COMMONWEALTH OF AUSTRALIA.

ONCHOCERCA GIBSONI:

THE CAUSE OF

Worm Nodules in Australian Cattle.

BY

J. A. GILRUTH, D.V.Sc., M.R.C.V.S., F.R.S.E.,

AND

GEORGINA SWEET, D.Sc.

With Notes on Worm Nests in Australian Cattle and in Camels

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Gilruth (1911)
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Onchocerca Gibsoni, The Cause of
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Published by the Government, Sydney,
N.S.W.

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With Notes on Worm Nests in Australian Cattle and in Camels

(Extracts from Report of Government Bureau of Microbiology of New South Wales for 1909),

BY

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Published by direction of the Honorable FRANK GWYNNE TUDOR, Minister of Trade and Customs.

SYDNEY:

W. A. GULLICK, GOVERNMENT PRINTER FOR THE STATE OF NEW SOUTH WALES.

1911.

*95641

It has been decided to publish the valuable report of Professor Gilruth and Dr. Sweet departmentally, owing to the special importance of the subject in its relation to one of the main primary industries of Australia.

It has been thought well also to reprint some notes on the same subject by Dr. Cleland and Mr. Johnston, which appeared in the First Annual Report of the Bureau of Microbiology of New South Wales.

It is noted, with great satisfaction, that Professor Gilruth and Dr. Sweet, as also the other investigators, find themselves in a position to state without qualification that no danger to man is to be feared from the presence of Worm Nodules in beef.

The Department is, however, furthering investigations into the remaining phases of the subject, with a view to the control of the spread of the disease and—it is hoped—to its eradication.

FRANK G. TUDOR.

Department of Trade and Customs,
25 April, 1911.

CONTENTS.

ONCHOCERCA GIBSONI:

The Cause of Worm Nodules in Australian Cattle.

By J. A. GILRUTH, D.V.Sc., M.R.C.V.S., F.R.S.E., Professor of Veterinary Pathology, and GEORGINA SWEET, D.Sc., Lecturer in Parasitology, Melbourne University Veterinary Institute.

Introduction.

This paper, which was read before the meeting of the Australasian Association for the Advancement of Science, held in Sydney, in January, 1911, presents a study of the distribution, the situation, the structure, the pathological effects, and, to some extent, the life-history of the parasite "*Onchocerca gibsoni*, Cleland and Johnston, 1910," the cause of what are known by such terms as "Worm Nodules," "Worm Nests," "Kernels," &c., within the briskets and thighs of cattle in certain parts of Australia. The importance of the parasite from the human point of view is but incidentally touched upon.

While the presence of the fibrous tumours which surround the parasite undoubtedly renders the portions of meat in which they are situated abnormal in appearance, and, consequently, more or less unsaleable, the parasites are not deleterious to the health of the host, for in the majority of cases a careful search is required to detect their existence, even on post-mortem examination. The parasites cannot reproduce themselves completely within the bovine system, a contention proved by the fact that although each adult female may be said to be continuously liberating numbers of motile larvæ, it is rare to find in any host over fifty matured females. Further, in our experiments, we have repeatedly injected thousands of living eggs and larvæ underneath the skin of cattle, yet post-mortem examination, months afterwards, has failed to show a single fully developed mature worm. Again, we have found that neither the adult parasite nor the immature sexless larvæ are able to retain their vitality under the most favourable conditions for more than two days after the death of the host. It does not, therefore, require even the process of freezing or of cooking to destroy the life of these parasites, but even were they more resistant than they are to ordinary influences, it is certain that these processes would speedily cause their death.

But beyond all this, a study of the life-history of parasites in general, and of those closely allied to this species in particular, enables us to confidently affirm that under no circumstances could they infect the human being, whether introduced along with the food or otherwise. Indeed, it may be further assumed that they are unlikely to be found in the tissues of any other domesticated animal, even in the closely-related buffalo, so specialised are such parasites for individual species of mammals.

Thus, from all points of view, the contention is justified that, so far as the public health of this or any other country is concerned, they are absolutely innocuous.

That from the commercial point of view these parasites are important to a country exporting large quantities of beef for human consumption cannot, however, be gainsaid, and it is to be hoped, therefore, that the further researches being conducted here and elsewhere will demonstrate the intermediate host, and so enable a policy to be outlined which may ultimately exterminate the parasite.

General.

Observations on the general subject of these parasites were commenced by us in 1909, independently of Dr. Cleland and Dr. T. H. Johnston, who have recently (February, 1910) published a preliminary report in the *Agricultural Gazette* of New South Wales, Volume XXI, 1910, p. 173, and further communications in the Proceedings of the Royal Society of New South Wales, Volume XLIV, 1910, p. 156–189, the substance of which is also contained in the Report of the Bureau of Microbiology, Sydney, 1910.

In Melbourne fresh material is difficult to obtain on account of the rarity with which Victorian catt e are affected, and it is only when northern New South Wale; or Queensland cattle which have been imported as stores, and fattened locally, are slaughtered at the abattoirs that there is any opportunity of securing specimens for examination. However, during the past year, thanks to the courtesy of Mr. John Robertson, Superintendent of the City Abattoir, we have from time to time received material. Further, one of us (J.A.G.) during a visit to Queensland examined a large number of affected cattle, both at slaughtering establishments and on tations under normal conditions. As is to be expected, our observations in many respects confirm those of Cleland and Johnston, although conflicting in regard to certain details.

History of Occurrence in Australia.

This has been fully dealt with by Cleland and Johnston. In addition to their observations it is worthy of record that several individuals in Queensland, who have been connected with cattle and the meat trade all their lives, are emphatic in their statements that they have known these nodules in the briskets of cattle for upwards of forty years.

As will be seen later, there is little doubt that the parasites first appeared in the cattle of the northern districts of Australia, and even now, comparatively speaking, the number of animals affected diminishes the further south one travels. Mr. Holt, G.M.V.C., Superintendent and Veterinary Inspector at the Hobart Municipal Abattoir, assures us that although frequent in animals imported from New South Wales, the nodules have never been found by him in cattle from King Island (Bass Straits), or in cattle bred in Tasmania.

It is certain that had this parasite been common or even rarely present in British and European cattle or their descendants in various other cattle-breeding countries of the world, such as North and South America, South Africa, and New Zealand, their presence would have been the subject of some comment at least, and in the absence of any reference whatever, either in scientific or stock journals, it is perfectly permissible to assume their absence. While it is possible, as indicated by Cleland and Johnston, that the buffalo, which was imported into Australia from Timor eighty-five years ago, is the true originating host, it must not be overlooked that possibly along with the buffalo, or at about the same time, cattle were also imported, for permission was given for such to be done. (Report, Bureau of Microbiology, 1910, p. 99.) This is important, for De Does has observed similar nodules in the pectoral region of cattle born in Java (Railliet and Henry—Comptes Rendus des seances de la Société de Biologie, T. LXVIII, 1910, p. 250.) Java, it should be remembered, is connected by a continuous chain of islands with Timor, and consequently it is more than probable the Timor cattle also harbour these parasites. Under these circumstances, therefore, it is probably unnecessary to assume a transference from an original host *e.g.*, buffalo, (*Bos indicus*) (?) to a new species (*Bos taurus*). (*See* Note, p. 34.)

Geographical Distribution of the Disease in Australasia.

In New Zealand these nodules have never been detected. All cattle slaughtered for export, and all cattle slaughtered for sale within towns of over 2,000 inhabitants, being the subject of very careful post-mortem examination in the Dominion by a body of qualified State Inspectors, it may be confidently stated that had such a diseased condition existed it would have been reported long ere this.

In Tasmania the disease has never been observed in locally-bred or in King Island cattle, although frequently detected in New South Wales cattle imported for immediate slaughter.

In Melbourne the nodules are from time to time encountered in cattle slaughtered at the abattoirs. The inspectors almost invariably state, however, that they are solely to be found in "northern" cattle, or cattle which have been imported into Victoria from northern New South Wales and Queensland. We have been assured, however, by one careful inspector that he has observed them occasionally in Victorian-bred cattle. There are records of their occurrence in cattle slaughtered in Adelaide, which is not surprising, seeing many of them are bred in the Northern Territory, and they appear to be well known in West Australia

In Sydney, as Cleland and Johnston have shown, they are frequently observed in cattle slaughtered at the abattoirs. Stanley (Gibson—Trans. Intercol. Med. Congress, August, 1892, p. 576) in 1892, stated that they might be detected at least in 50 per cent. of the animals slaughtered; but we think, from personal observations, this is extremely doubtful. In cattle from northern New South Wales, the Clarence and Richmond river districts, they appear to be fairly common, the opinion of Sydney Inspectors being confirmed by the Brisbane Inspectors and Works Managers.

So far as can be ascertained no cattle station in Queensland is entirely free of the parasite, though, naturally, some are more affected than others. From the experience of one of us (J.A.G.) we estimate that they may be found in at least 20 per cent. of the cattle on what may be termed the "cleanest" stations—possibly 50 per cent. on complete examination would be more approximate. For example, in one lot from a notoriously "clean" station in south-western Queensland, 10 per cent. on very careful examination by manipulation, using incision only when certain or doubtful, were found to be affected, but later on when the briskets of a number were partially dissected another 25 per cent. were found to harbour the nodules. Again, in two mobs from stations widely apart in north-western Queensland their presence could be detected in 60 per cent. by observation without any manipulation; more careful examination by dissection showed that every one of these animals contained from one nodule upwards.

All the evidence, therefore, available points strongly to a more general infection of herds the further north the cattle are bred and pastured. No information, however, points in the direction of soil, climate, rainfall, or management being contributory to the prevalence. Examination of records at freezing works, which was kindly permitted, entirely negatives any such supposition. Personal examination of cattle from different districts of the rich low-lying well-watered coastal country in the north, with heavy annual rainfall, showed them no more and no less affected than cattle from the dry western downs, and those from the high and cold basalt country. Further, close herding does not seem to have any effect; the proportion affected may be quite as great (often much greater) where the number of cattle per square mile is under a dozen, as where one to every 2 or 3 acres is pastured.

Age Incidence.

The nodules may be found in cattle of almost any age. Inspector Miller, of the Bowen Freezing Works, who has made a very complete examination by definite incisions of thousands of carcases, has found as large a percentage of 2- and 3-years old bullocks affected, and practically with as many nodules per individual average, as old cows.

The experience of J.A.G. supported this, no appreciable difference being found in the number of nodules present on the average in a hundred old cows from the number present in 3- and 4-years old bullocks, many from the same station as the cows. Further, on different stations he had an opportunity of thoroughly examining both ante- and post-mortem animals of various ages, with the following results:—

First Station.—Two Jersey cows, one 3 years old and one 4 years old. Manipulation in subcutaneous tissues behind the point of shoulder while alive detected nodules on each side of both animals. Two old cows, one 14 years old, the other 17 years old, were slaughtered and examined. The former contained twenty-five and the latter thirty nodules. All these cows were paddocked, that is, pastured in comparatively small areas (say, 50 to 200 acres), and were used for dairy purposes. No doubt, examination post-mortem, of the two young cows would have disclosed quite as many nodules in the inter-muscular spaces as were found in the old cows.

Second Station.—(Notorious for prevalence of these nodules.) Yearling heifer examined post mortem. Twenty nodules in brisket, varying in size from a pea to a large marble.

Another yearling, probably 10 months old, killed and examined showed twenty-four nodules, a group of five being clustered at one place over the sixth and seventh intercostal spaces. These varied in size from a split pea to a walnut.

Calf, about 3 months old, running with mother, killed and examined; no nodules could be detected anywhere.

Third Station.—In same district as previous stations, (recognised as comparatively "clean"). Cow, aged 8–10 years; killed and examined. Only four nodules, each the size of a marble, present.

Calf, 6 to 8 months old, running with mother; killed and examined. Four small nodules present.

Heifer, 18–20 months old; killed and examined. No nodules found after very careful examination.

(It may here be noted that on this station the cattle are dipped in arsenical solution every three to four weeks in order to combat cattle-tick infection, whereas on the other stations dipping is not carried out so frequently or so thoroughly.)

It may be observed that the older the animal, generally speaking, the greater the tendency for the parasites to be degenerated. For example, the parasites of all the nodules in the 17-years-old cow, and the majority of those in the 14-years-old cow were degenerated and calcified; while in the 8–10-years-old cow three of the four nodules contained degenerated worms, one of which was partially calcified, lying free in a muco-purulent fluid. In the younger cattle no degenerated worms were found.

These observations indicate very clearly that the most general period in the life of the host when the filaria enters or at least establishes itself in the system is during youth, probably the first year. They have, therefore, an important bearing on the general life-history, as will be discussed later.

New Growths (Nodules) induced by Parasite.

Location and Number.—In spite of the observations of some to the contrary, the experience of one of us (J.A.G.), gained from the examination of over 700 cattle affected, is that the nodules are invariably confined to two distinct and separate situations.

The commonest situation is the region of the brisket, chiefly the triangular outline formed by the junction of the ribs with the costal cartilages, especially between the fourth and sixth ribs, but often extending backwards to the tenth, and, at times, forward to the second rib. Frequently they are superficial, *i.e.*, in the subcutaneous tissues, but more often they are situated between the posterior portion of the superficial pectoral muscle and the anterior part of the posterior deep pectoral, between the posterior portion of the deep pectoral and the external abdominal oblique, and between the panniculus carnosus and the posterior portion of the external oblique, rarely deeper.

The number of the tumours varies in different animals, irrespective of the age of the animal. There may be only one or two, but there may be fifty in the one animal.

The other situation is the external surface of the hind limb, especially behind the femoro-tibial joint, and the groove leading upwards to the pelvis, anterior to the gluteus maximus, and even near the angle of the haunch. While occasionally superficial and readily detected, they are often under the dense subcutaneous fascia lata, when they are much more liable to be overlooked. Generally single in the hind limb, it is not very unusual to discover a group of four to six. Usually flattened, they present practically the same characters as those found in the fore limb.

It is well to observe that slaughtermen, and even inspectors, state they occasionally find such nodules elsewhere than in the situations mentioned. For example, that they have been detected on the inner surface of the thigh, in the groin, and even throughout the body. Other very careful observers, however, deny this. Certainly J.A.G. saw no indication of their presence elsewhere, even in the most badly affected cases, and we are strongly inclined to the opinion that such conclusions have resulted from small tumours of different origin being mistaken for these nodules.

Macroscopic Appearance.—In the vast majority of cases it is absolutely impossible to detect the presence of nodules during life, and, indeed, it is impossible without definite incision to be certain that none are present even in a dressed carcass. In some instances, however, during life, they may be detected by manipulation, and often by simple observation as definite spherical firm tumours situated almost in a direct line behind the point of the elbow. When present in the subcutaneous tissue they are generally globular and not pedunculated. Occasionally they may be so firmly attached to the dermis that the butcher in flaying the animal divides the nodule. Very rarely are they situated in the intra-muscular connective tissue, even in part. When found in the inter-muscular loose connective tissue, they are seen as flattened spherical, sometimes ovoid, bodies of very dense consistency, lying amongst a greater or less quantity of looser, flaccid tissue, which permits a considerable amount of free lateral movement, so preventing, no doubt, the bruising that otherwise would naturally tend to occur when the host is in the recumbent position on a hard surface. The nodules themselves are, in our experience, almost invariably difficult to remove from this loose connective tissue, and only rarely have we found them easy to enucleate, as observed by Cleland and Johnston. It is true that occasionally on incising the muscle immediately over a small tumour it may extrude, but this is generally because when the carcass is hung up and "dressed," the pectoral muscles are in a condition of great and unnatural tension, but while the nodule with some of the loose surrounding tissue may be then readily removed, it is not always the case, and in any circumstance cannot be termed "readily enucleated."

Occasionally evidence of recent hæmorrhage in the periphery of the nodule may be detected. Probably this is always the result of the falling of the animal when stunned prior to bleeding, for we have never observed it in tumours from the hind quarters.

The blood vessels supplying the nodule are always very distinct, generally tortuous to an extraordinary degree, no doubt owing to the frequent partial displacement of the nodules. The walls of these vessels, particularly the arteries, are especially thick and the lumina comparatively narrow.

The size of the nodule, as does the space occupied by the parasite within, varies very considerably. Generally speaking, the size of the former is that of a marble, about 2 cm., but it is not uncommon to find it reach that of a walnut, 3·5 cm. Occasionally we have found an individual nodule the size of a mandarine orange, about 5 cm., one of the largest measuring 11 cm. by 8 cm. In our experience, although it is very rare to find a nodule of less size than that of a small marble, they may be found as small as a split pea, 6mm. in diameter, but then only after careful search through a large number of animals. On section the tumour is seen to be composed of a very dense fibrous wall (*see* figs. 1, 1a, and 2), which varies very much in thickness in different nodules, enclosing a tightly-coiled mass of worm "*xx*" in tunnels, and lying bathed in a small quantity of opalescent fluid (*see also* figs. 30 and 32). This fibrous capsule has no general relation in thickness to the space occupied by the parasite; for example, in one nodule measuring 7 cm. in diameter the worm-area was 15 mm. in diameter, and in another measuring 11 cm. by 8 cm. the worm-area was only 9 mm. (*compare* fig. 2). Notwithstanding this, as Cleland and Johnston stated, the worm-area shows little variation in comparison with the thickness of the capsule Further, although the worm-area is usually centrally situated it is not invariably so, especially in the flattened ovoid tumours.

Calcareous degeneration is not uncommon, and occasionally a purulent form of degeneration may be seen in which fragments of the dead parasite lie free. Often these degenerations attack only one portion of the worm-area, the other containing still undegenerated parasite with living larvæ. These degenerations appear solely to affect the parasite and the tissue between the coils. Degenerated nodules may be found in any animal, but the older the host the greater the likelihood of their presence, as already shown.

Movement of Parasite.—Careful examination of the cut surface of a nodule taken from an animal soon after slaughter enables one to detect some movement of the adult female, especially manifested by a tendency for the cut ends to protrude very slightly but definitely from the tunnels. In such very fresh nodules a considerable length of worm may be withdrawn by gentle traction, showing that it lies practically free within the tunnels, and, moreover, possesses some freedom of movement while enclosed within the nodule.

Microscopical Appearance of Nodules. (*See* figs. 1, 2, 30, 31, 32)—Sections made serially of different sized nodules showed the general structure to be the same in each instance. The capsule is composed of dense fibrous tissue with many nuclei, and processes therefrom pass inwards, branching and anastomosing to form the walls of the spaces or tunnels within which the adult parasite lies, thus forming what we have termed the worm-area. In the very smallest nodules the fibrous capsule is often very thin, while the branches entering the worm-area are extremely delicate. A very notable feature of the "capsule," especially in the larger tumours, is the extraordinary thickness of the walls of the arteries compared with the very small size of the lumina. This thickening is due to a peri-arteritis, and is often accompanied by a definite end-arteritis, and not infrequently an obliteration of the lumen. In certain nodules a section of the wall seems to be chiefly composed here and there of arteries with greatly thickened walls, between which there is a comparatively loose new connective tissue with many newly-formed blood vessels.

In the thinner capsules, particularly those of very small infertile worm nodules, the thickening of the arterial walls, unless at the point of entry, is not marked. Further, in those nodules composed of much fibrous tissue, numerous larvæ can be seen traversing the tissue and often congregated in the vicinity of the blood vessels, whereas in those with very thin capsules, migrating larvæ are seldom if ever seen.

The fibrous bands forming the walls of the tunnel vary very much in thickness and in density; frequently they are only represented by a few delicate strands; at other times, especially towards the surface of the worm area, the breadth of these bands exceeds the diameter of the tunnels.

In the deeper portions of the worm-area, especially around the heads of the parasites, the tissue is much looser in character, the nuclei are more numerous, and there is generally greater or less infiltration by leucocytes, and especially eosinophiles, which are often massed at the edge of the tunnel wall. The leucocytes are undergoing degeneration in certain areas, as shown by the nuclear disintegration and indefinite staining reaction.

Structure of the Parasite.

As stated previously, the worm lies closely coiled in a very complicated manner in the interior of the nodule, usually, but not necessarily, situated centrally. At times the matrix immediately surrounding the parasite, especially around the head, is less fibrous than elsewhere, but not invariably so. As in the case of some allied forms it is practically impossible, even with the greatest care and patience, to extract the female worm entire, even after the preliminary use of digestive and other like methods. Fifteen and twenty fragments are good records. The length of the worm, found by adding together the lengths of the various pieces obtained by careful dissection, with the production of as few fragments as possible, was in three typical cases of fresh female worms 52·6 cm., 90 cm., 140·3 cm. (*compare* Cleland and Johnston, 97 cm.).

The size of the whole nodule varied but very little in the three cases, the first and third being almost identical (about 6 mm.), though the second was larger (15 mm.). The male (*see* fig. 9), of which a complete specimen has not previously been recorded, was 3·8 cm. to 5·3 cm., and in the case of the third nodule above mentioned, 4·6 cm. long. The nodules appear to us undoubtedly to contain either most generally one female only or, less often, one female and one male; even when no male can be found in the nodule the female is usually fertile, but not invariably so, the infertile ones being found in the smallest nodules. Whether the male has been present and fertilised the female and then left the nodule or degenerated, or occasionally the female is fertilised before the formation of the nodule, or possibly, though it seems improbable, the eggs are produced parthenogenetically, are all matters, at present, of conjecture. Most probably copulation takes place occasionally before the dense nodule wall is produced, though one act of fertilisation seems wholly inadequate to account for the enormous numbers of larvæ produced by each worm. This opinion is strengthened by the small number of sterile nodules (we have only found three, out of fully a hundred nodules examined for the purpose, to be sterile), the comparatively rare occurrence of the male in the nodule and also the apparent absence of any degenerated males in the nodules, while it does not seem possible for a mature worm to make its exit through such a tough, fibrous, wall as that surrounding the nodule. When both worms, male and female, are present, their anterior ends have a definite relationship to one another. They lie side by side (*see* figs. 3, 4, 5, and 37), the female head often slightly in advance of the male, in the same tunnel of the tissue of the nodule, quite on the outermost part of the worm area of the nodule, usually on its flattened surface and more or less towards one side. The two worms (fig. 4) then pass straight across the centre of the nodule to the opposite side, the middle of the male generally lying once coiled alongside and around the female. The hinder end of the male may occupy a tunnel by itself. The female then passes to one end of the outer region of the worm area, along that end and back again along the side to which the heads were pointing; from this side it enters more deeply into the coil formed by the remainder of its body. The female tail, when found, was at about half-way between the centre and the periphery.

General External Characters.

The specimens of this worm which we have examined show great variations in several details, especially in the female, though this does not appear to have been noticed by previous writers. The variations met with in three typical males and six typical females are recorded in the accompanying table. One or two of these may be due to differences in age of the worm, or in the amount of ante- and post-mortem contraction; but it is obvious on consideration that all cannot be the result of such factors.

	A.	B.	C.	Range.
Length of male	cm. 4·6	cm. 3·8	cm. 5·3	cm. 3·8–5·3
Diameter, anterior end, 0·15 mm ...	mm. ·052	mm. ·062	mm. ·062	mm. mm. ·052 –·062
Diameter, middle of length	·151	·144	·141	·141 –·151
Diameter, 0·5 mm. from anterior end	·082	·069	·082	·069 –·082
Diameter, level of male opening ...	·051	·042	·042	·042 –·051
Excretory pore from anterior end ...	·251	...	...	·251
Nerve ring from anterior end ...	·188	?	·172	·172 –·188
Cardia from anterior end	...	...	...	
Cardia—length	...	...	...	
—diameter	...	...	...	
Œsophagus—length	·72	·65	?	·65 –·72
diameter	·0155	·0155	·0155	·0155
Cloacal opening from tip of tail ...	·048	·052	·062	·048 –·062
Spicules—length ... ... { long	·155	·148	·155	·148 –·155
{ short	·094	·078	·078	·078 –·094
diameter ... ... { long	·010	·0078	·009	·0078–·010
{ short	·0078	·0061	·007	·0061–·0078

Part.	A.	B.	C.	D.	E.	F.	Range.
Length of female	cm. 90	cm. 140·3	cm. [52·6]	...	...	...	cm. cm. 52·6–140·3
Diameter ·15 mm. from anterior end	mm. ·115	mm. ·110	mm. ·123	mm. ·078	mm. ·094	mm. ·087	mm. ·078– ·123
,, middle of length	·42	·40	·45	·38	·39	·37	·37 – ·45
,, just in front of vulva	·125	·155	·207	·109	·106	·125	·106– ·207
,, at vulva	·125	·155	·18	·082	·106	·113	·082– ·18
,, level of anus	·207	[? ·207]	...	...	...	...	·207
Excretory pore from anterior end	...	...	·358	...	·379	...	·358– ·379
Nerve ring from anterior end	·188	·188	·175	·142	·172	·167	·142– ·188
Cardia from anterior end	·41	·69	·573	(not seen)	·86	·79	·41 – ·86
,, length	·031	·062	·034	...	·031	·031	·031– ·062
,, diameter	·031	·040	·034	...	·031	·031	·031– ·040
Œsophagus, length...	·52	·73	·65	·62	·92	·82	·52 – ·92
,, diameter	·020	·02	·0207	·02	·021	·0207	·02 –·021
Vulva from anterior end	·46	·69	1·138	·59	·57	·69	·46 –1·138
Vagina and common uterus length	1·656	3·45	1·794	5·10	4·68	2·001	1·656–5·10
Anus from posterior end	·207	[? ·175]	...	...	...	...	·207

Size and Shape.—The male, as would be expected in one of the Filariidæ, is not only much shorter, but also considerably thinner than the female. For example, at 0·15 mm. from the anterior end, the male is 0·052 to 0·062 mm., and the female 0·078 to 0·123 mm., and at a distance of 0·5 mm. the male is 0·069 to 0·082 mm., as against the female 0·106 to 0·207 mm., while the average diameter of the male is less than half that of the female, being 0·141 to 0·151 mm., as against 0·37 to 0·45 mm. in the female.

The peculiar shape found to be normal for the female head is not present in the male, even in specimens killed in 70 per cent. absolute alcohol at 65° C., the male head simply tapering to a blunt point. Cleland and Johnston state: "in the male, however, there was no trace of labial structures." Under high magnification and favourable conditions we have seen the three lips, though less distinct than in the female, and in one, three very minute papillæ were visible, corresponding to those of the female head.

The Female.—The anterior extremity, 0·5 mm., of the worm tapers more or less rapidly to a usually blunt tip; sometimes the head is smaller even though the worm is quite mature as seen in the presence of the embryos in the uterus close to the vulva, and the animal is uncontracted, as seen in the structure of the tip. Moreover, this anterior end is sometimes seen to be bent slightly ventrally so that the most anterior part of the head is the dorsal lip. As stated by Cleland and Johnston, Park's description of "teeth-like projections and briar-like barbs" on the head end is quite incorrect, but there is a feature of the normal well-preserved head end which shows clearly in four of the six typical cases chosen for tabulation as well as in others. This appears to have been undescribed so far, though it is present in the drawing given of the head in Jour. Roy. Soc. N.S.W., XLIV (1910), Pl. XIV, fig. 1.

The extreme tip is separated from the rest of the head by a fold and depression of the cuticle and dermis (*see* fig. 5), giving it the appearance of a half moon set in to the wider main part of the head. Cleland and Johnston state in their original description of the new species that "the head is not constricted from the rest of the body." The length of this terminal portion is 0·0132 to 0·0136 mm., and it is present in specimens A, D, E, F, though not so well defined in the specimen D. In the other two cases the head is lacking in this respect (*compare* fig. 6), the absence of the fold being almost certainly due to some contraction in these cases. At least two of those specimens in which this feature appears were fixed in 70 per cent. alcohol, at 65° C., and were excellently preserved, so that there can be no doubt that this is the normal state of the head end. As stated by Cleland and Johnston, " the mouth is small, rounded, and terminal, and appears to be surrounded, in the female, by three slight projecting lips." The lips, which are very small, can only be seen immediately around the mouth opening, and are sometimes almost indistinguishable, even in the female. Papillæ can be detected only occasionally, and then show under high magnification as three tiny papillæ on the outer side of the head, one corresponding to the centre of each lip (*compare* figs. 6 and 7a).

Cervical Papillæ.—These have not been observed in either male or female.

Excretory Pore.—As a rule no excretory ring and pore has been observable externally, but in two females at 0·358 and 0·379 mm., respectively, from the anterior end is a special development of tissue carrying excretory vessels to the mid-ventral line, though the excretory pore could only doubtfully be detected (*see* figs. 6 and 7). In the male the excretory pore was only doubtfully distinguishable in one case at 0·251 mm. from the anterior end.

Vulva.—This, which often appears as a tri-radiate slit or a circular opening on the mid-ventral surface, varies greatly in position compared with the position of 0·8 mm. from the anterior end given by Cleland and Johnston, namely, from 0·46mm. in an uncontracted specimen to 1·138 mm. in a specimen probably somewhat contracted, the most frequent position being at 0·57 to 0·69 mm. (*compare* figs. 5, 6, and 7).

Tail.—In the male (*compare* fig. 9) this is very fine, gradually tapering, somewhat bluntly pointed. The last part of the body is coiled spirally once or twice; the cloacal opening is (figs. 10 and 11) a transverse slit which lies at 0·048 to 0·062 mm. from the tip of the tail, the diameter of the body at this level being 0·042 to 0·051 mm. We do not understand the figures given by the authors of the species in reference to the position of the cloacal opening, namely, " the anus in the male is situated at 0·072 mm. from the posterior extremity, and then later on, " the cloacal opening is situated on a median prominence about 0·65 mm. from the end of the parasite." The latter figure should presumably read 0·065 mm. and is even then slightly in excess of what our specimens show.

The anal papillæ are given by Cleland and Johnston in their second account of the parasite as six pairs, with perhaps the representative of another pair of papillæ. Our specimens show very clearly seven pairs (figs. 10–12B), not, however, always bilaterally symmetrical or exactly comparable in different specimens. The figure represents what appears to be the normal arrangement of these structures, that is to say, there are three pairs ad-anal, one pair pre-anal, and three pairs post-anal papillæ. Of these the pre-anal are usually somewhat large, well separated, and readily seen (figs. 10 and 12a). Sometimes it is so far back as to be more correctly described as an additional ad-anal pair (figs. 11 and 12b, and *cf.* Cleland and Johnston, *loc. cit.*, Fig. 3) at other times these two pre-anal papillæ are very much closer to the median ventral line. On one occasion there was one very clearly marked additional papilla on the left side, some distance in front of the normal pre-anal pair, but none could be detected on the right side (fig. 12b). The three smaller ad-anal papillæ on either side are, rarely, so closely arranged as to appear almost continuous with one another at their bases fig. (11). The most anterior pair of post-anal papillæ are large and generally well separated, but may be much smaller and almost touching in the middle line. The middle post-anal pair are of fair size, and do not appear to show much variation. The posterior post-anal papillæ are situated almost on the extreme posterior end, and although smaller than the others are generally very clear.

In the female the tail is more bluntly pointed than in the male. The anal opening (fig. 8a) lies at a distance of 0·207mm., or in a less perfect specimen apparently 0·175 mm. from the extremity of the tail; the usual thickness of the body at this level being also 0·207 mm.

Cuticle.—As already described, the cuticle is raised up into one or sometimes two series of spiral ridges, each more or less irregular. Even in extreme cases these ridges only extend as far forward in the female as 0·34 mm. from the anterior end, while behind the anus there is practically no such ornamentation. No transverse striations of the cuticle have been seen, nor any longitudinal striations other than those due to the longitudinal arrangement of the muscles. In the male the spiral ornamentation is naturally much finer and less marked in character.

Internal Structure.

Owing, perhaps, to the conditions of pressure, &c., under which the worm lives, many details of its structure are extremely difficult to decipher, more especially as will be seen in connection with the nervous and excretory systems, which show an asymmetry and irregularity which is quite evidently a characteristic of the worm, independent of methods of fixation, preparation, &c.

Digestive System.—In the male the œsophagus is straight, and is 0·65 to 0·72 mm. long and 0·0155 mm. wide, that is, somewhat narrower than the female. Sometimes slight swellings are present on the œsophagus, just before it enters the intestine, but no definite "cardia," like that of the female could be found in any instance. The long, straight, intestine passes back to the cloacal opening, and, though much reduced, is similar to that of the female. The spicules will be described in connection with the reproductive system. In the female the long narrow œsophagus, sometimes straight, sometimes twisted (figs. 5, 6, and 7, and 35), varies from 0·52 to 0·92 mm. in length, and is 0·02 mm. in diameter. Just before it enters the intestine the globular "cardia," already described by Cleland and Johnston, is always found, though not always clearly distinguishable. The position of this cardia, measured from the anterior tip of the head, is seen to be at 0·57 to 0·86 mm., and has no invariable relationship to the position of the vulva, as affirmed by Cleland and Johnston. The extreme length and diameter of this cardia is usually 0·031 mm., though in specimen B, in which it was distended by a number of refractive granules, it was 0·069 mm. long by 0·04 mm. wide. The apparent condition of the junction of œsophagus and intestine varies naturally with the more or less sinuous condition of the œsophagus at the time of fixing; sometimes, as seen in fig. 5, the œsophagus is practically straight till it reaches the cardia at 0·41 mm. from the anterior tip, while in the specimen in which the extreme position of 0·86 mm. from the anterior end was reached, the œsophagus is much more sinuous. Though sometimes situated at the termination of the œsophagus, the cardia is at other times slightly in front of the entrance of the intestine.

As a rule it is easy, unless hidden by the vagina, to detect the exact junction because of the muscular walls, the cuticular lining and, therefore, sharply marked lumen of the œsophagus and cardia and the slightly wider non-muscular intestine (figs. 5, 6, 7, 8, 32, and 34), with irregular indefinite lumen and usually much darker walls. The walls of the cardia are more muscular than those of the remainder of the œsophagus, and the lumen not much greater.

The chyle intestine varies about 0·046 mm. in diameter, its lumen being in parts nearly obliterated. At about 0·207 mm. from the anal opening, where it passes into the rectum, the posterior end of the chyle intestine is suddenly constricted to about one-third its previous diameter.

The rectum (fig. 8) is á much swollen flask or pear-shaped structure, its total length being 0·2 mm., and its maximum diameter 0·082 mm. The lining of the rectum is chitinous, and it contains a considerable quantity of granular material.

Nearly 0·2 mm. in front of the junction of the chyle intestine and the rectum, there begins an irregular group of cells (*see* fig. 8), which extends back to slightly behind this plane, and, doubtless, comparable to those found in many other nematodes, though usually less numerous than in this form, and variously described in other forms as ganglion cells, or, more generally, as unicellular glands. They lie in *O. gibsoni* chiefly on the ventral surface, though they extend half-way up the sides of the body, being attached to the body wall. The granular material fn the rectum has a similar appearance to the content of the cells now under consideration. Whether these cells are the exact equivalent of the three large pear-shaped cells described by various authors (quoted by Looss in the "Sclerostomes of Horses and Donkeys," in the report of the Egyptian School of Medicine, Cairo, 1901, p. 58) is uncertain, though probable. Their large number in this form makes one hopeful that a further study of them may elucidate their morphological and physiological character—but as only one of the female tails we have obtained is of good histological preservation, and as so far the tail of the female has not been found or at least recorded by other observers, we do not wish to use it for section purposes, at all events at present.

Surrounding the body at the level of the anal opening is a muscle band, the fibres of which spread dorsally in a fan-like manner, very similar to that found in other nematodes in a comparable position.

In the anterior end of the body of several worms, but especially clearly in specimen C, were to be seen three small brownish yellow disc-like structures, the largest of which was 0·0189 mm., the others 0·0146 mm. in diameter, lying in the body cavity. They consist of about a dozen highly refractile yellowish granules, which are larger in the larger structures. Their position, in relation to the other organs of the body cavity, is indicated in fig. 6.

Muscular System and Longitudinal Bands.—The division into four quadrants usually seen in a transverse section of a nematode is in *Onchocerca gibsoni* very obscure, and often not really present through the greater part of its length (*see* figs. 32–34). A diagrammatic representation of what appears to be normal for the main length of the male and female worms is given in fig. 36. This shows practically only a dorsal and ventral part of the musculature, separated by more or less distinct lateral bands. Although shown almost symmetrical, these bands are nearly always strongly asymmetrical in the female (*compare* figs. 32–34), that on one side or the other being hardly noticeable. We have not been able to find any definite relationship of these reduced lateral bands to the interior or exterior part of the nodule, such as we thought possible.

When any particular coil is close to the boundary of the worm area, then more often the better developed band is towards the periphery of the nodule, but the reverse is often found towards the centre of the worm mass. The dorsal and ventral median bands are not distinguishable, their position being only detected in rare cases by very small dorsal and median nerve strands (*compare* fig. 36). The whole body wall is very thin, giving a relatively large body cavity, which only occasionally and in parts contains a granular material which nearly fills it, presumably coagulated hæmolymph.

In transverse section the irregular ridges of the cuticle are seen as papillæ-like points here and there on the surface. The hypodermis is usually thin, and embedded on its inner surface are the contractile parts of the muscular elements, which have the general appearance of a radiate border to the hypodermis. The inner protoplasmic parts of the muscles are vesicular, forming irregular meshes on the inner side of the body wall. These characters of the musculature are often hardly distinguishable, so attenuated do they become in the thinning out of the whole wall.

In the anterior part of the bodies of both male and female worms, however, the structure of the body wall more nearly approaches the nematode structure (*compare* fig. 37). This is only to be found, however, in that anterior part of the worms which does not exceed about 0·095 mm. in the male, and 0·175 mm. in the female. Here, as will be seen from the figure, especially in the female, the lateral bands are strongly developed, and together occupy about two-thirds of the entire body circumference. Sometimes each shows traces of a division into dorsal and ventral halves.

The dorsal and ventral ridges are only slightly developed, but are very definite. The four small remaining intervals are occupied by the muscle cells, the protoplasmic portions of which are comparatively very small. As one passes backwards this well-defined and symmetrical arrangement rapidly becomes lost with the increase in diameter of the worm, the great thinning out of the wall and consequent increase in the size of the body cavity resulting in the marked asymmetry described above.

Nervous System.—(*See* figs. 5, 6, 7, 32–34, 36, and 37.) This, together with the excretory system, is very difficult to observe, and what one does observe is difficult to interpret. The nerve ring, which is usually indistinct, especially in the male, lies from 0·172 to 0·188 mm. in the male and 0·142 to 0·188 mm. in the female from the anterior end. These variations have no relation to any condition of possible contraction of the worm. The most common distance is about 0·170 mm., that given by Cleland and Johnston, namely, 0·18 mm., being less frequent.

So far as can be determined at present, the nerve bands appear to form an irregular plexus around the head, in which what are possibly nerve cells are to be seen. No anal ganglia have been detected. Behind the nerve ring, with its nerve cells, the nerve fibres are arranged as a tiny bundle in the centre of the dorsal and ventral median bands, and in a more or less diffuse manner in the inner parts of the lateral bands (*see* fig. 37). With the change of structure of the longitudinal bands, as we pass backwards along the body, the character of the longitudinal nerves alters also.

Dorsal and ventral nerve strands are present, consisting of very few fibres, six to eight, which lie in the ordinary hypodermis of the body wall, no swollen or projecting bands being present.

The lateral nerve elements are, however, much more developed, though even here often impossible to find with certainty. In general it may be stated that there are two lateral longitudinal nerves more or less well developed on each side, as shown in figs. 33 a, b, c, 34, and 36. In the sub-cuticular layer of this region there are also sometimes to be found, even when the lateral nerves are difficult to determine a row of nuclei (*compare* fig. 33 a) which are apparently connected at all events at intervals by fibres with the lateral nerve strands. At other times these nerve fibres from the lateral nerves run out very definitely and end in branches immediately under the cuticle, though no sense papillæ have been detected. These nuclei may extend over the whole lateral band or may only show over its dorsal and ventral two-thirds.

Excretory System. (*See* figs. 6, 7, 32, 33, 34, 35, 36.) This when best defined, consists in the main part of the body length of a double or single canal (*see* figs. 33a and 33b) which lies between the two lateral nerve strands in the lateral band. Like these nerves, the excretory canals are sometimes hardly distinguishable on one side of the body (*compare* fig. 32), while in the same section the lateral band of the other side may be so vesicular in character (fig. 33c and 34), apparently due to excretory tissue, as to make it difficult to find any hypodermis or sub-cuticular tissue at all, and even on occasion to determine the boundary between this and the protoplasmic meshes of the muscle cells. One of the cavities in this structure near its centre is often more definite than the remainder, and evidently represents a normal excretory passage. Apparently the lateral bands are chiefly composed of what is potentially excretory tissue which may become more or less vesicular, or may be traversed by one or more definite canals that pass along one side of the body. On the other side it may be reduced almost and sometimes quite beyond recognition, at all events at parts. This asymmetry is totally unlike anything which we have been able to find in the literature at our disposal, though possibly it is not unique. In that anterior part of the body in which the four longitudinal bands are well defined, the excretory canals are most clearly seen in those parts where the lateral band shows the more marked division into two halves; the canals are then situated some distance below the cuticle and between the two halves of the lateral bands, and are slit-like in character (*see* fig. 37).

Near the level of the excretory pore two broad projecting ridges from the lateral lines (*see* fig. 35) approach the centre of the body cavity, near which they become much thinner and more sharply defined. They then unite, forming a narrow band almost homogeneous in nature as are the ridges; this runs ventralwards to the mid-ventral line. In each ridge can be traced a proportionally very small but distinct lumen, the lateral excretory vessel. Each of these is continued down into the median portion, and may further be traced to the very minute excretory pore which opens as described above.

Reproductive System—Male.—So far as we have been able to determine, the male reproductive organs are single throughout their length. The single wide vas deferens crowded with developing sperm occupies a large portion of the body cavity, compressing the intestine. It passes back to open as usual into the cloaca by the ductus ejaculatorius.

The two unequal spicules (*see* fig. 10) in our specimens are respectively 0·148 to 0·155 mm. long, by 0·0078 to 0·01 mm. wide, in the middle of its length, and 0·078 to 0·094 mm. long by 0·0061 to 0·0078 mm. wide. There is thus evidently a variation in the lengths of the spicules, but we do not find such a variation as is indicated by Cleland and Johnston, who have given as the respective lengths of these spicules 0·14 and 0·047 mm., and 0·197 and 0·082 mm. in their two reports. Both are hollow and have the usual funnel-shaped opening at the inner end and closed distal end. The longer spicule, which is the left-hand one, is usually once twisted and has a finely pointed distal end. The right-hand shorter spicule has an enlarged shoe- or boat-shaped outer end, not unlike that seen in such Filariidæ as some species of Oxyspirura, the grooved upper surface serving for a guide for the sharp end of the long spicule.

Female.—The ovaries are double and lead straight into the long and slightly coiled double uterus. The wall of the uterus (fig. 32), when undistended, consists of distinctly nucleated and granular cells surrounded by a very thin fibrous layer. When distended the wall appears as a very thin fibrous one in which nuclei are apparent, cell divisions being apparently lost. The two uteri unite without much change of structure to form a common uterus of remarkably varying length. This in turn opens to the exterior at the vulva by a short muscular vagina. The vagina is seen in specimen C, which was the only infertile one of these six, to be 0·414 mm. long, having close to the vulva an even more muscular swelling (*see* fig. 6). The single uterus, non-muscular or only slightly so, passes back for a distance of 1·38 mm. before dividing into the two uteri corresponding to the two much coiled ovaries. As remarked above, this specimen contains no fertilised eggs or larvæ.

In other cases the total length of the vagina and common uterus varies from 1·656 mm. to 5·10 mm., in each case being crowded with larvæ, as is also one or both halves of the bifurcated uterus. There is, so far as our specimens show, no relationship between the position of the vulva relative to the head and the length of the common uterus.

Development.

By counting the average number of larvæ in a transverse section of known thickness, and calculating the egg-bearing area of the shortest and longest worms measured, we have estimated the number of fertilised eggs and larvæ present in the worm at any one time as certain'y not less than 400,000 in the shortest to 2,000,000 in the longest. In the case of those nodules in which the male worm is present with the female the possibility or even probability of nearly continuous or at least repeated fertilisation enormously increases the reproductive capacity of these worms, a fact which undoubtedly points to the life-history being a very difficult one, with every likelihood of non-completion. As remarked above, very ew infertile nodules have been found, and even where fertile very often no sign of the presence or even past presence of a male could be found.

The unsegmented fertilised ovum (*see* fig. 13) is 0·017 mm. by 0·009 mm., the nucleus being large, round, and finely granular. Segmentation proceeds very rapidly, so that in good smears from the cut surface of a fertile nodule the full process of segmentation can be traced.

The first result of segmentation is very commonly met with in such a smear, and this two-celled stage shows very considerable variation in size, even more than shown in the figures (*see* figs. 14 and 14a), namely, from 0·019 mm. by 0·009 mm. to 0·02 mm. by 0·017 mm. Thence division proceeds more or less regularly, as shown in Figs. 15–18: four, five, six, seven, ten, fourteen, sixteen, seventeen, up to thirty-two celled stages being observed; the nuclei in the latter stages becoming smaller and more oval or elliptical. This fully-formed morula or mulberry stage is sometimes common. In the next stage normally the embryo loses the oval form and assumes the almost comma-like stage (fig. 19) found in the development of various other nematode eggs, though here the tail of the comma is very much less pointed than in such forms as *Agchylostoma duodenale* or *Ascaris lumbricoides*. Also we have been unable to detect any such definite difference in size of the nuclei at the two poles, such as is found in some forms, for example, *Stephanurus dentatus* Successive stages to this (for example, figs. 20 to 25) show a gradual elongation and narrowing of the protoplasmic body of the parasite, this increased length being compensated by a more or less involved coiling of the embryo, which, however, usually comes later to lie in a less complicated manner. The comparatively few large nearly spherical nuclei of the morula and comma stages become converted by rapid division, so that in the stage represented by figs. 22 and 23, in which the well-marked outline is clearly present, there may be as many as six rows of nuclei. The diminishing size and increase in number of the nuclei is shown in the figures, which are all drawn by camera lucida. It will be noted from the figures that in this development there is no division of the general protoplasm into cells corresponding to that of the original nucleus into the numerous nuclei of the later stages. The protoplasm with its nuclei forms at fir t an oval syncytium, which becomes much elongated into a thread-like syncyt um.

In some smears, however, obtained on different occasions, some strange and puzzling appearances were noted. The first of these suggests itself as being a stage immediately succeeding the morula stage, and shows the oval syncytium, the nuclei being arranged in a definite convoluted chain, as represented in fig. 26. A number of similar eggs were noted on several occasions. The second appearance (*see* fig. 27) shows a lobulated protoplasmic mass with a tendency to convolution, of bands of much smaller nuclei, and might be regarded in some way as intermediate between fig. 26 and figs. 24 or 25. The change in structure is apparently due to the longitudinal and transverse division of the nuclei forming the single chain just described, the form of a coiled chain of nuclei now much smalle and more numerous being retained in a more or less definite manner. In the light of present knowledge we cannot but regard these two apparent stages in the development as at least abnormal If they be not artifacts, which there is no reason to believe they are, then the oval syncytium of the morula stage in these cases must have become converted into the coiled solid cord or protoplasm which forms the fully developed embryo by division and arrangement of the nuclei and an aggregation of the protoplasm around them, the latter splitting in the lines between these linear aggregations of nuclei and protoplasm. So far as we are aware such a method of development is unknown in any other animal, and we cannot yet regard it as a normal method of development. The presence of such stages as shown in figs. 26 and 27, compared with those shown in figs. 19, 20, and 21, is very difficult to understand.

The larva (figs. 28 and 29) is now definitely outlined, and consists for the most part of two, three, or four layers of cells, regularly arranged, but showing here and there spherical nuclei, staining pinkish with Giemsa, as contrasted with the double row of purplish nuclei, of which the body is chiefly composed. At this stage the head is often differentiated, and rarely and indistinctly the beginnings of the V and tail-spots may be detected, becoming more definite very soon. The normal position of the larva in the latter part of this stage is in a flattened open coil, the head being nearest the enveloping egg membrane when present with the tail to the centre of the coil. Its length is usually 0·155 mm. The whole egg measures at this stage 0·043 to 0·045 mm. by 0·03 to 0·039 mm. In contradistinction to many forms the egg of this worm does not appear to possess an egg-shell invariably, or even usually, in its earlier stages, as shown in figs. 13 to 23, a fact which mainly accounts for the absence of empty egg shells, observed and commented by on Cleland and Johnston. Occasionally, however, a delicate homogeneous enveloping membrane, but with more deeply staining spots, is to be seen round the immature larva, for example, fig. 24. Evidently the adaptation of the egg to its environment does not require the constant presence of any special egg shell.

The normal dimensions of the newly-liberated larva are 0·23 to 0·35 mm. long by 0·0031 to 0·0041 mm. wide; no sheath is apparent. The larvæ when free in the common uterus are somewhat wavy and closely packed together. When free, whether in the surrounding fluid or traversing the fibrous capsule, their body is distinctly undulating, the head being straight and the tail sharply recurved.

The larva is now marked out more or less definitely into five areas. The extreme anterior (0·0025 to 0·0049 mm.) and posterior (0·0093 to 0·0132 mm.) ends are more or less hyaline in appearance, being devoid of nuclei. The distance of these areas from the anterior end, as seen in a typical larva of 0·25 mm., are, to the V spot, 0·06 mm., thence to *w* 0·071 mm., thence to *x* 0·048 mm., thence to the tail spot *y* 0·031 mm., thence to the tip of the tail 0·04 mm., and these figures may be taken as giving the average position of the areas in question. The extreme anterior end appears rarely to carry a spear-like process which stains more deeply than the rest of this hyaline portion. Immediately succeeding this hyaline head-end are two rows of long elliptical nuclei, one of which is often in advance of the remainder. Just in front of the well-marked spot, about 0·05 mm. from the anterior end, is a group of finely granular cells, evidently the rudiment of the nerve ring. The nuclei are much more densely packed just in front of and just behind the V spot; behind this again they are more separated, until just behind the indefinite gap often present at *w* they are most closely arranged. The gap at *x* is also often very ill-defined, the nuclei being, however, crowded back to and behind the very sharply-marked spot *y*. Although there is no sheath present the transverse striations of the surface of the body of the larva may be sometimes clearly seen.

The movements of the larvæ may be well studied in the fluid from a fresh nodule. Under such conditions their movement is seen to be sinuous and also whip-like, certainly progressive, and at times rapidly so.

In our preliminary examinations we constantly observed, on careful incision of the nodule without injury to the adult parasite, a slight oozing of the serous fluid from the worm-area. Examination of this fluid in the majority of cases revealed the presence of free larvæ; only when the parasite was cut were eggs detected. It was further noted that usually scrapings from just within the periphery of the fibrous tissue, when examined microscopically, would show the presence of free larvæ. These observations are confirmed by sections of worm nodules. It is remarkable, however, how comparatively few of these larvæ are to be found external to the parasite within the tunnels, even when the larvæ are singularly numerous in the dense capsule. That these larvæ are not squeezed into the fibrous tissue during the process of removal or handling, or carried by the knife during sectioning, or confined to one particular part, is shown by a number of serial sections of a large piece of the peripheral wall of the largest nodule showing no trace of adult parasite. In these sections the larvæ are seen to be very numerous, and just as numerous near the periphery as elsewhere (fig. 30).

Although frequently found lying in close proximity (fig. 31), in no instance have we been able to demonstrate their presence in a blood vessel; often, however, they may be seen within lymph spaces, and it seems to us probable they reach the blood stream by the lymph channels rather than by piercing the much thickened walls of the blood vessels. Like Cleland and Johnston, we have failed to detect any larvæ in the blood of infected animals, even by examination of large quantities after centrifugalising. We suggest that the arteritis, which is such a marked feature in the histology of the large nodules (*see* fig. 30), is probably due to the irritation caused by the presence and movements of the larvæ.

Within the nodule, even twenty-four hours after death of the host, living larvæ may almost invariably be detected. It is probable from the following evidence that they are not capable of living many days in the free state within the living host. As a result of numerous subcutaneous injections of enormous numbers of freely motile larvæ, eggs, &c., into cattle, examination of aspirated fluid, twenty-four hours later, often showed that most of the larvæ had disappeared; slight movement of some of the remaining larvæ was present, but motility had disappeared in the majority. On the second day, when the fluid was again aspirated, movement of the very few remaining larvæ had entirely ceased. Rarely are eggs found twenty-four hours after injection of such fluid. While this evidence is, of course, not conclusive, it indicates a comparatively brief history of the larvæ in the host of the adult.

Life History.

That the life history of these filariæ is an extremely difficult and probably complex one is indicated by a number of factors. There is, first of all, the enormous number of eggs and larvæ (averaging a million) present at one time in the fertile female, in addition to which there is the constant expulsion of free larvæ. This, compared with the comparatively few adults, fifty at most, found even in the most severely affected animal, alone demonstrates that the possibility of an individual larva ever attaining maturity is extremely remote.

Is an intermediary host necessary? By analogy with allied parasites this may almost be taken for granted. The possibility of a free existence must, nevertheless, be considered. Our observations and experiments negative this supposition. For example we have seen the larvæ do not live longer than thirty-six hours in normal saline, even at blood heat. Further, larvæ sown on plots of grass at about 30° C., in a moist atmosphere, rapidly died, and although frequent examination from twenty-four hours later up to six weeks were made of the grass and soil, nothing that would even suggest a development could be found. Again, on several occasions, we have injected large numbers of living larvæ into the subcutaneous and muscular tissues of young cattle. Subsequent post-mortem examination of one, four months later, failed to detect any indications of the development of a worm nodule. Similar results followed the smearing of larvæ on the skin of the axilla and groin. It should be noted that in none of these cases larvæ could be detected in the blood after inoculation. Desiccation of the larvæ, at blood heat, causes their death in at least twenty-four hours. These observations and experiments seem to answer our question in the affirmative: an intermediary host is required in the development of these filariæ.

Possible Intermediary Hosts.

Carnivora, e.g., Native Dogs (Dingo), Station Dogs, and Wild Pigs.—These may be excluded. Even the native dog never attacks healthy cattle, and rarely, if ever, devours the carcasses of bullocks. Cattle dogs on the stations are few, and rarely accompany the men; the amount of fresh meat with the exception of offal, they secure, is extremely small, and briskets are seldom if ever thrown to them. It would be difficult under any circumstances for any dogs to secure the living parasites.

Wild pigs, which are numerous in some coastal stations, may also be excluded. In any case, we have seen a carcass opened and left lying in the vicinity of a wild-pig camp and remain untouched by these animals.

Ticks.—The ticks may be likewise disposed of. The nodules were observed long before the advent of the tick in Queensland, and are numerous on many stations where the tick is unknown. In any case it is unlikely that the large larvæ of the filariæ would be able to pass into the egg of the tick. Further, the infection, were the parasite tick borne, would be very much greater.

Leeches.—These offer a possible intermediary. The fact, however, that the nodules are as numerous in dry districts, where stations mainly depend on artesian bores for water, is against the supposition.

Water Crustacea, &c.—These are, of course, also possible intermediary hosts.

Biting Flies.—These have certainly to be considered very probable intermediaries. As against their operation is the likelihood that, with such widely and easily spread insects, no part of Australia, including Tasmania, would by this time be free of infection by worm nodules; and, further, one would expect a greater and more general affection in individual animals.

As regards all these possible conveyers, the age incidence is a serious obstacle, and we are seriously inclined to suspect the intermediation of some parasite more liable to attack the younger animal.

The Louse.—This offers the most hopeful possibility. It may be one of the common species, or a new one hitherto undetermined. The louse is a frequent parasite, especially on young cattle, although rarely detected until the host becomes debilitated, when it rapidly increases in numbers, as is the experience of every stockman. Adult cattle are seldom under any conditions troubled to the same extent. The louse is a parasite which, it must be remembered, does not remain stationary. In cattle under station conditions, which are seldom in actual contact with each other, unless when travelled or yarded, the natural means of transmission would be by intermediary of the ground, particularly the camps and places of rest near water. Assuming the louse on swallowing a larva or larvæ loosens his hold and drops off—as we have observed he does under experimental conditions after inoculation of larvæ into a "lousy" cow,—on reaching a fresh host, the place most readily attacked would be where the skin comes in contact with the ground, and where it is comparatively soft covering loose areolar tissue, and, further, where there is little chance of the parasite being licked off. The regions behind the shoulder and behind the stifle meet these conditions, invariably and constantly touching the ground when the bovine is recumbent. The fact that of the hind quarters the right is the most frequent attacked, and that on this the bullock generally rests, is also suggestive. If, therefore, the louse injects the young filariæ into the subcutaneous tissues immediately after reaching a new host, the argument is fairly complete. At any rate some definite explanation is required to account for these filariæ establishing themselves invariably in the same regions; and this uniformity of condition is very difficult to understand on any other theory.

The reasons we consider indicative of louse transmission may be summarized as follows:—

1. The constant infection of young animals (one to two years) to an extent equal with that of old.
2. The frequent presence of lice on young animals in debilitated condition due to any cause.
3. The fact that in fat and adult cattle at abattoirs the nodules are practically never found smaller in size than one and a half centimetres in diameter, even after most careful examination. This indicates a seasonal incidence perhaps corresponding to a more or less recurrent loss of condition, due to circumstances connected with age and possibly food, thus favouring the entrance of the worm.

4. The situation of the nodules under the parts of the skin most readily attacked by the louse when picked up from the ground.

5. The gradual and slow advance of the infection from north to south.

Although, as above, the possibility of other blood-sucking parasites, including the mosquito, acting as intermediary hosts has not been overlooked, we are of opinion that at present the louse is worthy of most attention for these reasons. Should experiments on these lines which we are carrying out prove negative, and another intermediary host require to be sought for, complete proof will be a matter of difficulty, especially in Queensland, where it is impossible to be certain that experimental cattle, unless imported from the far south are, to commence with, free from any nodule.

Experiments thus far conducted on a heifer badly infested with lice (*Hæmatopinus vituli*), which was injected on several occasions subcutaneously with quantities of living and motile larvæ, eggs, &c., showed that as a result the adult lice drop off the skin within a few hours. That this is not due to the larvæ alone, but rather to the distension of the subcutaneous tissues, is proved by similar effects following injection of sterile normal saline. That the lice may, however, ingest larvæ, and that these may live and grow in the louse, was proved by the discovery of one living and motile larva in the body cavity of one of the lice removed from the skin of the infected area twenty-four hours after injection. This larva was entangled with the malpighian tubes from which it appeared to be trying to free itself. The passage of lice to and from the injected area was prevented by a ring of tar on a clipped surface. Lice from these inoculated areas have been transferred to a calf, and the results are being awaited with interest.

Protozoa Parasitic in Onchocerca Gibsoni.

(*See* figs. 32 and 34, *ut. p.*)

In smears made from the worm-area of a cut nodule one may often encounter isolated spindle-shaped cells which are not infrequently arranged in a rosette-like manner, much as is found in the Herpetomonas or Crithidia, as well as other types. In the examination of serial sections through the worm, these may be found in one or both of the genital tubes. A discussion of their morphology, relationships, and life history is reserved for a future paper.

For their assistance and courtesy extended in this investigation, we desire to record our thanks to the Inspectors and other officials of the Department of Agriculture in Queensland, especially to Mr. Orr, Chief Inspector of Stock; and to the managers of the various freezing works; and in addition, we express our grateful appreciation of the assistance rendered in the preparation of material by Mr. Norman MacDonald, B.V.Sc., Government Research Scholar of this Department.

ADDENDUM.

SINCE the above was communicated, two papers bearing on this subject of Onchocerciasis in Cattle, that have just appeared in European publications, have been received by us.

The first of these, "Un Nouveau Nematode Parasite du Bœuf," by Professor Neumann, of Toulouse (*Revue Veterinaire*, May, 1910), is of especial interest, dealing as it does with a condition in cattle in Algeria and Tunis, in some respects closely comparable with that herein described, and caused by an allied though quite distinct nematode hitherto unknown, viz., *Onchocerca gutturosa*, Neumann, 1910. The importance of this discovery in cattle in North Africa is considerable from an economic not less than a scientific point of view, as previously to this the "worm nodules" of Australian cattle have been regarded as unique, all other species of Onchocerca being known only from man in Africa, and such animals as are not under ordinary conditions used for food, *e.g.*, the horse, zebra, buffalo, and camel; or else from parts of cattle not used as food. Neumann considers it possible that the Australian *Onchocerca gibsoni* is the same as that of the Algerian form, but such is not by any means the case. The two species—*O. gutturosa* and *O. gibsoni*—are quite distinct, not only in structure, but also as a rule the position of the nodule, which in the Algerian form is usually on the inner face of the cervical ligament, rarely on the thigh, and apparently never in the sternal region, so that they are not, while thus situated, nearly so objectionable commercially as the nodules formed by *O. gibsoni*.

The second paper, a report to the Local Government Board, London, by Dr. MacFadden and Dr. Leiper (1911), on the

Onchocerciasis of Australian Cattle, offers little that had not already been published by Messrs. Cleland and Johnston. In reference to the general anatomy of the nematode, while confirming much that those authors and ourselves have stated, Drs. MacFadden and Leiper in several points agree more closely with ourselves in details in which we have differed from those authors. They have missed the presence of the first pair of caudal papillæ, which are undoubtedly present in the male, and so have incorrectly described the worm as having only six pairs of genital papillæ instead of seven pairs.

The detailed structure of the worm has not been described at all, nor is there any reference to the excretory system, so that we are unable to make any comparisons on these most difficult parts of the subject.

BIBLIOGRAPHY.

Bancroft, T. L. ... Rept. of Chief Insp. of Stock and Brands, Queensland, 1893, App. p. 4. (*See* Tryon.)

Barnard and Park ... Proc. Aus. Ass. Adv. Sci., V, 1893, p. 642.

Cleland, J. B. ... ... Jour. Agri. W.A., XV, 1907, p. 88; reprinted in Jour. Trop. Vet. Sci., IV, 1909, p. 491.

Cleland, J. B. ... ... Dept. of Agric., W.A., Bull. 34, 1909, p. 8; reprinted in Jour. Trop. Vet. Sci., IV, 1909, p. 316–334.

Cleland, J. B., and Johnston, T. H. Agri. Gaz., N.S.W., XXI, 1910, p. 173.

Cleland, J. B., and Johnston, T. H. Report of Govt. Bureau of Microbiology, Sydney, 1910, p. 91; and in Proc. Royal Society, N.S.W., XLIV, 1910, p. 156–189.

Dodd, S. ... ... Queensland Agric. Journ., Feb., 1910, p. 86.

Gibson, J. ... ... Trans. Inter. Med. Congress of Aus., 1892, p. 576.

MacFadden, A. W. J., and Leiper, R. T. Reports to Local Government Board, London, on Public Health and Medical Subjects. Food Reports, No. 11, 1911.

Morris, W. ... ... Proc. Royal Society of N.S.W., XIV, 1881, p. 337.

Neumann, L. G. ... Revue Vétérinaire, No. 5, May, 1910, p. 270.

Park, A. ... ... Veter. Jour. and Annals of Comparative Pathology, London, (222) XXXVII, Dec., 1893, p. 102–7.

Railliet, A., and Henry, A. Comptes Rendus de la Soc. Biol., LXVIII, 1910, p. 248.

Tryon, G. ... ... Queensland Agric. Jour., Feb., 1910, p. 81; reprinted in Jour. Trop. Vet. Sci., V, 1910, p. 511.

EXPLANATION OF PLATES.

All figures are outlined by the aid of camera lucida.

Reference letters.

a ...	... anus.
a.p. ...	... adanal papillæ.
b.v. ...	... blood vessels in wall of nodule.
c. ...	... cardia.
c.c. ...	... cells of doubtful character.
c'. ...	... indistinct cardia.
c.m. ...	... contractile part of muscle cells.
c.o. ...	... cloacal opening.
c.u. ...	... common uterus.
cut. ...	... cuticle.
d.n. ...	... dorsal nerve fibres.
d.s. ...	... developing sperm in vas deferens.
e. ...	... excretory canal (and excretory tissue generally).
e.b. ...	... excretory bands.
e.p. ...	... excretory pore.
e.x. ...	... exit of worms from common canal.
f.t. ...	... fibrous tissue of nodule.
i. ...	... intestine.
l. ...	... larvæ.
l.b. ...	... lateral band.
l.s. ...	... long spicule.
m. ...	... muscular layer.
m.b. ...	... muscle band.
n.p. ...	... nerve plexus (?)
n.r. ...	... nerve ring.
n.s. ...	... nerve strand.
œ. ...	... œsophagus.
o.p. ...	... oral papillæ.
p.m. ...	... protoplasmic part of muscle cells.
p.p. ...	... pre-anal papillæ.
pt.p. ...	... post-anal papillæ.
r. ...	... rectum.
s. ...	... structures of doubtful character.
s.s. ...	... short spicule.
t. ...	... tunnel in nodule.
ut. ...	... single uterus.
ut. o....	... uterus with ova
ut. p.	... uterus with protozoan parasites.
va. ...	... vagina.
v.n. ...	... ventral nerve fibres.
vu. ...	... vulva.
xx ...	... boundaries of worm-area in interior part of nodule.
u, v, w, x, y...	special points of larvæ.

Description of Figures.

Figure 1. Photograph of groups of whole nodules.
,, 1A. Same of four nodules, with large proportionate worm-area.
,, 2. Same, with small proportionate worm-area. ($=xx$)
,, 3. Partially dissected worm nodule. x 3.
,, 4. Two heads. Male and female. Partially dissected out.
,, 4a. Diagram showing method of coiling.
,, 5. Head of female, with forward position of vulva. x 124.
,, 6. Head of female, with backward position of vulva. x 78.
,, 7. Anterior portion of female worm back to bifurcation of uterus. x 50.
,, 7a. Head of female, showing papillæ. x 646.
,, 8. Tail of female. x 96.
,, 9. Whole male worm; drawn when living. x 2.
,, 10. Tail of normal male; side view. (Thickness of cuticle very slightly exaggerated). x 545.
,, 11. Tail of male, side view; with abnormal papillæ. x 568.
,, 12a. Diagram showing normal position of papillæ.
,, 12b. Diagram showing abnormal position of papillæ.
,, 13. Unicellular ovum. x 1060 (approx.).
,, 14 }
,, 14a } Two-celled embryo. x 1060.
,, 15. Four-celled embryo. x 10'0.
,, 16. Seven-celled embryo. x 1060.
,, 17. Sixteen-celled embryo. x 1060.
,, 18. Thirty-celled embryo. x 1060.
,, 19. Thirty-six-celled embryo. "Comma" stage. x 1060.
Figures 20 to 25. Successive stages in elongation and increase in size and complication of embryo. Fig. 20–22, x 1060. Fig. 23–25, x 1085.
Figure 26 }
,, 27 } Abnormal (?) stages in development of embryo. x 1085.
,, 28. Fully developed free larva from smear. x 610.
,, 29. Fully developed larva from lymph space, 0·12 mm. from periphery of nodule. x 610.
,, 30. Small portion of section of periphery of much thickened wall of a large nodule, showing its structure and larvæ lying in lymph spaces close to surface. x 100 (approx.)
,, 31. Section of large less thickened artery, showing larvæ in periphery of wall. x 100 (approx.).

Description of Figures—*continued.*

Figure 32. Transverse section of body of worm lying in tunnel. To show general structure and protozoan parasites lying in one genital tube. x 105.

" 33a }
" 33b } Transverse sections of lateral field, showing variations. x 105.
" 33c }

" 34. Section to show a symmetry and special development of excretory tissue on one side. x 105.

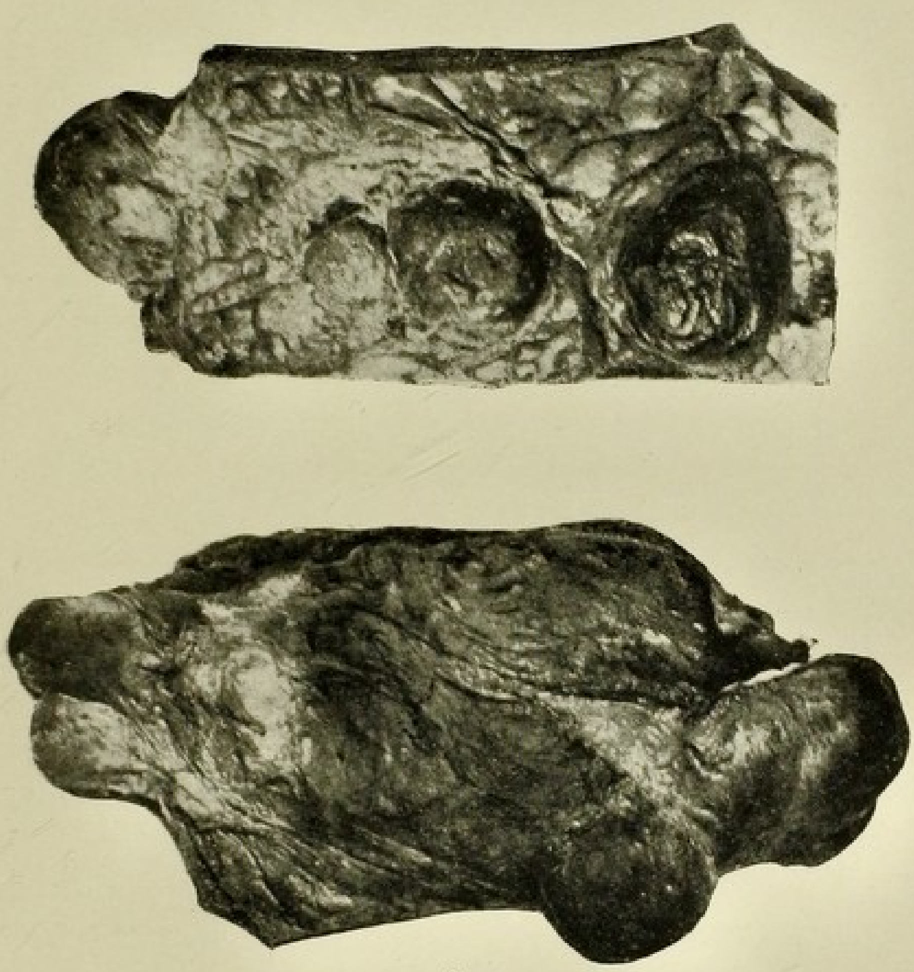
" 35. Transverse section through excretory bands carrying excretory canals towards mid-ventral line to excretory pore, as shown by dotted lines compiled from succeeding sections. x 112.

" 36. Diagram to show general relations of nervous and excretory tracts in greater portion of body.

" 37. Transverse section through male and female worms (anterior ends) and body of male. x 190.

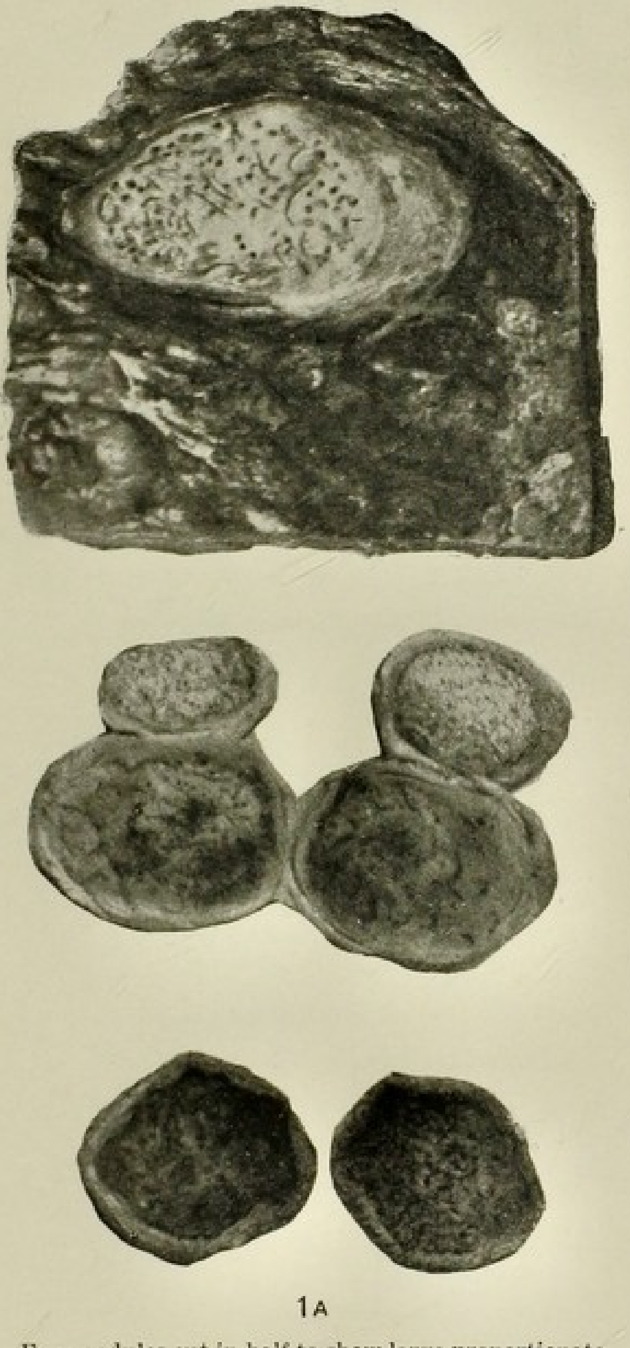
While this paper was passing through the press we have had an opportunity of consulting "Enterprise in Tropical Australia" (1846), in which the author, Mr. G. W. Earl, writes of the importation into the settlements at Melville Island and Raffles Bay of "stock from the Dutch town of Coepang, at the south-west extreme of the island of Timor" (p. 44), apparently *circiter* 1824. He also definitely records (p. 65), that in the year 1840, amongst a number of vessels which brought supplies, including cattle from neighbouring European settlements in the Indian Archipelago, "the 'Lulworth,' an English schooner on a trading voyage among the Indian Islands, . . . brought cattle, horses, and maize from Coepang" to the British settlement at Port Essington, other vessels also following later from Coepang.

June, 1911.



1

Two groups of nodules.

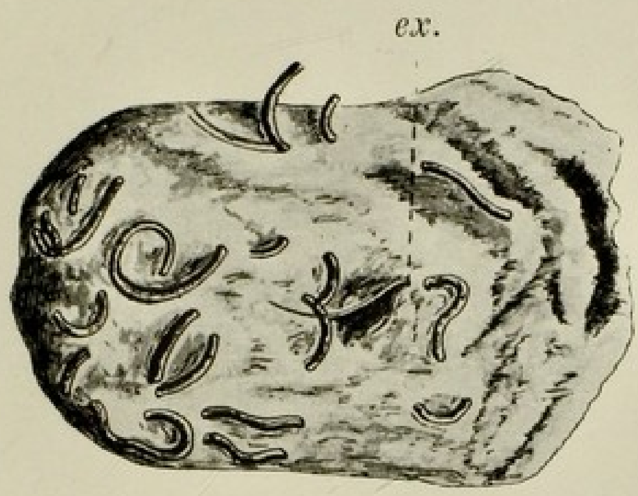


1A

Four nodules cut in half to show large proportionate worm-area and thin fibrous capsule.

2

Large nodule cut in middle, showing small area occupied by parasite (xx).



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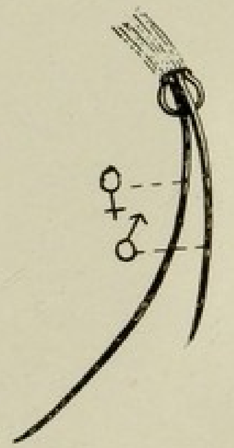

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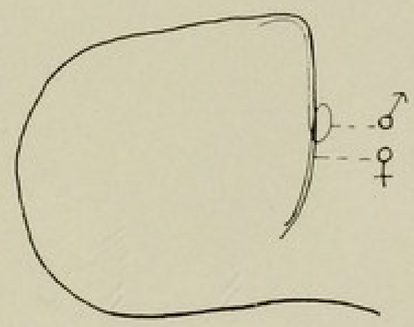
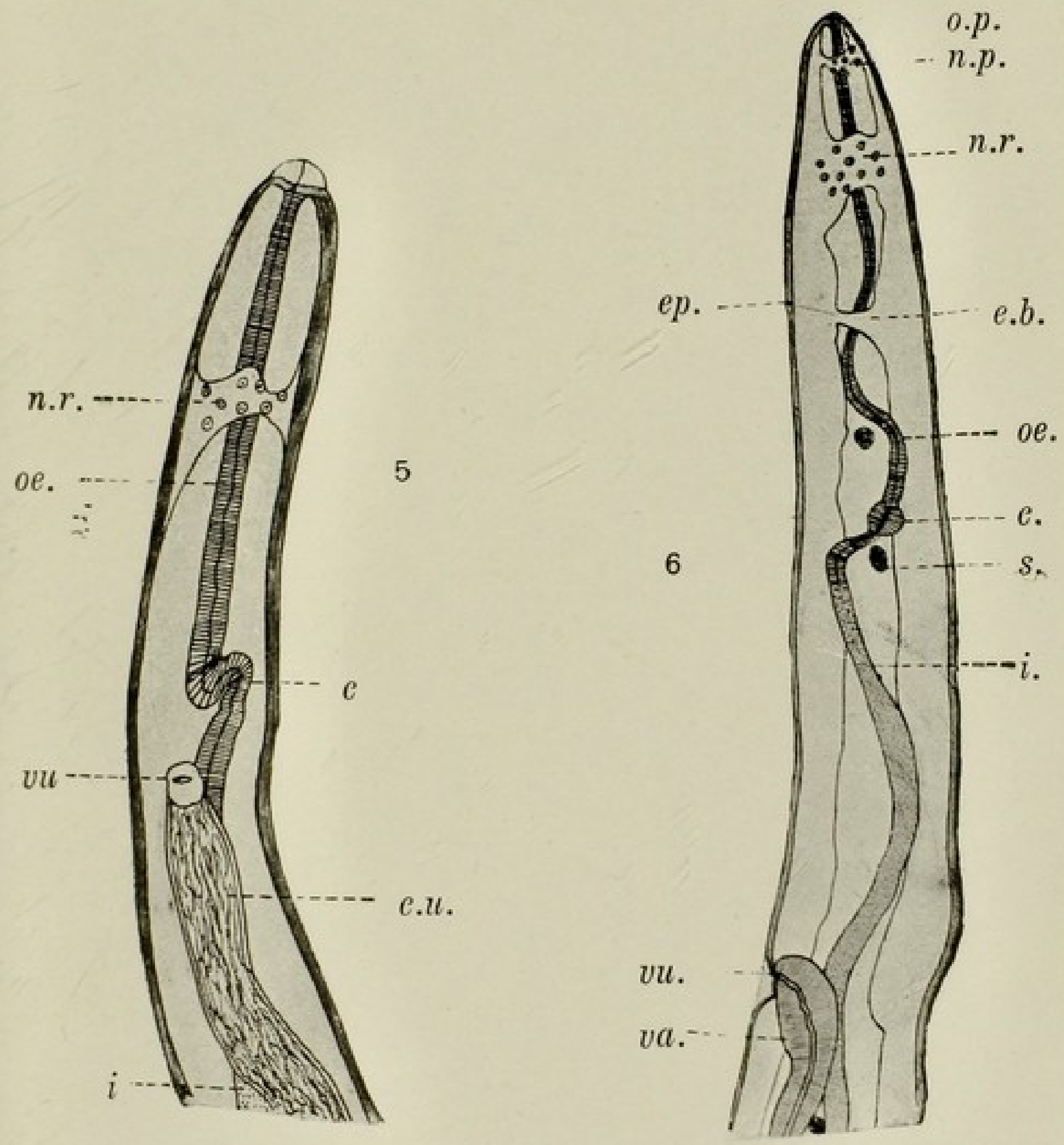
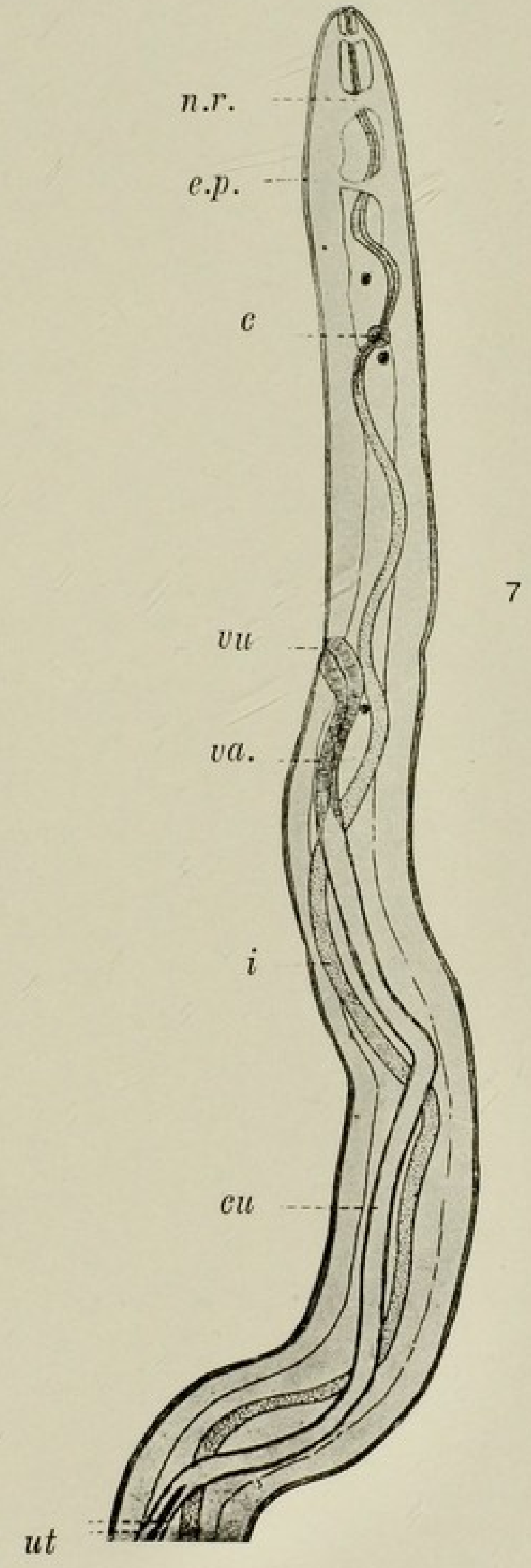


4A

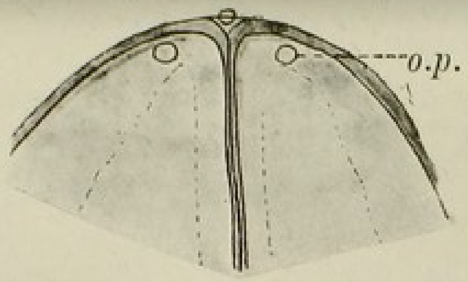
3. Nodule in which capsule wall is almost entirely dissected away, exposing the male and female heads lying together in one tunnel at *ex*.
4. The two heads magnified.
4A. Diagram illustrating relative position of male ♂, and of anterior end of female ♀.



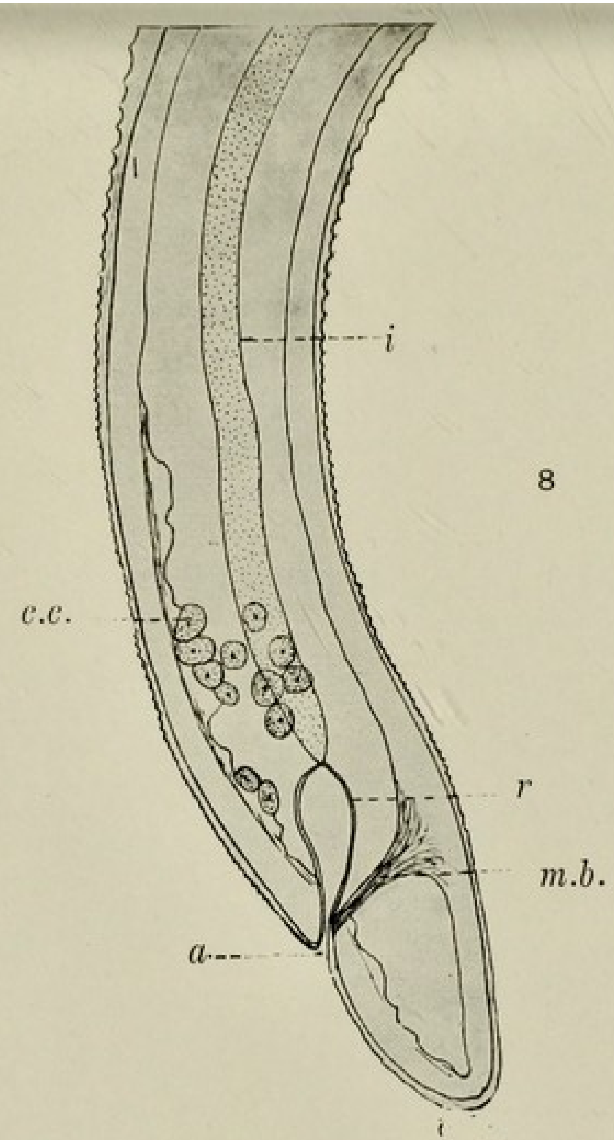
5 and 6. Views of two heads of females seen in optical section, showing variations in structure and in relative position of various parts.



Same female head as fig. 6, showing long common uterus (cu.)



7A



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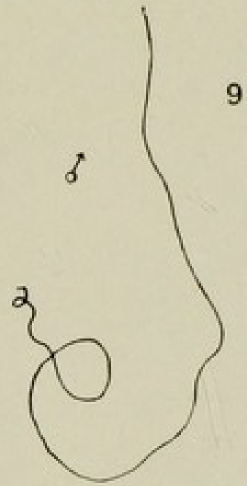
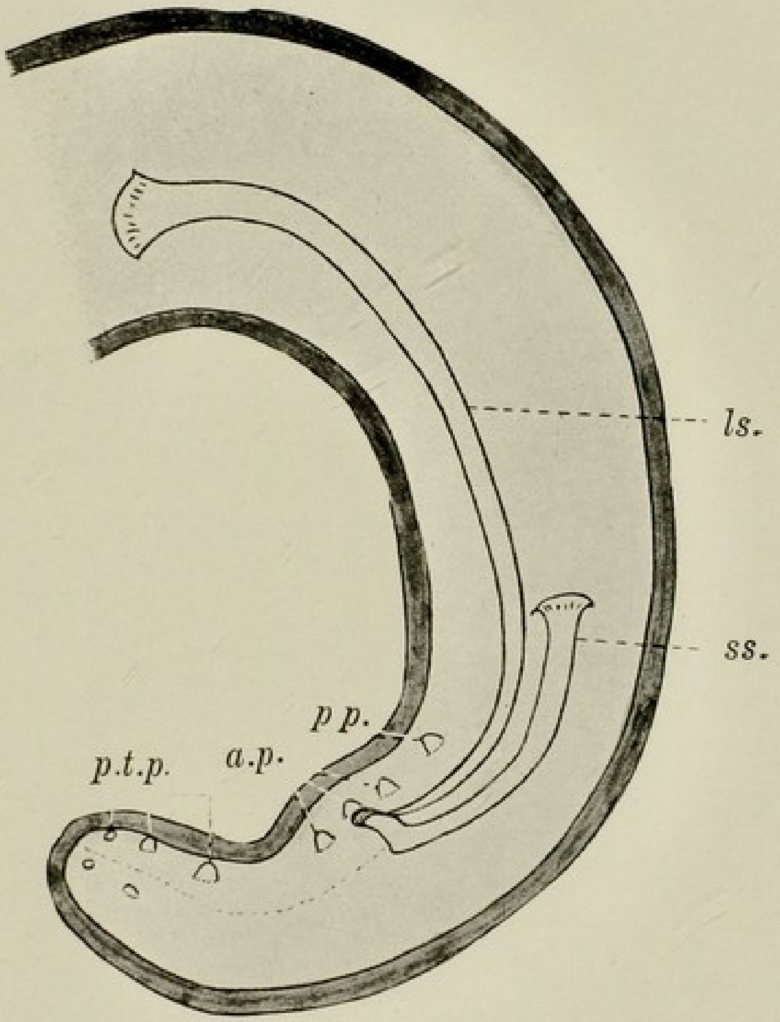


9

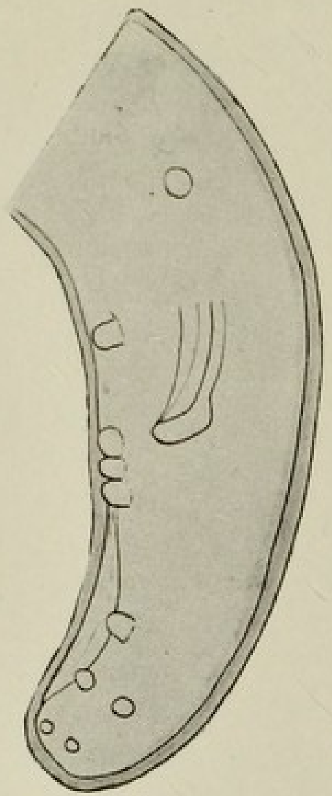
7A. Enlarged view of mouth region, showing three papillæ (much magnified). 8. Tail of female. 9. Complete male.

10

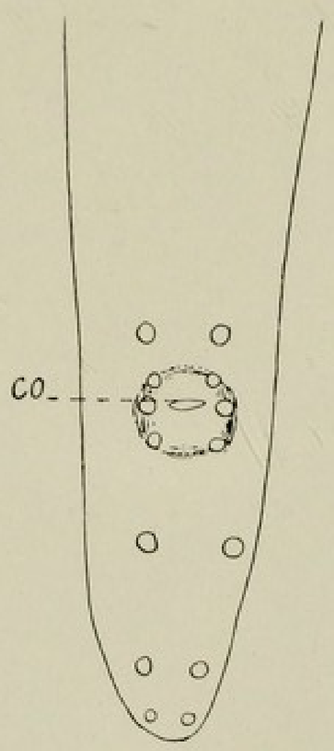


Tail of male seen in side view, showing papillæ and spicules.

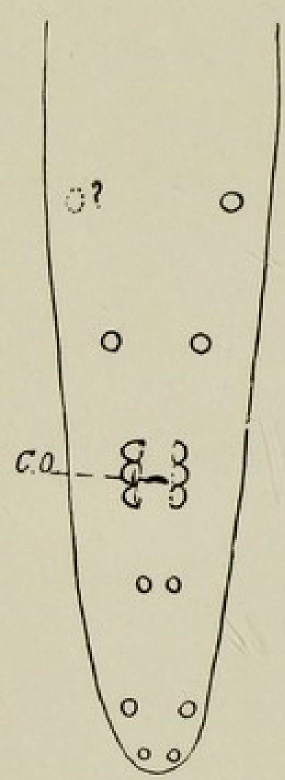
11



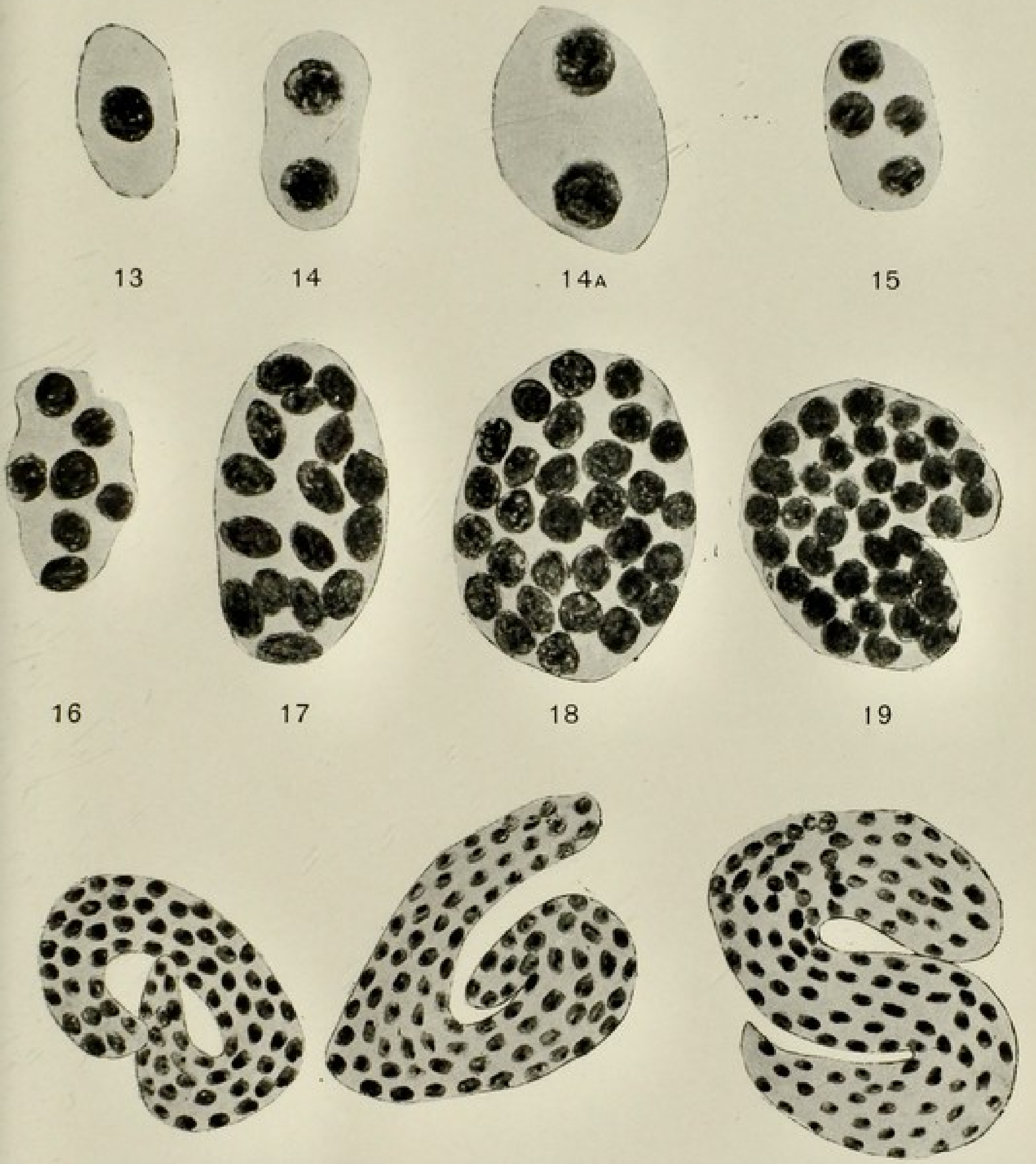
12A



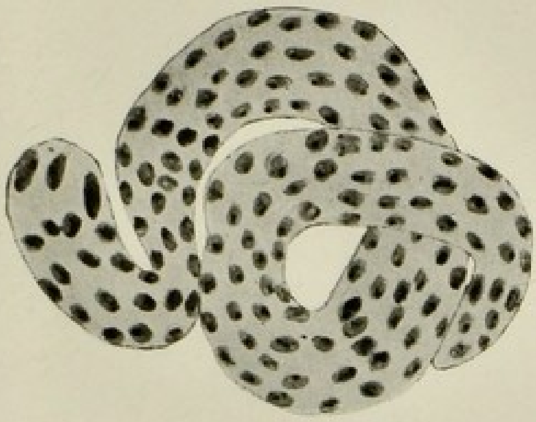
12B



11. Side view of abnormal tail of male, 12A. Ventral view of normal tail of male. 12B. Ventral view of abnormal tail of male



13-22. Consecutive stages in development of egg (13) to rudely outlined larva (22).



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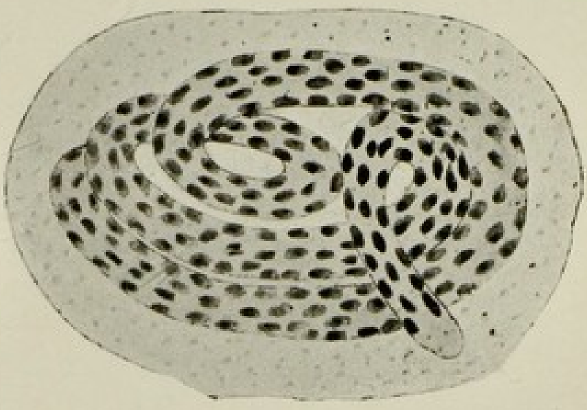

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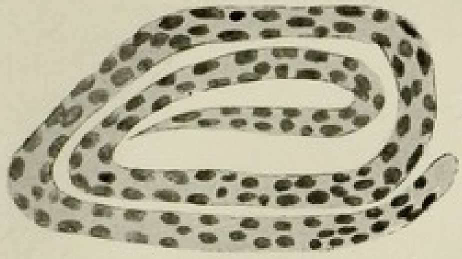

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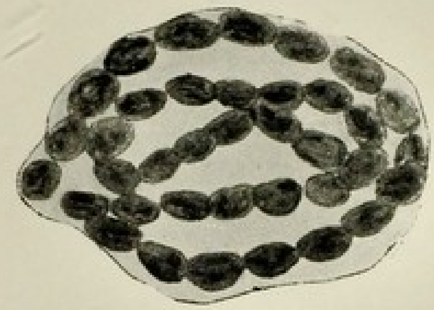

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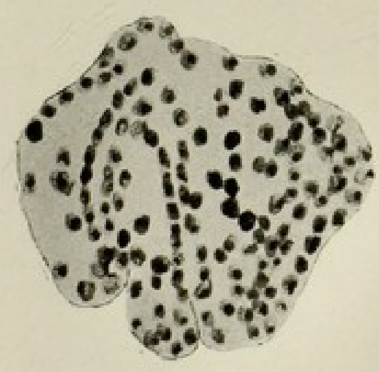
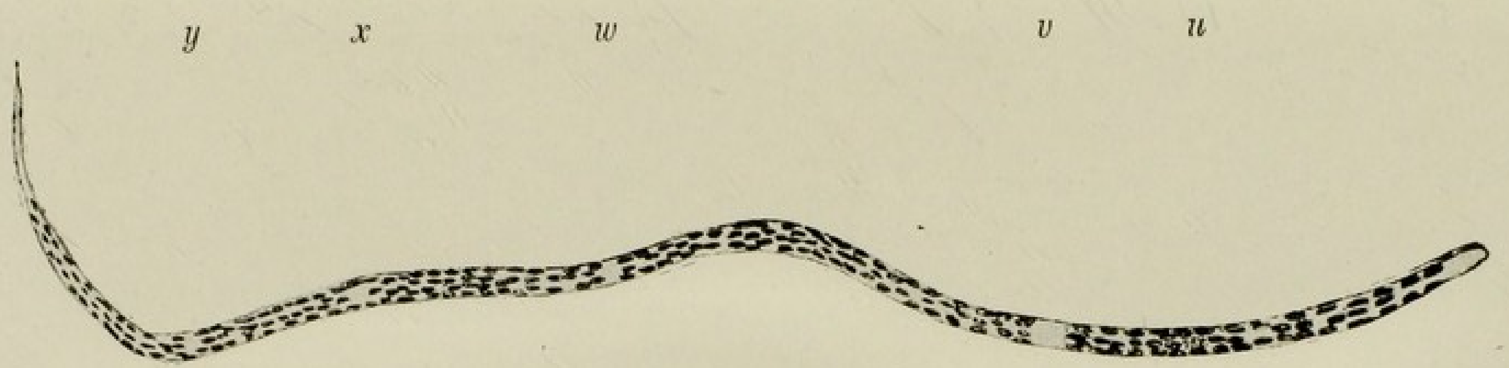


27

23-25. Subsequent stages in development of larva.

26, 27. Abnormally developed eggs.



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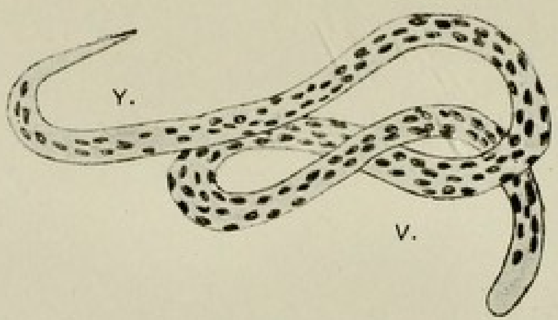
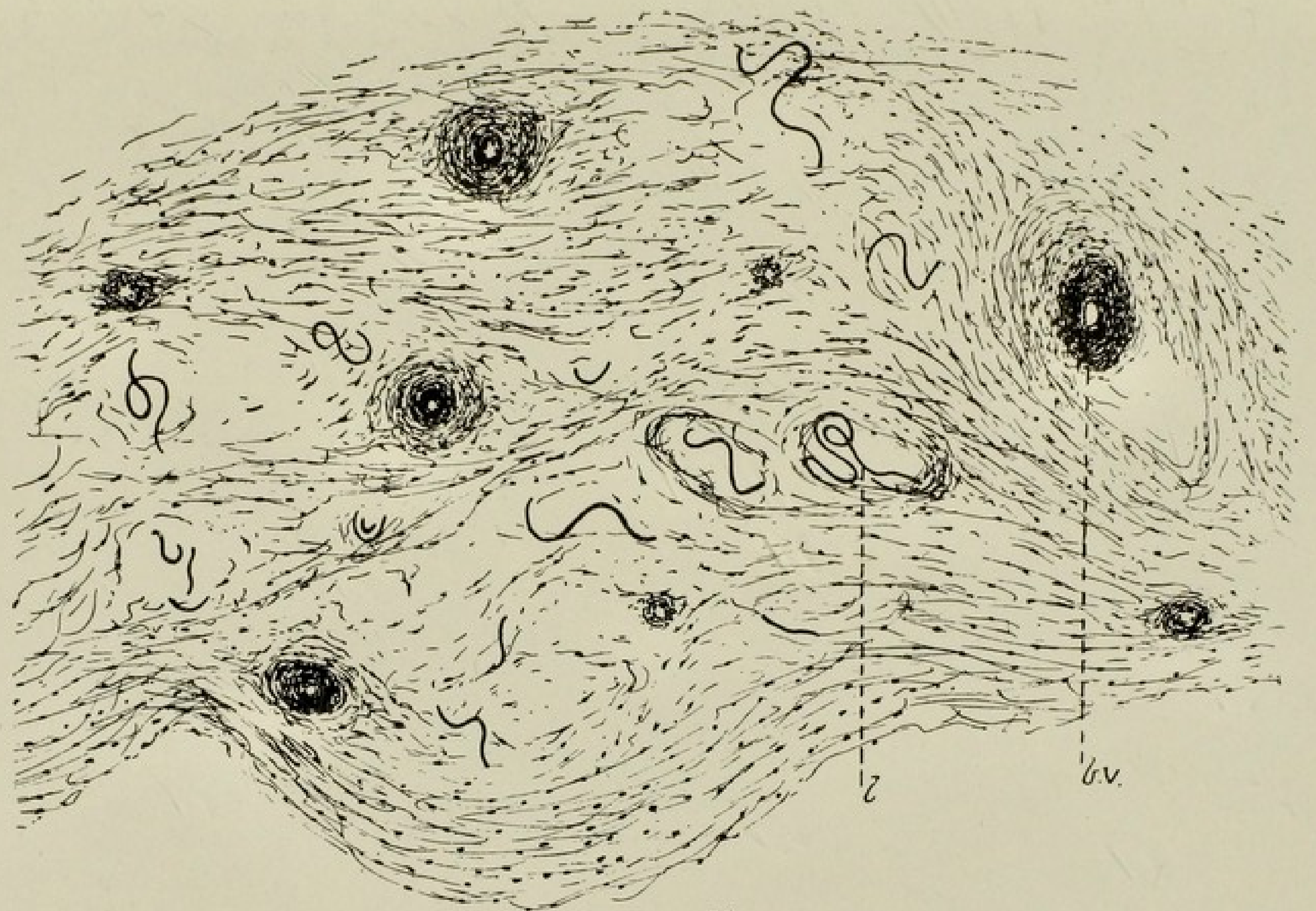


29

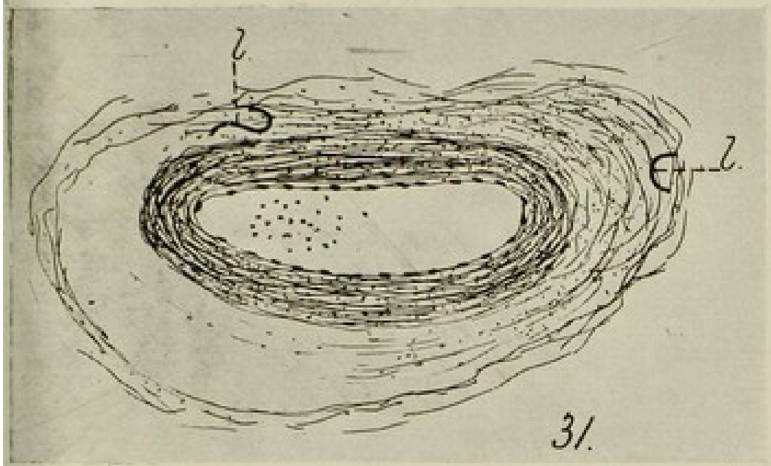
28, 29. Mature larvæ.

(28. From fluid around worm. 29. From periphery of fibrous capsule of nodule.)



30

Small portion of extreme periphery of very large nodule, with thick fibrous capsule, showing larvæ (*l*), and arterioles, with much-thickened walls.



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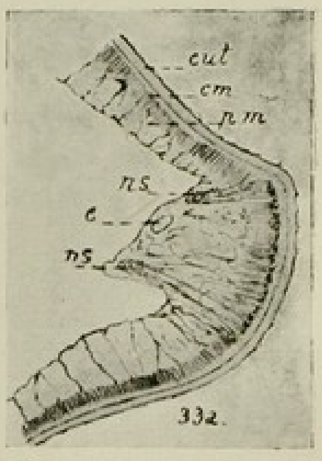
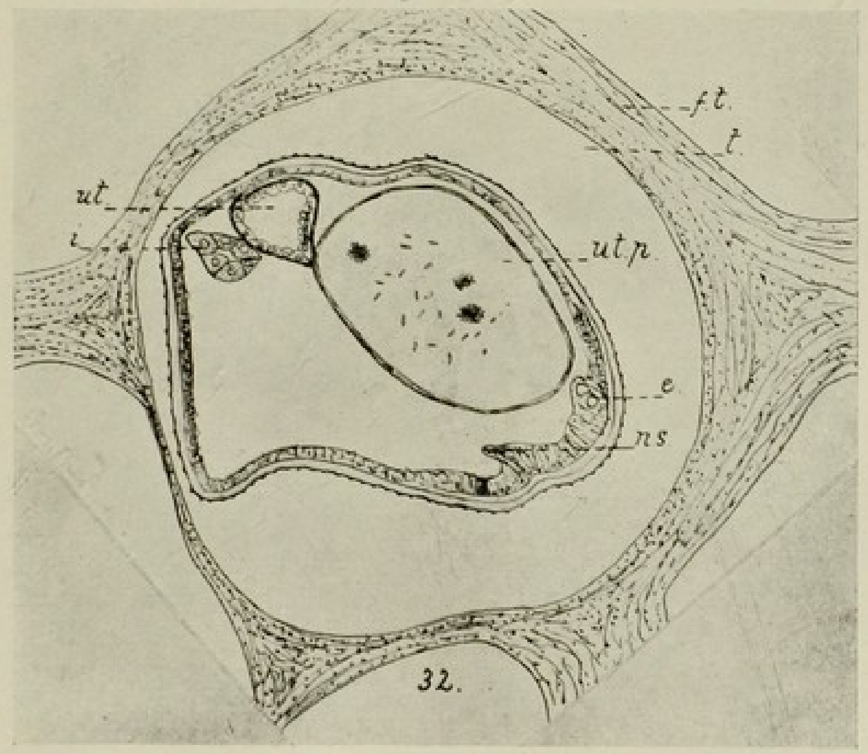


33A

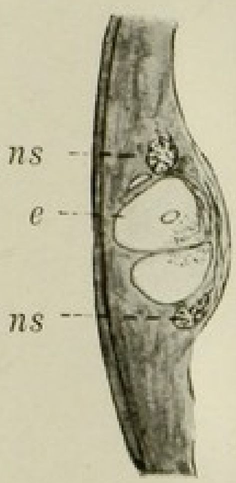


32

31. Section of artery in nodule wall, showing parts of two larvæ in wall of artery.

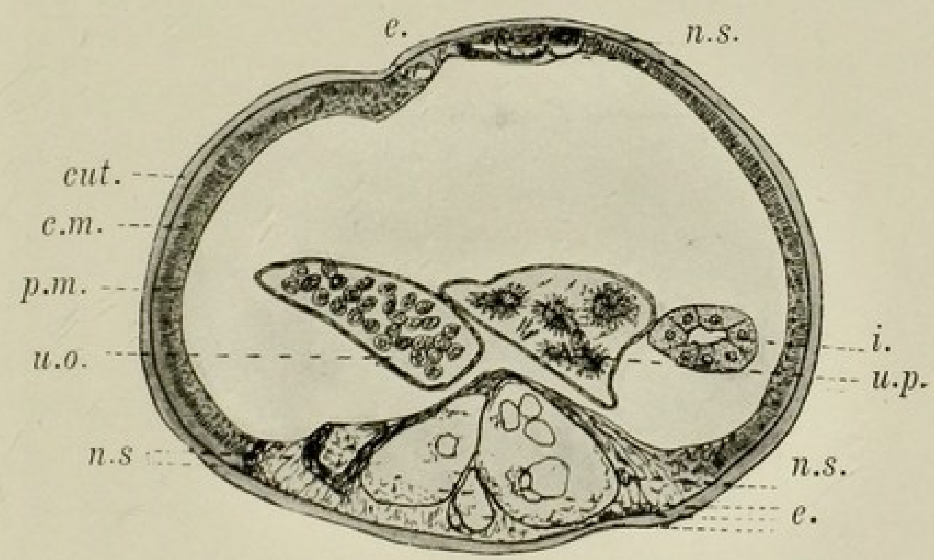
32. Section through female worm in tunnel, in middle of body—*i.* intestine; *ut.* uteri; *ut. p.* uterus with parasite.

33A. Small part of body wall, to show lateral field—with nerves and excretory canal.



33B

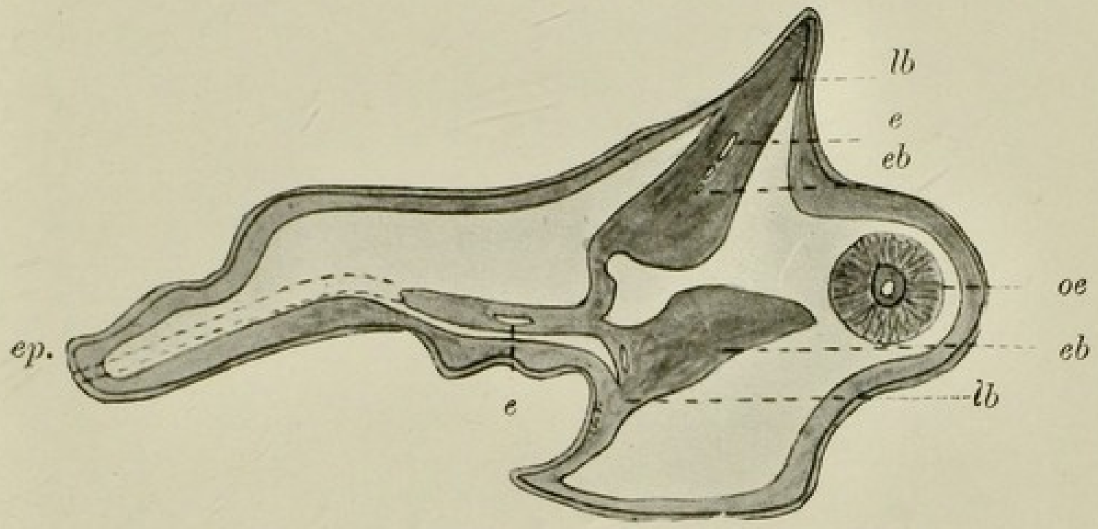
33C



34

33B, 33C. To show different character of lateral field as seen in different parts of worm—*e*, excretory tissue ; *n.s.*, nerve strands.

34. Transverse section of female worm showing asymmetrical nature of lateral fields and two uteri—one containing eggs, the other parasites.



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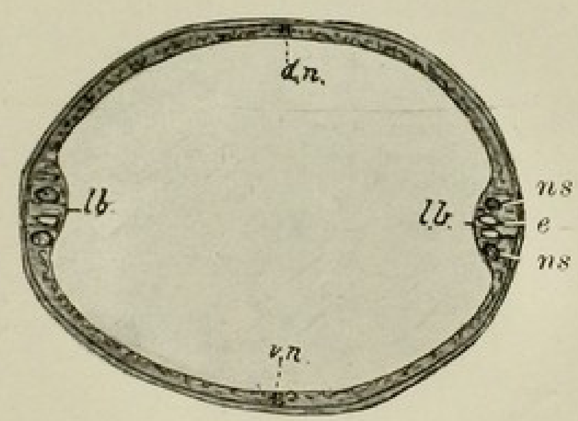
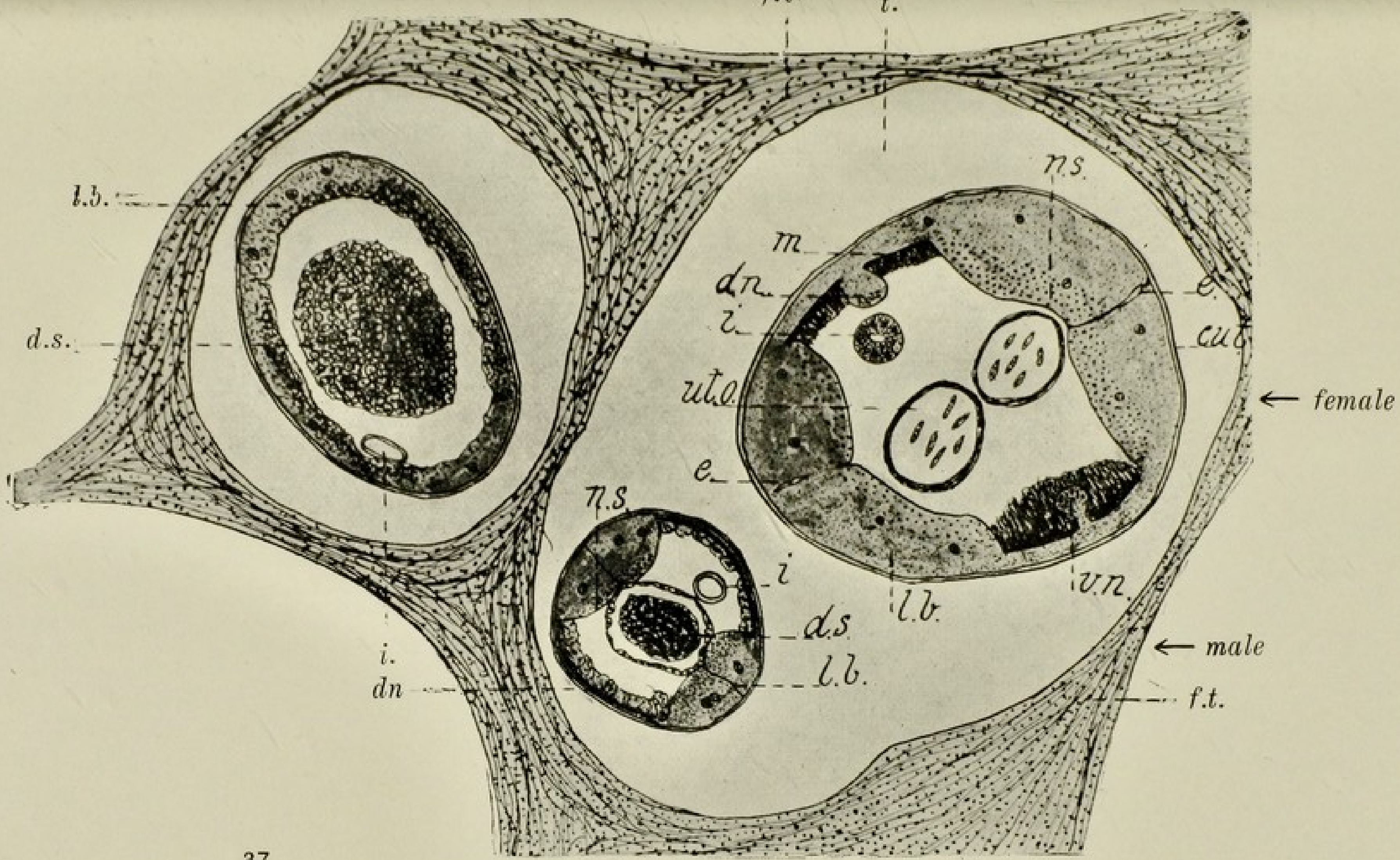


36

35. Transverse section of worm, to show privation of lateral excretory canals to form single tube opening in a subsequent section at *e.p.*
36. Diagrammatic representation of normal body wall of *O. gibsoni*, the asymmetry being greatly diminished.



37

Transverse section through two tunnels in nodule, showing male and female anterior ends in one tunnel and middle region of male in the other.

Notes on Worm Nests in Australian Cattle due to Filaria (Onchocerca Gibsoni),

AND

ON SIMILAR STRUCTURES IN CAMELS.

[*A reprint of Extracts compiled from the Report of the Government Bureau of Microbiology,* 1909–10, *and from the Journal of Proceedings of the Royal Society of New South Wales, July,* 1910.]

FOR the last thirty years, at least, fibrous nodules, containing in their centres much coiled nematode worms, have been known to be of frequent occurrence in the brisket and subcutaneous tissues of cattle from various parts of Australia. Though their presence has been often noted by various observers, a full description of the worm itself has never been published, owing to extreme difficulty in extracting it from its fibrous bed, though in 1892 and 1893 two papers appeared dealing with part of its anatomy, and with its pathological effects. Recently, we have had opportunities of examining a large number of the fresh nodules, and at last were fortunate enough to obtain those parts of the worm which are essential for descriptive purposes, with the result that the parasite appears to be one new to science.

Historical.—The first reference to the presence of these verminous tumours is one by Dr. William Morris,* before the Royal Society of New South Wales in 1880. He read notes on an encysted filaria found in the flesh of a bullock, and exhibited the cyst, portions of the mature worm, and the embryo. He mentioned the dense white fibrous tissue capsule, and noticed that the nodules may contain more than one worm. In 1892 appeared an accurate article upon the subject by the late Dr. John Gibson,† of Windsor, New South Wales. His specimens were received from Mr. Stanley, the New South Wales Government Veterinarian, at the beginning of that

* W. Morris, Proceedings Royal Society of N.S.W., xiv, 1881, p. 337.

† J. Gibson, Transactions of the Intercolonial Medical Congress of Australasia, 1892, p. 576.

year, and were labelled "Tumours from the brisket of a fat bullock, containing filaria-ova viviparous." Dr. Gibson's descriptions of the pathology of the tumours and of the embryo worms, and of those parts of the adults which he could extract, are excellent. He was unable, however, to obtain adult heads and tails. He mentions that Dr. Cobb, of the New South Wales Department of Agriculture, had undertaken the working out of this parasite, a matter which, if undertaken, was apparently never published. In the same year, Dr. T. L. Bancroft* reported finding the nodules in oxen in Brisbane and Rockhampton (Q.), and mentioned their having previously been found by Dr. Morris and the late Dr. J. Bancroft.

In the following year (1893), Dr. C. E. Barnard and Mr. A. Park, M.R.C.V.S.,† submitted a paper entitled "Notes on Spiroptera associated with Tuberculosis in Cattle." They noted the resemblance of the tumours to those caused by *Spiroptera reticulata* of the horse, and appear to have identified their parasite, as far as it could be identified from the arts of the worms they were able to extract, as that species.‡

Though these worm nests have been so well known for so many years, and have been continuously under the scrutiny of health and slaughtering authorities, who appear to have all accepted Park's diagnosis of them, no further scientific references to them appear until one of us § in 1907 recorded their presence in cattle in West Australia. In 1908–9 Mr. C. J. Pound, of Brisbane, reported having received such nodules for examination, and in the latter year one of us ‖ recorded their presence in New South Wales cattle.

The paucity of references during so many years may no doubt be interpreted as indicating that the presence of these worm nests cause little depreciation of the value of the animal or of its meat. Recently, however, the daily press has recorded that the presence of these nodules in Queensland meat in cold storage has been the subject of some concern to the authorities in London. The parasite does not appear to have attracted much attention outside of Australia, but

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* Bancroft, T. L., "Notes on some Diseases of Stock in Queensland," in report of the Chief Inspector of Stock and Brands for the year 1893, Queensland. Appendix, p. 4. Quoted by Tryon, Queensland Agric. Journal, Feb., 1910, p. 81.

† Barnard and Park, Proceedings of the Australasian Association for the Advancement of Science, v, 1893, p. 642.

‡ Tryon, in Queensland Agric. Journal, 1910, p. 81, has epitomised reports (dated August and September, 1893), letters and published writings by Park. In addition to articles in public newspapers, the latter include the following references that we have been unable to consult:—Vet. Jour. and Annals of Comp. Path., London (222), v, 37, Dec., 1895, pp. 102–7.

§ J. B. Cleland, Journ. Agric., Western Australia, xv, 1907, p. 88; reprinted in Journ. Trop. Vet. Science iv, 1909, pp. 491–8.

‖ T. H. Johnston, Proc. Linn. Soc. N. S. Wales, xxxiv, 1909, p. 412.

one of us,* when examining a number of camels imported from Karachi (in India) into Western Australia in 1907, found in several animals very similar fibrous worm nests, though in general smaller in size. These were situated in the subcutaneous tissues of the neck (where one was mistaken during life for an enlarged lymph gland), and under the tail. The identity of this parasite has not so far been possible, owing to failure to extract certain parts from the fibrous mass, so it cannot be said whether it is identical or not with that of cattle, though we believe it to be so.

The most recent publications on the subject, so far as we are aware, are one by ourselves describing shortly the parasite as a new species, *Filaria gibsoni*†; one by Mr. Henry Tryon, already mentioned, dealing with some of the literature and official papers; and another by Mr. Sydney Dodd, F.R.C.V.S.,‡ both in the Queensland Agricultural Journal of February, 1910.

Geographical distribution.—In Queensland cattle slaughtered at the Sydney abattoirs the nodules are common. Park's specimens were from cattle in the Burnett district of Queensland. Gibson quotes Stanley to the effect that at least 50 per cent. of the animals slaughtered in Sydney in or about 1892 were affected. This would include Queensland cattle, but also many bred in New South Wales. We are informed by Messrs. C. J. Vyner and W. G. Johnston, of the Veterinary Division of the Health Department of this State, that nodules can be found in cattle bred in the neighbourhood of Sydney. We have seen them from the northern rivers and western districts of New South Wales, and from the northern territory of South Australia. Barnard and Park state that the disease is unknown in Tasmanian bred animals. As mentioned above, one of us has recorded the presence of the nodules in cattle in Western Australia.

Popular names.—Amongst slaughtermen and those engaged in the meat trade, the nodules are known under such names as "stone-bruises" (from the supposition that they are due to injuries from lying on stony ground, or perhaps, from the density of the outer capsule), "white kernels" or "kernels" (as distinct from lymphatic glands), "worm-nests" and "worm knots," whilst the public are apt to view them as "cancers."

* J. B. Cleland, Trypanosomiasis, &c., in Camels, Dep. Agric., West Australia, Bulletin 34, 1909, p. 8, &c., reprinted in Journ. Trop. Vet. Science, iv, 1909, p. 316–334.

† Cleland, J. B., and Johnston, T. H.," Worm Nests in Cattle due to *Filaria gibsoni*. Preliminary Report." Agric. Gazette, New South Wales, xxi, Feb., 1910, pp. 173–4.

‡ Dodd, Sydney, "*Spiroptera reticulata* in Cattle." Queensland Agric. Journal, Feb 1910, p. 86.

Sites of the worm nests and age of infected animals.—By far the most common seat of the worm-tumours in cattle is in the subcutaneous tissues over the brisket and between the layers of its muscles. A number may be present in this situation (W. G. Johnston has counted twenty-one), scattered over the part, or several close together. Dr. Gibson also mentions their occurrence on the rump, and very rare instances in which they have been so numerous and so widely distributed over the body that the carcass has had to be condemned. Nodules have been noted just above the hock-joint, on the stifle joint, and on the outer muscle of the thigh (silverside). (Barnard and Park refer to their "abscesses" being found in the throat and neck and in the intestines, but, as our criticism elsewhere suggests, we believe many of these to have been due to tuberculosis pure and simple.) Sydney Dodd states that the nodules may be found in the connective tissue of any part of the body, even in very deep-seated situations. In the camel, as stated, we found them in the subcutaneous tissues of the neck and under the tail.

The presence of nodules is more common in old cattle. Gibson states it is rare to find them in animals under 4 years of age, and in the Hereford breed of cattle. Barnard and Park did not find any in beasts under 2 years of age, from which they believe that the parasite takes a year or more to develop. We have examined three small nodules from a young calf, aged 6 to 7 months, which came from the northern rivers of New South Wales.

Macroscopic appearance.—In living cattle, when the nodules are large or directly under the skin, they may actually be visible as rounded projections in the neighbourhood of the brisket or other parts, and especially so if on the limbs. In one of the camels, a worm nest was distinctly visible in the neck as a swelling the size of a walnut.

On examining the carcasses of slaughtered cattle hanging up in an abattoir, the larger worm nests at once attract attention as tense, firm, rounded projections embedded in the subcutaneous tissues, or in the superficial layers of muscle, having thin and stretched tissues over them. The brisket seems to be by far the commonest situation for these tumours; and those more deeply embedded, or of small size which are not visible to the eye during such inspection, may be at once felt by running the hand over the surface with moderate pressure, when they feel like marbles in the underlying tissues. An incision into the healthy structures stretched over them at once enables the nodule to be enucleated with more or less ease. When thus removed, they are of a pale yellowish tint, like fibrous tissue, and vary in size from that of a small marble to tumours 2 inches or more in diameter. They vary in shape from more or less spherical in small growths to flattened ovals in the largest, and are often of irregular contour, showing bosses and projections. The flattening and the irregularities of surface are probably all due to the resistance of the surrounding tissues, with consequent extension of the growth along the lines of least resistance.

On section of each nodule and towards its centre will be found the worm, or worms, in an intricately coiled mass, embedded in a comparatively loose but resistant fibrous stroma, with a varying quantity of serous or sero-sanguinolent fluid. This fibrous tissue is tunnelled by canals occupied by the parasite. The central worm mass proper varies very little in size in comparison with that of the whole worm-tumour; that found in the largest mass is little if at all larger than that found in a growth the size of a marble. This area occupied by the worm itself is completely enclosed in a delicate fibrous capsule, which can be shelled entirely out of the dense fibrous tissue forming the external coverings, leaving in the latter a cavity with slightly irregular walls. The outer covering consists of layers of very dense whitish fibrous tissue, much firmer than that between the coils of the worm itself, and varying greatly in thickness according to the size of the whole tumour. In small growths the layer is thin, but in those of one or more inches in diameter it is exceptionally hard and thick, and may form bosses and irregularities quite apart from the shape of the worm in its inner capsule.

Microscopical appearances.—Sections of the outer fibrous walls show that it consists of dense fibrous tissue containing a variable number of blood vessels and cells varying in number in different parts. In some places are scattered leucocytes, with numerous eosinophile granules. These may be dispersed singly or form columns between the fibrous tissue, or be collected into considerable masses in a little fibrous stroma. Such cells constitute by far the majority of those met with in sections of the wall, ordinary polymorphonuclear leucocites with few or no granules not being noticed. In addition to these cells are varying numbers of connective tissue cells, and also in the fibrous stroma itself branching cells with basophile granules—the mast cells of the tissues.

Degeneration, Injuries, &c.—Occasionally, in the outer layers of the fibrous capsule, a considerable amount of dark venous extravasated blood is found, apparently the result of direct injuries received during the last days of the animal's life, to which the prominence of the tumours renders them specially liable. This blood rarely extends beyond the outer layers of the capsule. In instances where the injury is older, the nests become yellowish and degenerated, probably from cutting off of the blood supply.

A remarkable instance of a foreign body embedded in a tumour was found in one case whilst cutting sections. Buried about half-way through the outer capsule was found a small fragment of woody or at least vegetable tissue, showing portion of a vascular bundle; and, leading obliquely to this from the outside, was a track, in the centre of which was a bullock's hair (its identification was unmistakable). Apparently a foreign body, probably a stake, had penetrated the hide and wall of the nest, had carried in with it a hair or hairs from the surface, and had left behind it on withdrawal these latter, as well as a fragment of its point. In the cavity occupied by these foreign bodies were a few embryos and eggs, showing that the central worm mass had been itself injured.

We have seen a few instances in which the worm has apparently died and become in part calcified, as evidenced by gritty matter, effervescing with acid, which was collected in small masses resembling the coils of the worm. In other cases, where the worm had died, the parasite was soft and becoming yellowish, and the surrounding tissue was also degenerated.

We have not seen any appearances other than the above-mentioned simple calcification, which at all resemble the lesions of tuberculosis or actinomycosis, and, further, we have not found tubercle bacilli in such degenerated worm nests.

In Tryon's reference to Gibson's paper is the remark that this author found tuberculosis associated with worm nests. This is evidently an oversight, as no reference to such an association occurs in the original account. Sydney Dodd's communication, already referred to, supports our contentions as to the harmlessness (from a public health aspect) of the condition, the rarity of caseation or calcification, and the absence of any connection with tuberculosis.

The Parasite.—For the purpose of examining the anatomy of the worm in detail, the dense outer fibrous capsule was removed, and the complete worm mass enclosed in its innermost thin capsule was shelled out. This inner capsule was then opened by means of small incisions, and, in some cases, its contents were carefully teased out at once, whilst in other instances the aids of early putrefactive processes and of pancreatic digestion were used to loosen the connective tissue surrounding the coils of the worm, and enable larger portions of the parasite to be extracted undamaged.

An examination of all the fragments removed in this way from individual worm nests revealed the fact that in many instances apparently only one female worm was present in each, that more rarely both a male and a female were present together, and that sometimes portions of at least two female worms were found. It must be borne in mind, however, that occasionally we entirely failed to extract either end of an individual (owing to the extreme difficulty in removing from its fibrous bed every portion of the worm), from which it will be obvious that the instances in which evidence of the presence of a single worm was alone obtained may really be less numerous than at first sight they appeared to be.

A brief description* of the worm has already appeared, but we deem it advisable to give a more detailed account of it here.

General Description.—The body is greatly elongated and closely coiled. As we have stated above, it is very difficult to extricate the filaria, and consequently its length is not accurately known. We have measured all the fragments obtained by teasing out a nodule, from which only one head (a female) was obtained, and found that the total length was 970 mm. Probably the male would be much shorter, as is usual in the filaridæ. The greater part of the body in both sexes is uniform in diameter, that of the female being from 0·38 mm. to 0·43 mm., whilst that of the male is only about 0·15 mm.

The whole of the cuticle, especially in the female, is ornamented with a very regular series of ridges, which travel round the body in a spiral fashion. There are really two series of spirals, as each ridge may be traced to the next but one. This structure appears to be the same as that figured by Railliet,† as occurring in *Filaria* (*Spiroptera*) *reticulata*,

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* Cleland and Johnston: "Worm Nests in Cattle due to *Filaria gibsoni*. Preliminary Report." *Agricultural Gazette*, N.S.W., xxi, 1909, pp. 173–4.

† Railliet, Traité d. Zool. Agric et Medic, Ed. II, 1895, p. 539.

Dies. Each ridge is made up of a series of projections and depressions. Throughout the greater portion of the worm these ridges are very distinct, but anteriorly in both the male and female, especially the former, they become gradually less prominent, and eventually indistinguishable. For instance, though very small, they may still be seen in the region of the vulva. The following measurements taken from a female worm show the progressive divergence of the spirals:—Just behind the vulva they are very low and numerous, there being about 140 rings in 0·5 mm. This number decreases rapidly until there are 15, then 14, and so on, until the usual number is from 6 to 8 in the same distance. In the case of the male there are about 100 rings in 0·5 mm. The ridges here are very small and closely set. The transverse striations figured by Railliet have not been seen by us in the species under review. The cuticle, however, is very finely longitudinally striated. All cuticular ornamentation appears to be absent from the tail and head end of the male. In his second report Parks stated that the specific name *reticulata*, which he gave the parasite, did not imply that it was the same species as found in the horse. The name was given from the reticulate appearance of the tissue. (Quotation from a lay newspaper.)

The head end of the female is wider and more rounded than that of the male. At a distance of 0·65 mm. from the anterior extremity of the former—*i.e.*, just in front of the vulva—the breadth is 0·16 mm., whilst the diameter measured at the same distance in the case of the male is only about half of this, being 0·085 mm. Park* stated that he obtained from the pus of a "tumour," by washing, a head which (he said) agreed in all particulars as regards size and shape with the rest of the parasitic worm; but until more than one was obtained he could not be certain that it did belong to that worm. This head was stated to have "teeth-like projections and briar-like barbs encircling in a spiral manner in numerous rows. . . ." We cannot find anything resembling Park's description. If his observation be correct, then the head cannot belong to this worm. Unfortunately, we have not succeeded, as yet, in finding the tail-end of a female, though we have obtained many male tail ends. These taper gradually and end in a fine rounded extremity, the posterior end being somewhat loosely spirally coiled.

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* Barnard and Park, *loc. cit.*, p. 644.

The mouth is small, rounded, and terminal, and appears to be surrounded, in the female, by three slight projecting lips. In the male, however, there was no trace of labial structures. The œsophagus is long, its lumen being very narrow. It extends backwards to the region of the vulva, where it forms a small pyriform structure, rounded at the anterior end, and whose transverse diameter is only slightly greater than that of the gullet. This appears to represent a cardia, an organ which is stated to be rare in species of filaria. The intestine passes back as a fairly wide tube. Its course may be straight, sinuous, or at times looped. The anus in the male is situated at about 0·072 mm. from the posterior extremity. The excretory system was not recognised. The nerve ring is a well-defined structure surrounding the œsophagus at about 0·18 mm. from the anterior end. The dermis of the body wall is relatively thick when compared with the muscle cells.

Special characters of the Male.—The male worm, as mentioned above, is much thinner than the female, and has a more delicate cuticular ornamentation. There is no depression of the body surface corresponding to that in the region of the vulva in the female. There are two unequal spicules. The larger is arcuate, with a twisted stem and a sharp pointed extremity. The proximal end is enlarged, as is usually the case. The length is about 0·197 mm. The second spicule is 0·082 mm. long, its distal termination being swollen and rounded. The cloaca is situated on a median prominence about ·65 mm. from the end of the parasite. On each side of it are four blunt prominent papillæ, which are thus peri-anal, 0·65 mm. from the end of the parasite. There is a pair just near the caudal extremity, and at about midway between these and the hindmost of the peri-anal there is situated another pair. There is thus a total of six pairs. At the caudal extremity is a slight rounded bilobed structure, which perhaps represents still another pair of papillæ. The arrangement of the papillæ is very much like that figured by Parsons* for *Filaria volvulus.* The gonad is double.

Special characters of the Female.—The vulva is situated in a shallow depression at about ·8 mm. from the anterior end. Vaginal glands are present. The vagina is short, and leads back into the large common uterine tube. The proximal part of the uterus may be considerably distended by the mass of contained embryos. The main tube is a wide organ (0·07 mm. diameter), passing back for about 2·2 mm., where it

* A. C. Parsons, *Filaria volvulus*, &c., Parasitology, I, 1908, p. 366..

bifurcates, each half being crowded with embryos. In some of the fragments they contain eggs, usually with a vermiform embryo within each, whilst in other fragments parts of the paired ovaries may be seen.

In our preliminary communication we stated that the worms were ovoviviparous and viviparous; but, as a result of having examined more material, we think that normally they are viviparous. As mentioned above, the uterus is crowded in its lower parts with free embryos, whilst further back eggs containing worm embryos are mingled with the free embryos. We have seen the young worms escaping through the vulva. In two instances, however, we saw embryo containing eggs in the vaginal region.

If a fresh "worm nest" be cut across, and a smear be made from the cut surface, eggs and embryos in various stages of development will be met with. Apparently the ova after fertilisation develop very rapidly, the embryos being stored up in great numbers until a favourable opportunity for their liberation arises.

The fully-developed embryo may be seen closely coiled up in its thin rounded or elliptical shell of about 0·03 by 0 045 mm. dimensions. Later the little worm becomes free in the uterine cavity, the shell, perhaps, becoming absorbed, as we have not noticed any empty egg cases.

Its length now varies from 0·22 mm. to 0·27 mm., being usually about 0·25 mm., the breadth being 0·0033 to 0·004 mm. The anterior end is blunt and almost straight, the tail being rather short but very thin and pointed. The œsophagus could be traced back for a short distance. The anus appears to be situated at about 0·021 mm. from the posterior end. The nerve ring is located relatively far back, being 0·07 mm. from the anterior end. The cuticle is very finely ringed, a few being indicated in the figure. Barnard and Park* drew attention to these very delicate structures, and devised an ingenious method of using them to obtain the total length of the adult. They found that there were at least 400 transverse striæ on the embryo, and on the supposition that these markings must necessarily become separated to form the striæ of the adult, they argued that the multiplying of the distance between any two embryonic striæ by 400 should give a rough estimate of the average length of the worm, viz., 36 inches. This agrees fairly well with our estimation of the length, especially when one takes into consideration

* Barnard and Park, *loc. cit.*, pp. 644–5.

the fact that the striæ of the embryo are very small and closely placed, and, therefore, hard to accurately measure. Any slight error must therefore become considerably accentuated when multiplied by 400. Our examination indicates that there must be many more than 400 rings in an adult worm, and this fact, together with the crowding together of those near the head end, at once discounts this method of estimating the total length. Barnard and Park* give the length of the embryo as being about one-hundredth of an inch. Gibson's† measurements are 0·004 mm. wide by 0·25 mm. long. The embryos are capable of active movement in water for hours after their extraction from the nodule.

Filaria Nodules in Camels.—We have examined some similar filarial nodules obtained by one of us from two dromedary camels imported into West Australia from India. Owing to the fact that they had all been preserved in formalin, we had greater difficulty in making a thorough examination of the worms. The anterior end and body fragments show the same characters andmea surements as those from the ox. The vulva is similarly placed. The ornamentation is alike, and the embryos are similar in regard to the head and tail ends and the annulations. We did not find any male specimens, and, consequently, cannot absolutely identify the filaria from the camel as being specifically the same as that from the ox, though we have little doubt as to their identity since they agree in all points of comparison in regard to the female worms, and in the subcutaneous habitat of the nematodes.

Comparison with other Camel Filariæ.—The finding of this parasite in camels raises the question of its identity with *Filaria evansi*, Lewis. Apart trom the differences in location of the parasites in their hosts, Lewis‡ mentions that the adults of *F. evansi* were found in tangled masses plugging the pulmonary arteries, and were also present in the mesentery. We cannot find in the meagre descriptions of the adults of *F. evansi* which are available to us any references to a cuticular ornamentation comparable to that of our parasite or *F. reticulata*, features so striking as to at once arrest attention.

Portions of an adult male filaria, presumably *F. evansi*, were taken from a bronchial tube of one of the West Australian camels. On examination, it was seen that though it possessed

* Barnard and Park, *loc. cit.*, pp. 644–5.

† Gibson, *loc. cit.*, p. 579.

‡ T. R. Lewis, Proc. Asiatic Soc. of Bengal, March, 1882, p. 63. Quoted in Journ. Trop Vet. Science, vol. ii, No. 1, 1907, p. 151.

fairly prominent annulations, yet it lacked the distinctive structures above referred to, and, moreover, the relations of the various parts at the head end were unlike in the two parasites. It was at first thought that this worm might be *Strongylus filaria*, Rud, a nematode which has frequently been found in camels in India, but this was not the case. We have also compared the embryos from the camel nodules with those taken by one of us from the blood of various camels in the same part of West Australia. These embryos* of *F. evansi* are of about the same length (0·23 mm.), but are much broader (0·006 mm.). In addition, the tail is relatively larger, and has a rounded end, whereas in the embryos of the ox parasite it is very finely pointed. Then again, the relations of the nerve ring and anus are different. Fine annulations are present in both.

E. and E. Sergent (1) mention that in Algeria a filarial embryo occurs commonly in the blood of camels, which show subcutaneous abscesses, the latter being possibly due to the death and disintegration of the parent worms. The size of the embryos is given as 0·25 mm. long by 0·008–0·01 mm. in width, with an obtuse anterior extremity, and a moderately tapering tail. Thus these do not agree with our parasite. F. E. Mason (2) met with similar embryos in an Egyptian camel also affected with abscesses, but failed to find any adult worms in these, though he succeeded in finding filariæ allied to *F. equina*, Abildg. (Syn. *F. papillosa*, Rud), in the blood-vessels of the male genitalia.

Comparison with certain Bovine and other Filariæ.—T. A. Ford (3) called attention to the presence of "aortic worms," producing tumours in Malayan buffaloes. These parasites (*Filariidæ*) were much more fully described, though not named, by G. L. Tuck (4), who also noted a somewhat similar condition produced by another worm (also belonging to the *Filariidæ*) in bullocks (Indian and Siamese). Both of these nematodes are quite distinct from the species now described by us. *Filaria gibsoni* is also quite distinct from *F. labiato-papillosa Alessandr* (Syn. *F. cervina*, Dies.), which occurs in

* It may be worth noting here that specimens of embryos of *Filaria evansi* were taken in one instance from a camel only a month old (West Australia.) This is almost certainly an instance of placental transmission.

(1) Ed. and Et. Sergent, C.R. Soc. Biol., lviii, 1905, p. 672, quoted in abstract in Journ. Trop. Vet. Science, ii, 1907, p. 150.

(2) F. E. Mason, Journ. Compar. Pathol. of Therapeutics, xix, 1906, p. 118, quoted in abstract in Journ. Trop. Vet. Sci., ii, 1907, pp. 149–50.

(3) T. A. Ford, Veterinary Record, 14th June, 1903, quoted by Tuck (22).

(4) Gnoh Lean Tuck, Studies from Institute of Medical Research, Malaya, reprinted in Journ. Trop. Vet. Sci., ii, 1907, pp. 69–100.

the peritoneal cavity and adjacent connective tissue of cattle and various deer (*Cervidæ*) (5). This last does not possess the cuticular ridges of *F. gibsoni*, and has a different arrangement of papillæ, being closely allied to *F. equina* of the horse.

It is now time that we should compare *F. gibsoni* with *Spiroptera reticulala*, Dies., or, as it should be called, *Filaria reticulata*, on account of the position of the vulva and of other filarial characters. This species was first described by Diesing in 1841, and made the type of a new genus, *Onchocerca*, Dies. The generic characters (freely translated) as given by him (6) are as follows:—Body filiform; male loosely spiral; female twisted into a close spiral; head continuous with the body; mouth terminal, orbicular; caudal extremity of the male, excavated below, and provided with two vertical lobes, the base of each of which possesses a great number of small hooks and a papilla on the upper margin of each lobe; filiform penis between the lobes; female attenuated and genital aperture situated anteriorly, &c. The type species, *O. reticulata*, Dies., is designated thus:—Body of female superficially delicately reticulo-annulate; male, length 1·5 cm., diameter 0·125 mm.; female, length 1·5 cm., diameter 0·25 mm. The host given is the horse. *Filaria reticulata*, Creplin, 1846, is given as a synonym. Dujardin (7), Schneider (8), and von Linstow (9), do not mention the species. Neumann (10), Davaine (11), Railliet (12), and Law (13), give an almost literal translation of Diesing's description, but add *Spiroptera cincinnata*, Ercolani (*S. cincinnati* in Law), to his list of synonyms. The various authors state that the parasite is peculiar to equines.

From the above it appeared that all the helminthologists who had touched on the parasite and whose works were available to us had accepted Diesing's statements regarding the structure of the male worm. Accordingly we had no option but to separate our worm from *F. reticulata*. Since the publication of our preliminary note, in which we, like Barnard and Park, drew attention to the marked similarity of the adult worms (especially the females), we have had

(5) *Raillet, l.c.*, p. 526.
(6) Diesing, 1841, quoted in his Systema Helminthum, i, 1851, p. 287.
(7) Dujardin, Hist. Nat. des Helm. ou Vers intestinaux, 1845.
(8) Schneider, Monographie der Nematoden, 1866.
(9) von Linstow, Compendium der Helminthologie, 1878, and Supplement, 1888.
(10) Neumann, Parasites (2nd English edition), 1905, pp. 552–4.
(11) Davaine, *Traite des Entozodires*, Paris, p. 103, 1877.
(12) Railliet, *l.c.*, p. 538.
(13) Law, Veterinary Medicine, v, 1903, pp. 439–440.

access to Pader's (14) paper on "Filariose du Ligament suspenseur du boulet chez le cheval," published in a journal which was not previously available in Australia. He dealt with the anatomy and histology of *F. reticulata*, and gave an account of the earlier references to the finding of this nematode. In his description he shows that the male of *F. reticulata*, like other *Filariidæ*, possesses two unequal spicules instead of one as described by Diesing, but these are considerably longer than those of *F. gibsoni*. Besides this, the arrangement and size of the papillæ, as given by Pader, are quite different from those of the male of our worm.

C. W. Stiles (15), in discussing the zoological characters of the genus *Filaria*, (Müller), points out that the type species *F. martis* (Gamelin) has a cuticle which possesses neither bosses nor striations. Hence, if the large genus *Filaria* be split up (as has been done) into various subgenera, now generally regarded as genera, the members of the subgenus (or genus, *sensu stricto*) *Filaria*, should possess a similar cuticle to *F. martis*, *F. reticulata F. volvulus*, and *F. gibsonia* could not accordingly be included. Diesing's generic name (*Onchocerca*) with *F. reticulata* as type is still available, but his generic diagnosis, in view of Pader's work, would need to be corrected in that the males possess two unequal spicules. *F. gibsoni* and *F. volvulus*, Leuckt, would come under the genus amended as suggested. The name of the worm with which this paper is concerned would thus become *Onchocerca gibsoni*.

It may not be out of place to recall the resemblance between the subcutaneous tumours produced in human beings by *O. volvulus* to those caused by *O. reticulata* in horses (16), and especially to those produced by *O. gibsoni* in cattle, and also to the worm tumours in camels. Besides this, the three parasites are very closely allied. The cuticular ornamentation is similar in all of them. Some excellent figures of *O. volvulus* are given by Fülleborn (17), and reproduced in an article on human filariæ by Fülleborn and Rodenwaldt (18). The arrangement of the peri-anal and post-anal papillæ is seen to be different from *O. gibsoni*. Parsons* has recently shown that the number and position of the papillæ are different to

(14) J. Pader *Arch. d. Parasitologie, iv*, 1901, pp. 58–95.

(15) Stiles, C. W. Bull. 34, Hyg. Lab. Public Health, Mar. Hospital Service, U.S.A., 1907, pp. 32–36.

(16) Pader, *l.c.*, p. 80.

(17) Fulleborn, F., *Beiheft* 7, zum. *Arch. F. Schiffsu. Tropenhygiene*, xii, 1908, p. 15, &c.

(18) Fulleborn, F., and Rodenwaldt, E., "Failarien" in Real-Encyclopadie der gesamten Heilkunde, Aufl. 4, p. 81, &c.

* Parsons, *l.c.*, pp. 364, 366.

those given by Fülleborn, and very closely resemble those found in *O. gibsoni*. The shape of the spicules in these parasites is very similar.

Our specimens were prepared according to the method advocated by Looss and Leiper.* Type slides have been donated to the Australian Museum, Sydney, co-types being retained by the Bureau of Microbiology, Sydney.

Means of Transmission of the Disease.—By analogy with *Filaria bancrofti*, Cobbold (*F. nocturna*, Manson), of man, an intermediate host might be expected to be the agent of transmission from animal to animal. Such a host would most likely be a species of mosquito, perhaps a biting fly, or possibly a tick, all being animals which pierce the skin and suck blood. Since the tumours are, in most instances, well below the surface of the skin, and their capsules are thick, it would further be necessary for the embryos, set free from the mother, to escape into and be present in the general circulation. As the embryos would be extruded from the vagina of the parent into the serous or sero-sanguinolent fluid present in the innermost sac, they would require to pass out from this by way of the lymphatics, or through the small vessels after piercing them. Gibson describes finding the embryos, both in the capsule of the worm nests and in the trabecular network, the majority being in lymphatic spaces, though occasional ones were found in the interior of blood vessels. Though, as this author has pointed out, the fibrous capsule and trabeculæ are well supplied with blood-vessels, we have not noticed any large and definite vascular trunks escaping from the nodules. This abundant blood supply is therefore probably obtained by small vessels piercing the capsule at many different points, and by these and by the lymphatic connections the embryos could enter the systemic circulation. Gibson failed to find the embryos in the general blood stream, but adds that his observations were very imperfect. Barnard and Park refer, in an addendum to their paper, to finding "young spiroptera in some of the blood-vessels," but do not state whether those of the general circulation, or of the wall of the worm nodule. We, ourselves, in sections of the growths, have seen the embryos free in the fibrous stroma surrounding the coils of the parasite, and also in the layers of the outer capsule nearest to the centre, but have not detected them towards the periphery. So far, we have not found any in the lumina of small blood-vessels, those present,

* Leiper, Wellcome Research Labs., Khartoum, Third Report, 1909, p. 187.

which were usually straight, or sometimes slightly coiled, lying in the fibrous stroma, presumably in lymphatic channels. Smears, made by shaving off layers of the outer capsule, have shown occasional embryos before the central worm-mass was reached. We have examined, with negative results, the following series of thick blood films, stained after removal of the hæmoglobin by distilled water. These films were all taken at night (6 p.m. to 2 a.m.) in case of nocturnal periodicity of the embryos.

1. From ear of bullock.—Worm nest on breast about sixth rib. (Supposed to come from Northern Territory of South Australia.)
2. From ear of bullock.—Worm nests on both breasts about fifth rib.
3. From foot of bullock.—Two large worm nests, one on each breast about fifth rib. (Upper Hunter River, New South Wales.)
4. From foot of bullock.—Worm nest buried in flesh at point of brisket and fourth rib. (Queensland bred.)
5. From ear of bullock.—Worm nests on each brisket from second to eighth rib. (Queensland bred.)
6. From foot of bullock.—Worm nest embedded in flesh of brisket about second rib. (New South Wales.)
7. From foot of bullock.—Worm nests on brisket. (Queensland.)
8. From foot of bullock.—Large worm nests on each brisket, about fourth rib. (Upper Hunter River, New South Wales.)
9. From ear of bullock.—Worm nests on brisket. (Upper Hunter River, New South Wales.)
10. From ear of bullock.—Worm nests on both briskets, sixth and eighth ribs. (Queensland.)

Twelve similar films from infected cattle taken from the aortic blood during the day time (6 a.m. to 3 p.m.) were also negative.

It may be that the embryos can only escape in numbers into the circulation before the fibrous capsule has become much thickened, and hence would be found in this situation in only an occasional animal. It is obvious that, if certain diptera are the intermediate hosts, embryos must, at one time or another, be fairly numerous in the peripheral blood of certain animals at least if the frequency of the infection is to be accounted for. Our results, however, do not support this hypothesis.

On the other hand, quite another analogy presents itself in connection with the guinea-worm (*F. medinensis*, Velsch) of man. This worm, after working its way through the tissues, eventually reaches a dependent situation such as the leg, where, after piercing the skin, it finally extrudes its embryos, which escape into a fluid medium. A species of Cyclops, or other freshwater crustacean, probably then serves as an intermediate host, and later the developing parasite enters the human system in drinking water. Several points suggest that a similar life-cycle may occur in this cattle Filaria. One is that the worm nests are almost always found in the subcutaneous tissues (we have a specimen in which the dermis itself is considerably thinned by the presence of the developing nodule), and especially in those over the brisket, a part of the body which would come in fairly close contact with the ground, or a fluid medium, when the animal was lying down or wallowing in water or mud. Another is that the screw-like external bands round the body of the worm are eminently suited for aiding its progress through the tissues of the host, the animal actually boring its way along. Such an architecture, indicating, we believe, the necessity for translation of the animal in the host's body, would be an extravagant waste in the case of a filaria which merely had to extrude embryos into the circulating blood, and to whom practically all the fibrous tissues, internal and external, should be equally advantageous for its development.

This second theory is beset with a grave difficulty, however, which consists in the dense fibrous capsule which surrounds the worm, especially in the older nodules, and which is evidently a reactive process on the part of the tissues of the host to the irritative presence of the parent worm or of its struggling embryos. It can hardly be imagined that the adult form can escape from such a prison to wander to the surface and extrude its embryos. We are not at all certain, however, that this imprisonment in a thick capsule is the normal fate of the filaria. We think that it is quite possible that, on their way to the surface, and especially when the sexes are in conjugation, a certain number, perhaps many, of the adult worms, as the result of the irritation to the tissues that their progress through them produces, are arrested and finally surrounded by a fibrous capsule, which becomes thicker as time advances, but which still leaves the worm and its embryos alive in the centre.* Those females, on

* Manson ("Tropical Diseases," 3rd edit., 1903, p. 624) refers to the premature death in man of *F. medinensis*, with the formation of abscesses of calcified cords, conditions somewhat analogous to worm nests of *F. gibsoni*.

the other hand, which escaped this fate, would reach the surface, pierce the epidermis, and liberate their embryos without perhaps doing any noticeable damage to the hide or attracting the attention of the slaughterman. An intermediate stage of the life history would then probably occur in some fresh-water animal, and the re-introduction of the parasite take place through drinking water containing these. So far we have not succeeded in finding the embryo alive after being in water for a few days.

Escape of the embryos from the nodules through the agency of ingestion by a carnivorous animal can practically be excluded. Dingoes (*Canis dingo*) are the only animals in Australia that could play this röle, and they could only do so by eating the nodules from a bovine that had died by accident in the bush, a comparatively rare event. Further, Dr. Gibson fed a young pup on minced worm-nests and bread for fifteen weeks. On killing the animal twenty-four hours after eating its last meal of this nature, he found no nematode embryos in the blood, and no living embryos in the stomach or intestines, though numbers of partly digested ones were found in the stomach and duodenum.

Barnard and Park's suggestion of direct transmission of the parasite we consider highly improbable. If such be the case, one would expect that animals harbouring a worm nest would later develop an enormous brood of young nodules. One of our colleagues, Mr. G. P. Darnell-Smith, B.Sc., has, however, inoculated a number of living embryos into the subcutaneous tissues of a calf 6 months old, and into a rabbit. As the former was only inoculated recently, no results can yet be expected. The rabbit was operated on four months ago, but so far there have been no developments.

Fulleborn† and Rodenwaldt,‡ in dealing with *O. volvulus*, mention that the embryos (which are similar in appearance to those of *O. gibsoni*) have not yet been found in the blood, though Brumpt§ found them in the peripheral parts of the tumours, and thinks that they can reach the lymphatics and finally the general circulation, and that consequently the transmitting agent might be a biting insect (*Tabanus*, *Glossina*, *Simulium*). He believes that transmission of *O. reticulata* occurs in the same way. As stated above, we have not succeeded in finding embryos of *O. gibsoni* in the blood of cattle.

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† Fulleborn, *l.c.*, p. 15.
‡ Fulleborn and Rodenwaldt, *l.c.*, p. 83.
§ Brumpt, quoted by Fulleborn, *l.c.*, pp. 15–17.

Parsons* mentioned that, in the case of *F. volvulus*, the parasite lives in a local dilatation of a lymphatic, and that the embryos probably pass from these into the general circulation, but that no observer had yet detected the microfilariæ in the blood. By analogy, he considered the transmitting agent to be some blood-sucking insect.

The economic aspect.—The fibrous nodules, as usually found, do not affect in any way the health of the beast. If Barnard and Park's statements of the frequency of abscesses of tubercular nature being superadded to the worm nests in cattle from the Burnett District of Queensland be correct, however, then consequent conditions of ill-health would supervene. We are disinclined to agree with them, as already stated, and believe they were dealing with two quite separate conditions, independent of each other, in the same animal.

As regards meat inspection, everything points to the harmlessness of their presence. During the preparation of the carcass by the slaughterman, the nodules are removed by a little snick with a knife over the stretched tissues, when the worm nest can be shelled out more or less easily. By running his hand firmly over the brisket, the meat inspector detects any further small nodules hidden from view, and removes them. The flesh of many thousands of cattle which have been thus treated has been eaten by the inhabitants of Australian cities. Even were the worm nests not so removed (and occasionally some do escape notice), no harm would follow. They would first of all probably be noticed either by the butcher or by the housewife; even if they escaped these two, and the carver at table, and were eaten unnoticed, no ill-results could be in any way expected. The worm itself is very small, and in its capsule, and, surrounded by fibrous tissue, is only about as large as a kidney bean. Dr. Gibson's experiment on a young pup fed on worm nest for fifteen weeks, at first alone, and later with bread added, show, it is true, that the animal at first became rapidly thin and emaciated, but it soon regained its good condition and remained well when the bread was added to the diet consisting only of worm nodules. This shows that, even if eaten raw, the worms are devoid apparently of toxic effects. Where the worm nodules are very numerous, as Dr. Gibson points out, the unsightliness of the carcass after their removal may lead to its condemnation.

* Parsons, *l.c.*, pp. 366-7.

Source of the Parasite.—Considering that the mammals of Australia are all marsupials, with the exception of *Canis dingo*, a few rodents, bats, and sea animals such as whales, seals, &c., and that there are no indigenous bovines, it seems reasonable to suppose that these parasitic worms were introduced along with bovines or allied ungulates at one time or another. The alternative view is that the worm's natural host is one of the indigenous animals mentioned above, and that its occurrence in cattle is more or less accidental. This would presuppose that the filaria in question could develop to a great extent, if not entirely, in a new host, removed by a large phylogenetic interval from its normal host, a condition unlikely to occur in such specialised parasites.* Further, in no indigenous Australian animal has any parasite been so far encountered resembling the one in question. The first hypothesis, therefore, seems by far the most rational to adopt, and may be stated as follows:—*Onchocerca gibsoni* is an introduction from outside of Australia, having accompanied its true host with the importation of the latter. This true host is either some variety of domestic cattle, or the buffalo now so prevalent in parts of Northern Australia, or, possibly, a more distantly-related ruminant, such as the camel or some other ungulate, such as the horse. It further follows that these parasites almost certainly do still exist in their original hosts in the country from which these came, and will be found there on systematic search.

It may be of value to review here the sources from which Australian cattle, buffaloes, and camels have been derived, so as to ascertain where to search for the home of the parasite.

Apart from the importation into Australia on numerous occasions of cattle, sheep, horses, &c., from Great Britain, an examination of works dealing with the early history of these colonies indicates several other sources. For instance, in October, 1787, when Governor Phillip and the First Fleet touched at the Cape of Good Hope on their way to Australia,† they took on board two bulls, six cows, forty-four sheep, and four goats, together with horses and hogs. For the greater part of a century after this date, doubtless many other vessels calling at the Cape similarly brought away some

* A notable exception in Australia to this rule is seen in the case of *Distomum hepaticum*, Abildg. This common parasite of cattle and sheep has been found on several occasions in the bile ducts of herbivorous marsupials, such as kangaroos and wallabies (*Macropus spp.*).

† History of New South Wales from the Records. By G. B. Barton. Vol. I, p. 72.

live stock. Cunningham* states that the horned cattle in New South Wales amounted to 21,513 in 1813, and to 68,149 in 1821, and were "derived from the Bengal buffalo variety, with smooth skins, short snail horns, and humpy shoulders, and from the various English breeds that have been at different times imported."

The Public Library authorities of Sydney have a MS. agreement between Captain Bremer and the Timor Government (1825) for the former to export cattle to Fort Dundas, a military and convict settlement founded on Melville Island, off the coast of the Northern Territory of South Australia. Acting on this authority, buffaloes were imported in or before the year 1826, but whether other bovines accompanied them or not does not appear. When Major Campbell,† on 19th September, 1826, relieved Captain Barlow at this post, he found that sixteen buffaloes for slaughter had just been landed from Timor. Later, in 1827–1829, the settlement was removed to Raffles Bay, on the mainland, and the animals were transported thither. In 1846, the buffaloes in Northern Australia had increased to a great extent, and Leichhardt‡ saw herds of buffaloes, and the whole country "as closely covered with buffalo tracks as a well-stocked run in New South Wales could be with bullock tracks." If the spoor of an animal with a divided hoof, seen by Sir George Grey§ in the north-west of Australia in 1837 and 1838, be really that of a buffalo, as he suggested, this may indicate that by means of Malay prows, or in some other way, these animals had been introduced into another part of Australia some years before the settlement at Fort Dundas, though they may have wandered from the latter place (which is about 1,000 miles away) in that time.

Camels seem to have been first introduced into Australia by Sir Thomas Elder‖ in 1866, when 124 were shipped from Kurrachee, in India, 121 of which were landed at Port Augusta, in South Australia. From this date various other shipments have been made from time to time from India,¶ the last

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* Two years in New South Wales. By P. Cunningham, surgeon, R.N., 1827. 2nd edit., Vol. I, p. 269.

† Campbell, "Memoirs of Melville Island and Port Essington." Communicated to Roy. Geographical Soc., Lond., 1834.

‡ Extract from Leichhardt's Diary, 1846, in South Australian Register of 26th December, 1862.

§ Journals of Two Expeditions of Discovery in North-west and Western Australia, 1837–9, by George Grey, Esq. Vol. I, 1841, p. 242.

‖ Journey across the Western Interior of Australia, by Col. Peter Egerton Warburton, 1875. Introduction by Charles H. Eden, p. 118.

¶ Haji, S. G., The Australian Camel Trade, and Trypanosomiases H. Trop. Vet. Sci., V, 1910, p. 72–88.

being the arrival in the north-west of Australia of 500 camels in 1907 from the same port as the first shipment. As it was in these latter animals that we found worm nests, it may be supposed that amongst those arriving in 1866 some also contained these parasites. Camels are now common throughout the drier parts of Australia.

To summarise, it will be seen that cattle have been introduced to Australia from Great Britain and South Africa; that buffaloes were brought from Timor at least; and that camels came from India. Horses seem to have been derived from European breeds and Arab stallions.

Worm nests in cattle appear to be unknown in Great Britain, and, with such complete examinations as have been made, can hardly have escaped notice if present in South Africa. It, therefore, follows that if the natural host of the parasite is one of the breeds of common domestic cattle, the worm nests may be present to-day in Indian cattle; whilst if the buffalo is that host, then those of Timor and allied parts should contain them. As already stated, our own observations show that *Onchocerca gibsoni*, or a closely allied worm, exists to-day in Indian camels, a fact which (judging from a reference in a recent Indian report by A. S. Leese, I.C.V.D.,* to the finding of them, under the term "Spiroptera nodules," by one of us in Western Australia) has not so far been recorded there.

We are greatly indebted to Mr. C. J. Vyner, M.R.C.V.S., Chief Veterinary Inspector to the Department of Public Health, Sydney, for his kindness in supplying us with ample material for our investigations and with valuable information as to the condition, and also to three members of his staff, viz., Messrs. Everett and Vidler, for obtaining blood films for us, and especially Mr. W. G. Johnson, for furnishing many important data and specimens.

Addendum :—While this paper was in the press, one of us received from Professor A. Railliet of Alfort, France, amongst a number of reprints, a paper dealing with "Les Onchocerques, &c.," by Railliet and Henry (*C.R. Soc. Biol. Paris*, lxviii, 1910, p. 248–251). In this note the authors cover some of the ground that we do in the above paper. They re-establish Diesing's genus *Onchocerca* with *O. reticulata*, Dies., from the foot of the horse as type, making a new species *O. cervicalis* for the parasite infesting the cervical ligaments of the same

* Report of the Veterinary Officer investigating Camel Diseases for the year ending 31st March, 1909.

animal. *Filaria volvulus*, Leuckt., is also brought into this genus. A fragment of a female nematode taken from a worm nest from the subcutaneous tissues of the head of a dromedary in the Punjab, by A. S. Leese, is described as belonging to a new species, *O. fasciata*. The only information given concerning it is that the breadth is from 403 to 475μ, and that the cuticle possesses feebly undulating ridges repeated at every three or four striæ. We have compared the *Onchocerca* (females) taken from the West Australian dromedaries, with that from local cattle, and notice that in the former the ridges are closer, lower, and less pronounced than in the latter. Besides this, transverse striæ are present. The diameter of the female body in most of the segments examined was about the same in each case, namely, from 180 to 400μ, more usually approximating the latter figure. We are able then to record the finding of at least two species of *Onchocerca* in Australia, viz., *O. gibsoni* in cattle, and *O. fasciata* in camels.

During the past few days we have received the "Annual Report of the Veterinary Officer investigating Camel Diseases for the year ending 31 March, 1910," by A. S. Leese, who, on page 13, mentions the finding of *O. fasciata* fairly commonly, coiled up in nodules in the subcutaneous tissues. He goes on to say that the parasite does not cause any perceptible harm to its host. We might add that the first reference to the presence of this nematode (at that time unidentified) appears to have been made in 1909 by one of us, who found them in 1907 in dromedaries recently imported into West Australia from India (Cleland, Bull. 34, Dept. Agric., West Australia, 1909, p. 8).

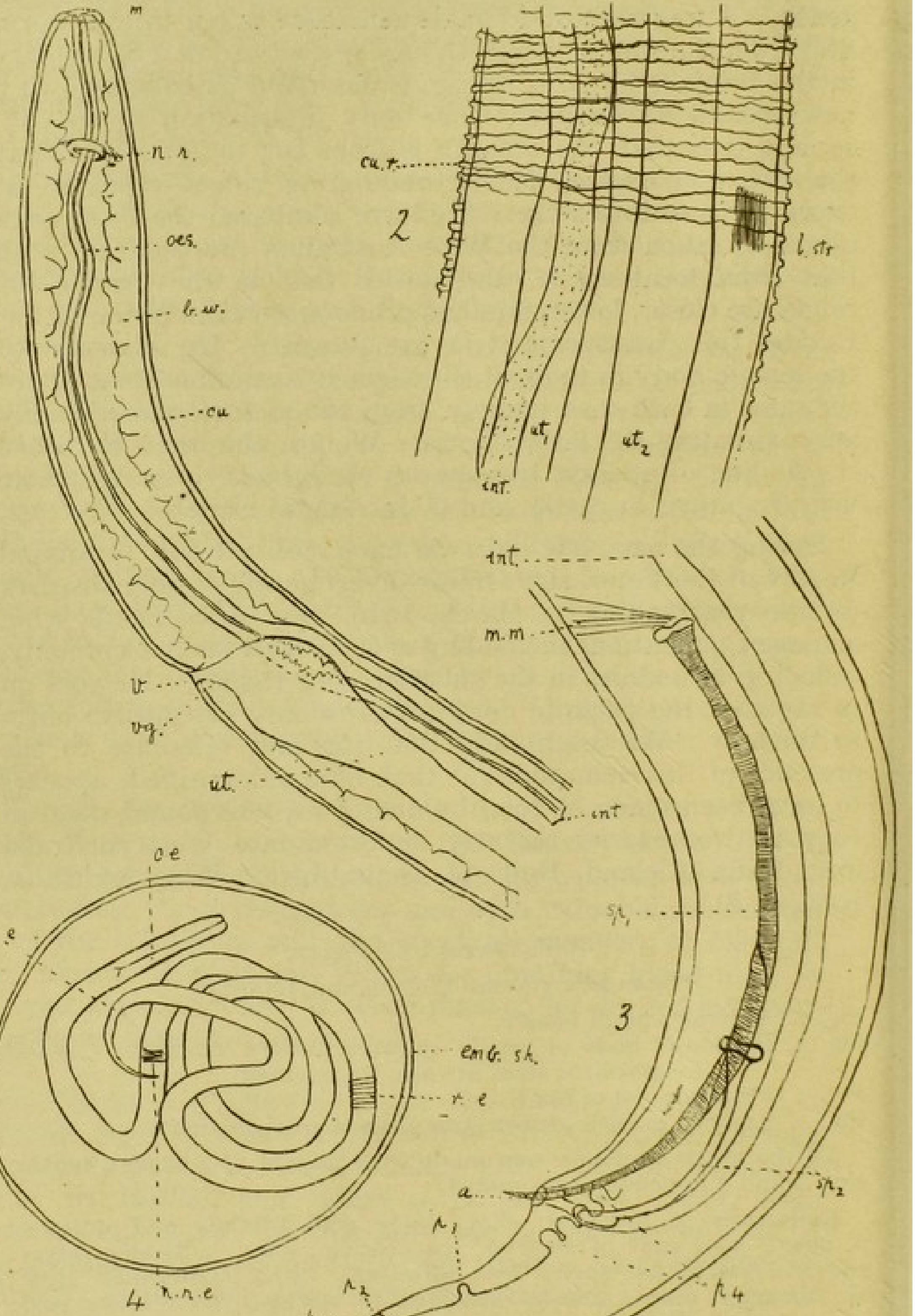
Explanation of Plate.

Onchocerca gibsoni, Cleland and Johnston.

Fig. 1. Anterior end of female.
Fig. 2. Portion of body of female, showing pattern on cuticle. A few longitudinal striæ are also represented.
Fig. 3. Posterior end of male.
Fig. 4. Embryo in shell (drawn from a smear preparation).

All the above sketches were made with the aid of a camera lucida. Nos. 1 and 2 are equally magnified.

References to lettering:—*b.w.*, body wall (dermis and muscle); *a*, anus; *a.e.*, anus of embryo; *cu.*, cuticle; *cu.r.*, cuticular ridges; *emb. sh.*, embryonal shell; *int.*, intestine; *l.str.*, longitudinal striæ; *m.*, mouth; *m.m.*, muscles attached to spicule; *n.r.*, nerve ring; *n.r.e.*, nerve ring of embryo; *o.e.*, œsophagus of embryo; *oes.*, œsophagus; p_1, caudal papilla; $p_2 p_3$, post-anal papillæ; p_4, four peri-anal papillæ; *r.e.*, rings on cuticle of embryo; $sp._1$, $sp._2$, (dotted) spicules of male; *ut.*, uterus (main trunk); $ut._1$, $ut._2$, uterine branches; *v.*, vulva; *vg.*, vagina.



Sydney : William Applegate Gullick, Government Printer.—1911.