Although the characters in the story are insects, parasites and doctors of public health, I think the narrative is essentially not a medical but a military and social history, and at the same time clearly an ecological one.¹

Background

Malaria has had a massive impact on the course of human history: defeating conquering armies, standing fast against colonisation, and devastating papal conclaves.² This account is of one short episode in a history which stretches back to the beginning of human history.

Ronald Ross entered this history on 10 April 1894, during a period of leave from the Indian Medical Service (IMS). This was a time when the empires of the western world were scrambling for control of equatorial Africa, with success hinging on the battle against disease. Not for the first time in its history, the war against malaria became a campaign for control of land.¹

The 19th century witnessed many advances in this campaign. Heinrich Meckel, a German pathologist, first observed Haemozoin (a pigment by-product of haemoglobin digestion by malaria parasites) in 1847. He noted the presence of granules of black-brown pigment in the blood and spleen of a patient with fever, though made no allusions to an association with malaria. In 1870, Achille Kelsh noted the temporal relationship between the appearance of Meckel’s pigment in the blood and malarial fever, but it was not until 1880 that the causal relationship was established. Charles Louis Alphonse Laveran, a French physician working in Algeria, observed the parasites in a blood smear of a deceased malarial patient and concluded the pigment was caused by those parasites.

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Camillo Golgi, an Italian neurologist, was the first to describe the reproductive cycle of the parasite in mammalian blood. Working on malaria between 1886 and 1892, Golgi elucidated the cycle of the parasite in red blood cells, noting the onset of fever with release of parasites into the blood.\(^3\)

It is at this stage of human understanding of malaria that Ronald Ross, a young army surgeon serving in the Indian Medical Service, began what would become a life-long association with the history of malaria. Ross called upon Patrick Manson at his home in Queen Anne Street, London on 10 April 1894. Manson, largely considered the father of modern tropical medicine, made his name elucidating the life cycle of Filaria, and the role of the mosquito in transmission. Drawing from his own work, Manson hypothesized a similar role for the mosquito in the life cycle of the malarial parasite, and it was this suspicion he passed onto Ross in 1894.

**Research in India**

Ross started for India upon the P&O ferry Ballarat on 20 March 1895. He spent his time onboard practising the laboratory skills he would require for investigation. By the time he landed in Secunderabad on 24 April 1895, Ross was a dab hand at blood films and dissection of cockroaches.

Ross commenced his research on arrival in Secunderabad, carrying out feeding experiments on any mosquito he could find. It would take three years of failed experiments for success to find him. These arduous years of study are well documented in the regular correspondence that passed between Ross and Manson. During this time Manson acted as both a confidant and publicist back in the capital. Manson’s letters are full of advice and encouragement for Ross. The letters not only trace the evolution of Ross’s experiments, they also document the evolution of the human component of this history: Ross and Manson’s relationship began as one of teacher and pupil, and eventually became one of equals. Ross advised Manson to have his copies of their letters bound as ‘the solution of the great malaria problem is history you know!’ Manson sardonically speculated that ‘they [would] have an interest and value in years to come to some medical

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Dryasdust writing the history of malaria when we are dead and gone – the bugs hunting us and not we the bugs’.  

During his three years of experimentation, Ross endured a number of interruptions. The first, in September 1895, was a transfer to Bangalore to deal with an outbreak of cholera. This interim, however inconvenient at the time, would later prove fortuitous as he later drew on his experiences and applied them to the mosquito-malaria theory. Ironically, after surviving cholera-stricken Bangalore unscathed, Ross promptly succumbed to cholera on his return to the 19th Madras Infantry in Secunderabad.

Ross published the results of his first successful experiment in the *British Medical Journal* in December 1897. In ‘On some peculiar pigmented cells found in two mosquitoes fed on malarial blood’, he describes findings from experiments up to his ‘Mosquito Day’, 20 August 1897. Ross encouraged a number of ‘dappled-winged’ mosquitoes to feed upon Husein Khan, a malarious patient.

Ross describes his experimental process: ‘…to feed mosquitoes, bred in bottles from the larva, on patients having crescents in the blood, and then to examine their tissues for parasites similar to the haemamoeba in man.’ (A note on the text: Ross proffered the term ‘haemamoeba’ as a replacement for the misnomer ‘malaria’. The nomenclature haemamoeba, Ross later explained in the report of his first expedition of the Liverpool School of Tropical Medicine, followed that of other amoeba. Clearly this never took off, and today we still call the disease for the historical suspect: bad air, from the old Italian - *mal aira*).

Ross noted in his report that he had ‘hitherto… employed … mostly brindled and grey varieties of the insect.’ He subsequently abandoned those species and commenced ‘…similar work on a new, brown species…’. Ross successfully isolated ‘…cells containing pigment identical in appearance to that of the parasite of malaria.’

Ross describes in detail the morphology of these ‘brown’ mosquitoes, a description that fits to the *Anopheles* genus of mosquitoes – recognized today to be the genus involved in the transmission of malaria:

The back of the thorax and abdomen is a light fawn colour; the lower surface of the same, and the terminal segment of the body a dark

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5 R. Ross, *On some peculiar pigmented cells found in two mosquitoes fed on malarial blood*, *British Medical Journal*, 2 (1897), 1786-1787.
chocolate brown. The wings are light brown to white, and have four dark spots on the anterior nervure. The haustellum and tarsi are brindled dark and light brown. The eggs – at least, when not fully developed – are shaped curiously like ancient boats with raised stern and prow, and have lines radiating from the concave border like banks of oars…

On 16 August 1897 Ross successfully fed eight of this species of mosquito on a patient in whose blood he had identified malaria parasites. Ross proceeded to kill a number of the mosquitoes each day leading up to the 20 August, when he finally identified ‘…some cells which seemed to be slightly more substantial than the cells of the mosquito’s stomach usually are… each of these bodies contained a few granules of black pigment absolutely identical in appearance with the well-known and characteristic pigment of the parasite of malaria.’

Following the publication of his findings, Ross was stationed in Kharwara. This was a region free of malaria, a punishment for publishing outside the official channels of the IMS.

Back in the capital of the Empire, Ross’s constant champion, Manson, made representations, and secured Ross a special duty, to last one year, in Calcutta. Here, he carried out feeding experiments on birds and successfully completed the mosquito stages of the parasite’s life cycle, however Ross was ordered away before he demonstrated the mosquito stages of the human form. The Italian zoologist, Giovanni Battista Grassi, and colleagues accomplished this in December 1898, siring a bitter feud, which would not be dampened by the honours bestowed upon both parties. The feud ignited over Grassi’s failure to credit Ross in his publication, despite having read Ross’s articles. A furious Ross responded by sending angry letters to the journals in which Grassi published his papers. Indignant letters continued to be sent to and fro for some time to come, each side sure of the prestige of their work over the other. But it was Ross who was granted priority when, in 1902, he was presented the Nobel Prize in Physiology or Medicine for his work in malaria.

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At the Liverpool School of Tropical Medicine

1898 was a pivotal year for Tropical Medicine: a separate section of the British Medical Association’s annual meeting was created for the subject, the first dedicated British journal devoted to tropical medicine was born, and Manson published his first edition of ‘Tropical Diseases: A Manual of the Diseases of Warm Climates’. Ross’s fortuitously timed discovery meant he was slung to the forefront of the discipline, acquiring a seat as the first Professor of Tropical Diseases at the newly formed Liverpool School of Tropical Medicine.

Two schools of Tropical Medicine, in Liverpool and London, were opened within six months of each other in the final year of the 19th century, Liverpool being the first to open its doors. Although he would have preferred London, fortune favoured Ross in his appointment to the Liverpool school, as the smaller size of the school meant he had a disproportionate effect on the direction of the school. He wrote of his intentions on joining the school in his memoirs:

The teaching-programme of the proposed school was a comparatively small matter, but I could make Liverpool a base for frequent scientific and sanitary missions to the tropics for the purpose of perfecting and applying my ideas. Boyce also had thought of expeditions, but chiefly, I believe, for smaller purposes, such as collecting teaching material.¹⁰

Ross led a tumultuous tenure at the Liverpool School. He frequently alienated other members of staff, angered the doctors of the Royal Southern Hospital, and twice quit. He wrote of his first day on the new ward in the Royal Southern Hospital, explaining how he thought he was to be the medical lead, and instructed a house surgeon on the treatment of one of the patients. The following day, Ross received an angry letter from an irate elder physician.

The first expedition of the Liverpool school was to Sierra Leone in August 1899. Ross and two other staff members went to ‘…enquire whether the discovery (of mosquito transmission of malaria) could not be turned to practical account for the better prevention of malarial fever.’ The intention was to find one or more species of mosquitoes hospitable to human malaria, and study the bionomics of these insects, with a view to better suggest

modes of prevention. Ross continued this line of research in the dozen years he spent at the Liverpool school. He produced numerous documents for the use of physicians in malarious areas. Drawing from his practical experience of public health, Ross concentrated on methods that destroyed the breeding grounds of the mosquito vector.\(^{11,12}\)

**Who was Ross?**

Ross was an interesting character. Given the opportunity, he would have gone for art or literature – and even published some novels and poems. One biographical history of medicine describes Ross as a ‘…poet, novelist, musician, scientist and reluctant physician…’.\(^{13}\)

The episode with the Italians is evidence of the ever-maladjusted Ross’s interactions with other people. He was quite a difficult man, with an ever-growing cohort of people with whom he had little tolerance. Sadly, this group would ultimately include the man who helped Ross find his fame: Patrick Manson. The two eventually became estranged, with Ross holding considerable animosity to his former friend. Ross published his memories of Manson in 1930. This ‘mean-spirited little volume’ attempted to belittle Manson’s input into Ross’ famous work.

**Conclusion**

This account is an example of how scientific discoveries are seldom made in isolation: it took a series of observations and discoveries, made by people separated temporally and geographically, but ultimately working to a common goal. Though undoubtedly a great discovery, it is difficult to conclude that Ross’s discovery was any more important, for without those preceding, Ross would not have been able to make his.

It is rarely that scientific discoveries are made in isolation. That is to say, there is a collective scientific consciousness that carries forward a

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train of curiosity directed to the understanding of natural phenomena.\textsuperscript{14}

\textsuperscript{14} E. R. Nye, \textit{Ronald Ross; malariologist and polymath} (MacMillan, Basingstoke 1997).