ADDRESS OF THE PRESIDENT

RESEARCHES IN LIFE HISTORIES OF PARASITES OF WILDLIFE

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President, Illinois State Academy of Science, 1943-44

INTRODUCTION

Since the beginning of the present war, reports have come into the news about parasites infecting our troops in the tropics. Some individuals perhaps are not exactly sure just what a parasite is. Parasites may be either plants or animals that have found a way to gain their living at the expense of some other organism, their host. This discussion is confined to animal parasites and animal hosts. Parasites are the most abundant animals in the animal kingdom because they have to insure their existence on or in other animals by producing prodigious numbers of their kind. They depend upon their hosts for their livelihood and take just enough of their sustenance so as to keep the hosts living and active until more parasites can be produced.

For the past twenty years I have investigated the life cycles of parasites of wild animals which heretofore had been unknown. It has been my good fortune for the past seventeen years to carry on research and teaching during the summer months at the University of Michigan Biological Station at Douglas Lake, Michigan. There it has been possible to see how parasites live with other wild animals such as fish, frogs, snakes, turtles, birds, and mammals. Wild animals native to this country often harbor parasites transmissible to man or his domesticated animals, or they may serve as reservoir hosts. For example, the broad fish tapeworm of man is also carried by the bear, the wolf, or coyote, while fish serve as intermediate hosts. The lung fluke of man is common in the mink. If man ate the same food as the mink, such as raw crayfish, which is esteemed in some parts of the world, he would be apt to contract lung fluke disease. From the standpoint of animals as carriers or as reservoir hosts it is necessary that we acquaint ourselves with the parasites of wild animals.

In one major branch of the animal kingdom, the Platyhelminthes or flatworms, there are two classes, all of which are parasites, the Class Trematoda, or flukes, and the Class Cestoda, or tapeworms. Among the Nemathelminthes, or round worms, over a thousand have been described as parasites and they may be found living in practically every other major group of animals.

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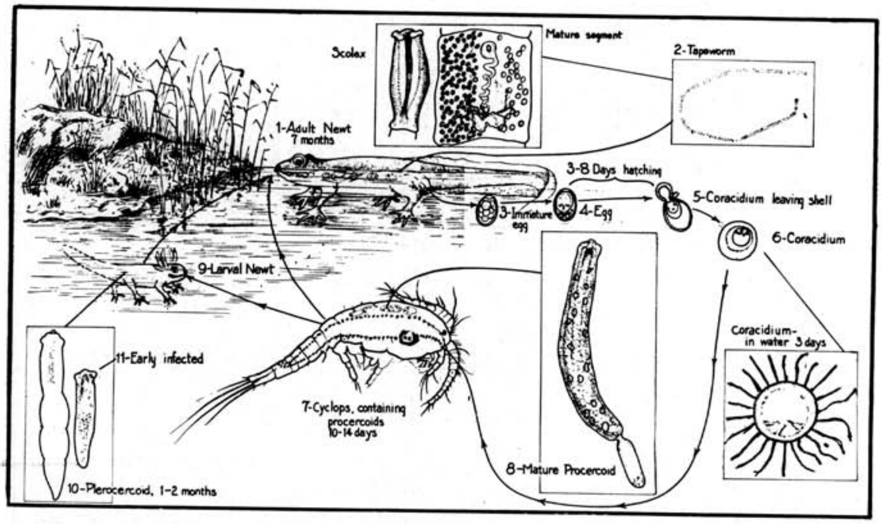

FIG. 1.—*Bothriocephalus rarus* Thomas, a pseudophyllidean tapeworm of the green newt, *Triturus viridescens*. (1) Adult tapeworm scolex and segment. (2) Complete tapeworm from the newt's intestine. (3-5) Eggs passed in the feces of the newt hatch in water in 3 to 8 days; (6) free-swimming coracidum hatched from egg (7) eaten by Cyclops develops within this copepod in from 10 to 14 days into a (8) procercoid in the body cavity of Cyclops; (9) a larval newt eating the infected Cyclops develops (10) plerocercoids within the newt's intestine where in seven months it matures. The larval newt may leave the pond as a red land phase for several months before returning with its tapeworm to the pond. The adult newt may transfer the larval tapeworm to its intestine either by eating the infected larval newt or by eating infected Cyclops.

In order to begin a life cycle study, one must understand the ecology of the hosts or have an intimate knowledge of the relationships of the hosts to their environment, where they live, what food they eat, and what factors influence their choice. One must also be on the alert for each scrap of information obtained and recorded. Information from nature must be taken when presented, otherwise days, weeks, and even years may go by before another such occasion arises.

This I can illustrate in an early attempt to solve a life cycle. The problem I chose seemed to be one that could be easily completed in one summer although I knew little about the host involved.

HOW A NEWT DEVELOPS A TAPEWORM

A small green newt, *Triturus viridescens* (Fig. 1), which lived in numbers in a beach pool had an interesting tapeworm. The newt's stomach contents indicated that it ate small water animals. Eggs passed with the feces hatched in well water at 72° F. within five days. The small spherical ciliated larval tapeworm appeared much like a one-celled animal as it rolled over and over in the water. Small aquatic animals called Cyclops, and relatives of crayfish and lobsters, ate these tiny worms. By examining the Cyclops under a microscope, it was possible to see the young tapeworm use its six hooks to push intestinal cells aside and to come into the body cavity of the copepod. After several days in this host the six hooks became inactive and the opposite end now began probing movements in the body cavity and functioned as the anterior end. The hooks became constricted into a small tail-like appendage. The body part appeared like the head or scolex end of the adult tapeworm and seemed ready for its next host. Young newts were found to have larval tapeworms and copepods which appeared like the experimental ones. It was now necessary to test this experimentally, and parasite-free newts were required. The surest way to have them free of parasites was to grow them.

Artificial ponds near the laboratory were stocked with water plants and newts from the beach pool, as I thought that in this way I could easily obtain a quantity of eggs and larvae. Much to my dismay, I found a few days later that every newt had disappeared. Many were found some distance from the ponds under leaves, their skins dry and their tails more slender. They just would not stay in water.

The next June, adult females were isolated in aquaria with water plants such as Elodea. One newt was observed laying eggs, small yellowish jelly-like spheres, which she attached singly to the nodes of the Elodea. After forty had been laid I decided to leave her there until the following morning to see how many more she would lay before I disturbed her. The next morning they were all gone, as she had eaten every one during the night. From then on as soon as a few eggs were laid, the newt was transferred to another aquarium. After eighteen days, the young newts hatched and were fed infected Cyclops. By the middle of July they were a brick red and were found climbing up the sides of the aquaria. This same migration was observed in the beach pool across the lake. These young amphibians would come to the water's edge and remain quietly until their external gills dried and then they moved off into the moss and leaves. This migration went on all summer as the adult newts were laying eggs in the pool from late June to late August. Under moist logs in the woods, larger red phase newts were found. They had immature tapeworms and the newts had changed their diet to small earthworms and gnats. By keeping red phase newts over until the following year, it was discovered that their tapeworms remained immature until the newt had changed to the green color phase and returned to the pond.

If adult newts were starved, their tapeworms shed their segments but left the head or scolex attached to the intestinal wall. If infected newts were rapidly changed from cold to warm water their tapeworms would be shed. If the worms were not removed from the aquarium the newt promptly ate and digested them. Thus after several summers' work, it was established that adult newts could become infected by eating infected young newts, by eating infected Cyclops directly, or as young newts become infected,—by eating Cyclops and carrying the infection over through the red phase until they returned to the pond a year later.

I soon learned that several life cycles had to be carried on at one time in order to take care of mishaps which might occur in any one problem and thus leave me empty-handed until another season. The foregoing account of a newt tapeworm cycle culminated in two papers on *Both-*

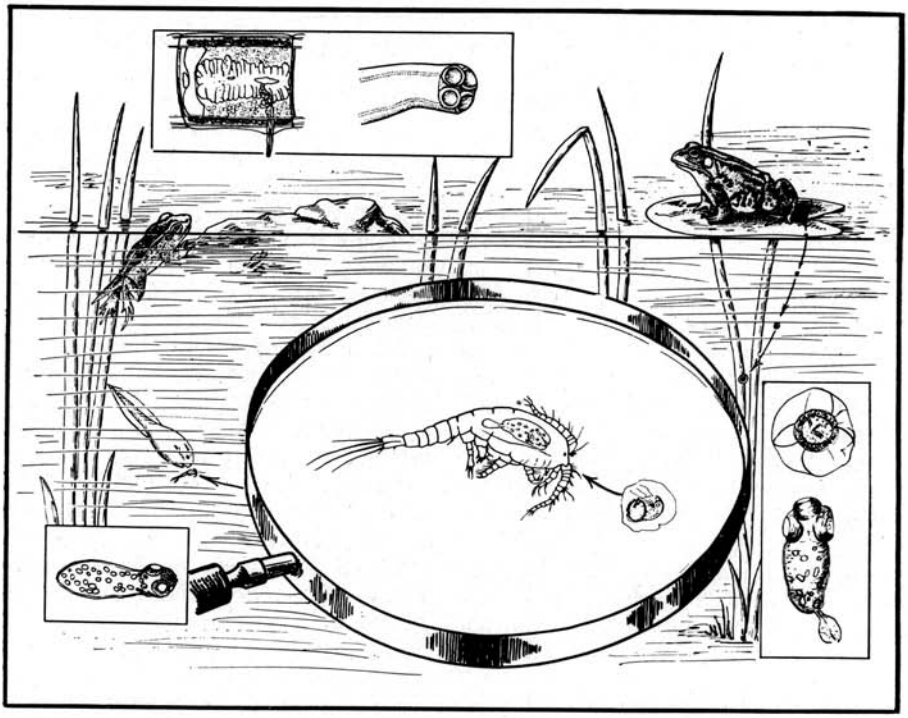

FIG. 2.—*Ophiotaenia saphena* Ossler, a tetraphyllidean cestode from the intestine of the green frog *Rana clamitans*. At top of figure a mature segment and scolex of the tapeworm from the frog. Eggs passed in feces and eaten by Cyclops produce a procercoid (lower right) which if sucked in with the Cyclops develops as a plerocercoid (lower left) in the intestine of a tadpole. By metamorphosis of the tadpole the tapeworm becomes mature in the young frog's intestine.

riocephalus rarus, the first account for any amphibian tapeworm of its kind.

HOW A FROG GETS ITS TAPEWORM

Frog tapeworms also engaged my attention, as nowhere in the literature was there an account of their life cycle. A new tapeworm in green frogs, *Rana clamitans*, was observed (Fig. 2). A heavy infection was found in frogs which lived in a roadside ditch on Burt Lake, Michigan. The work of describing the new worm was given to a graduate student and a paper appeared naming it *Ophiotaenia saphena* Osler. I concentrated upon the life cycle. Cyclops again served as the intermediate host. These little crustaceans would nibble on the gelatinous-covered egg until the larval tapeworm or onchosphere was released, then promptly swallow it. If a gravid segment of the worm was placed in a shallow dish containing Cyclops they were drawn to it as though by a magnet. They pounced upon the segment, ripping it open to get at the eggs. Many would gorge themselves so that due to the large number of worms penetrating their in-

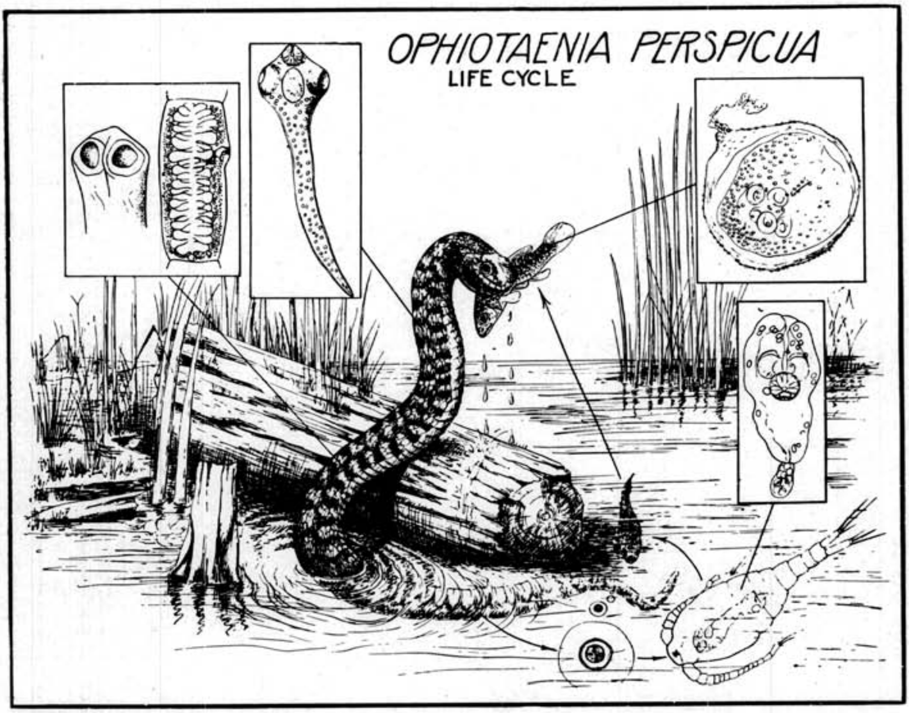

FIG. 3.—*Ophiotaenia perspicua* LaRue, a tetraphyllidean cestode of snakes. The eggs passed in the feces of the snake come into the water where they are eaten by Cyclops (lower right). In this copepod develops a procercoid (middle right) which if eaten by fish or tadpoles develops into an encysted plerocercoid (upper right) in the liver and mesenteries of these animals. A water snake eating an infected fish, frog, or tadpole develops mature tapeworms (upper left).

testinal wall, they were killed. Two weeks were required for the infective stage of the tapeworm, or procercoid, to develop. Laboratory-reared tadpoles sucked up the infected Cyclops and became infected. These immature worms in their intestines developed but slowly. With the metamorphosis of the tadpoles into frogs the tapeworms matured. In northern Michigan, as two years are required for tadpoles to metamorphose, it takes that long for the tapeworm to mature.

In the livers and mesenteries of frogs and mud minnows from this same habitat were other tapeworms which would not mature in the frogs. Water snakes and garter snakes had a tapeworm named *Ophiotaenia perspicua* (Fig. 3), which was abundant in these reptiles from this same general region. Liver and mesenteric cysts, the plerocercoid stage of this worm, fed to laboratory-reared snakes matured in them. Cyclops were infected by feeding on the eggs and the infection was transferred to tadpoles. This was the first completed life cycle of a tapeworm of snakes.

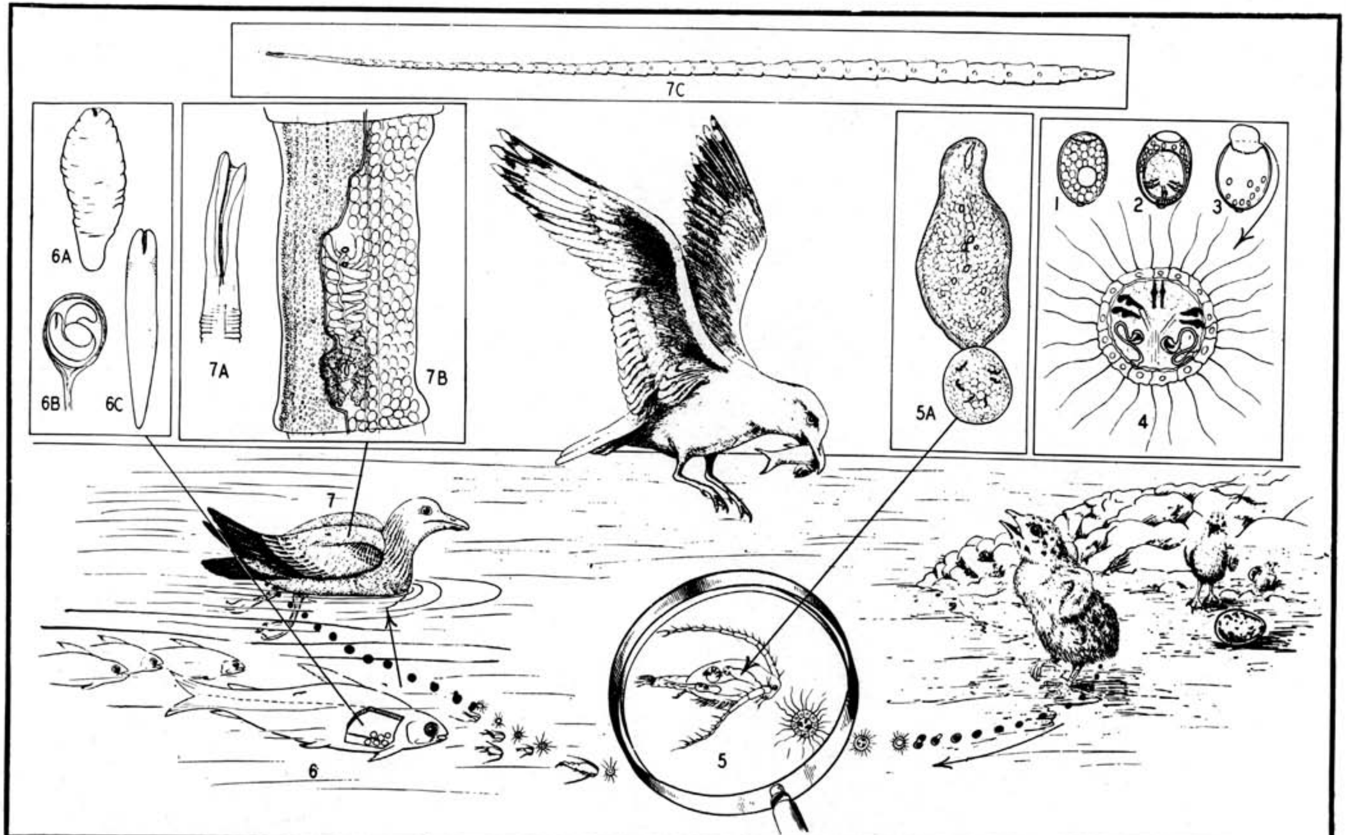

FIG. 4.—*Diphyllobothrium oblongatum* Thomas, a pseudophyllidean tapeworm from the gull. The eggs (1-3) develop a coracidium (4) which hatches in water in 10 to 14 days at 72° F. A Diaptomus (5) eats the coracidium and develops a procercoid (5-A) in 10 to 14 days. Herring or minnows (6) eating infected Diaptomus develop plerocercoids (6-A, B, C) in from 1 to 2 months encysted on the stomach wall or mesenteries. Young gulls fed infected fish by parent birds develop mature tapeworms within one month and shed them.

THE ROLE OF FISH AND MICROCRUSTACEA IN THE LIFE CYCLE OF A BIRD TAPEWORM

A Finnish worker Jarvi (1909) first directed attention to the stomach cysts of a tapeworm thought to be the broad fish tapeworm of man, which infested the herring in the lakes of Finland. For many years I had observed that they were abundant in herring from the Great Lakes. I had also received segments of tapeworms reported to be floating on the waters of Canadian lakes and the Great Lakes as well as Douglas Lake. The general picture of the infestation seemed to indicate a bird as the distributing agent. It so happened that in the course of host examinations in the laboratory, a new tapeworm related to the broad fish tapeworm of man was discovered. I have named it *Diphyllobothrium oblongatum* (Fig. 4) to distinguish it from *Diphyllobothrium strictus*, a tapeworm found by a Russian scientist Theodore Talysin in 1932. His worm found infecting fishermen in the region of Tomsk, Siberia, is a small one 47 cm. long and very similar to *D. oblongatum*. Since the herring gull was found to be infected with *D. oblongatum*, and only young birds at that, it became necessary to make many trips by means of a small fishing trawler to gull rookeries some 40 miles out in northern Lake Michigan to obtain infected birds, as only about 50 percent have the worms. The annual number of fledgeling birds taken over the past eight years is fourteen. This number is small in comparison with the great numbers that are killed by adult birds when the young get out of their territories or by the depredations of crows, or by the elements themselves. On one occasion we were caught on Pismier Island in a violent hail storm with no protection except that afforded by small shrubs about three feet

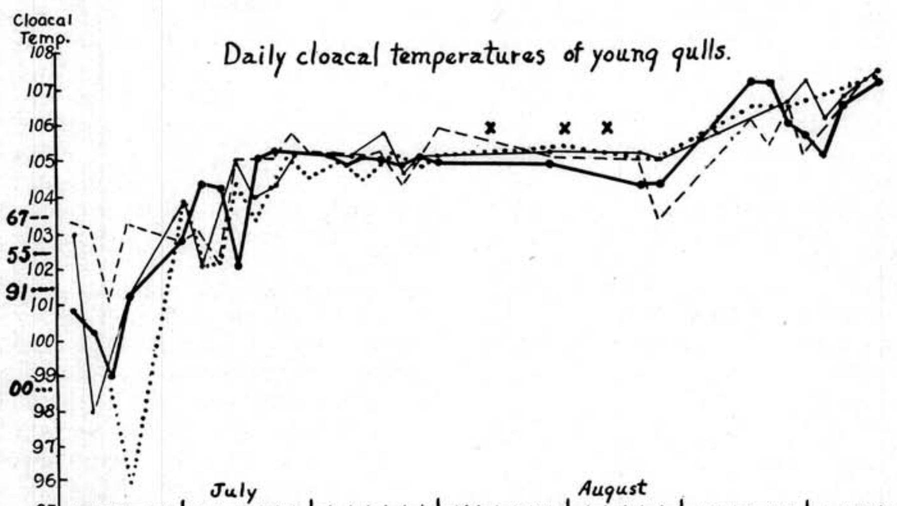

FIG. 5.—Daily cloacal temperatures of young gulls Nos. 67, 55, 91, and 00 fed Diphyllobothrium cysts after hatching in incubator; then birds removed to develop. Dates on which eggs were found in feces marked X. Autopsied on August 25, all tapeworms absent.

high. After the storm it was estimated that about ten percent of the thousands of eggs and young had been destroyed.

Observations on the island disclosed that the old birds fed their young largely on herring and minnows. Early in the summer the herring are near the surface far out in the lake. Later they feed in the shallow waters around the islands where they are taken by the fishermen. The gulls, both old and young, leave the rookeries later in the summer and flock to the inland lakes. Segments of tapeworms were found to be shed on the islands and in their adjacent waters. The herring of Douglas Lake have shown only two cysts in over one hundred fish examined in the past six years although great flocks of gulls are on the lake late in August. The unpublished work of a limnologist, Dr. Robert Campbell, on the vertical migrations of microcrustacea in Douglas Lake have shown that the intermediate host for this worm, *Diaptomus oregonensis,* both old and young, are found in Douglas Lake at a depth of 21 meters (that is, below the thermocline, in the cold water covered by a layer of warm water) where they would be available to the herring. If the tapeworm eggs were deposited in Douglas Lake, the herring should have shown heavy infections according to the number of birds present, as fifty percent of the young birds on the islands were infected.

Young gulls a week or so old and old birds could not be infected by feeding them cysts from lake herring, so gull eggs were obtained and hatched in an incubator at 103° F. Their cloacal temperatures (Fig. 5) were taken in the incubator and were found to be the same as the incubator temperature. The following day, they were removed from the incubator and fed tapeworm cysts. Their temperatures ranged from 95° F. to 98° F. Daily temperature readings were taken for six weeks, and it was found that tapeworm eggs began to appear in about four weeks, shortly after which the worms were shed. During this time the body temperatures of the gulls had risen to 106° F. and 107° F. The young birds were now in full plumage and ready to fly. The mean body temperature of the adult gull is 108° F. These data helped to explain the light infections of herring in Douglas Lake, and why I could not infect the older fledgeling gulls and adults.

A study was made of the development of the tapeworm in Diaptomus. Since this copepod is found in large bodies of water, it proved difficult to maintain for experimental purposes. By taking water in which fish had been kept for some time and then stirring it with a paddlewheel it became conditioned to keep the copepods alive so that they could be maintained in shallow dishes. Tapeworm eggs hatched within two weeks in these same dishes and the copepods became infected. After two weeks in the body cavity of the Diaptomus, these copepods were fed to guppies, small tropical minnows. Within one to two months, well-developed cysts were present on the stomachs and mesenteries of these fish. Further experiments with the eggs kept near freezing temperatures for as long as three years demonstrated that the larval tapeworms or coracidia will live and hatch and infect Diaptomus after that length of time. Eggs that come into the cold deep water of Lake Michigan may have their normal development so delayed as to extend the infection of Diaptomus and herring over many months.

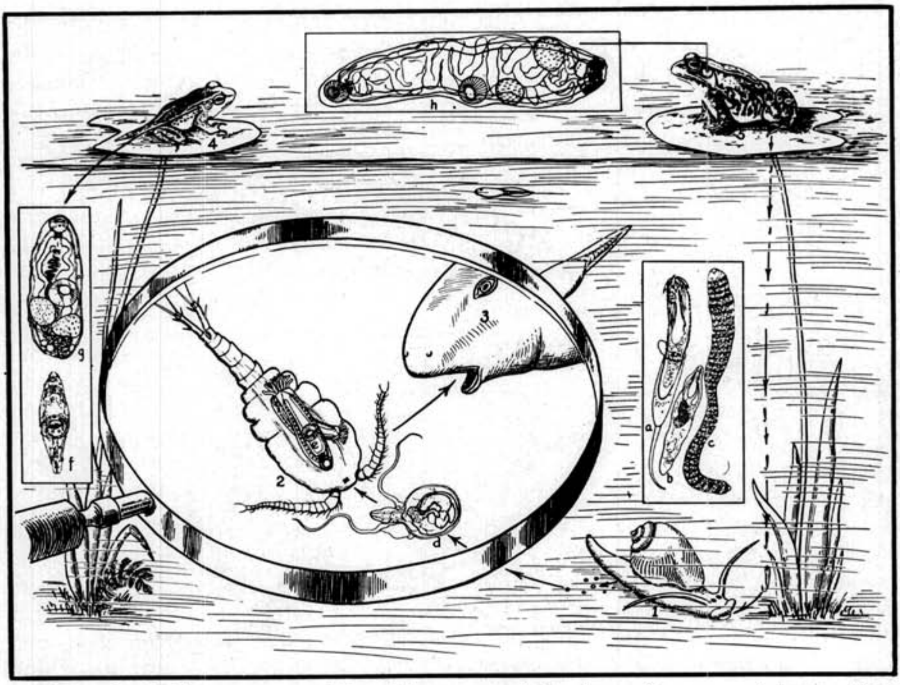

FIG. 6.—*Halipegus eccentricus* Thomas, a fluke from the ears of frogs. Eggs passed in the feces of the frog (1) are eaten by a snail, Physa. Within the snail intestine the egg hatches (a) and sheds its spiny tunic to become a sporocyst (b) just outside the intestinal wall; the sporocyst develops within its body cavity three or more rediae (c) which in turn within a month have 50 or more carcaria (d) encysted in their tails. The Cyclops by eating the cercaria become infected with mesocercaria free in their body cavity in 2 to 3 weeks (2). The frog tadpole (3) sucks up the infected Cyclops and the young flukes migrate from the stomach (f) to the mouth (g); with the metamorphosis of the tadpole (4). The adult fluke (h) finally migrates to the auditory tube in the adult frog (5).

A QUEEN FLUKE IN THE EARS OF FROGS AND HOW IT GETS THERE

Although much of my experimental work at the Biological Station has been with tapeworms and round worms, I found time to work on flukes. Flukes or Trematodes are flatworms without segments and in most of them well-developed sex organs of both sexes are present in the single body. Their life cycles may be very complex and a mollusk such as a snail or clam is necessary as an intermediate host.

Eggs may hatch in the water or in the intestine of the host. The larval stages that occur in the snail are the sporocyst, rediae, and cercariae. The cercariae break out of the snail to infect the next intermediate host, which may be eaten by the final host. In the life cycle of this fluke, *Halipegus eccentricus* (Fig. 6), which I found in the ears of frogs the eggs have spine-covered larvae. Since no cilia for locomotion were present, they had to be eaten by a snail. Snails belonging to the genera Physa and Helisoma proved to be the correct forms. The cercaria shed by the snails were encysted in their own tails. When a Cyclops

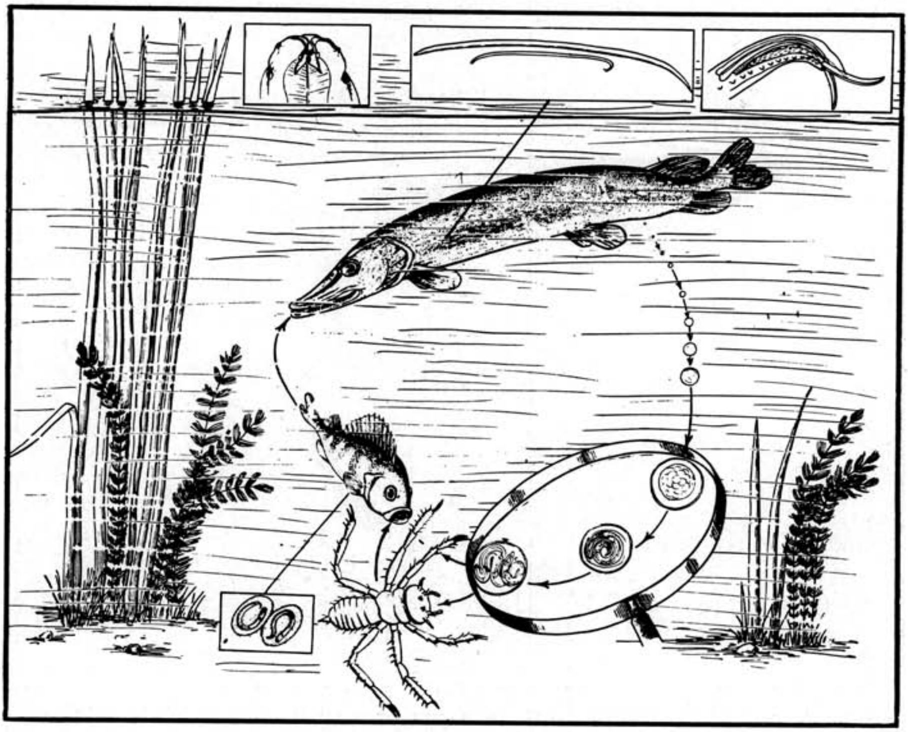

FIG. 7.—*Raphidascaris canadensis* Stafford, a nematode or roundworm from the intestine of the northern pike, *Esox lucius*. The head (upper left) and tail (upper right) of a male worm. The comparative sizes of the male and female worms. Cycle as follows: eggs passed in feces of fish come into the water and develop infective embryos within the egg in 24 hours; bottom feeding minnows feeding on eggs or eating first instar dragonfly which have fed on infective eggs develop liver or mesenteric cysts of this worm. The pike by eating infected perch or minnows gets the adult worm.

touched a release mechanism the larval fluke inside its own tail was shot out into the water by a coiled-up delivery tube. The passage through the tube was so rapid that I missed seeing it entirely in my early observations. The copepod quickly ate the larval fluke which penetrated into the body cavity and in two to three weeks was ready for its next host, a tadpole. With the metamorphosis of the tadpole into a frog, the young fluke traveled from the stomach into the mouth and then into the middle ear. Before this paper came out, Krull (1935) published a similar cycle for the worm *Halipegus occidualis* Stafford. The adult flukes were very similar but the larval stages differed so widely that my specimen had to be called *Halipegus eccentricus*. My delay in publication resulted in the discovery of a new species.

A ROUND WORM IN THE INTESTINES OF PIKE AND HOW IT DEVELOPS

For a number of years the classes in parasitology had been finding round worms, *Raphidascaris canadensis* (Fig. 7), in the intestines of the northern pike, *Esox lucius.* Masses of eggs would stream from the female worms when placed in water. As they have glassy clear egg shells it was possible for me to observe their development from the single cell stage to an active larva in only eight hours. Within twenty-four hours one molt had occurred in the egg and the larva was ready to infect some host. Encysted stages of the worm were found in abundance in the livers of perch taken from the lake. Fingerling perch, however, were not infected. Guppies were easily infected as they picked the infective eggs from the bottom of the aquarium. It was then discovered that the fingerling perch were plankton feeders, eating only microscopic life near the surface, whereas yearling perch feed near the bottom and on insect life on the vegetation. When eggs were presented to tiny first instar dragonfly nymphs they promptly ate them as they could see the wriggling worms turning about in their egg shells. Normally they eat only moving objects. Older nymphs were too large to see the eggs. Mature nymphs from the lake had walled off the worms in their body cavities with chitin so that unless they were eaten by fish, the worms would eventually die. Infected nymphs were fed to guppies and they in turn to fingerling pike and muskalunge, in which the worms developed normally in their intestines.

A ROUND WORM IN THE STOMACHS OF WATER BIRDS—ITS LIFE CYCLE

It was my good fortune in the fall of 1935 to be on the Rock River, Illinois, where the State Natural History Survey had its laboratory boat. I was interested in the gyrations of the gizzard shad over the surface of the water. Ordinarily they are bottom feeders. Aside from a fungus growth which covered their gills and seemed to be asphyxiating them, they had a number of round worms encysted in their mesenteries. Gizzard shad as a rule have few if any parasites. Since the round worms belonged to a group of nematodes infesting fish-eating birds and mammals and no life cycles were known, I thought this a good opportunity to solve it. Down the river a short distance from the boat, black cormorants were observed roosting in some dead trees. Two birds were obtained and a great number of this same worm, *Contracaecum spiculigerum,* (Fig. 8) were found mixed with the stomach contents of freshly eaten shad. Black bass, crappies, and shad from the region were all infected.

Large numbers of eggs were dissected out of the female worms and incubated in shallow dishes. In about seven days the dishes were filled with rapidly swimming larvae. Two molts occurred in the egg and one after hatching. Thus encased in three protecting sheaths they withstood considerable drying. Guppies ate them avidly so that after one month many fish died because of the growing worms. Chicks and white pekin ducklings given large doses of the worms did not become infected. They did not become infected when given infected fish. I evidently needed fish-eating birds.

The following spring fledgeling cormorants were obtained from the Illinois River. Feeding them presented a problem. Canned mackerel served as food but it had to be crammed by hand down their throats. They would not drink water even though a deep bucket-full was placed in their pen. Then I remembered that they had come from nests high up in trees and that the old birds must water them. A pop bottle of

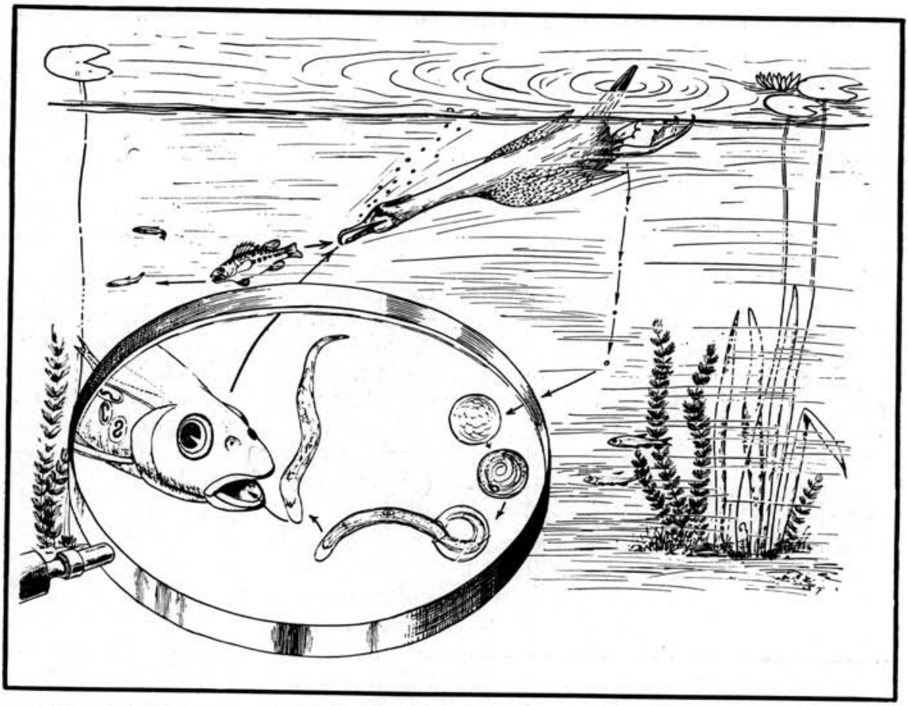

FIG. 8.—*Contracaecum spiculigerum*, a nematode parasite in the stomachs of fish-eating water birds. The eggs passed in the feces of the bird develop in the water and hatch in the water. As the larval worms swim rapidly about they are eaten by minnows. The worms encyst on the liver and mesenteries. The worms may be transferred to other fish eating the infected minnows and these carnivorous fish may be eaten to infect the cormorant or the cormorant may become infected by feeding on infected minnows.

water was soon emptied down each open beak. Thereafter my appearance with a pop bottle in hand was a sufficient cue for the birds to open their beaks and to set up a loud clamor sounding much like many doors opening on rusty hinges. Ten of the birds were given a treatment of carbontetrachloride to remove any worms fed to them by their parents. The worms were found to bury themselves in the stomach glands between meals and to come out and penetrate into the digesting food at meal time. Two of the treated birds used as controls were not fed infected guppies and had no worms when examined. After one month eight birds were shipped to Douglas Lake and the feeding of infected guppies was continued with the four that survived the trip. Three of them were sacrificed the latter part of August, and worms in different developmental stages were recovered. The fourth bird, a little male called Oscar, became such a pet that I turned him over to the Ann Arbor Zoo. Oscar was allowed to fish for himself on the lake but if he saw some one carrying a bucket or a pan he would fly in to shore hoping to get a free meal. As long as he was at the lake,

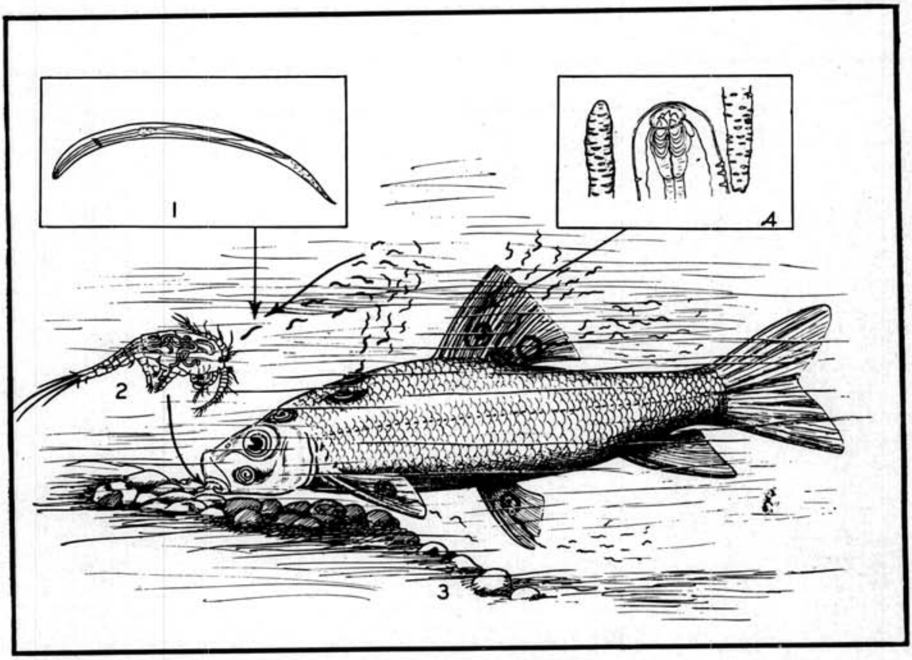

FIG. 9.—*Philometra nodulosa* Thomas, a dracunculid-like round worm parasitic in the skin of fish, *Catostomus catostomus*, etc. Larval worms (1) escaping by rupture of the fish's skin are eaten by Cyclops (2) where they mature to the infective stage within 2 weeks. Fish eating these copepods have the female worms (4) appearing in the skin within a year.

he returned to his pen at night to roost.

Contracaecum spiculigerum, this round worm parasite of cormorants, was found to be well adapted to its host and to adverse environmental conditions. Its eggs were frozen in ice in October and when thawed out the following March hatched 100 per cent. Guppies were infected with these larvae. It is therefore possible for eggs left in the late autumn to remain dormant until spring when they will hatch and infect fish, which in turn will infect birds.

HOW FISH, LIKE MEN, MAY HAVE A GUINEA WORM

In Sturgeon Bay, upper Lake Michigan, the most common sucker taken by fishermen is the red-horse, *Catostomus catostomus*. Quantities of them are shipped undressed or "in the round," as the fishermen say, packed in ice and sent to the New York market. During the latter part of June and the first part of July many are disfigured for the market by the presence of blister-like patches containing bright red round worms (Fig. 9). The worms are most abundant in the skin in the head region and in the dorsal and pectoral fins. This worm I described as *Philometra nodulosa*. It is a close relative of a worm infecting man which is found in Africa, around the Mediterranean, and in India. There it appears on the legs or backs of water carriers and is known as the Guinea Worm. It is thought to be the "fiery

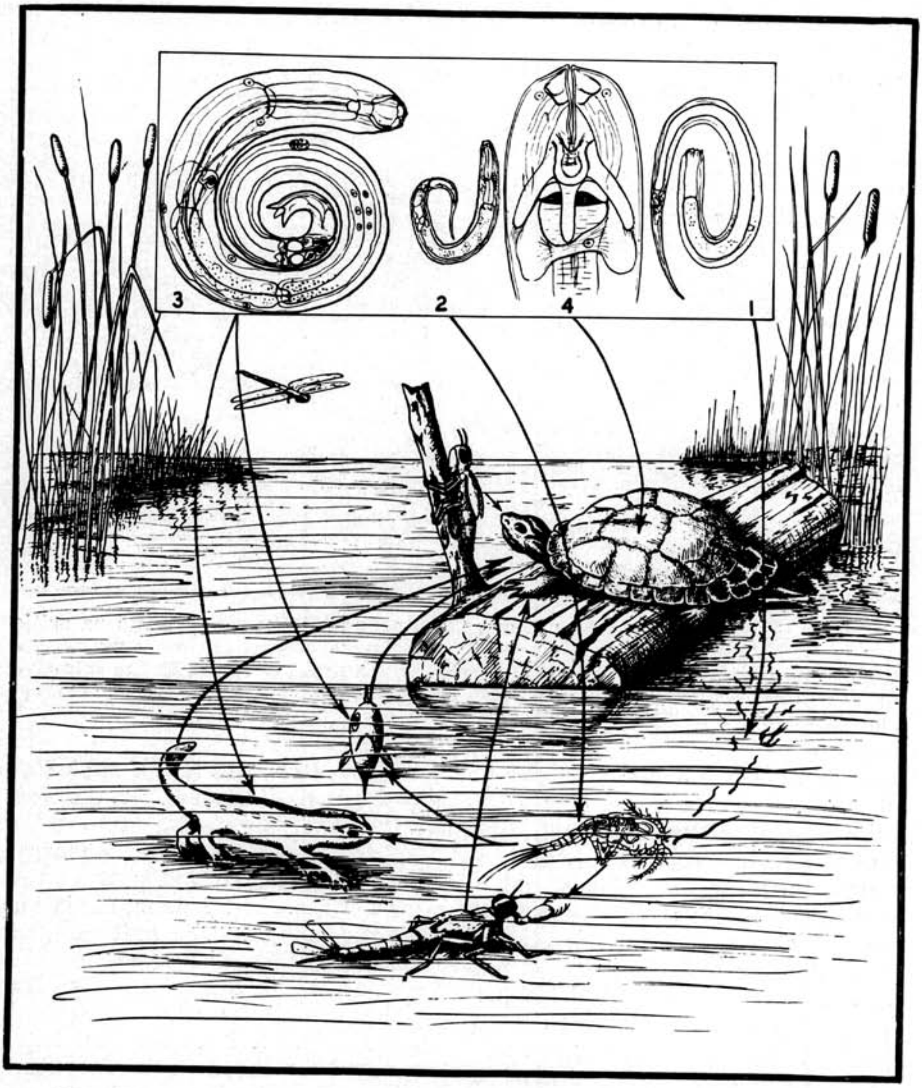

FIG. 10—*Cammallanus trispinosis* Leidy, a nematode inhabiting the small intestine of turtles. The female worms are ovaviviparous, the larval worms pass out with the feces (1) and are eaten by Cyclops. After two molts in the body cavity of Cyclops (2) within two weeks, if eaten by damsel fly or dragonfly nymphs, or newts, or salamander larvae, the worms (3) attached to the intestinal wall may infect turtles. In fish the worms burrow into the mucosa and infect turtles which eat them.

serpent" of the Children of Israel according to the biblical account. Like its relative the Guinea Worm, the breaking of the blister releases myriads of larval worms into the water where they are eaten by Cyclops. The young worms penetrate into the body cavity of the copepod and arrive at the infective stage within two weeks. Suckers feeding on the lake bottom pick up the now sluggish Cyclops. Fish examined late in December had males and female worms in the heart region. Late in June the female worms appear in the surface tissues filled with motile larvae but no males seem to be present. It has been recorded from black bass in an Illinois fish hatchery and in fish from Oneida Lake, New York.

THE PART PLAYED BY OTHER ANIMALS IN THE LIFE CYCLE OF AN INTESTINAL WORM OF TURTLES

The work of Rudolph Leuckart on Cammallanus, a nematode parasitic in the intestines of fish and turtles, clearly demonstrated that Cyclops were the intermediate hosts. This discovery led to the demonstration of the life cycle of the Guinea Worm of man by Fedtschenko in 1871. There were certain so-called free-living stages in the life cycle of Cammallanus that could not be accounted for.

A famous American physician and parasitologist of the past century, Joseph Leidy, described a worm from turtles, *Cammallanus trispinosis* (Fig. 10), which is the subject of this life cycle. The adult worms are a bright red color and are provided with true jaws which clamp on the intestinal epithelium. Each female produces hundreds of motile larvae which come into the intestinal lumen and pass out with the feces. In the experimental dishes they generally attached themselves to the bottom and coiled and uncoiled until eaten by a Cyclops.

After two weeks in the body cavity of a Cyclops they are ready for a second intermediate host. Damsel fly and dragonfly nymphs as well as young salamanders, newts, and fish were used for this purpose. The worms attached themselves to the intestinal wall of the insects and amphibians by means of their cup-like mouths and showed no further development after two weeks in this location. In the intestines of fish they buried themselves in the mucosa.

As more infected Cyclops were fed to damsel fly and dragonfly nymphs some of the worms passed out into the dishes in which they were kept. These worms remained active in the water for as long as three weeks. This helps to explain why some workers believed that there was a free-living stage in the life cycle. An examination of turtles in nature has shown identical worms in their intestines. These turtles can get their infection from eating nymphs, salamanders, or newts which have the young in their intestines.

In the spring of 1935 while examining the intestine of a spoonbill catfish, *Polyodon spathula*, I found large masses of these worms imbedded in the mucosa. Chunks of the intestine containing the worm were cut out and fed to three painted turtles on March 18, 1935. Previously to this the three experimental turtles and three controls were given a carbontetrachloride treatment to eliminate any possible natural infection. Three months later when all turtles were autopsied, the controls were negative for Cammallanus but the experimental ones had masses of adult worms.

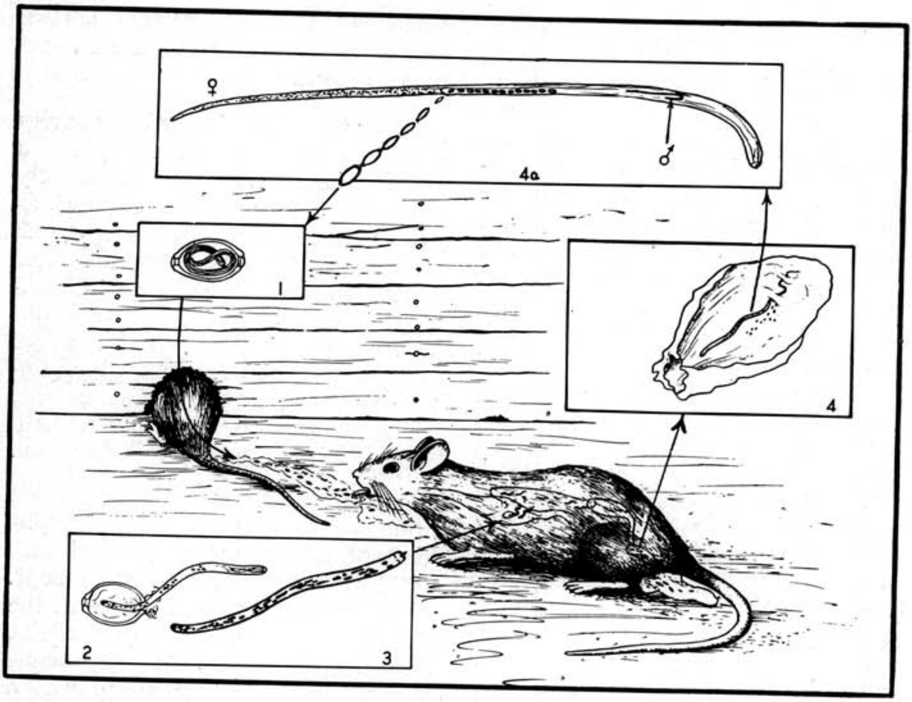

FIG. 11.—*Trichosomoides crassicauda* (Bellingham), a nematode which sews itself into the epithelial lining of the urinary tract of rats. Eggs passed in the urine are fully embryonated (1); hatching (2) in the digestive tract of the rat, the larvae (3) migrate through the body of the rat to become egg-laying adult females in 3 to 6 weeks sewed into the urinary bladder wall (4) while the male retaining many of its larval features wanders about and enters the female uterus (4-a) to complete copulation.

RATS AND THEIR RELATIONSHIPS TO ROUND WORM PARASITES

Rats are vectors or reservoir hosts to a number of helminth parasites found in man. *Trichinella spiralis* is a round worm commonly associated with cysts in pork which if eaten by man produces the disease known as trichinosis. It is estimated that over 10 percent of our population are carrying in their muscles the little cysts of Trichinella, having at some time eaten a few encysted worms in underdone pork. As there is as yet no known cure for the disease once acquired, and a heavy infection will kill the host, its prevention is the only safeguard. Cook all pork well before eating it.

Capillaria hepatica is a round worm parasite of this same group living in the livers of rats and mice, the muskrat, the beaver, the North American prairie dogs, and the peccary. Transfer to man may be made by eating infected livers not thoroughly cooked, or by the disintegration of the host, the eggs then picked up through contamination of food or drink. The worm produces a marked cirrhosis of the liver.

Trichosomoides crassicauda (Fig. 11) is another of these round worm parasites of the rat which lives sewed into the urinary bladder, the ureters, or kidney capsule. One of my first life cycle experiments was the study of this parasite's migration through the body of the rat. The eggs are passed in the urine and are fully embryonated when laid; when ingested in food or drink the larvae hatch and pass into the body cavity or circulatory system by means of their stylet, a sharp spear-like organ in the mouth cavity. Only those that arrive in the kidney will mature. The males are extremely small and retain many of their larval characteristics, including the stylet. They move freely through the tissues of the host while the female loses its stylet early and sews itself into the epithelial wall of the urinary tract. Most of the males are commonly found living in the uterus of the female worm. Infection then is direct and most rats show eggs in their urine in from three to six weeks after ingesting the eggs. One of my students working on an immunity problem with this worm has recently found a method for early diagnosis of the worms before eggs appear which may be applicable to the early diagnosis of human schistosomiasis.

FUTURE NEEDS FOR FUNDAMENTAL RESEARCH ON THE PARASITES OF WILD ANIMALS

There are those who believe that unless research is directly applicable to medicine it has no intrinsic value, but the foundations for the understanding of human helminthology have all been laid by the researches in parasites of wild or domesticated animals.

After this war and while men are returning from overseas service in parasite-infested centers throughout the world, certain diseases more or less new to this country may make themselves known. Filariasis, or more specifically "filarialelephantiasis" and "onchocerciasis," may become established more generally in the United States. Its worldwide distribution lies well below the 40th parallel north latitude and not beyond the 40th parallel south latitude. In Charleston, South Carolina, a small endemic center has been established since slave days when it was undoubtedly brought over from Africa. It is well established in the Caribbean and Central American countries.

Wuchereria bancrofti microfilaria are small round worms which circulate in the blood stream while the adults are confined to the deep lymphatic tissues. These lymphatics become greatly dilated when the worms are present in numbers. In occasional cases other lymph glands become involved such as those of the scrotum, inguinal glands, and mammary glands with huge enlargements of the legs known as elephantiasis. Another species *Onchocerca volvulus* with unsheathed larvae of two sizes resides only in the skin and produces nodules about the head region. The larvae may migrate into the eyes causing blindness. This type is more prevalent in Guatemala, whereas a body or leg inhabiting species is found in Africa. *Wuchereria bancrofti* is carried by several genera of mosquitoes all of which are present in the United States. *Onchocerca volvulus* is transmitted by blackflies belonging to the genus Simulium, a widely distributed gnat in this country. Culbertson and Rose working with filaria in cotton rats last March reported a drug neostam, which may well prove to be a cure for human filariasis.

More malignant, fatal malarias such as *Plasmodium falciparum* and *P. malariae* may also be brought in by war prisoners and returning soldiers. Here may be found all of the anophelene mosquito vectors necessary for life cycles and distribution. It does not necessarily follow that we may expect wide epidemics of tropical diseases, but that medical men should become well versed in parasitology and tropical medicine, that more research attention be directed to the parasite diseases of native wild animals which may serve as vectors or reservoir hosts of these parasitic diseases.

REFERENCES

Thomas, Lyell J. 1924.—Studies on the life history of *Trichosomoides crassicauda* (Bellingham). Jour. Parasit. 10(3):105-140. 5 pl.

———. 1929. *Philometra nodulosa* nov. spec. with notes on the life history. Jour. Parasit. 15:193-198. 1 pl.

———. 1931. Notes on the life history of *Ophiotaenia saphena* from *Rana clamitans* Latr. Jour. Parasit. 17:187-195. 2 pl.

———. 1934.—Further studies on the life cycle of a frog tapeworm *Ohpiotaenia saphena* Osler. Jour. Parasit. 20:291-294. Fig. A.

———. 1934.—*Cercaria sphaerula* n. sp. from *Helisoma trivalvis* infecting Cyclops. Jour. Parasit. 20:285-290. Figs. 1-2.

———. 1937.—*Bothriocephalus rarus* n. sp. a cestode from the newt, *Triturus viridescens* Raf. Jour. Parasit. 23(2):119-132. 2 pl.

———. 1937.—Environmental relations and life history of the tapeworm *Bothriocephalus rarus* Thomas. Jour. Parasit. 23(2):133-152.

———. 1937.—On the life cycle of *Contracaecum spiculigerum* (Rud). Jour. Parasit. 23(4):429-431.

———. 1939.—Life cycle of a fluke, *Halipegus eccentricus* n. sp., found in the ears of frogs. Jour. Parasit. 25 (3):207-221. 2 pl.

———. 1941.—The life cycle of *Ophiotaenia perspicua* LaRue, a cestode of snakes. Revista de Med. Trop. Parasit. 7(4):74-78. 1 pl.