The Purity of Natural Waters—I*

The Influence of Aquatic Organisms, of Domestic Sewage and of Industrial Waste

By Maximilian Marsson

In 1867 the Danish naturalist, Peter Erasmus Müller, while on a visit to Switzerland, first noticed that the waters of the Swiss lakes were teeming with small crustacea. Previously it had been considered that these clear waters contained no living organisms, and the confirmation of Müller's observations by the examination of bodies of water in other parts of Europe caused much astonishment. These investigations revealed not only minute crustacea, but also enormous numbers of rotifera and protozoa, thus showing that these animalcules were cosmopolitan in their distribution. The detailed study of these organisms in Lake Lemman was first undertaken about 1870 by the Swiss naturalist, F. A. Forel, and soon after 1880 other Swiss lakes were examined by Asper, Heuscher and Imhoff. They found that the microscopic organisms spent their lives swimming in the water, and that many low forms of plant-life were associated with these small animals. This is true of the ocean as well as of bodies of fresh water. The marine investigations were undertaken by Dr. V. Hensen, of Kiel, in order to study the transformation of matter in sea water, and in 1887 he published his important work on "The Determination of the Plankton, or the Animal and Vegetable Matter drifting about in the Sea." The appearance of this book marks a new epoch in hydrobiology, and particularly in respect to quantitative investigation.

THE PLANKTON.

By the term "plankton" Hensen meant "everything that drifts about in water," but it is preferable to define the word as embracing "all living matter that drifts involuntarily," as drifting dead matter is now called "pseudo-plankton." The plankton thus includes all living organisms drifting about or remaining suspended in the water between the surface and bottom, but without ever coming in contact with the latter; and its distribution depends mainly on winds and currents, being affected only in slight degree by the locomotive powers of the organisms themselves. In addition to suitable adaptations for nourishment, propagation and protection against foes, as usually found in the animal world, this large living community also requires the further peculiarity of organization which enables the individuals to remain suspended in the water without appreciable effort on their part. The quantitative investigation of freshwater plankton was advanced greatly by C. Apstein, a pupil of Hensen, who published in 1896 a comprehensive treatise on the subject.

The study of fresh-water and marine plankton is now carried on at biological stations in many places on the earth's surface. Austria has such a station which was established in 1888 by Prof. Fritsch of Prague at the Unteritz Pond, and Germany has one that was established in 1891 by Prof. Otto Zacharias at Great Plöner Lake. For practical pisciculture, biological experiment stations have been located at Muggel Lake and Trachenberg. The advantage of such stations consists in the possibility of studying systematically all conditions of aquatic life in every season, kind of weather and mode of illumination, and also of utilizing to the fullest extent many more observations afforded by constant proximity to the water than could be gained by occasional visits.

In the following pages it is my purpose to consider in somewhat greater detail the various groups of hydrophytes and hydrozoa, and especially their relation to the self-purification of water. The other factors of self-purification, such as the chemical and physical or mechanical agencies, will not be considered here. I have called attention particularly to the plankton, because its vegetable component is the fundamental food supply or condition of existence for all aquatic life. It comes from the products of the decomposition of the albumen which finds its way into the water from decaying animals and plants as well as from sewage. The self-purifying power of natural waters is merely the maintenance of the proper equilibrium between retrogressive and progressive metamorphosis, and frequent reference thereto will be made in the following.

In discriminating between vegetable and animal plankton, also taking into account the remaining aquatic

organisms that are found on the bottom and shores, we find that we must divide them into two classes, viz. Food Producers and Food Consumers. The plants which assimilate inorganic matter and build up organic compounds by means of their chromophyll coloring matter, belong to the first class; and all other organisms, such as microscopic protozoa, rotifera, etc., together with the larger ones up to the fishes, belong to the second class, or food consumers.

VEGETABLE PLANKTON: FOOD PRODUCERS.

Let us now consider the Plants somewhat more closely. In the waters algae play the most important part, as they exhibit the greatest diversity of form. They are found in all places where water has collected, even in the long-stagnant rain water, but their vegetation varies with the seasons and the character of the water. While the plankton contains many unicellular forms and coherent colonies, or strings of such, we find in shallow waters, streams, ditches, and shores mostly the confervæ, or threadlike algae which appear as thick mats or strands of light or dark green color. The blue-green group called schizophyceæ is also widely distributed, and representatives thereof usually produce the so-called "blooming" of our rivers and lakes, while others, especially the oscillatoria, often settle in strongly polluted water courses, such as the gutters and ditches of unsewered towns and the drainage channels of barnyards. When they form a covering of wet and polluted ground, they usually have a deep black color, but similar kinds are sometimes red, and have been mistaken for dried pools of blood.

The other groups of algae have only a few representatives in fresh water. Of these the diatoms and bacillariaceæ have been most extensively studied by microscopists, as they are found in all seasons in every water course and pool from the pole to the equator, and as well in icy streams from glaciers as in hot springs. They sometimes appear in such enormous quantities as to render a counting of individuals impracticable. It was formerly believed that in winter our frozen rivers and lakes were devoid of life, as the water was then unusually clear; but on closer examination by filtering the water through a net of fine silk gauze, or by killing the living organisms with alcohol, formalin, etc., and concentrating them by sedimentation or other means, an abundance of microscopic organisms of various kinds, and especially diatoms, will be found in all seasons. The cell body of these algae is held together by a silicious skeleton, which has often so delicate a structure as to be defined clearly only by the best microscopes; and hence certain species of diatoms, such as *Surirella Gemma* and *Pleurosigma Angulatum*, are used as test objects for the best objectives. Through their brown coloring matter, called diatomin these silicious algae are as capable of assimilating organic matter as are the green and blue-green algae by means of their normal green coloring matter called chlorophyll.

As the assimilative activity of the algae is a very important factor in maintaining the purity of our streams, it is necessary for us to consider briefly the structure of the microscopic plant cells, of which the higher plants are composed.

In opposition to the animal cell, a well-defined vegetable cell is inclosed by a dense skin, called the membrane. For this reason the cells of a plant are sharply separated from one another. Each such cell possesses a much greater independence than the cells of the body of an animal, or at least of the higher developed animals. In almost every plant cell there is a nucleus, the remainder of the volume being filled by the cell plasm or cytoplasm, which is rich in albuminous substances, and in which the carriers of coloring matter, or the chromatophores, are distributed. These three components (nucleus, cytoplasm and chromatophores) taken together are commonly called protoplasm, or more briefly plasm, which includes all the living constituents or protoplasts of the cell. The chief function of the cell is based upon a reciprocal action between the nucleus and the plasm. The chromatophores or chloroplasts, however, whose predominant green coloring matter is chlorophyll, exercise an important function in the cell, since with the help of the vibrations of light they are enabled to dissociate carbon from the carbonic acid that is contained in air and water, and to prepare with the elements of water organic matter having little oxygen. Polymeric carbonaceous products are thus formed which then develop into starch and certain kinds of sugar; and these compounds, in conjunction with the simplest combination of nitrogen, finally serve to form albumen and other complex combinations for the use of plants, whereby the weight of dry organic matter in the latter is in-

creased. The nitrogen required to form the albuminous compounds is obtained from ammonia and nitrates, and other elements found in the ground and water also appear to play a not less important part in the formation of albumen.

Assimilation.—This entire synthetic process, in which oxygen is dissociated from carbonic acid in the form of gas, is called Assimilation. It is the same in land plants as in aquatic plants. In the case of the latter, the highly developed as well as the microscopically small, the necessary supply of carbonic acid is derived only from the surrounding water. In the diatoms the starch is replaced by a fatty oil, which develops more abundantly in the species that grow upon the bottom than in the seamless species which live freely suspended in the water, and usually constitute the greater part of the plankton of sluggish streams. After the winter's cold has passed away and the heat rays of the sun are able to penetrate deeply into the water, however, the microscopic plants which have been dormant on the bottom are stimulated to renewed activity and multiply with amazing rapidity, whereupon they are lifted upward by the assimilation gases and appear on the surface of the water. In March, April and May, thick brown masses are seen floating in our rivers, and are commonly regarded as filthy or disgusting matter; but on examining a small portion thereof under a microscope, it will be found to consist of amorphous earthy and dead organic matter intermixed with bubbles of gas and swaying tangles of blue-green filaments called Oscillatoria, among which countless diatoms may be seen gliding to and fro. Both of these varieties of algae possess a remarkable power of motion, which render it possible for them to crawl about on the bottom or to move in the sludge on the bed.

The seamless diatoms of the plankton do not require this ability to move about, as they are held in suspension by their peculiar shape; but the species that live on the bottom have a seam at which pulsations of plasm that produce motion are manifested. It is very interesting to observe how a parallelism has developed between the biological relations and the morphological structure of an organism. The algae which are lifted from the bottom by gas bubbles and are not normal constituents of the plankton, are scattered about in running water and purify it by removing therefrom the carbonic acid which has accumulated during the winter. This is done by dissociating the oxygen from the acid and letting the former aerate the water. Such indirectly anti-putrefactive organisms generally develop in places where they are most needed, as in localities where the bottom consists of organic sludge or detritus of every kind instead of clean sand.

The production of oxygen, however, is not limited to the activity of the minute plants mentioned, but is maintained by all the other plants which are found in the streams throughout the entire year, even under the ice in winter, although in reduced numbers. As is to be expected, the assimilation gases act very energetically, especially in their nascent state, in oxidizing dissolved organic matter, and atmospheric oxygen is by no means so efficient. The plant life of a stream is therefore of the utmost importance, while the sun must be regarded as the source of the energy required for the development and growth of all these organisms.¹

To be continued.

Anti-typhoid Vaccination.—Very favorable reports are made with regard to the successes of anti-typhoid vaccination; especially the experiments of Prof. Vincent, in Morocco, are worthy of notice. The vaccine can be prepared in two ways. According to one method, says Comos, an extract of dead typhoid bacilli is prepared with ether; the product obtained is known as "autolysate." Another preparation consists of an emulsion in salt water of microbes killed with ether. The appended table of the results obtained by the use of this vaccine speaks for itself:

		Typhoid Fever.	Febrile gastric affections.	Total.	Deaths.
Non-vaccinated	Per	64.87	50.90	115.77	8.35
Vaccinated.....	thousand	0	0	0	0

¹Prof. R. Kolkwitz remarks on the action of oxygen: The question of the presence of atomistic oxygen in plant cells requires more thorough investigation, as it has not been found outside of the plasm. Compare W. Pfeffer, "Contributions to the Knowledge of the Processes of Oxidation in Living Cells," in *Abhandl. der Math.-phys. Klasse d. Kgl. Sachs. Ges. d. Wiss.*, 1889, vol. 15, p. 430. Marsson maintained that living specimens of *Riccia Fluitans* were capable of forming active oxygen.

*This fascinating epitome, reproduced from the *Engineering News*, of the important rôle played by the aquatic flora and fauna in maintaining the purity of streams and lakes was written by the late Dr. Maximilian Marsson, as the latest revision of a lecture which he had frequently delivered before the Royal Testing Station for Water Supply and Sewage Disposal at Berlin, Germany, with which station Dr. Marsson was connected at the time of his death. The lecture, as here translated by Emil Kuichling, originally appeared in "Mitteilungen aus der Königl. Prüfungsanstalt für Wasserversorgung und Abwasserbeseitigung," 1911, having been prepared for publication by Dr. Marsson's associate, Prof. R. Kolkwitz.