratory of Natural History.
2. University of Illinois.
3. Civil Engineers' Club of University of Illinois.

Chapel Hill, N. C.
1. The Elisha Mitchell Scientific Society.

Chicago, Ill.
1. Association of Engineering Societies.
2. Field Columbian Museum.
3. Journal of Geology, University of Chicago.
4. John Crerar Library.

Cincinnati, O.
1. Cincinnati Society of Natural History.
2. Lloyd Museum and Library.

Colorado Springs, Colo.

1. Colorado College Scientific Society.

Columbus, O.

1. Geological Survey of Ohio.
2. Ohio State University.

Davenport, Ia.

1. Davenport Academy of Natural Science.

Denver, Colo.

1. The Colorado Scientific Society.

Des Moines, Ia.

1. Iowa Academy of Sciences.

Duluth, Minn.

1. Historical and Scientific Association.

Evanston, Ill.

1. Northwestern University.

Granville, O.

1. Journal of Comparative Neurology.
2. Denison University.

Harrisburg, Penn.

1. Geological Survey of Pennsylvania.

Indianapolis, Ind.

1. Geological Survey of Indiana.
2. Indiana Academy of Science.

Iowa City, Ia.

State University of Iowa, Natural History Laboratory.

Ithaca, N. Y.

1. Cornell University.

Jefferson City, Mo.

1. Geological Survey of Missouri.

Kansas City, Mo.

1. Kansas City Review of Science and Industry.

Knoxville, Tenn.
1. University of Tennessee.

Lawrence, Kan.
1. University of Kansas.

Lincoln, Neb.
1. University of Nebraska.

Little Rock, Ark.
1. Arkansas Geological Survey.

Medford, Mass.
1. Tufts College.

Milwaukee, Wis.
1. Public Museum.
2. Public Library.
3. Literary Association of Wisconsin.

Minneapolis, Minn.
1. Minnesota Academy of Natural Science.
2. University of Minnesota.
3. Geological and Natural History Survey.

New Brighton, N. Y.
1. Natural Science Association of Staten Island.

New Haven, Conn.
1. Connecticut Academy of Arts and Sciences.

New York City .
1. American Geological Society.
2. American Museum of Natural History.
3. American Ornithologists' Union.
4. Apotheker Zeitung.
5. Columbia University, School of Mines.
6. Linnean Society.
7. New York Academy of Sciences.
8. New York Botanical Gardens.
9. New York Microscopical Society.
10. Troy Botanical Club, Columbia University.

Philadelphia, Penn.

1. Academy of Natural Science.
2. American Philosophical Society.
3. Association of Engineering Societies.
4. Commercial Museum.
5. The Franklin Institute.
6. Philadelphia Commercial Museum.
7. Sugar Best.
8. University of Pennsylvania.
9. Zoölogical Society.

Portland, Me.

1. Portland Society of Natural History.

Poughkeepsie, N. Y.

1. Vassar Bros. Institute.

Princeton, N. J.

1. Museum of Geology and Archaeology.

Ripon, Wis.

1. Ripon College.

Rochester, N. Y.

1. Rochester Academy of Sciences.

Sacramento, Cal.

1. University of California.
2. State Mining Bureau.

Salem, Mass.

1. Essex Institute.
2. American Institute for the Advancement of Science.

San Francisco, Cal.

1. California Academy of Sciences.

Seattle, Wash.

1. Library of University of Washington.
2. Young Naturalists' Association.

Springfield, Ill.

1. Geological Survey of Illinois.
2. State Entomologist.

St. Louis, Mo.

1. Academy of Science of St. Louis.

State College, Penn.

1. Agricultural Experiment Station.

Topeka, Kan.

1. Washburn Laboratory of Natural History.
2. Kansas Academy of Sciences.

Trenton, N. J.

1. Geological Survey of New Jersey.
2. New Jersey Natural History Society.

Washington, D. C.

1. Department of Agriculture.
2. American Microscopical Society.
3. Bureau of Ethnology.
4. United States Geological Survey.
5. National Academy of Sciences.
6. Philosophical Society of Washington.
7. Smithsonian Institute.
8. United States National Museum.

Wooster, O.

1. Ohio Agricultural Experiment Station.

Worcester, Mass.

1. American Antiquarian Society.

SOUTH AMERICA.

ARGENTINE REPUBLIC.

Buenos Aires.

1. Museo Nacional de Buenos Aires.
2. Sociedad Cientifica Argentina.

Cordoba:

1. Academia Nacional de Ciencias.

La Platta.

1. Direccion General de Estadistrica de la Provincia de Buenos Aires.

BRAZIL.

Rio de Janeiro.

1. Instituto Historico Geographico y Ethnographio.
2. Museo Nacional.

CHILE.

Santiago.

1. Deutscher Wissenschaftlicher der Ein.
2. Observatorio Nacional.
3. Oficina Hidorgrafica de Chile.
4. Sociedad Cientifica de Chile.
5. Sociedad Nacional de Mineria.

PERU.

Lima.

1. Revista de Ciencias.

URUGUAY.

Montevideo.

1. Museo Nacional.

ASIA.

CHINA.

Shanghai.

1. Royal Asiatic Society, China Branch.

INDIA.

Calcutta.

1. Asiatic Society of Bengal.
2. Indian Museum.
3. Royal Botanic Garden. (Sibpur, near Calcutta.)

Madras.

1. Archaeological Survey of South India.
2. Government Central Museum and Library.

Saharanpur.

1. Botanical Department of Northern India.

JAPAN.

Tokyo.

1. Deutsche Gesellschaft für Natur und Völkerkunde Ost-Asiens.
2. Geographical Society (Chi-ga-ku-kio-kuwai).
3. Botanical Magazine.
4. Anthropological Society.

NETHERLANDS INDIES.

Batavia.

1. Koninklijke Naturkundige Vereenigingin Nederlandsch-Indië.

Buitenzorg.

1. Botanischer Garten.

STRAITS SETTLEMENTS.

Singapore.

1. Royal Asiatic Society, Straits Branch.

AUSTRALASIA.

NEW SOUTH WALES.

Sydney.

1. Anthropological Society of Australasia.
2. Australian Association for the Advancement of Science.
3. Australian Museum.
4. Geological Survey of New South Wales.
5. Linnean Society of New South Wales.
6. New South Wales Zoological Society.
7. Royal Society of New South Wales.
8. University of Sydney.

NEW ZEALAND.

Wellington.

1. New Zealand Institute.
2. Polynesian Society.
3. Colonial Museum and Geological Survey Department.

QUEENSLAND.

Brisbane.

1. Geological Survey of Queensland.
2. Queensland Museum of Natural History.
3. Royal Society of Queensland.

SOUTH AUSTRALIA.

Adelaide.

1. Royal Geographical Society.

VICTORIA.

Melbourne.

1. Field Naturalists' Club.
2. Geological Society of Australasia.
3. Royal Geographical Society of Australasia, Victorian Branch.
4. Royal Society of Victoria.

WESTERN AUSTRALIA.

Perth.

1. Geographical Society of West Australia.

EUROPE.

AUSTRIA HUNGARY.

Brunn.

1. Naturforschender Verein.
2. Scientific Society.

Budapest.

1. Geologische Gesellschaft für Ungarn. (Magyarhoni Földtani Társulat.)
2. Magyar Természettudományi Társulat. (R. Hungarian Society of Natural Sciences.)
3. K. Ungar. Geologische Anstalt. (Magyar Királyi Földtani Intézet.
4. Magyar Tudományos Akademia (Hungarian Academy of Sciences).

Graz.

1. Naturwissenschaftlicher Verein für Steiermark.

Hermannstadt.

1. Siebenbürgisher Verein für Naturwissenschaften.

Innsbruck.

1. Naturwissenschaftliche-Medizinischer Verein.
2. Tiroler Landes-Museum. Ferdinandeum.

Klagenfurth.

1. Naturhistorisches Landes-Museum in Kärnten.

Klausenburg.

1. Medicinische Naturwissenschaftliche Section des Siebenbürgischen Museum Vereins.

Krakau.

1. Akademija Umiejetnósic (Academy of Sciences).

Leipa.

1. Nord Böhmischer Excursions-Club.

Prag.

1. K. Böhmischer Gesellschaft der Wissenschaften (Král. Ceské Spolecnosti Nauk).
2. Naturwissenschaftlicher Verein "Lotos."

Trieste.

1. K. K. Astronomisch-Meteorologiscses Observatorium (I. R. Osservatorio Marittimo).
2. K. K. Handels- und Nautische Akademie (I. R. Accademia di Commercio e Nautica).

Wien.

1. Allgemeiner Oesterr. Apotheker Verein.
2. Chemico-Technische Versuchsstation des Centralvereines für Rübenzucker-Industrie in der Oesterr. Ungar. Monarchie.
3. Kaiserliche Akademie der Wissenschaften.
4. K. K. Gartenbau Gesellschaft.
5. K. K. Geologische Reichsanstalt.
6. K. K. Naturhistorisches Hof Museum.
7. K. K. Universitäts Bibliothek.
8. K. K. Zoölogische-Botanische Gesellschaft.
9. Landwirthschaftliche Versuchs-Station.
10. Section für Naturkunde des Oesterreichischen Touristen Verein.
11. Wiener Illustrirte Garten-Zeitung.

BELGIUM.

Anvers.

1. Société Royale de Géographie.

Bruxelles.

1. Academie Royale des Sciences, des Lettres, et des Beaux-Arts de Belgique.
2. Musee Royal d'Histoire Naturelle de Belgique.
3. Société Belge de Géographie.
4. Société Belge de Microscopie.
5. Société Malacologique de Belgique.
6. Société Royale de Botanique de Belgique.

Liege.

1. Société Géologique de Belgique.
2. Société Royale des Sciences.

Louvain.

1. Université Catholique.

Mons.

1. Société des Sciences, des Arts, et des Lettres du Hainaut.

Tongres.

1. Société Scientifique et Littéraire du Limbourg.

DENMARK.

Kjobenhavn (Copenhagen).

1. Commissionen for Ledelsen af de Geologiske og Geographiske Undersögelse i Grönland.
2. Kongelige Danske Videnskabernes Selskav.

FRANCE.

Amiens.

1. Société Linnéenne du Nord de la France.

Angers.

1. Société Linnéenne de Maine-et-Loire.

Annecy.

1. Société Florimontane.

Besancon.

1. Académie des Sciences, Belles-Lettres, et Arts.

Beziers.

1. Société d'Etude des Sciences Naturalles de Béziers.

Bordeaux.

1. Académie National des Belles-Lettres, Sciences, et Arts.
2. Société Linnéenne de Bordeaux (Société de Medecine de Bordeaux).

Bourg.

1. Société d'Emulation Agriculture, Sciences, Lettres, et Arts de l'Ain.

Caen.

1. Académie Nationale des Sciences, Arts, et Belles-Lettres.

Chalon-sur-Saone.

1. Société des Sciences Naturelles de Saone-et-Loire.

Cherbourg.

1. Société Académique de Cherbourg.
2. Société Nationale des Sciences Naturelles et Mathématiques de Cherbourg.

Dijon.

1. Union Géographique du Nord de la France.
2. Académie des Sciences, Arts, et Belles-Lettres de Dijon.

Gueret.

1. Société des Sciences Naturelles et Archéologiques de la Creuse.

La Rochelle.

1. Académie des Belles-Lettres, Sciences, et Arts de la Rochelle.

Le Mans.

1. Société d'Agriculture, Sciences, et Arts de la Sarthe.

Lille.

1. Société Géologique de Nord.

Lyon.

1\. Académie des Sciences, Belles-Lettres, et Arts de Lyon.
1\. Société Botanique de Lyon.

Macon.
1. Société d'Historie Naturelle.

Marseille.
1. Société Scientifique Industrielle.

Montpellier.
1. Académie des Sciences et Lettres de Montpellier.

Nantes.
1. Station Agronomique.

Nimes.
1. Société d'Etudes des Science Naturelles.

Paris.
1. Ministere de l'Instruction Publique et des Beaux-Arts.
2. Préfecture de la Seine, Second Bureau de Cabinet.
3. Société Entomologique de France.
4. Société d'Ethnographie.
5. Société Française de Physique.
6. Feuilles des Jeunes Naturalistes.

Rouen.
1. Société des Amis des Sciences Naturelles (de Rouen).
2. Société Normandée de Géographie.

Toulon.
1. Société Académique du Var.

Toulouse.
1. Société Française de Botanique.
2. Université.

Tours.
1. Société d'Agriculture, Sciences, Arts, et Belles-Lettres.

GERMANY.

Augsburg.
1. Naturwissenschaftlicher Verein für Schwaben und Neuburg.

Bamberg.
1. Naturforschende Gesellschaft.

Berlin.

1. Apotheker-Zeitung.
2. Botanischer Verein der Provinz Brandenburg.
3. Deutsche Geologische Gesellschaft.
4. Deutscher Verein zum Schutze der Vogelwelt.
5. Gesellschaft für Erdkunde.
6. Gesellschaft Naturforschender Freunde.
7. Königlich Preussische Akademie der Wissenschaften.
8. Museum für Naturkunde.
9. Zeitschrift für Gartenbau und Gartenkunst. (Zeitschrift für die Gesammten Naturwissenschaften in Halle.)
10. Zeitschrift für Instrumentenkunde.
11. Zeitschrift für Praktische Geologie.

Bonn.

1. Mineralogisches Museum und Institut der Universität.
2. Naturhistorischer Verein der Preussischen Rheinland, Westfalens, und des Regierungsbezirks Osnabrück.

Braunschweig.

1. Verein für Naturwissenschaften.

Bremen.

1. Naturwissenschaftlicher Verein.

Breslau.

1. Schlesische Gesellschaft für Vaterländische Kultur.
2. Verein für Schlesische Insektenkunde.
3. Zeitschrift für Entomologie.

Danzig.

1. Naturforschende Gesellschaft.

Dresden.

1. Königliches Mineralogisch-Geologisch- und Prähistorisches Museum.
2. Naturwissenschaftliche Gesellschaft "Isis."
3. Verein für Erdkunde.

Dusseldorf.

1. Naturwissenschaftlicher Verein.

Elberfeld.

1. Naturwissenschaftlicher Verein von Elberfeld und Barmen.

Emden.

1. Naturforschende Gesellschaft.

Erfurt.
1. Academie Gemeinnütziger Wissenschaften.

Erlangen.
1. Physikalisch-Medicinische Societät.

Frankfurt-am-Main.
1. Physikalischer und Aerztlicher Verein.
2. Senckenbergische Naturforschende Gesellschaft.

Frankfurt-an-der-Oder.
1. Helios.
2. Naturwissenschaftlicher Verein.
3. Societatum Litterae (Redaction der).

Freiburg-im-Breisgau.
1. Naturforschende Gesellschaft.

Gera.
1. Gesellschaft der Freunde der Naturwissenschaften.

Giessen.
1. Oberhessische Gesellschaft für Natur- und Heilkunde.

Gœrlitz.
1. Naturforschende Gesellschaft.

Gœttingen.
1. Königliche Societät der Wissenschaften.

Greifswald.
1. Geographische Gesellschaft.
2. Naturwissenschaftlicher Verein von Neuvorpommern und Rügen.

Halle-an-der-Saale.
1. Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher.
2. Naturforschende Gesellschaft.
3. Naturwissenschaftlicher Verein für Sachsen und Thüringen.

Hamburg.
1. Naturwissenschaftlicher Verein.
2. Verein für Naturwissenschaftliche Unterhaltung.

Hanau.
1. Wetterauische Gesellschaft für die Gesammte Naturkunde.

Hannover.

1. Deutscher Seefischerei-Verein.
2. Naturhistorische Gesellschaft.

Heidelberg.

1. Naturhistorische-Medicinischer Verein.

Jena.

1. Medicinisch-Naturwissenschaftlicher Gesellschaft.
2. Universitäts-Bibliothek.

Karlsruhe.

1. Naturwissenschaftlicher Verein.

Kassel.

1. Verein für Naturkunde.

Kiel.

1. Mineralogisches Institut der Universität.
2. Naturwissenschaftlicher Verein für Schleswig-Holstein.
3. Universitäts-Bibliothek.

Kœnigsberg.

1. Botanischer Verein.
2. Königliche Physikalisch-Oekonomische Gesellschaft.
3. Universitäts-Bibliothek.

Landshut.

1. Botanischer Verein.

Leipzig.

1. Königlich Sachsische Gesellschaft der Wissenschaften.
2. Naturforschende Gesellschaft.
3. Verein für Erdkunde.

Luebeck.

1. Geographische Gesellschaft.

Lueneburg.

1. Naturwissenschaftlicher Verein.

Magdeburg.

1. Naturwissenschaftlicher Verein.

Marburg.

1. Gesellschaft zur Beförderung der Gesammten Naturwissenschaften.
1. Universitäts-Bibliothek.

Metz.

1. Académie de Metz.

Muenchen.

1. Königlich Bayerische Akademie der Wissenschaften.
2. Königliche Sternwarte.

Muenster.

1. Provinzial-Verein für Wissenschaften und Kunst.

Nuernberg.

1. Naturhistorische Gesellschaft.

Ploen.

1. Biologische Station.

Regensburg.

1. Historischer Verein für die Oberpfalz.
2. Naturwissenschaftlicher Verein.

Rostock.

1. Grossherzogliche Mecklenburgische Geologische Landes-Anstalt.
2. Verein der Freunde der Naturgeschichte in Mecklenburg.

Strassburg.

1. Kaiserliche Universitäts- und Landes-Bibliothek.
2. Kommission für die Geologische Landes-Untersuchung von Elsass-Lothringen.

Stuttgart.

1. Württembergische Vierteljahrshefte für Landesgeschichte.

Thorn.

1. Copernicus Verein für Wissenschaft und Kunst.

Ulm.

1. Verein für Mathematik und Naturwissenschaften.

Weimar.

1. Botanischer Verein für das Gesammte Thüringen.

Wernigerode.

1. Naturwissenschaftlicher Verein.

Wiesbaden.

1. Verein für Naturkunde.

ENGLAND.

Barrow-in-Furness.

1. Naturalists' Field Club.

Birmingham.

1. Birmingham Natural History and Philosophical Society.

Cambridge.

1. Cambridge Philological Society.
2. Cambridge Philosophical Society.

Cardiff.

1. Cardiff Naturalists' Society.

Chester.

1. Chester Natural Science Society.

Guernsey.

1. Guernsey Society of Natural Science and Local Research, Guille Allès Library.

Halifax.

1. Yorkshire Geological and Polytechnical Society.

Kew.

1. Hooker's Icones Plantarum.
2. Royal Herbarium.

Leeds.

1. Leeds Geological Association.
2. Leeds Philosophical and Literary Society.
3. Yorkshire Naturalists' Union.

Liverpool.

1. Liverpool Geological Association.
2. Liverpool Geological Society.

London.

1. Aristotelian Society.
2. British Museum, Natural History Division.
3. Geological Society of London.
4. Royal Botanic Society.
5. Royal Horticultural Society.
6. Royal Institution of Great Britain.
7. Royal Society of London.
8. Journal Society of Arts (Society for the Encouragement of Art, Manufactures, and Commerce).

Manchester.

1. Literary and Philosophical Society.
2. Manchester Field Naturalists' and Archaeologists' Society.
3. Manchester Geological Society.
4. Manchester Geographical Society.

Marlborough.

1. Marlborough College Natural History Society.

Newcastle.

1. Literary and Philosophical Society.
2. North of England Institute of Mining and Mechanical Engineers.

Norwich.

1. Norfolk and Norwich Naturalists' Society.

Penzance.

1. Penzance Natural History and Antiquarian Society.
2. Royal Geological Society of Cornwall.

Preston.

1. Preston Scientific Society.

Sheffield.

1. Literary and Philosophical Society.

Southport.

1. Southport Society of Natural Sciences.

Watford.

1. Hertfordshire Natural History Society and Field Club.

Wellington College, S. E. R.

1. Wellington College Natural History Society.

York.

1. Yorkshire Philosophical Society.

IRELAND.

Belfast.

1. Natural History and Philosophical Society.

Dublin.

1. Royal Dublin Society.
2. Royal Irish Academy.

SCOTLAND.

Edinburgh.

1. Edinburgh Geological Society.
2. Royal Physical Society.
3. Royal Society of Edinburgh.
4. Scottish Microscopical Society.

Glasgow.

1. Glasgow Geological Society.
2. Natural History Society of Glasgow.

Perth.

1. Perthshire Society of Natural Science.

ITALY.

Acireale.

1. Accademia di Scienze, Lettere, ed Arti degli Zelanti.

Bergamo.

1. Accademia Carrara di Belle Arti.

Bologna.

1. Accademia delle Scienze dell' Istituto di Bologna.

Brescia.

1. Ateneo di Brescia.

Catania.

1. Accademia Gioenia di Scienze Naturali.

Firenze (Florence).
1. Biblioteca Nazionale Centrale.
2. Reale Istituto di Studi Superiori.
3. Società Entomologica Italiana.

Lucca.
1. Reale Accademia Lucchese di Scienze, Lettere, ed Arti.

Milano.
1. R. Istituto Lombardo di Scienze e Lettere.
2. Società d'Esplorazione Commerciale in Africa.
3. Società Italiana di Scienze Naturali.

Modena.
1. R. Accademia di Scienze, Lettere, ed Arti.
2. Società di Naturalisti in Modena.

Napoli.
1. Società Italiana delle Scienze.
2. Società di Naturalisti.
3. Anomalo (L').

Padova.
1. Rivista di Mineralogia e Cristallografia Italiana.
2. Società Veneto-Trentina di Scienze Naturali.

Palermo.
1. Circolo Matematico di Palermo.
2. R. Accademia Palermitana di Scienze, Lettere, e Belle-Arti.

Pisa.
1. Societa Toscana di Scienze Naturali.

Roma.
1. British and American Archaeological Society.
2. Società Geologica Italiana.
3. Società Italiana delle Scienze.

Torino.
1. Accademia Reale delle Scienze.

Verona.
1. Accademia d'Agricoltura, Commercio, ed Arti di Verona.

NETHERLANDS.

Amsterdam.

1. Genootschap ter Bevordering van Natuur-, Genees-, en Heelkunde.
2. Koninklijke Akademie van Wetenschappen. (Royal Academy of Sciences.)

's Gravenhage.

1. Koninklijk Instituut voor de Taal-, Land-, en Volken-kunde van Nederlandsch Indië.

Groningen.

1. Natuurkundig Genootschap.

Haarlem.

1. Fondation de P. Tetler van der Hulst. (Teyler Stichting.)
2. Hollandsche Maatschappij van Wetenschappen.
3. Koloniaal Museum.
4. Nederlandsche Maatschappij ter Bevordering van Nijverheid.
5. Regts Geleerd. (Société Néderlandaise des Sciences Naturelles.)

Leiden.

1. Rijks Geologisch en Mineralogisch Museum.

Middelburg.

1. Zeeuwsch Genootschap van Wetenschappen.

Rotterdam.

1. Bataafsch Genootschap der Proefondtervindelijke Wijsbegeerte. (Batavian Society of Experimental Philosophy.)
2. Bataafsch Genootschap voor Physika.

Utrecht.

1. Koninklijk Nederlandsche Meteorologisch Instituut.
2. Provinciaal Utrechtsch Genootschap van Kunsten en Wetenschappen.

NORWAY.

Bergen.

1. Bergens Museum.

Christiania.

1. Norske Gradmaalings Commission.
2. Norske Meteorologiske Institut.
3. Den Norske Nordhaos Expedition.
4. Universitet.
5. Videnskabs Selskab.

Stavanger.

1. Stavanger Museum.

Trondhjem.

1. Kongelige Norske Videnskabernes Selskab.

Tromsœ.

1. Tromsö Museum.

PORTUGAL.

Coimbra.

1. Sociedade Broteriana.

Lisboa.

1. Academia das Bellas Artes.
2. Commissão dos Trabalhos Golagicos de Portugal.
3. Real Observatorio Astronomico de Lisboa. (Tapada.)

ROUMANIA.

Bukarest.

1. Academia Românа.
2. Institutul Meteorologic al Romaniei.
3. Société Roumaine de Géographie.

RUSSIA.

Ekaterinburg.

1. Uralskoie Obshchestvo Lubitelei Iestestvoznania. (Uralian Society of Frends of Natural Science.)

Helsingfors.

1. Geologiska Commissionen i Finland.
2. Kejserliga Alexanders-Universitet i Finland. (Magnitnaia i Meteorologicheskaia Observatoria.)

Kharkof.

1. Obshchestvo Ispytatelei Prirody pri Imper. Kharkofskom Universitetie. (Society of Naturalists at the Imperial University of Kharkof.)

Moskva.

1. Imper. Moskofskoie Obshchestvo Iestestvo-Ispytatelei. (Moscow Imperial Society of Naturalists.)
2. Imper. Zemledielcheskoie Obshchestvo v Moskvie. (Imp. Agricultural Society of Moscow.)

Odessa.

1. Club Alpin de Crimée.

Riga.

1. Gartenbau Verein.
2. Obschestvo Iestestvo-Ispytatelei. (Society of Naturalists.)

Sankt-Peterburg.

1. Geologicheskii Komitet. (Geological Committee.)
2. Glavnaia Fizicheskaia Observatoria. (Central Physical Observatory.
3. Imper. Akademia Nauk. (Imperial Academy of Sciences.)
4. Imper. Sankt-Peterburgskii Botanicheskii Sad. (Imperial Botanical Garden.)
5. Imper. Sankt-Peterburgskoie Mineralogicheskoie Obshchestvo. (Imperial Mineralogical Society.)
6. Institut Impérial de Médecine Expérimentale.
7. Sankt Peterburgskoie Obshchestvo Iestestvo-Ispytatelei. (St. Petersburg Society of Naturalists.)
8. Section Géologique de la Société des Naturalists de l'Université Impériale.

SPAIN.

Barcelona.

1. Real Academia de Ciencias y Artes.

Madrid.

1. Real Academia de la Historia.
2. Real Academia de Ciencias Exactes, Fisicas, y Naturales.

SWEDEN.

Gœteborg.

1. Kongliga Vetenskaps och Vitterhets Samhället. (Royal Society of Sciences and Belles-Lettres.)

Lund.

1. Kongliga Universitet.

Stockholm.

1. Geologiska Byran.
2. Geologiska Föreningen.
3. Historiska Museum.
4. Universitets Biblioteket.
5. Kongliga Svenska Vetenskaps Akademien.
6. Kongliga Vitterhets, Historie och Antiquitets Akademien.

Upsala.

1. Kongliga Universitet.
2. Kongliga Vetenskaps Societeten.
3. Universitets Astronomiska Observatoriet.

SWITZERLAND.

Aarau.

1. Naturforschende Gesellschaft.

Basel.

1. Naturforschende Gesellschaft.

Bern.

1. Naturforschende Gesellschaft (Société des Sciences Naturelles).
2. Schweizerische Entomologische Gesellschaft.
3. Schweizerische Naturforschende Gesellschaft. (Société Helvétique des Sciences Naturelles).

Chur.

1. Naturforschende Gesellschaft Graubundens.

Frauenfeld.

1. Thurgaunische Naturforschende Gesellschaft.

Freibourg.

1. Société Fribourgeoise des Sciences Naturelles.

Geneva.

1. Société Botanique de Genève.
2. Société de Géographie.
3. Société de Physique et d'Histoire Naturelle.
4. Geneva Conservatoire Botanique. Dr. J. Brisquet, Directeur.

Lausanne.

1. Société Vaudoise des Sciences Naturelles.

Neuchatel.

1. Société des Sciences Naturelles.

St. Gall.

1. Naturhistorische Gesellschaft.
2. Naturwissenschaftliche Gesellschaft.

Zurich.

1. International Entomological Society.
2. Naturforschende Gesellschaft.
3. Schweizerische Botanische Gesellschaft.

Madison, Wis., December 20, 1899.

PROCEEDINGS.

SECRETARY'S REPORT.

TWENTY-EIGHTH ANNUAL MEETING,

MILWAUKEE, WIS., DECEMBER 27-29, 1897.

The several sessions were carried out with few exceptions according to the following program which was printed for the meeting.

Monday Evening, December 27th.—Opening lecture, complimentary to the members of the Wisconsin Teachers' Association, and to the citizens of Milwaukee: "Dante," by *William F. Giese,* Assistant Professor of Romance Languages, University of Wisconsin.

Tuesday Morning, December 28th.—Reports of officers and other general business.

Reading of papers:—

1. Report on the progress of the Geological and Natural History Survey of Wisconsin. *C. Dwight Marsh,* President of the Academy, and *E. A. Birge,* Director of the Survey.
2. The fresh water sponges of St. Louis bay. *N. A. Harvey.*
3. Some economic aspects of the Greenback and Populist movements. *O. G. Libby.* (By title.)
4. Some differences between the conduct of private and public business. *Ernest Bruncken.*
5. Early general railway legislation in Wisconsin. *B. H. Meyer.* (By title.)
6. Railroad land grants. *J. B. Sanborn.*
7. An historical note on early American railroads. *Chas. H. Chandler.*
8. The relation of motives to freedom. *E. H. Merrell.*
9. The duration of school attendance in Chicago and Milwaukee. *Daniel Folkmar.*

10. On the meaning and function of thought-connectives. *E. T. Owen.*

11. The psychology of the "Sense of injury." *W. F. Becker.*

12. The fee system in the United States. *T. K. Urdahl.*

13. The succession-period of generations. *Chas. H. Chandler.*

14. On the relation of joints to the forces which produce them. *C. R. Van Hise.*

15. The origin of conglomerates. *G. L. Collie.*

16. Notes on the Itasca basin. *F. E. Lurton.* (By title.)

17. On a plan to gather information concerning Wisconsin diamonds. *Wm. H. Hobbs.*

18. Recent investigations to determine the relation of crystal forms to chemical composition. *Wm. H. Hobbs.*

Tuesday Evening.—Adjournment to attend the lecture before the Wisconsin Teachers' Association.

Wednesday Morning, December 29th.—19. Observations of nature and people in Eastern Siberia. *Isidor Ladoff.*

20. Observations on the nocturnal flight of migrating birds. *O. G. Libby.* (To be read by the Secretary.)

21. Unsteady motion in capillary tubes. *H. C. Wolff.*

22. Theoretical investigation of motion of ground waters. II. *C. S. Slichter.*

23. Pressures within a heterogeneous spheroid. *C. S. Slichter.*

24. Recent developments in the electro-magnetic theory of light. (Abstract. To be read by the Secretary.) *J. E. Davies.*

25. The action of dilute solutions of electrolytes on the sense of taste. *Louis Kahlenberg.*

26. Several nitrogen addition products of caryophyllene. *Edward Kremers.*

27. A new model of the lobule of the lung. *W. S. Miller.*

28. A study of the variation in the bileducts of the cat. *W. S. Miller.*

Wednesday Afternoon.—Adjournment to attend the sectional meetings of the Teachers' Association.

Wednesday Evening.—Lecture, Complimentary to the citizens of Milwaukee: "Modern methods of water purification." Illustrated by lantern projections. By *Erastus G. Smith,* Professor of Chemistry and Mineralogy, Beloit College.

TUESDAY, DECEMBER 28th.

MORNING SESSION.

The meeting was called to order at 9:10 a. m. by President C. Dwight Marsh.

The minutes of the Twenty-seventh annual meeting were read and approved.

The reports of the Secretary, Treasurer, and Librarian were read severally and adopted. The second was read by the Secretary in the Treasurer's absence.

The proposed amendment to the Constitution, as indicated in the following extract from the printed circular making the preliminary announcement of the meeting, was brought up for action:

"The attention of members is called to the following amendment to the Constitution, upon which it is intended to vote at the coming meeting. The amendment consists in adding certain words, which are indicated here by italics. To amend the first sentence of Article VII so as to read: 'The annual meeting of the Academy shall be held in Madison, between Christmas and New Year, *or at such other place as the Council may designate.*"

Prof. Birge moved to amend further by adding after the word "designate" the following clause: "but all regular meetings for the election of officers shall be held at Madison."

The amendment thus changed was passed.

The President appointed Messrs. Ernest Bruncken, G. E. Culver, and E. R. Buckley an auditing committee on the report of the Treasurer.

At 9:30 a. m. President Marsh reported on the work done in securing the passage of the bill by the State legislature for the Geological and Natural History Survey of the State. Members of the legislature generally were favorable to the measure when it had been explained to them. Members of the Academy had responded readily when asked for service. Among those most marked in assistance rendered were Messrs. Chas. R. Van Hise and John G. Gregory, and special credit was due to Miss Harriet B. Merrill. Considerable help was given by outside persons also, especially by Mr. Alfred C. Clas in connection with building stones. A bill was passed finally appropriating $5,000 for two years to carry on the survey.

Director E. A. Birge followed with an account of the work in progress on the survey. Three lines were pursued: scientific, economic, and educational. A hearty response had been received from others asked to co-operate in the work, although no compensation was offered except for expense actually incurred, especially from the members of the college faculties throughout the state.

President Marsh, also Secretary of the Survey Commission, and Prof. Chas. R. Van Hise, Consulting Geologist, followed with further remarks upon the work.

The numbers on the printed program were then resumed in order. Paper No. 2 was discussed by Messrs. E. A. Birge and C. Dwight Marsh.

During a short recess after paper No. 4, the President appointed a committee to nominate a candidate to fill the vacancy in the Committee on Library caused by the resignation of W. S. Leavenworth from membership in the Academy. The nominating committee consisted of Messrs. C. S. Slichter, Daniel Folkmar, and Miss Harriet B. Merrill.

The reading of papers was resumed. Paper No. 9 was discussed by Messrs. Bruncken and Flint.

The session was adjourned at 12:50 p. m.

AFTERNOON SESSION.

The meeting was called to order again at 2:00 p. m., and the first paper of the afternoon, No. 10, was read. It was discussed by F. G. Hubbard.

Paper No. 13 was discussed briefly.

During a recess which followed this discussion, the report of the auditing committee was adopted approving the report of the Treasurer.

On the recommendation of the nominating committee, Charles H. Chandler was elected to fill the vacancy on the Library committee.

Paper No. 14 was next given. It was discussed by Messrs. Ewing, Birge, Bruncken, A. S. Mitchell, and Merrell.

Paper No. 15 was omitted owing to the absence of the author, caused by illness.

The plan presented in Paper No. 17 was to publish notices in the newspapers published along the moraine regions calling attention to the possible finding of diamonds. Discussed by C. R. Van Hise and others.

Paper No. 18 was discussed by Messrs. E. G. Smith, Kremers, and Slichter.

The session was adjourned at 5:05 p. m.

WEDNESDAY, DECEMBER 29th.

MORNING SESSION.

The meeting was called to order by the President soon after 9 o'clock.

The President asked what action the Academy would take in view of the fact that the Secretary of State had announced his intention to issue no more permits for printing until all of the copy for a volume in question was at hand. Mr. C. R. Van Hise offered the following resolution:

"Whereas, It is of vital importance to the Academy that its transactions be issued in parts as heretofore, in advance of the completed volume, be it resolved,

That the Secretary of State be requested to grant an order for printing in continuation of this method of procedure; and that a committee be appointed to present this resolution to the Secretary of State."

The resolution was passed unanimously, and the President appointed Mr. Van Hise and the Secretary of the Academy as the committee.

Paper No. 19 was then read. Discussed by Messrs. E. G. Smith, Van Hise, Folkmar, and Hobbs.

Paper No. 21 was discussed by Messrs. Slichter and Van Hise; and No. 22 by Messrs. Upham, Birge, E. G. Smith, and Merrell.

Extensive remarks were made by Mr. Van Hise following the especially interesting paper, No. 23. He expressed it as his conviction that changes of pressure had much more to do with the folding of strata in the earth than did the secular contraction.

Paper No. 20 was next read for the author by A. S. Flint, who had been called away at the appointed time by his duties as secretary. Discussed by Messrs. Birge, Van Hise, Flint, and others.

Papers No. 24 to 28 inclusive were not read. In the case of the first the author had been detained at home by illness in his family. The author of No. 28 also was not feeling well enough to make the journey to Milwaukee.

The session adjourned at 12 o'clock noon.

A pleasant feature of the meeting was a six o'clock supper at the Plankinton House given by the Milwaukee members of the Academy to the visiting members. The time was spent in an informal reception in the parlor and friendly conversation at the tables, with no general speeches.

In the course of the meeting, on the recommendation of the committee on membership, twenty-two persons were elected to active membership, and five persons were transferred from the list of active members to that of corresponding members. Three life members were elected. Five resignations from membership were offered and accepted. The names of all these were printed in the Preliminary Report of the Secretary, Vol. XI, pp. 564–5 of the Transactions.

Albert S. Flint,
Secretary.

TWENTY-NINTH ANNUAL MEETING.

MILWAUKEE, WIS., DECEMBER, 27–28, 1898.

The several sessions were conducted in accordance with the following program for the meeting with a few exceptions as noted in the following:

Tuesday, December 27th.—Reports of officers and other general business.

Reading of papers.

1. Lake temperatures. Edward A. Birge.

2. Reports on the progress of the Geological and Natural History Survey of Wisconsin. (Illustrated by maps and specimens.) *Edward A. Birge*, Director of Survey, *C. Dwight Marsh*, Secretary, and others, including the following:

3. Wisconsin building stones. *Ernest R. Buckley.*

4. Preliminary account of work done on the lake regions of Vilas and Oneida counties, Wisconsin. *Dexter P. Nicholson.*

5. Contributions from the histological laboratory of the University of Wisconsin. (Illustrated by models and diagrams.) *William S. Miller.*

6. Cell fusions occurring without nuclear fusions. *Robert A. Harper.*

7. Further facts in relation to the succession-period of generations. *Charles H. Chandler.*

8. The apparent size of the sun. *Charles H. Chandler.*

9. Theoretical investigation on the motion of ground waters. III.—Mutual interference of two or more artesian wells. *Charles S. Slichter.*

10. The maximum gravitational attraction at the pole of a spheroid. *Elwyn F. Chandler.*

11. On the habit of finger-counting. *Elwyn F. Chandler.*

12. Combinations of Pythagorean triangles as giving exercises in computation. *Truman H. Safford.* (To be read by Charles S. Slichter.)

13. Lantern projections of three dimensional curves and surfaces. *Charles S. Slichter.*

14. A study of the class of electric and magnetic oscillations known as aphotic. *John H. Davies.* (By title.)

Wednesday, December 28th.—15. Forestry reform in Wisconsin. *Ernest Bruncken.*

16. Some facts in regard to the development of Epischura. *C. Dwight Marsh.*

17. The block system of arranging insect collections. *Harriet B. Merrill.*

18. Spines of trilobites and their significance. *George L. Collie.* (By title.)

19. The crystallography of a gold telluride from Cripple Creek. *William H. Hobbs.*

20. The crystallography of a new reduction product of turpene. *William H. Hobbs.*

21. The volume relations of original and secondary minerals in rocks. *Charles R. Van Hise.*

22. Chemistry of chocolate and cocoa. *Isidor Ladoff.*

23. The electric properties of non-aqueous solutions. *Azariah T. Lincoln.* (By title.)

24. The effects of the presence of pure metals upon plants. *Louis Kahlenberg* and *Edwin B. Copeland.* To be read by the latter.

25. Revision of the pronouns; with special consideration of relatives and relative clauses. *Edward T. Owen.*

26. The migration of graduate students in American universities. *Ernest R. Buckley.*

27. Mind and matter. *Edward H. Merrell.*

28. Arts and letters in Wisconsin; having to do especially with the art of music. *Fanny Grant.*

29. Some effective weapons of public reform. *Duane Mowry.*

30. A study in Chartism: a chapter in English industrial history. *Edward D. Jones.* (By title.)

TUESDAY, DECEMBER 27th.

MORNING SESSION.

The meeting was called to order by President Marsh at 9:30 a. m. in the Museum Room of the Public Library.

In the absence of the Secretary who was detained at the Washburn Observatory on account of the lunar eclipse, Mr. E. F. Chandler was elcted secretary *pro tem.* The annual report of the librarian was read by the secretary and accepted. On account of absence among officers and committees other business was postponed and the reading of papers taken up.

A motion was made by Professor C. R. Van Hise and discussed by him and others, that a committee be appointed by the chair to formulate the opinion of the Academy in regard to the State Geological and Natural History Survey, and in regard to the benefits which will accrue to the state by its continuation and extension, and to present the same to the Legislature. The motion was carried.

Messrs. C. R. Van Hise, A. L. Ewing, and Ernest Bruncken were appointed as the committee.

Adjourned at 12:30 p. m.

AFTERNOON SESSION.

The meeting was called to order by the President at 2:35 p. m., and the reading of papers resumed.

Papers No. 6, 8 and 10 were discussed by Messrs. Harper, Birge, Van Hise and others. Nos. 9, 12, and 13 were omitted on account of the absence of Professor Slichter, who was detained at home unexpectedly by serious illness in his family.

The annual report of the treasurer was read by the secretary and referred to an auditing committee appointed by the president and consisting of the following members: G. E. Culver, C. H. Chandler, and Ernest Buckley.

After discussion of the subject by Messrs. Van Hise, Birge, and C. H. Chandler it was voted: That it is the sense of the Academy that the library should be put in the custody of the State Historical Society, but that the details of any such arrangement be left to the discretion of the Council.

The question of the extension of the library by exchanges was discussed by Messrs. Birge, Hobbs, Van Hise, and Buckley.

The question of having a duplicate card catalogue made at the expense of the Academy in case a card catalogue of it is made by the State Historical Society was, on motion, referred to the Council.

It was voted that the Council be instructed to make any arrangements which may be practicable for securing the right to the use of a room or rooms when necessary in the State Historical Library building.

A talk on the Protective Coloration of Animals (illustrated by lantern slides), was then given by Mr. W. H. Dudley of Platteville.

Adjourned at 5:45 p. m.

WEDNESDAY, DECEMBER 28th.

MORNING SESSION.

The meeting was called to order at 9:30 a. m. The Secretary was present and read his report, which was approved, together with the minutes of the preceding annual meeting. The reading of papers was then resumed.

In presenting paper No. 15, Mr. Bruncken, Secretary of the State Forestry Commission, stated the recommendations to be made to the Legislature by the Commission.

The main features of these were: 1st, that the state should devote to forest cultivation such land unsuited for agriculture as still remains public land and such other lands as may be turned over to it by private companies or the national government; 2nd, that a chief forester be appointed, who in turn should appoint assistants especially to supervise the work of fire-wardens; 3rd, that the condition of forest growth be studied and such measures taken as have been approved by the best forest service in other states and countries. The subject was discussed by Professor Van Hise, who urged that the Commission consult with the President of the State University as to the coordination of the Commission with the University and the State Geological and Natural History Survey. Professor Birge also spoke and thought the forester contemplated in the bill would be of little service beyond that of administration. He cited the State Fish Commission as an example of an efficient body having the direction of work closely related to scientific investigation and expressed the hope that the direction of any work of forestry cultivation would be intrusted to the College of Agriculture of the State University which is well prepared for it.

In presenting paper No. 16, Professor Marsh took occasion to say that the credit for the work done in preparation was largely due to Mr. E. E. Hemingway of Ripon College.

Paper No. 17 was next given. Miss Merrill pronounced the block system as useful in arranging and exhibiting insect collections as the card catalogue is for reference to books in a library.

Papers No. 18, 19, 20, and 21 were given in accordance with the program, but No. 22 was deferred in the absence of the author.

Paper No. 24 was discussed by Messrs. Van Hise, Birge, Schlundt, and others.

AFTERNOON SESSION.

Professor C. H. Chandler reported from the auditing committee that they had examined the vouchers of the Treasurer and found all correct.

The committee on membership recommended the following for active membership:

E. B. Copeland, Madison.
Dr. Otto Dietrich, Milwaukee.
W. H. Dudley, Platteville.
Dr. S. Graenicher, Milwaukee.
E. L. Hancock, Shullsburg.
R. A. Harper, Madison.
V. E. McCaskill, Stevens Point.
Dr. George Meyer, Oconomowoc.
F. E. Millis, Appleton.
Duane Mowry, Milwaukee.
Ole S. Rice, Madison.
H. W. Rohde Madison.
A. W. Tressler, Ripon.
Gustavus Sessinghaus, Madison.

The committee also recommended the following for corresponding membership:

G. P. Bacon, Elgin, Ill.

The secretary was instructed to cast the ballot for all of the candidates recommended. This was done and all were declared elected.

Papers Nos. 25 and 26 were read, but No. 27 was passed over in the absence of the author. Papers Nos. 28 and 29 were read, after which the meeting was declared adjourned.

No evening addresses or sessions were attempted at this meeting, as it was deemed best to leave members free to attend the evening lectures before the State Teachers' Association or for other engagements.

The attendance at the sessions ranged from thirty to forty persons, nearly all members.

The following statement was presented by the Secretary at this meeting as part of his report and accepted:

All of the members-elect of the last annual meeting, with one exception, have since qualified, by the payment of dues.

The membership, as published in Vol. XI of the Transactions, is constituted as follows: Honorary, 6; life, 12; active, 178; corresponding, 55; total, 251.

The account of the printers for Vol. XI was settled in full March 26, 1898. The volume contains 526 pages devoted to original papers and memorial addresses, and 50 pages devoted mostly to the business of the Academy. In pursuance of the resolution passed at the last annual meeting with regard to the publication of separates and the entire volumes, it was agreed by the Secretary of State that Vol. XII should be published in two parts, and that the permit for Part I should be issued when all of the copy for that part was at hand. The permit was issued accordingly May 16, 1898. Since then the printing has proceeded with ordinary facility with the exception of an interruption of one month due to the editor's absence. All of the author's separates are distributed, or should be by this date, and the complete edition is about to be finished. The issue consists of 393 pages, all devoted to original papers. On account of the approaching meeting of the legislature the printers will be unable to take up the Academy work again until next April, at which time it is expected that the printing of Part 2 of Vol. XII will begin.

ALBERT S. FLINT,
Secretary.

THIRTIETH ANNUAL MEETING.

MADISON, WIS., DECEMBER 28-30, 1899.

The present meeting is the first one held in Madison since four years ago. The intervening meetings have been held in Milwaukee in order to avail ourselves of the presence of some of our members at the meeting of the Wisconsin State Teachers' Association, and other advantages of a metropolis.

Of the fourteen candidates elected to active membership at the last annual meeting six have qualified, sending their dues to the treasurer: Dr. Otto Dietrich, Milwaukee; Mr. E. L. Hancock, Shullsburg; Dr. E. B. Copeland, Madison; Prof. R. A. Harper, Madison; Mr. H. W. Rohde, Madison; and Prof. W. H. Dudley, Platteville.

The present membership is as follows: Honorary, 6; life, 10; active, 163; corresponding, 46; total, 225. The secretary and treasurer in consultation have dropped from the active list thirteen names of those whose dues were four dollars or more in arrears and from whom repeated notices by mail elicited no response. The secretary in making up the list of members for Vol. XII of the Transactions, has learned of the decease of two active and six corresponding members. The names of these are printed in Vol. XII of the Transactions.

On account of the extra amount of work required of the state printer during the session of the legislature, the permit for the printing of Vol. XII, Part 2, of the Transactions was not asked for until May 17, 1899. It was then granted, in compliance with the present understanding between all of the officers concerned, that all of the copy for the entire publication shall be at hand. The printers agreed, however, near the close to take on two additional papers, since their interest in the new regulation is simply to avoid long gaps in the progress of the work.

Part 2 is now in press through page 579, closing the list of members. There are yet to follow the list of exchanges, furnished by the librarian, a few shorter divisions, such as the Proceedings, and the index of the entire volume. This last is all written out so far as the volume is printed. The secretary regrets not to have the volume completed before his retirement from office, but Part 2 should be issued now within a few weeks.

The following program as announced for the meeting was carried out without material exception:

Thursday, December 28.—1. A study of the lead regions of Wisconsin, Illinois, and Iowa. *Orin G. Libby.*

2. Household words—their etymology. *James D. Butler.*

3. A problem in longevity. *Charles H. Chandler.*

4. A new geometrical and analytical solution for determining the principal axes at any point of a rigid body. *Charles S. Slichter.*

5. An elementary explanation of the probability curve. *Charles S. Slichter.*

Reading of memorial sketches of the following deceased members: Harlow S. Orton, John G. Meachem, Sr., Christian Preusser, Alice Aikens Bremer, Wayland S. Axtell, James C. Foye.

Evening Session.—Academy banquet, complimentary to visiting members, followed by the address of the retiring president, Professor C. Dwight Marsh, of Ripon College, 8:00 o'clock. "The Plankton of Fresh Water Lakes.

Friday, December 29.—Reports of officers and other general business. Reading of papers.

6. The ice ramparts formed along the shores of lakes Mendota and Monona during the winter of 1898–99. *Ernest R. Buckley.*

7. The principles controlling the deposition of ores. *Charles R. Van Hise.*

8. The nepheline syenite of the Wausau district. *Samuel Weidman.*

9. The graphite deposits of central Wisconsin (preliminary note). *Garry E. Culver.*

10. Chlorine in natural waters—its accurate determination and significance. *Erastus G. Smith.*

11. The action of light on certain nitroso compounds. *Oswald Schreiner.*

12. The sour taste of acid salts and their electrolytic dissociation. *Louis Kahlenberg.*

13. The historical development of chemical symbols from the times of alchemy to the present. (Illustrated by lantern slides.) *Oswald Schreiner.*

Saturday, December 30.—Election of officers and other general business.

Reading of papers.

14. The absorption of the sun's energy by water. *Edward A. Birge.*

15. Some of the undeveloped natural resources of Wisconsin: clays, road materials, and marls. *Ernest R. Buckley.*

16. Account of some work done on the state survey. *Dexter P. Nicholson.*

17. The work of the Wisconsin Geological and Natural History Survey. *Edward A. Birge.*

18. On the changes of length of substances in an alternating magnetic field. *William M. Jolliffe.* (By title.)

THURSDAY, DECEMBER 28th.

AFTERNOON SESSION.

The meeting was called to order by the president, Professor C. Dwight Marsh, at 2:40 p. m. in the geological lecture room, Science Hall.

Paper No. 1 was discussed by Messrs. Van Hise and Buckley; No. 3, by Messrs. E. G. Smith, Daniells, and Slichter; and No. 5, by Professor Daniells.

On motion by Professor Van Hise the president appointed the following as a committee on nomination of officers for the ensuing term of three years: Messrs. Van Hise, Nicholson, and Flint.

EVENING SESSION.

In the evening at six o'clock the local members had the pleasure, in accordance with the printed program, of tendering a complimentary banquet to the visiting members. The Woman's Alliance of the Unitarian church furnished the banquet in the dining room at the church. Eighteen local and nine visiting members sat down at the tables. Professor Slichter presided and after-dinner remarks were made also by Messrs. Daniells, Marsh, and Van Hise. At eight o'clock the company adjourned to the church parlor, where with other friends that had come in they listened to a very interesting address by the retiring president, Professor C. Dwight Marsh.

FRIDAY, DECEMBER 29th.

MORNING SESSION.

The meeting was called to order by the president at 9:45 A. M. in the chemical lecture room on account of the temporary disarrangement of the heating apparatus at Science Hall.

The reports of the secretary and librarian were read by the secretary and accepted.

The report of the treasurer was read by that officer and the following were appointed as auditing committee: Messrs. C. S. Slichter, E. A. Birge, and E. G. Smith.

The committee on membership recommended a list of persons for active membership and the secretary was instructed to cast the ballot for the entire list. This was done and the candidates declared elected. The names are given at the close of these minutes in one list, in alphabetical order, together with several names handed in later.

The reading of papers was then resumed.

Paper No. 6 was discussed by Messrs. Van Hise, Birge, E. G. Smith, Slichter, Owen, and Cheney.

In closing paper No. 7, Professor Van Hise declared that it would be essential for the economic geologist of the future to have a mastery of chemistry as a tool. The paper was discussed by Professor Daniells.

Before adjournment the resolutions passed at the last annual meeting were read by the secretary. After some discussion the following motion offered by Professor Van Hise was adopted: That the council be authorized to make such appropriation as they deem necessary for furnishing an Academy room in the new Historical Library building, provided such room is assigned for the exclusive use of the Academy.

AFTERNOON SESSION.

The meeting was called to order by the president at 2:40 p. m. in the geological lecture room and the reading of papers resumed.

Paper No. 10 was discussed by Messrs. Daniells and Kahlenberg.

Professor E. G. Smith moved on behalf of the visiting members that a cordial vote of thanks be passed to the Madison members for the entertainment of the previous evening and for the many other courtesies shown the visiting members.

SATURDAY, DECEMBER 30th.

MORNING SESSION.

The meeting was called to order by the president at 9:30 a. m. in the geological lecture room.

The auditing committee reported that they had examined the treasurer's accounts and found them all correct.

The committee on nomination of officers submitted the following names. In doing so the chairman, Professor Van Hise, explained that the third name for the publication committee was put in at the insistence of the first two members of the nominating committee:

Your committee on Nominations make recommendations for officers as follows:

For President, Charles S. Slichter, of Madison.
Vice-President for Letters, Harriet B. Merrill, of Milwaukee.
Vice-President for Arts, Charles H. Chandler, of Ripon.
Vice-President for Science, Erastus G. Smith, of Beloit.
Secretary, Frank C. Sharp.
Librarian, Louis Kahlenberg.
Treasurer, Ernest R. Buckley.
Curator, Samuel Weidman.

Publication Committee: The President, *ex officio;* the Secretary, *ex officio;* Albert S. Flint.

Library Committee: The Librarian, *ex officio;* Reuben G. Thwaites, Charles S. Slichter.

Committee on Membership: The Secretary, *ex officio*; John G. Gregory, of Milwaukee; Dexter P. Nicholson, of Appleton; Hiram D. Densmore, of Beloit; John J. Davis, of Racine.

The following two amendments to the Constitution, which had been duly proposed, were then submitted to vote and passed unanimously:—

In *Article V—Council,* after the word "treasurer" add the words "the librarian."

In *Article IX—Amendments,* for the words "three months" substitute the words "one month."

The committee on membership recommended several additional names for active membership and two names for corresponding membership. The secretary was instructed to cast the ballot of the meeting for all the names as recommended. This was done and the candidates declared elected. The list of all the persons elected at the annual meeting is as follows:

ACTIVE MEMBERS.

L. O. Atherton
Helen Blair
Emma Cowles, Milwaukee
Clarke Gapen
H. W. Griggs
L. M. Hanks
J. T. W. Jennings
J. B. Johnson
W. M. Jolliffe
T. R. Ll-Jones, Hillside
W. G. Kirchoffer, Baraboo
C. K. Leith
C. E. Magnusson
G. C. Mors
S. V. Peppel
Ellen C. Sabin, Milwaukee
T. K. Urdahl
J. M. Winterbotham

CORRESPONDING MEMBERS.

Dr. George W. Moorehouse, Cleveland, Ohio.
Prof. Ormond Stone, University of Virginia.

The residence of the members-elect is at Madison unless otherwise specified.

The reading of papers was then resumed.

Paper No. 14 was discussed by Messrs. Van Hise and Slichter and No. 15 by Prof. Van Hise.

In presenting paper No. 17 Prof. Birge asserted that more money probably was expended in Wisconsin by the U. S. Geological Survey the past year than by the State Survey itself.

The attendance at the several sessions of the meeting had ranged from twenty-five to thirty.

The program having been completed and all business on the calendar attended to, the meeting was adjourned in good season for the visiting members to take the noon trains for their homes.

Albert S. Flint,
Secretary.

REPORT OF LIBRARIAN, 1897.

The librarian would beg leave to call the attention of the academy in his report to two things, namely, the present inaccessibility of the library, and the plan of work which he desires to follow during his term of office. The present librarian entered upon his duties but a short time before the meeting of the Legislature; and as soon as that body began its session, the room of the academy was partitioned, one part being used as a committee room, and the other serving as a cloak room for the members of the Legislature. This partition still remains; the former cloak room being at present the headquarters of one of the capitol janitors, while the second and larger part of the room was, soon after the adjournment of the Legislature, given to the Free Library commission, and is at present used by them. The steady growth of the library has nearly filled all available case room; and the librarian, but a short time ago, found it necessary to have all the back numbers of the Transactions of the academy, which were stored underneath the book cases, removed to Science Hall, to give him some place to put the rapidly accumulating material. Owing to these circumstances the usefulness of the library is at present very much curtailed, and the time is not far off when it will be necessary—all available shelf-room having been completely filled—to store the more recent acquisitions to the library in some place other than the academy room.

The librarian has deemed it advisable to pay particular attention to the increase of the exchange list. While but four new exchanges have been added to the list during the past year, the librarian is preparing a list of societies whose publications it would be advisable to have and hopes to effect a number of exchanges. Now, while the library has of necessity lost much of its usefulness, it seems advisable to pay particular attention to this point, and give the time to the increase of the library which later must go towards arranging it when the academy will be so fortunate as to occupy other quarters..

Madison, Wis., December 27, 1897.

REPORT OF LIBRARIAN, 1898.

Following the line of work outlined in his last report the librarian has endeavored to increase the exchange list of the academy, having however, during the year, restricted the work entirely to foreign societies, leaving those within the United States to be worked over during the coming year. The director of the state survey has added very much to the possibilities of this work by placing the first two Bulletins of the survey at the disposal of the librarian, who thus combining the publications can undoubtedly obtain many more exchanges than could be procured by the Transactions of the academy alone.

Having received from the Smithsonian Institution a copy of its foreign exchange list, the librarian carefully marked the names of those institutions with whom he thought an exchange desirable; the same list was then examined by the director of the survey who marked many additional exchanges. Each of these institutions will receive copies of the first two Bulletins of the survey, volume XI of the Transactions of the academy, and a circular requesting them to exchange their publications with the academy. While a large number of these requests have been forwarded to scientific societies, other branches of the academy are well represented; and we hope that the increase to the library resulting from this work—five hundred and fifteen requests having been sent out—will be extremely beneficial to all members.

Madison, Wis., December 27, 1897.

REPORT OF LIBRARIAN, 1899.

A brief view of the principal work done by the librarian during his term of office is best given as follows:

1st. Acknowledging the receipt of all exchanges received during the last three years;

2nd. Distributing volume XI and volume XII, part I, of the Transactions;

3rd. Sending nearly five hundred copies of the volume XI of the Transactions to foreign institutions, and with each volume a circular letter requesting that, should its publications warrant it, the Wisconsin academy be placed upon their exchange list;

4th. Sending, with the same request, forty copies of volume XII, part I, of the Transactions, to societies within the United States.

It is as yet impossible to report what number of new exchanges has been added by the method adopted by the librarian, as answers are continually being received, and it will be some time before the final result can be obtained. The only report to be made is that, during my term of office, ninety-two new exchanges have been added to our list.

No list of the exchanges received by the Academy having been printed since the publication of volume IX of the Transactions, it was thought advisable to publish a new list, that the members might know what exchanges were being received by the Academy.

This list, it is hoped, will be of use to the members in showing them what exchanges are in the library, and also useful to the librarian in that the members, having this list, can add to their copies the names of any societies with which an exchange would be desirable, and then report these to the librarian.

A letter from the Smithsonian Institution reported that fifty-four copies of volume XII, part I, of the Transactions were destroyed by the burning and sinking of the steamship "Patria" of the Hamburg-American Line; but, as a list of the societies to which these copies were sent had been kept in Washington, another copy has in each case been furnished.

WM. S. MARSHALL,
Librarian.

Madison, Wis., December 28, 1899.

REPORT OF TREASURER, 1898.

The following statement of the financial transactions of the Academy for the year ending Dec. 27, 1898, is herewith respectfully submitted:

Receipts.

Dues and fees from members, Dec. 29, 1897, to Dec. 27, 1898	$187 00	
Interest on bond for one year	50 00	
Balance in treasury Dec. 28, 1897	241 27	
		$478 27

Disbursements.

Jan. 11.	To L. S. Cheney for cash paid for stamps, Vr. 1	$5 00
Jan. 24.	To Taylor & Gleason for printing (Treasurer), Vr. 2	4 50
Feb. 14.	To Tracy, Gibbs & Co., for printing (Secretary), Vr. 3	19 25
Feb. 24.	To L. S. Cheney for cash paid for stamps, Vr. 4	1 00
Mch. 5.	To A. S. Flint, for hired clerical services, postage and stationery, Vr. 5	12 97
Mch. 19.	To H. B. Merrill, for typewriting and postage, Vr. 6	6 00
Mch. 19.	To Burdick, Armitage & Allen, printing, Vr. 7	4 50
Apr. 13.	To Tracy, Gibbs & Co., for printing (Librarian), Vr. 8	9 50
Apr. 13.	To Capital City Paper Co., for paper and twine, Vr. 9	1 43
Apr. 13.	To H. A. Buehler, for clerical services (Librarian), Vr. 10	5 40
Sep. 21.	To Franklin Engraving and Electrotyping Co., zinc plates, Vr. 11	1 73
Sep. 30.	To E. G. Birge, for clerical services (Librarian), Vr. 12	2 55
Sep. 30.	To Capital City Paper Co., for mdse. (Librarian), Vr. 13	2 12

Oct. 6.	To L. S. Cheney, for cash paid for stamps, Vr. 14	3 00	
Dec. 12.	To A. S. Flint, for postage, stationery and express, Vr. 15	10 44	
			$89 39
	Balance		$388 88

L. S. Cheney,
Treasurer.

Madison, Wis., December 27, 1898.

We certify that we have this day examined the report of L. S. Cheney, treasurer of the Wisconsin Academy of Sciences, Arts and Letters and find it to be in due form, properly vouched, and correctly balanced.

G. E. Culver,
C. H. Chandler,
E. R. Buckley,
Auditing Committee.

Madison, Wis., December 28, 1898.

REPORT OF TREASURER, 1899.

The following statement of the financial transactions of the Academy for the year ending Dec. 27th, 1899, is herewith respectfully submitted:

Receipts.

Dues and fees from members from Dec. 27, 1898, to Dec. 27, 1899	$139 00
Interest on bond for one year	50 00
Balance in treasury, Dec. 28th, 1898	388 88
Total	$577 88

Disbursements.

Jan. 11.	To capital City Paper Co., paper for librarian	$3 82
	To Tracy, Gibbs & Co., postals and printing for librarian	4 85
	To B. F. Coen, clerical work for librarian	60
	To J. R. Hegg, clerical work for librarian	5 00

Jan. 23.	T. C. W. Jarvis, carting books for librarian..	7 50	
	To J. R. Hegg, clerical work for librarian...	5 17	
	To W. S. Marshall, cash expended for academy	2 00	
Feb. 14.	To L. S. Cheney, cash paid for stamps......	5 00	
	T. C. D. Marsh, expenses for Academy......	1 61	
	To Miss H. B. Merrill, cash for lantern service	5 00	
	To Tracy, Gibbs & Co., printing for secretary.	15 70	
Mch. 10.	To Helen Flint, clerical services for secretary	1 72	
	To Wm. Burrowbridge, carting books for librarian	3 25	
	To E. D. Clifford, typewriting for secretary.	1 89	
Apr. 18.	To J. R. Hegg, clerical services for librarian.	4 87	
	To Capital City Paper Co., paper for librarian	2 12	
Sep. 30.	To L. B. Wolfenson, clerical services for librarian	10 65	
Oct. 2.	To L. S. Cheney, postage stamps............	5 00	
Oct. 3.	To W. S. Marshall, postage and drayage.....	11 55	
Oct. 19.	To Franklin Eng. & Elect. Co., making plates.	35 14	
Oct. 20.	To stamps received for dues applied for use of society	1 00	
Dec. 18.	To J. R. Hegg, clerical work for librarian..	1 65	
	To Franklin Eng. & Elec. Co., making plates	4 36	
			$139 45

Receipts	$577 88
Disbursements	139 45
Balance	$438 43

L. S. Cheney,
Treasurer.

Madison, Wis., December 28, 1899.

Madison, Wis., Dec. 30, 1899.

We have this date examined the accounts of the Treasurer and found them to be all correct and properly vouched for.

Chas. S. Slichter,
E. A. Birge,
E. G. Smith,
Auditing Committee.

Madison, Wis., December 28, 1899.

TRANSACTIONS OF THE WISCONSIN ACADEMY OF SCIENCES, ARTS, AND LETTERS.

GENERAL INDEX.

Vol. XII, Parts 1 and 2, 1898-99.