FRESHWATER INVESTIGATIONS DURING THE LAST FIVE YEARS.

HENRY B. WARD.

It is just five years since the first report was published from the Plön Biological Station, the first general public enterprise of that character founded on fresh water and devoted to the solution of its problems. It is also just five years this summer since the Michigan Fish Commission inaugurated work on the Great Lakes by opening a laboratory on Lake St. Clair. The Plön station has given a great impetus to freshwater work in Germany, and to the efforts of the Michigan Fish Commission and its corps of scientists can be traced much of the energy now devoted to lacustrine investigation in this country. The half decade which has intervened since 1893 has seen great progress in this field and in view of the general interest taken in fresh water work at the present time it may not be adjudged untimely to give a résumé of the results achieved during this brief period. It seems fitting also to publish in this connection a bibliography which has been the result of much work on my part and which I hope may be of some service to other workers in this field, especially as no extended bibliography on this subject has yet been published and no summary of progress in this line is available in English at least.

While no effort has been spared to make the list of papers complete, it is too much to hope that no reference has been omitted which should have a place in its columns. On the main lines of investigation, however, I hope that no important article has been overlooked, but I should esteem it a favor to have errors or omissions called to my attention by those who note them. So far as possible all references have been verified from the original and have been abstracted for the summary of progress, but in case of those articles not accessible, which in the list are designated by a star, it seemed better to make use of such reviews as were at hand in the various journals, or given in brief form on the cards of the Bibliographical Council at Zurich, in order that the cross references might be as complete as possible.

Of course such a bibliography could not reasonably be expected to give all references on some subjects which are in part included so that it is perhaps wise to state more specifically the limits of the work undertaken. With the exception of a single reference to Hensen, the father of plankton methods, a reference indispensable to all work, no mention has been made intentionally of any paper except as it deals in part at least with freshwater investigations. Nevertheless, some of the papers not seen may easily be devoted to marine studies even though no reference thereto is contained in the title. The bibliography is also essentially confined to zoological refercnces although some of the important papers on physical, chemical and botanical topics are cited. The papers of this character given are quoted from many sources, yet certainly do not comprehend all of importance on these topics. Their inclusion here is justified by their importance and bearing on the general problems of fresh water work, their immediate relation to the studies of certain investigators and localities, or their occurrence in such sources as render them easily accessible to the general student. Under the topics of taxonomy and geographical distribution, also, no effort has been made to collate all possible references; the endeavor has been rather to include all those papers of general or special interest and those of most immediate importance and accessibility to American students. Undoubtedly there is room here for cousiderable difference of opinion and the special student of a particular group or region will not find this bibliography extensive enough for his purposes, but I hope none the ess that it may be sufficiently representative to give a succinct and precise idea of the extent of our knowledge as to the distribution and composition of the freshwater life of the globe and the conditions under which it is found. In the systematic part greater emphasis is laid upon those groups which are plankton forms, whereas others have received at most passing attention. There is also a considerable amount of literature bearing upon the technical phases of the subject, in its relation for instance to the purity of a city water supply, which has been included so far as references were found without any effort having been made to cover the entire ground.

It is in dealing with the field of plankton work that I have endeavored to include every article, however small, and to add references to such reviews as were noted in order to make the contents of the original articles more widely useful. In this I have been greatly aided by the admirable reviews of Zschokke in the Zoologisches Centralblatt; more recently Kofoid has undertaken similar abstracts in the American Naturalist. No effort has been made however to distinguish here between comments, reviews, and abstracts, or to include all such notices in the bibliography. A slight delay in the printing of the paper enables me to include references up to the close of 1898.

In so extended a review the method of citation must necessarily be brief yet such as to allow of the ready finding of papers cited. I have adopted the following:—The name of the author together with the year of publication of the article, bearing a letter affixed if necessary, forms the designation of the paper. The title of the article is not abbreviated, but written precisely as given by the author. The name of the journal is shortened as much as consistent with clearness and three or four which are in constant use, are designated as follows :

B. C. Biologisches Centralblatt.

J. R. M. S. Journal of the Royal Microscopical Society, London.

Z. A. Zoologischer Anzeiger.

Z. C. Zoologisches Centralblatt.

The abbreviations *vol.*, *pt.*, *p.*, etc., are entirely omitted but the following arbitrary order of arrangement will enable any reference to be read with ease.

The number of the volume is printed in lower case Roman numerals, and comes first, except that an antecedent Arabic figure may designate the series, if such exist. All other numbers are Arabic, and the last of these bearing no added designation is the page number. The latter may however be followed by the number of figures or plates in which case these numbers are always accompanied by a designative abbreviation, *fig.* or *pl.* The number, part, or article, is quoted only when paged separately, unless there was some uncertainty concerning some other part of the reference. Many references are incomplete, because (1) the article was entirely inaccesible, (2) the reprint in my library did not show the precise location of the article, or (3) disagreement between my card catalogue and the printed reference in one of the bibliographical records left uncertain the source of the error, and the paper referred to was not accessible here.

An example will perhaps make the method of citation clearer:

xiv, 4, means vol. xiv, page 4.

xiv, 4, 4, means vol. xiv, part or number 4, page 4.

4, xiv, 4, 4–42, means series 4, vol. xiv, part 4, page 4–42.

xxi, 1–3, 17–92. 4 pl. 7 fig., means vol. xxi, part 1 to 3, p. 17 to 92, 4 plates, and 7 text figs.

It is but fitting that I should acknowledge here my indebtedness to the various sources of information especially the bibliographical records in zoology; to the many individuals only a general acknowledgment of the courtesies can be made, but of my debt to Professor J. E. Reighard of the University of Michigan, who kindly placed his entire card catalog at my service, special mention should be made.

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Rev. Z. C., iii, 203-5.

96a. A New Method for the Quantitative Determination of Plankton Hauls.
Trans. Amer. Mic. Soc., xvii, 255-60; also in Stud. Zool. Lab. Univ. Nebr., No. 13.
Rev. Z. C., iii, 225; Ber. Fisch. Ver. Ost-Preussen.

96b. A Biological Examination of Lake Michigan in the Traverse Bay Region.
Bull. Mich. Fish. Comm., 6, 1-71, 5 pl.; also in Stud. Zool. Lab. Univ. Nebr., No. 16.
Rev. Z. C., iv, 176-7; J. R. M. S., 97, 25; cf. Nat. Sci., x, 8-9.

98. Report of the Zoologist. Fish Food in Nebraska Streams.
Ann. Rept. Nebr. Bd. Agr., 97, 272-9; also in Stud. Zool. Lab. Univ. Nebr., No. 28.
Rev. Z. C., v, 606.
Brief discussion of conditions and list of species found.

98a. Aquacultural Experiment Stations and their Work.
Proc. Amer. Fish. Soc., xxvii, 125-9.

WARD, R. H.

95. Improved Methods of Collecting Aquatic Micro-Organisms.
Amer. Mo. Mic. Jour., xvi, 33-41. 1 pl.

WARREN, H. E., AND WHIPPLE, G. C.

95. The Thermophone, a New Instrument for Obtainining the Temperature of a Distant or Inaccessible Place and Some Observations on the Temperature of Surface Waters.
Amer. Meteorol. Jour., xii, 35-50. 2 pl.

*95a. The Thermophone, A New Instrument for Determining Temperatures.
Tech. Quar., viii.

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98. Faune rotatorienne du bassin du Léman (1re partie).
Rev. Suisse Zool., v, 263-354. 6 pl.
Abst. Am. Nat. xxxiii, 163.

98a. Faune rotatorienne du bassin du Léman (2me partie).
Rev. Suisse Zool., v, 355-785. 10 pl.

WEBER, M.

*97. Beiträge zur Kenntniss der Fauna von Süd-Afrika, I. Zur Kenntniss der Süsswasserfauna von Südafrika.
Zool. Jahrb., Abt. Syst., x, 135-200. 1 pl. 2 charts.
Rev. Z. C., iv, 825-8; J. R. M. S., 97, 275.

WELTNER, W.

*94. Forschungsberichte aus der Biologischen Station zu Plön.
Zeit. f. Fischerei, ii, 5.

*95. Spongillidenstudien, III. Katalog und Verebreitung der bekannten Süsswasserschwämme.
Arch. f. Naturges., 95, i, 114-44.
Rev. Z. C., ii, 521-2.
Taxonomic; data on distribution, regions, etc.

95a. Biologische Süsswasserstationen.
In M. von dem Borne, Künstl. Fischzucht, Berlin, 186-96. 16 fig.

*96. Die Cladoceren Ost-Afrikas.
Deutsch Ostafrika, iv.

*96a. Die Coelenteraten und Schwämme des Süssen Wassers Ostafrikas.
Deutsch Ostafrika, iv, 1-8. Rev. Z. C., iv, 401.

WESENBERG-LUND, C.

*94. Grönlands Ferkswandentomostraca, I. Phyllopoda branchiopoda et Cladocera.
Vid. Med. Nat. Forh. Kjobenhavn. p. 82.

*96. Biologisk Undersogelser over Ferskvandorganismer.
Vid. Meded. Nat. Forh. Kjobenhavn, (5), vii, 105-74.

98. Ueber dänische Rotiferen und über die Fortpflanzungsverhältnisse der Rotiferen.
Z. A., xxi, 200-11. Rev. J. R. M. S., 98, 309.

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94. Some foreign Rotifers to be included in the British Catalogue.
Jour. Quekett Mic. Club, 2, v, 420-6.
Rev. Z. C., iv, 181-2.
Faunal list with important biological data.

WHIPPLE, G. C.

94. Some Observations on the Growth of Diatoms in Surface Waters.
Tech. Quar., vii, 214.
Rev. J. R. M. S., 95, 345; Amer. Mo. Mic. Jour., xvi, 140-5.

94a. Synura.
Amer. Mo. Mic. Jour., xv, 257-62. 1 pl.
Cf. Ann. Rept. Boston Water Board, xviii.

94b. A Standard unit of size for Micro-Organisms.
Amer. Mo. Mic. Jour., xv, 377-81, 2 fig. 1 pl.
Abst. J. R. M. S., 95, 386.

95. The Thermophone.
Science, n. s., ii, 639-43.

95a. Some Observations on the Temperature of Surface Waters; and the Effect of Temperature on the Growth of Micro-Organisms.
Jour. New Eng. W. W. Assn., ix, 202-22. 5 pl.

96. Experience with the Sedgwick-Rafter Method at the Biological Laboratory of the Boston Water Works.
Tech. Quar., ix, 275-9.

96a. Some Observations on the Relation of Light to the Growth of Diatoms.
Jour. New Eng. W. W. Assn., xi, 1-26. 5 pl.

*96b. Report on the Organisms in the Boston Water Supply.
Ann. Rept. Boston Water Works, xix.

97. Microscopical Examination of Water, with a Description of a Simple Form of Apparatus.
Science, n. s., vi, 85-9.

97a. Raphidomonas.
Jour. New Eng. W. W. Assn., xi, 348-56. 1 pl.
Extraordinarily abundant in Lynn water supply on one occasion.

97b. Biological Studies in Massachusetts, No. 1.
Am. Nat., xxxi, 503-8. 2 pl.

97c. Biological Studies in Massachusetts, No. 2. Microscopical organisms.
Am. Nat., xxxi, 576-81.

97d. Biological Studies in Massachusetts, No. 3. Geographical distribution of microscopical organisms.
Am. Nat., xxxi, 101-626.

98. Classification of Lakes according to Temperature.
Am. Nat,, xxxii, 25-33.

*98a. Some Observations on the Growth of Organisms in Water Pipes.
Jour. New Eng. W. W. Assn., xii, 1.

WIERZEJSKI, A.

93. Die Räderthiere Galiziens. (Czeckish; German abstract).
Anz. Akad. Wiss. Krakau, xxvi, 161-265. 3 pl.

*95. Przeglad fauny skorupiakow galicyjskich-Krakau, 56 pp. 1 pl.
German resumè as Uebersicht der Crustaceen-Fauna Galiziens.
Anz. Akad. Wiss. Krakau, Juni 95, 170-8.
Rev. Z. C., ii, 346-7.
Systematic-faunistic.

WILLE, N.

96. Resultate einer vorläufigen Untersuchung über Organismen in Christiania-Trinkwasser. (Mitth. Biol. Ges. Christ., 17 Okt. 95).
B. C., xvi, 125-6.

WOLCOTT, R. H.

94. The Insecta and Acarina of Lake St. Clair. A Preliminary Report.
Bull. Mich. Fish Comm., 4, 55-6.
Systematic-faunistic.

98. New American Species of the Genus Atax (Fab.) Bruz.
Zool. Bull., i, 279-85, 6 fig; also Studies Zool. Lab. Univ. Nebr., No. 23.
Systematic-faunistic.

WOLTERSTORFF, W.

*96. Die "Zoologische Station" des naturwissenschaftlichen Museums zu Magdeburg.
Blatter f. Aquar. u. Terr. Freunde, vi, 13-5.

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96. Preliminary report on Collections of Turbellaria from Lake St. Clair and Charlevoix, Michigan.
Bull. Mich. Fish Comm., 6, 94-5.
Faunal list with notes.

96a. Report on the Turbellaria collected by the Michigan State Fish Commission during the Summers of 1893 and 1894.
Bull. Mus. Comp. Zool., xxix, 239-43. 1 pl.

97. On some Turbellaria from Illinois.
Bull. Mus. Comp. Zool., xxxi, 1-16. 1 pl.
Systematic-faunistic study. Valuable bibliography.

YUNG, E.

97. Le Plankton d'eau douce.
La Semaine Littéraire, 97, 519-21.
Popular discussion of methods, investigators and results.

ZACHARIAS, O.

93. Forschungsberichte aus der biologischen Station zu Plön.
I. Fauna des grossen Plöner Sees. II. Beschreibungder neuen Formen. III. Biologische Mittheilungen.
Theil 1, Berlin, 52 pp. 1 taf.

93a. Die mikroskopische Organismenswelt des Süsswassers in ihrer Beziehung zur Ernährung der Fische.
B. C., xiii, 155-60; Jahresb. Centr. Fisch. Ver. Schles.-Holstein.

93b. Fauna des Grossen Plöner Sees.
B. C., xiii, 377-82. (From Forsch-ber. Biol. Stn. Plön, i.)
Merely a list of species.

94. Forschungsberichte aus der Biologischen Station zu Plön.
Theil 2, Berlin, vii and 155 pp. 2 taf. 1 landkarte.
Rev. Z. C., i, 215-8.

94a. Faunistische Mittheilungen.
Forsch-ber. Biol. Stn. Plön, ii, 57-90.

94b. Forschungsergebnisse am Grossen Plöner See.
Z. A., xvii, 33-5.
Review of two years work at Plön.

94c. Beobachtungen am Plankton des Grossen Plöner Sees.
Forsch-ber. Biol. Stn. Plön, ii, 91-137.

94d. Ueber die Vertheilung der Planktonorganismen innerhalb eines Sees. (From Forsch-ber. Biol. Stn. Plön, ii.)
B. C,, xiv, 122-8; Trans. Rev. Biol. Nord France, vi, 185-94; Boll. Sci., xvi, 89-92, 113-16; Abstr. J. R. M. S., 94, 552.

94e. Ueber Periodizität und Vermehrung der Planktonwesen.
B. C., xiv, 226-30.

94f. Aus der biologischen Süsswasser-Station am Gullsee in Minnesota.
B. C., xiv, 299-300.
Review of Nachtrieb, 94.

94g. Die biologische Süsswasserstation der Universität von Illinois.
B. C., xiv, 559-60.
Review of Forbes, 94.

94h. Biologische Untersuchungen in amerikanischen Seen.
B. C., xiv, 605-7.
Short review of the work of Reighard and Ward.

94i. Ueber die wechselnde Quantität des Planktons im Grossen Plöner See.
B. C., xiv, 651-6.
Rev. Z. C., i, 736; J. R. M. S., 94, 552.

94k. Das dritte Arbeitsjahr der Biologischen Station zu Plön.
Z. A., xvii, 448.

94l. Statistische Mitteilungen über das Plankton des Grossen Plöner Sees.
Z. A., xvii, 457-61.

95. Forschungsberichte aus der Biologischen Station zu Plön. Theil 3. Berlin. 209 pp. 2 pl. 3 tab.
Rev. Z. C., ii, 70-3.

95a. Faunistische Mittheilungen.
Forsch-ber. Biol. Stn. Plön, iii, 73-96. 2 taf.
Description of new species and data regarding known forms.

95b. Ueber die wechselnde Quantität des Plankton im Grossen Plöner See.
Forsch-ber. Biol. Stn. Plon, iii, 97-117.
Based on weighings made regularly from March to September.

95c. Ueber die horizontale und verticale Verbreitung limnetischer Organismen.
Forsch-ber. Biol. Stn. Plon, iii, 118-28.

95d. Fortsetzung der Beobachtungen über die Periodicität der Planktonwesen.
Forsch-ber. Biol. Stn. Plön, iii, 129-44.
Record of daily observations throughout the year.

95e. Statistische Mitteilungen aus der Biologischen Station am Grossen Plöner See. II-XII.
Z. A., xviii, 28-29, 70-1, 87-9, 125-7, 140-2, 190-3, 256-9, 305-8, 367-71, 414-9, 448-52.
Tables of amount and composition of plankton hauls.

*95f. Uber die Ziele und Gesichtspunkte einer wissenschaftlichen Durchforschung der Süsswasserbecken.
Deutsche Fisch. Zeit., xviii, 89-91. (Beilage.)

95g. Ueber den Unterschied in den Aufgaben wandernder und stabilier Süsswasserstationen.
B. C., xv, 378-84.

95h. Ueber den Frühjahrs-Vegetation limnetischer Bacillariaceen im Gr. Plöner See.
B. C., xv, 517-9.

95i. Ueber die vertikale Verteilung limnetischer Crustaceen, insbesondere über diejenige von Cyclops oithonoides.
B. C., xv, 686-8.
Rev. Z. C., iii, 324-5; J. R. M. S., 95, 631.

95k. Ueber die Möglichkeit einer biologischen Bonitierung von Fischteichen.
B. C., xv, 847-8.

*95l. Ueber das Gewicht und die Anzahl mikroskopischer Lebewesen in Binnenseen.
Helios, xiii, 103-5, 113-9. Also in Gaea, 1896, 1, 31-6.

*96. Planktonmessungen im Grossen Plöner See.
Corr. Bl. f. Fischzucht, iii, 7-8.

96a. Sucherokular mit Irisblende.
B. C., xvi, 30-1; also Forsch-ber. Biol. Stn. Plön, iv, 288-90.

*96b. Ueber Periodicität und Vermehrung der Planktonwesen.
Zeit. f. Fischerei, ii, 149-53.
96c. Ueber der natürliche Nahrung der jungen Wildfische in Binnenseen.
B. C., xvi, 60-6.
*96d. Orientirungsblätter für Teichwirthe und Fischzüchter.
1. Die naturliche Nahrung der jungen Wildfische in Binnenseen.
2. Verschiedene Mittheilung über das Plankton unserer Seen und Teiche.
Plön, 8°, 12 pp, and 16 pp.
96e. Forschungsberichte aus der Biologischen Station zu Plön.
Theil 4. Berlin. 290 pp. 1 taf. 45 fig. 1 karte.
96f. Quantitative Unterschungen über das Limnoplankton nebst Anleitung zur Vornahme von Zahlungen und Volumenmessungen.
Berlin. 64 pp. From Forsch-ber. Biol. Stn. Plön, iv, 1-64.
Rev. Z. C., iii, 445-7.
96g. Ergebnisse einer biologischen Excursion an die Hochseen des Riesengebirges.
Forsch-ber. Biol. Stn. Plon, iv, 65-87.
96h. Monatsmittel der Plankton-Volumina.
B. C., xvi, 803-6.
Abst. Z. C., iv, 52.
97. Forschungsberichte aus der Biologischen Station zu Plön.
Theil 5. Stuttgart. 180 pp. 4 taf. 1 tab.
97a. Neue Beiträge zur Kenntniss des Süsswasserplanktons.
Forsch-ber. Biol. Stn. Plön, v, 1-9. 1 taf.
Description of new limnetic species.
97b. Biologische Beobachtungen an den Versuchsteichen des Schlesischen Fischereivereins zu Trachenberg.
Forsch-ber. Biol. Stn. Plön, v, 10-28.
97c. Zur Mikrofauna der Sandforter Teiche.
Forsch-ber. Biol. Stn. Plön, v, 112-4. 1 text fig.
List of forms from fish ponds; cf. Lemmermann, 97.
*97d. Leipziger Plankton.
Zeit. f. angew. Mikr., iii, 141-6.
98. Das Heleoplankton.
Z. A., xxi, 24-32; Rev. Z. C., v, 160-1
98a. Das Potamoplankton.
Z. A., xxi, 41-8; Rev. Z. C.,v, 161.
98b. Forschungsberichte aus der Biologischen Station zu Plön.
Theil 6. Abt. 1, Stuttgart. 87 pp. 3 pl.
Rev. B. C., xviii, 299-301.
98c. Summarischer Bericht über die Ergebnisse meiner Riesengebirgsexcursion von 1896.
Forsch-ber. Biol. Stn. Plön, vi, 1-8; Rev. Z. C., v, 353.
98d. Forschungsberichte aus der Biologischen Station zu Plön.
Theil 6. Abt. 2, 87-219. 2 taf. 1 karte.
Rev. B. C., xviii, 718-20.

98e. Untersuchungen über das Plankton der Teichgewässer.
Forsch-ber. Biol. Stn. Plön, vi, 89-139. 1 taf.
Rev. Z. C., v, 488-9.

98f. Ueber einige interessante Funde im Plankton sächsischer Fischteiche.
B. C., xviii, 714-8.

98g. Ueber die mikroskopische Fauna und Flora eines im Freien stehenden Taufbeckens.
Z. A., xxi, 670-3.

ZACHARIAS AND LEMMERMANN.

96. Ergebnisse einer biologischen Excursion an die Hochseen und Moorgewässer des Riesengebirges.
Berlin. 80 pp. 26 fig. 1 pl. (From Forsch-ber. Biol. Stn. Plön, iv).
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95. Les observations du Dr. Hofer sur le Plancton dans le lac de Constance.
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Rev. Z. C., iii, 315.

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98. Ueber tierisches Potamoplankton.
B. C., xviii, 522-4; Rev. Z. C., v, 605; J. R. M. S., 98, 528.

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95. An Attempt to Explain the Origin of the Fauna of Lakes in European Russia. (Russian).
Bull. Ac. Imp. St. Pet., iii, 2. 19 pp. 1 map.

96. Essai d'explication de l'origine de la faune des lacs de la Russie d' Europe, (Communication preliminaire).
C. R. III. Cong. Int. Zool. Leyde, 183-95. Rev. Z. C., iii. 581-3.

97. What the Hydrobiologic Station on Lake Glubokoe (Deep Lake) Has Done and Ought to do. (Russian).
Arb. Ichth. Sect. K. Russ. Acclim. Ges., ii, 202-6. 1 pl.
Rev. Z. C.. iv, 430-2.

ZSCHOKKE, F.

94. Die Tierwelt der Juraseen.
Rev. Suisse Zool., ii, 349-76. 1 Taf.
Rev. Z. C., i, 737-8 (= Zschokke, 94a); J. R. M. S., 95, 42.

94a. Neuere Arbeiten über die Tierwelt des süssen Wassers.
Z. C., i, 733-8.

95. Die Fauna hochgelegener Gebirgseen (with appendix by Stingelin).
Verh. Naturf. Ges. Basel, xi, 36-133. 1 pl.
Rev. Z. C., ii, 99-102: B. C., xv, 506-17 (= Imhof, 95, q. v.).

95a. Die biologische Station zu Plön nach den Forschungsberichten. Teil 2 u. 3. B. C., xv, 408-15.

97. Fauna Helvetica. Seenfauna.
Bibl. schweiz. Landeskunde, iv, 6, 24 pp. Rev. Z. C., v, 353-4.
Including references to all forms except insects, from 1680-1897.

SUMMARY OF PROGRESS.

Among the general works treating of freshwater subjects the limnologic monograph of Forel easily deserves the foremost place, both by virtue of the breadth of its scope and by reason of the completeness and precision of its treatment. Planned to cover the entire field for a single lake, Geneva in Switzerland, the work is worthy of the magnificent sheet of water with which it deals. It is truly monographic and an indispensable aid to every limnologic enterprise. Thus far but two volumnes have appeared, the first of which (Forel, 92) falls really just without the time limits of this review, yet for completeness calls for mention here. It first deals with the apparatus employed and the plan of the entire work, and then covers the sections on I Geography, II Hydrography, depth, shore, bottom, III Geology, IV Climatology, V Hydrology, sources, outflow, level. The second volume (Forel, 95) handles sections VI Hydraulics, current, movements, *seiches*, waves, VII Thermics, VIII Optics, transparancy, color, mirages, IX Acoustics, X Chemics, density, odor and value as drinking water.

The American student possesses in Russell (95) a valuable discussion of the geologic and physiographic features of North American lakes and lake systems. Lampert (98) has given a semi-popular yet thorough and accurate presentation of life in fresh-water. The larger part of the work is devoted to a systematic and biologic description of the genera which occur in the German waters, but there are also important chapters on the history of freshwater investigation and on general limnologic questions. Apstein has published (96) a convenient and valuable work on the freshwater plankton which presents the extensive investigations of the author on Holstein lakes in comparison with the results achieved by other workers elsewhere. The details of the work are referred to under special topics later in this article. Klunziger (97) has given an admirable review of the methods and results of plankton work, with special reference to the problems of fish culture, and Field (98a) has presented a concise study of the same question.

But few bibilographies bearing upon the subject of freshwater investigations have yet been published. That of Dolley (96) is most largely marine, while those of Apstein (96) and Field (98a) are exclusively confined to plankton studies. Others treating of single genera or groups occur in systematic papers on these forms.

The work of Mez (98) is rather of a technical character for use in water analysis and treats of Protozoa alone among animal forms, discussing particularly their relation to the quality of the water and their dependence upon its physical and chemical character. American students are awaiting eagerly a somewhat similar work by Whipple, which is already announced.

Stokes (96) is a convenient summary, largely taxonomic, of freshwater genera; it contains, however, data on apparatus for collecting and notes of a biological character.

In the line of apparatus for special work on limnetic questions much has been done and yet mostly in the direction of adapting that used in marine investigations to the conditions in fresh water. A recent and comprehensive discussion of the former may be found in Hensen (95), whose assistant, Apstein, was the first to apply the same methods to freshwater studies; the latter has given (96) an extended account of the forms of apparatus used in his plankton investigations and somewhat generally applied by others also. Forel (92, 95) mentions numerous pieces of apparatus used in physical, chemical and metereological studies on Lake Geneva. Here also Ule (94). Frič and Vávra's account (94) includes figures of many kinds of smaller collecting appliances, and Klunziger (97) refers in a general way to plankton apparatus. R. H. Ward (95) speaks of the advantages of the Birge net, particularly in shore collecting and among marsh plants.

Of new physical apparatus, the thermophone invented by Warren and Whipple (95, 95a; cf. also Whipple, 95) is undoubtedly the best instrument yet devised for recording water temperatures. See Linsbauer (95) for a method of determining the amount of light at a given depth.

The vertical net, planned by Hensen and first used by Apstein in fresh water, is described by the latter (96). Some improvoments in detail were made by Reighard (94a) and by Kofoid (97) while the latter adapts the vertical net by an ingenious arrangement to oblique hauls in shallow water. In a later paper (98a) he gives a careful account of the best method for the construction of the vertical net. Vertical closable nets worked by sliding weights are described by Birge (97a) and Marsh (97), and a horizontal net which can be opened and closed by a cord by Lakowitz (96). The former are prompt and accurate in action and may be used at any depth, having been tested up to 130 m., while the latter is apparently cumbersome, if not uncertain in action, and on the authority of the author can be made use of only up to 20 m. in depth. As to the material, fine silk gauze, of which such nets are constructed, Frenzel (97a) makes some criticisms regarding its inconstancy; since while a single haul does not usually close the pores to a noticeable extent there are exceptions, and furthermore continued use is sure to modify its filtering capacity, thereby falsifying all calculations. The pores are closed by accumulated detritus, not by diatoms or other small planktonts. The net should be vigorously washed and wrung out each time to clean out the pores. Hensen (97) questions these statements regarding clogging and objects to such drastic treatment in cleaning the net. Recently Kofoid (97a) has attacked the accuracy of results obtained by the vertical net on the opposite basis: that it allows the escape of too many organisms since "the silk retains from 5 per cent. to less than 0.1 per cent of the total *number* of organisms present excluding bacteria, as contrasted with the catch of the Berkefeld filter;" volumetrically the catch equals from one-half to only one forty-fifth of the amount actually present in the water. Reighard (98) calls attention to the fact that the larger size of the nets used by some observers makes clogging a less important factor than in studying silt-laden waters with a small net. Shrinkage being largely if not entirely eliminated by previous treatment of the net, leakage is the only uncertain factor, and since the organisms which escape thus are the smallest, their volumetric importance may be slight; but they must be investigated numerically by other methods as the numerical estimations made from catches of the vertical net are evidently most open to question.

As the vertical net does not collect all the material in the column of water through which it passes, various means have been adopted to ascertain the portion of water actually strained or the coefficient of the net. Hensen's earlier, extremely complicated method was pointed out by Reighard (94a) and Ward (96b) to be open to question, and the former proposed an experimental method (94b) for precise determination of the efficiency of the net. Hensen (95) advocates the use of a tin plate covering the mouth of the net except a small opening in the center. By counting the number of individuals of a well marked species caught under these conditions and comparing with the number caught by the full opening of the net, its coefficient may easily be obtained. The method, however, evidently affords more opportunity for error than that proposed by Birge (97a) who filtered the entire column of water in a tin cylinder having the diameter of the net opening in order to ascertain the coefficient of the net. This was found to be about two, and the difference between maximum and minimum hauls of the net was no greater than that shown by the column of water in the cylinder at sucessive tests.

For Crustacea alone Birge found that the clogging of the net in an 18 m. haul did not markedly affect its coefficient over that employed for the 8 m. haul until after the rapid increase of the phytoplankton in July. For the short haul the clogging made at no time any visible alteration in the coefficient which in the opinion of Birge is furthermore one of the most constant factors, and quite as accurately determined as any other. However, Frenzel (97a) is inclined to think the coefficient decidedly variable. Kofoid (97a) ascertained the coefficient of the net in use at the Illinois station, according to the original method of Hensen, to be 1.32; experimentally it was shown to vary from 1.5 to 5.7, where the greatest variation is largely due to the clogging of the net by heavy plankton hauls. Reighard (98) proposed to eliminate all of the difficulties connected with clogging, shrinkage and net coefficient at once by measuring the volume of water that actually passes through the net in each haul. To this end a small current meter is to be placed in the mouth of the net and the volume calculated from the rate of the current passing through the opening. Experiments in this direction are now in progress.

As a substitute for the vertical net in obtaining the plankton from a certain quantity of water, several investigators experimented almost simultaneously with a plankton pump, so constructed that a definite amount of water is delivered by a single stroke, the depth from which it comes being regulated by the position of the mouth of the attached hose. The greatest difficulty which presents itself is the proper filtration of the water discharged from the pump. The advantages urged in its favor are (Kofoid, 97) greater accuracy in determining the volume strained, the wide applicability of the method in shallow water, in currents, under ice, amid vegetation, for water very rich or very poor in plankton, and the rapidity of the process. The pump used by Kofoid was very large. Frenzel (97) who advances much the same arguments in favor of this apparatus, which he used with particular success in obtaining plankton under the ice, gives no particulars regarding his pump. Fordyce (98) describes a pump which is easily portable and can be used with advantage in small bodies of water.

A centrifugal apparatus has been used with success by Juday and Kofoid (97) on preserved material in the measurement of plankton volumes. Dolley (96) has employed a larger form, called by him the planktonokrit, in the precipitation and measurement of living plankton. This machine has been used by Field (98) who later (98a) maintains its great superiority for volumetric estimation over all other methods yet discovered. Jackson (96, 98) found, however, that while good results were obtained with Infusoria and Rotatoria, the reverse was true if Cyanophyceae were present, as these are not thoroughly precipitated owing to low specific gravity. The material is also matted together, preventing equal distribution on the slide if numerical estimation is to be employed. Kofoid (97a) emphasizes the selective error of the centrifuge on living plankton.

In microscopical water analysis for technical purposes the Sedgwick-Rafter method almost universally employed has been subject to modification in detail by Jackson (96, 98), while Whipple (96) has analyzed most clearly the various errors of the method and the value of each. The same author has also (97) planned a simple form of apparatus for water analysis. Leeds gives a valuable discussion and summary of these methods.

In the filtration of plankton organisms Kofoid (97a) found that the sand filter retained only 40 to 65 per cent of the number of organisms present and advocated as more satisfactory and precise the Berkefeld filter. Reighard (98) objects to the contamination of the plankton resulting from the use of the latter, and Jackson (98) considers that the slow rate of filtration makes its use entirely unpractical.

For the manipulations connected with the enumeration of individuals in plankton hauls various minor pieces of apparatus have been suggested; only the more important need be noticed here. Whipple (94b) advised the employment of an ocular with a field suitably ruled, and Zacharias (96a) introduced an ocular of large field with an iris diaphragm. As the enumeration of organisms recorded without reference to size and character is extremely misleading, Whipple (94b) proposed a standard unit of size, 20x20 microns, as a means of correcting the error. Tables for common organisms and an ocular with ruled field assist in the computation. Comparison of lines platted to show the numerical and areal values of the organisms in a haul with the albuminoid ammonia curve for the same demonstrate the much closer correspondence of the areal estimation with the amount of organic substance present. By the use of logarithmically ruled paper Scourfield (97a) was able to represent extreme ranges in number of organisms while at the same time proportionate changes in number are indicated by lines having the same angle of slope in whatever part of the chart they may be situated.

The freshwater stations of the world have not all been founded within the last five years. Yet only the Swiss and Bohemian stations can be said really to antedate this, and even then much of their important work comes within this period. As to what constitutes a "station" and what each has accomplished I have spoken in another place,* and shall refer here only briefly to such articles concerning the origin, management and functions of those formal enterprises as would not easily be included under other headings. A general account of such institutions is given by Lampert (98), and for America by Kofoid (98b). Scourfield's appeal (96, 97) for the foundation of a British station, and Frič's presentation (97) of Europe's example contrast well the position of the two countries in this movement.

The oldest definite station in Europe, the Bohemian, is described in Frič and Vávra (94, 97). The Plön station and its opportunities are set forth in Klunziger (96), Zacharias (93, 94, et alia), Zschokke (95a). Other German stations are noted by Woltersdorff (96), Frenzel (95). In Hungary, Entz (97), and in Russia Zograf (97) record similar enterprises. In Italy Garbini's long and successful investigations on Lake Garda entitle that station to a high rank. In North America work on the Great Lakes is recorded by Reighard (93), on Lake Mendota by Birge (95, 97), on Gull Lake, Minn., by McMillan (93), Nachtrieb (94), Zacharias (94b), and on Turkey Lake by Eigenmann (95). The work of the Illinois station at Havana, the most extensive American enterprise of this character thus far, is fully set forth in the reports of the director (Forbes, 94, 97) which are inspiring appeals to limnobiologic investigation. Other references to this station are Kofoid (96a), Ross (97b)

* Science, n. s., ix, 497-508.

Zacharias (94g). The technical station of the Boston water works is well described by Whipple (97b) who sets forth clearly the importance of such an enterprise in its relation to the water supply of a great city.

Last year the United States Fish Commission made a preliminary survey of the region about Put-in-Bay, Lake Erie, with reference to the fitness of this point for an experiment station in connection with the government fish hatchery. The work will be continued the coming summer (H. M. Smith, 98.) The necessity for an aquacultural experiment station, the right of such a foundation to governmental support, its proper location and function and allied questions are discussed by Ward (98a). Zacharias (95g) believes that a wandering lacustrine station is of secondary importance; some evidence to the contrary could be found in the work of Frič and Vávra (94, 97), Reighard (94), Ward (96b).

The temperature conditions of freshwater lakes were discussed by Fitz Gerald (95). In temperate climates, deep lakes show a winter curve running from 0° C at the surface to 4° C at the bottom, while the summer curve is reversed, extending from 24° C at the top to 7°–10° C at the bottom. Whipple (95a) shows that a temperature difference of 3° C prevents wind from maintaining circulation and the lower region remains stagnant until the fall overturning mixes the water of the lake. Birge (97a) made a most careful study of the temperature conditions and variations in Lake Mendota. The warming of the water in the spring is gradual and uniform until the difference between top and bottom is 7°–8° C. Then gentle winds with high temperature lead to the formation of a mass of warm water on the surface so thick that however the wind may blow there is always a warm stratum floating on the colder water. Immediately below the warm water is a layer a meter or less in thickness in which the temperature falls very rapidly; this layer Birge names the thermocline. Below it the temperature falls gradually to the bottom of the lake. Once formed, late in June, at about eight meters of depth, it moves downward slowly and irregularly, depending upon the action of the wind, and reaching the bottom as a result of the late September gales, disappears. These conditions are of extreme biological importance since below the thermocline the water is stagnant during the entire summer and becomes unfit to support most forms of animal life. The sub-thermoclinal water is reported by Whipple (95a) and others to be malodorous, deficient in oxygen and rich in the products of decay. Its overturning is the occasion of a rapid increase in the diatoms of the plankton.

Whipple (98) distinguishes three types of lakes, polar, temperate and tropical, according to the surface temperature, which in lakes of the first type is never above that of maximum density (4° C), in those of the tropical type never below that point, and in lakes of the temperate type sometimes above and sometimes below it. He also designates three orders of lakes on the basis of the bottom temperature, which in those of the first order is practically constant at or near the point of maximum density; in those of the second order the bottom temperature fluctuates but never very far from the same point while in lakes of the third order the bottom temperature rarely varies from that of the surface. With regards to periods of circulation which are so important for the development and distribution of the plankton, he says: "Speaking in very general terms, we may say that lakes of the first order have no circulation; lakes of the third order no stagnation (except in winter); and lakes of the second order have both circulation and stagnation." According to Birge (98) the thickness of the surface stratum of warm water depends on the wind, the exposure of the lake, and among those similarly located in these particulars, upon the area of the lake, being less in a lake of smaller area. The bottom temperature of a small lake is likely to be lower than one would expect from the depth merely and that of a large lake higher. Here also Ule (93), Langenbeck (93) and Dolan.

The amount of oxygen present in various parts of a water basin and the dissemination of gases through the water is of the greatest importance in its bearing on conditions of existence in a lake. Drown (93) found that in water basins in winter under the ice there is a deficiency in the amount of oxygen present, which increases from the surface downward. In some reservoirs the bottom water becomes even malodorous and as poor in quality as during the summer stagnation period. This was true only of lakes rich in organic material. The careful and extended investigations of Hoppe-Seyler (96) on Lake Constance, Switzerland, show a deficit of oxygen in deeper waters above the calculated amount. The amount present, however, is still sufficient to satisfy the respiratory needs of the abyssal animals, even the most sensitive fish, such as trout. Knauthe (98) maintains that in somewhat turbid waters the micro-organisms demand more oxygen than fish and larger forms and in stagnant waters far more than is contributed by the atmosphere. In daylight the microscopic green plants give off oxygen to the water so abundantly that in strong sunlight the maximum is reached in a few hours. Even moonlight causes an appreciable increase in the quantity of oxoygen; but in darkness the amount sinks in five or six hours of summer temperature to the minimum necessary for the Cyprinidae.

Calkins (93) groups the odors of freshwater into three classes (1) those of chemical or putrefactive decomposition, (2) those of growth, i. e., excretory products, and (3) those of physical disintegration. All evidence points to oil globules as the specific cause of those odors grouped under the last two classes. Certain odors are associated with definite organisms. Jackson and Ellms (97) were able to add to the evidence concerning natural odors and the organisms producing them and to distinguish sharply between the natural odor and that produced by the decomposition of the same organism. Here also Whipple (94a).

The geological and physical features of individual lakes have been studied by Ule (94a) at Plön, Pero (95) in Italy, Large (97) in Indiana, Wagner (97) in Bohemia, and Lorenz von Liburnau (98).

Among the articles noted on the phytoplankton Schröter (97) presents the most general survey of plant life in the water. He distinguishes by the vegetation three general types of water basins, swamp, pond and lake; the swamp plants rise with vegetative organs above and free from the surface of the water. In the pond true submerged plants are wanting and only submersed plants with swimming leaves and submersed plants with emersed leaves are normally present. To the single plankton organism the term planktont is applied and among the lake plants the author differentiates (1) the floating flora, or phytoplankton with the eulimnetic species of the open water, the bathy-limnetic forms, half floating, half inhabitants of the littoral zone, and the tycho-limnetic plants, stray elements of shore or bottom flora; (2) the swimming flora, pleuston, driven about on the surface and with organs fitted to an aerial existence; (3), the bottom flora or phyto-benthos, bound to the substratum and consisting of flowering plants, Characeae, sessile algae and mosses, epiphytic and endophytic algae, and fungi and bacteria. Each individual body of water has its own characteristic flora as is shown by comparison of a series of lakes. A careful study of the plankton shows numerous adaptations to the conditions of its existence.

These general principles are repeated and emphasized by examples in the general part of Schröter and Kirchner (96) which deals with the flora of Lake Constance based upon about five years of study. The special discussion of the algal flora of the lake by the second author includes an account of characteristic features and of the composition of each part of the flora. There were found in the lake the very large number of 361 separate species. No quantitative investigations were made on the plankton. Here also Bruyant (94) and Magnin (95).

Among the Cyanophyceae Strodtmann (95, 95a) and Klebahn (96, 97) find in the so-called "red bodies" the cause of floating. So long as these are present in sufficient numbers the algae swim at the surface, when they are scanty or wanting the algae sink slowly or rapidly to the bottom. The "red bodies" are actually gas vacuoles in the protoplasm, present in all the plankton Cyanophyceae, but entirely wanting in the fixed forms.

On the diatoms of the plankton Zacharias (95h) gives statistical records from the enumeration of plankton hauls during the year showing the number found at different seasons and the maxima and minima of various species. Whipple (94) notes the effect of the fall overturning of the water in producing a maximum of diatom development by the distribution of an abundant food supply from the stagnant substratum of the water. In a later paper (96a) are recorded more detailed observations on the effect produced by other causes. The maximum of diatom growth is shown experimentally to be just below the surface of the lake, to be greater in light-colored water and to vary in close correspondence to the variation in the intensity of the light. Apparently the diatoms possess no power to move upward toward the light but are carried upward by convection currents in the water. Such conditions prevail particularly in the fall circulation period. Pero has studied very carefully the distribution of the diatoms in the lakes of a single canton in the Alps.

The "water bloom" has been studied by Klebahn (96) who finds that thirteen different species may give rise to the phenomenon. According to Strodtmann (98) it is only indirectly the cause of actual damage, varying in amount under different conditions, and is of direct value as food, particularly to the Cladocera and Copepoda which are so important as fish food. Here also Richter (94) and Thomas (97). Seligo (97) discusses the damage done by the introduced *Elodea canadensis* and believes it probably overdrawn. After considering its relation to the general biology of the water, the author emphasizes the small value of the shore plants in the food relations of freshwater and yet on the other hand the known greater abundance of fish where such plants are found.

For Plön and other lakes in Holstein, Klebahn (95) describes the aquatic vegetation, the regions into which it may be divided and the forms in each. Here also Lemmermann (95, 96a). Lemmermnan (96), Müller (98) and Schröder (98) report on the flora of the lakes in the Riesengebirge, and the latter undertakes to distinguish the formations of the freshwater algae, as limnophilous, potamophilous, sphagnophilous crenophilous, geophilous, lithophilous and kryophilous, giving faunal data regarding each. Concerning other local floras there is noted the report of Pieters (94) on that of Lake St. Clair, Thompson (96) on Lake Michigan and Whipple, Jelliffe and others on the flora of city water supplies in this country.

On the flora of ponds used for fish culture Lemmermann (97) and Schröder (97) have made some investigations. The former reaches certain preliminary conclusions as to the economic worth in such ponds of different forms of vegetation.

The freshwater fauna may be considered from two main standpoints which indicate thus principal subdivisions of the subject. One may investigate the forms of which it is constituted or the location in which these forms are found, discussing accordingly first their composition and second their distribution.

Regarding the composition of the freshwater fauna it may be said that nearly every paper listed in the bibliography contributes some notes of importance. Under this heading, however, it is the intention to bring together briefly only those which for one reason or another lay particular emphasis on this feature, dealing with taxonomic groups of various size in their faunal relations. As noted previously the bibliography makes no claim to completeness on extra-plankton topics. Its shortcomings are undoubtedly most noticeable under the present heading. Greater attention has naturally been devoted to contributions treating of North American forms while literature on freshwater vertebrates has been entirely omitted, and that on insects almost wholly.

On Protozoa Blochmann presents a very satisfactory general summary. Schewiakoff (93a) is the most important contribution on the group within the limits of this review. In Europe Levander (94a), Entz (96), Francé (97), deal with the protozoan fauna of a single region; similarly F. Smith, Kofoid (96) J. C. Smith and Hempel in this country. Here also Garbini (94a), Butschinsky. Among papers dealing with one or more subdivisions of the group may be noted Schaudinn, Frenzel (97b), Schewiakoff (93), Seligo (93), Švec and Francé (97a). On the Porifera Weltner (95), Hanitsch and Vángel (97).

Fuhrmann (94), Borelli, Szigethy, Vejdovsky, Volz and Woodworth have contributed to a knowledge of the Turbellaria, while Böhmig and Montgomery deal with the Nemertines. The results of Daday's work (97a), on Balaton Nematodes make one wonder whether these free living forms have not been much neglected heretofore.

On the Rotatoria, a most important plankton group, there has appeared the recent valuable memoir of Weber. Wierzejski (93), Levander (94b) and Daday (97b) have contributed to a knowledge of the group in Europe, and Kellicott, Jennings and Hempel in the United States. Here also Eckstein, Garbini (95a), Kertész and Hood. Imhof (95a) and Walker treat of the Mollusca in connection with freshwater investigations. Call discusses the relation of the molluscan fauna to different hydrographic basins in a region belonging to several drainage areas.

The splendid monograph of Piersig and the papers of Koenike, Daday (97d) and Wolcott (98), together with briefer articles by Soar and Nordenskiöld comprise the studies on Hydrachnids listed. On the entomology of a freshwater body the work of Hart easily takes the first place; articles by Klapálek, Wolcott (94), and Garbini (95d) are also noted.

Among the articles on the Crustacea, those of Garbini (95c) and Wierzejski (95) are general in their scope. The Entomostraca have been studied by a host of investigators, among whom may be noted Daday, de Guerne, Herrick, Mrázek, Poppe, Richard, Rizzardi, Sars, Scott, Scourfield, Steuer, Turner, Vávra and Wesenberg-Lund. On the Ostracoda particularly are noted the works of Brady and Norman, Vávra, and in this country Turner and Sharpe.

The magnificent monograph of Schmeil on the Copepoda deserves prominent notice. Valuable articles on the group are Mrázek, Marsh (95), E. B. Forbes, Schacht and Brewer On the Cladocera the revision of Richard (94, 96) is a model of completeness and accuracy. Birge (93, 94), Ross (96), Turner (93) in this country, and Stenroos (95, 97), Stingelin (95), Weltner (96) in Europe, have contributed to a study of the same group. On all of the plankton crustaceans much emphasis has been laid and in most of the articles noted under the head of distribution may be found important taxonomic notes on these groups.

The distribution of freshwater life may be regarded from the standpoint of the single body of water or through a comparative view of different bodies of water. In the latter case one may consider those bodies which are within a given geographic area, or those which are associated in character. Accordingly it is permissible to speak of the geographic, the hydrographic and the areal distribution of freshwater organisms. In considering first the geographic distribution of freshwater animals, regions are designated by ordinary geographic terms since a basis for subdivisions into faunal regions has not yet been worked out save in Russia by Zograf. Of general value on the geographic distribution of freshwater animals is the work of Schewiakoff (93a) on the Protozoa which seems to indicate a cosmopolitan distribution for these forms. Frenzel (97b) doubts this on the basis of studies in South America, since of 88 species found in Argentina, 44 are new. The accuracy of these studies has, however, been questioned.

Observations on Australian forms are reported by Chilton and Sars, from the Pacific Islands (Samoa) by Krämer, from Sumatra by Richard (94c) and from Ceylon by Poppe (95b) and Daday (98). From eastern Asia Richard (94b) is the only record of the freshwater fauna noted. From Asia Minor Barrois (94) and Richard (95, 96c) complete the list.

Northern Africa is touched upon in Barrois (93) and Richard (93). German East Africa has a well planned biological survey of governmental character in progress. Reports touching upon this topic are Mrázek (95), Weltner (96) and Vávra (97). Poppe and Mrázek (95) treat of nearly the same territory and Weber (97) deals with African faunal regions based on a study of the fishes, decapod crustaceans and mollusks. The work of Moore in Central Africa is considered under the fauna relicta. Concerning island faunas Barrois (96) and Richard (96b) report from the Azores and Richard (98) from the Canaries. The species are mostly cosmopolitan or known from adjacent portions of Africa and Europe.

Single brief reports characterize also our knowledge of the South American freshwater fauna, from the west Borelli, from the east Dahl, Ihering, Frenzel (97b) and Richard (97b), and from the south Vávra (98), with a single note on South Georgia from Poppe and Mrázek (95a).

In Europe extreme northern points are noted in Richard (98a), Scourfield (97b) and Wesenberg-Lund (94). Lauterborn (94a) on the fauna of Helgoland, Scott and Duthie on that of the Shetland Islands, Scott on Scotland, Western, Scourfield and Soar on England and Wales, and Hanitsch and Hood on Ireland, record the advance in knowledge from these regions. From Norway, Wille and Huitfeldt-Kaas, and from Finland, Levander, Nordenskiöld and Stenroos are noted.

From Germany, Schmeil, Piersig, Lampert (98) and Apstein (96) are of general import; more limited in area is the work of Zacharias, Apstein (93) and others from Holstein; Hartwig, Frenzel and others from Central Germany; Lauterborn from the Rhine; Lameere from Belgium; Klápalek, Švec, and Frič and Vávra from Bohemia; Jaworowski and Wierzejski (93, 95) from Galicia; Daday, Entz, Francé, Vángel, and others from Hungary; Schmeil (93a, 94), Lorenzi, Steuer and Richard (96a) from the eastern Alps, and Vávra (93) and Richard (97) from Bulgaria and Albania. The Russian articles, probably exceedingly incompletely recorded, are Zograf (96) and Butschinsky (96).

No region has been more carefully studied than Switzerland and the Alps. The work of Imhof (95a) and especially of

Zschokke (95) and of his students and associates Stingelin, Fuhrmann and others, is of great value. On the northern slope of the mountains Hofer, Heuscher and Steck, toward the west and south and in the Jura Forel, Blanc, Pitard, Studer, Weber, de Guerne et Richard, Blanchard et Richard and Pugnat. On the south of the Alpine chain, Garbini, Pero, Fuhrmann (95), Klunzinger (97a), Wagner (97a); in Italy, Rizzardi and Garbini, and in Portugal, Nobre and de Guerne et Richard (96) are among those noted in the list.

On this continent the work of E. B. Forbes, Herrick and Turner, Schacht, Sharpe, Turner (94) and Wolcott (98) is general in extent. On the freshwater fauna of Canada are noted Koenike and Ross (97); on that of the Atlantic coast region Montgomery, Calkins, Whipple, and others; on that of the Great Lakes and contiguous territory, Birge, Jennings, Kellicott, Kofoid (96), Marsh, Reighard, F. Smith, Walker, Ward (94, 96a), Wolcott (94) and Woodworth (96); on the freshwater fauna of the central region Eigenmann, Hart, Hempel, Kofoid (96b, 98), Woodworth (97), and others; further south Herrick (95), Turner (94) and Seurat; on the plains toward the west Brewer and Ward (98); in the mountains S. A. Forbes (93), and on the island of Hayti, Richard (95a) record the work of the period under consideration.

Viewed from the hydrographic standpoint, freshwater organisms may be discussed with reference to the particular environments which each type of water basin affords; one may distinguish roughly the brook, river, swamp, pond and lake as types of environment. These have been very unequally studied as accords with the difficulty and probable results of the investigation. Stockmayer (94) has given a brief summary of the general biologic aspect of the life of the brook, or in fact of water in general, and of the problems to be solved by a station located in a region rich in brooks; such a station is certainly a great desideratum in freshwater work. No record appears of work done on such a body of water.

The importance of studies on a river have been emphasized by Forbes (94, 97) and the particular problems with which one has to deal in such a location. Under the direction of the same investigator there has been opened on the Illinois River a station which is devoted primarily to the problems of a river system. Some of the results are given in the papers of Hart, Hempel and Kofoid. Lauterborn (93, 94) and others have done some work on the fauna of a river, and recently the topic has received more attention. Schröder (97a, 98a) finds in rivers the phytoplankton much in excess, the diatoms constituting the ruling forms. In shallow ponds with not too strong an inflow the zooplankton is far richer than in streams where it decreases with increasing current. Zacharias (98a) shows that the potamoplankton is formed in plant-grown bays on the river shore, and multiplies perhaps in slow-flowing streams. Zimmer (98) finds that the character of the potamoplankton varies with the hight of the water. He distinguishes (1) autopotamic forms which find their conditions of existence only in flowing water. These include at most very few animals. (2) Eupotamic forms, living either in standing or flowing water, including most species of the river plankton. (3) Tychopotamic forms, torn by chance from quiet waters in which they live normally, and finding no possibility of reproduction in the current. The potamoplankton is very poor both in species and individuals as compared with the limnoplankton. The Rotatoria constitute its chief element, adult Crustacea are rare, and only one protozoon has been observed. It is interesting to note that in a lake of the Jura, Zschokke (94) records that the variations of level and the strong current give it partly the character of a river. Here the littoral zone is almost barren but the limnetic fauna rich in species though poor in number of individuals.

No specific report is on record during this period concerning the investigation of a swamp. The closest resemblance to such conditions are presented by Lake Nurmijärvi (Stenroos, 98) which possesses in fact a maximum depth of one meter. Here could be distinguished nevertheless the characteristic regions of the pond or lake fauna. The extreme richness of such shallow bodies of water is indicated by a total of 460 species recorded from this lake. The paper contains most valuable observations on the characteristic fauna in each floristic region and on its structural and ecological peculiarities. Zacharias (98) calls the floating fauna of shallow natural or artificial water basins the *heleoplankton* and has studied it from a number of places. The majority of limnetic forms recur here and certain Rotifera rare or lacking in lakes are found in such basins. Characteristic is also the abundant development of the microphyta and of the Ceriodaphniae. Here also Bigney and Pitard (97a). Frič and Vávra (94) treat of two ponds, of somewhat different character, and give a complete and clear picture of pond life, and the changes it undergoes. Here also Ward (98). The characters of a pond are precisely stated by Zacharias (98) who has found in such water basins almost all the eulimnetic organisms of true lakes. The Rotatoria are more numerous, and in the phytoplankton the desmids are the chief factor.

On the fauna of a lake many investigations have been made within the past five years, and the profitless preparation of mere faunal lists seems fortunately to have passed its maximum since an increasing number of the later papers has considered not merely the composition of the freshwater fauna or of one of its groups, in the region studied, but also the biological relations and the origin of the fauna. Among the large number of lacustrine investigations of all degrees of completeness, only the more extensive can be mentioned in this connection. The monographic work of Forel on Laka Geneva, Switzerland, has already been sufficiently characterized. Lake Plön, Holstein, has also been extensively studied by Zacharias and his coadjutors. Garbini's careful investigations on Lake Garda, Italy, and those of Entz and his confréres on Lake Balaton, Hungary, are also deserving of prominent mention. Schwarzsee, Bohemia, under Frič, Mügglesee, Germany, under Frenzel, and numerous other individual lakes in Europe have been subjected to careful investigation with valuable results. In North America Reighard has studied Lake St. Clair, Eigenmann Turkey Lake and Ward the northern portion of Lake Michigan in conjunction with numerous colaborers. Birge has devoted himself singly to Lake Mendota and Marsh to Green Lake.

Other investigators have turned their attention toward a series of lakes or a given type of lake rather than toward a single body of water. Thus Apstein (94) has achieved valuable results from the study of Holstein lakes, Pero has devoted himself to Swiss lakes in a single canton and Hartwig to those of Brandenburg. But the most striking instance of this specialization is Zschokke whose investigations on elevated lakes have established so clearly the biological features of such locations that subsequent studies have added only details to the general picture he has painted. The results of this author are summarized in a final paper (95) which presents further a comparison of the author's work with that already achieved in other regions. This paper includes a careful study of two lake regions in the Alps, a group of small sub-nival bodies of water in the Rhaeticon chain and numerous lakes of Wallis near St. Bernard. Both a littoral and a limnetic fauna is present and in them most freshwater groups are represented, though in European nival and subnival lakes Helizoa, sponges, *Bosmina*, Isopoda and Decapoda are wanting and mollusks are scantily represented. The bulk of the Alpine freshwater fauna consists of resistent cosmopolitan species which recur in part in lakes of high altitude elsewhere. To these are added (1) here and there rare forms from the plains, (2) pure mountain forms often of northern character, (3) abyssal inhabitants of sub-alpine lakes which find a suitable environment on the shores of elevated Alpine lakes. The composition of the lacustrine fauna varies from place to place even within a single mountain chain, but in general unfavorable environment increases with the altitude. The limit of suitable environment, i. e. the upper limit of animal life, lies at different altitudes in different mountain ranges, but appears to be higher in massive ranges than in neighboring chains of lesser magnitude. The presence of certain forms adapted to the particular locality and the absence of other species imparts to the scanty fauna of a mountain lake a decided individuality, often apparently in strong contrast to that of a neighboring basin.

In an earlier paper (94) Zschokke presented the results of studies on lakes in the Jura showing a typical mountain character. Previously de Guerne et Richard (93) had investigated the limnetic fauna in the same region and (94) in the Pyrenees. In the Cottian Alps Blanchard et Richard (97) found similar faunal conditions. Here also Blanc, Pitard, Imhof (93), Pugnat (97). The varying fauna in adjacent basins is explained by the last mentioned author on the ground of variation in the exposure and illumination of the water. Studer (93) attributed the poverty of the limnofauna in the lake of Champex to the excessive illumination of the shallow water in the absence of shore and bottom plants. Imhof (95a) investigated the horizontal and vertical distribution of the aquatic mollusca in the Alps. They are more numerous in the territory of the Rhone and the Po, and manifest in small and in elevated lakes a rapid reduction in number. On the southern slope of the Alps Fuhrmann (95) finds the fauna of the elevated lakes similar, though somewhat richer. In the Julian Alps Lorenzi (97) finds a cosmopolitan fauna in which the plankton consists of tychopelagic forms alone. In the Riesengebirge according to Zacharias (96g, 98c) the limnetic fauna is scanty but similar to that of the Rhaeticon lakes studied by Zschokke. The species present are typical cold water forms. The same poverty and cosmopolitan cast in the fauna is reported by Frič and Vávra (97) who attribute the scanty shore and bottom fauna to the lack of vegetation. The disappearance of certain elements in the fauna can be traced definitely to the introduction of game fish. In the Tatra lakes, Galicia, Wierzejski (95) found typical Alpine conditions in the poverty of species in the abundance of cosmopolitan forms and in the contrast in proximate basins of equal altitude. The lakes show, however, as Daday (97) remarks, notable richness of fauna even up to an altitude of 2,000 m. Here also Richard (96a, 96c). In Syria Barrois (94) found an unusually rich limnetic fauna of cosmopolitan Entomostraca and Rotatoria. The Sea of Tiberius, though strongly saline, has a pure lacustrine fauna.

One of the earliest investigations on elevated lake regions and the only one yet made in this country is that of Forbes (93) in Wyoming and Montana. Noteworthy is the careful study of the entire environment and its influence on the fauna. In this Forbes made valuable contributions to the general character of the fauna of elevated lakes which were utilized by Zschokke in the paper already noted. Among the features discussed by Forbes are the extreme poverty of the vertebrate aquatic fauna, the ruling species being rather Amphipods, leeches and insect larvæ, great rarity of mollusks, the abundance of Entomostraca, largely cosmopolitan species, and the sharp contrast of the fauna in adjacent water basins. There exists a deepwater fauna in many of these lakes, of which something was ascertained. In general the fauna proved to be richer than that of lakes at corresponding and even less elevation in Europe. The influence of environment was well shown by variations in the fauna, such as the abundance of mollusks in a lake lying within a lime formation and their rarity in all other elevated waters.

Only one investigator has yet endeavored to group into regions in accordance with their fauna, the lakes of any continental area. Zograf (96) divides the lakes of Russia into four regions, based upon the distribution of the fish and crustaceans. The first region includes the large water basins in the northwestern portion of Russia, the second surrounds the first, the third includes the lakes of Central Russia and is little known, and the fourth takes in the steppe lakes bordering upon the south. Geological evidence supports this general classification, the first three being in territory covered by glacial sheets in different periods and the last constitutes the remains of a miocene sea covering southern Russia.

In discussing the distribution of the fauna within a single body of water authors have regularly adopted Forel's lacustrine regions and the majority have also made use of the terms introduced by Pavesi to designate the plankton organisms as eulimnetic or regular inhabitants of the open lake and tycholimnetic or chance members of the same region. The general composition of the plankton may be judged from the statement of Strodtmann (96) that about 80 organisms occur in the plankton of Holstein lakes of which, however, less than 40 are usual or important. All authors agree in noting the limited number of species which are found in the plankton and equally regarding the extreme abundance of individuals which make up its volume. These organisms, moreover, are not at all times the same species but manifest certain variations to be noted later. Among the species of animals which the plankton contains the Rotatoria are said to be the most important.

The total amount of plankton taken in the vertical net or plankton pump and preserved in some suitable fluid is estimated in several ways. (1) After settling in graduated tubes for twenty-four hours the volume is read off from the tube, Apstein (94), Reighard (94), Ward (96). Or the volume is measured in a centrifugal machine, Juday (97). (2) Under suitable precautions the entire amount is weighed, Frič and Vávra (94), Zacharias (95, 95b). Or a known quantity of a haul, measured by the first method, is taken, weighed both before and after incineration, and the amount of organic material in the entire haul calculated, Ward (96a). (3) The organisms in a definite portion of a haul are counted under suitable precautions and the number of organisms in the entire haul calculated therefrom. This method, first used by Hensen in the ocean, has been applied to freshwater by Apstein (94, 96). Zacharias (94d) employed it in abbreviated form. Another simplified form is given by Birge (95a).

There is no known relation between the results obtained by these different methods and consequently no comparison can be made between the results obtained by one method and those obtained by another. Furthermore while the work of one observer at a given time is capable of comparison with that done at another, it seems perfectly clear that the work done by one observer can not be directly compared with that done by another even if the same method is employed. Difficulties in this connection are noted by Kofoid (97), Reighard (98) and others.

Apstein (94) would divide lakes into two classes, plankton rich and plankton poor, the first characterized by an abundance of *Clathrocystis* and absence or rarity of *Dinobryon*, and the second by reverse conditions. This classification is questioned Reighard (94), Zacharias (94) and Strodtmann (96) on the basis of investigations in other lakes. The total amount of plankton is believed by Steck (93) to depend on the length of the shore line, and Reighard (94) also regards this as an important factor. Many observers have noted that there is in general proportionally less in a larger than in a smaller lake, and this has been found by Reighard (94a), Hofer (95), Walter (95), Zacharias (95b), Strodtmann (96) and others to be capable of more precise statement in the principle that the amount of plankton per cubic meter of water varies inversely as the depth. Other factors affect the development of the plankton, chief among them being light, (Stenroos, 98), transparency of the water, (Steck, 93), and temperature, (Zschokke, 95). Walter (95) emphasizes also the relation between the depth and the area of the lake.

In Norwegian lakes presenting a great variety of conditions as to altitude, depth and rapidity of change in water contained therein, Huitfelt-Kaas was able to show that shallow waters are especially favorable for the development of the plankton while deep basins are under otherwise like conditions notably poorer. This is true only in summer and is probably controlled largely by temperature conditions. Even more important, however, is the drainage area of the lake and the proportionate inflow and outflow, so that in basins with rapid change in water much less plankton is found than in more stable lakes. Here it is evident that a shallow lake may be even less favorable for the development of the plankton than a deeper one by virtue of the greater instability associated with a limited volume.

On the question of horizontal distribution Apstein (94), Reighard (94a) and others have maintained the existence of uniformity. Zacharias was inclined to question this (94c, 94d) but has since then changed his views (95c). In the case of recent observers who have noted nonuniformity in distribution

(Pitard, 97, Garbini, 98a) and particularly the presence of a greater amount near the shore*, it is probable that proper regard was not paid to depth and that there really exists no considerable difference. Uniformity of horizontal distribution has been shown to be modified by large inflow and by the existence of areas more or less separated from the main body of the lake, by shallows, or in deep bays (Huitfelt-Kaas, Zacharias.)

Regarding vertical distribution, Hofer (95) is alone in placing 35 m., or in one case 65 m., as the lower limit of the plankton. Other observers have noted no such limit and Ward (96b) found plankton even down to 130 m., although he shows that in comparison with the upper portions of the water the deep stratum, 25 m. to the bottom, contains very little plankton.

All investigators agree that the upper strata of the water contain proportionately more plankton than any below. Reighard (94) found at a depth of 5 m. that half the plankton occurred in the upper one and one-half meters of water. Apstein (94) and Ward (96) show that much more is found in the surface 2 m. than in any equal stratum below this. From enumeration of the Crustacea alone, Birge (97a) demonstrates that in water having a total depth of 18 m. during the summer 45 per cent is found in the upper 3 m., 25 to 30 per cent in the 3–6 m. level, 15 to 18 per cent in the 6–9 m. level, leaving only 8 to 12 per cent for the lower half of the water. In the fall and winter, however, the distribution of the Crustacea is nearly uniform.

Francé (94) found in Lake Balaton a regular diurnal migration of at least a part of the plankton, governed by light and storm. Zacharias (95) was unable to find any such movement of the plankton in Lake Plön. It is, however, confirmed for Lake Balaton by Daday (97c) in his investigations on the limnetic Crustacea. Marsh (97) and Birge (95a) are positive that it does not exist in the lakes which they studied. Pitard

* Two observers make directly contrary statements in this respect concerning the same lake (Blanc, 95, and Pitard, 97).

(97c, 97d) notes the much greater amount of plankton in the surface stratum at night than can be found during the day when a large amount is first met at 5 m. and the maximum at 10 m. Birge (97a) on the basis of precise enumeration is able to show concerning distribution in the upper meter of water that (1) on calm, sunny days the upper 10 cm. of the lake may be almost devoid of Crustacea, while at a depth of 50 cm. the numbers are considerable and may be very great; (2) the upper meter is populated largely by immature Crustacea; (3) in stormy and cloudy weather the Crustacea approach nearer the surface though the number in the upper 10 cm. is always less than at 50 cm.; (4) at night the young become more evenly distributed in this layer and the adults rise from below the 1 m. level towards the surface. Though this is only necessarily true of the single lake studied, it must be said that the observations far exceed in accuracy of data any others yet published.

The vertical distribution of the plankton as a whole is, however, often quite different from that of the individual species. Data regarding these are given by many investigators, none of whom equal Marsh (97) and Birge (97a) in accuracy and amount of evidence presented.

In studying the seasonal distribution of the plankton Apstein (94) found the existence of a minimum in February in contrast with a summer maximum. Zacharias (96f) shows that the monthly mean remains much the same in different years, and gives (96h) a set of records covering hauls made at a definite point every ten days throughout the year. These give a minimum during the winter, a small maximum in May and another greater in amount in August; both the rise to the maximum and the decline from it are very rapid. Huitfeldt-Kaas finds a single maximum in Norwegian lakes in July-August, and a winter minimum in January-February. The approach to the latter is a gradual one, but the former exhibits a rapid rise and fall within a brief period. Here also Sernow.

For Entomostraca, Scourfield (93) places the maximum in September, while Birge (97a) finds a spring maximum in May, followed by a rapid decline to the early summer depression in

June; then a midsummer maximum in July, a late summer minimum in August and an autumn maximum in September or October, followed by a decline to the winter minimum of December to April.

The seasonal distribution of individual organisms has been studied by a host of observers, prominent among whom is Zacharias. In the first report of the Plön station (93) records of certain species are given and others are added in each subsequent volume. Calkins (93a) notes a definite culmination for each organism, no two falling at the same time, though most occur during the summer. The diatoms find a maximum in the spring with low temperature of the water, the Cyanophyceae at the end of the hot season with a high temperature of the water and the algae in general at the time of the fall overturning. Zacharias (95d) and others find a considerable agreement in the periodicity of organisms in successive years, while Birge (97a) looks upon the periodicity as really biennial.

At Plön Zacharias (96h) is able to distinguish a winter and a summer plankton and also for a brief period a fall and spring plankton. In October and November the Copepoda rule so that there is nearly a pure copepod plankton; from March to May the diatoms are almost alone and in enormous numbers. This is related to temperature as Schröder (98a) shows that in colder alpine lakes and in streams the diatoms rule while in ponds and lakes of higher temperature their place is taken by the Schizophyceae. Precise data on the seasonal distribution of different Crustacea are contained in the work of Marsh (97) and Birge (97a) who have traced individual species through long periods.

Lauterborn (98) has made observations of importance on the limnetic Rotatoria—nearly half are eurythermic, or perennial; about the same number are stenothermic of the summer variety and only two stenothermic with preference for the winter temperature. The summer and winter forms are all monocyclic, while the perennial species are dicyclic or polycyclic, i. e. producing males and "winter eggs" two or more times yearly.

In dicyclic forms the first sexual period falls in the spring and the second in the fall.

Lundberg and Stingelin (97) discuss seasonal dimorphism among Cladocera and shows that in some instances the succession of species is actually only a succession of broods. Lauterborn (98a) shows great variations among Rotifera at different times of the year.

The extreme change in environment in the case of those lakes which are frozen in winter has attracted the attention of numerous observers to the life of the water at that time. According to the observations of Lauterborn (94) the microfauna under the ice is rich in species and often in individuals; even the limnetic fauna endures through the winter, some species in large numbers. Certain Rotatoria are found in summer only, and some Protozoa in winter only. However, accordingly to Zacharias (94e) in Lake Plön, the Protozoa are the first to disappear, then the Rotatoria, the Crustacea reaching a minimum in February and March. The periodicity of these forms is, he believes, ruled not by temperature but by the surface and depth of the water basin. In Finland also, Levander (94) finds a rich limnetic fauna, consisting of various groups, which persists under the ice of lakes and ponds. Of Cladocera, according to Stingelin (95), most forms persist through the winter though those with ephippia disappear, and many forms manifest a marked seasonal dimorphism which as yet has been worked out in only a few species. The investigations of Birge (97a) show that 7 out of the 11 limnetic species of crustacea in Lake Mendota are perennial and present in considerable numbers in the winter plankton, and these numbers are singularly uniform from January to March with a minimum near the first of this period. The Rotifera and the phyto-plankton are also regularly present in this period and become abundant before the breaking up of the ice. Hartwig (98b, cf. 98a) gives precise data for another lake concerning the occurrence and abundance of numerous winter species. Here also Lampert (96). Sundvik believes that the fish may in some cases pass the winter dormant while frozen in the ice of small ponds which are entirely congealed.

Wesenberg-Lund (96) emphasizes the adaptations to the climatic conditions of freshwater existence, particularly to the ice, which are necessary in organisms coming from the sea. This necessity is most evident for surface forms and is manifested in the formation of winter eggs and winter buds. Land animals must undergo modifications particularly in the organs of respiration to fit them for an aquatic life.

In reference to the littoral fauna as a whole only a few scattered notes are at hand. Various authors have attributed the richness of a lake fauna to the development of the littoral area. Reighard (94a) has expanded the idea to a considerable extent. Others have attributed to the opposite cause the poverty of a lacustrine fauna as Ward (96d) in the case of Pine Lake. In this connection it has been frequently pointed out that the development of the littoral flora is an exceedingly important factor. On the whole, but little attention has been paid to the littoral fauna as a whole although isolated groups of organisms from it have been carefully studied. When the reverse has been true, the results attained are rather striking. Thus Entz (97) and his colleagues in the investigation of Lake Balaton found an exceedingly rich littoral fauna, and some progress was made in the distinction of shore "formations" and the characteristic fauna of each. Thus Francé (97) distinguished as protozoan formations, the peat bogs, the muddy shore with reeds, the bottom mud, the sandy and rocky shore, and the plankton.

The investigation of underground waters has received some attention. In New Zealand, Chilton (94) discovered in subterranean streams many forms also common in surface waters, but all pale and transparent. In all the Crustacea save one, eyes were entirely lacking, and in that one no retinal pigment was present. On the other hand, the antennae and other appendages were noticeably elongated. In the caverns of the Adelsberg, Schmeil (94) noted that the subterranean Entomostraca were colorless or pale in contrast with similar forms from surface waters. In the former eyes were present to be sure, but the pigment was much reduced. According to Garbini (96) subterranean forms present these same differences in color from individuals of the species found at the surface but are further distinguished by diminutive size and weakness. Only two species were found which were characteristically subterranean. Lauterborn (94a) notes that much the same species are present on Heligoland in a dark closed well as in an open light one. The fauna was here very scanty. Here also Lorenzi (98). Packard (94) and Lendenfeld (96) have given summaries of our knowledge regarding cave animals with frequent references both morphological and ecological to the freshwater fauna of such localities. The observations of Garbini (96) were made largely on material from water-pipes. Whipple (98a) has made similar studies in Massachusetts. Here also Viré.

Though numerous experimental researches have been made on the ability of animals to become acclimatized to higher temperatures, there have been few observations on the forms which occur under similar conditions in thermal springs. Both Bruner (95) and Kellicott (97a) record species collected from boiling springs, but without more precise data concerning conditions.

The importance of the plankton as fish food was pointed out by Zacharias (93a) and Frič and Vávra (94) and discussed in detail in connection with the food relations of the water by Reighard (94) and Ward (95). Here also Field (97).

Walter (95) demonstrated by statistics the proportional relation in fish ponds between the amount of plankton and the growth of the young fish. Kochs (92) found that Entomostraca could be enormously multiplied by the use of fertilizers in the water, and Zacharias (97) reports that the fertilization of fish ponds doubles the amount of plankton present. Variations in the fertility of different water basins call for more precise investigation and for the selection of suitable areas for intensive aquaculture as in agriculture. Here also Hofer (96).

Istvanffy (94) shows that the diatoms are an important source of food supply to the young fish, but that the species of diatoms in question are those which grow on the shore plants and only rarely the plankton forms. Strodtmann (97) has undertaken valuable statistical investigations on fish food according to which certain species are clearly plankton eaters while others depend upon littoral forms for food. Here also Walter (96b), Grevé (97), Dröscher (97a). Recently, Brockmeier (98) has observed that in some instances gastropods make direct use of the plankton as food.

The problem of the origin of the freshwater fauna has been attacked from many sides. Of a general character may be noted the discussion of Forel (94) who holds that the littoral fauna has come by immigration from the marsh and river, the limnetic has been brought in by birds largely and the abyssal has been differentiated in the lake itself. The distribution of freshwater animals according to de Guerne (93) is influenced (1) by geographic reasons, (2) by zoologic features of the organism. Even to the weakest a current forms no barrier.

A number of observers have studied brackish water basins and the modifications in transition from marine to freshwater conditions. Levander (94a) found in an inlet of the sea typical marine and brackish water forms together with those of the freshwater in about equal numbers. Field (97) studied a long pond manifesting all degrees of salinity and found the greatest number of forms near the point of mean salinity. The forms, however, were more like the hali- than the limno-plankton. An increase in size of various species on prolonged stay in brackish water indicates one possibility in the production of species. Butschinsky (96) noted the mixed character of the fauna in somewhat similar brackish lakes and its variation with changes in the concentration of the salt. Lemmermann (98) investigated a strand lake which had been dammed and in which the salinity was constantly decreasing. The plankton which was notably rich manifested some irregularities traceable to the variable salt content of the water and certain species were localized at various places.

According to Scharff (95) the fauna of Ireland has come by direct extension from Scotland and Wales, with which the connection previously existing broke down during the pleistocene period. Hanitsch (95) holds, however, that among the freshwater sponges three of the six species are American. The importation occurred by means of gemmules borne on floating pieces of wood in the Gulf Stream, or indirectly by migrating birds through Greenland. The failure of these species to spread further is explained on the ground of their inability to compete with native species.

Simroth (96) believes that a secondary adaptation of many land plants and animals has followed upon their remigration into fresh water. Such groups as Hydrachnids show clear evidence of a land life. Fresh water has been furthermore a place of refuge for many ancient forms such as the Ganoids, the Dipnoi and the Branchiopoda. Here also Guppy.

Beddard and Lankester show how tropical animals actually are transported from place to place on aquatic plants. Garbini (95b) has obtained positive evidence of passive transportation of freshwater animals in that ten species representing seven groups were actually collected in transit on mammals, birds, amphibians and aquatic insects, thus evincing the important rôle of these forms in the dispersion of the aquatic fauna. Schewiakoff (93a) rightly regards currents of air and water and actively migrating animals as the efficient means of distribution for protozoa. Their successful introduction depends according to Francé (97) not on meteorological conditions but on hydrological surroundings and on associated plant forms. Kofoid (96b) states briefly the agencies, human and meteorological, important in dispersion.

The insufficiency of our knowledge and the impossibility of drawing reliable conclusions regarding the distribution of freshwater forms from the data at present on record are shown by the statements of Hartwig (98) concerning rare Entomostraca and Jennings (98) on a supposed Asiatic rotifer.

The fauna of island lakes is believed by Richard (98) in the case of the Canary Islands to be introduced in the egg stage by birds and winds. Barrois also notes for the fauna of the Azores that the cosmopolitan European species which are present are characterized by resting stages of some sort, indicating thus passive introduction by birds, water insects and also by man. Such a population must have come gradually to the islands.

The success with which plankton organisms may be transported during some stage in their life history is further evinced by the ease with which some of these organisms can be raised from dried mud, as done by Sars. In this dried condition such forms may remain years without losing power of development under satisfactory conditions of environment. The older experiments on that point have recently been confirmed by Atkinson.

Among other agencies in dispersion must be noted the glacial epoch and Voigt has followed out with great care the effect upon the population of mountain brooks produced by the glacial period and the present gradual supplanting of one species by another.

According to Garbini (94) the limnetic fauna is a passive importation from northern centers of dispersion, and Strodtmann (96) finds its extended uniformity both in Europe and North America evidence of a previous common center in northern polar regions from which the limnetic fauna spread southward. The marine forms in Lake Garda Garbini (94) believes are not a *fauna relicta* but either active migrants from the Adriatic in most part or in a few cases passive transports from the northern ocean.

Of especial interest on this question is the discussion concerning the origin of the Nemertines, a purely marine group with scattered freshwater species. According to Montgomery (95a) these forms are of double origin, (1) direct migrants through rivers to lakes and (2) relict forms in lakes. Their recent origin is shown by variable structural features. Du Plessis (95) would limit the former to rivers and to lakes never occupied by the sea. Garbini (96a) thinks those of Lake

Garda certainly not of a relict character but introduced passively from northern freshwater bodies.

The presence of a *fauna relicta* in African lakes has received strong confirmation in the recent investigations of Moore on Lake Tanganyika. This water basin contains a medusa, six quasi-marine gastropods, two prawns, one crab and several protozoa, all marine in character and together constituting what the author calls a halolimnic fauna. These geographically isolated forms can not have made their way up the stream flowing from the lake, in fact only one occurs on that shore where the outlet empties into the sea; they cannot have been carried overland, being deep water forms in part at least; they are not like modern oceanic forms, but are similar to Jurassic types. The common freshwater fauna was marked in geologic deposits of that period, hence it originated previous to these halolimnic forms which are consequently evidence of the contamination of the lake by a deep arm of the sea in what is geologically speaking no very remote period of time.

Günther (94), speaking of the relict forms in Africa, notes that the freshening of the water must have come very gradually since evaporation is so rapid in the tropics. Rizzardi (94) finds in a small crater lake a considerable fauna relicta and concludes that this demonstrates the marine origin of the water basin. In discussing another lake Garbini (93) had previously shown that such a fauna may owe its origin to passive introduction. Hoernes (97) states still more sharply the argument in the case of Lake Baikal; a relict fauna does not necessarily demonstrate the relict character of the water basin. The former may have come, as in Lake Baikal, indirectly from the marine source through other bodies of water, no longer in existence; and the connection was in this case more probably with the Mediterranean than with the northern ocean.