REVIEW OF RESEARCH IN PARASITOLOGY IN MALAYA*

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HISTORICAL

The present status of research in Malaya cannot be satisfactorily surveyed without the background knowledge of the past. This can best be achieved by the perusal of that excellent outline of medical development in Malaya over the past half century contained in the commemorative history of the Institute for Medical Research, Kuala Lumpur 1900-1950 written by Dr. J.W. Field and his colleagues.

Among the subjects of interest to us which have received special attention by the research workers in Malaya are malaria, filariasis, hookworm infection and scrub typhus, and the transmitting agents of some of these diseases.

MALARIA

Throughout the history of tropical enterprises, the opening up of the land, especially when done with imported labour, has produced violent outbreaks of malaria, and Malaya was no exception. With the rapid felling of jungle and the opening up of huge tracts of the country for cultivation and the consequent introduction of large numbers of non-immune labour forces into this country at the turn of the century came an alarming increase in malaria. The necessity for a general campaign against malaria soon became evident. Malaya can lay claim to the honour of being one of the first countries in the world to have successfully applied the knowledge of the mode of transmission of malaria in its control. Jungle clearing, drainage and filling were the main measures adopted in the coastal plains of Selangor, but as this was extended to the tidal zones and the inland areas it was found that other methods had to be evolved owing to different vectors being responsible for the transmission of malaria in these places. The credit for introducing special methods of attack according to the type of vector found should go to Sir Malcolm Watson whose method of attack, known as "species sanitation", has been extensively used in other parts of the world. Professor Williamson introduced the naturalistic control measures whereby the natural processes which tend to limit the multiplication of vectors are extended or intensified. Dr. Field showed before World War II the value of drug prophylaxis using quinine and atebrin among concentrated and disciplined labourers of the estates.

It was recognised very early that the chances of success of malaria control by anti-mosquito measures were dependent upon an intimate knowledge of the identity and habits of the vectors. The Institute for Medical Research which was started in Kuala Lumpur in 1900 has been closely associated with the solving of problems connected with malaria and mosquitoes. Hamilton Wright the first Director of the Institute published in 1901 the first volume of the "Studies" of the I.M.R. on malaria and mosquitoes. He also instituted feeding experiments to determine the relative susceptibility to infection of Malayan mosquitoes. Leicester published the "Culicidae of Malaya" in 1908 and described in it 16 species of Anopheles. A large number of entomologists have devoted their attention to this subject, and today we have about 60 species and subspecies of *Anopheles*, about six of which are known to carry human malaria.

Very early in the malaria campaign it was established that the Malayan species of *Plasmodium* were identical with those causing malaria in others parts of the world although subsequent work has shown the existence of strains of species which are antigenitically distinct exhibiting varying degrees of virulence, susceptibility to drugs and the ease with which known vectors may be infected. Green instituted investigations on the staining techniques for the laboratory diagnosis of malaria, and Field evolved a rapid method of staining thick films which is extensively used today.

With the introduction of modern synthetic insecticides and the newer drugs, the I.M.R. carried out controlled experiments over a 3-year period on their uses under Malayan conditions and showed that all methods were effective in reducing but not eliminating malaria or the vectors.

Although the concept of complete eradication of malaria from a country had been accepted as feasible by the World Health Assembly as

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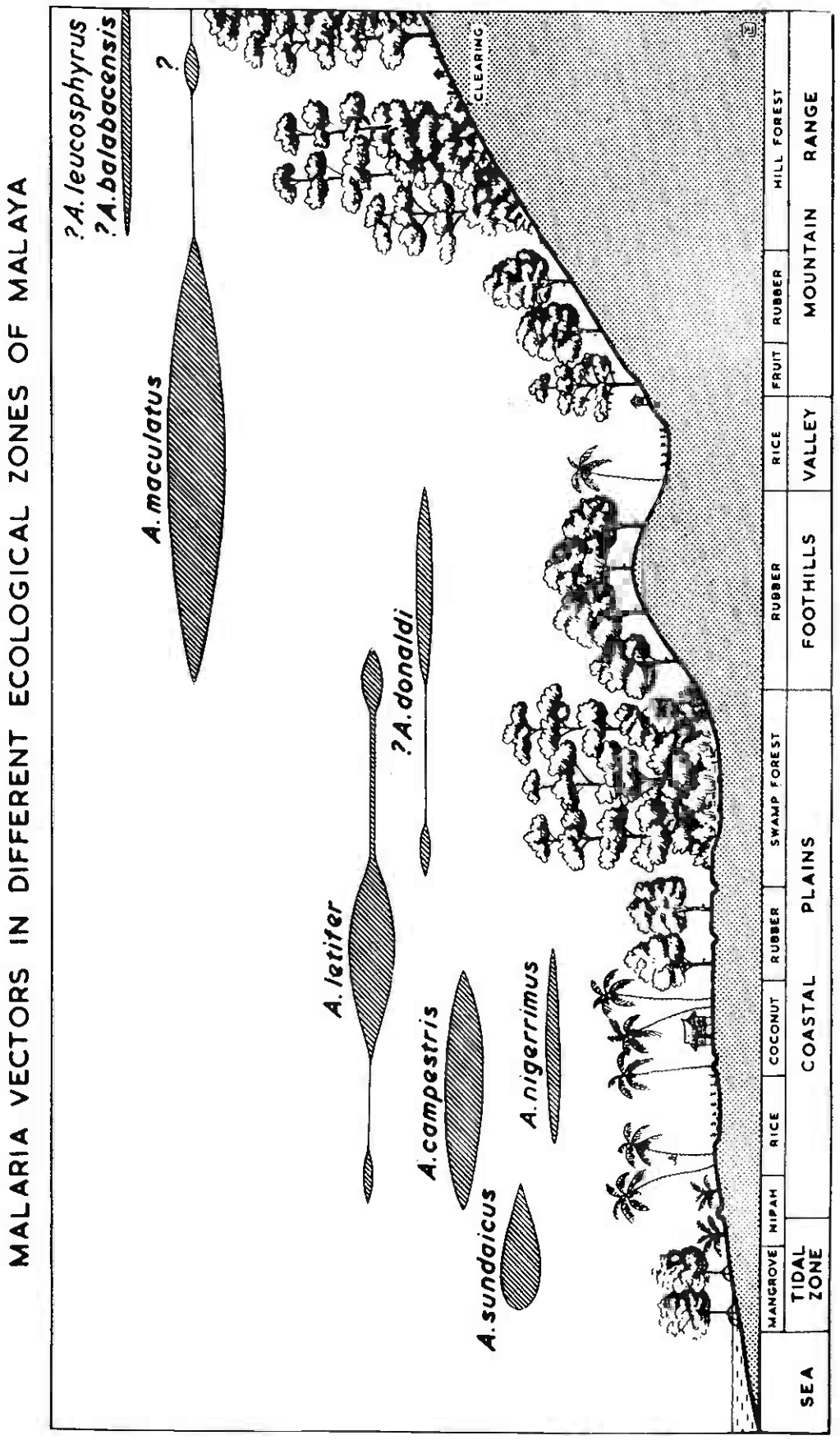

MALARIA VECTORS IN DIFFERENT ECOLOGICAL ZONES OF MALAYA
?A. leucosphyrus
?A. balabacensis
?
A. maculatus
CLEARING
?A. donaldi
A. letifer
A. campestris
A. nigerrimus
A. sundaicus
SEA
TIDAL ZONE
MANGROVE
NIPAH
RICE
COCONUT
RUBBER
COASTAL PLAINS
SWAMP FOREST
RUBBER
FOOTHILLS
RICE
FRUIT
RUBBER
VALLEY
MOUNTAIN RANGE
HILL FOREST

early as 1955, Malaya had not taken positive steps to initiate action until 1961 when a pilot project was commenced. This delay may appear strange considering that Malaya has been a pioneering country in malaria control, but Malaya has been preoccupied waging a war with the Communist terrorists. Besides, there was some doubt if we will be able to achieve the same degree of success attending eradication campaigns in some countries of Europe and America. We have not one but several vectors some of which are exophilic and transmission of malaria is not seasonal but perennial. The delay in commencing a country-wide eradication programme has been a blessing in disguise as Malaya can now benefit from the experience of a number of neighbouring countries which have had to gain it the hard way. Malaya is awaiting the results of the pilot project of the malaria eradication campaign now being carried out in Selangor.

ENTOMOLOGICAL STUDIES

Entomological investigations include the systematics and bionomic studies and the search for vectors. The tropical rain forest zone with uniform climate has resulted in the evaluation of several groups of closely allied or sibling species in Malaya. Gater (1933) started work on the umbrosus group which has been continued by Reid (1950) and today it represents 9 or 10 similar-looking species. Reid (1953) also worked on the hyrcanus group recognizing 8 species in the place of the two subspecies known then. Crawford (1938) first observed differences in the pupae of *A. barbirostris* and Reid who commenced work on the barbirostris group in 1941 has only now been able to unravel the problem and introduce new names to bring the total numbers of species in this group to eleven. Colless (1956) worked on the leucosphyrus group commenced by Reid in 1949 and showed it to consist of seven species and subspecies. As all these groups contain vectors of malaria their separation from the innocuous but very similar looking species of a group is important.

The biology and relation to disease of the Malayan *Anopheles* have been studied by a large number of workers particularly Watson (1921) Gater (1931) Hodgkin (1956) and Wharton (1950). These studies have made it possible to pinpoint the particular species involved in the transmission of malaria in Malaya. They are *A. maculatus* Theobald, 1901, *A. letifer* Sandosham, 1944. *A. campestria* Reid, 1962, *A. sundaicus* Rodenwaldt, 1925 and *A. nigerrimus* Giles, 1900; possibly also *A. donaldi* Reid, 1962, *A. leucosphyrus* Donitz, 1901 and *A. balabacensis introlatus* Colless, 1957. *A. umbrosus* Theobald, 1903, *A. letifer* Sandosham, 1944, *A. baezai* Gater, 1933, *A. roperi* Reid, 1950, *A. hackeri* Edwards, 1921, *A. pujutensis* Colless, 1948, *A. leucosphyrus* Donitz, 1901 and *A. balabacensis introlatus* Colless, 1957 in which sporozoites have been found are vectors of animal malaria.

Owing to the difficulty of getting Malayan anophelines to mate in cages in the insectarium, recourse has been had to artificial mating and colonies of several generations have been maintained with *A. maculatus* and some success has been obtained also with *A. balabacensis* and *A. hackeri.*

MALARIA AS A ZOONOSIS

Eyles *et al* (1960) showed that *P. cynomolgi bastianellii* from a Malayan monkey can be transmitted to man by mosquito bites and further work confirmed this and showed that *P. cyromolgi cynomolgi* can also infect man and that simian malaria can be transmitted from man to man by anopheline mosquitoes.

A U.S. Public Health Service Research team including Dr. D.E. Eyles and Dr. M. Warren have been carrying out collaborative studies in conjunction with the staff of the I.M.R. Divisions of Malaria (Dr. A.B.G. Laing and Dr. A. A. Sandosham), Entomology (Dr. R.H. Wharton) and the Medical Zoology (Dr. F.L. Dunn) on the problem of whether monkey malaria constitutes a zoonosis.

Studies to determine the species present and the prevalence of malarias in monkeys and apes have resulted in the description of two new species from Malaya, *Plasmodium fieldi* from the pig-tailed macaque (*Macaca nemestrina*) and *P. coatneyi,* which was first isolated inoculating sporozoites from wild caught *A. hackeri,* from the long-tailed macaque *M. irus.* A new species of *Plasmodium* is being described from the flying lemur (*Cynocephalus variegatus*). What appears to be a new species of *Plasmodium* in white-handed gibbon (*Hylobates lar*) is being studied. The slow loris (*Nycticibus coucang*) and tree shrews (*Tupia* spp.) have shown no malaria parasite. Peculiarities of a local variant of *P. cynomolgi* are being studied. The similarity of aberrent *P. vivax* described by Field (1942) to heavy infection of *P. c. bastianellii* has been noted.

Selected strains of monkey malaria are being sent to U.S.A. to try and infect human prison volunteers.

A search is made to determine the vectors in nature of simian malaria. Sporozoites obtained from wild-caught anophelines have shown that *A. hackeri, A. leucosphyrus* and *A. balabacensis introlatus* are among the known vectors while *A. pujutensis* is suspected of being one. Sporozoites from *A. leucosphyrus* and *A. balabacensis introlatus* did not infect human volunteers. Inoculations of sporozoites from wild-caught *A. maculatus, A. umbrosus, A. letifer* and *A. roperi* did not produce infection in monkeys. Sporozoites from *A. umbrosus* failed to infect man and after screening large numbers of forest animals and birds it has been established by Wharton and his fellow-workers that *A. umbrosus* is a natural vector of *P. traguli* of the mousedeer (*Tragulus javanicus*). Several thousands of wild-caught *Mansonia* have been fed on uninfected rhesus monkeys without result although experimentally it has been shown that *M. uniformis* produces *P. cynomolgi* sporozoites, which however fail to reach the salivary glands.

The frequency with which Malayan *Anopheles* are attracted to monkeys on the ground and in the canopy and to man on the ground have been studied. *A. leucosphyrus* and *A. balabacensis* have been shown to bite both man and monkeys on the ground and in the canopy, and one or both of these may well be responsible for transmission, if it does occur in nature, of simian malaria to man.

Experimental studies on the susceptibility of Malayan *Anopheles* to simian malaria infection have been made and the most susceptible mosquitoes found are also vectors of human malaria (*A. sundaicus* and *A. maculatus*). Further work on this aspect is being carried out with members of the *leucosphyrus* group.

Attempts are being made to determine if human infections transmissible to monkeys exist in Malaya. Blood from people who live in close association with monkeys has been inoculated into uninfected rhesus monkeys without positive results so far.

The study of monkey malaria has been extended to Cambodia where in some areas members of the leucosphyrus group are more plentiful and where contact between mosquitoes, man and monkeys is much closer and where man and monkeys are more highly infected with malaria parasites than in Malaya.

OTHER BLOOD PARASITES

Hepatocystis semnopitheci has been found in the Malayan pig-tailed macaque (*M. nemestrina*) and the banded leaf monkey (*Presbytis melalophos*). *Hepatocystis* spp. has been found by Dunn in a member of insectivorous as well as fruit bats in the course of a survey of Malayan bat parasites. *H. vassali malayensis* has been described by Field and Edeson (1950) from the Malayan squirrel and Garnham and Edeson (1962) have described *H. fieldi* from the mousedeer. *Haemamoeba gallinacea* has been recorded in local fowls and Hoo (unpublished) has worked on its pathogenicity in domestic chicks. *Haemoproteus* spp. have been recorded from a number of birds and a lizard and *Leucocytozoon* sp. from the chick. *Trypanosoma* spp. are recorded from the domestic fowl, the mousedeer, slow loris and bats and *Babesia* spp. have been found in the forest rat and the anteater.

From the examination of blood smears from 1000 birds Laird (1960) records *Trypanosoma, Toxoplasma, Plasmodium, Haemoproteus, Leucocytozoon* and microfilariae.

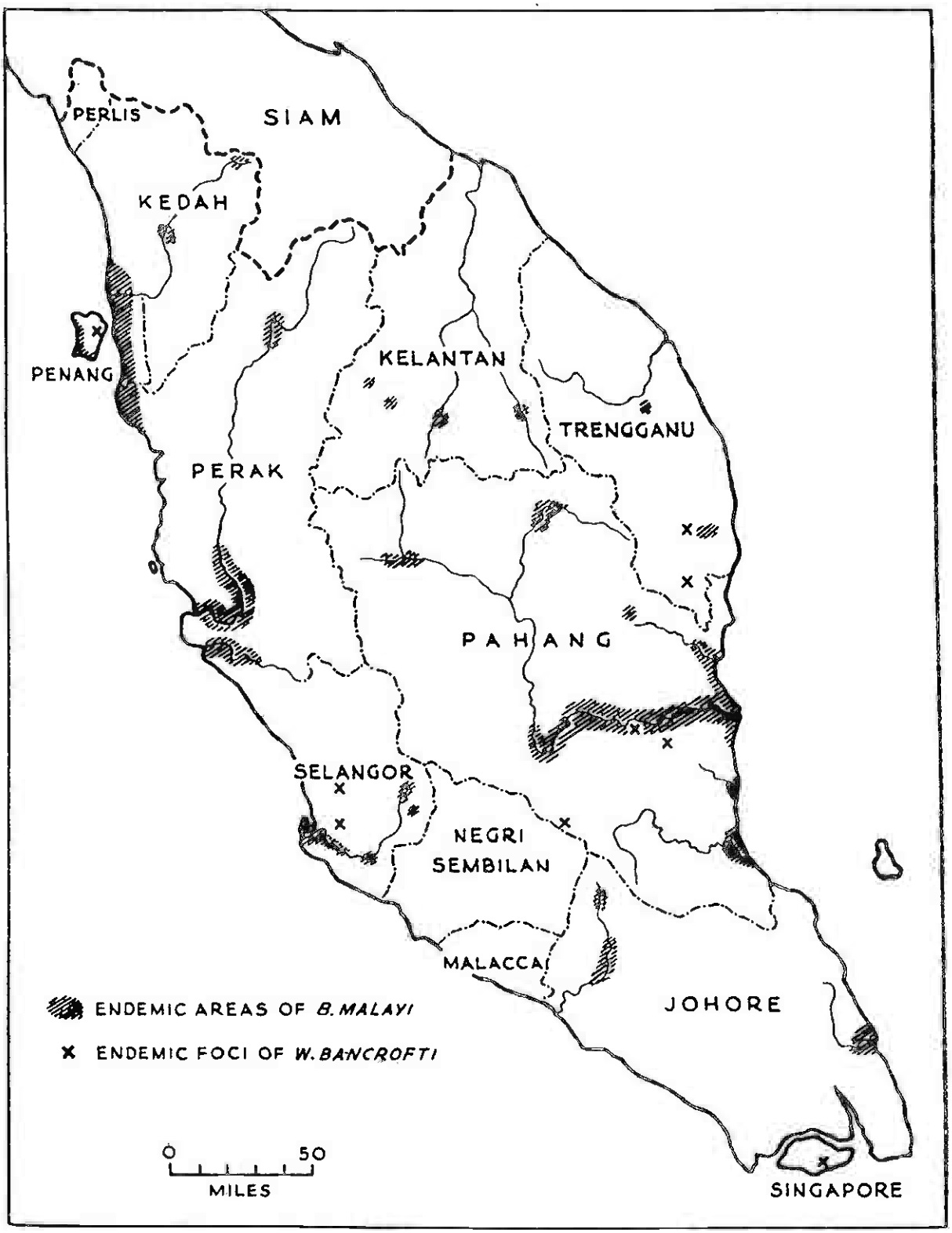
FILARIASIS

Filariasis due probably to *Wuchereria bancrofti* was encountered among the labourers who came to open up the country from South China and South India in the early years of this century. Although transmission occurred, it was not considered to be a public health problem and nothing was done till 1934 when Strahan and Norris found elephantiasis prevalent among the indigenous Malays of North Province Wellesley. The causative organism was identified by the writer as *W. malayi* which had recently been described from Java. This species was subsequently assigned to a new genus *Brugia* Buckley, 1958.

The Institute for Medical Research began an investigation in 1936 and Poynton and Hodgkin (1938) showed that filariasis due to *Brugia malayi* was endemic in certain rural areas of Malaya, the incidence being particularly heavy in the estuaries of big rivers. The infection was largely transmitted by species of *Mansonia* which bred in the extensive fresh-water forest swamps on the banks of the rivers as they run into the sea. Poynton and Hodgkin (1939) later found microfilariae indistinguishable from those of *B. malayi* in the blood of certain monkeys which raised the question of zoonosis.

A filariasis enquiry was started by the Institute for Medical Research in Kedah. Subsequently, investigations were made in Penang and in 1953 a research unit of the Institute for Medical Research was established in East Pahang where the Pahang River flows into the sea.

DISTRIBUTION OF FILARIASIS IN MALAYA.



Among those associated in the recent filariasis research have been Wilson, Edeson, Buckley, Wharton, Reid, Turner and Laing, and their work has been summarised by Wilson (1961) and Laing and Wharton (1960,61) in the I.M.R. Annual Report, from which sources much of this information has been obtained. Based on their experience, Government has instituted a programme of control of filariasis in the heavily infected areas by mass treatment with diethylcarbamazine (hetrazan, banocide, etc.) given in weekly doses for six weeks. It has been in progress for the last three years in the States of Kedah, Penang, Province Wellesley, Perak, Selangor, Johore and Pahang, and is under the supervision of the I.M.R. as it is still regarded as a research project.

THE FILARIAL PARASITES AND THEIR VECTORS

Wuchereria bancrofti has been found in immigrants from India and China. There are also endemic foci in Malaya, those in the cities like Singapore being due to transmission of this species to local inhabitants, the vector being chiefly *Culex pipiens fatigans*. Small endemic foci of possibly an indigenous strain of *W. bancrofti* infection occur widely scattered in rural areas of the country and affect the Malays and aborigines. Wharton (1960) showed that in East Pahang the vector was a species very similar to *A. letifer*.

There are two forms of *Brugia malayi* in Malaya associated with different types of terrain. This was first noticed by Turner and Edeson (1957) who showed that *B. malayi* in the freshwater swamp forest of East Pahang did not show a marked rise in microfilarial counts at night and that microfilariae could be found in the peripheral circulation throughout the day. The *B. malayi* of the rice fields and open swamps of Penang and Kedah, however, showed a marked nocturnal rise of microfilariae which were rarely found by day. The former is referred to as the semi-periodic form and the latter as the periodic form of *B. malayi*. The semi-periodic type is transmitted by *Mansonia bonneae, M. dives, M. annulata* and *M. uniformis*, more or less in that order of importance, while the known vectors of the periodic form are different mosquitoes being *Anopheles campestris* Reid, 1962 (formerly referred to as the dark-winged form of *A. barbirostris*) and to a lesser extent *Mansonia uniformis, M. indiana* and *M. annulifera. B. malayi* occurs, sometimes in association with *W. bancrofti*, among aborigines in various parts of the hilly country. Both periodic and semi-periodic forms of *B. malayi* have been encountered in some of these situations, and although the vectors are not definitely known, it is felt that *M. dives, Anopheles donaldi*, and *Aedes chrysolineatus* may be involved in some of these areas.

A study of animal filariasis revealed natural infections of *B. malayi* in the Malayan leaf monkeys *Presbytis obscura, P. melalophos* and *P. cristata*, the long-tailed macaque, *Macaca irus*. the pig-tailed macaque *M. nemestrina*, the domestic cat *Felis domestica*, the wild cat *F. bengalensis*, the civet cat *Paradoxurus hermaphroditus* and the pangolin *Manis javanica*.

It appears probable that the leaf monkeys, which have very high infection rates, constitute a zoonosis and provide a reservoir of infection of semi-periodic *B. malayi*. This is evident in East Pahang where there was an earlier return to high microfilariaemia following mass treatment over a three-year period than elsewhere where animal infections are not known.

To complicate the picture in Malaya, we find another species in animals, namely *B. pahangi*, the microfilaria of which is very similar to that of *B. malayi* and the infective larvae of both species in the mosquitoes are identical in appearance. *B. pahangi* appears to be a parasite principally of carnivores but is also fairly common in the slow loris and in the dusky leaf monkey. It has been possible to experimentally infect a human volunteer with *B. pahangi*, but there is no evidence that it infects man in nature. The known vectors of *B. pahangi* are *M. annulata* and *M. dives*.

Laing (1961) found a single case of *Dirofilaria magnilarvata* in a four-year old child in East Pahang. This filarial parasite is found as natural infection in the gibbon *Hylobates lar*, the long-tailed macaque *M. irus* and the dusky leafy monkey *P. obscurns*.

A total of more than eleven hundred mammals and birds have been examined for filarial infections in East Pahang during the I.M.R. (1955-1960) survey, the results of which are embodied in the Annual Report for 1960.

EXPERIMENTAL STUDIES

TRANSMISSION: Transmission experiments have shown that *B. malayi* can infect a wide variety of animals such as the long-tailed macaque, the rhesus monkey, slow loris and the civet cat, the domestic cats being particularly suited. The semi-periodic form is more easily transmissible than the periodic form. A low grade infection lasting eight weeks was obtained by inoculating *B. pahangi* in a human volun-

teer. It has been established that the infective larvae of *B. malayi* penetrate the cat's lymphatic system within a few hours and although subsequent development may take place anywhere in the lymphatic system, large numbers failed to remain near the site of inoculation.

VECTORS IN NATURE: In an attempt to determine the natural vectors of *Brugia* spp. in Malaya, many experimental inoculations were attempted into cats and rhesus monkeys of infective larvae from wild caught mosquitoes. *B. pahangi* developed from *Mansonia annulata* and *M. dives* and the semi-periodic *B. malayi* from *M. bonneae*. Infective larvae of *Dirofilaria mangnilarvata* obtained from wild caught *M. dives* infected a rhesus monkey.

EXPERIMENTAL VECTORS: Studies on the development of periodic and semi-periodic *B. malayi, B. pahangi* and *W. bancrofti* have been reported. Whereas *M. dives* and *M. bonneae* are efficient vectors for semi-periodic *B. malayi,* neither are good hosts for the periodic form and *M. bonneae* failed to produce infective larvae. On the other hand *Anopheles campestris* is a good vector of the periodic form but a poor host for semi-periodic *B. malayi.* Somewhat similar results were found with the rural and urban strains of *W. bancrofti. Culex fatigans* was a good host for Singapore urban strains but a very poor host for the rural strain transmitted by the species close to *Anopheles letifer.*

A large number of experimental infections have been attempted on naturally and experimentally infected hosts of the human and animal filarial infections. In addition to confirming the importance of the vectors found naturally infected, it has been established that *Aedes togoi,* an imported species, carriers period and semi-periodic *B. malayi, B. pahangi* and the rural strain of *W. bancrofti.* Whereas the Malayan strain of *A. aegypti* was relatively more refractory to *B. malayi* and *B. pahangi,* the Liverpool strain, especially the selectively bred strain, is highly susceptible to these filarial worms.

LONGEVITY: The longevity of *Brugia* infections have been studied in experimental animals and it has been established that the semi-periodic infection of *B. malayi* may last as long as 5 years in a domestic cat, the periodic form for at least $3\frac{1}{4}$ years in a rhesus monkey, and *B. pahangi* longer than $6\frac{1}{2}$ years in a cat.

PERIODICITY: *B. malayi* in man was shown to be periodic in the coastal rice fields of Kedah and Perak but semi-periodic in East Pahang. Natural infections of the long-tailed macaque and leaf monkeys in East Pahang *B. malayi* showed nocturnal periodicity. When the infections were transmitted to cats, the infection which subsequently appeared were variable, conforming more to the semi-periodic pattern. When semi-periodic *B. malayi* from man was transmitted to cat it remained semi-periodic, when transmitted to leaf monkeys it turned periodic. Periodicity studies done at intervals of several months showed no significant change. Further transmission (monkey—cat—monkey) showed that the microfilariae after being semi-periodic in the cat reverted to a nocturnal periodicity in the monkey nearly approaching that of the true periodic infection. These experiments indicate that the periodicity of *B. malayi* microfilariae can vary considerably, being influenced by the vertebrate host.

FILARIASIS CONTROL IN MALAYA

Arising from their researches, the I.M.R. in its Report No. 61 of 1960 recommended a campaign for the control of filariasis in the country as a whole. The aim of the campaign was not to set out to eradicate the infection but to bring it down to and keep it at a level at which no clinical symptoms occur by means of mass treatment with diethyl-carbamazine supplemented by anti-mosquito measures except in the areas with extensive swamp forests breeding *Mansonia* spp. The drug is given in a dosage of 5 mg. per kg. body weight at weekly intervals for six weeks.

In the Pahang Tua area where the semi-periodic type occurs with a heavy infection of leaf monkeys, the microfilaria rate per cent and the mean number of microfilarae for 20 c.mm. of blood fell as a result of mass treatment and retreatment of positives but a survey after three years shows an increase in infection rate and the load although not to the same extent as found originally. In the Kota area of Kedah, however, where the periodic type occurs without animal reservoirs of infection, the infection had tended to remain very low three years after mass treatment.

SCRUB TYPHUS

Malayan research has made one of the greatest contributions towards a more clear understanding of the tropical forms of typhus. Most of the clarification was done at the Institute for Medical Research during the decade following 1924 when the investigations commenced. The various typhus fevers were then recognized as a very widespread group of diseases. The classical epidemic typhus was spread by lice. One form in America, another in Africa and a third

in India were spread by ticks. A form in Japan and another in Sumatra were spread by mites. Finally, a large number of infections, which had clinical peculiarities and generally referred to as tropical typhus, were of unknown origin. Fletcher and Lesslar by their serological and epidemiological studies showed there were two types of tropical typhus in Malaya. By applying the Weil-Felix reaction to these fever cases they found that one group was positive to the Warsaw X 19 or "W" strain and negative to the Kingsbury or "K" strain and vice versa. One group occurred in outbreaks in rural areas localised in time and place and the other was scattered involving indoor workers. This at once suggested that the two forms had different vectors.

Lewthwaite, Savoor, Anigstein and Gater carried on the work and attacked the problem by studying the bacteriological, clinical, pathological and vectorial aspects as well as the response to experimental infection of animals. Gater found *Leptotrombidium* (= *Trobicula*) *akamushi* to be the commonest mite on estate labourers but *T. deliensis* the commoner species on rats. He thought the two mites were varieties of the same species.

The responses of various laboratory animals to infection were studied and the white mouse ultimately proved to be the animal of choice. Lewthwaite and Savoor isolated the causative organism of scrub typhus by infecting material into guinea pig from rats trapped in localities where typhus had occurred. This proved to be the same as the organism responsible for tsutsugamushi disease in Japan. These workers also showed that the coastal fever of Australia and the Sumatran mite fever transmitted by *L. deliensis* were identical with the Malayan scrub typhus. They subsequently managed to culture the organisms in eggs after six or eight passages with a view to preparing a vaccine when World War II broke out.

Smadel and his team of the U.S. Army worked in Malaya soon after the war and established the efficiency of chloromycetin in the treatment of scrub typhus.

Current studies on the vector mites of scrub typhus in Malaya focus on their distribution. Another mite *L.* (*L*) *arenicola* found on rats caught in the grass near the seashore has recently been described by Traub. Since this species represented the dominant chigger on rats at the site of a scrub typhus outbreak and since *Rickettsia tsutsugamushi* has been isolated from pools of these chiggers collected from another coastal site in Malaya, this new species is considered another suspected vector of scrub typhus.

Audy and Harrison working in Malaya between 1946 and 1958 studied in detail the habits, habitats and mite infestation of the host rats of the scrub typhus vectors. They developed a concept of "islands" of mites in the fields, scrub and forest fringe based on differential mite counts on different rats in different localities and formed hypotheses regarding clusters of mites at resting places of certain rats following the observation of rather specific home ranges for rats under consideration and characteristic degree of chigger infestation among individuals of the same species within the same general area. This information was gained by trap-mark-release studies of rats in several localities in Malaya. The concept of size of a mite focus being several yards in diameter was based on experiments of Traub on the laboratory bred white rats exposed to grass fields in 27 square foot enclosures.

In the writings of Audy, considerable interest has been shown in "sylvatic scrub typhus' or "jungle tsutsugamushi" leading from studies of trombiculids closely related to *L.* (*L.*) *akamushi* found in secondary vegetation in Japan reported by Nagayo in 1921. Later the Imphal Team in India and Burma in World War II suggested one possible source of jungle tsutsugamushi in what may be natural reservoirs of *L.* (*L.*) *deliensis*. Traub, Erick and Dierks in 1950 reported the isolation of *R. tsutsugamushi* from forest rats, *Rattus edwardsi, R. mulleri* and *R. rajah*. In the same course of studies *R. tsutsugamushi* was isolated from a pool of 50 *Euschoengastia indica* (now *Laurentella audyi*). Audy and Harrison's observation of *L. deliensis* on *Rattus mulleri* found in the forest fringe in Malaya was to them curiously similar to observations suggesting "occult sancturies" of *L. deliensis* in forests of India and Burma. Yet forest tsutsugamushi remained a mystery with respect to its natural history.

During the past year Hubert working at the Institute for Medical Research in Malaya following the lead of Traub et al., who placed laboratory-bred rats in enclosures to determine the distribution of vector mites. Hubert developed a method of using rabbits in harness which could be staked out with foot retaining lines. He used 30 minute exposures in contrast to 40 hour exposures of Traub to estimate relative mite population in the specific area. He later found that black plastic plates which had been effective in North America for collection

of *Entromtricula alfreddugesi* was applicable to *L.* (*L.*) *akamushi* and *L.* (*L.*) *deliensis* in Malaya. For estimation of numbers of larval mites within the area of one plate only 2 minutes' exposure was required. The new methods allowed him to survey a considerable area in Malaya in the past year. He has found that only *L. akamushi* is found in the grass and scrub vegetation and on entering the forest there is a sharp demarkation at the forest edge between the habitat of *L. akamushi* and *L. deliensis*. Patches of *L. deliensis* can be found actually more frequently and in greater numbers on the forest floor than *L. akamushi* can be found on the ground in the fields.

McClure has initiated a study of vector mites on birds in the Malayan forests. The forest bird that has thus far been found most frequently infected is the brown babbler. There are usually 20 to 50 vector mites on this species. 502 have been collected and aliquots identified have shown 99.5 percent to be *L.* (1) *deliensis*. The other mite found was *Walchiella oudemansi*. One pool of 25 mites from a brown babbler has yielded *R. tsutsugamushi*, indicating that the *L.* (*L.*) *delinensis* which are found on the ground only in the forest and sedge are infected with scrub typhus rickettsiae and must now be considered for the role of major forest vector to explain the scrub typhus infection of the forest rats. It is also a well known ground vector which threatens man with its disease burden. If man is infected in the forest with this disease, as has long been suspected in a forested island, Jarak, forty miles off the coast of Malaya, this is not only a scrub typhus but forest typhus and may be best described simply as tsutsugamushi disease.

McClure and Nadchatram have studied trombiculids on some migratory birds during the past year and have found *L.* (*L.*) *scutellaris* on the Siberian Thrush (*Geckichla siberica*) and Greyhead Thrush (*Turdus o. obscurus*) captured in the mountain forest of Malaya. This is a finding of interest in that *L.* (*L.*) *scutellaris* has never been previously found in Malaya but is a well known tsutsugamushi disease vector of Japan.

Nadchatram of the I.M.R., supported by The Bishop Museum of Honolulu, has been able to collect trombiculid mites from Laos and Vietnam. This collection as well as material from India, Thailand, Java and Australia are being studied by Domorow and Nadchatram who have described about 40 species and have classified them into natural groups.

HELMINTHIC PARASITES

Except for identifying the common parasitic helminths of man and domestic animals little has been done in the past in Malaya. Great impetus was given to general sanitation and control of hookworm disease as a result of a very extensive survey of the infection in Malaya by the Rockfeller Foundation between 1915 and 1920.

The Colonial Office Scrub Typhus Research Unit at the I.M.R. made extensive collections between 1948 and 1952 of vertebrate animals (more than 20,000) representing 115 species of mammals, 30 species of birds and about 90 species of reptiles and amphibians. Opportunity was taken by the writer to collect from these the endoparasites (now in the University of Singapore collection) a preliminary report of which appeared in the Malaysian Parasites II (1954). Collections have been continued by the Medical Zoology Division of the I.M.R. All these are being gradually sorted out by taxonomists. Audy (1957) gives a review of the literature of Malayan parasites in Malaysian Parasites XXXIV.

Since then, the staff of the Division of Medical Zoology in the I.M.R. and of the Zoology Department of the University of Malaya, Kuala Lumpur have extended the studies of helminths. The parasites of the Malaysian primitive primates (tree shrews, lorises, tarsiers) are being surveyed by Dunn. Morphological and life history studies of the filarial worm *Breinlia* sp. in the slow loris, the splendidofilarine heart worms of the forest rat and filarial worms of the flying lemur and other forest mammals are in progress. A survey of helminths of small mammals of Pulau Tioman has been undertaken. The parasites of fresh-water fishes are being studied by Adams and also the helminths of cats and dogs. Other studies by Lie Kian Joe include *Angiostrongylus cantonensis* in Malayan rats and in intermediate hosts, *Echinostoma* spp. in man, animals and in the snail hosts, *Phaneropsolus bonnei* and other parasites in monkeys, eggs of *Poikilorchis* sp. in abscess wall of man and life history of *Diphyllobothrium* (*Spirometra*) spp.

ENTOMOLOGICAL STUDIES

Much of the entomological work in Malaya has been undertaken in connection with the studies on malaria, filariasis and scrub typhus and has been dealt with under those headings. The culicines became important with the finding of the prevalence of virus infections in Malaya. Colless in Singapore and Wharton, Mac-

donald and Traub in Kuala Lumpur have done work on the systematics and biology of the non-anopheline mosquitoes of which more than 200 are recorded from Malays; some of this information has been summarised in Malaysian Parasites XVI (1957). Included in this study is the biology and ecology of forest species and *Aedes* spp.

Malaysian Parasites XXXV and XXXVI countain a summary review and records of Tabinidae (Diptera) with descriptions of new species by Philip (1957) and Malaysian Parasites XVII describes four new species of fleas. Several papers in the Malaysian Parasites are devoted to the ticks and mites of Malaya.

The susceptibility of insects to residual insecticides has been the subject of study by Reid, Wharton, Moorhouse and Thomas.

REFERENCES

The literature on tropical parasitology in Malaya is too large to be listed here. Hence, only a select list is given from which (particularly Field's Fifty years of Medical Research in Malaya) other sources of information could be obtained.

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