1889.

NEW ZEALAND.

PARASITIC DISEASES AFFECTING RABBITS

IN THE WAIRARAPA DISTRICT (REPORT ON),

Presented to both Houses of the General Assembly by Command of His Excellency.

REPORT ON THE PARASITIC DISEASES AFFECTING RABBITS IN THE WAIRARAPA DISTRICT.

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University College, Auckland, 20th February, 1889.

An interim report on the present subject was submitted to the Hon. the Minister of Lands in May, 1888 (Parliamentary Paper H.–18, 1888). Since that time my experiments have been completed, and I am now able to speak more definitely of the value of the diseases as a means of combating the rabbit-pest. The delay in concluding the report has been due to the slow development of the bladder-worm disease, and the time required to work out the results of a very extensive series of experiments on more than forty animals, including rabbits, dogs, cats, ferrets, and sheep. These experiments have been carried out single-handed, and with no assistance except in the feeding of the numerous animals under observation.

The report will be arranged under the following heads:—

I. The decrease of rabbits in the Wairarapa, and the causes to which it has been assigned.

II. Observations and experiments on the parasitic diseases of rabbits found in the Wairarapa.
1. The bladder-worm *(Cœnurus serialis)*: its nature. Mode of studying its development.
2. Experiments on rabbits. Development of the bladder-worm.
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I. The Decrease of Rabbits in the Wairarapa.

The rabbits in the Wairarapa district, and especially on the plain, have unquestionably been greatly diminishing in numbers during the last few years. The diminution has been attributed to the following causes: (1) Poisoning—chiefly with phosphorized grain in the winter time; (2) trapping, and the use of dogs; (3) the liberation of the natural enemies—viz., cats, ferrets, and, more recently, stoats and weasels; (4) parasitic disease—viz., that caused by the bladder-worm.

It is, I believe, generally admitted by stock-owners and farmers in the Wairarapa that the winter poisoning by means of phosphorized grain, followed up by rabbiting during the rest of the year, has been the most efficient cause of the decrease of the rabbits. A very large number of ferrets—probably not fewer that three thousand—and a considerable number of cats have been turned out, and more recently stoats and weasels have been liberated. It is not easy to gauge with accuracy the amount of destruction accomplished amongst the rabbits by animals which seek concealment from the eyes of man; but I was able to satisfy myself that both ferrets and cats are numerous in some places, at least, and that they appear to render good service.

With reference to the fourth cause, it is well known that it has been claimed that the bladder-worm has been largely instrumental in reducing the rabbits, and that it affords a remedy for the rabbit-pest worthy of the reward offered by the New South Wales Government.

It will be desirable, therefore, to describe the life-history and effects of this and other parasites, as shown both by my observations in the Wairarapa and by experiments in the laboratory, somewhat fully. We shall then be in a better position to form a correct estimate of the value of the disease with reference to the rabbit-pest.

II. Observations and Experiments on the Parasitic Diseases affecting Rabbits in the Wairarapa.

Some hundreds of rabbits were examined by me in the Wairarapa, and I found in them the five following parasites, most of which were widely spread in the district: (1) Bladder-worm *(Cœnurus serialis);* (2) smaller bladder-worm *(Cysticercus pisiformis);* (3) Coccidia, producing a disease of the liver; (4) mites, producing a form of itch or scab; (5) lice. Of these the bladder-worm *(Cœnurus serialis)* and the liver-coccidia are by far the most important to us, for they are the cause of greater injury to rabbits.

1. The Bladder-worm (Cœnurus serialis).

The bladder-worms (incorrectly called "bladder-flukes") are well known to be the larval forms of tape-worms. Two distinct kinds were found by me in rabbits in the Wairarapa; but one of these appeared to be rare, and is not of so much importance as the second and larger form. This latter is shown by my experiments to be the larval form of a particular kind of tape-worm inhabiting the intestine of the dog.

A rabbit infested by this bladder-worm has one or more swellings in connection with the muscles of the body. This swelling may have an external position, on one of the limbs or on the outside of the trunk, neck, or head, in which case it may at once attract attention; or it may have an internal position, and be found in the cavity of the abdomen or chest. (See fig. 6, Plate I., which represents a rabbit with such a swelling on the left side of the face, the white fur towards the angle of the jaw being brought into sight by the swelling.) When the rabbit is dissected and the swelling examined, a bladder is found imbedded in the muscular tissue. The bladders vary in size according to their stage of development, but are often of the size of a fowl's egg, while the largest I have seen was 3½in. long and 2¼in. in breadth. The bladder fits closely into a cavity in the muscles, this cavity having a smooth lining of connective tissue. This lining, of course, is simply formed by the development of the connective tissue which unites the bundles of muscular fibres. It is usually thin, and is sometimes of extreme tenuity, forming merely a surface-covering. The bladder-worm itself consists of a delicate white membrane, enclosing a cavity filled with a clear serous fluid. The outer surface of the bladder is sometimes smooth and rounded as an egg; sometimes it shows numerous lobes and processes. To one side of its inner surface are attached a large number of round white bodies rather smaller than a mustard-seed. (See Plate I., figs. 7 and 8.) Examination with the microscope shows that each of these bodies consists of the head of a tape-worm, recognisable by its four suckers and crown of hooks, situated within a small sac or pouch-like involution of the wall of the bladder. (See Plate II., fig. 10.) These "head-sacs," as we may term them, are placed close together in series or in irregular groups, which are usually elongated. These groups always show a more or less marked radial arrangement. It is clear that we have here an example of that particular form of tape-worm larva to which the name of Cœnurus, or many-headed bladder-worm, has been given.

Modes of studying the Development of the Bladder-worm.—It is a well-established fact in the natural history of the tape-worms that the larval form is found in one animal, whilst the corresponding adult form is found in the intestine of some other animal, which preys upon the bearer of the larval form. It is, of course, usually the natural enemy of the animal harbouring the larval form which serves as the bearer or host of the adult tape-worm. The question, therefore, to be decided by my inquiries was, which of the natural enemies of the rabbit served as the carrier. The only carnivorous animals occurring in the district and feeding upon the rabbits were dogs, cats, ferrets, and hawks. Stoats and weasels had, indeed, been introduced into the district, but the bladder-worm was known to exist there long before their introduction. Hawks were far less open to suspicion than dogs, cats, and ferrets, and I therefore endeavoured to discover whether any one or more of these three animals served as bearer of the supposed tape-worm. There were two ways of attacking the problem: the first was to ascertain whether the bladder-worm, if given to these animals, would develop within them into a tape-worm; the second was to discover whether these natural enemies of the rabbit, living near rabbit-warrens where the bladder-worm was prevalent, harboured any tape-worm, and, if such a tape-worm were found, then to administer its eggs to rabbits, and watch for the development of bladder-worms within them. Both methods were adopted, and both have led to the same result—namely, that the dog, and the dog only, is the bearer of the adult tape-worm of which this bladder-worm is the larval form.

A wild ferret and two wild cats were obtained from the immediate neighbourhood of a rabbit-warren where the bladder-worm was relatively abundant, and were examined. All three were free from tape-worm. On the other hand, it was found on inquiry that the rabbiter's dogs were commonly infested with tape-worms. At the Dry River Run, indeed, all the dogs were said to be so troubled. Specimens of their tape-worms were therefore obtained, and were found to include two kinds, one (a single specimen only) the well-known *Tænia elliptica*, and the other a kind I was led to regard with much suspicion. The dogs, it should be stated, from which the tape-worms were obtained had been bred on the estate, and had never left the rabbiter's home except to go rabbiting. They had been fed chiefly on rabbit, often uncooked, and only occasionally on mutton. The presence of the *Tænia elliptica* was explained by the fact that the larval form of this tape-worm is found in the dog-louse (*Trichodectes canis*), but the other tape-worm, found in great numbers, was most naturally referable to the rabbit or sheep on which the dogs were fed. The head of this tape-worm was not at first obtainable, but in order to test the supposition ripe joints of the tape-worm were administered to rabbits. These ripe joints, it should be said, contained great numbers of minute ova, in each of which a mature embryo was already present. I soon found that the experiment gave positive results, and that the embryos developed in the rabbit into bladder-worms. Subsequently, as material was available, other rabbits were infected, in order to ascertain more exactly the effects of the disease.

2. Experiments on Rabbits. The Development of the Bladder-worm.

The first rabbit fed with eggs of the dog's tape-worm died thirteen days after infection. On dissecting it no bladder-worms were seen at first, but it was noticed that the muscles were marked with irregular thick yellowish or reddish lines, and careful examination showed that the lines were the tracks of young bladder-worms, marked by yellowish-white or blood-stained matter due to the irritation of the tissues. At the somewhat thicker end of each track a minute translucent bladder of about the size of a pin's head (more exactly, from 0·6mm. to 1·6mm. in length) was found in the midst of the granular material. A very large number of these minute bladders were found in this rabbit—indeed, I estimated the total number as being at least five hundred. A second rabbit, fed with a smaller number of tape-worm eggs, died on the twenty-first day after infection, and about a score of bladder-worms were found in it, and, corresponding with the longer period allowed them for development, they had attained a larger size—of $\frac{1}{12}$in. (1·1mm.–2·5mm.). Although none of these little bladders showed as yet any trace of the formation of the tape-worm heads, the source from which the eggs had been obtained, and other evidence, induced me to state in the interim report that the genetic connection between the bladder-worm of the rabbit and the tape-worm of the dog was sufficiently demonstrated. Further experiments on over a score of rabbits and a number of dogs have fully confirmed the opinion then expressed.

I have found that the bladders first show signs of the formation of the tape-worm heads at the end of the fourth week. The smallest bladder-worm in which I have seen any trace of the formation was just four weeks old, and was only $\frac{1}{6}$in. in length. As a rule, the rudiments of the heads (or, rather, head-sacs) do not appear till the worm has attained the size of a pea—*i.e.*, about $\frac{1}{3}$in. or $\frac{1}{4}$in. in length. At the end of seven weeks the bladders, usually oval in form (and measuring $\frac{1}{2}$in. in length by $\frac{1}{3}$in. in breadth), carry more numerous head-sacs, some of them being more advanced than others. As the development proceeds the bladder becomes larger, whilst the number of head-sacs increases. In the fifteenth week the bladders may be from 1in. to $1\frac{1}{2}$in. in length, and the head-sacs are approaching their full size and are very numerous. (Plate I., fig. 7.) I have counted 211, 295, and 424 respectively in three bladder-worms obtained from the same rabbit on the hundred-and-first day after infection. Amongst those heads which are nearly or quite mature may, however, be found others which are in various earlier stages of development. The size of the bladder-worm, and also, apparently, the number of heads, may go on increasing for some months longer. A bladder-worm $2\frac{1}{2}$in. in length contained 740 head-sacs, whilst the largest I have seen was $3\frac{1}{2}$in. by $2\frac{1}{4}$in., and contained nearly a thousand heads.

It should be mentioned that there is a considerable amount of variation in the rapidity or extent of development of the different bladder-worms of the same age, and found in the same rabbit. The statements given above apply, therefore, to the average length of time required for the different degrees of development. Moreover, the development of the bladders may be arrested at any stage, but more especially during the earlier stages. I have found in several cases bladder-worms which had died and were undergoing disintegration. The death of the parasite may be due either to an unsuitable position in which it has settled, or it may be due, especially in the earlier stages, to the resistance which the tissues of the rabbit offer, in a greater or less degree, to the foreign organism. The bladder-worm being dead, its walls lose their elasticity and are ruptured, whilst the collapsed walls of the bladder are converted into a cheesy mass, which seems to be slowly absorbed. I have seen reason to believe that at times very many of the bladders fail to reach their full development, perishing during the first few weeks of their growth; and this is, of course, a point of much importance when we desire to estimate the effect of the bladder-worm on the rabbit.

By comparing the different stages in the development of the bladder-worms we are able to trace the origin and mode of development of the tape-worm heads. They generally originate in small sacs or pouches formed by the growth inwards of certain parts of the wall of the bladder. At the bottom of this sac the tissue thickens, and gives rise to the four suckers and the rostellum, with its crown of hooks, characteristic of the tape-worm head. (Plate I., fig. 10.) The heads are developed, as it were, inside out. The opening of this sac becomes constricted, but is never entirely closed, a small aperture being left. (Plate I., fig. 9.) The heads are always restricted to one-half of the bladder, and their arrangement will be best understood by reference to figs. 6–8, Plate I. The long, irregular groups or series in which the heads are disposed have a roughly-radiate arrangement, which is most marked in the younger specimens. In the larger bladder-worms, with more numerous heads, the groups may be broader and less regular. Fig. 8 shows such a bladder-worm pinned out to show the heads more clearly. In this the radiate arrangement is less marked than usual, but is still clearly traceable.

I should mention here that in the older specimens small bladders are not infrequently found outside of, but in contact with, a large central bladder. They are evidently derived by budding from the surface of the older bladder-worm, for, although they are sometimes found quite free and detached, yet in many cases I have found them still connected with the parent bladder-worm by a wide or by a narrow, slender stalk. These daughter-bladders give rise to tape-worm heads precisely in the same way that the parent does. This mode of multiplication may be compared with the formation of daughter-cysts in the Echinococcus—the "hydatid" of man and some of the domestic animals—by external budding. I have also observed cases in which the bladder-worm of the rabbit has given rise to daughter-bladders by internal budding; but these are not so numerous as cases of external budding.

It has been stated that the bladder-worms were found by me only in the muscles. They are found in all the muscles of the body except those of the distant parts of the limbs, where perhaps the conditions as to temperature or liability to injury are unfavourable. I have found them even in the muscles moving the eyeball, in the walls of the heart, in the diaphragm, and even, in two cases, in the unstriated muscle of the wall of the intestine. In no case, however, did I

find a bladder-worm in any other organ. Special search was made for them in the brain and spinal cord, but without success. As the bladder-worm grows larger it frequently projects on the surface of the muscle, so that it may seem to lie external to it, and project, for instance, into the cavity of the abdomen. But even in such cases careful examination almost invariably shows a thin sheet of muscle-fibres spread over the projecting bladder-worm.

When the eggs of the tape-worm are swallowed by the rabbit the secretion of the stomach destroys the strength of the shell, so that the embryo is able to escape. This embryo is armed with six hooks (see figs. 1 and 2, Plate I.), by means of which it works its way into the wall of the alimentary canal, and thus gains access either to the lymphatics or the blood-vessels. Thence it may be carried with the blood-stream to the various organs of the body. On reaching the ultimate ramifications of the blood-vessels the embryo appears to bore through the wall of some capillary. The commencement of the track found in early stages in the muscles may probably indicate the point at which it leaves the blood-vessel. We have seen that the bladder-worms are only found in the muscles, but we may readily believe that many embryos are led by chance to take up their abode in other organs of the body, but that they fail to develop there. Even where the bladder-worms were most numerous they only represented a very small proportion of the eggs which had been given to the rabbit.

All rabbits are not equally susceptible to the bladder-worm disease. Some individuals seem to furnish a specially suitable home for the development of the bladder-worm, and great numbers of the parasites may be found in them. Sometimes the number is so great that they produce a considerable disturbance in the system, owing probably to the numerous points of local inflammation set up. Hence, such rabbits may die during the first two or three weeks after infection. Other rabbits, again, affording less suitable conditions for the development of bladder-worms, a comparatively small number of them are found. Yet other rabbits may enjoy complete immunity, the bladder-worm being quite unable to develop within them. Some of my rabbits were fed several times with tape-worm eggs, but all attempts to infect them failed. I obtained evidence showing that the younger rabbits were more susceptible than the older ones; but on this point my observations were necessarily limited, as all the experiments were conducted on wild rabbits, and at the time of the year no very young rabbits were obtainable. But, although young rabbits are more susceptible, yet it is only some of the older rabbits which enjoy immunity from the disease.

It is not easy to explain why some rabbits should afford so much better a home for the growth of the bladder-worm than others; but the phenomenon is not one confined to the particular bladder-worm of the rabbit which we are considering, but has been shown to occur in the case of other bladder-worms. I will only mention here the bladder-worm of the armed tape-worm of man (*Tænia solium*). This bladder-worm is found in the pig. It is of small size, and forms the so-called "measles" of pork. Haubner fed five young pigs with abundant ova of *Tænia solium*. Of these, two remained quite free from infection, a third contained only forty or fifty measles, another several thousands, and the last one still more. Leuckart fed five young pigs with very numerous ova: each of them received at least a whole tape-worm, whilst some of them were fed two or three times. On dissection, after the lapse of various intervals of time, the number of measles which were found to have developed were said to be respectively a single one, a few hundreds, two or three thousand, several thousand, and twelve thousand. Even in the last instance, where the measles were most numerous, only one per cent. of the eggs administered had developed.

3. *Experiments on Carnivorous Animals with the Bladder-worm.*

As I have already mentioned, the chief carnivorous animals which feed upon the rabbit in the Wairarapa are the dog, cat, ferret, and hawk; and of these it is the first three which were open to suspicion as bearers of the adult tape-worm of which the bladder-worm is the larval stage. I endeavoured therefore to ascertain by experiment whether the bladder-worm, if given to these animals, would live in them and develop into the corresponding tape-worm. Two young ferrets and a young cat were obtained and fed several times with bladder-worms, which they swallowed greedily. But in all three animals the attempt to rear the tape-worm failed.

Having already ascertained that the dogs in the district were often infested with tape-worm, it was still more desirable to try a similar experiment with dogs. It was undesirable, for obvious reasons, to do this with dogs from the district which might already contain tape-worms; and rabbits carrying bladder-worms were therefore taken up to Auckland, with the intention of experimenting there on dogs free from tape-worm. The diseased rabbits, however, died at sea, and it was found impossible to import more from the Wairarapa. I had fed rabbits with the ova of a tape-worm procured from a dog in the Wairarapa, and, after the lapse of a little over three months, bladder-worms had developed in these rabbits to a stage sufficiently advanced for experiments. Some of these bladder-worms were given to three dogs, the first two receiving each some three to four hundred heads, and the third two complete bladder-worms, each containing nearly three hundred heads. Of these three dogs, two developed the same kind of tape-worm, which agreed in its characters with the tape-worm found in the dogs in the Wairarapa, from the eggs of which the bladder-worm had been reared. To render the matter still more conclusive, proglottides of the tape-worm thus reared in the dogs were given to rabbits, and in the majority of these the Cœnurus was developed.

4. *Characters of the Tape-worm* (Tænia serialis) *reared in the Dog.*

The tape-worm thus reared in the dog's intestine from the Cœnurus of the rabbit has a long, narrow, flattened form (see Plate II., fig. 1). Its length may be from 16in. to 24in., though it may appear either longer or shorter, for the tissues of the body are contractile in a very high degree. It consists of a minute head, a somewhat narrower unjointed neck, and a series of joints or segments, which gradually increase both in length and witdh as their distance from the head-end

increases. As the segments grow they develop the reproductive organs—a separate set for each segment—and eggs are formed and undergo their development, so that the last segments contain ripe eggs—*i.e.*, eggs containing fully-formed embryos. The ripe segments drop off one by one at the hind end of the tape-worm, and pass out of the dog. These separate segments are frequently known as proglottides. As the proglottides drop off behind, new segments are gradually separated in front from the neck, so that the tape-worm always has about the same number of joints, though it is constantly shedding proglottides behind.

The head of *Tænia serialis* is somewhat pear-shaped when viewed from the flatter surfaces (*i.e.*, the dorsal or ventral surface) (fig. 2, Plate II.), tapering gradually behind to the narrowest part of the neck. Its extreme width is about $\frac{1}{25}$in. (1mm.), but it must be borne in mind that the shape and dimensions are liable to variation with the state of contraction. As seen from in front it appears flattened in the same manner as the body, but not to anything like the same extent, its outline being rather oblong. (Plate II., fig. 3.) The head bears four suckers, of moderate size only, two on each side. They have the diameter of about 0·28mm. The extreme end of the head is armed with a crown of twenty-eight or thirty hooks arranged in two concentric circles, each circle having the same number of hooks, and with their roots imbedded in the rostellum, a circular disc of muscular tissue (0·29mm.–0·32mm.). (Plate II., figs. 3 and 4.) The hooks of the inner circle (Plate II., fig. 12*b*) are the larger (0·145mm –0·153mm.); those of the outer are shorter and more strongly curved (0·096mm.–0·101mm.). Both suckers and hooks, of course, serve for the attachment of the head to the walls of the dog's intestine. The unjointed neck is about $\frac{1}{12}$in. in length. The total number of segments or joints is from a hundred and fifty to a hundred and sixty. This number includes all the first small and short joints which can be distinguished in the neck with the aid of the microscope. The character of these first joints will be gathered from enlarged drawing (fig. 2, Plate II.). Each joint in the tape-worm is in a slightly more advanced stage than the one in front of it, so that the whole series presents some hundred and fifty or more stages in the development of the segment.

In each segment a complete set of reproductive organs, both male and female, is present, the male maturing rather earlier than the female. It may be well to add here, as more or less distinctive characters of this tape-worm, that traces of the *vas deferens* appear about the sixtieth segment, but it is first distinct about segment 70. The rudiment of the genital pouch appears on the average at segment 82. The numerous roundish testes are discoverable in segment 80, but are most distinct and definite in segments 91–100. The first branches of the uterus appear in segment 102, and by segment 115 the uterus-branches cover the whole of the genital area. In the following segments the eggs may be seen passing through the stages of their development, which it is unnecessary to describe here. The first appearance of the chitinoid egg-shell is in segments 130–135. These segments of a tape-worm in which the uterus of a tape-worm has assumed its full number of branches are sometimes termed "ripe," and the number of ripe segments is used as a character in the discrimination of various forms of tape-worms. By other writers the term "ripe" is apparently restricted to those segments in which the eggs are fully developed, and contain a mature or nearly mature embryo within the thick chitinoid egg-shell. As already observed, each joint is slightly more advanced than the one in front, so that there is a certain amount of difficulty in drawing the line between ripe and unripe segments. If we employ the term in its narrower sense we may say that *Tænia serialis* has about half a score, sometimes more and sometimes fewer, for the ripe joints do not appear to detach themselves very regularly, so that the same tape-worm may have at one time a larger and at another time a smaller number of ripe segments.

As the segments grow they change their form, for they increase more rapidly in length than in breadth. The details will be best understood by a reference to the illustration in Plate II., fig. 4. The last few segments are rather less than $\frac{1}{2}$in. in length (more exactly, 10mm.–12mm.).

The proglottides, when separated from the tape-worm, still retain the power of locomotion for awhile. They leave the intestine of the dog, passing outward with the fæces, or sometimes independently. They possess great contractility, by means of which they crawl away and hide themselves under grass, sticks, or any shelter which may be available. If the ground be damp they may be able to crawl to the distance of a foot or more, but exposure to very dry air soon brings them to rest. I have frequently found them lying under the shelter of straws. They evidently recognise the value of shelter, for when the straws or similar objects are very scanty the proglottides may still be found under them. On several occasions I have seen the proglottides mount the blades of grass and remain attached there as they dried up. A striking difference is shown in the form of the proglottis whilst crawling, according to its state of contraction. These changes of form are shown in fig. 5, Plate II.

If a proglottis be placed on a plate of glass, and the trail left by it be examined under the microscope, it will be seen to be marked by vast numbers of eggs, which appear to be squeezed out of the proglottis by its powerful contractions whilst crawling, and so are left behind. Indeed, I have examined proglottides in which almost all the eggs were thus lost whilst crawling, not more than a few score, and in one case only about a dozen, being left inside. It would seem to be a provision which secures a wider distribution of the eggs, and is a point of some importance in considering the possibilities of the natural infection of rabbits. The proglottides of the tape-worm were first obtained seven or eight weeks after administering the bladder-worm. If we allow fifty days as the time necessary for the growth of a hundred and fifty joints, we shall have the joints produced at the rate of three per day.

5. *Resemblance of Cœnurus of the Rabbit to the Cœnurus producing a Disease in Sheep. Evidence of its Distinctness.*

The only species of bladder-worm of the Cœnurus form—*i.e.*, one producing a large number of heads in connection with a single bladder—which is generally and definitely recognised is the one known as *Cœnurus cerebralis*. This is found in the sheep, and receives its specific name of *cere-*

bralis from the fact that it is found in the brain. The tape-worm stage of the parasite is found in the dog. This parasite is, or used to be, exceedingly common in certain parts of Europe, and produced serious ravages in the flocks of sheep, and occasionally even in cattle. The disease it causes is known as "gid," or "sturdy." Leuckart states, on the authority of the famous stock-breeder Von Nathusius-Hundisberg, that a loss from this parasite amounting to 20 per cent. of the flocks was reduced to 1 and 2 per cent. by exercising the necessary supervision over the sheep-dogs.

Before we can discuss any proposal to use the Cœnurus of the rabbit as a remedy against the rabbit-pest, we must decide clearly and definitely whether the Cœnurus of the rabbit is identical with that of the sheep, or whether it is altogether distinct.

Cœnuri have been found not only in the sheep and rabbit, but also in several other animals. *Cœnurus cerebralis* is said to occur in the brain of the sheep, ox, mouflon, antelope (sp.), roebuck, reindeer, dromedary (all of which are ruminants), and horse. Cœnuri have also been found outside of the brain in the rabbit, hare, a squirrel, jerboa, coypu, spalax (all rodents), a lemur, and once each in the sheep, calf, and cat. Sometimes these have been attributed to *C. cerebralis* and sometimes to distinct species.

The earliest mention of the Cœnurus of the rabbit is that by C. B. Rose, who, in a letter to the *London Medical Gazetteer*, 9th November, 1833, after speaking of *Cœnurus cerebralis*, stated that he had seen another Cœnurus in the muscles of the rabbit. He says, "When the warrener meets with a rabbit thus affected he punctures the tumour, squeezes out the fluid, and sends the animal to market with its brethren." As he could detect no difference in structure between this Cœnurus and the *Cœnurus cerebralis* of the sheep, he was unwilling to consider it a different species. In France the Cœnurus has been found in the rabbit by Gervais, Rousseau, Prince, Baillet, Bailly, and Davaine. In 1847 Gervais described a Cœnurus of the rabbit under the name of *Cœnurus serialis*, because the heads were arranged in series. A Cœnurus of the rabbit is preserved in the Oxford University Museum under the name of *C. cuniculi*, a name which was adopted by Cobbold. The name *C. serialis*, however, appears to have the right of priority. Baillet (1858) gave the Cœnurus of the rabbit to two dogs, in which he subsequently found a Tænia, which he called *T. serialis*. He described the characters of the tape-worm; but they differed so slightly from those of *Tænia cœnurus*—the tape-worm corresponding to the *Cœnurus cerebralis* of the sheep—that zoologists do not seem to have been in any way satisfied that the *Tænia serialis* was a good and distinct species. The Cœnurus of the rabbit has also been found in Germany, and in Italy its occurrence is recorded by Perroncito.

It may, I think, be said that the existence of a second Cœnurus in the rabbit, distinct from the *Cœnurus cerebralis* of the sheep, has not yet been demonstrated. In support of this statement we may quote Küchenmeister and Zürn, who refer the Cœnurus found by Perroncito in the abdominal cavity of the rabbit to *Cœnurus cerebralis*.* Leuckart says, with reference to Cœnuri found outside the brain, that they may "in part, perhaps, represent distinct species." Moniez† refers to experiments of Perroncito (whose paper, I regret to say, I have been unable to procure) on rabbits and sheep with eggs of *Tænia serialis*. The rabbits died accidentally a few days later, and were not dissected, and the sheep gave a negative result. Moniez was of opinion that further experiments were necessary before a definite conclusion could be arrived at. W. H. Jackson, in the most important text-book of zoology‡ recently published, says that *Cœnurus cerebralis* is "found most usually in the brain of the sheep, though sometimes in other parts of the body of this ruminant, as also of rodents." But on page 664 of the same work there is a footnote as follows: "It is possible that there is more than one species of Cœnurus. The identity of the two forms occurring in the sheep and rabbit has not been established, and there are others known." Many other references might be given having the same purport, but the above will suffice.

I propose, therefore, to give here the evidence I have collected showing that the *Cœnurus serialis* of the rabbit is distinct from the *Cœnurus cerebralis* of the sheep. The evidence, from five sources, is arranged under as many heads:—

(*a.*) The *Cœnurus serialis* of the rabbit is abundant in many parts of the Wairarapa; but, so far as I could hear from the Sheep Inspectors and farmers, there is no trace of "gid" or "sturdy" amongst the sheep which feed on the same ground with the rabbits. Nor, indeed, have I been able to hear of the existence of this sheep-disease in New Zealand. The freedom of the sheep from the Cœnuri, whilst the rabbits are so frequently attacked, is in itself the strongest presumptive evidence that the Cœnurus of the rabbit cannot develop in the sheep.

(*b.*) The Cœnurus of the sheep and other ruminants is confined to the brain, whilst that of the rabbit is found only in the muscles. It should be mentioned that Eichler found a Cœnurus about the size of a goose-egg in the subcutaneous tissue of a sheep. This, however, appears to be quite an exceptional occurrence.

(*c.*) Anatomical evidence is obtained from the structure of the Cœnuri of the rabbit and sheep respectively. The *Cœnurus serialis* of the rabbit has the heads arranged in linear groups, the arrangement in lines being specially marked in the less advanced stages, but still traceable in the oldest. Again, these series radiate from a centre. In the *Cœnurus cerebralis* the groups are not linear, and are arranged irregularly. Again, the *Cœnurus serialis* is remarkable for the formation of daughter-bladders by budding, both externally and internally: the *C. cerebralis* does not show this character, though it often has a more or less irregular outline.

(*d.*) Further anatomical evidence is obtained from the comparison of the tape-worm (*T. serialis*) reared from the rabbit's Cœnurus with *Tænia cœnurus*. I have not been able to procure specimens of *Tænia cœnurus*, but I take for the comparison the description given by Leuckart, who will be

* "Parasiten des Menschen," 2te Auflage, p. 59.
† "Essai Monographique sur les Cysticerques," 1880.
‡ "Forms of Animal Life," Rolleston and Jackson, 1888, p. 323.

recognised by all zoologists as a sufficiently accurate authority. The characters of the *Tænia serialis* are taken from my own examination of the tape-worms reared in dogs fed with the Cœnurus of the rabbit. At first sight the two tape-worms seem to be singularly alike; but careful measurements show a sufficient number of differences. As is well known, there is often considerable difficulty in distinguishing the different species of tape-worm, owing to such resemblances, so that the apparent similarity of the two now under consideration need not be deemed to prove their identity.

T. cœnurus is said to be 30cm.–40cm. (12in.–16in.) in length. I have found *T. serialis* 40cm.–60cm. long, and sometimes longer. *T. serialis* has not more than a hundred and fifty segments before the first ripe one, using the term "ripe" in its narrower sense *(v. supra)*: *T. cœnurus* has nearly two hundred. The number of hooks in *T. serialis* is twenty-eight to thirty—more frequently thirty: in *T. cœnurus* it is usually twenty-eight, but varies from twenty-four to thirty-two. The larger hooks are smaller in *T. serialis* than in *T. cœnurus*, being 0·15mm. long in the former and 0·16mm. in the latter; the small hooks are much the same size in both, being from 0·096mm.–0·101mm. in *T. serialis* and 0·1 in *T. cœnurus*. A comparison of the hooks of *T. serialis* (see Plate II., fig. 12) with those of *T. cœnurus* (fig. 11, reproduced from Leuckart) shows that they differ both in curvature and in other minor points. In *T. serialis* the curved and pointed end is not so nearly in the same straight line with the posterior root of the hook, and there is a constriction near the base of the curved part. The points described as specially characteristic of the hooks of *T. cœnurus*—viz., the heart-shaped form of the anterior root of the large hook, and the slenderness of the posterior root of the small hook—are not characteristic of the corresponding parts in *T. serialis*. It must be mentioned, however, that the hooks show some variety in these minor points. The ripe segments appear to be distinctly larger in *T. serialis*, and the uterus, with its branches, covers a smaller proportion of the width of the segment than in *T. cœnurus*. (Compare fig. 10, Plate II., a segment of *T. cœnurus*, magnified 10–15 diams., after Leuckart, with figs. 8 and 9, of segments of *T. serialis*, magnified 6½ diams.)

The above points will be sufficient to show that anatomical differences do exist; but we cannot expect to find very wide differences between the two tape-worms, for the fact that both have larval forms of the Cœnurus type proves that they are closely allied, and may therefore be expected to show a general resemblance to one another.

(*e.*) The most conclusive evidence, however, is to be derived from feeding-experiments on the sheep. If *T. serialis* is really identical with *T. cœnurus*, then the eggs of *T. serialis* should, when administered to a sheep, give rise to a bladder-worm in the brain, and produce the disease known as "gid."

Cœnurus cerebralis is more particularly found in young sheep. I obtained, therefore, the youngest sheep available at the time of the year, which was just before the lambing-season. The sheep must therefore have been ten to twelve months old. It received at different times some forty to fifty proglottides of tape-worms reared from the *C. serialis* of the rabbit—*i.e.*, it must have received over a million eggs. Nevertheless the sheep showed no sign of "gid," and, when finally dissected some three or four months later, showed no trace of bladder-worm in brain, muscles, or any other part of the body. A few months later another lamb, four or five months old, was obtained, and eggs of *T. serialis* were given to it. At the time of writing the lamb is still perfectly healthy. It appears to me that the evidence brought forward is amply sufficient to demonstrate that the Cœnurus of the rabbit is specifically distinct from that of the sheep.

6. *Smaller Bladder-worm of Rabbit* (Cysticercus pisiformis).

It will be desirable to make a brief reference here to this small bladder-worm, though it was only found by me twice in rabbits from the Wairarapa, and always in small numbers. But in wild rabbits captured in the Waikato for the purpose of experiments this well-known Cysticercus was almost always found—generally only from one to half a score specimens in a rabbit. One rabbit, however, formed a marked exception, for it contained over four hundred small cysts, of which over two hundred were counted on the great omentum. This bladder-worm is round, and about the size of a pea—hence its name of *pisiformis*. It is a very familiar form in Europe, and is the larval or cystic stage of *Tænia serrata*, a tape-worm of the dog. I have found the tape-worm in dogs in the neighbourhood of Auckland.

The earlier stages in the development of the *Cysticercus pisiformis* are passed in the rabbit's liver; it then makes its way out of that organ, and, after passing a certain time free in the abdominal cavity, it becomes encysted and attached to the peritoneum, especially to the folds which form the great omentum and to the peritoneal covering of the rectum. Whilst present in small numbers it causes very little injury to the rabbit, but there is reason to believe that when very large numbers develop simultaneously serious disturbance is produced in the liver. It must be seldom, however, that this parasite can, under conditions obtaining in nature, cause the death of a rabbit.

7. *Liver-coccidia of the Rabbit.*

I have already stated in my interim report that a considerable proportion of the rabbits examined by me in the North Wairarapa were more or less affected with a disease caused by minute animal parasites belonging to the group of Gregarinida, and known as Coccidia *(Coccidium oviforme)*. It will be unnecessary for me to repeat here the description already given in a previous report.

The Coccidia undergo development in water or in moist places, the contents of each Coccidium breaking up and transforming into four oval spores. Each spore has a delicate membranous wall, and contains a curved rod-like body, with thickened ends, whilst against the concavity of the curve rests a round granular mass, which, with osmic acid and picrocarmine, stains more deeply than the rod-like body. The rod-like body is believed to be the true germ.

So far as I am aware, no experiments have been hitherto recorded to show in what form the liver-coccidia enter the rabbit. From experiments of Waldenburg on the *Coccidium perforans* (Leuckart) of the intestine of the rabbit (a species distinct from the liver-coccidia) it seems probable that the spores in the condition just described are capable of developing further when given to a rabbit. Three rabbits obtained from the Waikato, where the disease is not known, were fed with large numbers of Coccidia which had been kept in water until the spores were formed as above described. When the rabbits were dissected several weeks later all were found with perfectly sound livers. This result must, however, be considered as purely negative evidence: the experiment may have failed because the rabbits were unsuitable subjects. I should have preferred to experiment with younger rabbits; but it was winter-time, and the youngest rabbits available were some eight months old.

Want of material has prevented me from investigating the matter further; but this is of the less importance because the disease, though frequently fatal to rabbits, is not one which could be recommended for the object now in view, as it has been known to affect human beings.

8. Disease due to Scab- or Louse-mites and Lice.

Two external parasites were found in the rabbits in the Wairarapa—namely, the scab- or louse-mite and a kind of louse. As these are readily distributed by the contact of the rabbits in their burrows, they are not uncommonly found together on the same animal. The scab- or louse-mite is a minute species of mite, just visible to the naked eye. I have not been able to find any description of this species in the books available in Auckland, but it is probably a species of Symbiotes. It is clear, however, that it does not burrow into the skin like the true itch-mites, but lives upon the surface. This mite is therefore distinct from the true itch-mite (the *Sarcoptes cati* of Hering and Gerlach, or *S. cuniculi* of Gerlach, or *S. minor* of Furstenberg) found on the cat and rabbit, which burrows in the skin and causes a much more formidable injury. The *Sarcoptes minor* is not uncommon on the Continent of Europe, and is especially destructive to cats in the larger towns. The intensity of the malady produced varies from time to time, sometimes causing very severe epidemics. The mite found on the Wairarapa rabbits, confining its attacks to the surface, seems to be comparatively harmless, though all the rabbits which have any large number of the mites show scabby spots.

The rabbit-louse *(Hæmatopinus ventricosus)* is a much larger animal than the mite, being readily seen by the naked eye. Sometimes it is found in considerable numbers. It may be seen with its beak buried in the skin, whilst its abdomen becomes round and distended with the dark-coloured blood it has sucked up. In a majority of the rabbits seen by me in the Wairarapa I found a larger or smaller number of either lice or mites, or both. As a rule, the number of parasites was small, and the injury done to the rabbit was insignificant. A few of the rabbits carried greater numbers, and these were marked by scabby patches. Mr. Orbell states that he has found rabbits showing scabby symptoms of a similar kind, but in a much higher degree, with the hair falling off over large areas of skin. Some of the rabbiters, too, state that they have found rabbits largely denuded of hair, and with scabby patches, and so thin as not to be able to run more than a few yards at a time. More recently the same mite has been noticed by Agent H. Hull in Southland. On the Sunnyside Station a diseased rabbit was dug out of a burrow: the skin showed scabby patches outside and dark spots inside, and it adhered to the flesh. Mites were discovered by the aid of a lens, and some of these were afterwards identified by me as belonging to the species found in the Wairarapa. It is not improbable that a rabbit may occasionally succumb to these parasites; but I am of opinion that the combined effects of the mites and lice are seldom so serious as to lead to the death of the rabbit.

III. Value of the Diseases as a Means of dealing with the Rabbit-pest.

1. General Conditions.

Any disease, to be suitable for this purpose, must fulfil the following conditions: (1) It must be sufficiently destructive to rabbits; (2) it must not be injurious to man or any of the animals useful to man.

When we know that these conditions are satisfied we have still to consider the economical aspects of the question—*i.e.*, whether the good effected would be commensurate with the cost of the employment of the disease; for, be it observed, what is really required is a cheaper means of destroying rabbits than the customary poisoning, rabbiting, &c. Of the five parasitic diseases found in the rabbits in the Wairarapa only two cause a disease of such intensity as to at all satisfy the first of the above conditions; the other three seldom cause death to the rabbits. The two parasites which concern us here are the bladder-worm and the liver-coccidia.

Before discussing to what extent the two diseases are valuable, it may be well to observe that evidence of the injurious effects of a disease may be adduced from the following considerations: (*a.*) The disease may be shown to be more or less widely prevalent. It is clear that it is not enough that a disease should have an intensive character and have the power of causing death: it is also essential for our purpose that it should affect a large proportion of the rabbits in the district. (*b.*) The intensive or destructive character of the disease may be shown by the fact that rabbits are found dead or clearly suffering a serious amount of injury from the presence of the parasite. (*c.*) The character and power of the parasite may be gathered from the results of experiments on rabbits in the laboratory. But here we must bear in mind that the conditions in the laboratory are not quite the same as those in nature: the mere confinement of rabbits in hutches introduces a condition very different from that of the full freedom of the wild rabbit. Nevertheless, the detailed knowledge of the natural history of the parasites will give us a fuller knowledge, and enable us to form a sound judgment on many points which it is difficult to observe in animals in a state of freedom.

2. The Bladder-worm.

A comparatively small proportion of the rabbits examined by me in the Wairarapa were affected by the bladder-worm—not more than 5 per cent. The rabbiters, however, state that it is no uncommon thing to find 20 per cent. of the rabbits with one or more bladder-worms. The men would only notice the advanced stages of the disease, so that a larger percentage of the rabbits may really be affected. But it is important to notice that this does not apply simultaneously to the whole of the Wairarapa district. There is a great deal of difference in the prevalence of the disease in different localities, and even in the same locality the disease may be common at one time and scarce at another. In one instance during my visit four out of six rabbits shot in one day were found to contain bladder-worms. It should be observed, however, that the time of my visit—shortly after the close of some months of dry summer weather—was not the time at which we should expect to find the greatest number of rabbits affected with the disease. The rabbiters, too, at the Dry River Run and elsewhere, I found, were in the habit of giving their dogs medicine to expel their tape-worms—a measure calculated to reduce the prevalence of the disease.

I could not obtain any positive evidence that rabbits are ever found lying dead on the ground, or in a dying condition, from the disease. The rabbiters state that they sometimes find rabbits lying dead on the ground, but the hawks have always been at them, so that it is too late to find out what the cause of death may have been. I was able to observe for myself the great number of hawks in the district, and their activity in attacking rabbits caught in traps or lying on the ground. We must remember further that many of the rabbits would probably die in their burrows.

Most of the affected rabbits obtained by me in the Wairarapa contained only a single bladder; some had two, and in one instance I found three. The rabbits were for the most part still in moderately good condition, but not equal in this respect to their brethren free from the bladder-worm. When we remember that the parasite frequently attains the size of a fowl's egg, weighing, with the included fluid, 1½oz. to 2oz., and occasionally reaches double the size, we can see that even a single specimen must, to some extent at least, act as a drain on the strength of its host, whilst two or three or more will have a still greater effect. The parasite of course draws its nourishment from the system of its host, whilst the addition of some ounces of weight to a rabbit means a tax on its powers, and must hinder it in escaping from its enemies, especially if the parasites are in a position in which their bulk interferes with the rabbit's power of locomotion. That even a single bladder-worm weakens a rabbit is shown by the fact that I have not been able to have any infested rabbits brought alive from the Wairarapa to Auckland, all having died on the voyage, though other rabbits, free from the parasite and sent at the same time, have arrived safely. Still, though a single bladder-worm weakens a rabbit, it is clear that the rabbit may live a very long time notwithstanding the presence of a bladder-worm, and even of two or more.

We may now with advantage consider the results obtained with rabbits artificially infected with the bladder-worm. It may be well for me to state that, in order that my results may more fairly be taken as a basis in estimating the effects of the disease on rabbits in a state of nature, I endeavoured to keep the rabbits under conditions approaching the natural ones.

I have found that when the rabbits are fed with large quantities of eggs some of them may die within the first two or three weeks. These are the rabbits in which the largest proportion of the eggs develop. But the number of bladder-worms developed is by no means simply proportional to the number of eggs which a rabbit swallows, but depends far more on its constitutional power of resistance. Even in cases where the greatest number of bladder-worms have appeared, and the rabbits have died at an early stage of the disease, the number of parasites present did not correspond to more than about 1 per cent. of the eggs administered. Usually the percentage of eggs which developed was far lower, and over 30 per cent. of the rabbits failed to take the disease at all, though some of them were fed several times with the tape-worm eggs.

The development of the bladder-worm is, as we have seen, slow; so that if a rabbit contains only a small number of bladder-worms it may live a considerable time. But as the bladder-worms grow older they become larger and larger, and so, of course, the ill effects of their presence become more marked. One of my experimental rabbits died at a date which was 104 days after the first infection with one proglottis, and forty days after a second infection with two proglottides. It was found to contain twenty bladder-worms. Most of these dated from the first infection, three from the second infection. The largest bladder-worm was 1½in. long by 1in. in width; most of the others were about 1in. in length. Another rabbit died at the same stage of the disease from the presence of seven bladder-worms. A third died forty-eight days after infection, and contained seventeen bladder-worms, the largest being ⅜in. in length.

Avoiding unnecessary details, we may say that the effect of a single bladder-worm will, as a rule, hardly be shown during the first three or four months, but that afterwards, as it continues to increase in size, it may be a source of weakness to the rabbit; but I have not been able to find any evidence that a rabbit affected with a single bladder-worm only might not live till death came to it from some other natural cause. But with the increase of the number of parasites the tax on the strength of the rabbit becomes greater than it can bear, and it succumbs to the burden, sometimes directly, sometimes indirectly, being brought into a low and weak condition, in which it readily falls a victim to other adverse influences, such as weather, scarcity of food, or enemies.

We must add, however, that the bladder-worm sometimes settles in a position in which its mere presence is more than an inconvenience, and interferes with some of the essential functions of life. The bladder-worms, as commonly found in the muscles of the limbs or trunk, are in a position in which they do not interfere with other organs; but I have seen them in a good number of instances in positions where they must have been distinctly hurtful. Thus, I have several times found them in the muscles moving the eyeball, producing displacement of the eye. In one case a bladder-worm was growing in the tongue, and by producing a swelling at its base had rendered it

difficult for the rabbit to swallow. In another instance a group of bladder-worms was found on the outside of the jaw. Their pressure had caused absorption and perforation of the jaw-bone, and subsequently the weakened bone had been broken. Again, I have found the bladder-worm pressing on the larynx and windpipe. In three cases they were present in the muscular walls of the heart: in one of these the bladder-worm was nearly the size of a marble, and was already developing the head-sacs of the future tape-worms; but at this stage the rabbit had died. In one instance I found a large bladder-worm in the diaphragm, one half projecting into the cavity of the chest and pressing on the lungs, the other half projecting into the cavity of the abdomen and displacing the liver.

We have already seen that the rabbits in the Wairarapa are usually found with only a single bladder-worm, and that three was the largest number found by me. We have also seen that the presence of a single bladder-worm, though more or less injurious, will seldom be fatal to a rabbit. We are therefore naturally led to inquire whether rabbits in a state of nature are frequently infested by a larger number of the parasites. The rabbiters state that they have observed rabbits with more than three bladder-worms, and it is possible that the scarcity of such observations is due to the parasites causing the death of the rabbits at a relatively early stage, before their size would attract an unskilled eye. An examination of the conditions for the spread of infection will aid us at this point of our inquiry. The infection is due to rabbits swallowing the eggs of a tape-worm with their food. These tape-worms live in the intestines of the dog, and produce proglottides containing the eggs. When the proglottides are ripe—*i.e.*, contain eggs with embryos, ready to cause the infection—they drop off from the tape-worm and pass out of the dog. I have calculated that each tape-worm may produce three proglottides a day. An estimate of the bulk of the uterus and its branches gives the result that each proglottis will contain a bulk of 0·745mm. of eggs. I am indebted to my colleague Professor Aldis for the mathematical calculation of the quantity of eggs of the given size and form which would fit into one cubic millimetre. From these data I estimate that an average proglottis will contain about thirty thousand eggs. Now, a single dog may harbour from one to forty or more tape-worms. Allowing that a dog contains ten only, it will distribute thirty proglottides a day, each containing thirty thousand eggs—*i.e.*, it will distribute nine hundred thousand eggs. If we could insure that all the eggs should reach the race of rabbits and develop within them, there would be no further trouble with the rabbit question. But we cannot do this, and the chances are immensely against any particular egg reaching a rabbit; and if it does reach a rabbit the chances are a hundred to one against its developing there. In my experiments I could, of course, secure the proglottides, and insure that a rabbit should swallow as large a number of eggs as I pleased. In nature the proglottides are usually distributed with the droppings of the dog. If the weather be dry and the droppings fall in a dry place the proglottides cannot move away. But if the weather be wet, or, at least, the ground be moist, the proglottides creep away and hide themselves in the grass, or sometimes climb up the stalks. As the proglottides creep along, the eggs are squeezed out and smeared over the ground. If rain come, or the spot be marshy, water may further distribute the eggs. If the eggs are in a moist place they retain their vitality for some days: I have infected a rabbit with eggs which had been kept in water for seventeen days. It is not necessary that the eggs should be actually in water—all that is needful is that the air around should be saturated with moisture. Hence the eggs will keep good for a fortnight or more during the cooler part of the year so long as the surface of the ground is moist; but exposure to a current of dry air or to the full rays of a hot sun is quite sufficient to destroy their vitality. It will be seen, therefore, that the chances of infection during hot, dry summer weather are but small unless the proglottides are deposited in the neighbourhood of springs or on marshy places. Moreover, at all times of the year the chance of infection is greatest on moist ground, though in broken country, where the hill-tops are quite dry, the presence of moist patches of ground on the hill-sides and in the gullies is sufficient to allow the spread of the infection to a certain extent.

The spread of the eggs by the proglottides, whilst it may favour the extent of prevalence of the bladder-worm, is less favourable to the occurrence of cases of infection by large numbers of the parasites. Sometimes, however, the proglottides retain a considerable number of eggs within them, and a rabbit may, by eating a whole proglottis, incur the risk of multiple infection. I have seen that rabbits will eat the proglottides attached to grass or green food. Of the nine hundred thousand eggs which may be distributed by a dog in a day, but a small proportion will be picked up by rabbits whilst they still retain their vitality. And even after they have got so far as the rabbit's stomach their dangers are not at an end. Some will have insufficient vitality to resist the digestive action of the rabbit's gastric juice; others will fail in boring their way through the walls of the stomach. Of those which succeed in passing from the interior of the stomach many will go astray in various parts of the body, only a small number securely establishing themselves in the muscles of the rabbit. Even then the tissues have a certain power of resistance, and the bladder-worm may die at various stages. The power of resistance in some rabbits, especially older ones, is so great that some individuals enjoy a complete immunity. No wonder, then, that so great a fertility on the part of the tape-worm is necessary in order to contend with the great risks to which the continuance of the race is exposed.

It will be readily understood that where the conditions for the spread of the disease are more than usually favourable the immense fertility of the tape-worm permits (within certain limits) a greatly-increased prevalence. The bladder-worm disease, like so many parasitic diseases, is eminently liable to variation, and, if the conditions are favourable, considerable epidemics are likely to occur. But such epidemics, though they may depend on causes having a wider influence, such as the character of the weather in any particular season, will, as a rule, be due to circumstances which have a local extent only. Hence the epidemics will not be experienced in equal measure throughout a whole district, but only in those localities where there is a recurrence of the favourable conditions. For a hot and dry climate like that of the greater part of Australia the disease would be of far less value than in the moist climate of New Zealand.

To what extent, it will be asked, can the prevalence or severity be increased? The only means which can be adopted to secure the maximum destruction by the disease is to increase the chances of rabbits swallowing the tape-worm eggs. We must keep as many tape-worms as possible in the neighbourhood—that is, we must make sure that each dog carries his due complement of tape-worms, and we must see, further, that the dog passes frequently over ground where the rabbits feed. It would be useless, of course, to keep the dogs chained up at home. The rabbiter's pack of dogs will obviously be the most suitable for the purpose, though any dogs will do which are kept under supervision. It will not do to liberate dogs to run wild and keep down the rabbits, as has been done in the case of cats, ferrets, &c., for dogs would quickly learn to attack the sheep.

The disease, of course, can be encouraged largely, though not indefinitely, by increasing the number of dogs in the neighbourhood; but here the question of cost and other practical matters demand consideration. The rabbiter's dogs and any other dogs already kept could, of course, be employed to disseminate the disease without incurring any special expense (always supposing the dogs do not suffer—a point to be considered later on). But these dogs have already been unconsciously used in the way indicated, and, though some of them have had their power of distribution restrained by medicine to cure the tape-worm, it will, I believe, be necessary to increase the number of dogs to secure any much greater prevalence of the disease. With the increase of the dogs expenses will arise, though it will clearly be desirable to use the dogs for rabbiting also. If the dogs are not made useful in other ways, I doubt if the results they produce in disseminating the bladder-worm disease would, as a rule, be commensurate with the cost of maintaining and supervising them.

We have seen above that the bladder-worm that we are now considering has been found in various parts of Europe, and we are therefore naturally led to ask, What are its effects there? Has it been found to cause any destructive epidemic among rabbits? I have not been able in the literature of the subject to find any statement of any serious epidemic of the kind, and, though the disease has been long and firmly established in various parts of Europe, I do not find any record of its occurring anywhere so commonly as it appears to have done in the Wairarapa.

The greater prevalence which the bladder-worm has shown in the Wairarapa is probably due in part to the moisture of the climate during a considerable portion of the year, in part to the abundance of both rabbits and dogs, many of which are used chiefly or entirely for rabbiting, and are allowed to feed upon uncooked rabbits, and so are generally infested with the tape-worm. In England the rabbit is valuable for the market; in the rabbit districts in New Zealand it is at best looked upon as food for dogs. There can be no doubt that the disease has been introduced into the Wairarapa from Europe, and probably England, where it has been found in Norfolk, near Oxford, and in Ayrshire. It is most probable that the disease has been brought by a dog infested with *Tænia serialis*.

In the "Transactions of the New Zealand Institute," Vol. xx., p. 457, will be found a statement by Sir J. Hector "that in America he had seen large tracts of country cleared of rabbits in a few months by the propagation of this disease"—namely, bladder-worm. In the absence of detailed evidence, I think it highly doubtful whether the disease which is said almost to exterminate the Canadian rabbit (not the same species as the English rabbit) is due to a bladder-worm. The statements made by Mr. C. N. Bell, of Winnipeg, do not bear out any such idea. The two known bladder-worms of the rabbit (the *Cœnurus serialis* and *Cysticercus pisiformis*) are most certainly not likely to effect such sweeping destruction. Although known so long in Europe, nothing of the kind has ever been observed there.

It may be asked why the Cœnurus is more injurious to rabbits than a good many other bladder-worms are to their hosts. The injury is partly due to the size which this bladder-worm attains and partly to the positions it sometimes occupies. The *Cysticercus pisiformis*, the other bladder-worm of the rabbit, is of very much smaller size, and I have found over four hundred examples in a single rabbit, which was not obviously suffering from its load of parasites. But a single Cœnurus may have a bulk greater than two hundred of the *Cysticercus pisiformis*, and the latter, though they may create a good deal of disturbance in their early development in the liver, subsequently settle in a position in which their presence does little harm. We are, however, acquainted with bladder-worms which do create injurious epidemics in other animals—for instance, the other species of Cœnurus *(C. cerebralis)*, which formerly caused serious losses amongst flocks of sheep. This bladder-worm was probably more hurtful than the Cœnurus of the rabbit, for it occurred in the brain, an organ specially susceptible to injury. The Echinococcus, or hydatid of man and some of the domestic animals, is also an example of a large form of bladder-worm, causing severe injury to its host. As is well known, it is very prevalent in the Colony of Victoria, and is often fatal to human life.

Second Condition.—The disease must not be injurious to man or any of the animals useful to man. The best evidence showing that the bladder-worm satisfies this condition is that, although from time to time it has been so common in the Wairarapa, yet the stock feeding on the same ground have never suffered. The Cœnurus of the rabbit, however, bears a certain resemblance to the Cœnurus producing a disease in the sheep, and I have therefore taken considerable trouble to find out whether the two species are distinct or not. The results are detailed above (II., 5), and the evidence there given shows that the Cœnurus of the rabbit is distinct from that of the sheep, and that sheep fed with the eggs of the *Tænia serialis* remain free from bladder-worm.

There remains, however, one point to consider, and that is, What is the effect of the tape-worm on the dog? Do the dogs suffer when harbouring the tape-worm? I do not think they suffer to any serious extent: the dogs which I have seen as hosts of the tape-worm have been in apparent good health. Of course, the parasites require to be fed, and the dogs may be a little thinner and consume rather more food than they would otherwise do; but if at any time a dog seems to suffer from its parasite it will be easy to secure a little rest for it by administering a dose of medicine to

expel the whole or a portion of the tape-worms. In some animals, it is true, the presence of tape-worms is distinctly injurious—as, for instance, the *Tænia expansa*, which I have found in New Zealand on several occasions as a cause of debility in lambs. On the other hand, dogs seem to suffer less from their tape-worms, of which no fewer than eleven species are recorded, some being of very common occurrence. The natives of Abyssinia are almost without exception infested by the unarmed human tape-worm *(Tænia mediocanellata)*. So far from regarding this as a cause of weakness or disease, they say that in many ways its presence exercises a beneficial influence on the health, and if they have the misfortune to lose their parasite they take measures to obtain another.

3. Value of the Liver-coccidia.

Although the disease caused by the liver-coccidia does not satisfy the second of our conditions —namely, that the disease must not be injurious to man or any of the animals useful to man—it will be necessary to refer to it here, because it is a disease capable of inflicting serious injury on rabbits, and has, I believe, been operative in some degree in reducing the rabbit-pest in the Wairarapa. I have not had the opportunity of acquiring sufficiently ample data to enable me to decide to what degree it has been operative, but I found the Coccidia present in a larger percentage of rabbits than the bladder-worm. Near Masterton, out of nineteen rabbits dissected in one morning, eleven were affected by this disease, and five of them badly. I may add here evidence from other sources as to the destructiveness of the disease. A few years ago, whilst investigating the natural history of the liver-fluke for the Royal Agricultural Society of England, I paid some attention to the parasitic diseases of rabbits. The rabbits in certain localities near Oxford had, after a series of wet seasons, been greatly reduced in numbers, and were found lying about dead on the ground. Some of these were brought to me for examination. One of them proved to have been killed by the liver-fluke; in another the liver was extensively invaded by the Coccidia, which had been the cause of death.

Leuckart says of the liver-coccidia of the rabbit that the disease is endemic in many warrens, so that scarcely a sound rabbit is found. "As soon as the disease reaches a considerable development, the rabbits are constantly seen to perish. After passing, perhaps, a few weeks in a sickly condition, they become very thin, lose the desire to eat and their former activity, begin to breathe more quickly and violently, and die at last in convulsions."

The disease has been found in man on at least four occasions; in one case it was the cause of death. On this account the artificial encouragement of the disease could not be advocated. Nevertheless the disease has been introduced into the district, and it would be a difficult matter to stamp it out if it were desired. It seems not improbable that it will develop further, and, whether we wish it or not, may prove the cause of death to a certain proportion of rabbits. Men, however, are very seldom exposed to the risk of infection with the liver-coccidia, and that only where uncleanly habits prevail; so that the presence in the district of this disease threatens little danger to human life.

4. Possibilities of Destruction of Rabbits by Parasitic Disease.

Surprise is often expressed at the rapid rate of increase of rabbits in Australasia. This is not to be attributed to the greater fecundity of the rabbit here, but rather to the absence of those checks upon its naturally rapid increase which operate in keeping down the rabbits in other parts of the world. Every living being in a state of nature is subject to an active or passive struggle for existence. It constantly endeavours to increase its kind and extend its area, whilst it meets with various adverse influences, or checks to its increase, against which it may be said to struggle. Even in Europe the rabbit sometimes increases to such an extent as to become a nuisance; but there the checks to its increase are much greater.

These checks may be grouped as follows: (1) Action of man; (2) scarcity of food (this is chiefly due to climate, for there are few of the herbivorous animals which can compete with a rabbit); (3) destruction by carnivorous animals; (4) effects of climate, both direct and indirect; (5) parasitic diseases. It must be admitted that in New Zealand, where population is scanty, the climate mild and generally favourable, where there are large areas of natural grasses, no indigenous carnivorous animals to prey on the rabbits, and no indigenous parasitic diseases to thin their numbers, the rabbit escapes most of those adverse influences which keep it in check elsewhere. The population, however, is increasing rapidly, and carnivorous animals have to a certain extent been established, whilst several parasitic diseases have (though unintentionally) been introduced. The climate here is sufficiently moist to encourage the spread of some of these parasites. Wherever the population is even moderately thick the rabbit difficulty is not felt, for the action of man easily keeps the rabbits in check. There are, however, many districts in New Zealand which are not likely to attract a considerable population for very many years to come, but where there is a wholesome though not a rich pasturage for sheep, the land carrying perhaps a sheep to one, two, or even three acres. It is here particularly that the injurious effects of the rabbit-pest are felt, for, though the rabbits could of course be kept down by human agency, this result could only be attained at a cost which would more than swallow up the whole of the profit of sheep-farming on such land. It is here, then, that the destruction of rabbits by carnivorous animals or parasitic disease would be most welcome.

The parasitic diseases of the rabbit which we have been discussing would have a limited but appreciable influence in this direction. It must not be expected, however, that they will prove the means of suddenly or completely exterminating all the rabbits in a district. Many infective diseases possess great powers of destruction, but there is no instance known of any infective or parasitic disease in nature which possesses the power of absolutely exterminating any species of animal. Any parasitic organism which should mercilessly cause the death of all the members of a species would thereby defeat its own object, for with the extinction of all suitable victims the

existence of that specific parasite would come to an end. If we read through the records of destructive epidemics which have attacked man and the domestic animals we shall find that, though the number of deaths may be large, yet it is but small as compared with the number of individuals left alive. The disease takes its proportion of victims—it may be a very high proportion in certain localities—but if we extend our view so as to take in a wide district, we find that the tax seldom amounts to 10 per cent. of the species affected. I may mention here, as an example of a destructive epidemic, that the loss of sheep from liver-fluke in the British Isles in the winter and spring of 1879–80 was estimated at three millions, or about 10 per cent. of the total number of sheep. But that season was one of a succession of wet years, and the disease was unusually prevalent, the losses in an average year being one million, or about 3⅓ per cent. These losses were unequally distributed, for in some localities the disease was not known, in others it was severely felt.

One of the most prominent characteristics of parasitic diseases is their unequal development in different localities and in different seasons. So with reference to the diseases due to the bladder-worm and liver-coccidia, we may expect in some localities a more extensive development and useful results, whilst in other localities the diseases may not meet with the necessary conditions, and little or no good may result. Further, we have seen that moisture is favourable to the spread of these diseases: we may expect them therefore to be more prevalent in moist or ill-drained localities, and to be more useful in wet seasons and climates than in dry ones. Hence over a great part of Australia the diseases would be less effective than in New Zealand.

When animals of the same kind are densely crowded together on the same ground, as is the case with the rabbits in the infected districts, one of the conditions for the spread of a parasitic or infectious disease is best fulfilled. When the number of animals is reduced the danger of infection will diminish.

5. Summary.

1. The reduction of the rabbits in the Wairarapa has been chiefly due to measures adopted by man. The most valuable of these measures has been the winter poisoning, which has been followed up during the rest of the year by trapping, &c. Cats and ferrets, too, seem to have done good work.

2. Certain parasitic diseases have appeared in the district, and have been widely though unequally prevalent.

3. Of these parasitic diseases two only—those due to bladder-worm and liver-coccidia—deserve special notice as being capable of destroying rabbits. There is reason to believe that these have assisted to a small extent in destroying rabbits in the district.

4. The employment of the liver-coccidia for the destruction of rabbits cannot be advocated, as in rare instances the parasites have been known to attack man. They are, however, present in the district, and it would probably be impossible to suppress them. Fortunately, the danger to human beings is very small indeed, and the disease may prove of further use in killing rabbits.

5. The bladder-worm may be usefully employed against the rabbit-pest; but it must not be expected that it will destroy more than a small percentage of the rabbits in the district. Like all parasitic diseases, it is variable and apparently capricious in its distribution, and its propagation is limited by conditions which will vary with locality and season. It would be more useful in a moist climate than in one which is hot and dry. It assuredly cannot be regarded as furnishing alone a sufficient means of dealing with the rabbit-pest, nor will it render unnecessary the ordinary methods of the destruction of rabbits, but must be looked upon as simply a minor and auxiliary means of destruction.

DESCRIPTION OF PLATES.

PLATE I.—ILLUSTRATES THE BLADDER-WORM OR CŒNURUS STAGE IN THE RABBIT.

Fig. 1. Egg of *Tænia serialis*, showing the six-hooked embryo within the egg-shell. Magnified 630 diameters.

Fig. 2. Embryo freed from the egg. As this is a view from the side, one of the lateral pairs of hooks is not represented. Magnified 630 diameters.

Fig. 3. Portion of muscle from rabbit showing the tracks made by the bladder-worms during the early stages of their development. At the enlarged end of each track a minute bladder-worm is to be seen. The rabbit had been fed with tape-worm eggs thirteen days previously. Natural size.

Fig. 4. Young bladder-worms at early stages of their development: (*a*) From a rabbit thirteen days after it had been fed with eggs of tape-worm; (*b*) three weeks after infection of a rabbit; (*c*) four or five weeks. All natural size.

Fig. 5. Young bladder-worm (about six weeks old), showing the "heads" in an early stage of development (about forty "heads" are present in rudiment). They show a radial arrangement from the first. Magnified 4½ diameters.

Fig. 6. Rabbit which had been infected with eggs of *Tænia serialis*. It shows a large swelling on the left side of the face, the white fur towards the angle of the jaw being brought into view by the swelling. This was subsequently proved to be due to the presence of a bladder-worm. From a photograph taken ninety-five days after infection.

Fig. 7. Two bladder-worms of small size but carrying mature tape-worm heads. The bladder-worms have been hardened in spirit and then divided by a razor longitudinally. Those halves only are shown which bear the heads. From rabbit which died one hundred days after infection. Natural size, from a photograph.

Fig. 8. A large bladder-worm, opened and pinned out to show the "heads" on its inner wall. The "heads" here are larger than in Fig. 7, and are much more numerous (about 740). Natural size, from a photograph.

Fig. 9. A group of four "heads," or "head-sacs," showing how the mouth of sac opens on the outer surface of the bladder-worm. Magnified 10 diameters.

Fig. 10. A vertical section through a head-sac, showing the tape-worm head in the position in which it is developed—*i.e.*, inside out. At the end of the cavity of the sac (which usually has a more spiral direction than is here shown) are to be seen the rostellum, with a portion of the crown of hooks and two of the suckers. Magnified 60 diameters.

Fig. 11. Shows two head-sacs—(*a*) with head in position in which it is developed; (*b*) sac turned inside out, so that the head now assumes its proper position. Drawn with *camera lucida*. Magnified 10 diameters.

Fig. 12. A group of bladder-worms produced by budding from a single original bladder-worm. Some of them are free, others are still attached by a wide or slender stalk. About natural size.

PLATE II.—ILLUSTRATES THE TAPE-WORM OR TÆNIA STAGE OF TÆNIA SERIALIS AS FOUND IN THE DOG.

Fig. 1. The tape-worm *(Tænia serialis)*, reared in a dog which had been fed with the bladder-worm *(Cœnurus serialis)*. It consists of a head and neck, together with a series of joints or segments, increasing in size from the head towards the hind end. The joints, *a*, *b*, *c*, *d*, are shown on a larger scale in figs. 6–9. One free joint (=proglottis) is shown natural size.

Fig. 2. The head and neck and first few joints of the same tape-worm. Magnified 28 diameters.

Fig. 3. The head of a similar tape-worm, showing the flattened form, the four suckers, and the rostellum with the crown of hooks. Magnified 28 diameters.

Fig. 4. Crown of hooks of a similar tape-worm, drawn with *camera lucida*. Magnified 146 diameters.

Fig. 5. Free joints or proglottides of *Tænia serialis* in different states of contraction, as observed in proglottides when crawling.

Fig. 6. The ninety-first segment (*a*) of the tape-worm in fig. 1. Shows the reproductive organs shortly before the formation of the eggs: *t.*, testes; *v.d.*, vas deferens; *g.*, germarium (germ-forming gland) of right side; *y.*, vitellarium, or yolk-forming gland; *u.*, uterus; *v.*, vagina; *s.*, genital sinus; *e.*, excretory vessel. Magnified 13 diameters.

Fig. 7. The hundred-and-fourth segment of the same tape-worm. Shows the first branches developed from the uterus as the primitive eggs pass into it. Magnified 13 diameters.

Fig. 8. About the twentieth segment from the end, showing the uterus with its numerous branches. This segment is slightly contracted. Magnified 6½ diameters.

Fig. 9. One of the last segments (*d*). The uterus and its branches are crowded with eggs containing mature embryos. Magnified 6½ diameters.

[Figs. 6–9 are reduced from drawings made with *camera lucida*. Much care was taken to secure accuracy in the details of the branches of the uterus.]

Fig. 10. Segment of *Tænia cœnurus*, for comparison with figs. 8 and 9. After Leuckart. Said to be magnified 10 or 15 diameters.

Fig. 11. A small (*a*) and large (*b*) hook from *Tænia cœnurus*. Copied from Leuckart for comparison with fig. 12. Magnified 280 diameters.

Fig. 12. The corresponding hooks of *Tænia serialis*. Drawn with *camera lucida*. Magnified 280 diameters.

Postscript.—The writer finds that, contrary to his expectation, the engraver has slightly reduced the scale of the figures. The figures are therefore smaller than is stated above; thus in Plate I. thay have been reduced in the proportion from 100 to 97, and in Plate II. from 100 to 93.

[*Approximate Cost of Paper.*—Preparation, nil; printing (2,000 copies), £11 10s.]

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Plate. I.

Fig. 1

Fig 2

Fig 3

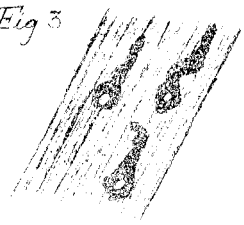


Fig 4

Fig 5

Fig. 6.

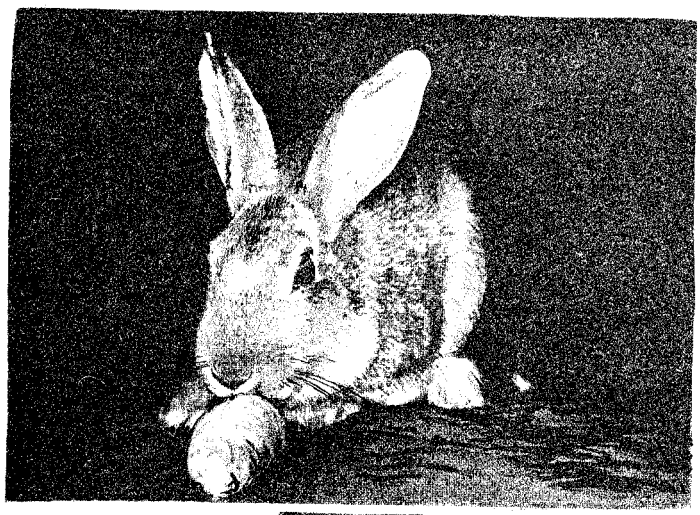
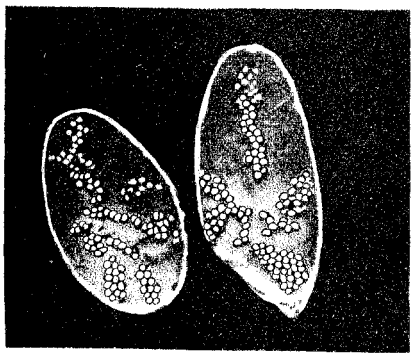


Fig 7



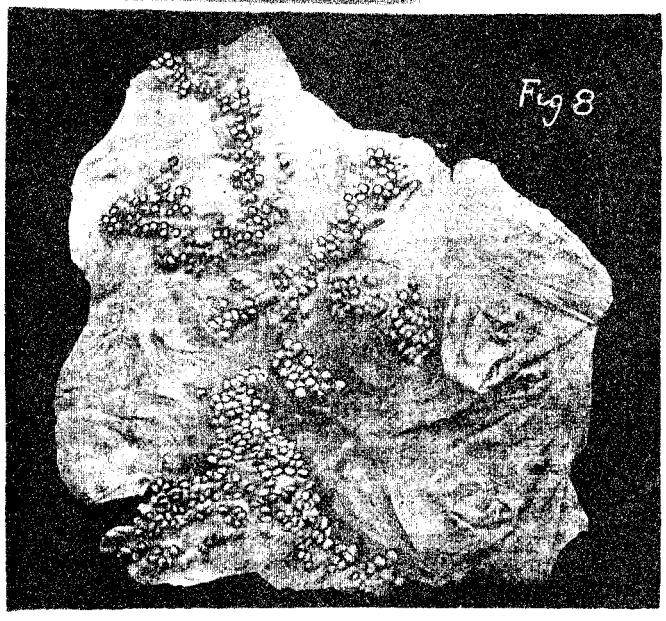


Fig 9

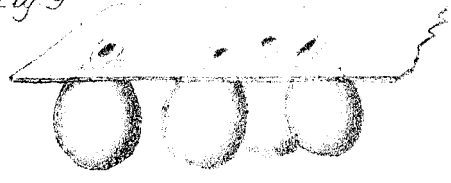


Fig 10

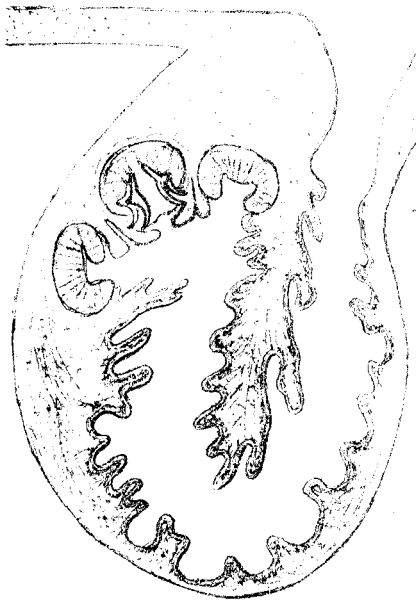


Fig 11.

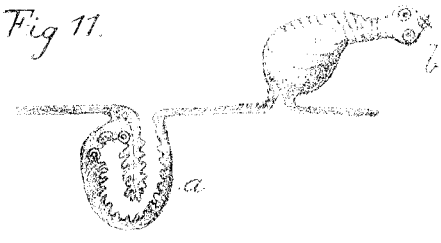
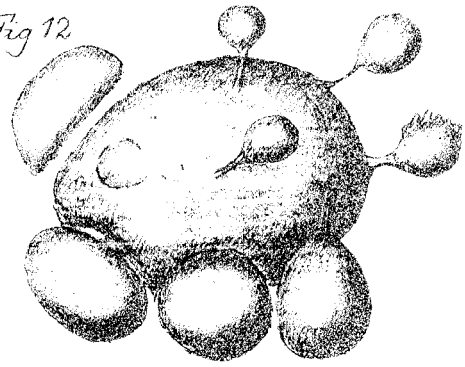


Fig 12



A. P. W. Thomas del.

Plate II

Fig. 1

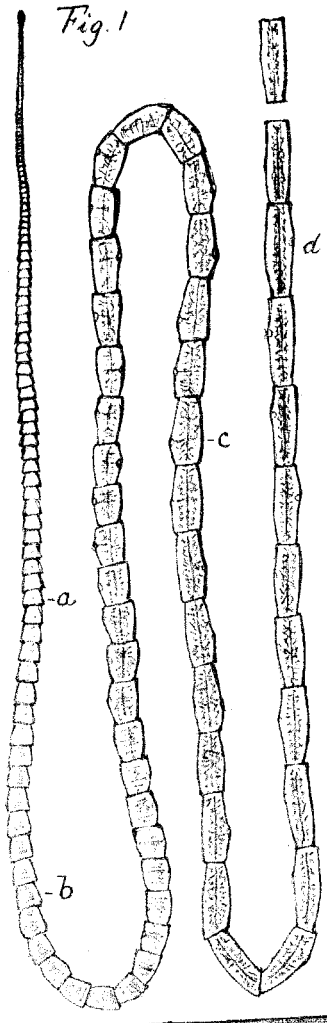


Fig 2

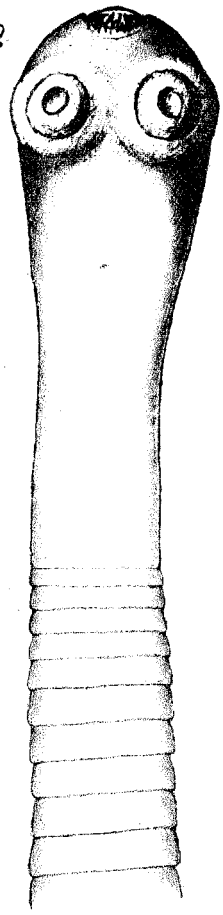


Fig 6

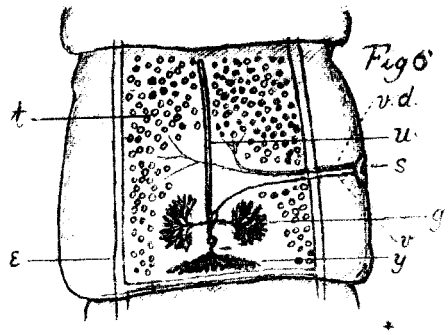


Fig 7

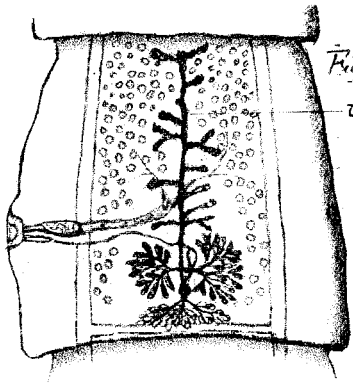


Fig 8

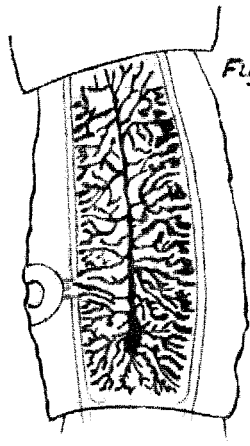


Fig 3

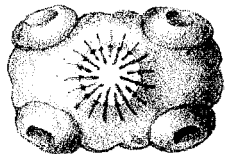


Fig 4

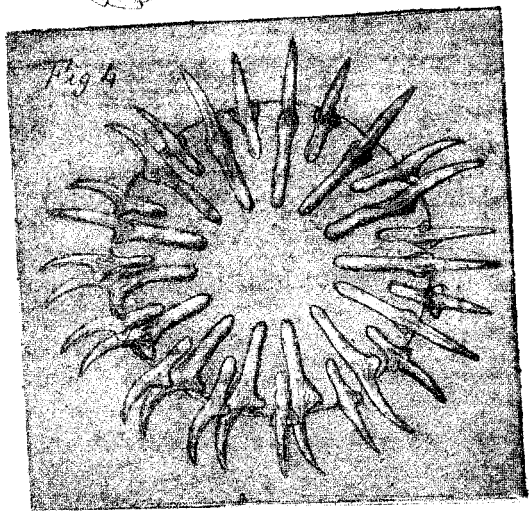


Fig 5

Fig 9

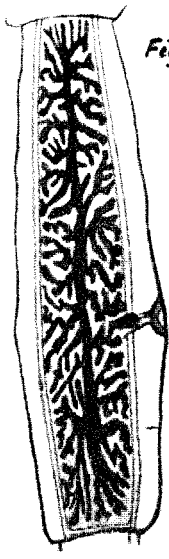


Fig 10

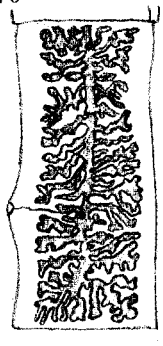


Fig 11

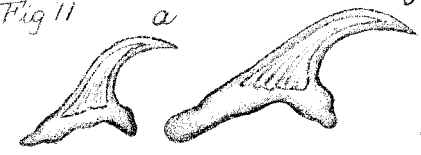
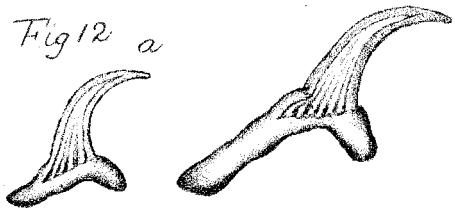


Fig 12



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