REPORT ON THE RESULTS OF THE BILHARZIA MISSION IN EGYPT, 1915.

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(Continued from p. 190, vol. xxvii, 1916.)

PART V.—ADULTS AND OVA.

The morphology of the adult worms, and of the eggs recovered from cases of bilharziosis in Egypt, has been dealt with exhaustively by several previous writers, notably by Bilharz, Leuckart, Fritsch, Lortet and Vailleton, and particularly by Looss.

In parasites generally there are certain small variations within the limits of a species both in size, shape, etc., of adults and of eggs. In Bilharzia hematoobia unusually striking and constantly recurring departures from the normal have been described. In Looss' monograph on the adult anatomy it is recognized that a number of these do actually occur, but others are, in his opinion, due to errors in interpretation by previous workers. These abnormalities, rather than the normal anatomy, are our more immediate concern. The differences that have been recorded in the shape of the eggs are of special interest. As early as 1851 Bilharz had noticed that certain of these, passed in the faeces, were distorted, the small terminal spine of the typical egg being apparently displaced laterally. These lateral-spined eggs he regarded as abnormalities.

In 1864 Harley [214] was so struck by the absence of these atypical forms in cases of bilharziosis seen in South Africa, that he named the South African parasite Distoma

\[1\] These numbers refer to titles in the Bibliography of Bilharziosis which accompanied the earlier sections of this Report.
capense, to distinguish it from the Egyptian parasite which gave rise to both types of eggs. The subject remained one of merely academic interest until 1902, when Sir Patrick Manson saw in London a case of intestinal bilharziosis, contracted in the West Indies, in which lateral-spined eggs only were present. In the following year he put forward the suggestion that: “Possibly there are two species of Bilharzia, one with lateral-spined ova, depositing its eggs in the rectum only, the other haunting bladder or rectum indifferently” [328]. This view was revitalized by Sambon in a series of papers, commencing with one in 1907, in which he formally named the new species after Sir Patrick Manson, “in appreciation of this, one of his many genial intuitions” [425, 426, 427, 428]. Sambon’s new species met with an unsympathetic reception, more especially from Looss, who held, with many elaborate arguments, and with some apparent success, that vesical and intestinal lesions in bilharzial infections in Egypt were caused solely by the one species, B. hamatobia. The whole controversy cannot be reviewed here, but the curious reader will find in the prolonged debate, “a stimulating vituperativeness” which makes it highly entertaining, if somewhat cruel reading.

Sambon’s Species. In his “Remarks on Schistosomum mansoni,” Sambon [425] explained that his “determination is based principally on the characters of the eggs,” but that in addition, he had “taken into consideration their different geographical distribution, the different anatomical habitat, and the different pathogenicity of the two species.” He maintained that “the lateral-spined ova are not found occasionally only, within the distributional areas of S. haematobium, as would necessarily be the case if they were the product of this species, but have a peculiar and wide geographical distribution of their own, being absent in many places where endemic haematuria and its causative agent are prevalent (Cyprus, South Africa).”

Looss’ Theory. The opposing theory put forward by Looss was, briefly, that “unfertilized females are not capable of producing other than abnormal eggs.” These abnormal eggs were for the most part the lateral-spined variety, and where they contained a miracidium this was attributed to parthenogenesis. Looss’ position, which met with clever criticism from Sambon, became somewhat changed later in the light of his own further observations, but his main tenets remained, and his final ground became, theoretically, unassailable without the aid of experimental evidence.

Looss’ Arguments. In Looss’ opinion “the strange and striking differences presented by the clinical and pathological pictures of bilharziosis as seen in various places” could be explained “on the presumptive life history of the parasite, in connexion with the habits of the host and the conditions of the country” [295]. Commencing with his postulate that infection is direct and takes place at all times through the skin, he maintained that the miracidia proceed to the
liver, where they develop into sporocysts, from which worms escape later into the portal veins. As at post-mortems it is not uncommon to find males, obviously of the same size and age, alone in the portal vein, he assumed that “they must have been generated at about the same time; this would become comprehensible on the assumption that they were generated in one sporocyst.” The female worms which are less common likewise would originate from a sporocyst. Applying these postulates to the ordinary conditions found in the Delta, it appeared to Looss that “several miracidia penetrate the body at short intervals and thus males and females will be present.” “In this case the females will not have long to wait for fertilization.” While waiting they will have produced a few abnormal eggs but being almost immediately captured by the males are carried off to the pelvic organs, with the result that “there is urinary bilharziosis characterized by the apparition of terminal-spined eggs in the urine; the same eggs may appear in the feces, but the lateral-spined ones will be so scarce that they seem to be altogether absent.” [295].

In countries where conditions are unfavourable for infection, i.e., where the population is scattered and the people do not bathe in crowds, or where water is scanty or swiftly running, and the chances of miracidia entering the skin are small, then the following train of events may be presumed: “On a single occasion a few miracidia manage to enter the skin and one gets safely to the liver. It produces males. The worms grow to sexual maturity, but finding no females they wait for a certain time and then undertake the journey to the pelvic organs alone. The liver is again free from worms; the infection remains without consequences.” This may recur as male producing miracidia are so common. Eventually a miracidium enters alone which gives rise to female worms. In due time these “begin to lay lateral-spined eggs.” The oviposition goes on, perhaps, for a long time. The number of lateral-spined eggs increases steadily; all are carried to the liver.” Some of these worms may migrate successfully as far as the large bowel.

Eventually there will be a “strong infection of the liver and some isolated patches in the wall of the intestine, but no terminal-spined ova will ever appear, nor will there be a regular infection of the bladder. After some time, the lateral-spined eggs of the liver begin to appear in the feces, and they continue being voided in this way for several years.”

Looss details other circumstances under which a secondary infection with terminal-spined eggs may be contracted by a case showing originally Manson’s intestinal bilharziosis if a sufficient interval has lapsed between the entry of the two miracidia. Lastly, infection by a large number of miracidia at a single exposure would result in a pure case of “urinary bilharziosis” [295].

Looss concludes that, from his point of view, “no sharp line of demarcation between the two types” exists. “They are simply the opposite ends of a continuous series of intermediary stages” [295].
Looss' Criticism of Sambon's Species.

After detailed criticism of Sambon's arguments, Looss dismisses them with the conclusion that "in all the evidence there is not the slightest detail which would really point to the existence of a distinct species in the West Indies and certain parts of Africa." He adds that one of the fundamental facts on which his views rest is that in 1852 Bilharz actually found in Egypt that "the eggs of S. hematobium and S. mansoni may occur in one and the same individual."

Replying in 1909, Sambon [428] pertinently points out that Bilharz's alleged observation has never been confirmed and that the interpretation that both lateral-spined and terminal-spined eggs were actually seen in the same individual worm does not necessarily follow from Bilharz's statement. In turn he attacks Looss' hypothesis, especially his assumption of the occurrence of parthenogenesis in the adults.

Looss' Readjustment.

The effectiveness of this criticism is revealed by the readjustment of his position by Looss in 1911 [298]. He now recognized that "the question of the formation of these eggs and the question of their fertilization are in reality independent." He is still of opinion that the uncopulated females are incapable of giving their eggs the normal shape. After fertilization the change to normal shape will not take place immediately; there will always be a transition period. There is thus no longer any necessity of admitting on the part of the egg cell a capability of developing by parthenogenesis." "I have received the impression that when once the production of normal eggs begins, the others are, as a rule, quickly evacuated." "That the females of S. hematobium can, and do, produce the two forms of eggs is beyond question even now."

American parasitologists attempted to settle the controversy by suggesting that possibly the eggs of S. mansoni were normal eggs similar to the abnormal forms, with distorted spine, produced by S. hematobium [271].

Bearings on Present Inquiry.

Obviously the possibility that, in Egypt, man harboured two distinct species of bilharzia worm complicated the transmission problem, already rendered intricate by the presence there of bovine and avian infections.

It was realized, however, that the full solution was not an essential preliminary to the conduct of experiments which were more urgently needed to provide the necessary data on which to base prophylactic measures for the protection of the troops. The Bilharzia cercariae found in Bulinus and in Planorbis, as well as other cercariae, were found to react in practically identical manner to changes in their environment; whether these were physical, such as exposure to heat, drying, etc., or chemical, such as exposure to dilute amounts of sodium bisulphate, etc. The B. cercariae showed the same limited capacity to survive in water and
caused local irritation due to penetration of the skin in animals exposed to infection by immersion. Thus the earlier parts of this report were written with reference to "bilharzia," without touching (save inadvertently by the use of "B. hamatobia" in the old inclusive sense) on the problem of the unity or duality of the parasite concerned in the causation of bilharziosis. Indeed, the success of these experiments led to a further delay. The lethal effect of very dilute solutions of coal tar derivatives on the cercariae raised the hope that if minute quantities of these substances could be got into the portal system unchanged, they might be found to destroy the bilharzia worms there. Thus, by cutting short the egg-laying period, the subsequent severity and duration of an infection might be considerably diminished.

Surgeon-General Ford was of opinion that a satisfactory method of treatment might prove of considerable service. Expert co-operation in the pharmacological aspects of the problem was obviously desirable. As soon, therefore, as it was evident that animals were being infected successfully, I decided to infect as many animals as were then available and to return to England to carry on further work on these lines. Infections were accordingly made from P. boissyi and from Bullinus. It was hoped that these would provide material still needed for the zoological inquiries not yet completed. A return in the autumn was foreshadowed, if facilities were obtainable, in the event of the need arising for further investigations through failure of the material or the upcrop of new problems.

EXPERIMENTAL TREATMENT NEGATIVE.

Most of the infected animals survived the homeward journey. Dr. H. H. Dale, F.R.S., kindly carried out a series of tests and the animals were afterwards dissected. It was agreed that none of the substances of known anthelmintic or cercaricidal value could be introduced into the portal system in doses lethal to adult parasites. This cleared the ground for a continuation of study of the specific nature of the cercariae found respectively in Bullinus and Planorbis.

The Cercariae in Planorbis and Bullinus.

In addition to the cercaria provisionally identified as that of an avian bilharzia worm, three bilharzia cercariae were provisionally differentiated from material collected at El Marg (figs. 45, 46, 47, Part III). Of these, one (fig. 45) infested P. boissyi; with it, later, but seen much less frequently, was a large form (fig. 46). This mollusc was not found in some other villages where bilharziosis was also prevalent. It was, therefore, apparent that even if eventually it was proved to be a carrier of infection to man, other species of mollusca must also be concerned. The search was therefore continued, and several weeks later, at the commencement of June, examples of the genus Bullinus was found to be likewise infested with Bilharzia cercaria of slightly different appearance (fig. 47). As cercariae, naturally discharged, became available from each source, animals were submitted to infection by immersion, and later by the mouth.
The animals first submitted to infection died from blockage of vessels by the growing worms before these had attained their full size. Such hyperinfection was at first courted to establish the fact that the animals in experimental use were actually susceptible. Later this had to be avoided to ensure that the infected animals would survive sufficiently long to show the effect of drug treatment on the worms in the portal system, and to give the growing worms sufficient time to attain sexual maturity and produce eggs whereby the specific character of the infection could be finally identified. This proved a much more difficult task. Too slight an immersion might result in a failure to infect or a failure to infect with enough to ensure the presence of females as well as males. Mishaps from all these causes befell in the animals taken to England, and as will be seen, necessitated a return to Egypt for further material.

Before leaving for London, two or three eggs only were seen. The first occurred in a female taken from the mesentery of a mouse that had survived until June 24. The others were seen a few days prior to sailing. These eggs were lateral-spined and were the result of infection with cercariae from P. boissyi. According to Looss' theory these were the early abnormal products of young sexually mature females of B. hamatobia; according to Sambon they should be regarded as characteristic ova of B. mansoni, the cause of intestinal bilharziosis; according to American parasitologists, they were merely early abnormal products of B. hamatobia, simulating the true lateral-spined egg of B. mansoni, the cause of bilharziosis in the New World. Males were present as well as females, but this fact had now no significance, since Looss had himself abandoned the view that the females produced eggs parthenogenetically. The females found had only reached the egg-laying state. It was possible that they were just entering Looss' "transition period."

Sufficient time had not elapsed since the submission of animals to infection from Bulinus to warrant an examination of these prior to sailing.

After reaching London, in July, animals continued, as before, to die from hyperinfection with young adults. At the beginning of August, four monkeys which it had been hoped would survive several months, began to pass eggs and died within a fortnight of intense infection. These eggs were lateral-spined. The cercariae used had been obtained from P. boissyi. No other type of egg was found. It could not be said, however, that the worms had become mature sufficiently long to have passed through Looss' "transition period."

Certain of the rats which had survived until September showed at post-mortem an extraordinary condition of the liver. This was enlarged and deeply pigmented with black amorphous granules. The surface was speckled with minute white spots. These were found to contain accumulations of lateral-spined eggs. The final peripheral veins were frequented by paired adult worms. The liver
from these cases was macerated and the eggs released in enormous numbers. Every described variation in size and shape of lateral-spined egg was then found, but no terminal-spined eggs were seen. These animals had been infected from *P. boissyi*.

It had proved impossible to obtain material of the occasional large cercaria in *P. boissyi* for experimental purposes, but it was anticipated that in the very large series of infections made with cercariae from *P. boissyi* for the experiments with drugs this cercaria would give evidence of its presence. Neither in the eggs nor adults resulting, however, was any indication seen of another species. The nature of this large cercaria remained, therefore, a perplexing mystery.

During September the animals submitted to very slight infection were still alive and were anxiously watched for evidence of successful infection. No eggs were passed, and as the length of time that had now elapsed since immersion was considered sufficient to allow of the worms attaining sexual maturity, those treated with cercariae from *Bullinus* were killed and examined. The results were disappointing. It was evident that in the attempt to infect so slightly as to ensure the survival of the animals for some months the number of cercariae that had actually entered had not been sufficient to ensure successful infection with paired adults. This experiment was repeated with certain of the animals slightly infected with cercariae from *P. boissyi*. No adult worms were found.

Reviewing the position early in October, I realized that the materials now available were insufficient to enable me to deal effectively with the question of the zoological relationship of the bilharzia worms that caused the symptoms of vesical and intestinal bilharziosis. Certain facts might justify a reopening of the Sambon-Looss controversy, which had reached a position of stalemate, but they would not render the final position taken by Looss untenable. With the *B. cercariae* available, it was clear that a complete solution was possible. The completion of this report was, therefore, postponed. I was granted permission to return to Egypt, and was enabled to do so by the Committee of the London School of Tropical Medicine, which allowed me to resume an unexpired portion of the Wandsworth Research Scholarship, which I had previously held.

Two series of experiments were seen to be required and were instigated immediately after I reached Egypt in November:

1. To lightly infect animals with *P. boissyi* cercariae so that they would survive several months and thus enable the female bilharzia worms to pass the "transition period."

2. To heavily infect animals with *Bullinus* cercariae to ensure a successful diagnosis of the specific nature of this form. In view of the successful and heavy infections that had followed the administration of *P. boissyi* cercariae by the mouth, it was decided to make the crucial experi-
ments by this method, which appeared to afford a more accurate means of control in the dosage. To ensure longevity monkeys were used. Additional experiments were made by immersing rats and mice in infective fluid, and other monkeys were subjected to skin infection.

These new experiments proved, after the necessary lapse of time, completely successful.

The smaller animals were killed week by week to watch the progress of the development. Worms were first recovered from a mouse, infected by immersion, on the seventeenth day. These were of course, very immature, but they showed differences in the development of the gut from those previously reared from *P. boissyi*. This difference persisted during the growth of the worms, as seen from later dissections, until the adult size was almost reached. The two lateral branches of the gut failed to unite early. In several of the experiments, males only were found. After five weeks, males and immature females were recovered from the mesenteric vessels of mice infected by immersion, but the numbers were small. A mouse, injected subcutaneously with cercariae obtained from *B. dybowskii*, by dissection showed eight adults, of which none were females, when killed thirty-seven days later. In this series, worms were found after the sixth, seventh and eighth week, but the females had not yet begun to lay eggs. On the ninth week, however, the production of eggs had commenced.

Turning to the series of infections by the mouth, the following contrast is interesting: Two Indian monkeys, taken to Egypt from London for the purpose of these experiments, were given infective fluid to drink on the same day. The female monkey received fluid containing cercariae naturally discharged by *P. boissyi*; that administered to the male monkey contained cercariae naturally discharged by *Bullinus*. The female monkey began to pass lateral-spined eggs in the faeces on the forty-second day, and died from bilharzial dysentery on the sixty-sixth day. The male monkey showed no eggs in faeces or urine on the forty-second day and was killed. Many male and female worms were found in the liver and mesenteric vessels, but no eggs were found either free or in the females.

In the worms recovered from these older infections from *Bullinus*, the lateral branches of the gut had now united, and a short cæcum was developing. The males showed a further point of difference from those found in infections by *P. boissyi*, viz., the testes were less numerous, numbering only four to five. As this number had been recorded for *S. haematobium*, and was found to occur normally in *B. bovis*, it was still impossible to say whether the *Bullinus* infection was due to the bovine or the human parasite, without the evidence provided by the eggs. A further monkey had meanwhile been infected from *Bullinus* by the mouth. This passed numerous eggs in the twelfth week, and died of intense intestinal bilharziosis five weeks later. No eggs were found in the urine nor were any found in scrapings of the bladder wall. The eggs were terminal-spined without exception and corresponded to those found in man, not those in
cattle. Female worms found post mortem contained the eggs in numbers. This result confirmed the earlier find in mice which had been infected by immersion. Other animals gave confirmatory evidence. We had now established experimentally that the cercaria derived from P. boissyi gave rise to lateral-spined eggs, whilst those derived from Bullinus gave rise, solely to terminal-spined eggs. In both cases infection was restricted to the intestine, but this was probably due to differences in the venous connexions of the bladder. Undoubtedly the gut wall was the primitive habitat of all the bilharzia worms.

The young but sexually mature B. hematobia, derived from Bullinus infection, were well able to lay terminal-spined eggs. Although the very earliest efforts did not conform completely in full size and shape to the standard egg, no evidence of a tendency to the formation of eggs with laterally-distorted spine was forthcoming.

To completely clinch the matter, a final experiment seemed desirable. Animals—monkeys and rats—were infected very lightly with P. boissyi cercariae and kept alive for nine months. The living female worms, found post mortem at the end of that period were still producing lateral-spined eggs; one or two only at a time. For these coupled worms, the "transition period" must surely have long since passed.

The terminal-spined and lateral-spined eggs found in bilharzial infections are, therefore, the normal and characteristic products of two distinct species, B. hematobia and B. mansoni, and are spread by different intermediate hosts. The young females in each species produce slightly atypical eggs, but these slight variations do not "form a continuous series of intermediate stages between the two types."

As transmitter of the parasite of urinary bilharziosis in Egypt, Bullinus fulfils all requirements as far as distribution is concerned. It is found in the larger canals, in the smaller irrigation channels and finally, in the village ponds or "birkets." B. hematobia cercariae have been found in the species B. contortus, B. dybowskii, and once in a specimen which was recognized as B. innesi. These species would appear to correspond to the forms named Physa alexandrina by earlier workers.

The more restricted distribution of Planorbis boissyi would appear to correspond equally satisfactorily with the less universal occurrence of intestinal bilharziosis due to B. mansoni in Egypt. In the course of this inquiry, it was not found in the large canals or in the village "birkets." It appeared to frequent the smaller irrigation channels and drains where these were permanent. It was found also in marshes. Both carriers were found susceptible to drying, Bullinus extremely so.

The intermediate host of B. bovis remains to be discovered. This parasite was first found by Sonsino at Zagazig, some miles north of El Marg. Several animals were seen infected at the Cairo abattoir, but the majority of these came from the south. The veterinary inspector in charge informed us that B. bovis was much more common in Sudanese than in Egyptian cattle.
It may be that the large cercaria occasionally seen in *P. boissyi* at Marg is the infective stage, but of this there is no evidence save that no other Egyptian mammal is known to harbour Bilharzia.

At first it had occurred to me that these differences in size might be accounted for by the separation of the sexes in the bilharzia worms in contrast to the normal state of hermaphroditism prevailing among the Trematodes.

In his postulates Looss had argued in favour of sporocysts giving rise to adults of one sex only, to explain the frequent presence of males only in an infected person. This highly suggestive hypothesis may well prove true for the sporocysts and their resulting cercaria in the molluscan host.

Experience shows that if the cercaria discharged from one specimen only be used for experiment, the resulting worms may be of one sex only. Owing to the extreme fragility it was impossible to isolate a single "tube" of cercariae from an infected liver and so put the matter to experimental proof. Experimentally infected animals, like naturally infected persons, usually show a marked predominance of male over female worms. This would seem to be a happy provision of nature to ensure that no female that had successfully gained her way into the final host should lack opportunity of producing offspring.

There is one other matter relating to the bilharzia problem as presented by the village Marg which was for a long time puzzling, but for which a tentative explanation may be suggested. Urinary bilharziosis prevailed among the children in Marg to the extent of ninety per cent. The incidence of intestinal and particularly Manson's intestinal bilharziosis could not conveniently be ascertained. The presence there of infection with lateral-spined eggs was revealed by the find of specimens in the urine of one of the infected children. Now in the small canal within the confines of the village, *P. boissyi* was relatively more frequently infected with cercariae, i.e., with *B. mansoni* than was *Bullinus* with *B. haematobia*. After many visits the habits of the residents became fairly well known. The shelving banks of the canal served as a public latrine. The sides and uncovered bed of the channel were strewn with faecal deposits. The Egyptian squatting for the purpose of defecation faces the bank to observe anyone approaching. Consequently, any urine discharged falls on to the dry surface at a higher level than that at which the stool is deposited. This urine sinks into the dry soil leaving bilharzia eggs on or near the surface where they are exposed to the destructive effect of sun and wind. The eggs passed in the faeces are not so readily killed. It is well known that bilharzia eggs will remain alive and unhatched, in a fairly consistent stool, for weeks under suitable conditions. At Marg the level of the water in the canal rises and falls with a varying periodicity owing to the control in the amount of flow by the irrigation department. The consequence is that the sides of the canal, and especially the flatter portions of the bed, are automatically and
periodically washed. The bulk of the lateral-spined eggs will be set free and will rapidly hatch in the immediate vicinity of the proper intermediary *P. boissyi*. The terminal-spined eggs which hatch are only those that have been passed in the feces, and to this limited extent the *Bullinus* snails will become infected. Within the village the stream is too shallow for bathing. In the summer the children proceed higher upstream and to the parent canal where *Bullinus* is unaccompanied by *P. boissyi*. It does not necessarily follow, therefore, that the incidence of bilharzial dysentery and hematuria due to *B. mansonii* and *B. hematobia* respectively should correspond to the incidence of infection in the respective intermediary hosts within the village. Unfiltered water for all uses is taken from this stream into every house in Marg, so that the chances of infection within the home seem very great, both from the use of the water for drinking and for washing. Practically nothing appears to be known of the prevalence of intestinal bilharziosis, especially among women.

**Explanation.**

When first seen by Bilharz the lateral-spined egg was an enigmatical body. It was first thought to be possibly a kind of pupa; only later did Bilharz conclude that it was definitely egg. Bilharz’s find of this peculiar body within the female is recorded, as translated by Looss, thus: “such a body was, though once only, but quite undoubtedly, found in the uterus of a female worm, the posterior part of which contained the normal ova.”

Sambon contends that Bilharz did not here actually refer to a lateral-spined egg, but to a pigmented body and that “he only says that a peculiar brownish yellow body, furnished with a lateral spine was found only once within the oviduct of a female worm, the posterior part of which contained the ordinary ova.” There is no clear indication, according to Sambon, that the ordinary ova were terminal-spined ova or that the point of his remarks had reference to the position of the spine, rather than to the dark yellowish discoloration.

To this objection Looss replies later by quoting a further statement by Bilharz: “Strange to say, the eggs appear under two different forms. The two forms were found within the oviduct of the mother as well as in the tissues of various abdominal organs of man.”

The latter quotation to my mind brings no support to the contention that Bilharz found the two types within the same individual worm. Here he apparently wishes to convey that the shape of the egg was already determined before the egg left the female and was not a result of distortion in passage through the tissues—a view that has been held later by others.

On the other hand, having read carefully the original text, I am fully

convinced by its context that Bilharz really believed that he had seen the two types in the female, when he wrote the first statement, and that the shape of the egg, not its colour, was what he wished to bring under notice. Earlier in the same paper he describes the normal ova as terminal-spined. An even more important paragraph in this paper has not been utilized by Dr. Sambon. Bilharz states that this body occurred in one of the first females that he examined. A drawing was made at the time, but no importance was then attached to the observation. A similar condition had not been met with again. Now it seems legitimate to infer that an observation made at the commencement of the research might not have the accuracy or detail of later results when more material was available. The eggs with lateral spine are very striking objects, even when seen through the body of the females, but the ordinary ova observed by Bilharz may have been only apparently terminal-spined. My own suggestion is that Bilharz met with one of those females seen occasionally in which egg-laying has only just commenced. I have figured a series of eggs from one such female in the Journal of Tropical Medicine for 1911 [271]. The outlines are reproduced here. The first-formed egg (1) is lateral-spined, and lay just within the vulvar opening. The others (2 to 6) lay one behind the other towards the ootype, (6) having just passed from the ootype. All the eggs were rolled to show the greatest amount of lateral displacement of the spine. The later samples, it will be noticed, were incomplete and did not contain an ovum. These were, in fact, casts of the ootype in egg-shell

![Fig. 1. A series of eggs (1 to 6) found within the uterus of the same female Bilharzia. (Journal of Tropical Medicine and Hygiene, 1911, p. 130.)](image)
without normal content. If Bilharz met with a female similar to this one at the commencement of his investigations, he might well have concluded that the worm contained both types of egg.

When these sketches were made, I thought they might give support to the view put forward by Ward that the terminal-spined type of worm produced at first abnormal eggs with a sort of lateral spine; not identical with the lateral-spined egg of the New World.

On this interpretation the female was actually, in Looss' "transition period," but the formation of standard terminal-spined eggs had not been reached. I now believe that the female was one just commencing to lay; that ovulation had not fully set in; and that after producing one or two complete eggs a number of casts of the ootype in egg-shell were thrown off. I have since met with similar abnormal lateral-spined eggs in the material obtained by maceration of the liver of animals experimentally infected with S. mansonii in Egypt.

Other Modes of Infection.

Among South African tribes there is a widespread belief that the cause of hæmaturia there, which we know to be bilharzia, enters the body through the orifice of the penis during bathing.

To prevent this certain races, such as Zulus, wear a basket-like protection. Pfister [323] has shown that a similar belief and a like form of protection prevailed among the ancient Egyptians. Its mode of use is to this day figured on the walls of some of the ancient temples of Egypt.

The belief, so far as I am aware, is no longer current among the native populace in Egypt. It has however spread in South Africa among the white population although the protective measures do not seem to be in vogue with them. The matter is of interest here because, as I am told, troops proceeding to Egypt were instructed that they could avoid bilharzia infection while bathing in the canals there, if they took the precaution of wearing the European equivalent of this ancient speciality.

During the field work in Egypt certain observations seemed to afford a rational basis for this ancient belief. Often one found small and very agile leeches on the nets and collecting gear. These were indeed a great pest for unless they were carefully excluded from the aquaria they rapidly destroyed the molluscs. Now I have heard of one or two cases where such a small leech entered the penis during bathing, and, lodging in the urethra, gave rise to profuse bleeding. This I believe is the probable origin of the association of a penile ingress with bilharzial hæmaturia and in so far as these penile sheaths have proved efficacious this is probably due to the exclusion of leeches.

In this report it has been shown that infection through the mouth is readily induced experimentally. As the acidity of the stomach destroys the cercariae, it has since been argued that such experiments are of little practical significance, giving merely an extension of the area of skin infection. I am personally inclined to attach much more importance to this
demonstration of mucous membrane invasion; more especially as it brings me into line with the conclusions of Day. This distinguished observer came to the conclusion from a close study of the conditions of infection in Egypt that the nasal and oral ablutions, carried out as a part of religious ceremony, played no small part in the repeated infections with bilharzia seen in the Egyptians, more especially of male sex. One of the most heavily infected sites in Marg was at the water's edge immediately in front of the local praying ground upstream of the village.

From the established facts regarding the mode of spread and of infection it is evident that troops deriving their water supply for all purposes from the large public water-works run no risk of infection, even though the washing places become accidentally contaminated with urine containing bilharzia eggs. The risks were among those stationed in small parties on the various bridges, roads and canal crossings throughout the Delta and among the troops occupying new camps on the freshwater canal, in the Fayum and elsewhere. Although supplied with pure water for drinking purposes, this had often necessarily to be supplemented by local supplies for general purposes. At one such place it was pointed out to me that the daily ration of water could be supplemented with ease "from a wee bit burn" which seemed to be of clear good water. A brief examination showed however that there were many Bulinus in this stream, which was simply an irrigation channel derived from a main canal on which was a large native population a mile or two inland.

Asked on one occasion what I thought were the risks from uncontrolled access to canals in the neighbourhood of camps during the summer I put down a conservative estimate of ten per cent. It is therefore, of interest, and indicative of the value of the propaganda and prophylactic measures afterwards undertaken, that in two squadrons stationed at one of these camps during the summer of 1915 no less than twenty-seven, i.e., about twelve per cent strength contracted bilharziosis.

With the information at the disposal of the troops bilharziosis should now be treated as one of those diseases for which the individual is mainly, if not entirely, personally responsible.

**Morphological Differences Between the Two Egyptian Species.**

After the publication of *B. mansoni* as a distinct species in 1911, several American workers made a study of the anatomy of adult worms collected in the West Indies, Panama and Brazil, in search for morphological characters by which the species with lateral-spined egg could be distinguished from the terminal-spined form found in the Old World.

Comparing their finds with the formal descriptions given by Looss and others, they noted and briefly described the following peculiarities.

Holcomb [233] found that the adults of *B. mansoni* had a brown colour and a somewhat larger ventral sucker. Piraja da Silva [444] was struck by
the unusual appearance of the anterior end of the male worm which differed in outline from that figured, after Looss, as characteristic of the Egyptian worm in most text-books. The female appeared to taper towards the posterior extremity instead of ending abruptly. The cæcum approached the end of the body more closely. The oviduct united immediately with the vitelline duct instead of passing forwards to fuse with it at the ootype. The spinous papillæ did not seem so salient.

Flu [172] saw differences in the manner in which the anterior edges of the lateral walls of the gynecophoric canal joined the body in the male and in the female in the presence of a coiled ovary in full grown specimens.

A further point of apparent differential importance was noted by myself in 1908 as a result of an examination of a batch of male bilharzia worms, collected at post-mortem by the late Dr. Turner, from cases of mixed infections in natives of Portuguese East Africa and Nyasaland. I quote the following interesting portion from my half-yearly report to the Colonial Office in May, 1908: “In cases of mixed infections (as ascertained by microscopical examination of bladder and rectal walls) I have been able to separate into two groups males having four somewhat angular large testes and males having seven to nine small spherical testes. In other cases all the males obtained belonged to one type. ‘The difference in character and especially in number of testes would be considered as a specific character of some reliability if occurring in other groups and if constant as it seems to be here. In order that this character can be utilized in support of the view that the two forms of bilharziosis, rectal and urinary, are caused by parasites specifically distinct, it remains to be shown that males having one particular type of testes are usually or always in sexual conjunction with females producing one type of egg.

“Granted for the moment that these types of testes and of egg be found to occur constantly, the probabilities are that the male with four testes is the mate of the female giving rise to terminal-spined egg; for this is the normal arrangement of testes figured by Looss and the terminal-spined ovum is the one recognized by him as the normal product of the mate of this form.

“In support of this view, I am able at present to offer only one actual observation, in itself a striking one, owing to the lack of females in my material. In the one specimen of a paired couple in my possession, the testes can easily be made out to be seven. The female lies in the gynecophoric canal, but its posterior half is broken off. Lying also in the canal, however, is a small ‘clot’ containing several lateral-spined ova. We have, then, evidence of the association of the multitesticular male with the female having lateral-spined eggs.”

Replying to the points of difference as set out by Piraja da Silva, Flu, etc., Looss [300] maintained that these features were to be seen equally in specimens of B. haematobia in Egypt, and that they might be explained at least in part by varying degrees of contraction in the preserved worms.
As the chief monographs on the anatomy of the adult bilharzia worms were based on materials collected in Egypt, such material quite probably came from mixed infections. A comparison of the anatomy of adults of *B. mansoni* from uncomplicated cases in the New World with these published descriptions of *B. hamatobia* was not likely to lead to acceptable conclusions.

It is evident then that a final settlement of the specific differences between the adult worms of *B. hamatobia* and *B. mansoni* must be based upon a comparison of specimens taken from cases of unmixed infection and preferably from cases in South Africa and the West Indies respectively, where such infections occur.

The bilharzia worms that have been reared experimentally from *Bulinus* and *Planorbis* unfortunately, do not attain in the laboratory animals the full growth met with in their natural hosts. Although sexually mature and actually producing eggs, the worms are still young and small. Differential characters based upon measurements are likely to be fallacious under these circumstances. Morphological differences, may, however, be relied on; especially where these can be verified by reference to full grown adults taken from the human body in unmixed cases of vesical and intestinal bilharziosis. Unfortunately, an opportunity of obtaining such material has not been forthcoming hitherto. The following account of the differential characters as 'seen in experimentally reared worms must be regarded as a purely tentative attempt to differentiate the two species. It will be noticed, however, that it gains some extraneous support in the observations on the anatomy of *B. mansoni* quoted above.

In the males reared from *Bulinus*, the testes appear to number four or five almost constantly. They are also of fairly large size.

In males reared from *Planorbis*, the testes number seven to nine, and appear to be relatively small. Differences between the two sets of males are noticeable in the shape of the anterior portion bearing the suckers, and the relative size of the suckers is probably also to be regarded as of specific account.

In females reared from *Bulinus*, the eggs are constantly terminal-spined, even in small young females. The ovary is smooth and situated near the middle of the body. The lateral branches of the gut are lengthy and the cæcum correspondingly short. With this the range of the yolk glands which surround the cæcum throughout its length is apparently short.

In females reared from *Planorbis boissyi* the eggs are constantly lateral-spined. Usually one, seldom two, and very rarely, four eggs, occur in the uterus at one time. This is due to the short length of the duct. The lateral branches of the gut unite early, and there is a very long cæcum. The yolk glands surrounding the cæcum have, therefore, a correspondingly long range. The ovary lying in the fork made by the union of the gut branches is elongated and is within a short distance of the uterine pore.
Bilharzia hematobia (s. str.), developed from cercariae discharged by Bulinus spp.

A—E = Immature stages from liver showing delayed union of gut.

F = Adults in copula from mesenteric vein, showing short cæcum and corresponding changes.

ov. = Ovary.

c. = Commencement of cæcum.
The difference in the point of union of the lateral branches of the gut in the two species is common to male and female. It is a very noticeable feature in the growing worms. The posterior portion of the young worm would seem to be a growing tissue, which, by its continued lengthening, changes the relative measurements of the various parts of the gut almost until maturity is attained.

The attainment of egg-production is more rapid in *B. mansoni* than in *B. hematobia*. In experimental infections from *P. boissyi* eggs were found after six to eight weeks, from *Bullinus* after nine to twelve weeks, depending on the intensity of infection and on the host.

The developing worms and coupled adults reared from *Bullinus* infections are illustrated in figure on p. 251.

The question of nomenclature remains now to be reconsidered in the light of the foregoing results. The generic name *Bilharzia*, proposed first by Cobbold [92], gained almost universal acceptance, especially in medical works and in contributions on the clinical and pathological aspects of infection. I have used the name *Bilharzia* in the present report, as it is the one by which the disease is commonly diagnosed. Within recent years, however, the name *Schistosoma*, given by Weinland [515], in 1858, has been revived under the present operation of the Laws of Nomenclature. It is the more correct, although Cobbold states that under the 'laws in use at the time, Weinland accepted the priority of *Bilharzia* over *Schistosoma*. If the former generic term is used, the species should read, *Bilharzia hematobia*, and if the latter *Schistosoma hematobium*. It is to be hoped that on grounds of use and suitability, the specific names of *Bilharzia hematobia* and *Bilharzia mansoni* may retain their present application. Doubtless some day, it will, however, be noticed that the *Distomum hematobium* originally named by Bilharz, was based upon mixed material, and is, therefore, a composite species. Harley, the first reviser of the species, split this *D. hematobium* into two components. To the species giving solely terminal-spined eggs, he gave the name *D. capense*, restricting the name *D. hematobium* to that form found in Egypt which produced both kinds of eggs. I foresee that the name *B. hematobia* may thus be reserved by purists in nomenclature to the single specimen described by Bilharz, which conforms with these requirements.

There finally remains the *Bilharzia magna* found by Cobbold in a monkey. The type and only specimen, is preserved in the Hunterian Museum. It is a fragment of a male. I have been quite unable to identify it with either of the species now recognized in man. This is a happy circumstance, for we may now without anxiety retain the specific name of *B. mansoni* (with which the whole species problem has been indissolubly connected), in its rightful place to recall for future students the insight of one who took no part in controversy, but silently worked through others less inspired, for the eradication of many of the great pests of the Tropics.
Throughout this report the naming of the various fresh-water molluscs is based upon Pallary's monograph. It has not seemed desirable to attempt to determine to what extent the various specific names of the genus Bulinus, such as B. contortus, dybowskii, alexandrinus, innesi, etc., are synonyms of one another or of the names brocchi, etc., used by Jickeli and older workers. The name Bulinus is itself subject to controversy. Sowerby, Fischer and others use the older spelling Bulinus, while some are inclined to adopt a more recent synonym Isidora. By keeping to that of the most recent and best illustrated paper on the subject, which, moreover, is published in Egypt, we have avoided introducing confusion for local workers who may be interested more especially in the public health side of the question.

**PART VI.—BEARING OF PREVIOUS WORK ON B. JAPONICA AND CONCLUDING REMARKS:**

Given the premises laid down by Looss as a result of prolonged study of local conditions in Egypt, his theory, "based upon a large number of anatomo-pathological and helminthological facts deliberately weighed and compared," could not be overthrown simply by an argument from analogy. If it were otherwise, those who accepted and supported his views bear a heavy responsibility for failing to apply the analogies resulting from the experimental data afforded by experiments with B. japonica; the first and most fundamental of which, made by Fujinami and Nakamura in 1908, excluded, for this allied species, the possibility of direct transmission.

In the opening section of this report, I have traced the evolution of scientific opinion regarding the mode of spread of Bilharzia hamatobia. The analogies presented by B. japonica have there been referred to only to show how these were definitely set aside by the exponents of the theory of direct infection in Egypt. I have refrained from using them as an a priori argument, because in the proved facts of the life cycle of another common Egyptian parasite of man there was a strong opposing analogy, in support of the possibility of an exceptional occurrence of direct infection among parasites requiring usually an intermediate host. Hymenolepis nana has been shown experimentally to be capable of direct transmission although the other members of the genus have arthropod intermediaries.

Moreover, the object of my own work has been to arrive at a solution of the various problems, presented by the bilharzial diseases in Egypt, by direct observation and experiment, rather than by the inductive method.

I propose to relate now the various published facts concerning the life-history of B. japonica that were available at the outbreak of war; to show in what respects these failed to afford the data necessary for a rapid solution of the bilharzia problem in Egypt and in what way my own investigations on this Oriental species, while confirming previous conclusions of Japanese observers, gave a new method by which the infective
stage could be quickly and accurately delimited in the molluscs of a heavily infected locality. By its use the peculiar difficulties which have so long beset the bilharzia problem in Egypt were speedily overcome.

Before dealing with these investigations, I must recall that the problem of the bilharzia worms was not one of a peculiar and new type of larval development. It concerned rather the seat of this development and the exact route by which reinfection of man took place.

Holders of the theory of direct transmission were in agreement with their opponents that the larval metamorphosis of the bilharzia miracidium is absolute evidence that the miracidium cannot develop directly into an adult worm, but must pass through the stage of the sporocyst which in its turn produces, either and probably at once, or by one or more intermediate generations, the definite worms.

The fundamental problems for each species of bilharzia worm were these: (1) Did the species follow its typical larval development in the liver of man or of a mollusc? (2) Did infection take place through the skin or by the mouth? (3) If a mollusc was an essential intermediary, what were the species concerned in the transmission of each species of worm? As regards the B. japonica, the first and second of these problems were, to my mind, conclusively settled by the researches of Fujinami and Nakamura in 1908.

In those regions in the Far East where man is infected with B. japonica, infections also occur naturally in cattle, cats and dogs. Using these animals therefore, as tests and controls, the following experiments were made. In the first investigation numerous miracidia were hatched in water. Dogs were then immersed in this. No results followed. In the second series, cattle, cats and dogs were submitted to possible infection by immersion in rice-fields and neighbouring ditches and streams reputed to be sources of infection. Intense infections with B. japonica ensued.

In 1910 other animals, not found naturally infected, were proved susceptible by experimental immersion, viz., mice, white rats, guinea-pigs, rabbits and monkeys.

In these experiments, described by Fujinami in a paper issued from the Internationale Hygiene Ausstellung in Dresden, in 1911, young parasites only 0·15 millimetre long were found in the portal system on the third day after immersion.

In 1911 Miyagawa described the invasion forms, as seen in the peripheral vessels and cutaneous tissues in two to twenty-four hours after immersion. These forms were smaller than those seen by Fujinami but differed in no essential respect. Oral and ventral suckers and a gut were already present.

In 1913 Miyairi, by experimentally infecting local molluscs with miracidia, found a sporocyst in an unidentified snail, stated to be a
Lymnæus, as Katsurada announced in a footnote to an article on "Schistosomiasis japonica," in December (cf. Bkt. 72, p. 378). Miyairi's original publication is in Japanese, but Kunagawa gave a summary of the chief points in an abstract published in the Tropical Diseases Bulletin, in March, 1914.

They noticed also that in the infested locality there are many snails in the waterways and ditches. Of these snails a great many Cercariae parasitize one which has a dark coloured shell with seven spirals. The authors carefully picked up a number of young non-infected snails and tried whether the miracidia entered their bodies or not. They found that the miracidium enters the body of the snail, penetrating the cuticle with the lips and proceeds to the gills and the wall of the digestive canal. After twelve days the first rediae appear and gradually concentrate to the hepatic ducts, elongating, and a number of the second rediae are seen. The authors put mice into the vessel in which the full grown snails were fed, for three hours every day and repeated this experiment for four days. After three weeks they found a great many Schistosoma japonicum in the livers of the mice. The authors conclude that this kind of snail is an intermediate host of S. japonicum."

Judging by titles, other papers appeared in Japanese journals, but these are inaccessible. During 1914, Katsurada (according to an Italian abstract) "confirms the assertion of Miyairi and Sudzuki, but regards the question of the intermediate host of S. japonicum as not altogether cleared up."

It is evident that the above information, while definitely establishing a molluscan intermediary for B. japonica was of little value as a guide to the elucidation of the special problems surrounding the B. hematobia transmission, and gave no facts regarding the bionomics of the infective stage, or of the carrier, upon which to base prophylactic measures. In Egypt all attempts to advance by infecting with the miracidia had failed, even in Looss' skilled hands. Sonsino and others had found no means of identifying the B. cercariae among the numerous developmental stages found in the snails of the endemic area in Egypt. There was not available for experimental purposes any animal of known susceptibility but man. Lastly, there still remained no explanation of the frequency of bilharziosis amongst very young children in Cairo.

In an article published in Mense's Handbuch in 1914, Looss admitted when dealing with B. japonica, that after Miyagawa's experiments the existence in this species of a free swimming cercaria was quite plausible. Under B. hematobia, however, he states that if it is correct that there is an intermediate host in the Oriental species, "then B. japonica must differ essentially in its development from B. hematobia." That Looss' view was still maintained by others is shown by the advice tendered to the

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1 Full titles and abstracts of the preceding and of all available publications on B. japonica are to be found in the volumes of the Tropical Diseases Bulletin.
Army in Egypt for dealing with an outbreak of bilharziosis amongst the troops stationed at Kasr' Nil Barracks during 1912. In an article in 1915 by another authority in Egypt the following occurs: “Any small puddle or hole may become defiled, and in a very short time the water or mud is alive with miracidia, which may become applied to the bare feet, arms or hands, penetrate the skin directly and so lead to infection.” “Certain evidence we have none nor has any intermediate host ever been discovered.”

Reviewing the bilharzia problem in the Spring of 1912, in the light of Fujinami's experiments and the repeated failures to infect monkeys and other animals with the miracidia of *B. hematobia*, I concluded that the time had come to renew the attempt made by earlier workers to establish a molluscan transmission for this parasite.

In view, however, of the lack of success which had attended the previous efforts of Sonsino, Lortet and Vailleton, and others to follow the miracidia, a new method of approach seemed called for.

The occurrence of *Bilharzia magna* in *Cercocebus fuliginosus* rendered it not improbable that by subjecting monkeys of this species to immersion in water containing the various cercariae, found in the endemic area, a positive result might eventuate. As *B. hematobia* occupied a peculiar habitat in man and did not naturally infect any other animals a negative result might follow. In any case such an empirical method would obviously involve the purchase, transport and maintenance of a large number of monkeys or necessitate an unusually prolonged investigation, for which the necessary financial support was not likely to be forthcoming.

The experiments of Fujinami and Miyagawa appeared to me to open up a possibility that a morphological clue might be established by which the bulk of cercariae of unknown origin could be excluded microscopically; thus bringing the experimental use of monkeys within practical limits.

Was there any outstanding feature which distinguished the adult distomes from the adult bilharzia worms and which had, in all likelihood, persisted from the sexless cercarial stage? In the cercaria there are organs, like the tail, which are purely larval structures, and others, like the suckers and the gut, which persist from the body of the cercaria through adult life. In some cercariae, however, the gut has not yet formed although there is an oral sucker.

The suckers are, both as regards structure and position, very similar in distomes and bilharzias. The alimentary canal is, on the other hand, markedly different. The bulk of the distomes have a separate muscular pharynx. There is no pharynx in the bilharzia worms.

If this distinction were one which persisted from the cercarial stage then it afforded an easily determined morphological clue by which one could immediately exclude the vast majority of cercariae, which are distomes.

It might be that the pharynx, originally separate, became fused with
the oral sucker in the adult as occurs in the amphistomes. Without definite evidence it was, therefore, impossible to come to a trustworthy conclusion regarding the absence of a pharynx in the cercaria of bilharzia.

Happily such evidence was now procurable as a result of the discovery of the "invasion forms" of *B. japonica* by Fujinami and Miyagawa. From the description of these bodies, which were said to possess oral and ventral suckers and a developed gut, it was evident that they were infecting cercariae, but there was no mention, in either paper, of the presence or absence of a pharynx.

It was obviously necessary to establish this point by actual observation, not merely by inference, if it was to be utilized as a basis for experimental work.

My plan then was, in 1912, to proceed to Japan, and by repeating the original experiments or by examining the original preparations to settle this question; to confirm the expected value of the clue by examining the molluscs of the district where Fujinami has conducted his immersions and which was known to be intensely infected; and thence to proceed to Africa. If one or more of the molluscs there was found to contain cercariae exhibiting this peculiarity, then it would be possible to attempt the experimental transmission of bilharzia to monkeys with every prospect of success.

These plans were, however, subject to other counsels and it was not until the summer of 1914 that I felt free to carry out my original scheme. This I was then enabled to do fully, thanks to the cordial co-operation of Professor Fujinami. Through him I was able to examine the "invasion forms" and to establish the value of my morphological clue by a visit to the rice fields of Katayama, where the ease with which the test could be applied to the molluscs in an endemic area was quickly demonstrated. With cercariae exhibiting this morphological peculiarity, mice were afterwards infected successfully with *B. japonica*.

In the meantime, however, Miyairi and Sudzuki, as related above, had succeeded by another method of approach in tracing the metamorphosis in a closely allied, if not identical, snail, in the South Island of Japan. My own observations therefore confirmed generally the results of these workers, apart from establishing my chief, ulterior object; which was to provide a simple and reliable means of attacking the complex problems of *B. haematobia*.

In regard to details, concerning which only the abstract by Kumagawa was available, I was unable to confirm the presence of "rediae" in the development of *B. japonica*. From my own observations I had concluded that the *B. cercariae* originate in sporocysts. I was not in a position, pending fuller information, to decide whether these "rediae" were actually developmental stages of bilharzia or of some other species with which the
On my return voyage, after the outbreak of war, I visited Egypt and found that though the results of the recent work on *B. japonica* were known there, it was still held that they gave no solution to the special problems presented by the *B. haematobia*.

Considering that the new facts derived from my own observations on *B. japonica* would enable me to overcome the experimental difficulties which had hitherto surrounded the Egyptian question and realizing the immediate importance of some simple and efficient prophylactic measures for the large bodies of troops then proceeding to Egypt, I sought and obtained the occasion for the investigations in Egypt related in this report. A study of the accounts given by Sonsino and Looss of the cercariae found by them in the course of their search showed that they had not seen and passed over the *B. cercariae*. The bulk of their cercariae possessed a distinct pharynx. In a few it was absent but in these there was merely an oral sucker without any development of oesophagus or gut. It was evident that these forms had still to undergo maturation before they could become infective to their definitive hosts and as some possessed a definite perforating spine and other peculiarities of forms that undergo encystment in fishes and other secondary hosts, these cercariae were readily excluded. It was therefore necessary to find further cercariae which had hitherto been overlooked. The search for this was made by the method of intensive study of a small heavily infected area. The fact that *B. japonica* developed in a genus of the family *hydrobiidae* was of no assistance. Indeed by those unversed in the bionomics of helminths this might have been taken, disastrously, as an additional and invaluable analogy. In point of fact the Egyptian bilharzia worms were found to infest two genera of freshwater mollusca belonging not merely to a different family but to a different order. In other words, *B. japonica* and *B. haematobia* (s. lat.) were found in snails as distantly related in classification as are the lice to the mosquitoes. In

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1 In Egypt we found commonly present in the species which were actually intermediaries for the various *Bilharzia cercariae* additional developmental forms; some developing in rediae and other, bifid-tailed, forms developing in sporocysts which bore a superficial resemblance to *B. cercariae*. It is obvious from the illustrations given by Cawston that such forms were mistaken by him for *B. cercariae*. Thus, prior infections may prove a serious source of fallacy to those endeavouring to advance experimentally from the miracidia unless the results are carefully checked by the morphological method.

In a report written on my return from China in October, 1914, I had to content myself with the statement that my results confirmed Miyairi’s main conclusion, and that in the absence of any accessible publications a comparison of the detailed conclusions was for the present impossible. Apparently during the closing months of 1914 Miyairi and Sudzuki published in Japan, in German text, a detailed account of their findings. From this, which is well illustrated, it is now evident that divergence of view regarding these “rediae” is due solely to a difference in interpreting the same structures.
its application to these new cercariae, the morphological clue fully vindicated its use. Within three months no less than four *B. cercariae* were obtained by this method of exclusion. Two of these were selected, on epidemiological and other grounds, and with these two alone, experiments were made on *Cercocetus fuliginosus* and other animals. These forms proved to be the infective stages of the two bilharzia worms which cause bilharziosis in man in Egypt. No experiments were made with any other cercariae.

Here I may well bring to an end a Report that has been kept open much longer than was intended, and of which the earlier sections were written while experiments were yet in progress. Much material remains which, when elucidated, should add further to our knowledge of these and allied Egyptian parasites. Its description, however, scarcely comes within the terms of the present inquiry which were "to investigate bilharzia disease in Egypt, and advise as to the preventive measures to be adopted in connexion with the troops." These objectives, I believe, have been fully achieved. A complete zoological study of the adult parasites, or of their development, has not been attempted. Such attention as has been given to their morphology and bionomies has been directed to those points concerning which an understanding was essential as a basis for prophylactic measures. The difficulties which beset the inception of the work in a strange country, with some elements critical and hostile, were quickly overcome. Sickness, however, almost wrecked the inquiry at its commencement. Within a month of our arrival Dr. Cockin had fallen sick, and was invalided home. Three weeks earlier I had been admitted to hospital with scarlet fever. It was not until the beginning of April that, foregoing my convalescence, I was able to start field investigations at Marg. Early in May the opening of the Gallipoli campaign, with its rush of wounded and the attendant excitement in Cairo, brought pressing local suggestions for the foreclosing of my mission. As on some other occasions, one found comfort in the aphorism of Huxley: "Surely there is a time to submit to guidance, and a time to take one's own way at all hazards."

But the pervading restlessness could not be wholly withstood. Later, in June, when it seemed advisable to transfer the work to London, my second colleague, whose assistance had been invaluable, decided to remain in Egypt for general service with the Royal Army Medical Corps. The position of the inquiry was full of anxious uncertainties, and I had still to complete many of the crucial experiments. The collections made in the field had still to be worked out, and the experimentally infected animals examined histologically. The extensive literature of Bilharziosis had to be overhauled. Finally, new experiments had to be made. These were the circumstances in which the preparation of the Report had to be undertaken, and sole responsibility assumed for the conclusions arrived at and for the views herein set forth.

To the various authorities who aided the investigations in Egypt, I have already expressed my deep indebtedness.
I have now to acknowledge the warm encouragement received from home authorities, especially from Colonel W. H. Horrocks, C.B., who found time amid heavy burdens to write emphasizing the practical objectives to be kept strictly in view; from the Medical Research Committee, who not only gave more than ample financial credit for the field expenses, and to illustrate this report; but also maintained, through Sir W. M. Fletcher, F.R.S., a gracious interest in the progress of the work.

Thanks are due to Sir David Bruce for privileges enjoyed under his command at Millbank, and to the officials of the Zoological Society of London, especially to Dr. Chalmers Mitchell and Mr. R. I. Pocock, F.R.S., for supervising the supply by dealers of properly identified Cercocebus fuliginosus, which were the mainstay of the experimental work.

Finally, I have to express my special indebtedness to the Committee of the London School of Tropical Medicine for most generously enabling me to continue under other auspices a series of investigations which they had initiated during 1913, and which they would probably have supported alone to a successful conclusion if more peaceful times had prevailed.