XX.—ADDITIONAL OBSERVATIONS ON THE FUNGUS DISEASE AFFECTING SALMON AND OTHER FISH.

By A. B. Stirling.*

* * * By the kindness of James Tait, esq.,† I received a common river-trout and a minnow, both of which were captured near Kelso bridge in Tweed River; both specimens were affected with fungus—the *Saprolegnia ferax*. I may here mention that I have noticed several able letters, which have appeared in the Scotsman newspaper from time to time, in which the writer states that the fungus is only a secondary attack, and that a primary disease of an inflammatory kind first affects the head and other parts of the salmon before the fungus can settle upon it. I do not for an instant doubt the fact that the writer saw fish with sores of the kind described by him upon them, when there was no fungus present to cause them. I can only say that, among all the fish which I have received for examination, consisting of salmon, sea-trout, smolts, common trout, grayling, and minnows, I have not seen one with a sore on which this fungus was not present; while on every fish examined there were some patches of fungus which could easily be wiped off, leaving only a slight stain, and in some instances no mark could be discerned, and no loosening and shedding of the scales or ulceration of the subjacent surface. Again, in every instance where the fungus was rank, long-seated, and felted, sores in every degree, from slight abrasion to sloughing, were found under them. With reference to the trout and the minnow before mentioned, the trout had fungus seated upon the gums of both the upper and lower jaws, which involved both the teeth and lips, and had spread upward and backward upon the head, and its destructive progress could be easily traced. First, the skin of the lips was broken in several places, and shreds of it were hanging loose, to which the fungus was adhering; while, as it spread backward over the nostrils and crown of the head, the skin and its pigment spots could still be seen intact where the fungus was seated, a portion of which had been carefully shed aside to expose the skin. On each of the pectoral fins a patch of young fungus was seated, and the mucous coat was seen through the fungus to be quite entire; the same appearance was seen upon the anal fin and scaled parts of the body. The minnow had only

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†Of Kelso.

one patch of fungus upon it, which was seated within its mouth on the inner margin of the right lower jaw; it filled the mouth, which was distended by its growth; and every other part of its body was free from fungus or blemish of any kind.

The reason why most of the fish affected with fungus are first attacked by it upon their heads may arise from various causes. All river fish present their heads to the downward current of the water, whether they are swimming or at rest, and as the spores of the fungus are floating down with the stream the heads of the fish are the first parts to come in contact with and be affected by them. Further, the mucous glands are most numerous and active upon the head of the fish, which is also more thickly covered with mucous than other parts of the body, and the spores which fall upon it adhere more readily; and the fins and tail, from their continuous waving motion, are more liable to arrest the passing spores than the parts of the body from which they spring, and, from this cause, are generally affected sooner than the bodies of the fish.

The number of the dead and dying fish of all kinds removed from the river Eden in 1878 by the police, and published by Mr. Buckland in his report for that year, show that there were 1,271 salmon, 140 fresh-water trout, and 40 brandlings or parr, being over 50 of the large fish to every one of the smaller. About 1,000 of the salmon were clean fish, and it may be inferred that the trout and parr were also clean, which goes far to show that the so-called disease is as much a mechanical as a functional one. Further, from documents descriptive of the effects of the disease in the river Tweed, in the lower district, during this season, 1879, which were collected by the police from taxmen and practical fishermen on the river, I find that the proportion of large fish affected, dead, or dying—namely, salmon and sea-trout—is very great compared with the smaller fish which were found to be affected in a similar way. The smaller fish alluded to consist of river-trout, grayling, smolts, perch, and gray mullet.

From observations of the fungus, and of the fish affected by it, I am led to believe that the so-called salmon disease does not depend upon a prediseased condition of the fish. It is a true parasitic attack, to which every fish in any affected river seems to be liable, as every kind of fish, irrespective of condition, appears to be a proper nidus for the propagation of the *Saprolegnia ferax* when a living spore from that fungus attaches itself to it. While engaged during the spring and summer in the microscopic examination of the *Saprolegnia ferax*, I observed that as the season advanced many of the patches of fungus seated upon the fish were barren, consisting of spear-shaped filaments only, having no zoosporangia at their apex, and consequently they produced no zoospores. The filaments were long and very thin, and almost void of protoplasmic contents, indicating that the plant was losing its force and in a state of decay.

The *Saprolegnia ferax*, in all probability, is always present in our rivers

in more or less active condition. It is believed that this fungus has two modes of reproduction, namely, by oospores and by zoospores. The oospores are few in number, and may be looked upon as ova, and they required sexual impregnation. They are called resting spores, from a belief that they remain dormant in the water for an indefinite period, which may continue for many years; and during this phase of their life they may germinate in limited numbers, providing only for the continued existence of the species. While in this state of abeyance there is no plague of fungus, from the ova only producing neutral or barren plants, which bear no fruit or seed. After a period of longer or shorter duration, a season, or a series of seasons, may follow, during which an unknown influence arises which acts upon the resting spores, by which they are stimulated to great reproductive energy, and the plants they produce being fruitful, the asexual mode of reproduction commences.

The zoospores are produced in pod-like cases called zoosporangia, which are situated at the apex of the filaments, and may be looked upon as fruit or seed. They are the ciliated spores and are the media by which the fungus is communicated to the fish. The zoospores are produced in great numbers, each zoosporangium containing from 100 to 150 of them. The oospores or ova are produced in a globular sack, which forms at the root-ends of the filaments or upon the roots themselves. Those sacks are called oogonia, and each sack contains a few oospores or ova, three or four to nine being the numbers I have observed in the four instances in which I have seen them in the whole courses of my investigations.

Suppose an oospore (resting spore) to be capable of producing, under favorable circumstances, a plant carrying 100 filaments, and each of the filaments to produce 100 zoospores, 10,000 germs would be derived from a single ovum or resting spore, every one of those germs being capable of producing a plant as productive as that from which it derived its existence; a multiplication of innumerable millions would be produced in a few days, the ciliated spores being as plentiful in the water as snow-flakes are in the air during a snow-shower; and in this way the plague of fungus, the so-called salmon disease, is originated.

I obtained in April the living fungus from a grayling caught by Mr. J. Williams, student of medicine, when angling in Keerfield Pool in the Tweed, near Peebles. It had been cut in two halves and the tail portion selected; it was packed in a tin vessel with wet moss, which had preserved the fungus in active vegetative growth, when I received it on the morning after its capture. A pale pink bloom was plainly visible over the whole surface of the matted fungus, and, when it was held up between the eye and the light, a new growth appeared to cover the older fungus on its outer surface to about one-eighth of an inch in height.

When examined under the microscope in water, free ciliated zoospores, which had escaped from the zoosporangia situated at the extremities of the filaments, were observed in motion; they moved in a fitful way, by shorts jerks, not by a continuous movement.

Those zoospores were pyriform in shape during the short time they were observed in motion; on becoming stationary the cilia disappeared, being probably withdrawn into the body of the spore, which then assumed a globular form. This change took place in a very short time—not exceeding ten minutes—and while under observation minute projections became visible on the edge of the spore, which grew into delicate filaments of considerable length. I have succeeded in fixing the development of the fungus in this state, and it can be seen in various stages of growth, all of which were ciliated spores within the space of one hour.

This, the asexual mode of propagation, is remarkable for the rapidity with which it is accomplished. A few of those ciliated spores become attached to any part of either a healthy or a diseased fish; in one hour the cilia will have disappeared and a filament of some length will have sprouted from the spore. Thus, in a single day, a fish on which no fungus could be discerned is to-morrow seen to be affected, and in three days is spotted or patched over with fungus from head to tail.

In the second or sexual mode of production of spores a short pedicle is pushed out from one of the sides of a filament, on which a globular sack—oogonium—is formed, and within this sack a number of oospores are produced, which are spherical in shape and have a cell-wall or envelope, and some are provided with a nucleus in the center. These, after impregnation, escape from the oogonia, and are probably capable of living in the water for an indefinite period, in a dormant or resting state, until the conditions arise which are favorable for their germination.

It may be asked, how does the fungus affect the fish, and do any recover from its effects? The fungus produces a local irritation and inflammation of the integument, as is evidenced by the congestion and even ecchymosis of the true skin, by abrading of the scales, and in the more advanced stages by ulceration and sloughing, affecting the whole thickness of the integument and mucous surface.

Wherever the fungus adheres and spreads, the function of the skin is necessarily interfered with. Light, which is so essential to the fish in promoting its pigmentary secretions, is cut off from a large portion of its skin. Endosmosis, exosmosis, and the secretion of the mucus for lubrication are destroyed, and in this way constitutional symptoms would be occasioned which, if the disease continued, lead to the death of the fish.

The second question, "Do any fish recover from fungus attack?" may now be answered more hopefully. The fishermen and watchmen on the Tweed report having seen several fish with new skin growing over the sores upon their bodies, from which this fungus had disappeared, and I am inclined to believe that this is so. A male kelt has been sent to me by Mr. List, which was taken in tidal water below Berwick bridge. This fish is 2 feet in length, and weighs about 3 or 4 pounds; it is supposed to have been affected with fungus, and to have completely recovered from its effects. No particle of fungus could be found upon

any part of its body, and there was only one raw sore. This sore was only five-eighths of an inch in length and three-eighths in breadth. It had evidently been larger, and had a smooth healing border. All the upper surface of the head and snout were covered with skin, but very uneven over its whole surface, from depressions and projections which may have been caused by sores which have been healed over, and the hinder part of the operculum had an irregular cicatrix of considerable size upon it. The breast and belly, from the gill-covers to the vent, were blood-streaked and spotted, and there were brownish marks upon both its back and sides as if fungus had recently adhered to it. All the fins were entire—not one ray was broken—and the fish as a whole looked remarkably well for a kelt, and if it had been affected with fungus, which I fully believe, its recovery has been almost perfect.

A salmon taken at some distance up the river, and which is affected with fungus, has been taken down to Berwick, and placed in a box or corve, and is now anchored in the river, in the tideway, where the water is at all times less or more salt, and at intervals is towed out to sea, where the full influence of the salt water acts upon it; and when I last heard of it considerable improvement had taken place. Mr. G. H. List has paid particular attention to the protection of any fish being affected with fungus disease in any of the coast fishing stations; and, after the most careful inquiry, no trace of any fish in the least degree diseased at any of those stations could be got, nor, as far as any fishermen either knew or heard of, was any salmon with fungus upon it ever seen in salt water.

I have tried to propagate this fungus upon dead flies, spiders, and other small animals, following the directions of Pringsheim, "N. A. A. L. C.," 1851, p. 417,* who says: "All that is required to obtain a living specimen of this singular plant is to allow the body of any small animal, such as a fly or spider, to float for a few days in rain-water exposed to the light. By this method a crop of *Saprolegnia* may be obtained at any season." In this way I got a fungus upon the flies and spiders after an exposure of from 12 to 20 days, which, on examination, was found to be a common mold, exactly similar to that produced upon a solution of gum-arabic, gelatine, and meat infusions. I have tried to propogate the *Saprolegnia* fungus upon minnows, but without success hitherto, doubtless because the method adopted did not provide the proper means, there being wanting the necessary stimulus which exists in the river, or, what is more likely, the life of the fungus itself. The minnows were placed in a large glass vessel filled with town water from the tap. A piece of skin with this fungus adhering to it was taken from a salmon smolt and placed in the water along with them. In three days they had eaten up both skin and fungus, and remained unaffected. Several large patches of this fungus were then taken from the skin of a

* Cited by Dr. Burdon Sanderson in his paper on the "vegetable ovum," Cyclopædia of Anatomy and Physiology, edited by Dr. Todd.

salmon and placed in the vessel along with them. In a few days it had all disappeared, and produced no effect. Another method was suggested by Mr. G. H. List, who also kindly furnished me with material for the trial. Pieces of skin with this fungus growing upon them were cut from the bodies of dead salmon at the river side, and were put into wide-mouthed bottles, which were at once filled with river water, the skin not being allowed to dry. On receipt of the bottles the pieces of skin, along with the water in which they were brought, were emptied into the vessel among the minnows. The water in the vessel was not changed for three days, at the end of which time the minnows were still unaffected. Fresh water was then put in the vessel, and the pieces of skin retained in the water, which was changed every second day for eight days. The minnows were not disturbed by the pieces of skin. They nestled under them and nibbled every morsel of fungus from them, hiding and playing about them until they had to be removed from putridity. All the minnows are still alive and are in beautiful condition, taking food greedily, worms cut small and crystals of sugar being their favorites. They have been kept since 14th May till now (12th July) and are as healthy and lively as when put in the vessel.