HELMINTH PARASITES OF MAN AND ANIMALS

With special reference to
those common in Thailand and adjacent countries.

By
*F. W. WITHERS, M. A., M. R. C. V. S.
Lecturer, Dept. of Veterinary Science, Chulalankarana University.

Mr. Chairman, Ladies and Gentlemen,

I wish first to thank the Society for inviting me to read a paper at one of its meetings. As a recently joined member I am honoured by being asked to address you. A word in explanation of my title is, I think, neccessary. The subject "Parasitology" usually includes the protozoan, helminth and arthropod parasites, that is all animal parasites, be they unicellular or multicellular. Broadly speaking we may take a parasite to be *an animal which lives in or on another animal (the host) and does harm to it.*

My first idea was to address you on the subject of "parasites in general", but the inclusion of protozoa would make a paper either far too long or much too sketchy, and I gave up the idea. I then found that, if I dealt with the Helminths as I would like, there was no time to include the Arthropods—insects, ticks and mites, etc., which are of great interest both as actual external parasites and as vectors of numerous protozoan and virus diseases. So I have fallen back on the "Worm-parasites" which alone constitute a wide enough field for one paper! I shall therefore confine what I have to say to those parasites included in the invertebrate phyla, *Platyhelminthes and Nemathelminthes.*

I regret to say that most veterinary students, and I think most medical students also, regard Helminthology as the most "dry as dust" subject in their whole curriculum! I did, little knowing that I should one day be called upon to teach it. I realised very soon that if my students found the subject as boring a recital of morphological detail and zoological classification as I did, I could hope for little enthusiasm, and for that reason I have tried to make the subject more interesting by emphasising its practical application and the great interest of the life—histories and the adaptations of these lowly creatures to their particular modes of life. I have stressed structural detail (apart from its relation to function) only as a necessary evil which is essential for purposes of classification.

The parasitic worms or Helminths may be divided broadly into three classes : the *Trematoda* or flukes ; the *Cestoda* or Tapeworms and the *Nematoda* or Round worms. The first two are referred to as

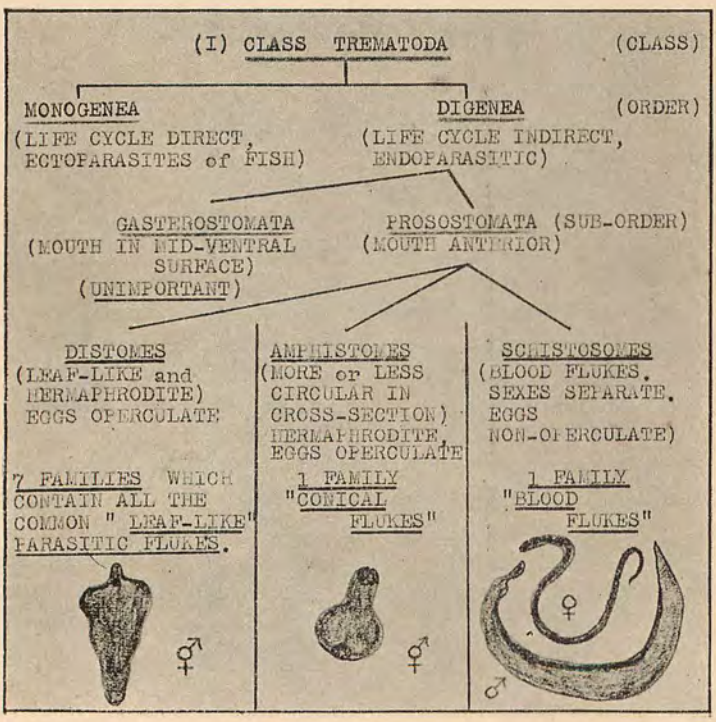
*Lecture, illustrated with charts, drawings, photographs and specimens, delivered on November 22nd, 1940 before the Natural History Section of the Society.

"Flat worms" and with the *Turbellaria* constitute the phylum *Platyhelminthes*. The third belongs to the phylum *Nemathelminthes*. No simple general descriptions are applicable to these different classes, as they present great multiplicity of form and size. Generally speaking the flukes are flattened, rather leaf-like creatures, although some of them are fleshier and circular in cross-section, and a few are more distinctly worm-like in superficial appearance. The tape-worms are well-known to everyone. They are flattened and most of them segmented, and since each segment is really a complete organism in itself, a segmented tape-worm may be regarded as a "colonial" association, with communal nervous and excretory systems. The majority of both flukes and tape-worms are hermaphrodite. The round-worms are adequately described by their common name, being circular in cross-section with either bluntly or sharply pointed extremities, and in the great majority of cases the sexes are separate, and the females larger (often very much larger) than the males.

Trematodes or Flukes.

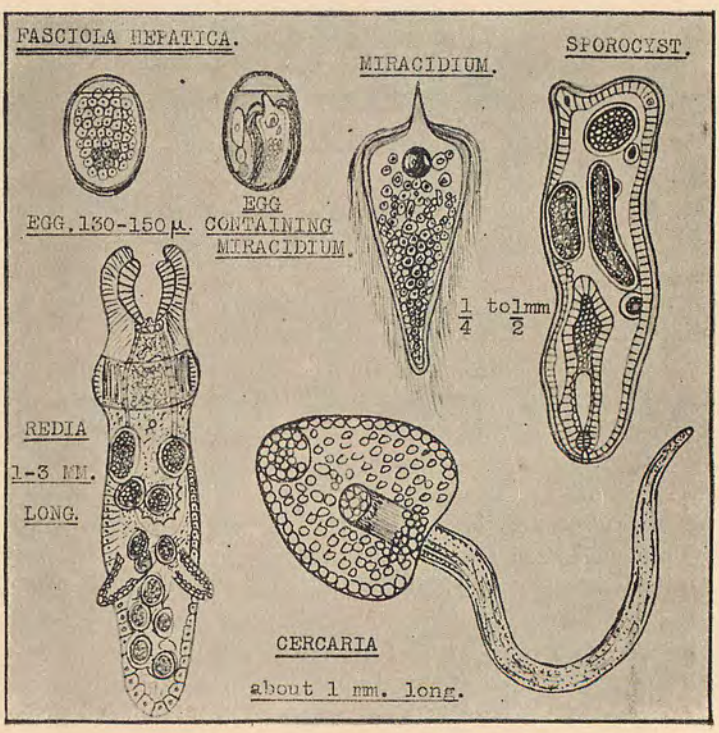
The flukes are divided into two orders: the *Monogenea* and the *Digenea*.

I

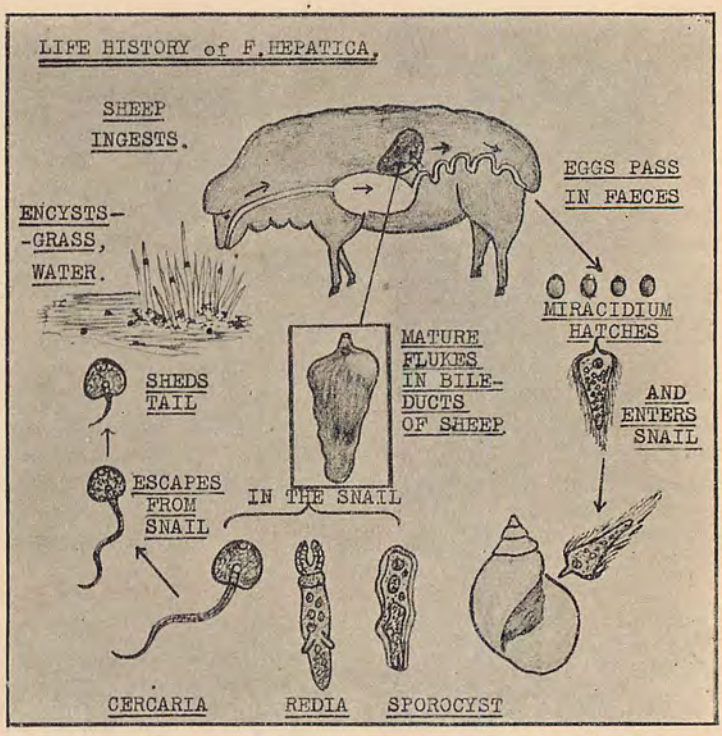


In the first, the life-cycle is direct, that is—there is no intermediate host. Most members of this order are external parasites of fishes and other aquatic animals. The other order, the *Digenea*, by far the more numerous and important, contains all the endoparasitic forms. They have an indirect life-cycle, with metamorphosis, alternation of a sexual with one or more parthenogenetic generations, and one or more intermediate hosts. The life-history of the members of this order, which contains all the important fluke parasites of man and domestic animals, is well typified in the development of *Fasciola hepatica* — the common liver-fluke which was worked out in great detail by Thomas. It has become the classical example of trematode life-history and is familiar to all students of zoology. The mature parasites are flattened, leaf-like creatures about 2—3 cm. long by about 1 cm. broad. and inhabit the liver bile ducts of a wide range of mammal hosts—chiefly herbivores: sheep, goats, cattle, buffaloes, the pig and camel; equines; various wild ruminants and sometimes man. The life-history of this parasite, which was eventually worked out in detail only by the slow piecing together of much isolated evidence, forms an interesting historical commentary on the methods of scientific research. I have tried to illustrate the

II



III



larval stages and to represent the life-cycle graphically in charts II & III. The eggs of the parasite are passed in the faeces of the host, having entered the intestine with the bile, and under suitable physical conditions they hatch in wet or swampy pastures. The first larva is a *Miracidium*, a minute, roughly triangular, ciliated organism provided with an anterior spine for piercing the intermediate host. These larvae die unless they find a suitable species of snail within a few hours. If successful they actively penetrate the snail, throw off their ciliated coat and develop into a sac-like structure—the *Sporocyst*. This develops parthenogenetically the next larval generation—the *Rediae*, which in their turn produce a further generation known as *Cercariae*. The Redia stage is capable of producing a second generation of rediae under certain conditions, but eventually the final larval stage, the cercaria, is produced; *this is the only stage which is infective for the final host*, which it enters passively in the food or drink after casting its tail and encysting itself on the leaves of forage plants or grass, or in water. After entering the alimentary tract of the host the cercaria escapes from its cyst and penetrates the intestinal wall, whence it migrates

through the peritoneal cavity to the liver, pierces the capsule and proceeds to take up its permanent position in a bile duct in which it finally becomes a mature fluke about 2-3 months from the time of infection. Exceptionally young flukes may reach the liver via the blood stream or by crawling up the bile duct from the duodenum. In the former case flukes are occasionally found in erratic sites in the body of the final host. Heavy infestations of the parasite cause the condition of *fluke—disease* or "*liver rot*" in sheep, which is extremely common and causes heavy loss in all countries where sheep-rearing is carried out on a large scale. The parasite is cosmopolitan in distribution, is frequently found in cattle and other animals, and the intermediate hosts are different species of snails in different countries, but especially various species of *Limnoea*, small water-snails which are specially common on swampy and ill-drained pastures. Such localities are "black spots" for their high incidence of fluke disease in domestic ruminants, and the logical preventive measures comprise avoidance of such localities where possible, drainage when practicable, and the destruction of all likely species of snails, without which the life-history of this parasite is incapable of completion.

I have dealt rather fully with the life-history of *Fasciola* because it illustrates so well the rather complex larval stages and the importance of the intermediate host for the continuation of the parasite. There are a number of species of digenetic flukes with similar life-histories which are found in the bile ducts, the pancreatic ducts, and the duodenum of various domestic and wild animals and in some cases man. Some are small (e. g., a few millimetres in length), and others considerably larger than *Fasciola hepatica*, e. g., *F. gigantica* and *F. magna*, the latter may reach a length of 10 cms. in the liver and more rarely in the lungs of cattle. Some species require a second intermediate host and these are often fish of various kinds which the cercaria penetrates after escaping from the snail, becoming encysted in the subcutaneous tissues, e. g., at the bases of the fins. Infection of the final host is then effected by the ingestion of raw fish, and the definitive hosts of such flukes are usually fish-eating mammals such as carnivores, pigs or man.

One such parasite (*Opistorchis* (or *Clonorchis*) *sinensis*) is the cause of "*Asiatic liver fluke disease*" and is widely distributed. The first intermediate hosts are various snails, and the second, fishes (mainly *Cyprinidae*). According to some authorities almost every species of fresh-water fish examined in China has been found capable of acting as an intermediate host for this species. It is a common

human parasite and occurs also in the liver and sometimes in the pancreas and duodenum of dogs and cats and the pig.

Another well-known human intestinal parasite which also occurs in the pig in S. E. Asia is *Fasciolopsis buski.* The life-history closely follows the classical Fasciola pattern with snails as intermediate hosts. The latter feed on plants such as the *water chestnut* and *water calthrop* which are much cultivated for food in China and are commonly fertilised with human excreta. The cercariae encyst on the tubers of these plants which are often eaten raw by human beings.

Another fluke of some general interest is *Paragonimus westermannii,* the so-called "lung fluke". The mature form of this species is found in the lungs, more rarely in the brain or spinal cord and other organs of a wide range of hosts including man, numerous carnivores, cattle, goats and the pig, and is not uncommon in this region of Asia. It, or very closely allied species are also found in America and in S. Africa. The eggs are laid in the cysts which the adults occupy in the lung tissue and are found in the sputum in human cases, but in animals, (which do not expectorate), they are swallowed and eventually passed in the faeces! The miracidia penetrate various snails as first intermediate hosts, and the cercariae encyst in various water crustacea such as crabs and crayfish as second intermediate hosts; infection of the mammal host taking place by the ingestion of the infected crustacea or by drinking water contaminated by matacercariae which have escaped from them. A Japanese worker, Yokogawa, has studied the life-history of this parasite and has shown that there is a migration in the body of the final host involving passage through the peritoneal cavity and the diaphragm to the chest and so to the lungs where it encysts.

Among the flukes, which I have already mentioned as being more fleshy and circular in cross-section, the *Amphistomes* or conical flukes, are found a number of species which occur in large numbers in the first and second stomachs (rumen and reticulum) of ruminants in this and neighbouring countries. Some are found in immense numbers in the rumen of buffaloes, literally crowding the mucous membrane in thousands like small red peas. Considering the numbers in which they occur they appear to be remarkably benign in mature animals; but before finally settling down in the stomachs, some of these parasites appear to spend a period attached to the intestinal

mucosa, where in young bovines they may cause noticeable digestive disturbances. They later migrate forward to the stomachs.

One cannot leave the flukes without mentioning a group which is quite different from all the others in exhibiting marked sex dimorphism and specialisation of habitant, viz, the *Schistosomes* or "Blood flukes." These parasitise various blood vessels, notably the portal and mesenteric vessels of a wide range of hosts, including man, various herbivorous animals, dogs and cats and pigs, and are widely spread geographically. *Schistosoma japonicum* (the "Bilharzia" of the older medical and zoological writers) is a well-known human parasite. Numerous other forms are met with: *S. haematobium* (the original form discovered by Bilharz in Egypt) and *S. mansoni* (Africa and S. America) are human parasites, also *S. bovis* (in cattle and other ruminants in southern Europe, Africa, India, Malaya, and Indo-China), *S. bomfordi* (in cattle in India), *S. spindalis* (in cattle in India and Sumatra) and *S. indicum* (in equines and the camel in India), are all well-known species. In these the infective larvae or cercariae are peculiar in being fork-tailed; the intermediate hosts are snails, the redia larval stage is omitted; the cercaria is capable of penetrating the skin or mucosa of the final host, and infection may occur in this way or by drinking infected water; the sexes are separate and exhibit marked differences, both are elongate (the female being very slender and to casual inspection nematode-like in appearance); she lies in a gutter-like groove (the "Gynecophoric canal"), formed by the inturning of the lateral margins of the male body. These parasites often cause a dermatitis by skin penetration; haemorrhages and various lesions in the intestine, and in various other organs which may be traversed during abnormal or erratic migration; and in general pain, fever, loss of condition and anaemia.

CESTODES OR TAPE-WORMS.

It is probably among the cestodes or tape-worms that we find the most spectacular life-histories and the closest contact between human medical science and animal parasitology. These parasites, well-known to everyone in general form, exhibit as their larval or intermediate stages cysts (or bladders) of various kinds in the intermediate hosts, and it is these cysts that are usually of far greater importance from the medical and economic points of view, than the mature worm parasites in the final hosts.

IV

(II) CLASS CESTODA (TAPEWORMS).

I SUBCLASS CESTODARIA (Unsegmented, Single Set of Reproductive Organs): Parasites of Fish.

II SUBCLASS EUCESTODA (Polyzoic)

(A) ORDER PSEUDOPHYLLIDEA

(I) *Fam. Diphyllobotheriidae.*

(B) ORDER CYCLOPHYLLIDAE

(I) *Fam. Mesocestoididae*

(II) *Fam. Taeniidae*

Taenias of Man, Dog, Cat, etc., and Echinococcus, with cystic stages in Mammalian Intermediate Hosts.

(III) *Fam. Dilepididae*
In all groups of Vertebrates.

(IV) *Fam. Davaineidae*
Chiefly Parasites of Birds.

(V) *Fam. Hymenolepididae*

(VI) *Fam. Anoplocephalidae*
Tapeworms of Herbivores.

The classification of tapeworms is somewhat complex; I have illustrated it briefly in chart IV. The subclass *Cestodaria* contains the unsegmented forms which are parasites of fish. The tapeworms of man and domestic animals are polyzoic or segmented and belong to the *Eucestoda*. Most of them fall into the order *Cyclophyllidea* and by far the most important family from the economic point of view is the *Taeniidae*. The typical segmented tapeworm consists of a head or scolex provided with suckers and in many cases hooks, followed by a short "neck", and then by the strobila or body consisting of numerous segments. Each segment is a complete hermaphrodite organism, and they regularly progress in development from new immature segments at the neck-end to mature segments lower down, and so to gravid or egg-containing segments at the posterior extremity. New segments are continually added behind the neck, slowly develop and travel down the body, whilst the gravid segments are regularly detached from the posterior end to rupture and discharge eggs in the gut, or to pass out in the faeces of the host and distribute eggs outside. Unless the "head" of a tapeworm is removed from the intestine of an affected person or animal the whole structure is therefore capable of growing again.

In the genus *Taenia* alone as at present constituted there are no fewer than ten species of tapeworms, the adult-forms of which are found in the small intestine either of man, dogs and cats or other carnivores, and which are responsible for the formation of cysts in various organs of mammalian intermediate hosts, infestation of the final host being kept going by the ingestion of cystic meat or offals. This group includes of course the two important human tapeworms: *T. solium* and *T. saginata* with their corresponding small rice-grain-like cysts in pork and beef respectively, the so-called "measly" meat of very wide, almost cosmopolitan occurrence. The consumption of measly meat in a raw or inadequately cooked state is responsible for dissemination of these parasites. The other taenias occur as intestinal parasites of dogs, cats and other carnivorous animals, and the cystic stages are found in the peritoneal cavity, serous membranes and in various organs of a wide range of animals such as cattle, sheep, goats and pigs, rabbits and hares, rats and mice, each one appropriate as a source of food for the final host which must ingest the cyst or its contained scolex or scolices to become infected. In one case known by a variety of names (*Multiceps multiceps, Coenurus cerebralis*, etc.), the definitive host is the dog and the cyst occurs in the brain or spinal cord, commonly of sheep, causing the condition of "Staggers," "Sturdy" or "Gid," well known to veterinary surgeons, farmers and shepherds, wherever sheep are reared. Most of the tapeworms of this genus are large; the Taenias of man may attain a length up to 8 or 10 *metres*, and in dogs and other carnivores they are commonly 20 or 30 centimetres up to one or two metres in length and may comprise hundreds of segments; the cysts vary in size from the rice-grain "measles" of pork and beef to spherical bladders several centimeters in diameter. Also a member of the family *Taeniidae* (but now promoted to the dignity of a genus to itself) is that minute but most important parasite of the dog, the tapeworm *Echinococcus granulosus*, a creature only a few millimetres long and consisting of but 4 or 5 segments, but whose intermediate stage is the well-known *Hydatid cyst* of man and a large number of other mamalian intermediate hosts including all domestic mammals (even the elephant) and many wild ones. The Hydatid cyst may occur in almost any site in the body and its medical and surgical significance in man of course depends entirely on its situation and size. Medical members will know far more about this than I do, but in domestic animals

we find hydatids most commonly in horses, cattle and pigs, and chiefly in the liver and lungs, and they are only brought to light at post-mortem examination or during meat inspection. A medical friend has told me that hydatid cyst in man has a very high incidence in Australia. Recently an investigation in S. Wales has revealed a comparatively high incidence there related to an unfortunate degree of slackness in the disposal of infected carcases and to the intimate way in which dogs are kept by human beings. The "*Casoni test*" is commonly employed as a diagnostic aid and surgical removal is not an uncommon procedure. I should like to know if any member can give us an idea of the incidence of hydatid cyst in man in Thailand. The cysts of these Taeniidae contain besides fluid one or more invaginated scolices or rudimentary heads growing from their walls which after ingestion by the final host grow into mature tapeworms. The cysts are of different kinds according to the species, some are *cysticerci*, bladders containing only one head, others, *Coenuri* or *Multiceps* in which a number of scolices grow from the cyst wall; and in the case of the hydatid this is a sort of super-multiple type from the walls of which grow brood-capsules, each containing numerous scolices capable of almost unlimited proliferation under suitable conditions, with the formation of so-called daughter cysts and grand-daughter cysts; hence the danger of releasing the contained minute brood capsules or scolices which may have become detached ("hydatid sand") by accidental rupture of the main cyst during surgical removal. I have tabulated in chart V a list of the Taeniidae giving a few details as to final and intermediate hosts, sites and sizes.

V

Tapeworms with Cysts in Mammals.		
Tapeworm & Final Host.	Cysts & Intermediate Hosts.	Remarks.
TAENIA SOLIUM. Man.	CYSTICERCUS. CELLULOSAE. Pig (Muscle).	Worm up to 8 m. Cysts small.
T. SAGINATA. Man.	C. BOVIS. Cattle (Muscle).	Worm up to 10 m. Cysts small.
T. HYDATIGENA. Dog etc.	C. TENUICOLLIS. Pig, Cattle, Sheep (Liver, Abdomen).	Worm up to 5 m. Cysts 5 cms. +
T. PISIFORMIS. Dog.	C. PISIFORMIS. Rabbits, Hares (Liver, Abdomen).	Worm up to 2 m. Cysts Pea size.
T. OVIS. Dog.	C. OVIS. Sheep & Goat (Heart & Muscle).	Worm up to 1 m. Cysts small.
T. TAENIAEFORMIS. Cat etc.	C. FASCIOLARIS. Rats & Mice (Liver, Abdomen).	Worm up to 60 cms. Cysts very small.
T. MULTICEPS. Dog.	COENURUS CEREBRALIS. Sheep & Goat (Brain).	Worm up to 1 m. Cysts 5 cms. +
T. SERIALIS. Dog.	C. SERIALIS. Rodents.	Worm up to 70 cms. Cysts 4 cms. +
ECHINOCOCCUS GRANULOSUS. Dog & Cat.	*Hydatid Cyst.* *Man* & Many Mammals.	Worm 3–9 mms. Cysts 5–10 cms. +

Perhaps the commonest and most cosmopolitan cestode of the dog is a member of another family (Dilepididae) *Dipylidium caninum*,

Up to 50 cms. long it also occurs in the small intestine. The intermediate or cystic stage is a minute organism, scarcely more than a small scolex invaginated into a membranous covering and called a "Cysticercoid" which occurs in fleas and lice. Human, dog and cat fleas (*Pulex irritans*, *Ctenocephalides canis* and *C. felis*) as well as the common dog louse (*Trichodectes canis*) can all apparently act as intermediate hosts. The insects are infected as larvae by swallowing the worm eggs, and in turn as adults they re-infect dogs by being themselves swallowed. Human cases of infestation by this worm sometimes occur in children by the same agency, probably when playing with dogs. The parasites also occur in cats, but much less frequently.

Two families of the *Cyclophyllidea*, viz: the *Davaineidae* and the *Anoplocephalidae* are typically parasites of birds, and of herbivorous mammals respectively. The intermediate hosts of the former are species of snails and slugs and various insects, commonly eaten by fowls and other domestic and wild birds; the life-histories of the herbivorous cestodes are unknown but it is presumed that they must involve passage through intermediate hosts.

Another tapeworm of some interest belongs to the family *Diphyllobothriidae* of the order *Pseudophyllidea*. This order presents certain notable structural and developmental differences from the *Cyclophyllidea*. A number of its species occur in fishes. The best known form however is the so-called "broad-fish" tapeworm, *Diphyllobothrium latum*, found in the small intestine of man, who is probably the normal final host, although a number of fish-eating mammals such as the dog and cat, the fox, seals, porpoises and the polar-bear also harbour it. It is specially known in Switzerland, in Baltic countries and in the Great Lakes region of North America but is probably world-wide in distribution. It may attain a length of ten metres and comprise three or four thousand segments. The first intermediate hosts are water-fleas (copepods), and the second fish, commonly pike, perch, trout and salmon, in the liver or muscles of which the infective larvae settle. The larval stages are peculiar to the family and comprise a series of small organisms known as *Coracidia* (the larvae which hatch from the egg in the water), *Procercoids* (in the water-flea), and *Plerocercoids* (in the fish). Raw or inade-

quately cooked fish is of course the infective agent. It is said that caviare made from pike-roe is a common source of infection in man.

Taking tapeworms as a whole it will be seen that they are of great economic and public health importance. The dog particularly harbours tapeworms which are responsible for cystic stages in man and many animals; and the reduction of the incidence of these parasites, both by the treatment of individual dogs, and by suitable measures designed to prevent access by dogs to offals and waste material from abattoirs etc., is an important duty both of private persons and of public authorities.

NEMATODA OR ROUND WORMS.

The class Nematoda contains a very large number of orders, families and species; it is in fact by far the most prolific of the helminth classes and I am afraid time precludes their adequate treatment. The classification is based largely on morphological detail and I can do no more than indicate the main divisions in a chart VI. Many nematodes are free-living. Some are found in hot springs, some in arctic waters; and some in vinegar, etc., showing great variety of adaptation to environment. I must confine my remarks to some of the more interesting and spectacular parasitic forms which are of economic importance. Various types of life-cycles are found depending largely on the degree of adaptation to a parasitic existence. Some are direct, whilst others involve passage through an intermediate host. Some are truly oviparous, others lay eggs containing fully-developed larvae, and some are viviparous. True metamorphosis is absent, the larvae as a rule developing in four stages known as first, second, third and fourth stage larvae separated by ecdyses or moults. The larval stages and the adults differ from one another mainly in size and in minor structural detail. As a rule the third stage larva is the *infective* one, the earlier stages are either free-living in water, damp soil, etc., or within the egg. In the first case the infective larvae eventually enter the intermediate or the final host as the case may be. When development takes place in the egg, the latter is ingested by an intermediate host or by the final host, and the infective larva is almost immediately released. In the viviparous forms the larvae enter the blood of the host and are often transferred to another host by the agency of blood sucking vectors as in the Filaroidea.

VI

(III) Class Nematoda (Round Worms)

I. ORDER ASCAROIDEA (3 Lips)
5 Families.

II. ORDER TRICHINELLOIDEA (Anterior Part of Body often Narrower than Posterior Part)
1 Family.

III, ORDER STRONGYLOIDEA (Caudal Bursa in the Male)
5 Families.

IV. ORDER SPIRUROIDEA (2 Lateral Lips, Posterior End of Male Usually Coiled)
6 Families.

V. ORDER FILAROIDEA (Lips usually absent. Larvae are Microfilariæ)
2 Families.

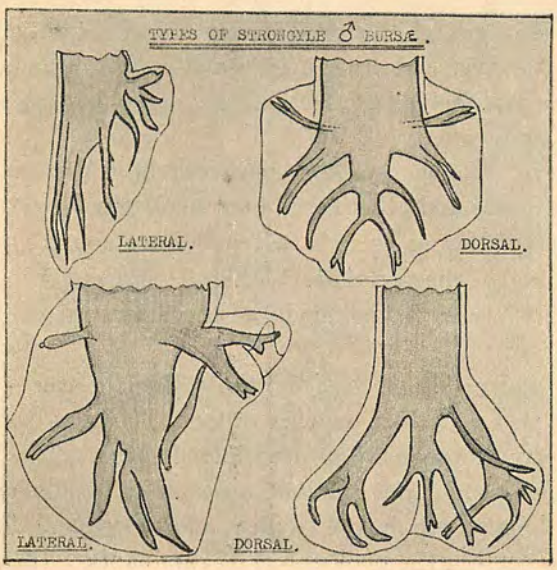
VI. ORDER DIOCTOPHYMOIDEA (Alimentary Canal attached to Body Wall by Muscle Bands. Male with Cup-Shaped Bursa)
1 Family.

Of the three-lipped nematodes (order Ascaroidea) or *Ascarids* the common pig species, *Ascaris lumbricoides* is well-known and of considerable economic significance throughout the world. The life-cycle is direct but the larvae make prolonged migration through the host tissues after the egg is swallowed, viz. from the intestine, in the blood stream via the liver, heart and lungs; they return via the trachea to the mouth and are swallowed a second time to become mature in the intestine. Migration causes loss of condition, emaciation, often so-called "parasitic or verminous pneumonia" and frequently death in young pigs. Another species of *Ascaris* occurs in horses; and species of the closely allied genera (*Toxascaris*, and *Toxocara*) occur in dogs and cats; they exhibit similar life-histories. Two species of this order are of some economic importance in domestic fowls and other poultry, viz *Heterakis gallinae*, and *Ascaridia galli*, both with direct life-cycles and without migration through the tissues. It is claimed that the protozoan disease "black-head" of turkeys is often conveyed through the egg of *Heterakis gallinae*.

The genus *Oxyuris* (family *Oxyuridae*) contains the well-known "seat worm" of the horse (*O. equi*), a parasite of the large intestine. The ovigerous female protrudes the anterior part of her body from the anus to deposit small clumps of eggs on the hair or skin of the perineal or perianal regions, causing intense pruritis. An

allied species of the same family is the "pin-worm" (*Enterobius vermicularis*), which infests children causing a similar skin irritation.

The Order *Trichinelloidea* which includes the so-called "whip worms" from the configuration of the body with a thin anterior portion and a wider posterior part, likened to a stock whip, also contains that well-known and probably cosmopolitan species, *Trichinella spiralis*, affecting man, the pig and other carnivores. The larvae of this species are found coiled up in minute ovoid cysts about $\frac{1}{2} \times \frac{1}{4}$ mm. in size in the voluntary muscles especially those of the diaphragm, tongue, jaws and ribs. The mature worms (male up to 2 mm., female up to 4 mm.) are intestinal parasites of man, the pig, the rat and numerous other mammals. After fertilization the male dies, and the female then penetrates the intestinal wall and in the lymph spaces of the gut produces large numbers of embryos (1500 per female), which migrate via the blood and lymph vessels in the body of the host to the favoured muscles, where they pierce the sarcolemma and proceed to encyst, each larva generally occupying a cyst; but sometimes as many as seven are found coiled up together. Infection is by eating affected, uncooked meat, usually pork in human cases. So widely-distributed was this parasite at one time that a common procedure at meat inspection was the systematic examination of pork with a "trichinoscope" especially in Germany. Owing to improved hygiene and inspection the incidence is now



much lower. Encysted larvae can apparently remain alive and viable for many years, but if the life-cycle cannot be continued they eventually die and the cysts become calcified nodules. "Rheumatic" symptoms with fever often accompany infestation of the muscles with this parasite.

The order *Strongyloidea* which is characterised by the presence of a typical structure, the "*caudal bursa*", an elaborate cuticular system of ray-like processes at the hind end of the male worm, contains a large number of families and a very great variety of species. Among them are the typical "Strongyles" or "red worms" of horses, responsible for much loss of condition, especially in young horses, with anaemia accompanied by digestive disturbance and even ascites. One species (*Strongylus vulgaris*) is the cause of the "parasitic aneurysms" so often seen in branches of the anterior mesenteric artery in post-mortem examinations of horses. In these cases sac-like aneurysms filled with thrombus material in which lie numerous coiled larvae are often seen. Frequently erratic forms of these larvae are found in other sites such as the lungs, on the pleura, etc. Caseation or calcification of the larval nodules is common.

The "Kidney worm" of the pig, *Stephanurus dentatus* is another member of this order, which occurs here and in neighbouring countries, although specimens are rather rare. It is found in the peri-renal fat, in the kidney pelvis and in the ureters and when the site is anatomically connected with the urinary tract the eggs pass in the urine. It often exhibits erratic migrations in the body and may be found in the liver and other organs and even in the spinal canal. The life-cycle is direct and infection can occur by ingestion or by skin penetration.

The well-known *Syngamus trachea* or "Y-worm" of fowls, turkeys, pheasants and other birds is a small Strongyle, and occurs in the windpipe; the males and the females are found in permanent contact forming a characteristic Y-shaped figure. Another species (*S. Laryngeus*) occurs in the larynx of bovines in this and neighbouring countries.

The family *Ancylostomidae*, the "Hook-worms" of man and animals are also contained in this order. They are so common in tropical countries as scarcely to need introduction. The genera *Ancylostoma*, *Uncinaria*, and *Necator*, all contain hookworms affecting either man, dogs or cats in the tropics; and the genera *Bunostomum* and *Gaigeria* contain the hookworms of ruminants. Hookworms are

serious intestinal parasites. The infective larvae enter the host either through the skin or by the mouth. There is migration in the blood stream via the heart and lungs, the majority becoming arrested in the lung capillaries, whence they pass to the alveoli and so up the respiratory passages to the pharynx and down again to the intestine. The adults attach themselves to the intestinal mucosa and suck blood causing anaemia, and often oedema with general weakness and emaciation. Hookworm disease of animals is commonest in dogs and other carnivores confined to a small area of moist ground facilitating concentration. Carbontetrachloride and tetrachlor-ethylene are satisfactory drugs for the treatment of dogs, but precautionary calcium therapy is advisable.

In man a form of dermatitis known as "creeping eruption" is often an accompaniment of hookworm disease and is due to wandering larvae of *A. braziliense* or *U. stenocephala* making thickened tracts in the skin, chiefly on the feet and legs.

The family *Trichostrongylidae* contains a large number of nematodes which are parasitic in the alimentary tracts of ruminants, including the well-known *Haemonchus contortus* or "twisted wire worm" of the fourth stomach of cattle, sheep and goats. Specimens of this parasite are very characteristic, the female showing the peculiar appearance of a "barber's pole," owing to the spiral winding of the white genital organs around the red intestine, and the male possesses a distinctive bursa.

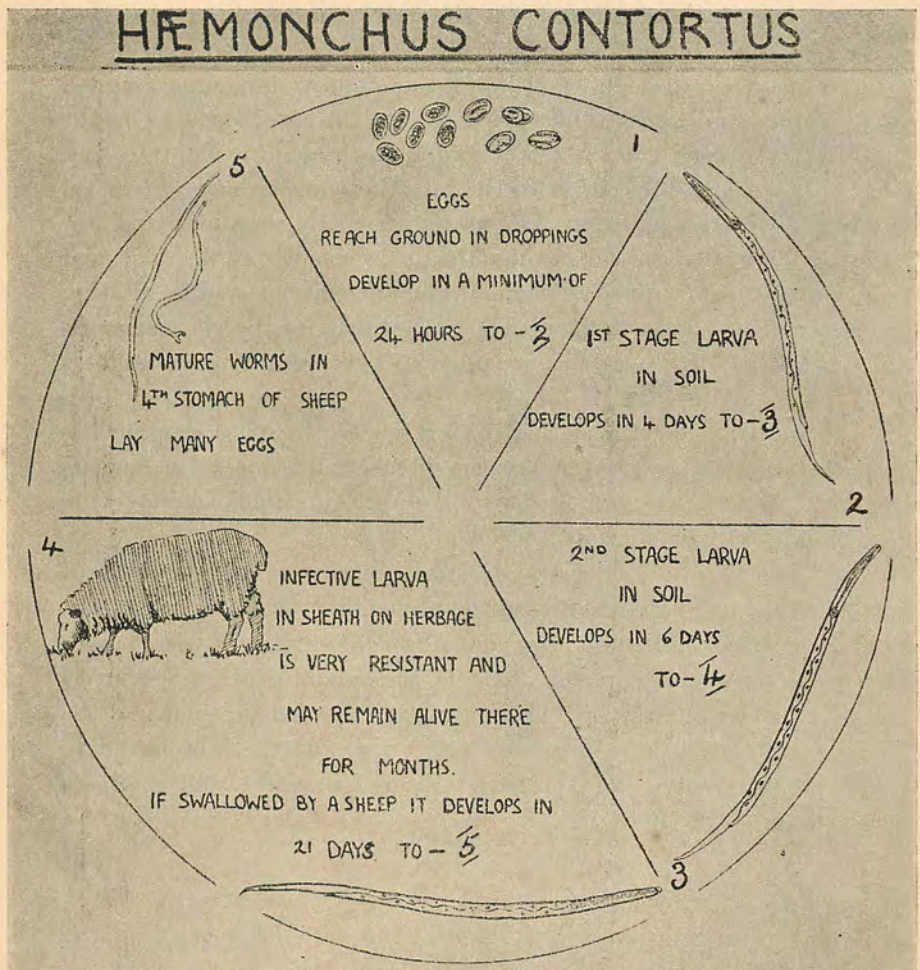
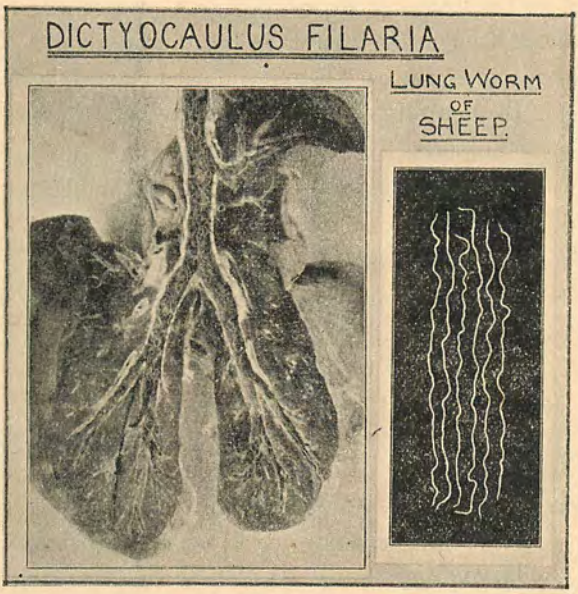


FIG. 15.—Life history of the stomach worm of sheep, showing various stages of its development, and the duration of each stage under favourable conditions on the ground. The eggs and larvae, being scarcely visible to the naked eye, have been greatly magnified.

The family *Metastrongylidae* comprises the "lung worms" so common in the bronchi, bronchioles, lung tissue or pulmonary vessels. Many species occur in cattle, sheep and goats causing the chronic cough known to English farmers as "husk." Others occur in pigs and in several wild ruminants. Among the lung worms is the parasite *Protostrongylus rufescens* of sheep, which causes a parasitic pneumonia taking the form of numerous small yellowish-grey foci in the lungs often referred to as "pseudo-tuberculosis" from its simulation of



pulmonary tuberculosis. The family also contains an interesting tracheal parasite of the dog, *Oslerus osleri* which has been recorded from India as well as several temperate countries as far apart as N. America, England and New Zealand. These small (5—15 mm.) parasites live in or under the tracheal mucosa, frequently at the bifurcation of the bronchi, where they cause the formation of sizeable granulomatous tumours. A rasping cough is the most marked symptom, and confirmation of suspected cases is readily made by bronchoscope. The life-history is completely unknown.

In the *Spiruroidea*, the Spirurid worms, there are typically two lateral lips, and the tail of the male is spirally coiled. The order contains the genus *Habronema*, several species of which are parasitic in the stomach of horses. The larvae develop in flies after being ingested by the fly maggots, chiefly of house flies (*Musca*) and the stable flies (*Stomoxys*). Horses either eat infected flies accidentally, or are infected when bitten by flies and larvae enter the wounds. Catarrhal gastritis or even large tumours of the stomach wall result from internal infection, while the condition of "summer sores" ("bursati" in India) is a cutaneous form resulting from the infection of existing wounds by the larvae.

Spirocerca lupi is a spirurid worm of the dog and other canidae. It occurs in dogs in Bangkok. The worms are found in the

oesophageal and stomach walls, or the aorta; sometimes in nodules in the pleural or peritoneal cavities or in lymphatic glands. The eggs are ingested by coprophagous beetles and the worm larvae become encysted in the insects. If unsuitable final hosts eat the beetles, the larvae again encyst in these animals, e. g., amphibia, reptiles, birds may become so affected. Dogs are infected by ingestion of the beetles or of other infected animals.

Numerous "eye worms" of animals found in this part of the world also belong to this order and constitute the family *Thelaziidae*. Several species of the type-genus *Thelazia* occur in the conjunctival sac in cattle, buffaloes and the horse in tropical countries, and there is a canine species found under the third eyelid of dogs. The life-cycles are unknown. The genus *Oxyspirura* of the same family contains a common eye parasite of domestic fowls and turkeys (*O. mansoni*). The eggs of the worms pass down the lachrimal duct. The intermediate hosts are cockroaches, which are ingested by fowls, and the larvae apparently wander up the oesophagus, pharynx and lachrimal duct to the eye and settle under the nictitating membrane. Within half an hour of feeding infested cockroaches to unaffected chicks these worms have been found in the eyes!

The family *Gnathostomidae* of this order contains the genus *Gnathostoma*. A paper by Dr. Svasti Daengsvang on the life history of *G. spinigerum* was read before this Society on Nov. 17th, 1939, in which the author gave an account of this parasite and of his work with Dr. Chalerm in 1936 in elucidating its life-history. It is one of the commonest parasites of cats, as well as the cause of the human cases of cutaneous disfiguration described and illustrated by Dr. Svasti in his paper. (see Jour. Thail. Res. Soc. N. H. S. Vol. XII, pages 161-170, 1939-40.

The next nematode order with which we are concerned viz the *Filaroidea* contains parasites of considerable importance and interest in medical parasitology, as well as our commonest dog-parasite in Bangkok, and two species which occur here in cattle and buffaloes. They are long, thin, thread-like worms, the male much smaller than the female; and the larvae, which are produced in a fully developed condition, occur in the blood in large numbers as the so-called "microfilariae." In certain species they show a definite periodicity with regard to their movements in the peripheral blood coinciding with the habits of the intermediate host.

Two human species, *Wucheria bancrofti* and *Loa loa* illustrate this well. The vectors of the former are mosquitoes and the microfilariae have a nocturnal periodicity in the perliphera blood; flies which bite by day are the intermediate hosts of *Loa loa*, and in this case the microfilariae are found in the peripheral blood during the daytime. In fact Manson named the larvae of these two parasites "*Filaria sanguinus hominis nocturna*" and "*F. s. h. diurna*" respectively. The life histories and development in the insect vectors of these human forms have been worked out in great detail. In the dog we have our very common parasite, the "heart worm," *Dirofilaria immitis*, the mature forms of which occur in the right ventricle of the heart, and sometimes in the pulmonary artery and even in the lungs; with the larval forms in the circulating blood. A recent case which I am showing as an exhibit, was very advanced indeed. There were masses of worms in the right ventricle of the heart, in the pulmonary artery and in lung cavities with ruptures in two places through the parietal pleura and extensive haemorrhage into the thorax. The dog was coughing and vomiting blood and died whilst under examination. We have also found these worms in a lion which came here with a circus last cold weather and died in Bangkok. In Dr. Jones' experience they are almost universally found in light or moderate numbers in middle aged or old dogs in Bangkok. The vectors are mosquitoes, and several species of *Anopheles*, a *Myzorhynchus*, a *Myzomyia*, and several species of *Culex* have been recorded as capable of acting in this capacity. Microfilariae, if numerous, are easily found, and a heavy infestation can be detected by examining a fresh, uncovered drop of blood under low power. The pulsating movement of the red cells, when the larvae move amongst them, is very characteristic. The larvae are about 0.25 mm. long. "Fouadin" in repeated doses clears the blood of the larvae. Some infected dogs show chronic cough and a tendency to tire easily, but others show no marked symptoms. Thrombus formation and embolism of branches of the pulmonary artery are always a possibility.

Onchocerca Gibsoni, a Filarid worm which occurs in nodules on the brisket and limbs of cattle, is a fairly common parasite encountered in meat inspection in Bangkok. It occurs also in India, Ceylon, Malaya and Australia. The life cycle in unknown.

Another filarial parasite, which appears to be very common in buffaloes in this country, is *Elaeophora poeli* which is found in the

thoracic aorta. The parasite causes thickening of the vessel wall, with numerous wavy fibrous tracts. Nodules up to a centimetre or more in diameter occur on the wall of the aorta and the male worms are coiled up in these in organising thrombus material. The large female worms are fixed in the nodules several to each by their anterior extremities, the remainder of the body hanging free in the lumen of the vessel. This parasite appears to cause no noticeable symptoms in buffaloes but is apparently very common. I have seen cases at the abattoir, and of seven buffaloes killed on one occasion at the Pakchong Vaccine & Serum Farm I found these parasites in five.

The family *Philometridae*, which, according to Baylis, is somewhat doubtfully assigned to the Filarial order, contains the notorious "guinea worm," *Dracunculus medinensis*, the reputed "fiery serpent" of the children of Israel. It is a human parasite, but is also recorded in the horse, cattle, dog and various wild animals. The male, although stated to have been seen by some observers, has never been adequately described. The female may reach a length of a metre or more, and is found in the subcutaneous connective tissues forming superficial ulcers of the skin through which embryos are discharged on contact with water. The intermediate hosts are species of *Cyclops* (water-fleas), accidentally ingested in drinking water by man and other animals.

The last order, the *Dioctophymoidea*, contains what is reputed to be the largest nematode known: *Dioctophyme renalis* (formerly called *Eustrongylus gigas*), although it probably does not exceed the guinea-worm in size. This is the "kidney-worm" of the dog and other wild carnivores and has occasionally been recorded in the pig, horse, cattle and man. Males may measure up to 35 cms. and females up to about a metre in length. They are blood-red in colour. Eggs pass in the urine, and, although the life-history is not well-known, fish probably act as intermediate hosts. The right kidney appears to be the more commonly invaded and in advanced cases only the capsule may be left as a distended bladder containing one or more worms and a haemorrhagic fluid. The worms are sometimes found in the peritoneal cavity and in other organs.

Before concluding I should perhaps mention the *Acanthocephala*, a group which some authors refer to as a class co-equal with the Nematoda, whilst others regard it as an "appendix" of the latter class. Its claim to fame is the inclusion of a fairly well-known

parasite of the small intestine of the pig whose name always gives me some strange satisfaction, *Macracanthorhynchus hirudinaceus*, the thorny-headed worm. It is a fairly big worm, the females reaching 35 cms. long, very characteristic in appearance, and as I have one in a bottle here I need not describe it. All the worms of this group are without an alimentary canal and they feed like cestodes. This particular species has a transversely wrinkled cuticle superficially simulating segmentation. Beetles act as intermediate hosts, *Melolontha vulgaris*, several dung beetles and a water beetle, *Tropisternus collaris* are recorded. These parasites sometimes perforate the intestine of pigs and may therefore cause peritonitis.

As a rule the *leeches* are briefly mentioned when dealing with worm parasites. They are of course members of another phylum, the *Annelida* or true segmental worms, of which they constitute the class Hirudinacea. They are all occasional ectoparasites mostly on the skin, but in animals they often attach themselves to the mucous membranes of the mouth, pharynx or nasal cavity and may crawl into the rectum. They cause anaemia, sores which are often refractory and a good deal of local irritation. Their pharyngeal glands secrete an anti-coagulant which delays normal clotting of blood, and a wound therefore bleeds for some time. There are numerous species which are very troublesome in tropical forest areas, especially in the rainy season in places where undergrowth is dense. Everyone has seen them attached to blades of grass and bamboo leaves wriggling frantically and waiting for the unfortunate man or animal to pass their way, and for whose proximity they possess an uncanny instinct.

I claim no originality whatever for this paper. It is simply a review of the helminth parasites, and the only difficulty has been to include the chief forms as well as those of local interest while endeavouring to avoid a mere dull recital of species. I hope it has not bored those of you who have no special knowledge of zoology, nor seemed rather "potted science" to those with biological training. I also hope my listeners will not go away with the impression that every human being and animal in the tropics is riddled with parasitic worms, sucking their blood, filling their hearts, livers, lungs and kidneys, crowding and pushing one another in the stomach and intestines until it is a wonder that any mammal or bird succeeds in living! There is a balance in nature, and under natural conditions host and parasite seem to adjust themselves to one another and to

come to some sort of working arrangement. It is certainly not to the advantage of the parasite to kill a perfectly good host. All wild animals harbour worm parasites but very few show any symptoms, much less die from parasitic infestation. Man upsets the balance of nature. He crowds himself and his animals together often in unsuitable and insanitary surroundings. He breeds animals in large numbers for their products and, without knowing it, he often encourages parasites to multiply rapidly by giving them through ignorance or laziness the very conditions which they need to thrive. It is then that they become a menace, causing loss of condition, serious disease or even the death of their hosts, and great loss to mankind.

The solution is largely a matter of rational management. A knowledge of the habits and life-histories of parasites helps us to formulate sensible preventive measures and to apply commonsense hygiene to ourselves and to our animals. This has been done and is being done to an increasing extent in this and in most countries to-day, and is a part of the general application of scientific knowledge to the common well-being, which, is the real aim of progress.

Discussion.

Dr. R. P. Jones remarked: I congratulate Mr. Withers on a very interesting paper dealing with parasites of great economic importance. Veterinarians in Thailand have to discover not only the helminths and other parasites which exist here, and plan for their control, but they must, in addition, be ever watchful against the introduction of others from abroad. So far comparatively little has been done in this direction, but the necessity for investigation is becoming one of some urgency, because under the Government scheme of improved animal husbandry, cattle, pigs, and fowls are being imported. These animals, no doubt, all harbour parasites, some of which, perhaps, do not naturally occur here, but which may find conditions here particularly favourable, and so may become a menace to the livestock industry.

We know climatic conditions have a great influence upon the incidence of helminth diseases. This was well illustrated in Wales. There, farmers were accustomed to losing a few sheep a year from disease of the liver due to fluke infestation. However, after two successive rainy summers and a mild winter, conditions were produced favourable to the parasites. Sheep throughout the country died

in their thousands, and the industry was ruined until control was established.

The majority of people view with concern, if not alarm, a personal infestation with tape worms. This feeling is not, however, universal. The Abyssinian looks upon his tapeworm as his most cherished possession, and, so long as he possesses it, he considers he is guarded against all evil. Most African natives are heavily infested.

The treatment of animals suffering from helminths has been, hitherto, by no means satisfactory. Effective medicaments are irritant and debilitating, and on weakened animals are dangerous to administer. Comparatively recently considerable research has been carried out on the anthelmintic properties of a chemical curiosity called Phenothiazine, a tasteless, odourless powder. It has proved almost one hundred per cent effective against several genera of worms. Its great advantages are, that most domestic animals readily eat the drug when mixed with the food, that it possesses a very wide margin of safety, and that it renders a big proportion of the eggs infertile, thus reducing infestation of larvae.

I feel sure Mr. Withers will find in Thailand a wide field for research in the subject upon which he has lectured this evening.