SCIENCE

VOL. LIX APRIL 4, 1924 No. 1527

CONTENTS

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. McKeen Cattell and published every Friday by

THE SCIENCE PRESS

Lancaster, Pa. Garrison, N. Y.

New York City: Grand Central Terminal.

Annual Subscription, $6.00. Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

Entered as second-class matter July 18, 1923, at the Post Office at Lancaster, Pa., under the Act of March 3, 1879.

PRESENT LINES OF ATTACK ON ANIMAL PARASITOLOGY[1]

IN treating the subject suggested by the secretary of this section, it is my desire to follow out his suggestion by discussing some of the general problems at present being attacked in the field of animal parasitology in order to point out if I can what measure of success is being achieved in each field and what appears to be immediately in sight for future consideration. Evidently within the limits of such an address only general statements can be made and details must be cited sparingly if at all. Animal parasitology has developed more in the last decade than in the entire previous period of recorded science, and the contrast in America is even more striking than in Europe.

Before taking up the general discussion, I wish to deal with a particular item that was included in the duty laid upon me. In common with many other speakers on this occasion which marks the seventy-fifth anniversary of the organization of the American Association for the Advancement of Science, I was asked to review briefly the work done on this topic of animal parasites, under the auspices of the association. I have elsewhere commented on the fact that when about 1845 the distinguished naturalist Dr. Joseph Leidy, founder of American parasitology, began to study and write on animal parasites, he entered upon virgin territory, for no work had been done previously on that subject in America, and for many years he worked alone. The start of his studies was roughly coincident with the founding of the association. Leidy's work was done in Philadelphia, and he does not appear as a contributor on this theme to the printed volumes of the association. In all the early years these volumes contain only four papers on parasitology, and but one of these was more than trivial, *viz.*, that by Weinland on "Human cestodes new to science"; this paper outlined his well-known book with the same title, published a little later in the year.

Between 1885 and 1890 a number of important studies on insect parasites and parasitism were presented at meetings of the association. Especial mention should be made here of the work by C. V. Riley, who was evidently a leader and inspirer of the group of workers. Beginning in 1892 came a series of papers on helminthology, slowly but steadily increas-

[1] Read before Section N, at the Cincinnati meeting on December 29, 1923.

ing in numbers, until to-day the joint program of the American Society of Zoologists and of the section on zoology in the association devotes one or more sessions to the consideration of papers on parasitology.

This relation of the association to the subject conforms reasonably clearly to the general attitude of the country. The early students of parasitology in Europe had no contemporaries here in the same subject. Leidy found the field unoccupied and worked in it alone for many years before activity was manifested first in entomology, later in helminthology and finally very recently in protozoology.

THE GENERAL SITUATION AT PRESENT

The years of the Great War were a period of tremendously rapid advance not only for workers in the field of animal parasitology who were given position, authority and material support that enabled them to attack vigorously the problems in this field, but also for the solution of those problems which under the conditions of warfare presented themselves in acute fashion and in concentrated form. Out of this has come a wealth of discovery exceeding that of any previous period even though it be given time limits manyfold greater. It is not necessary that I should review here in detail these discoveries or their practical application in measures for the protection of the combatants. It is interesting to note that in some cases the method of handling the problem in a practical way was developed beyond our knowledge of the causal organisms. Thus we do not yet know the character[2] of the organism causing typhus or trench fever, though we have had positive demonstration of their transmission by lice and have been able to work out measures of control which at least under conditions in time of peace will serve to limit the spread of the diseases if not actually to exterminate them. Of course this situation was not novel, for a parallel instance is to be found in yellow fever, where, thanks to the splendid work of a series of American investigators, and even at the sacrifice of life by some of the leaders, positive evidence was secured regarding the transmission of the disease out of which grew promptly the effective measures for its control. It was indeed many years after the magnificent work done by the commission, consisting of Drs. Reed, Carroll, Agramonte and Lazear, that Noguchi was finally able to determine the causal organism as a spirochete and to round out the life history.

But even when all such cases have been taken into account, it must be recognized clearly that the speed at which such investigations progressed was very greatly accelerated by the conditions of the war, and we find ourselves to-day in possession of increased information and new problems to a degree that could not have been predicted or probably realized under any other conditions. In examining this situation, however, one must recognize that the methods for utilizing the information gained regarding these parasites and for limiting their immediate attacks upon their hosts have outrun distinctly at numerous points the information concerning the structure, development and bionomics of the causal organisms, and also of their transmitting agents in those cases where such are found. The further effective progress of the clinical worker is thus being retarded and in some instances entirely stopped and additional information concerning the parasites must be worked out if the work is to continue to develop. This information is needed in the oldest as well as in the newest phases of the subject.

[2] Recent papers by Wolbach and others indicate that the solution of this problem is being approached.

THE MORPHOLOGY OF ANIMAL PARASITES

The morphologist faces a wealth of problems which have not yet fully presented themselves, but which are rising out of the uncertainty of the situation with increasing distinctness. There is a time-honored list of human parasites, for example, to which it has been customary to assign forms that present themselves often without very careful examination into the character of the material in question. To the worker unfamiliar with the field many forms in a given group present a relatively uniform appearance and any human tapeworm, for instance, is likely to be labelled with the name of the common species *Taenia saginata,* provided only it has a head without hooks or if the general appearance of proglottids under the lens seems to correspond to a book figure of that species. It is worthy of note that at various times trained observers in different parts of the world have commented on certain peculiarities of specimens that they have secured, or have confessed their unwillingness to designate the material unequivocally as part of the common species. The latest of such instances comes from Japan where Isobe speaks frankly of his difficulty in reconciling the appearance of specimens of an unarmed human tapeworm with the classic description of the species *Taenia saginata.* Thus, even in connection with one of the oldest and, one might say, the best known of human parasites there exists a real doubt as to its range, and one with justice might adopt as a working hypothesis the view that very likely other closely related species are present in various parts of the world and have up to date been confused with the classic European form. Such a hypothesis does no violence to the teachings of the past in this field. For even the masters of helmin-

thology have confused with each other species of the more or less similar form which on careful study were found to be clearly distinct.

I am well aware that many will regard such a study as suggested as of relatively little significance, and it is rather the tendency for those who deal with these organisms in a practical way to feel that accurate morphological determinations are of very subordinate value. I can not share such a view. It appears to me clear that our experiences indeed furnish the best of evidence that this attitude is untenable. It was not of secondary significance that Stiles by careful morphological study demonstrated the existence of a new hookworm which previously had certainly been encountered frequently, but which always had been confused before that with the type of hookworm first described. I am sure the magnificent progress which has been made in handling hookworm disease, as well as our comprehension of the problem, depends in a very evident way upon the demonstration that he furnished of the existence of the second species which has proved to be not only unlike in distribution as well as structure to the older form but also has manifested particular bionomic factors that are of significance in the attack upon the problem of eradicating the hookworm disease. Indeed, the discoveries in this direction have not reached the limit, even though splendid contributions have been made by a long series of energetic and effective students of the problem.

One of the ever-present problems in animal parasitology is the elimination of errors which have crept into earlier records by virtue of lack of precise determination of the forms involved. It is unnecessary to call attention in detail to the many cases in which workers in the field have been led astray by preliminary determinations that grouped together as identical forms that really were distinctly or sometimes conspicuously different in structure. By virtue of such errors many serious mistakes have been introduced into general discussions concerning the life history, distribution and significance of parasitic organisms. Recent thorough revision of the actual material utilized by earlier investigations and now in European collections has resulted in clearing up certain elements of confusion in earlier records. It is of course impossible to apply this method to testing all the records of earlier students, but its value has been so distinctively proved that it should be carried much further and all the collections available in the museums of the world be subjected to renewed and careful study at the hands of specialists on the various groups. One can not too strongly insist upon the need for the study of the original specimens or of material collected in the same territory and from identical hosts. Unfortunately, many revisions have been merely literary studies of the figures and descriptions of earlier authors and have in some instances certainly contributed further to the confusion existing. Textual analysis and critical sentence study is of little value in the determination of scientific data, and the imperfection of earlier observations and descriptions leads under such circumstances only to the repetition or amplification of error. The important fact is not what the earlier author said or what he thought he found but rather what the conditions actually are in material such as he studied. Only by attacking the problem from that standpoint is it possible to make contributions of permanent value or real advances upon the work of the original authors.

The work of Looss on the structure of parasitic worms and the fundamental revision he was able to make by following out this method is complete justification of the value of such procedure and stands in sharp contrast with the uncertain findings and confusing statements of some contemporaneous revisers who depend more largely, if not entirely, upon textual analysis of the records of earlier authors.

LIFE HISTORY PROBLEMS

Some 50 years ago parasitologists were actively interested in working out life cycles and through the efforts of Leuckart and others a series of classic examples of the development of individual parasites was added to our knowledge and have been incorporated as typical instances in lecture courses and textbooks ever since. Indeed, they had come to be so thoroughly established in the individual mind as the actual and perhaps necessary course of development that the scientific world did not react favorably to studies which seemed to modify these older conceptions. Undoubtedly, the first of these newer studies both in rank and time is the story of the development of the hookworm as worked out by the painstaking researches of Looss. It is worth noting that when that distinguished parasitologist presented his communication outlining the life history of the hookworm to the International Zoological Conference at Berne in 1904, I myself heard distinguished older workers in the field label the account as a fairy tale to be ranked with the stories of Baron Munchausen and the tales of the Arabian Nights! But Looss was right and the value of his results was so evident that recently many have been led to attack anew life history problems in other parts of the field. The most noteworthy contributions in this line have been made on the Nematodes among which migrations in the host tissues seem to be the rule rather than direct development as was formerly held. The technical difficulties in the way of following out such life histories have proved serious, so that progress has been slow and many

interesting species still await a successful attack upon the secrets of their wanderings. Especial mention should be made of the noteworthy contributions in this field by Fülleborn.

Problems of epidemiology are fundamentally dependent for their solution upon the correct determination of the life cycles of the parasites in question. It can not be too strongly insisted upon that the determination of such life cycles is only possible with the worker who has devoted adequate attention to the precise morphology of the adult parasite and its various larval stages. Much confusion has been introduced in various cases by faulty determinations. It is unquestionably true that the larval forms of many different species are strikingly alike and only a most precise consideration of their morphology will suffice to furnish diagnostic data adequate for their discrimination. Thus, in the intensive search after the life history of the Japanese lung fluke (Paragonimus) and of the Japanese liver fluke (Clonorchis), which was undertaken simultaneously by a considerable number of Japanese investigators, these workers were led more than once into serious error because though able and highly trained investigators in their fields, they were not familiar with the minute structure of the larval forms being studied. Other species which were concomitantly present in the larval hosts were confused with the proper stages, and conclusions were drawn from experimental work that were seriously misleading. A splendid example of the opposite condition is furnished in the work of Leiper on the life history of the blood fluke (Schistosoma). That investigator, trained by Looss who must certainly be recognized as the master of the most accurate modern morphological methods, was able to find a solution for developmental problems in this species which had been vainly attacked by numerous able predecessors. The exceedingly precise studies of Faust, Cort and others on the microscopic structure of the cercariae have furnished a basis for accurate discrimination between stages of the three species parasitic in man, and the value of the results stands in sharp contrast with the confusion introduced into the field by some industrious and enthusiastic workers who have been unfortunately without that technical knowledge of the group necessary to make their work of permanent value.

Much has been done through the experimental infection of hosts to secure larval forms in known stages and to determine the period essential for development under fixed conditions. These data are of the utmost importance in preventive medicine, and it is almost trite to emphasize the fact that the treatment of parasitic diseases must always be primarily and often in its entirety a problem of prevention rather than of repairing the difficulty after the malady has made its appearance.

No better illustration of this feature could be given than that furnished by *Ascaris lumbricoides*. The dictum of earlier investigators that this species developed directly to maturity in the intestine after ingestion of the infective stage had been accepted without question, notwithstanding a lack of knowledge of what actually happened. When, however, the investigations of Stewart, Ransom and his coworkers, Fülleborn, and others established the facts in the life cycle of Ascaris, then an entirely new field was opened up. The migration through the tissues and the attacks upon the lungs were early seen to be directly connected with conditions in the host previously unexplained and not regarded as in any relation to the parasite. Its serious import to the host at once became evident and one could for the first time get a time picture of the significance of an organism previously considered of minor clinical and practical importance.

NEW FIELDS OF STUDY

Among the points of attack which seem to afford largest opportunity for valuable work at the present time, one may undoubtedly list prominently the field of microscopic organisms. We are only just beginning to know the significance of recent studies on protozoa which have already yielded extensive information concerning certain known types and which have resulted in the discovery of an immense number of hitherto unknown forms. Unfortunately, up to the present date our knowledge of most species has remained extremely fragmentary. The results of intensive studies on the intestinal amoeba have gone far beyond our expectations and have revealed a wealth of detail concerning the different types involved in the causation of disease, important data on their life histories and most significant features in their biological peculiarities. While one is forced to recognize the progress that has been made along these lines, it is still impossible to lose sight of the large gaps in our knowledge even regarding this and other "better known" organisms among the protozoa. The work already done is leading in directions entirely unsuspected at the start, and if only a part of the remarkable discoveries of Kofoid and others stand the test of repeated investigation the results will form one of the most brilliant chapters in the history of this field. One needs only to mention Trypanosomes and Trypanosomiasis to suggest at once to the mind an immense literature which has resulted from the studies of recent years and out of which has grown not only valuable results for the specific problems attacked but also influences that are far-reaching in the field of chemo-therapy.

Of all such organisms only occasional forms parasitic among lower animals have been subjected to extended investigation, although many of them are of

marked economic importance and great biological interest. Even among the parasites of man there are many protozoa which have been brought to our attention by isolated observations that will doubtless repay richly intensive study. One can not too strongly commend the type of attack being made upon such problems by Hegner and his associates at Johns Hopkins University. A thorough intensive investigation of the structure, life history and bionomics of a few forms will lay solid foundations for future work and render the conquest of the field more rapid and more certain than would be possible under methods that resulted in a more extensive examination of a larger number of species. It is also fortunate that an intensive attack has been organized against parasites of lower animals where continued study, experimental work and control of conditions essential for a thorough testing of the results and interpretation of them is possible; and more rapid progress is assured than if the beginning had been made only on the parasites of man. Indeed, in reviewing the field, it is noteworthy to see how many instances present themselves in which the investigation of human parasitic diseases has been held up by lack of an adequate basis in general knowledge concerning the parasitism of such forms.

Signs are not lacking to indicate the growing significance of a group of spirochetes to which recent investigators have assigned the causal organism found in connection with important diseases, the etiology of which has long waited for the demonstration of the causal organism. A study of this group has hardly been started as yet, although in Noguchi's demonstration of *Leptospira icteroides* as the causal organism of yellow fever marked progress has been made towards the determination of such forms and the methods for their study as well as for testing them in their relation to disease. Here it is certainly of the utmost importance that a thorough investigation be made of the problem of their nature and relationships and the determination of their proper assignment to plants or to animal organisms will yield biological evidence of the relationship of these two groups that will be of far-reaching significance in general biological studies.

Of marked importance are recent studies on the flagellates of plants and their relations to insect flagellate parasites. In the opening of this new field of work especial mention should be made of Franchini's investigations. Nothing could illustrate better than these studies the intimate and far-reaching relations to parasitism. Indeed, although hardly begun, they have already thrown some light on the problem of the origin of parasitic protozoa long known from the blood of vertebrates. It is not too much to hope that along this line may be reached the solution of problems of human disease hitherto entirely unexplained. Studies such as that contained in the paper just presented[2] by Strong show unmistakable relations between flagellates parasitic in plant and animal hosts that involve also the human species.

Within very recent times there has been published by J. Jackson Clarke, of London, investigations concerning a whole series of little known and less understood micro-organisms which he is inclined to consider closely related to some unusual groups of plants known only to a few technical workers in that field and not heretofore considered of general significance in human parasitology. While the results of this investigator have not as yet met with confirmation they open up a territory in which knowledge is scanty and interpretation exceedingly difficult. The investigation of such problems as this will demand the attention of specialists highly trained in the particular field of botanical research and an ultimate decision concerning the biological character of these organisms can not be reached by the investigator, however well trained in other lines, who is unfamiliar with the types to which it is claimed they are to be attached.

NEED OF COOPERATIVE RESEARCH

The application of results already obtained concerning the structure, life history and bionomics of parasitic worms to the prevention and treatment of disease requires the attention of specialists in the field of medicine if adequate results are to be achieved. Ultimately, then, the problems which are developed and carried to a more or less successful solution by parasitologists require for their fullest utilization cooperative work from the specialists in the medical field. It is just here that the work of this section may be expected to yield valuable results. Neither class of investigators alone can hope to achieve adequate success from a study of the problems that present themselves. The cooperation that in the past has been manifested in partial fashion or at individual points must be developed to include the entire subject. It is certainly desirable that workers of both types should find opportunity to carry on further investigations simultaneously and in close touch with each other. The splendid results that have grown out of such cooperative action in the few individual cases in which this method has been followed in the past promise even richer success when the method shall have become more general. While individual effort will still yield valuable results the most far-reaching success will fall to those who are able to organize and work out in a cooperative way an intensive study of some of the great problems concerning individual parasites that present them-

[2] "Relationship of certain parasitic infections of plants to animals," by Richard P. Strong.

selves. One needs only to look over the work done recently in the study of hookworm disease by the group organized at Johns Hopkins under the leadership of Cort, to recognize the full justification of this contention. May we not hope that in the immediate future many such undertakings may be similarly organized and be able to secure equally strong support Under such conditions one may safely prophecy rapid progress in the solution of the problems which present themselves in this field.

HENRY B. WARD

UNIVERSITY OF ILLINOIS

A FAULT MAP OF CALIFORNIA

A MAP which shows the the distribution of earthquake risk in California has been published by the Seismological Society of America and can be obtained from the Secretary, Dr. S. D. Townley, of Stanford University, California. The base of the map was prepared by the U. S. Geological Survey in cooperation with the California State Department of Irrigation and is both accurate and on a scale to show details. It shows the mountains and valleys by relief shading, drawn by John A. Renshawe of the survey, and carries the net of township surveys and Spanish landgrant boundaries, so that any property in the state can be located. It also exhibits the submarine contours from the shore out to the depth of 2,000 fathoms as determined with unusual detail and accuracy by the U. S. Navy by means of the Sonic depth-finder in 1922. Upon this base the known faults, which traverse the Coast Ranges from Mexico to Humboldt County and encircle the Sierra Nevada, have been mapped by the undersigned.

The Fault Map of California, although neither complete nor perfect, presents a large array of facts, which may be useful in various scientific and practical ways. The research student who is occupied with problems in structural geology relating to faulting and folding will find in it examples of those structures actually in course of development. The isostatic equilibrium of the Sierra Nevada and of the great coastal scarp may be examined in the light of more complete evidence than we have previously had. The displacements of triangulation stations, recently determined by the Coast and Geodetic Survey to be of significant magnitude, may be accurately indicated on it in relation to the faults which limit the moving masses. The teacher of geology or geography who desires to illustrate some point connected with the relief of the earth's surface will find the facts clearly displayed in the beautifully shaded base map produced by Renshawe. The investigator of submarine relief is given an unusual opportunity to study the forms of the ocean bottom in the detailed contours drawn on the soundings secured by the navy with the cooperation of the Hydrographic Office. Here are forms attributable to faulting, to aggradation by terrigenous sediments, to submarine erosion, or to subaerial erosion, now submerged.

On the practical side the map serves to define the areas of earthquake risk in a way which may enable the dwellers in any given valley, or township section indeed, to determine the proximity or distance of a probably active fault. Engineers should no longer build in ignorance of the existence of dangerous rifts. Insurance men should no longer lay a blanket premium on buildings in California where the risk is quite as unequal in different parts as it is between Tokyo and New York. The conditions of building and the building regulations of communities should take account of the facts that are brought out in the Fault Map.

While we have sound reason for the opinion that these things are so, we recognize that the Fault Map as it now stands is a first attempt to present the facts on this scale and, like other first attempts, can be much better done another time. It is to be hoped that one of its principal services will be to stimulate the study of faults and their relations to earthquakes.

A noteworthy feature of the Fault Map is that it expresses a distinction between active faults and dead faults. This distinction appears to have been recognized first by Branner, Gilbert and Lawson, after the California earthquake of 1906, and the term "rift line" was used in the report of the Earthquake Commission to describe one type of outcrop of an active fault. The great San Andreas fault exhibits this type. Its relation to the shock of 1906 was evident throughout the entire distance, 190 miles, along which the disturbances of the ground were traced, and it exhibited peculiar topographic features, both in its relation to mountains and valleys and also in the peculiar occurrence of various minor features in longitudinal arrangement, by which it or other faults of like recent activity could be followed. The definition of an active fault is thus that it is a fault on which there has been a movement within a period so recent that sequential displacements may reasonably be expected to occur along it. It is obvious that the definition can not be applied with exactitude when it comes to distinguishing an active from a dead fault. There are active faults which are known to have suffered displacements within our experience, and there are dead faults which can be proved not to have suffered any displacement since the Pliocene; but between the unquestionable examples there is a wide range within which conscientious observers may differ as to the classification. It is also true that men are cautious in earthquake countries in ascribing dangerous activity to any feature that might give rise to an