

CLASSICS OF BIOLOGY AND MEDICINE
THE MOSQUITO-MALARIA THEORY — I

**The Role of the Mosquito in the Evolution of
the Malarial Parasite: The Recent Researches
of Surgeon-Major Ronald Ross, I.M.S.^a**

At the meeting of the British Medical Association in Edinburgh Dr. Patrick Manson, the President of the Section of Tropical Diseases, gave by special request and with the permission of the Secretary of State for India and of Surgeon-Major Ronald Ross, I.M.S., a lecture and exposition of the work done lately by the latter in the investigation of this subject. Surgeon-Major Ross has also sent an advance copy of his recent report on the cultivation of *Proteosoma*, Labbé, in grey mosquitos. From this report we make the following extracts:

On March 13th I commenced to examine them. Out of fourteen of them pigmented cells were at last found in one. Believing as I did that these cells are derived from the gymnosporidia I judged from this experiment that the grey mosquito which now contained them had fed itself on one of the birds which happened to be infected by a parasite capable of transference to the grey species of mosquito. As all the birds had been placed together in the same net the question now was which of them had the mosquito fed herself upon. This could be easily ascertained. A number of mosquitos of the same species had meanwhile been fed separately on the crow and two pigeons with halteridium; but out of thirty-four of these examined not one contained pig-

mented cells. Hence I came to the conclusion that the mosquito with pigmented cells had not derived them from the crow and the two pigeons. The larks and sparrows remained. The blood of these had not yet been carefully searched. I now found that three of the larks and one of the sparrows contained *proteosoma* (Labbé) and therefore thought it possible that the mosquito had been infected from one of these. Accordingly, on the night of March 17th and 18th a number of grey mosquitos were released on the three larks with *proteosoma* and next morning it was found that nine of these had fed themselves. On the morning of March 20th — that is, from forty-eight to sixty hours after feeding — these nine insects were examined. Pigmented cells were found in no less than five of them. After the long-continued negative experiments with this kind of mosquito (and, indeed, I may say, after three years' doubtful attempts to cultivate these parasites) this result was almost conclusive. It indicated, as was surmised before, that when a certain species of mosquito is fed on blood containing a certain species of gymnosporidia pigmented cells are developed. Hence it would follow, as an easy corollary, that the cells are a stage in the life-history of the gymnosporidium in the mosquito.

It was now necessary, however, to confirm and amplify this observation and obtain formal proofs of the theorem by repeating these experiments and by studying the pigmented

^a Originally published in *The Lancet*, pp. 488-489, 1898.

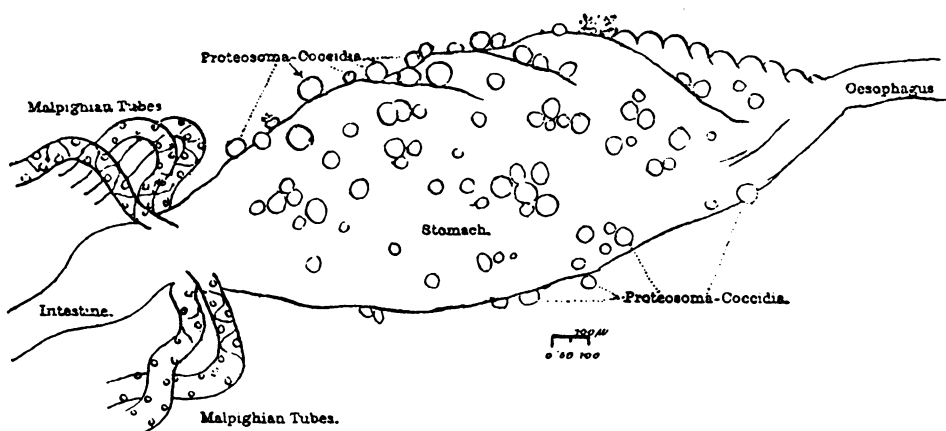


Figure 1. Figure reproduced from Surgeon-Major Ross's report and showing appearance of coccidia on the sixth and seventh day.

cells themselves. Accordingly from March 18th to the present date (May 21st, 1898) many differential experiments have been completed by feeding grey mosquitos as follows: (a) on larks, sparrows, and a crow with proteosoma; (b) on crows, pigeons, and other birds with halteridium only; (c) on a lark and a sparrow with immature proteosoma only; (d) on a healthy sparrow. Only the insects fed on group (a) have contained pigmented cells.

MacCullum had previously shown that in the case of the analogous parasite — the halteridium — the flagellum, of the flagellated phase, after breaking away entered certain spherical, pigmented halteridia, causing them to be transformed into little travelling pigmented vermicules, which, in virtue of their sharp beak and mechanical power, traverse freely red and white corpuscles. Analogy suggests that a similar thing occurs in proteosoma and that the travelling pigmented proteosoma vermicule enters the tissue of the mosquito's stomach and becomes Ross's pigmented bodies, in the same way as Manson has shown took place in the case of the *filaria sanguinis hominis*. Arrived in the stomach wall of the mosquito, the proteosoma increases rapidly in size until it projects beyond the stomach walls into the cœlom or body cavity of the mosquito as a rounded body, which he styles the proteosoma-coccidia. During its progress and growth various changes take place in size and in the appearance of the contents of the coccidia. Pigment diminishes and

then disappears and as the parasite protrudes into the cœlom it is seen that the contents have a more or less granular appearance.

I have said that after this point I have witnessed no further growth of the coccidia, even in mosquitos kept alive to the twelfth day. Hence we may perhaps expect that they have become ripe for sporulation. No such thing has, however, been observed; and we may therefore conjecture, unless I happened to have overlooked it, that it may occur either (a) in the living insect after twelve days, or (b) some time after the insect's death. Further research is therefore required on this which now becomes the most important and interesting period of the life-history of the gymnosporidia, because on it depend our chances of future progress. To plunge into hypothesis for a moment we may remark that since the mature coccidia find themselves in a closed cavity — namely, the body cavity of the host — there appear to be no means by which they can escape from that host during its life to undergo sporulation in external nature, as is the case with *coccidium oviforme*. It would appear then that sporulation should occur either within the living host, as with *elmeria*, or within the dead host. The first would point to a completion of the life cycle by a direct infection of men and birds by the coccidium spores in the mosquito; the second to a more circuitous infection, perhaps by a second generation living free in water.

In the paper read by Dr. Patrick Manson at the Edinburgh meeting of the British Medical Association the speaker was able to quote from telegraphic communications with Surgeon-Major Ross which showed that the further researches spoken of have been undertaken. The next stage seems to be that the coccidia now burst and what Surgeon-Major Ross calls germinal vermicules which had formed in its interior are set free in the body, blood and tissues of the mosquito. Then came a step in the investigation of great consequence: it was no other than the discovery of these vermicules in the venemo-salivary glands of the mosquito. Surgeon-Major Ross during dissection of the mosquito found a couple of head glands with a duct leading towards the proboscis of the animal and traced the parasite vermicules into these glands. The climax of the discovery was now within his grasp and he elucidated it thus: He allowed mosquitos to feed on birds infected with proteosoma; after a few days he fed the mosquitos on birds whose blood was void of any parasite infection. He found in due course that the parasite-bearing mosquito had infected the healthy birds and that their blood was charged with proteosoma.

Thus the analogy between bird and human infection has only to be proved to establish that the mosquito is a carrier of malaria and an infector of man. Much has yet to be done, however, before the full significance of the mosquito in malaria is worked out. Malaria, we know, multiplies without the intermediary of any vertebrate. Does it do so solely in mosquitos? If so, we have yet to learn how it passes from mosquito to mosquito. Does it multiply in other media? If so, what are they? There is here given merely the outline of Surgeon-Major Ross's work. Doubtless he or others will soon grapple with the other problems it suggests and show how to solve them. It is impossible in a short space to give in detail the multitudinous experiments and observations which he has carried out. Suffice it to say that they have been done in a masterly way. The practical applications of the discovery are immeasurable and the establishment of the fact that as the bite of the snake or the rabid dog inoculates the blood of the victims of these creatures so the mosquito conveys malaria, would open up a new and hopeful phase as regards the prevention of disease in the tropics.