harmonious system. But it is to microscopic researches that we owe the most striking manifestation of the "Ewig Eine" of the organic world, because these demonstrated a fundamental agreement in structure between plants and animals which was not dreamt of at the beginning of the century.

Although the microscope had been applied during the two preceding centuries to the study of the minute structure of plants and animals, and although Bichat at the beginning of the century made such notable progress that he has been named the father of modern histology, yet Schleiden and Schwann may be said to have inaugurated in the early forties a series of researches into the "cellular" structure of organisms which has culminated within recent years in the most far-reaching discoveries regarding the most secret internal movements of their elements, disclosing the most surprising agreement between plants and animals, both in the origin of new constituent cells and the early history of their eggs. Truly, Treviranus would be at no loss for a point of view to-day.

Not only was the structure of organisms living and extinct questioned as to the applicability of the doctrine of evolution, but also their distribution on the surface of the earth, and thus was initiated a new line of geographical researches, already pioneered by Humboldt. What had been established as to the wonders of the life of the ocean by the earlier investigators of the century such as Chamisso—for Gœthe is not the only poet-naturalist worthy of mention here—merely stimulated fresh enquiry, with the result that expeditions like those of the Challenger have much extended our knowledge in this direction.

Perhaps the most interesting among the results recently obtained is that which has explained to us the cycle of organic life in the ocean. On land the forests and plains furnish the food for hosts of phytophagous animals which again are preyed upon by carnivorous forms. In the sea carnivorous creatures, great and small, seem to predominate. Whence comes the initial food-supply for them? "Plankton" studies have shown that even in the icy seas of the polar regions the vegetation of the ocean is amply adequate for the support of its teeming animal life, but it is embodied in organisms of the humblest structure, which make up in numbers for their microscopic size, while the herbivorous animals which feed upon these are also numerous and inconspicuous.

If we owe to the improved microscope of the 19th century the sharper insight into life-processes referred to in the preceding paragraphs, it is no less true that it has opened to us an entirely new world of infinitely minute plants and animals, the investigation of which has yielded results which will be remembered as the chief achievements of the biology of the 19th century. Beginning with Pasteur's study of the silk-worm disease, his investigations on the organisms involved in fermentation and putrefaction, his refutation of "spontaneous generation," and continuing with the resultant improvements introduced by Lister in the treatment of wounds, the establishment by Koch of the parasitic origin of the infectious diseases, the economic applications of bacteriology, the revelation of the rôle played by "nitrobacteria" in the soil, down to the discovery of anti-toxins and the complicity of the mosquito in distributing malaria, we have in the latter part of the 19th century a series of brilliant researches of the widest theoretical interest and of far greater practical importance than those referred to at the beginning of this article.

Returning, in conclusion, to the speculative aspect of modern biology, we may detect as a *fin de siècle* characteristic the tendency to leave aside for the time being the discussion of Darwinian and Lamarckian factors, and to interrogate Nature directly as to the causes of evolution. Such is the attitude of students of the "mechanics of development," but years of patient experiment must precede any attempt to estimate their results. Perhaps my successor, who will sum up for the VARSITY of January, 2001 the achievements of biology in the 20th century, will be able to dispose of these in a few words, but we may confidently anticipate that experiment will yield more lasting contributions to knowledge than much of the speculation which has hitherto prevailed.

OPTICS IN THE NINETEENTH CENTURY.

BY G. R. ANDERSON, M.A.

Long ere the dawn of civilization a number of facts relating to light must have been forced on the observation of prehistoric man—the alternations of day and night would indicate that the sense of sight was dependent on something coming from the sun—the shadows cast by various objects would show that this light must travel in straight lines—and the images of surrounding objects in still water would be a subject of thought to even the crudest intellect. Notwithstanding the fact that the laws of optics are everywhere in evidence the progress of the science has been very slow, nearly all the important work having been accomplished in the last three centuries.

In the sixth century B.C., Pythagoras had formulated a theory of vision similar to what was twenty-two centuries later developed by Newton and known as the emission theory of light, according to which it was held that vision was produced by particles projected on the retina of the eye from a luminous body. This doctrine was attacked by Aristotle about 350 B.C., who held that light was not a train of material particles but an action of a medium which he called *diaphanes* and here we have the first intimation of the now universally accepted undulatory theory which was developed during the nineteenth century. Other ancient writers, among them Plato, Ptolemy, Euclid and Cleomedes, treated of optics, and in Arabia considerable attention was given to the subject about the twelfth century.

The seventeenth century was marked by a number of discoveries of the utmost importance, to wit: the introduction of the telescope, the determination of the velocity of propagation, the laws of reflection and refraction, the analysis of white light by the prism, the foundation of the wave theory by Huygens and its application to the explanation of double refraction. Newton combated the wave theory and adopted the emission theory by which he was able to explain the phenomenon of polarization which did not appear to him explicable on the assumption that light was produced by undulations.

Coming to the beginning of the nineteenth century we find things very much in confusion. Newton had formulated his corpuscular or emission theory, and in order to explain certain phenomena of interference had been forced to invent various supplementary theories resulting in arbitrary laws for which there appeared to be no plausible reason. The wave theory, as already stated, was assumed by Huygens, but there were many difficulties in the way that had hitherto prevented its acceptance, notably in the matter of rectilinear propagation and polarization. The researches of Dr. Young on interference about 1802 successfully disposed of one of these difficulties and paved the way for future discoveries along the same line. It is to Fresnel that the chief credit must be accorded for placing the wave theory on such a footing that the older emission theory became at once and forever a matter of history. In a series of remarkable papers issued between 1815 and 1827, he disposed of the objections to the undulatory theory, explained the phenomena of