

17.—A CONTRIBUTION TO THE LIFE HISTORY OF *DIBOTHRIMUM CORDICEPS*
LEIDY, A PARASITE INFESTING THE TROUT OF
YELLOWSTONE LAKE.

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[With Plates CXVII-CXIX.]

I.—INTRODUCTION.

In July and August, 1890, I was requested by the Hon. Marshall McDonald, U. S. Commissioner of Fish and Fisheries, to investigate this interesting parasite. My instructions were to join with Prof. S. A. Forbes, of Champaign, Illinois, in the field work of an expedition sent out by the U. S. Fish Commission for the purpose of investigating the life of the principal lakes and streams of the Yellowstone National Park, Wyoming, the special work assigned to me being to determine, if possible, the cause of the prevalence of parasites among the trout of Yellowstone Lake.

I desire in this connection, to express my deep gratitude to Professor Forbes for the unabated interest which he took in my branch of the work and for the valuable hints and suggestions which I received from him. I should also be remiss if I did not express my personal obligations to Capt. F. A. Boutelle, U. S. Army, Superintendent of the Park, whose enthusiastic interest in the expedition and prompt assistance in many ways contributed very much to the successful conduct of the investigation. Mr. Elwood Hofer, our esteemed guide and friend; and Mr. F. D. Booth did much volunteer work which receives but inadequate compensation in this mention of their names.

II.—BIBLIOGRAPHY.

The literature relating to this parasite is confined for the most part to the reports of the U. S. Geological Survey, under Dr. F. V. Hayden.

The first mention of the worm that I find is in the Report on Montana and Adjacent Territory for 1871, p. 97, where Dr. Hayden remarks as follows respecting the trout of Yellowstone Lake:

We were able to discover but one species of fish in the lake, and that was trout, weighing from 2 to 4 pounds each. Most of them are infested with a peculiar intestinal worm, which has been described by Dr. Leidy in a subsequent portion of this report as a new species, under the name *Dibothrium cordiceps*.

I make the following extract from a report prepared at Dr. Hayden's request by Mr. Campbell Carrington and published in the report cited above, pp. 97-98.

A curious fact * * * is connected with these fish, namely, that among their intestines, and even interlaced in their solid flesh, are found intestinal worms varying in size, length, and thickness, the largest measuring about 6 inches in length. On cutting one of these Trout open, the first thing that attracts your attention are small oleaginous looking spots clinging to the intestines, which, on being pressed between the fingers, break and change into one of these worms, small, it is true, but nevertheless perfect in its formation. From five or six up to forty or fifty will be found in a trout, varying, as I said before, in size, the larger ones being found in the solid flesh, through which they work their way, and which in a very short while becomes almost putrid. Their number can generally be estimated from the appearance of the fish itself; if many, the trout is extremely poor in flesh, the color changes from the healthy gray to a dull pale, it swims lazily near the top of the water, losing all its shyness and fear of man; it becomes almost savage in its appetite, biting voraciously at anything thrown into the water, and its flesh becomes soft and yielding. If, on the other hand, there are few or none, the flesh of the fish is plump and solid, and he is quick and sprightly in all his motions. I noticed that it was almost invariably the case when a trout had several scars on the outside of the body that it was free from these worms, and therefore took it for granted that the worms finally worked their way through the body, and the flesh on healing up leaves the scars on the outside; the trout in a short time becomes plump and healthy again.

Mr. Carrington, after proposing a theory to account for these worms, further states that "while all the fish above the upper falls are more or less affected by them, below and even between the upper and lower falls such a thing as a wormy trout is never heard of."

Allusion to the wormy trout of Yellowstone Lake is made by F. H. Bradley in Hayden's Report on Montana, Idaho, Wyoming, and Utah, 1872, p. 234.

Capt. William A. Jones, in his Report on Northwestern Wyoming, including Yellowstone National Park, 1873, p. 22, speaks of this parasite as follows:

We find, as others before us, that the trout of the lake (Yellowstone) are perfectly splendid in size and condition, but are full of parasitic intestinal worms, which leave the intestines and enter the flesh.

The specimens submitted to Dr. Leidy for examination were in a bad state of preservation. It was therefore difficult to make out details of structure. Upon comparing my specimens with Dr. Leidy's figures I was at first led to think that there might be two distinct species of the genus *Dibothrium* represented by the parasites of these trout, but I now think that the difference must be due to the macerated condition of the material upon which Dr. Leidy based the original description.

I make the following extracts from Dr. Leidy's notice of this worm, which was published in Hayden's Report on Montana and Adjacent Territory, 1871, pp. 381-382:

Among the specimens submitted to me were several of the worms inclosed in oval sacs imbedded in fragments of flesh. The sacs having remained unopened preserved the contained parasite from the general decomposition of the others, so as to enable me to ascertain its character. It belongs to the genus *Bothriocephalus*, or rather to that section of it now named *Dibothrium*. Two species have long been known as parasites of the salmon and other members of the same genus of fishes in Europe, but the tape-worm of the Yellowstone trout appears to be a different one.

Two of the best-preserved specimens of the tape-worm measure 5 inches in length by a line in width at the broadest part. The head, almost a fourth of a line in diameter, is obcordate, as represented in the magnified figures subjoined. The two bothria or suckers are thick and discoidal, placed back to back, obcordate in outline, and directed with their broad and slightly depressed surface toward the margin or narrower diameter of the body. The body is flat, thick, with rounded margins, and is narrowly annulated. The annulations appear to be due to muscular bands, and number about ten to the line. If other segments exist, independent of these annulations, as a character of the worm, the

condition of the specimens does not allow of their distinction from transverse fractures at irregular distances. No genital apertures could be detected at the sides or at the margins. Internal organs of any kind could not be seen, but the soft interior tissue of the body is filled with round corpuscles resembling in appearance starch-granules. These proved to be composed of carbonate of lime, as they were completely dissolved by acetic acid with the evolution of carbonic acid. From the shape of the head this tape-worm might appropriately be named *Dibothrium cordiceps*.

My attention was first called to this parasite in December, 1889, when specimens were sent me for identification by the U. S. Commissioner of Fish and Fisheries. These had been collected the previous autumn by Dr. Jordan, who published some account of them in his report on the fishes of the Yellowstone National Park.* These specimens, although in a good state of preservation, were in poor condition to show superficial characters owing to their crumpled and contorted condition. The bothria on the larger specimens were indistinguishable. The larva have the power of retracting the head, which character indeed seems to be retained to a certain degree in the larger specimens, and specimens on this account often do not exhibit the specific characters plainly. The report in which I published an account of this parasite, and which contains notes on the anatomy of this and another *Dibothrium* from the sucker (*Catostomus ardens*), gives, therefore, a rather meager description of the superficial anatomy of this worm. In my first report on this worm I suggested that some of the fish-eating birds inhabiting the lake would probably be discovered to be the final host of this parasite of the trout. When, therefore, the opportunity was afforded me of investigating the matter, I made an examination of such piscivorous birds as I could secure, with the result given below.

III.—LARVAL STAGE.

In the larval stage, *Dibothrium cordiceps* occurs either in cysts among or on the viscera of its host, the trout (*Salmo mykiss*); free, on or among the viscera; beneath the peritoneal lining of the abdominal cavity; or burrowing in the muscular tissue of the body-wall.

The cysts, which are in reality blastocysts or nurses, within which the larvæ develop, are of various sizes. Some were found less than 1 millimeter in diameter, others were 12 millimeters or more in the longer diameter. The smaller cysts are globular or sub-oval, the larger ones are oval. The smaller larvæ up to a centimeter or more in length are lanceolate, flattish, tapering rather abruptly and uniformly to each end. The larger specimens are linear, increasing slightly in breadth posteriorly, with a blunt truncate or emarginate termination; the body is crossed by fine transverse wrinkles, closely crowded together, but in the longer specimens presenting the phenomenon of distinct segments one-half millimeter or more in length. In the living specimens the vascular system is quite evident. It consists of four longitudinal vessels, two near each margin, the smaller vessel of each pair being near the margin. Branches from each of the marginal vessels extend to the other and from each of the larger vessels to the other. These branches also anastomose with each other by means of secondary branches (Fig. 11). The aquiferous vessels unite with two oval vessels at the posterior end, which is often emarginate, with a terminal pore at the emargination (Fig. 13).

The head in the living worm is small and extremely variable, sometimes stretching out until it is linear and not more than one-fourth the ordinary diameter (Fig. 6);

* Bull U. S. F. C., 1889, pp. 41-63.

sometimes abruptly linear from the body, which then appears to be shouldered anteriorly (Fig. 4); at other times the whole anterior part of the body becomes exceedingly attenuate; sometimes it is swollen or truncate at the apex (Fig. 5); sometimes rounded linear or spatulate; sometimes triangular, wedge-shape, and even retracted until it is no longer distinguishable. The bothria, or suckorial pits, are lateral, and the head is flattened so that its broadest aspect is seen when the worm is lying on its edge or shorter diameter (Fig. 9). The edges of the bothria are rather thin and lip-like and are often crumpled or thrown into sinuous folds owing to longitudinal contraction of the head (Figs. 1, 2, 3, 7).

The color is usually ivory white or translucent white with an occasional tinge of yellow.

There is no indication of genital organs other than that mentioned in my previous paper of clusters of nuclei, shown in thin sections, lying along the median line near one of the lateral faces, thus indicating that in the adult the genitalia are median and the apertures lateral.

DISTRIBUTION.

This parasite occurs, so far as known, only in the Rocky Mountain trout (*Salmo mykiss*). I have found it in the trout of Yellowstone Lake, Yellowstone River above the lower falls, and in Heart Lake. I did not succeed in getting any fish from below the lower falls, for examination. I am told, however, that wormy trout are never found in the river below the lower falls. It is very probable, however, if careful search were made for them, that an occasional trout in the river and its tributaries below the lower falls would be found with cysts of this parasite. At the Grand Cañon Hotel I examined some trout which were said to have been caught below the upper falls and found one with cysts in the abdominal cavity and a large larva among the abdominal muscles. In Heart Lake I found the trout not infrequently infested with this parasite, occurring in cysts and free on and among the viscera, but not among the muscles.

Dr. Jordan reports that the trout of Riddle Lake, which drains through Solution Creek into Yellowstone Lake, are apparently free from parasites. It may be that this conclusion would have to be abandoned if an examination were made of several of the large trout of that lake.

Following is an abstract of notes made at the time of collecting, inserted here for the purpose of showing the actual occurrence of this parasite in the fish examined:

HEART LAKE.

All of these trout were taken in front of our camp near the Rustic Geyser Basin, with trammel-net and hook and line.

(1) *July 26.*—Found one trout near shore with wounds on its sides, from the effects of which it was dying; had evidently been struck by a fish hawk; no dibothria.

(2) Ten trout examined; a few cysts found on serous coat of intestine and pyloric cœca; only two of the number had many cysts, about a dozen each. The serous coat of the intestine of these two was somewhat congested and the swim-bladder was more deeply colored than in the others.

(3) *July 28.*—Eight trout examined, most of them with a few cysts, as in No. 2. In one there was a larval *Dibothrium* in the abdominal cavity on the outside of the

serous membrane. It was translucent white, bluish with transmitted light, 20 millimeters in length and 1.75 millimeters in breadth.

(4) Four trout examined; a few cysts in each, and a free larva 31 millimeters in length, yellowish white; one cyst, 9 millimeters by 4.5 millimeters in the two principal diameters; when opened, liberated an active larva 15 millimeters in length and 1 millimeter in breadth. Along with larva in the cyst was a considerable amount of milky-white nutrient material. Larvæ were seen to make their escape from cysts that had been left lying for an hour or two in water.

Mem.—The Dibothrium cysts are found in the majority of the trout, but usually not in great numbers. Often the development appears to have been arrested, and the cyst degenerates into a calcareous or waxy calculus.

(5) *July 29.*—Six trout examined; only one found with cysts in abdominal cavity.

(6) *July 30.*—One trout examined; a few cysts among pyloric cœca.

YELLOWSTONE LAKE.

(7) *August 1.*—Five trout examined; taken in trammel-net near camp on west arm of lake near Lake-shore Geyser Basin; all with cysts, two with many, one with worms in flesh, three with worms escaped from cysts, and one with worm under peritoneum, not yet in flesh. Of these five trout the first was a male about 35 centimeters in length, few cysts; the second a female, same size, about thirty small cysts, the largest 3 by 6 millimeters, on pyloric cœca, some of the cysts with the larvæ escaping, some yellowish and waxy, two cysts on ovary, the largest 12.5 millimeters in length, cyst about size of a small pea in the liver; the third, a male, same size, several cysts on pyloric cœca, one larva about 5 centimeters in length nearly free from its cyst; the fourth, a male, same size, two or three cysts on pyloric cœca, one cyst under peritoneum, not in flesh; the fifth, a male, a little larger than the others, about thirty-six cysts on the pyloric cœca, one larva 38 millimeters long outside of pericardial cavity, two cysts in testes, one larva in flesh a short distance back of right ventral fin 5 centimeters in length, coiled irregularly, flesh surrounding it inflamed and sore, pit made from peritoneal side, two others under peritoneum of air-bladder, surrounded by inflamed tissue, with apparently a good deal of lymph exuded. One of the larvæ taken from the muscles of the latter specimen, after lying in water for two hours, measured 24 centimeters in length, and an hour or two later 34 centimeters in length; greatest breadth 2.5 millimeters.

(8) *August 2.*—One trout caught with hook and line near warm water of geyser basin, a spent female; two hundred and twenty cysts of various sizes on pyloric cœca; one larva in flesh, beneath peritoneum, on left side back of pectoral fin; one on left side back of gill slit; two on right side back of gill slit; one in liver; a few cysts scattered along intestine and ovary; fish in poor condition. Five trout examined, caught with hook and line a short distance from entrance of warm water; few cysts, no flesh worms. Five others from near warm water, caught in trammel net, more or less infested with cysts; one large larva in intestinal wall of one of the fish, intestine adherent to body wall and larva beginning to penetrate the latter; one larva in flesh above the lateral line, near the dorsal fin; four others from same lot; several cysts, none in flesh. Nine others, caught with hook some distance from warm water; no worms in flesh; a few cysts on intestines and in ovaries of a female.

(9) *August 3.*—Twenty-two trout examined; seventeen of these with from few to many cysts; six of the latter with larvæ escaping from cysts or under peritoneum; one larva measured 54 centimeters in length after lying for eighteen hours in water; five without any parasites.

(10) *August 4.*—Three trout examined; two males with few cysts, one female with several cysts, and one larva burrowing under the ribs.

(11) *August 6.*—Four trout caught with hook, north end of lake, not far from outlet; one or two cysts in each of three males; one female had a few cysts on pyloric cæca; no flesh worms.

(12) *August 7.*—Thirty-one trout caught with hook, north end of lake; five with worms in the flesh, twenty with cysts only, for the most part with only two or three; six without parasites.

(13) *August 9.*—Nine trout caught with hook in southeast arm of lake, not far from inlet; one with several cysts in abdominal cavity and larvæ under peritoneum. Six taken from near mouth of cold stream from mountain side; four of the latter with cysts on pyloric cæca, and one with a larva about 30 centimeters long in flesh near back-bone; five others, no flesh worms, two with cysts.

(14) *August 13.*—Examined a number of small trout from 12 to 20 centimeters in length, caught in the head waters of Alum Creek, South Fork, above hot springs. No cysts or other evidence of parasites discovered after very careful search.

(15) *August 25.*—Examined twenty trout caught in Yellowstone River near outlet of lake; only one was found to be much infested with parasites. It was a female and in poor condition. The parasites were on and among the pyloric cæca; no flesh worms noticed. On same date examined another lot of about a dozen trout superficially. Only one of them was in bad condition. Upon opening it a large number of larval dibothria were found in the abdominal cavity. The soldiers who were fishing there said that they found the fish of the river less commonly parasitized than those of the lake.

(16) *August 26.*—At Grand Cañon Hotel examined three small trout caught just below the upper falls. There was no indication of dibothria in these fish. A large trout, 36 centimeters in length, also said to have been caught below the upper falls, was in poor condition, and had several cysts and migrating dibothria on the pyloric cæca. There was, in addition, a large larva under the peritoneum and burrowing through the kidneys into the muscular tissue. Another specimen, said to have been taken above the upper falls, was also in poor condition. There were many cysts in the abdominal cavity, but no larvæ in the flesh. Another from the lake was in good condition, but had several cysts on the pyloric cæca.

In the above extracts from my notes the only parasite of which account is taken is *Dibothrium cordiceps*. As a matter of fact the trout are infested by a number of parasites. A small *Distomum* is common in the lower intestine, and a slender, white nematod in the intestine in the vicinity of the pyloric cæca. Nematods are not uncommonly found encysted among the viscera, and some very peculiar soft globular cysts, filled with a granular fluid, looking like tumors, covered with a layer of peritoneum, which is richly supplied with capillaries, when opened liberate a small nematod. The latter have not yet been studied. A lernean parasite is also common, usually on the fins or at the base of the fins, and not rarely in the mouth.

When the size of the trout is not mentioned it may be understood to be about 35 centimeters long.

Spent females seemed to be more commonly parasitized to a serious degree than others, although my examinations have not been extensive enough for safe generalizations in this particular.

From this investigation one might conclude that the trout of Yellowstone Lake are not so badly infested with the flesh parasites as they have been in previous years. This may be due to the fact that the observations were made earlier in the season than those of Dr. Jordan for example, who found the worms more abundant than they appear to be now. It is to be noted, however, that larvæ in various stages of development are obtained from the same individual. In one case cysts no larger than a grain of wheat were associated with others larger than a pea, and others from which the larvæ had escaped and begun to burrow into the flesh of their host, attaining a length of 16 centimeters or more and a breadth of 3 or 4 millimeters.

It may properly be inferred from this that the source of infection continues through several months of the year, thus showing marked contrast with the large ligula of the Witch Creek sucker, *Catostomus ardens*, in which case the nearly uniform size of the parasite points to a source of infection supplied, perhaps, by the short sojourn of some migrating piscivorous birds.

With regard to the escaping of these parasites through the skin of the host, mentioned by Mr. Carrington, I was unable to find any confirmatory proof. In a few instances I found that the parasites had penetrated the muscular tissues and were lying immediately beneath the skin; more commonly they were on the peritoneal side of the body wall or burrowing in the muscles. I saw no evidence in the fish which I examined that parasites had escaped. If it can be demonstrated that these parasites really do leave the intermediate host and take to the uncongenial medium of the water, it would furnish an instance of self-destruction unusual among cestod parasites.

I was frequently asked, while in the Park, if these worms are in any way injurious to man. I think it can be safely answered that they are not, except as their presence might make the fish less acceptable to the palate. Fish, perhaps more than any other animals, are required by nature to harbor parasites. There is probably not a food fish in the world that does not furnish a home for one or more species of parasites in some stage of the latter's existence. Fortunately fish parasites, as a rule, do not live in man; at any rate, the various processes of preparation for food to which fish flesh is subjected effectually destroy the vitality of the parasites. It may be, if not pleasant reading to the fastidious, at least consoling to the timorous, to know that forms closely related to the subject of this sketch are in some places actually eaten as food and esteemed as delicacies by those who eat them, who, it may be inferred, ask no questions either for conscience' sake or for the sake of knowledge. Ligulæ, parasites of the European tench and of other related fish, are used as food in Italy, where they are sold in the markets under the name *maccaroni piatti*, and eaten usually under the mistaken notion that it is the roe of the fish. It is also eaten in Lyons by many, where it goes by the appropriate and truthful name of the *ver blanc*.*

* Donnadieu, Contribution à l'histoire de la Ligule. Extrait Journal de Anatomie et de la Physiologie, P. 1.

IV.—ADULT STAGE.

I have found a large *Dibothrium* in the white pelican (*Pelecanus erythrorhynchus*), which is evidently the adult form of *D. cordiceps*, of which the trout (*Salmo mykiss*) is the intermediate host.

Of the four birds examined, two contained this parasite. These were situated about the middle of the intestine. They were in several fragments in each case, but there was no tendency shown to separate into individual proglottides. Some of the fragments were slender and attenuated, and when studied subsequently proved to be the older parts of the strobiles degenerated into slender ribbons of connective tissue and still containing eggs. In one of the birds, the length of the fragments, which evidently belonged to a single strobile, was about two meters. There was in addition to this an approximately equal amount of attenuated fragments of degenerated portions of the strobile.

The fine impression made by the stately movements of the pelican while on the water or in the air is not sustained on closer acquaintance. It has an abominably rank and fishy smell. It is grievously tormented with parasites. The alimentary canal of an adult bird is from 2 to 2½ meters in length, and throughout its whole extent it is liable to be infested with various parasites. Least numerous and least painful are the dibothria in the intestine.

The mouths of each of the four birds examined contained hundreds of some mallophagous parasite. These were attached to the mucous membrane by the head, and required a sharp pull with the forceps in order to detach them. They were attached in clusters, so that a dozen or more could be removed at one time with small forceps. They were on the inside of the pouch, near the larynx, in the larynx itself, in the beginning of the œsophagus, and in the buccal cavity generally. The œsophagus contained an immense number of a rather slender nematod, 10 to 15 millimeters in length; these were usually attached to the mucous membrane, and left a small round hole when removed. In the lower part of the œsophagus and in the stomach there were also large numbers of nematods. These were larger than those in the œsophagus, with thickish, usually dark-colored, bodies; they were not attached to the mucous membrane, but in the stomach were in the midst of the food.

The stomachs of each of the birds contained practically nothing but partly digested fish.

Much of the stomach contents of each of these birds had suffered so little from the processes of digestion that the size of the fish could be easily estimated. In each case the fish which had constituted the last meal of these birds were from 30 to 36 centimeters in length, or, in other words, the average size of the trout of the lake. There was a little gravel or coarse sand at the bottom of the stomach and occasionally a little vegetable débris, the feather of a small bird, etc. These apparently had been swallowed incidentally to the main business of eating. These birds were found breeding on Molly Islands, in the southeast arm of Yellowstone Lake, July 10, 1890.

SUPERFICIAL CHARACTERS.

The following description of the superficial characters is based on an alcoholic fragment with scolex attached, and measuring about 75 centimeters.

Head, in lateral view of body, elongated, wedge-shaped (resembling exactly some heads of *D. cordiceps* from cysts in *Salmo mykiss*, which I have collected), largest at base, tapering slightly towards apex, narrower than neck, except immediately at base, where it is of same breadth as neck (Fig. 17). In marginal view of body the head is broader than the neck and subsagittate (Fig. 18). Bothria lateral, lips rather thin and flexible.

	Millimeters.
Length of head	2.00
Diameter, corresponding to marginal diameter of body80
Diameter, corresponding to lateral diameter of body55
Diameter of neck, lateral80
Diameter of neck, marginal60

Neck, immediately behind head, crossed by fine lines which, less than 2 millimeters back of the head, divide the body into short but evident segments. The body increases in breadth slowly and uniformly, and at a distance of 30 millimeters from the head is 2.5 millimeters broad; at 60 millimeters, 4.5 millimeters broad, at which point the segments are about 0.5 millimeter in length. At about 40 millimeters from the head a faint, darkish, median line is discernible, which becomes darker and more evident farther back. With a lens this median line is seen, in maturing segments, to be occupied by the reproductive apertures. The dark color is due to clusters of ova. The reproductive apertures are lateral, near the median line of the strobile, not far from the anterior edge of each segment, and on but one of the lateral faces of the strobile. From some of the apertures a short, blunt cirrus was seen protruding.

For about 15 centimeters the strobile was thickish with entire margins, then for about 10 centimeters it was characterized by remarkably ruffled margins. This was in the widest part of the strobile. The segments were here much crowded. The strobile in this ruffled portion is also thickish, at least when it is compared with the succeeding portions. At this point the breadth is 7.5 millimeters, the broadest part of the strobile; the length of the segments, 0.34 millimeter; the thickness about 1 millimeter (Fig. 21).

Beyond the ruffled portion, the strobile becomes flatter, much thinner, and decreases in breadth, while the segments become squarish. A characteristic scalloped margin is produced (Fig. 23) by the frequently concave margins of segments and their prominent posterior edges. Near the posterior end of this fragment the segments had the following dimensions: Length, 2 millimeters; breadth, 4.5 millimeters; thickness, 0.5 millimeter or less. The ruffling of the margin of the median portion of the strobile may be due in part to the action of the alcohol.

Another fragment, smaller in most of its dimensions than the above, presents some characters which should be noted. The entire length is 22 centimeters. The head is somewhat contracted longitudinally and is bluntly rounded in front.

	Millimeters.
Length of head	1.00
Diameter of head, corresponding to marginal diameter of neck	0.75
Diameter of head, corresponding to lateral diameter of neck	0.75
Marginal diameter of neck	0.50
Lateral diameter of neck	0.75

Neck almost immediately crossed by fine transverse striæ, which give rise to distinct segments 5 or 6 millimeters back of the head, where they are one-eighth of a

millimeter in length and 1 millimeter in breadth. The terminal segments in this fragment are 2.75 millimeters broad and 1.25 millimeters in length.

This fragment, for the most part, resembles the larger specimen, being flattish, white, roughened by transverse wrinkles, and having its margins at one part of its course ruffled. In one place, however, 7 centimeters from the head, and for a distance of 3 centimeters, it is shrunken, attenuated, and yellowish. A segment in this part measured 1.5 millimeters in length and barely 1 millimeter in breadth. Immediately beyond this the normal segments were 5.75 millimeters in length and 2.5 millimeters in breadth.

Some slender, attenuate fragments, previously alluded to, looking when first collected like tangles of narrow braid, were at first supposed to be a distinct parasite. Subsequent examination demonstrated them to be fragments of mature portions of the large *Dibothrium*. Following is a more detailed account of these fragments than has yet been given: One fragment, measuring 34 centimeters in length, was very thin, and about 1.5 millimeters broad. In some places segments could be made out. These were much attenuated. Some of them were measured and found to be 3 millimeters in length. In some shorter fragments, which were quite irregular, being flat in places and in others cylindrical, segments were noticed which were 4 millimeters in length and 1.25 millimeters broad. Another fragment, 33 centimeters in length, was reduced throughout the greater part of its length to a mere filament one-fourth of a millimeter or less in diameter. Another fragment, about 30 centimeters in length, was reduced to less than one-half of a millimeter in diameter throughout most of its extent, but widened in each direction, so that each extremity was a little over 1 millimeter in breadth.

A thin fragment was placed in glycerine, and was then seen to contain ova along its entire extent. The ova lay along the median line in clusters, which were somewhat continuous. In this the jointing was indistinct. In some of these fragments the joints are distinct, although there is no tendency in the joints to separate. A fragment, 35 centimeters in length, showed distinct joints in part of its course; in other places the joints were indistinct. This fragment was flat and thin and about 1.5 millimeters wide where it was flattened; in other places it was not quite so wide, owing to a tendency to roll up at the margins. Both the flattened portions and the attenuated, cord-like portions of these fragments were found to contain ova, which were seen to be abundant in specimens made transparent in glycerine. These slender fragments are evidently portions of the larger strobiles, in which the muscular tissue has degenerated, and the whole structure is reduced to a narrow band of connective tissue containing ova.

ANATOMY.

In order to make a comparison of the structure of the adult with that of the larva, portions were stained with borax carmine and cut into thin sections. These were made in three directions, transverse, longitudinal parallel to the margin, and longitudinal parallel to the lateral face.

Sections of the head show that while that organ is somewhat smaller than it is in the larger larvæ, the muscular fibers are much more abundant and more strongly developed (Fig. 34). In outline and arrangement of parts they are the same. There appear to be three principal systems of muscles or contractile fibers in the head,

longitudinal, circular, and radial. Some of the radial fibers, however, are continuous with longitudinal fibers of the body. The first of these, the longitudinal, is fairly well developed in the larval stage, the latter two, the circular and radial, but feebly developed. Each is represented by many strong fibers in the adult. In both larva and adult there is a layer of well-developed longitudinal fibers immediately beneath the cuticle of the bothria. (Fig 34, *s c.*)

The layers of the body have the following disposition (Fig. 27):

(1) The cuticle, which appears, when highly magnified, to contain minute circular fibers.

(2) A thick granulo-fibrous layer, the outer portion of which consists mainly of longitudinal fibers, which, in transverse sections, are seen to be continuous, with radial sheets of connective tissue. The inner portion of this layer is less distinctly fibrous and more granular. In transverse sections the connective tissue of this layer appears as radial fibers, which become thicker near the cuticle, where they are more or less parallel, somewhat branched, the branches anastomosing. Toward the inner part of the layer they lose their parallelism and form a mesh of fine fibers. This layer contains the peripheral system of vessels, which, however, is not so prominent as it is in the larval stage. Towards the inner edge of this layer in mature and maturing segments the granular parenchyma is collected into roundish masses, forming the vitellaria.

(3) A layer of coarse longitudinal muscle fibers. In the interstices between these fibers there are fine connective fibers which extend from the outer granulo-fibrous layer, and are continuous with connective fibers of the central core.

(4) A thin layer of fine circular fibers surrounding a central space.

(5) The central core of the body. This space, where not occupied by the genitalia and the vessels of the water-vascular system, is filled by a network of connective fibers in mature segments, but in the anterior immature part of the strobile it contains much granular protoplasm, from which later the genitalia develop, the testicular lobules developing towards the margins, while the cirrus bulb, vas deferens, vagina, ovary, shell-gland, and uterus develop in the vicinity of the median line.

The marginal canals and the aquiferous vessels, which lie in the central core, have practically the same characters, proportions, and disposition as they have in the larval form, as elucidated in my former paper.

A few nuclear clusters, which appear in some of the transverse sections made near the anterior end of the head, are probably nerve ganglia (Fig. 34, *n*). Calcareous bodies, so abundant in the larva, appear to be entirely wanting in the adult.

GENITALIA.

The genital apertures are close together, but distinct, lateral, about on the median line; the male orifice much larger than the female and situated near the anterior edge of the segment; the female orifice is situated behind the male orifice and a little to one side. Sections show that the male orifice (Fig. 25) communicates directly with the relatively large, oval, cirrus bulb, which contains muscular fibers in a loose, open tissue, among which the cirrus is usually retracted. The bulb is embedded deeply in the segment, lying for the most part in the central core between the longitudinal muscle layers. At its base it is in connection with a sub-globular organ (Fig. 25, *p*), which appears to be a short vas deferens, or, since its walls are rather thick and dense

and composed of fine fibers, presumably contractile tissue, it may also function as an ejaculatory duct. The vas deferens joins this from the posterior side. The cirrus is apparently invaginated by means of numerous retractor fibers, which are inserted on the inner wall of the bulb and to the cirrus (Fig. 25, *a*). The testes are oval granular bodies lying in the central core rather towards the margins (Fig. 32, *t*). They communicate with the median vas deferens by means of minute ducts.

The vagina opens near the cirrus, posteriorly to and a little to one side of it. It pursues a somewhat tortuous course posteriorly, apparently reaching the ovary on its dorsal side; near its beginning it expands into a seminal receptacle (Fig. 26.) The ovary (Figs. 27, 33) appears to be a single mass of nucleated cells lying near the posterior edge of the segment and towards the ventral side, near the ventral layer of longitudinal muscles. Its longest diameter is transverse to the longitudinal axis of the segment. The shell gland, as I have made it out, lies near the ovary, somewhat posteriorly on its dorsal side (Fig. 33, *s g*). The uterus is a very voluminous organ beginning on the dorso-posterior side of the ovary and lying in broad folds rather toward the dorsal side of the segment, the folds extending some distance on either side of the median line and occupying nearly the entire length of the segment (Figs. 27, 28, 33). Its caliber is much larger than the diameter of a single ovum. In the older segments the walls of the uterus apparently give way, since the ova in them are seen to be in masses in the central part of the strobile. (Fig. 24.)

There is no indication that the segments separate in any other way than in long chains when mature.

Sections made parallel with the lateral faces of the strobile show a small pore lying a short distance back of the genital apertures and on the same side, *i. e.*, the ventral side of the strobile. This is apparently the external orifice of the uterus from which ova may be discharged.

The ova are rather large, about 0.07 millimeter in length and 0.035 millimeter in breadth. The walls are thin and usually collapsed in alcoholic specimens on one side, so that, in mounted specimens, the ova appear to be bowl-shape. They are of an amber color, do not stain readily, and their contents are granular. They lie in somewhat transversely parallel clusters along the median line, the masses of ova occupying a space approximately equal to one-third the breadth of the strobile.

By counting the ova in a series of sections carried through a mass of ova in a maturing segment, it was estimated that the segment contained 2,300 ova. The fragments from the intestines of one of these pelicans contained approximately over 2,000 segments. This would make 4,600,000 eggs from this strobile. This estimate does not include the ova in the attenuated fragments, which would probably yield as many more. These numbers are only approximations, but they probably are far below the actual numbers. It would be much within the bounds of probability to say that for each pelican on Yellowstone Lake in any season there are 5,000,000 eggs of *Dibothrium cordiceps* discharged into the waters of the lake, under such conditions that make it probable that a small percentage of them eventually obtain lodgment in their proper intermediate host, the trout.

V.—REMARKS ON CESTODS.

• During my sojourn at the hotel on Yellowstone Lake, at which time I met several tourists and others from various parts of the country, from England, and from France,

all of whom were more or less interested in the so-called "wormy trout" of the lake, and were especially anxious to know something of the cause of the malady, I found that with an occasional exception it was necessary for me to preface any remarks I had to make in answer to queries by giving a short disquisition on tapeworms in general before I could make it clear that I was not a raving theorist when I stated that the cause of the wormy trout was probably the wormy pelican.

Since this report is likely to fall into the hands of some who may be interested enough to read it, but whose previous reading on the subject of tapeworms has never extended beyond the obtrusive headlines of some quack advertisement, I have deemed it expedient to give a very brief account of the life history of a typical and familiar cestod worm, following this with an equally brief statement of what has been found out with respect to the life history of a near relative of *Dibothrium cordiceps*, before giving an account of what is the probable round of life of the latter worm.

The cestods, then, are a peculiar natural order of worms, all the members of which are parasitic during all or at least the greater part of their existence. As a rule, two animals of different kinds, and related to each other as eater and eaten, are required to enable the cestod to complete its life history. One of these is called the final and the other the intermediate host, the cestod being in each case a more or less unwelcome guest.

Probably the best-known member of this order is the common pork tapeworm (*Tænia solium*), whose intermediate host is usually the pig, in whose flesh it passes the larval or encysted stage of its life, constituting the so-called "bladder worm" or "measles" of measly pork. In order to attain the adult stage it is absolutely necessary that the bladder worm be swallowed by the proper animal. In this case the proper animal is man, in whose intestine the bladder worm becomes the adult tapeworm. The pig is therefore an intermediate and man a final host of the common tapeworm. The life history of the tapeworm proceeds, therefore, in this wise: Man, partaking of improperly cooked pork containing larval tapeworms, swallows one of the latter, which, being liberated by the action of the digestive fluids from the cyst of connective tissue in which it is inclosed, soon finds a lodgment on the walls of the duodenum or other part of the small intestines, where it clings by means of an exceedingly small head provided with minute hooks and four small sucking disks. The body gives rise to a chain of joints or segments, which rapidly mature, and are voided with their contained eggs in the natural way, and, under certain conditions not necessary to detail, find their way into the stomach of the pig. A minute embryo is there developed from each egg, which penetrates the walls of the stomach or intestine, burrows through the tissues, and finally comes to rest, usually in the muscular tissue, where it becomes encysted and develops into the bladder worm. Thus the humble round of its passive, though somewhat eventful, life is complete.

The worm which infests the trout belongs to the genus *Dibothrium*, or as it is frequently written, *Bothriocephalus*. It has been known for some years that certain forms related to this genus, which as larvæ, known by the name *Ligulæ*, infest many of the European fresh-water fishes, more especially the *Cyprinidæ*, reach their final or mature stage in a variety of aquatic birds. This has been demonstrated by the experiments of Duchamp and Donnadiou, who succeeded in raising mature *Dibothria* in the intestines of ducks, which had been fed *Ligulæ* from the Tench. The migrations in this case, as made out by Donnadiou, are as follows: The eggs develop in the water,

where they give rise to ciliated embryos, which bear a close resemblance to ciliate infusoria. These pass into fishes, particularly the *Cyprinoids*, where they become established in the peritoneal cavity. The round of life is completed in the intestines of aquatic birds, where the eggs are rapidly formed.

VI.—REASONS FOR REGARDING THE PELICAN AS THE FINAL HOST OF D. CORDICEPS.

While there seems to be no reason to doubt that the tapeworm found in the pelican is the adult of the trout parasite, it may be well to sum up the evidence which has led to that conclusion.

In the first place, it is to be noted that the parasite of the trout is a true larva and shows no signs of assuming the adult condition in the trout. Even the largest specimens, which have left their blastocysts and migrated into the tissues of their host, show but the faintest beginnings of the reproductive organs. Moreover, no cestod is known to attain the adult condition elsewhere than in the alimentary canal of its proper host. Again, out of the large number of trout examined there was not a single case of a mature worm of this genus in the alimentary canal. A few of the large trout of Yellowstone Lake were convicted of cannibalism, since their stomachs contained remains of trout, the only species of fish in the lake. There is no doubt that a large number of trout of the lake are eaten by larger fish of the same species. If the flesh worm of the trout ever matures in the intestine of the trout, or, in other words, if the trout is both intermediate and final host of this parasite, I should have found some evidence of it. Failing to find the adult in the trout, search had to be made among the animals which feed on the trout. A very brief consideration of the fauna of the Yellowstone region was sufficient to make it clear that the adult form of this worm must live in the intestine of some of the fish-eating birds that inhabit the lake. Moreover, since the cause of infection must extend through several months of the year, as shown by the variety of sizes of parasites occurring in a single fish, the final host is seen to be more probably a bird that stays through the summer than one which is only a visitor. Pelicans abound on the lake, one or more of them being usually in sight, on any part of the lake, at any time of day during the summer months. They have numerous roosting-places and at least one breeding-place on the lake. They are known to be notorious fish-eaters. It is clear, therefore, that collateral evidence alone points strongly to the pelican as a, if not the, final host of the flesh worm of the trout.

Evidence of a more direct nature, however, was obtained by the capture and examination of four pelicans. Their stomachs contained partly digested remains of large trout, and practically nothing else, thus demonstrating their ability to capture the large trout of the lake, and showing that they live exclusively on a fish diet; in the intestines of two of them were tapeworms, which there is no reason to doubt are the adult stage of the trout parasite. When one of these worms from the pelican is compared with a parasite from the flesh of the trout, the head with its characteristic bothria, or pits, is found to be practically unchanged. The strobile, or jointed body of the worm, is, as might be expected, much longer and larger in every way. There do not appear, however, any characters in one that are contradicted in the other.

On August 9, on the shore of the southeast arm of Yellowstone Lake, I picked up at the edge of the water three fragments of a *Dibothrium* strobile. The largest of these fragments was 70 millimeters in length and 6 millimeters in breadth. It was

mature, contained ova, and was evidently identical with those found in the intestine of the pelican.

This fact confirms what seemed probable from a study of the worms from the pelican, viz: that the strobiles are passed in chains from the birds. The excessively parasitized condition of some of the trout may thus be accounted for.

Again, some of the contents of the rectum of a pelican, in whose intestine specimens of *D. cordiceps* had been found, was preserved in alcohol for examination. Upon examination of a small portion of this material several ova were found which were easily recognized to be ova of *D. cordiceps*. A small fragment of the strobile of the same parasite was also found, which was much frayed evidently by the digestive processes of the host.

It may therefore be taken as demonstrated that both ova and fragments of the strobile of *D. cordiceps* find their way into the water where they may be swallowed by the intermediate host, the trout.

Of course this argument does not quite amount to a demonstration. If some one who has the time, opportunity, and inclination would conduct a series of experiments of feeding specimens of trout parasites to ducks, in which they might develop, or, better, to pelicans, in which I think they will certainly develop, it would serve to raise a part of the history of this worm entirely out of the regions of conjecture.

There remains also to be ascertained the fate of the eggs of the pelican tapeworm after they have been consigned to the water.

VII.—CONSIDERATIONS RELATING TO THE PARASITISM AMONG THE TROUT OF YELLOWSTONE LAKE.

In these considerations two problems will be discussed: First, to account for the abundance of parasitized trout in Yellowstone Lake; and, second, to account for the migration of the parasite into the muscular tissue of its host.

In order to reach a proper understanding of the matter, a brief review of some of the physical features of Yellowstone Lake and the surrounding region is necessary. Yellowstone Lake is a large body of water of very irregular outline, containing about 150 square miles of surface and having a coast line of approximately 100 miles. It lies near the great continental divide and empties through the Yellowstone River into the Missouri-Mississippi River system. About 18 miles below the lake there are two falls in the river. The upper fall is 109 feet in height, the lower, which is one-half mile farther down stream, is 308 feet in height. On the western side of the continental divide there are three lakes, much smaller than the Yellowstone, but still quite considerable bodies of water. These are called Heart, Lewis, and Shoshone, respectively, and each is not more than 8 miles in an air line from the nearest point on Yellowstone Lake. Lewis and Shoshone Lakes empty through Lewis River into Snake River, a tributary of the Columbia. Between them and Snake River there are falls of some 60 feet in height. Heart Lake empties into Snake River through Heart River, but there are no falls on this latter stream.

The natural distribution of fish in these lakes presents some peculiarities which should be mentioned here. In Lewis and Shoshone Lakes there are no fish. This is not due to an absence of food nor to the presence of conditions unfavorable to life, since these lakes were found to be swarming with amphipods, entomostracans, and

insect larvæ. Plainly, therefore, the presence of falls on Lewis River, insurmountable by fish, must be regarded as the real reason why there are no fish in these lakes.

In Heart Lake, on the other hand, there are three or four species of fish, viz, the trout (*Salmo mykiss*), the chub (*Leuciscus atrarius*), the sucker (*Catostomus ardens*), and probably the blob (*Cottus bairdi*), all common species in the Rocky Mountain waters. This fish fauna is therefore what we might expect to find in the lake.

In Yellowstone Lake there is but one species of fish, viz, the trout (*Salmo mykiss*), identical with the trout of the waters on the western side of the continental divide. The lake was found teeming with this species of fish and no other by the first explorers of the region. It is not at all probable that the lake was stocked by the aborigines, and the explanation given by Dr. Jordan is doubtless the correct one, namely, that the trout gained access to the waters of the Upper Yellowstone through Two-Ocean Pass, where the waters of the Yellowstone and the Snake arise from the same swampy meadow on the great continental divide. Prof. F. V. Hayden has shown (Bull. U. S. Geological Survey, vol. v, No. 2, "The so-called Two-Ocean Pass") that during times of high water caused by the melting snows, there is actual connection between Atlantic Creek, a tributary of the Yellowstone, and Pacific Creek, a tributary of the Snake. It seems reasonable, therefore, that the trout, an active and somewhat gamy fish and fond of the colder streams, should make its way over the divide, while it would be exceedingly unlikely that the more logy sucker and chub should, under the circumstances, attain a like distribution.

Since there are no fish in Lewis and Shoshone Lakes it is obviously necessary to make a comparison here only between Heart and Yellowstone Lakes.

The invertebrate life of these lakes, while affording one or two interesting contrasts, presents no differences that would have any bearing on the presence or absence, abundance or scarcity of parasites. There is but little difference in elevation, Heart Lake being 7,469 and Yellowstone 7,741 feet above ocean level. The depth, so far as known, is much the same, although the Yellowstone, being much the larger body of water, will probably be found to have the greater depth. A depth of 146 feet was obtained at a distance of about 800 feet from the west shore of Heart Lake, where the bottom temperature was 40° F. A depth of 159 feet was obtained on the west arm of Yellowstone Lake at a distance of 2,000 feet from the shore, the temperature at bottom being 42° F. A depth of 195 feet was found at a distance of about a mile from shore at the north end of the lake. The temperature of the surface water varied with the time of day, but was practically the same in the two lakes. Near shore, at our camp on the west arm of the Yellowstone, on August 2, at 9 a. m., the surface temperature was 54° F. So far as the temperature of the lake water is concerned and the invertebrate life of the two lakes, the fish in Heart Lake and those in Yellowstone Lake are living under substantially similar conditions. Whatever influence the presence of warm water from hot springs and geysers exerts, the conditions are practically the same, since each has geyser and hot spring regions on its borders and each receives warm tributaries from such regions.

I think it likely that after all the only difference between the two lakes, that touches this question, lies in the fact that, while in Heart Lake the trout are associated with the chub and the sucker, and consequently suffer or profit as the case may be by the mutual reaction which this association implies, in the Yellowstone they are alone and neither profit by the presence of another species, which they might use for

food, nor suffer from having a part of their food supply appropriated by another species, nor receive partial immunity from sudden death by having their co-species furnish a part of the food of their common enemies.

Indeed I am not sure that the proportion of parasitized trout in Yellowstone Lake is so overwhelmingly greater than it is in Heart Lake. While I did not find any flesh parasites among the Heart Lake trout, I found that a great many of them had the parasites in the peritoneal cavity, both encysted and free among the pyloric cœca.

Pelicans were seen frequently during our stay on Heart Lake and their breeding place at the south end of Yellowstone Lake is only 10 or 12 miles away. It would be very strange, therefore, if the trout of Heart Lake were found to be free from these parasites.

Neither am I at all certain that the parasites of the Heart Lake trout never penetrate the flesh of their hosts. However, after examining a great many trout from this lake without finding any penetrating the flesh, it may be worth while to consider this question: Why should the parasites of the Yellowstone trout have the habit of burrowing into the flesh of their hosts, while those of Heart Lake seldom or never do?

I am not sure that I can give an altogether satisfactory answer to this question. It appears to me, however, that the reason for this difference is to be found in the peculiarly isolated and circumscribed situation of the trout in Yellowstone Lake. In Heart Lake the trout have at least two species of fish besides their own to feed upon; in Yellowstone Lake the trout, if they are to eat fish at all, are obliged to resort to cannibalism. This is certainly done to some extent. In a few cases I have found evidence of it in the stomachs of the Yellowstone trout. In each such case the cannibal was a trout above the average size. Mr. Elwood Hofer had also observed this fact and stated as the result of his observation that "occasionally a cannibal is met with, and when it is, it is sure to be a big fish."

The Yellowstone Lake trout are confined to the lake and the river above the upper falls. It is true that this species is found in the river between the falls and below the lower falls, being quite abundant in the Yellowstone River and its tributaries. It is not likely that large fish could be carried over the lower falls and live; small fish and ova, however, might be so transported uninjured. Whatever may be the truth with regard to the passage of fish over the falls, it is certain that no fish could return to the lake after having once made the descent. The trout of the lake, therefore, are compelled to pass their whole life within the limits of the lake and its tributaries, or if they do leave, the door is shut behind them with no hope of its ever opening for their return. In Heart Lake the case is different; not only can the trout leave the lake at will, either by tributary streams or by the outlet, but having left they can return again.

To what extent these fish migrate with the changing seasons and diminishing food supply, I have no exact knowledge. Whatever may be their habits in this regard, the trout of Yellowstone Lake are forced to limit their migrations to the lake and its tributaries, and to the less than 20 miles of river between the outlet and the upper falls. The trout, being thus circumscribed in their range, if from any reason their food supply should fail, must suffer the consequences. They can not seek new feeding-grounds. If their food should be of such a kind as to produce peculiarities of flavor, or if it should contain the germs of disease or parasitism, they will be continu-

ally exposed to the source of contagion or parasitism with no respite, with no seasons of relief except what may be incident to the nature of the germs. It follows, therefore, from the peculiar conditions surrounding the trout of Yellowstone Lake, that if there is a cause of parasitism present in successive years the trout are more liable to become infested than they would be in waters where they had a more varied range. Trout would become infested earlier and in greater relative numbers, and the life of the parasites themselves, that is, their residence as encysted worms, must be of longer duration than would be the rule where the natural conditions are less exceptional.

Again, in such cases of parasitism as that under consideration, where the parasite is a larval cestod and the intermediate host the only animal of its kind in this region, the final host is more likely to partake of parasitized food than he would be if part of his food consisted of other species of fish not harboring this parasite. For example, it may be supposed that pelicans, when in the vicinity of Heart Lake, feed indifferently on trout, chubs, and suckers. Even if the trout stood an equal chance with the others of being eaten, which is hardly to be supposed since it is a more active fish than they, it would then constitute but one-third of the food of the pelican. The chances of the pelican's becoming parasitized would therefore be diminished to one-third what they would be from its diet on Yellowstone Lake. But with this diminished parasitism in the final host would go a smaller amount of eggs from the adult parasites to be disseminated where the fish are likely to get them.

As a matter of fact there can not be this difference between the parasitism of the trout of Yellowstone and of Heart Lake, as these bodies of water are so near together that the pelicans found on the one are the same individuals which visit the other.

While in camp on Heart Lake, and also on the west arm of the Yellowstone, we saw several pelicans, but secured no specimens. After we reached the hotel on Yellowstone Lake I made an excursion to the southeast arm of the lake for the purpose of securing specimens of these birds. The southern end of the lake is as yet almost never visited, and we discovered that the pelicans not only roost, as was known, but also breed on the small islands there. Four pelicans were obtained on Molly Island in a deep bay on the west side of the southeast arm of the lake. Our party were in two rowboats, Mr. F. D. Booth, with our only shot-gun, in company with Messrs. Thompson and Coughlin, visited the island and shot the birds for me. As we had found the pelicans thus far rather shy, I and my companion, Mr. Curl, did not approach the island, but rowed across to the northern shore, keeping well outside of the island for fear of frightening any birds which might be there. I thus, much to my subsequent regret, missed seeing the breeding-place of these interesting birds. Mr. Booth reported that they could easily have secured a boat load of the birds if it had been deemed necessary. He estimated that there were at least five hundred pelicans, young and old, on the island, less than one hundred of which were young. The young were large enough to take care of themselves by running and swimming, but could not fly much. The old birds refused to leave the neighborhood of their young and so could readily be shot. The specimens secured were all adults and measured 92, 96, 97, and 98 inches, respectively, from tip to tip of the wings. They had an exceedingly rank, fishy smell, and the gentlemen who visited the breeding-place bore testimony in a variety of select epithets that the smell of the place was horribly bad. The result of an examination of these birds has already been given. Many gulls were also found breeding on this island.

It is probable that other small islands in the southern end of the lake, for example, Peale's Island in the south arm, may also be breeding-places of the pelican. We saw them on our return, roosting on the south end of Frank's Island, but we did not pass near enough to ascertain whether it was a breeding-place or not.

It is easy to see from the foregoing why the fish of Yellowstone Lake should be greatly infested by these parasites. There are probably not less than one thousand pelicans on the lake the greater part of the time throughout the summer, of which, at any time, not less than 50 per cent. are infested with the adult form of the parasite, and since they spend the greater part of their time on or over the water disseminate millions of tape-worm eggs each in the waters of the lake. It is known that eggs of other *Dibothria* hatch out in the water, where they swim about for some time, looking much like ciliate infusoria. Donnadieu found in his experiments on the adult *Dibothria* of ducks, that the eggs hatched out readily in warm water and very slowly in cold. If warm water, at least water that is warmer than the prevailing temperature in the lake, is needed for the proper development of these ova, the conditions are supplied in such places as the shore system of geysers and hot springs on the west arm of the lake, where for a distance of nearly 3 miles the shore is skirted by a hot spring and geyser formation with numerous streams of hot water emptying into the lake, and large springs of hot water opening in the floor of the lake near shore. Trout abound in the vicinity of these warm streams, presumably on account of the abundance of food there. They do not love the warm water, but carefully avoid it. Several persons with whom I talked on the subject while in the park assert that diseased fish, that is to say, those which are thin and affected with flesh-worms, are more commonly found near the warm water, that they take the bait readily, but are logy. I frequently saw pelicans swimming near shore in the vicinity of the warm springs on the west arm of the lake. It would appear that the badly infested or diseased fish, being less active and gamy than the healthy fish, would be more easily taken by their natural enemies, who would learn to look for them in places where they most abound. But any circumstances which cause the pelican and the trout to occupy the same neighborhood will multiply the chances of the parasites developing in both the intermediate and final host. The causes that make for the abundance of the trout parasite conspire to increase the number of adults. The two hosts react on each other and the parasite profits by the reaction. About the only enemies the trout had, before tourists, ambitious to catch big strings of trout and photograph them with a kodak, began to frequent this region, were the fish-eating birds, and chief among these in numbers and voracity was the pelican. It is no wonder, therefore, that the trout should become seriously parasitized.

It may be inferred, from the foregoing statements, that the reason why the parasite of the trout of Yellowstone Lake migrates into the muscular tissues of its host must be found in the fact that the life of the parasite within the fish is much more prolonged than is the case where the conditions of life are less exceptional.

VIII.—REMEDY.

A natural inquiry following the discovery of the true nature of this parasite will be: What remedies, if any, are proposed?

A very effective remedy, and one which suggested itself immediately to Captain Boutelle, he being an enthusiastic lover of the gentle sport of fishing, is to extermi-

nate the pelican. It would, indeed, be a lamentable result of my investigation if that dire calamity should befall the unwitting cause of this peculiar malady. One of the most charming minor effects of the singularly beautiful scenery of Yellowstone Lake to my mind is produced by the presence of these noble birds. I do not think such heroic measures are either called for or advisable. The trout of the lake can never figure as the food supply of a large number of people. Their abundance or scarcity neither raises nor lowers the price exacted of tourists by the hotel association. They are destined to contribute more to sport than utility. A speedy remedy is therefore not necessary.

With the increase in numbers of visitors to the lake will go greater destruction of trout by enthusiastic fishermen. This will probably reduce the number of diseased fish at a more rapid rate than it will that of the healthy ones, and if the precaution be taken not to leave dead fish on the shore, and not to throw them in the water, where in either case they would probably be eaten by the pelican, the chances of the latter's becoming infested with the parasites will be correspondingly lessened. And particularly if the lake be stocked with some other species of fish (of which I think the chub of Heart Lake is most suitable, since it is an omnivorous feeder, and therefore not likely to interfere seriously with the food of the trout, while furnishing the latter with much-needed animal food, and at the same time lessening the chances of the trout's being eaten by the pelican, and since the parasite does not develop in the chub) a lessened parasitism of the pelican would result; and with fewer parasites in the pelican would go a diminution in the number of ova disseminated in the water, and consequently a lessening of parasitism in the trout.

It is probable, also, that the presence in the lake of some fish which would form a part of the food of the trout would result in imparting a more vigorous constitution to the latter and make it better able to withstand the strain of excessive parasitism.

At any rate, before a war of extermination is waged against the pelican it would be well to ascertain whether or not *Dibothrium cordiceps* develops in other fish-eating birds. My own investigations have not been extensive enough to enable me to decide this question. Beside the pelican, the only birds of the lake that I had an opportunity to examine were three species of duck, none of them piscivorous, one hawk, one heron, and three gulls. In one of the latter I found a *Dibothrium* bearing some resemblance to the trout parasite, but evidently a distinct species.

WASHINGTON AND JEFFERSON COLLEGE, January 1, 1891.

EXPLANATION OF FIGURES.

The following letters have the same significance in relation to all the figures where they are used.

<i>c.</i> cuticle.	<i>p. v.</i> peripheral vessels.	<i>ov.</i> ova.
<i>b.</i> bothrium.	<i>m. v.</i> marginal vessel.	<i>P.</i> cirrus.
<i>l. m.</i> longitudinal muscles.	<i>a. v.</i> aquiferous vessel.	<i>P.</i> cirrus bulb.
<i>c. m.</i> circular muscles.	<i>vit.</i> vitellaria.	<i>d.</i> vas deferens.
<i>f. v.</i> fibro-vascular layer.	<i>o.</i> ovary.	<i>t.</i> testes.

Drawings by the author.

PLATE CXVII.

- Figs. 1 to 14. Larval stage of *Dibothrium cordiceps* Leidy, from peritoneal cavity and muscular tissues of the trout (*Salmo mykiss*).
- Fig. 1. Sketch of head from life, marginal view, lateral of body, from muscular tissue of host; after lying in water three or four hours this specimen measured 34 centimeters in length and 2.5 millimeters in breadth, nearly linear, \times about 12.
- Fig. 2. Head of specimen from flesh of host, marginal view of head, lateral of body, alcoholic, \times about 12.
- Fig. 3. Same view of another specimen, alcoholic, \times about 12. Lateral view of same specimen shown in Fig. 8.
- Fig. 4, 5, and 6. Sketches from life showing some of the diverse shapes assumed by the head and neck of a living worm, each magnified about 12 linear diameters.
- Fig. 7. Head and neck of an alcoholic specimen, \times about 12.
- Fig. 8. Lateral view of head, marginal of neck, same specimen as sketched in Fig. 3, \times 12.
- Fig. 9. Lateral view of head, marginal of neck; large specimen, 35 centimeters in length, from flesh of host, alcoholic, \times 12.
- Fig. 10. Median segment of same specimen, \times 12.
- Fig. 11. Anastomosing vessels of water-vascular system, middle of body, compressed, sketch from life.
- Fig. 12. Water-vascular system, posterior end of large specimen, compressed, sketch from life.
- Fig. 13. Posterior end of another smaller specimen, compressed, sketched from life; *a*, pulsating vessel; *t. p.*, terminal pore.
- Fig. 14. Posterior end of large specimen, alcoholic, \times 12. The emargination is sometimes deeper and sometimes not so deep as this.
- Figs. 15 to 34. Adult stage of *Dibothrium cordiceps* Leidy, from intestine of the white pelican (*Pelecanus erythrorhynchus*).
- Figs. 15, 16. Marginal view of head, lateral of neck of two different alcoholic specimens, \times about 15 and 24, respectively.

PLATE CXVIII.

(Adult stage of *Dibothrium cordiceps* Leidy, intestine of white pelican.)

- Fig. 17. Marginal view of head, lateral of neck, alcoholic, \times about 24. Same specimen as shown in next figure.
- Fig. 18. Lateral view of head of specimen figured in No. 17.
- Fig. 19. Lateral view of head of another specimen, \times 15, alcoholic.
- Fig. 20. Segments of body towards anterior end, alcoholic, ventral surface, \times 4.
- Fig. 21. Antero-median segments, ruffled margin, dorsal surface, alcoholic, \times 4.
- Fig. 22. Median segments of small fragments, alcoholic, \times 12.
- Fig. 23. Mature segments from large specimen, alcoholic, \times about 5.

- Fig. 24. Longitudinal section, near median line, parallel to margin of strobile; the uterine walls have been absorbed and the ova lie in masses; the segmented appearance of the body is here shown to be only superficial.
- Fig. 25. Transverse section through cirrus bulb, highly magnified; *a*, retractor muscles of cirrus.
- Fig. 26. Transverse section through beginning of vagina, showing the enlargement of that organ near the vaginal orifice into a seminal receptacle, highly magnified.
- Fig. 27. Transverse section of mature segment showing the different layers of the body.

PLATE CXIX.

(Adult stage of *Dibothrium cordiceps* Leidy, intestine of white pelican.)

- Fig. 28. Diagrammatic sketch of mature segment, showing relative position of genitalia, etc.
- Fig. 29. Ovum as seen in a thin section of a mature segment; the knife has cut away a part of the shell exposing the granular contents collected into spherical masses, highly magnified.
- Fig. 30. Diagram of female generative organs, from ventral side; *v. d.*, vitelline duct.
- Fig. 31. Section of vagina, highly magnified, showing ciliated interior.
- Fig. 32. Portion of transverse section of segment, highly magnified; *Par.*, parenchyma of inner core of body.
- Fig. 33. Longitudinal median section, parallel to the margin, through cirrus bulb, uterus, vagina, etc.
- Fig. 34. Transverse section of head; *n*, nerve ganglia, a row of which extends across the section from the inner margin of one marginal vessel to the other. The heavy stippling represents the cut ends of longitudinal muscles; *s. c.*, subcuticular longitudinal fibers particularly well developed in the bothria.





