

## RECENT PROGRESS IN OUR KNOWLEDGE OF PARASITIC WORMS.

A PAPER READ AT THE BRITISH ASSOCIATION FOR THE  
ADVANCEMENT OF SCIENCE. ANNUAL MEETING 1912,  
SECTION D.—ZOOLOGY.

By WILLIAM NICOLL, M.A., D.Sc., M.D.

*(Lister Institute of Preventive Medicine, London.)*

DURING the course of the last few years our knowledge of parasitic worms in all their various relations has advanced and increased to a very considerable and satisfactory extent. From the purely zoological point of view the advances have been of the highest order, many important discoveries having been made, not only in connection with the morphology but also, and particularly, in connection with the development and bionomics of these worms. At the same time there has been a steadily increasing improvement in our ideas of their classification and relationships which has resulted in a much wider and more accurate conception of their zoological nature. While these rapidly accumulating discoveries have greatly extended the knowledge at our disposal, they have, in addition, rendered such facts easier of study and of use, with the result that the economic value of the subject as a whole has been very materially enhanced. Helminthology shares with Protozoology and Entomology the, in some respects, unenviable distinction of being of intrinsic importance not only to medicine, but also to veterinary and agricultural science. It has a smaller but no less definite economic importance in relation to fisheries. Apart from their purely zoological interest it is particularly as agents of disease that the parasitic worms are of importance, but there are a number of other matters connected with habits and distribution, on which a study of parasites may throw considerable light.

There are in this way several different lines along which progress has been made. It is in many cases not a little difficult to estimate the relative importance of these advances, and it is a common experience that discoveries which appear, at first, to be of only academic interest occasionally prove of the greatest economic value. In consideration of the meeting at which this paper is being read, chief attention must naturally be paid to those features which are essentially of zoological interest and importance, but some space will also be devoted to their economic bearing. It is impossible in a short review, such as this, to deal adequately with all the work on the subject, so that, for the most part, only the work of the best known authorities will be considered.

It is frequently a matter of difficulty to determine exactly what period of time is covered by the term recent. With our present rate of advance, ideas and views change with such remarkable rapidity that any one discovery, no matter of what importance, does not long remain a novelty, and it is generally the case that those of second rate value remain entirely unknown except to a few for whom they possess an especial interest. There is the further consideration, however, that in the course of time the matters of fundamental importance become common knowledge and, I venture to think that, under ordinary circumstances, a period of five or six years will elapse before this is the case. I have accordingly chosen this as the period with which to deal.

It may be well, first of all, to consider the men who have been chiefly engaged in carrying out the work. Foremost amongst these must be mentioned the names of Looss, Fuhrmann, and Odhner, who have been mainly responsible for the great advances made in our knowledge of the flat-worms. Looss has also devoted considerable attention to the round-worms, which have received further treatment at the hands of Railliet and Henry. Amongst others whose work may be specially mentioned are Von Linstow, who has devoted himself to helminthological research for the past fifty years, Stiles, Ransom, Ward and Linton, the foremost exponents of the American School, Lühe in Germany and Goldschmidt, whose researches have been chiefly histological. In addition reference must be made to the excellent work of Porta and of Monticelli in Italy, of Weinberg in France and of Leiper, Shipley and Miss Lebour in this country. Even this long list, however, does not by any means exhaust the number of those who have specially interested themselves in the subject and have done outstanding work in it.

In dealing with such a large volume of very varied work it seems advisable to consider it, as far as possible, under separate sub-divisions, such as systematic, morphological, developmental, etc., and although many papers will require to be discussed under more than one heading, the best idea of the whole subject will probably be obtained in this way.

Considering then in the first place the systematic work, it will be found that the bulk of it has been devoted to Trematodes, in which class several of the large groups have received exhaustive treatment. The most outstanding contributions have been those on the North African Trematodes by Odhner (1911), the Echinostomes of Birds by Dietz (1910), the Distomes of North American Fishes by Linton (1910), and the important work of Looss (1907) on the Hemiuridae. Two other monographs of considerable value have been those of Stiles and Goldberger (1910) on the Paramphistomes and of Kossack on the Monostomes (1911). Of systematic work on the Cestodes the major portion has been done by Fuhrmann, the chief of whose numerous contributions is a monograph on the Bird Cestodes (1908). This work has been augmented by Ransom's monograph on the Taenioid Cestodes of North American Birds (1909). A fair amount of work has also been done on the tape-worms of Mammals by Janicki (1906). The most outstanding systematic work on parasitic Nematodes has undoubtedly been that of Railliet and Henry on the Strongyle or bursate Nematodes. In an extended series of short papers they have given the outline of a classification of these forms, which, on the whole, appears fairly successful. Their work unfortunately lacks the exhaustive character which ought to be expected in publications of such importance, and much of it will require to be gone over in greater detail. A much fuller account has been given by Ransom (1911) of the Nematodes parasitic in the alimentary canal of Ruminants. With regard to the Acanthocephala or Echinorhynchs the most extensive work has been done by Porta (1909 *a* and *b*) and by Lühe (1911). These authors have materially increased our knowledge of this very remarkable group and have devised more efficient means of identification.

The general aim of the majority of these works has been to deal with the smaller taxonomic units; the arrangement of the higher groups has not been seriously altered except in the case of the monogenetic Trematodes which Odhner (1912) proposes to divide into Monopisthocotylea and Polyopisthocotylea, basing his classification on the internal anatomy as well as the suckers, instead of entirely on the latter as has hitherto been done. On the whole, although there has

been in some directions perhaps a tendency to excessive sub-divisions, the systematic work has been of the greatest value and has served as a basis for, and criterion of, work done in other departments.

Most of the works above-mentioned have dealt at the same time with faunistic and morphological questions. Very large additions have been made to the number of known species, but in consideration of the fact that only a few circumscribed regions have as yet been thoroughly investigated and that even in Europe new forms are constantly being discovered, it is evident that an enormous amount of parasitic material remains unknown. Outside Europe it is only in the United States and in the Nile Valley that a serious attempt has been made to study the parasitic fauna in general. It may be added, however, that a good beginning has been made in Australia by Miss Sweet, and T. H. and S. J. Johnston. Asia and South America remain practically untouched.

Of morphological matters only a few of the more interesting can be discussed here. One of the most remarkable of these is the discovery by Odhner (1910) of a gigantic blood-fluke in the blood vessels of a gull. It is a form closely related to the well-known human blood-fluke, but it is remarkable in possessing no suckers. This may be interpreted as an adaptation towards its mode of life, and such a view is borne out by the discovery of another blood parasite, possessing the same peculiarity, but not otherwise at all closely related to the former, namely *Sanguinicola*, a parasite of fishes. By its discoverer it was at first regarded as a Turbellarian and later as a Monozootic Cestode. A separate order, indeed, was created for its reception. Odhner (1911), however, showed that it is in reality a digenetic Trematode, and that a closely related form, *Aporocotyle*, was known as long ago as 1900. Further interest in this matter has been stimulated by Linton's discovery of a similar form, *Deontacylix*, in an American fish. All these forms present a great resemblance to Monozootic Cestodes but differ from them in possessing an alimentary canal. Another remarkable discovery in Trematode anatomy was made by Leiper (1908) to the effect that in a curious new avian Echinostome (*Balfouria*) there is communication between the intestine and the excretory bladder. This observation was confirmed by Odhner (1910), who found the condition present not only in *Balfouria* but also in another allied species, and in a widely different genus of fish Trematodes (*Haplocladus*). A further case is reported by Looss (1912). Odhner interprets the condition as the formation of a secondary anus. This discovery will involve a revision of the generally accepted belief that the Trematode intestine usually ends blindly, and

probably not a few other cases will be discovered. The above-mentioned genus *Haplocladus* offers the further peculiarity that it has only one asymmetrical intestinal coecum instead of the usual symmetrical pair.

Another important contribution to the anatomy of the flat-worms was made by Goldschmidt (1909) and extended by Von Hofsten (1912). It relates to the function of the so-called shell-gland which has hitherto been believed to be the active agent in producing the material for the egg-shell. It has, however, been shown by these authors that this function is actually performed by the yolk-gland cells which contain the shell substance in the form of small droplets. This substance is liberated in the ootype and it is not impossible that the secretion from the shell-gland may have some influence in causing this liberation. It is further shown that the yolk-cells possess little nutritive function.

The old question of the homology of Laurer's canal in the Trematodes and Cestodes has been raised anew by Odhner (1912), who maintains that the original view of Stieda is the correct one and that Looss' later view cannot be admitted. The latter view, which has received acceptance of late, is that Laurer's canal in the digenetic Trematodes is the homologue of the functional uterus in the Cestodes. This is a view that does not bear very critical investigation and from the topography of the "shell-gland complex" Odhner concludes that the real homologue is the Cestode vagina. On the other hand, in the monogenetic Trematodes Odhner denies that the gastro-intestinal canal is the homologue of Laurer's canal; he regards it as a structure *sui generis*. In certain of the Monogenea the functional vagina is undoubtedly the homologue of Laurer's canal, in others it is entirely absent. This is not remarkable in view of the fact that Laurer's canal is frequently absent in the Digenea. Odhner has also introduced the new term "ductus vaginalis" to designate the duct leading from the paired vaginae into the yolk-duct in the Polyopisthocotylea.

An important contribution to our knowledge of the excretory system of Platyhelminths has been made by Willem (1910), while many new structural details of the Amphistomes have been investigated by Stiles and Goldberger (1910). The descriptive scheme advocated by Stiles has not found general acceptance and it is doubtful if it will be much used outside America. According to this scheme the Trematode body is divided into hypothetical zones and fields, bounded by lines passing through fixed points and the internal anatomy is described in relation to these. The terminology, it may be remarked, is not pretty, while

the new method is not less cumbrous than the old one and is hardly so exact.

On the Cestodes the most interesting work, perhaps, is that by Cohn (1906 and 1911), Kofoed and Watson (1910) and Watson (1911) on the orientation of the Cestode strobila. From the detailed study of the nervous system these authors come to the conclusion that the scolex or so-called head of a tape-worm is really the posterior end. Valuable work has also been done by Gough (1911) on a group of Cestodes which he has formed into a sub-family Avitellininae, characterised by the absence of yolk-glands. Interesting work on the histogenesis and cytology of the Cestodes has been accomplished by Young (1910) and Richards (1911).

With regard to Nematodes the most remarkable work is that of Looss (1905-1911) on the anatomy of the hook-worm (*Agchylostoma duodenale*), of Goldschmidt (1908-1911) on the nervous system of *Ascaris*, and of Martini (1908 and 1909) on the sub-cuticula and lateral fields of Nematodes. Looss' monograph is probably one of the most exhaustive ever written on a single species. Goldschmidt's work is no less remarkable. He has traced out the entire nervous system of *Ascaris lumbricoides* and *A. megalocephala* to its finest ramifications, and has shown that it is constant in arrangement. He has also been able to show that the nerve cells in *Ascaris* do not multiply but simply increase in size as the animal grows older. Another paper which appears worth mentioning here is that of De Baillon (1911) on the muscle fibres of *Ascaris*.

Passing on now to a consideration of the bionomics of these forms and dealing first with the early life-history we find that several interesting matters have been investigated. For instance there is the discovery of the intermediate host of the Japanese liver-fluke (*Clonorchis endemicus*) by Kobayashi (1910 and 1911). Some of the credit of this discovery is due to Askanazy (1906). This fluke passes its intermediate stage encysted in certain fresh-water fishes and infection is acquired by eating these. There is also the discovery of the mode of infection of the Japanese blood-fluke (*Schistosomum japonicum*) by Katsurada and Hashegawa (1910). It is some years since Looss advanced the hypothesis, based on circumstantial evidence, that the blood-flukes have no intermediate host and that infection takes place through the skin. The work of Katsurada and Hashegawa has demonstrated experimentally the correctness of Looss' views. Perhaps the most important other contributions to Trematode development is that of Haswell (1909) on

*Temnocephala*. Practically nothing of very great moment has been done on the development of the Cestodes apart from the already mentioned work of Young (1908) on histogenesis in *Cysticerci*, and of Child (1907) on the development of the germ cells in *Moniezia*. Perhaps the most interesting detail in life-history is the discovery of further cases of fleas acting as intermediate hosts of tape-worms. The new observations were made by Dampf (1910) and Nicoll and Minchin (1911). Altogether four cases are now known, namely, the dog tape-worm (*Dipylidium caninum*), the rat tape-worm (*Hymenolepis diminuta*), and two others of which the adult forms are not definitely known.

The most important work on Nematode development is without question that of Looss (1911) on the human hook-worm (*Agchylostoma duodenale*). In a very exhaustive monograph he has dealt with practically all the points of importance in the life-history of this exceedingly formidable parasite. It is impossible to refer in detail to all the questions discussed by Looss, many of which, indeed, have a wide bearing on the general subject of Nematode development. The most vital facts are that the larva of this worm can enter its host by penetrating the unbroken skin, and that in the life-cycle there is no heterogenesis or double sexual cycle. The original statement of both these facts dates from an earlier period than we are considering here, but they have been so seriously criticised during the intervening years that only now can they be regarded as having received absolutely irrefutable confirmation. Another classical Nematode, of which the life-history has been established, is the Guinea-worm (*Dracunculus medinensis*). We owe our knowledge of the life-history of this worm to the researches of Fedtschenko, Graham, and most recently, Leiper (1906). In the last place mention must be made of the very considerable amount of general cytological and developmental work which has been done upon *Ascaris*, the most outstanding being that of Zur Strassen (1906) and Martini (1906).

There remain for consideration several scattered observations on the bionomics of parasitic worms in general. Of these only a few can be mentioned here. Some interesting notes were made by Jammes and Martin (1908, 1909 and 1910) on the conditions of development of Nematode eggs. They found that the egg-shell is practically impermeable, except to gases, at ordinary temperatures, but when the temperature is raised the impermeability is modified and several substances such as hydrochloric acid, sodium carbonate, etc., are able to permeate. They also found that Nematode eggs may be classified

according to the temperature at which they develop best, some only developing at a temperature lower than that of the host, some being relatively indifferent and others doing best at the temperature of the host. In this way they read an evidence of the manner in which parasitic Nematodes have become adapted to their modes of life. Hamill (1906) has confirmed the earlier view of Weinland that there is in *Ascaris* an antibody which resists tryptic digestion. This question of the nature of the substances secreted by parasitic worms is a very wide one and has called forth a considerable amount of work. The idea of toxins has bulked largely in medical literature dealing with the subject, but, although there is a *prima facie* element of reason in the idea, no satisfactory experimental or clinical demonstration of a general nature has yet been forthcoming. The most important of recent work on this matter is that of Flury (1912) and Weinberg (1912). Another matter which may be most appropriately referred to here is that of the formation of pearls by parasitic worms in their larval stage. This was first brought into prominence about ten years ago by Jameson who showed that pearls in the common edible mussel owed their origin to the presence of larval Trematodes. A few years later Herdman and Hornell advanced the view that Ceylon pearls had a similar origin, the agent in this case being a larval tape-worm (*Tetrarhynchus*). This view has led to an economic attempt to encourage the presence of this tape-worm on oyster beds so as to increase the yield of pearls. Doubts, however, have been cast on the correctness of these observations by Jameson (1912) who considers that some other causal agent must be sought for in the case of the Ceylon pearl oyster.

Coming now to a consideration of the economic, and more particularly the medical relations of parasitic worms, we find that many problems involving the health of both men and animals have been extensively investigated and that a fair measure of improvement has resulted. The disease which has attracted most attention during these latter years is Schistosomiasis or Bilharziosis. This is the particularly intractable disease due to the presence of blood-flukes (*Schistosomum*) and although not so notorious or widespread as Ankylostomiasis or Filariasis it is usually more difficult to treat and indeed no cure has yet been discovered. The chief work done in regard to the Egyptian form of the disease has been of a clinical and pathological nature by Goebel (1907), Glaesel (1910) and Letulle (1911). These contributions, although they have served to fix a definite pathological picture of the disease, have not added materially to our knowledge of the subject. A more important



contribution is that of Katsurada and Hashegawa, already referred to, on the mode of infection. Another question of some moment is the possibility of the existence of a second species of *Schistosomum* in Egypt and of yet another in South America, both differing from the ordinary form in the possession of lateral-spined eggs. Sambon (1909) and Da Silva (1908 and 1909) have supported this contention, but it has been strenuously opposed by Looss (1911) who maintains that one and the same species produces both varieties of eggs and that the variations have their origin in the egg-producing apparatus. As far as can be judged, Looss' view appears to be the more probable one.

Probably no parasitic disease, other than malaria, has aroused such widespread interest or has called forth such a mass of literature as hook-worm disease (Ankylostomiasis). It was a remarkable discovery, indeed, that the greater bulk of the very numerous cases of tropical anaemia was due to the infection with the hook-worm. The worm itself was discovered about 70 years ago, but little was known regarding it for 40 years, and it was not until 15 years ago, when Looss started to deal with the subject, that the material points in the life-history began to be known. Reference has already been made to Looss' conclusive monograph which summarises practically all our present knowledge on the subject from the biological side. It is impossible to discuss here the numerous medical contributions which have been made regarding treatment, prophylaxis, and so forth, but reference must be made to the Milroy Lectures (1911) by Boycott, who, in association with Haldane, did much good work in studying the disease as it occurred in this country in the Cornish tin mines.

Hydatid disease, again, has furnished the subject of much investigation. Occurring as it does, not only in man, but also in many of the domesticated animals it has been dealt with extensively both by medical men and by veterinarians. In Germany it has formed a favourite subject for Theses and Dissertations, the most considerable of which is that by Becker (1907). The most noteworthy results have been achieved in two directions, first by Dévé (1907-1912) who has studied the experimental production of hydatids, and secondly by Weinberg and numerous others who have been concerned with a means of diagnosing the presence of the disease, which is an extremely difficult matter by ordinary clinical methods. To Weinberg undoubtedly belongs the chief credit of utilising a method of diagnosis which gives promise of being a reliable and useful aid to medicine, namely, the serological method. Serum-diagnosis is one of the most recent of medical methods and has been found of great

use in a number of diseases which owe their origin to specific organisms. The presence of these organisms causes the production of certain antibodies in the blood. It is then found that the blood serum gives a definite reaction with an extract made from the parasite. More than one variety of reaction can be made use of, but the most invariably successful is that known as complement deviation. No method is absolutely unimpeachable, but this one has been found correct to the very considerable extent of 90 % of cases. A useful monograph and review of the whole subject has been written by Pfeiler (1911).

Of a different nature is the work done by Tallquist (1907) on the anaemia produced by the presence of the broad tape-worm (*Dibothriocephalus latus*). This parasite occurs particularly in Finland and the adjoining region, although it is known in all parts of Europe and it gives rise to a very severe and fatal form of anaemia. In view of the fact that our present knowledge of the causation of anaemia is extremely limited, the work of Tallquist is of great importance. It is a widely accepted hypothesis that anaemia, in general, is caused by some poisonous substances finding their way into the blood and causing destruction of the blood cells or of the tissues from which they are formed. Tallquist's work supports such a view in this particular case, for from the tape-worm he extracted poisonous substances which, when injected into the blood of healthy animals, caused marked anaemia. That is practically as far as he was able to go, but it represents a very material advance.

Another matter which has received a very considerable amount of attention is the relation of worms to intestinal diseases in general and, in particular, to appendicitis, enteritis, typhoid fever and dysentery. The chief exponent of this line of investigation is Guiart (1910) who has brought forward a large amount of evidence together with not a little hypothesis in support of the view that intestinal worms may be the predisposing, if not the chief, cause of some of these diseases. Similar views have been advocated by Shipley (1909) in this country. They have been supported by a number of observations, chiefly in reference to appendicitis, and are to the effect that in cases of this disease thread-worms are frequently found in the appendix. The theory is that the worms injure the wall of the appendix and lead to the invasion of pathogenic bacteria. The most important and thorough contribution to this subject has been made by Garin (1911) who has found that the whip-worm (*Trichuris trichiura*) damages the intestinal mucosa and is certainly responsible for a large proportion of cases of

intestinal inflammation. It is not a little difficult to estimate the exact value of these observations in general. One is quite prepared to believe that worms exercise a harmful influence in the intestine and that they may aid in causing disease when the necessary other factors are present, but that they are in themselves a specific cause of inflammatory lesions is opposed to present bacteriological views. It must not be forgotten that such worms as are incriminated, namely *Ascaris lumbricoides*, *Oxyuris vermicularis* and *Trichuris trichiura*, are extremely common amongst certain classes of the community and that as a rule they give rise to few symptoms. Their frequent occurrence, therefore, in cases of disease which are brought under notice, is not to be wondered at. There is a certain element of coincidence, moreover, for *Ascaris lumbricoides* and typhoid fever, for instance, are both correlated with the same insanitary conditions.

Passing on now to diseases of animals. I would specially select two which have aroused interest and concern in this country. The first of these is grouse disease. For many years, even for at least a century, the grouse of this country have been subject to severe periodic epidemics of disease. These occurrences give rise to much speculation, but it was not until 1865 that an earnest attempt was made to thoroughly investigate the matter. The result of that investigation provided two conflicting opinions, namely that of Klein who held that the disease was of bacterial origin, and that of Cobbold who showed that parasitic Nematode worms were a very likely cause. The recent commission on grouse disease has made a very thorough study of the disease, and the results published last year have demonstrated the correctness of Cobbold's views. The parasite in question is a Strongyle worm (*Trichostrongylus pergracilis*) which infects the coeca in enormous numbers. Chief credit in this work is due to Shipley and Leiper, who have made a careful study of the anatomy and life-history of the parasite.

Another disease which has caused considerable uneasiness in this country is what is known as Onchocerciasis or worm nodules in cattle. This was first brought into prominence by its discovery in frozen carcasses imported from Australia. It was the subject of much alarm and called forth a special inquiry by the Local Government Board. Leiper (1911) succeeded in demonstrating the exact nature of the disease and its harmlessness to man. The nodules are caused by parasitic Nematodes of the *Filaria* family, namely *Onchocerca gibsoni*. The parasite does not apparently injure the health of the animal, but it renders the meat

unsightly. It does not infect man though it is closely allied to a similar human parasite. Earlier investigations had been carried out by the Australian Authorities at Sydney and Melbourne and full reports were published by Cleland and Johnston (1910) and Gilruth and Sweet (1911). The life-history of the parasite, however, is still a mystery, and until that is known little can be done towards eradicating the disease.

Of the other diseases of domesticated animals probably most work has been done on Trichinelliasis in pigs and Sclerostomiasis in horses, but not much of it has been of an outstanding character. One of the most interesting new facts disclosed is that the faeces of swine infected with *Trichinella* are infective for other animals. This statement was made by Resslering (1910) and confirmed by Raebiger (1911). Such a fact introduces an anomaly into the life-history of this parasite, which had not hitherto been suspected, and it is of great importance from an epidemiological point of view as it largely increases the chances of infection.

It may be of some interest to give a brief account of the new worm parasites which have been added to the already long list of those infecting man. Within the period under consideration 11 new forms have been discovered. Many more have been described as new but have been found later not to be so. Of the total number four are flukes, four tape-worms and three Nematodes. The new flukes are *Fasciolopsis fülleborni*, *F. goddardi*, *Echinostomum ilocanum* and *E. malayanum*. With regard to the first two there is considerable controversy as to whether they are really distinct from the better known species *Fasciolopsis buski*, and the question must still be regarded as unsettled. There seem to be well-marked differences between these forms at the time of collecting but beyond that we have no structural details. The new tape-worms are *Taenia bremneri*, *Dibothriocephalus parvus*, *Diplogonoporus brauni* and *Braunia jassyensis*. Of these the last is the most interesting. It is the first representative of the Liguline tape-worms ever found in man, and is characterised by being unsegmented externally. The new Nematodes are *Lagochilascaris minor*, *Agamofilaria georgiana* and *Physaloptera mordens*, of which the last mentioned is probably the most interesting.