FOREWORD

It is an honour for me to have the opportunity to write a few words in appreciation of Scientist Nadchatram's life and work. I hope he will agree to my using the appellation "Nad" for him. It is a term of friendship and respectful address used by his numerous friends overseas. Our association began in 1963 with my joining the staff of the George W. Hooper Foundation (HF) at the University of California Medical Centre in San Francisco. Director J. Ralph Audy, who hired me, had previously been at the Institute of Medical Research (IMR) as Head of the Division of Virus Research and Medical Zoology and, as Nad relates in his historical summation of scrub typhus research, that led to a collaborative program between HF and IMR. Many of my associates spent one to several years at IMR (or the University of Singapore), but it was not my good fortune to do so. However, in subsequently working at the Bishop Museum in Hawaii, I was able to go to Papua New Guinea on repeated occasions, and thereby work on the verterbrates and their parasites of a tropical forest fauna similar to that studied by Dr. Nadchatram in Malaysia. While not wanting to suggest that my accomplishments attained the high level of his, I do wish to note parallels in our experience. When I first went to Hawaii in the summer of 1969, it was Nad, completing studies there under a grant, who showed me many of the high points. In this report, he notes 14 now deceased scientists whose research in Malaysia should be recognized; I was interested and slightly surprised to recognize that all but a couple of them had significant interactions with my own career.

The term *scientist* is used above, and it is particularly fitting for Dr. Nadchatram. It derives from *science*, meaning "knowledge", and Nad has become knowledgable at the professional level in a wide range of areas, which he demonstrates in this report. He sets forth in clear fashion the fundamentals of Acari-related conditions, including rickettsiae (notably scrub typhus), viral diseases, and conditions caused directly by acarines (such as tick bite and scabies in its zoonotic form). He was a participant in most of the research carried out in his own country, so that he is able to write of it with familiarity and authority. It should be obvious that this report will be of unusual value to anyone concerned with research in medical zoology in Malaysia. However, I would emphasise that medical zoologists anywhere in the world can benefit from it.

I was pleased to read of two topics that Dr. Nadchatram covers and to learn of government programs in Malaysia that have begun to address them. These are conservation of natural resources and the abatement of global warming. Few countries have addressed these problems adequately, but it is well that there is an awareness of the need to do so.

Other than scientist, a term that describes Dr. Nadchatram is *naturalist*. I wonder if anyone can do justice to field research in biology who does not have the appreciation of nature that is suggested by the second term. Nad's feelings on one occasion, recalled after 40 years, are expressed here as delight in the beauty and complexity of untrammeled nature when rambling "in the park like primary forest interspersed with tall trees forming the canopy high above."

Anything more that might be said is presented in the work that follows, as written by Dr. M. Nadchatram. I advise you to read, profit, and enjoy.

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THE AUTHOR

M. Nadchatram is a retired Entomologist with some 40 years experience in the study of medical acarology. He began his foray into the world of parasitic ticks and mites in 1948 when he joined the Institute for Medical Research (IMR) as a laboratory technologist. During this time at IMR, he had the opportunity to participate in a number of zoological expeditions in the Asia Pacific region, including Nepal, Papua New Guinea, Laos, Vietnam, Indonesia and his own country, Malaysia. In 1976, Nadchatram was appointed Entomologist at IMR and was the Founding Head of the Division of Acarology, retiring in December 1982. On retirement from IMR, he was appointed Senior Teaching Fellow in the Faculty of Science, University of Singapore for six years from 1983 to 1988.

Inspired and motivated by his revered guru, Dr J. Ralph Audy, Nadchatram made numerous scientific contributions and discoveries of ecological and epidemiological importance in medical acarology. The results of his original scientific work in some 160 publications were accepted and published in several international journals, mostly in the Journal of Medical Entomology, before he was promoted to a position of entomologist in 1976. His work ranged from systematics and ecology, to conservation of natural resources. Held in high regard by his peers overseas, Nadchatram's name is commemorated in 15 biological taxa.

Nadchatram was also a Research Fellow at the Department of Entomology, B.P. Bishop Museum, Hawaii, U.S.A. from 1967 to 1969; and a part-time consultant on vector biology for the World Health Organisation. In addition, he has served as senior lecturer on applied parasitology and entomology as well as ectoparasite biology to post-graduate students from SEAMEO (Southeast Asian Ministers of Education Organisation) countries from 1970 to 1981.

His academic achievements include graduating with distinction in general, medical and veterinary acarology from the University of Maryland, College Park, U.S.A. He is also a public health and entomology graduate of University of Hawaii, Honolulu.

Nadchatram is a founder member and was president of the Malaysian Society of Parasitology and Tropical Medicine (MSPTM). He was awarded the Sandosham Gold Medal in 1980. In 2007, the MSPTM unanimously elected him its Honorary Member.

Aged 80 years, his message to the younger generation of Malaysian scientists is that communication and net-working with colleagues should be regarded as a functional part of research.

THE BENEFICIAL RAIN FOREST ECOSYSTEM, WITH ENVIRONMENTAL EFFECTS ON ZOONOSES INVOLVING TICKS AND MITES (ACARI), A MALAYSIAN PERSPECTIVE AND REVIEW

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Abstract. Ticks and mites are second only to mosquitos in importance as vectors of human infectious diseases. This paper reviews recorded information on zoonotic infections based primarily on studies conducted in Malaysia since 1948, but with some attempt at a global perspective. The tropical rain forest ecosystem is reviewed. The paper summarizes some 35 years of studies on the involvement of ticks and mites in human health and welfare in Malaysia. This is also an attempt to introduce the field to those who may be interested, in view of our limited knowledge relative to the importance of these vectors, and their potential of transmitting newly emerging diseases that may be introduced to the country. Tropical rain forest is a stable environment. Though Acari-borne zoonotic diseases evolved in the forest, infections are manifested through the alterations mostly by man-made activities. The parasitic Acari have preferred environmental conditions and biotopes that determine their distribution in nature, particularly within the tropical rain forest and consequently the environmentally altered areas that are the source of greatest risk for diseases. Acarines also vary in their vector potential. This article reviews the biology and ecology of all those species known to have zoonotic importance. Zoonosis in this paper refers not only to diseases that are transmitted from animals to man, but also those parasites of animals that cause dermatitis and other skin conditions in humans. This paper documents all Acari-borne zoonoses and distinguishes between those caused by viruses and those caused by rickettsiae. Emphasis is placed on Langat Virus, a tick-borne virus discovered and documented in Malaysia, with notes on the life-history and ecology of the vector *Ixodes granulatus* from which Langat virus was first isolated. Another tick-borne virus, the Lanjan virus was also isolated from *Dermacentor "auratus"* at the IMR. The paper mentions three other viral infections that have been isolated in Malaysia from ticks, vertebrate reservoirs or both. The tick-borne rickettsial infection, boutonneuse fever is reviewed. The distribution is given for Q-fever, a disease caused by a pathogenic agent that is rickettsia-like. Information to clarify the status of *Dermacentor* ticks, human tick bites, and the presence of questing ticks on vegetation are also given. Tick-caused human otoacariasis in Malaysia and elsewhere is discussed, with notes on terminology. Based on a report by Induharan *et al.*, tick paralysis is believed to occur in Malaysia. The potential importance and introduction of Lyme disease to Malaysia is discussed. The epidemiology and ecology of scrub typhus and its vectors is reviewed, including the colourful history of its study at the Institute for Medical Research (IMR). Scabies is now recognized as a zoonosis and the condition is described. Sarcoptid mites are suspected to represent more than one species. Scrub-itch and dermatitis caused by chigger mites, macronyssid mites and astigmatid mites are discussed. The importance of birds and bats in the dispersal of parasites is discussed. As examples of classical Acari-borne zoonoses, a viral disease from India and a rickettsial disease from America are briefly described. The elucidations of the natural history of these tick-borne diseases are described as epics of biomedical history. Though the essence of this paper is on environmental effects of zoonoses caused by ticks and mites, the environment in relation to human welfare and diseases is also discussed.

INTRODUCTION

Zoonoses are diseases or conditions which are biologically adapted to and normally found in/on animals but which under certain conditions infect or infest humans. In this paper an effort is made to review Acari-borne zoonotic diseases and the causative acarine agents in Malaysia, and to relate classical examples of the natural history of Acari-borne zoonoses from other countries, based on the author's experience having worked at the Institute for Medical Research (IMR), Kuala Lumpur for close to 35 years. Zoonotic diseases are inextricably linked to their environment (Pavlovskii, 1966) which makes it necessary to gain knowledge of the factors involved.

In many medical and scientific fields progress has been slowed or stopped because some curative discoveries in human and veterinary medicine have seemed to make research unnecessary. This is unfortunate, because the ecological analysis of many diseases has been set back (Pierce, 1974). Indifference, lack of knowledge, and limited communicative skills have consequently contributed to a lack of progress. This review is presented in the hope that public health authorities will pay heed to the importance of fundamental research, including taxonomical, biological and ecological aspects of medical science.

All colour pictures used here were taken by Nadchatram during his period of working at the Institute for Medical Research over 3 decades. Excepting outdoor photography, a camera plus close-up lens, a binocular and compound microscope with photo-attachments were used to capture the macro-images. Other figures used are by courtesy of the respective authors, and the publications in which they appeared are gratefully acknowledged.

Systematic treatment of host animals

For the study of parasites of animals it is very important to have the host animals identified accurately. I have had the pleasure of working with Dr Lim Boo Liat, the leading vertebrate zoologist and naturalist of some 60 year-friendship. Dr Lim understudied Professor J.L. Harrison who was the first vertebrate zoologist at the IMR after WW II. Professor Harrison had made significant contributions, especially in the systematic studies of small mammals in Malaysia. Working on parasites, one needs to have a working knowledge of the animals involved and species of doubtful status examined by an authority for confirmation of the identification. It is very important for this subject to be continued and that the Unit of Medical Zoology be resurrected and placed in the Infectious Diseases Research Centre. There have been a number of publications on mammals of Malaysia in the recent history, the earliest being Chasen (1940). Prior to Chasen there were the volumes of *The fauna of the British India*. After WW II it was followed by Medway (1969, 1978) and Harrison (1974). A more comprehensive and detailed study is that of Boonsong & McNeely (1977). This work encompasses detailed ecological, taxonomical and distributional information on many species illustrated with black & white and colour pictures. This work also treats all murids as of the genus *Rattus*. It is, however an excellent and important book of reference for mammals of Thailand and the neighbouring countries of Southeast Asia. Before the publication of Musser (1981), which resulted in the taxonomic revision of all rat species of Malaysia, the fauna was treated in the genus ***Rattus*.** Subsequently, Corbet and Hill (1992) revised the mammal fauna of th e Indo-Malayan region. This is the most current treatise on mammals of Malaysia and names of the host animals follow this publication. For those interested in other books on Malaysian mammals, Chapter 14 of Harrison (1974) lists the titles prior to those given here.

Higher Systematics of Acari

According to Ross *et al.* (1982), in the hierarchical system of classification, Acari is a member of the subphylum Chelicerata, which is one of three subphyla of the phylum Arthropoda. The other two subphyla are Trilobitomorpha and Mandibulata. The Chelicerata comprises three classes, Merostomata, Pycnogonida and Arachnida. The merostomes and pycnogonids are aquatic while the arachnids are terrestrial, with the exception of some forms which have become secondarily adapted to life in water. The class Arachnida consists of the better known scorpions and spiders, and Acari is one of some 11 subclasses in Arachnida, which are the ticks and mites. In terms of number of species there are some 50,000 Acari roaming freely and living their own life-styles on the surface of the earth. Many more thousands await to be discovered.

The first book on mites introduced to the IMR was "Introduction to Acarology" by Baker & Wharton (1952). This was followed by many other monographic publications from the U.S.A., Europe and Australia. Notable among them were: Womersley (1952), Baker *et al* (1956) and Strandtmann & Wharton (1958) were among the many. One of the major publications was that of Krantz: The Manual of Acarology (1970), with the second edition that appeared in 1978. Easy to read, comprehend, and follow, these manuals formed the basis of my research and teaching commitments in acarology for many years. I was in touch with Professor Jerry Krantz recently, and it is pleasing to note that the next edition of the Manual of Acarology, with multiple authorship and edited by Krantz, is soon to be published and released. Another relevant publication on arachnids and mammalian diseases is a multi-authored work edited by Nutting (1983). It is in two volumes. Volume I discusses mammalian diseases and Vol. II broadly covers wildlife diseases and control.

Systematic study is critical for the understanding of agents and the diseases communicated by them between animals and humans.The systematics of the higher classification might differ from one author to another. But as long as the systematics follows a referenced work it is alright to follow it. I have followed the manual of Krantz for more than three decades. Krantz (1978) recognized Acari as a subclass and proposed the following higher grouping of the Acari.

CLASS: ARACHNIDA

SUBCLASS: ACARI

ORDER	***SUBORDER***
OPILIOACARIFORMES	NOTOSTIGMATA
PARASITIFORMES →	TETRASTIGMATA MESOSTIGMATA (e.g. Macronyssidae, Laelapidae) METASTIGMATA (e.g. Ticks – Ixodidae, Argasidae)
ACARIFORMES →	PROSTIGMATA (e.g. Trombiculidae - chigger mites) ASTIGMATA (e.g. *Sarcoptes* and scabies mites) CRYPTOSTIGMATA (soil mites)

ECOLOGICAL GROUPING OF ACARINE PARASITES

The IMR had a continuing concentration on Acari-borne zoonoses beginning in 1947 (IMR Ann. Rep., 1959), and broad based investigations were pursued to enquire into the importance of ticks and mites in human health. Taxonomical, biological and ecological information was gathered to assess the natural history of Acari and their involvement with humans. Maintenance and spread of acarine zoonoses is dependant on many factors. Notable among these are the habitat of the natural hosts of the parasite, population size, immunity of the host, vector transmission efficiency, virulence of pathogenic organisms, and most importantly the life-style of humans themselves, who are incidental or accidental victims of the infected vector. Worldwide approximately 12% of 50,000 or so known Acari live as various forms of paraites and of these less than 100 species are recognized to be of medical or veterinary importance (Krantz, 1978). Parasitic Acari have been classified as host-dwelling, nest-dwelling and field-dwelling (Audy, 1958). Host-dwelling parasites are those that will complete their entire life cycle on or in the body of the host. A good example is the scabies mite, *Sarcoptes scabiei*. Nest-dwelling parasites complete their life-cycle in the nest of the host and feed on the host at intervals, being transported about to a limited extent. Several species of argasid ticks and most gamasid (Mesostigmata) mites are examples of this group. Many small mammals make their nests in burrows in the ground. On abandonment of the nests by their original occupants, the nests are used by other small mammals, and this offers opportunity for transfer of nest parasites to new hosts. Field-dwelling parasites are those that attach to an animal and feed continuously to repletion, but drop off along the trails of the host where they continue development to a subsequent stage of the life-cycle in appropriate soil sheltered by vegetation, and await suitable hosts to which they can attach for further feeding. Classical examples of this group are the trombiculid mite vectors of scrub typhus and hard ticks of the family Ixodidae that are capable of transmitting viral and rickettsial pathogens to humans.

VALUE OF THE TROPICAL RAIN FOREST

Most Acari-borne diseases evolved in the forest, its environment altered mostly through man-made activities. What will it take to protect our rain forest, to have clean air, clear rivers, a home for our wildlife and trees that

Figure 1a. The value of rain forest.

will soar high and form canopies, without much human interference? About half the world's forests are in the tropics, the area between the Tropic of Cancer and the Tropic of Capricorn. Tropical rain forest of Southeast Asia is found in Sumatra and Borneo and down the Malay Peninsular from Southern Thailand to Singapore. The lowland rain forest is similar to lowland rain forest in Central and West Africa, the Amazon Basin and Central America, New Guinea and coastal north-eastern Australia, and in other parts of Asia where pockets of rain forest occur: south-western India, Myanmar (Burma), Sri Langka, southern China, and Taiwan (Rubeli, 1986). Rain forests once covered some 15.3 billion acres. In recent times they have been cut at a rapid rate to make room for agriculture and settlements. Between 1985 and 1990, 210 million acres of rain forests were cut and cleared in India, Malaysia and the Philippines (Mastrantonio & Francis, 1997).

The rain forests are lush and steamy with towering trees, epiphytes, dense under stories of smaller trees, and wines. The largest remaining areas of tropical rain forests are in Brazil, Democratic Republic of Congo, Indonesia and Malaysia. The rain forests support thousands of species of plants and animals. All forests have both economical and ecological value, but rain forests are especially important in global economy. These forests cover less than 6 percent of the Earth's land area. The diversity of life in rain forests is astonishing. The forests of Peninsular Malaysia have about 2,500 different species of trees of similar size, and in a single acre up to 60 species are growing, according to Ripley (1965).

Rain forests do more than respond to local climatic conditions; they actually influence the climate. Through transpiration, the enormous numbers of plants in rain forests return huge amounts of water to the atmosphere, increasing humidity and rainfall, and cooling the air for kilometers around. In addition, rain forests replenish the air by utilizing carbon dioxide and giving off oxygen. By fixing carbon they help to maintain the atmospheric carbon dioxide levels low, and counteract the global greenhouse effect. Rain forests also moderate stream flow. Trees slow the onslaught of tropical downpours, use and store vast quantities of water, and help hold the soil in place. When trees are cleared, rainfall runs off quickly, contributing to floods and erosion.

Before the dawn of agriculture approximately 10,000 years ago, forests and open woodland covered about 15 billion acres of the globe. Over the centuries, however, about one-third of these natural forests have been destroyed. According to a 1982 study by FAO, about 27.9 million acreas of tropical forests are cut each year. In India, Myanmar, Malaysia, Indonesia and the Philippines, the best commercial trees are depleted. If deforestation is not controlled or stopped the world will lose most of its tropical forests in the next few decades. The specific effects of deforestation will be discussed in subsequent pages with reference to disease transmission and how best to protect the natural environment for the well-being of humans, animals and plants, with particular reference to the natural history of Acari-borne diseases and the ability of acarines to transmit them.

THE CHANGING ENVIRONMENTAL SCENE

A particularly important factor to Malaysia as well as to the other Southeast Asian countries is that development of the country is continually changing the local scene. In order to make some good guesses as to how a zoonosis can occur, it is also necessary to have some idea of the ecological factors that affect the populations of the organism in nature. Most acarines that are vectors of zoonoses are believed to have lived in association with their animal hosts in a stable structure such as in a forest which has for a long time been in equilibrium with the climate and soil, untouched by humans. Under pressure of increasing human population, the natural environment, in this case the rain forest, is altered to give way to plantation cultivation, opening of new roads and construction of buildings for commercial and residential purposes, and for other agricultural practices. Consequently, a new environment is created in the area that was cleared of forest. The introduction of a single plant species such as oil-palm, coconut, or rubber, usually encourages specific creatures to enter the plantation. Also areas cleared of forest and neglected for a long period of time are colonized by vigorous weeds and plants that are usually introduced from other countries, particularly in Africa, South America and North America: for example, lalang grass (*Imperata cylindrica*) from Africa, the sensitive plant, *Mimosa pudica* from Brazil, *Melastoma malabathricum* or straits rhododendrom, from South America, Lantana from Mexico, *Eupatorium odoratum* or Burmese bizat and other weeds that form the scrub habitat (Figure 1b).

In these situations some animals and their parasites that once lived in a forest environment become adapted to the new environment and thrive.

The eventual removal of the forest can have a serious effect on the flora and fauna. Broadly speaking, it will simplify the forest environment with respect to number of plant species and consequently increase the number of introduced species, both plants and animals, introduced from different countries and different parts of the same country. Audy (1948) discussed the effects of deforestation. The ecological concepts discussed by him are still valid in the Malaysian context. Following the same concept, it is revised with the aid of Harrison (1974), and the discussion updated in this paper. The forest is extremely complex, and the natural balance within it gives the impression of stagnation; although the number of different species of plants and animals is greater than anywhere else, there is nevertheless, an impression of uniformity. To understand the implications of deforestation and settlement, the chief types of terrain need to be separated among primary and secondary forest, forest fringe, grassland or scrub, and plantations, and settlements, i.e. rural towns and villages, with respect to zoonoses (Fig. 6).

The rain forest is a very stable structure in which the vegetable kingdom is paramount. The great variety of life is so dispersed as to provide uniformity. In the primary rain forest individual trees of a species may be very widely separated. Three major families thrive in the rain forest: Dipterocarpaceae, Palmae and Begoniaceae. The forest canopy provided all their needs. The Dipterocarpaceae family

Figure 1b. Scrub habitat
(at the fringe of a patchy secondary forest in the background)

of trees is important because it forms the main canopy of the rain forest and provides the niche for other plants and wildlife. Briefly, it is possible to divide the animals of the rain forest into six layers (Harrison, *loc. cit).* These are the (i) upper air community, i. e. insectivores bats which hunt above the tree canopy level, (ii) animals confined to the crown of trees feeding predominantly on leaves, fruits, or nectar; (iii) middle-zone flying animals; (iv) middle-zone scansorial animals, which range up and down trunks entering both the canopy and ground layers; (v) large ground animals, without climbing ability; (vi) small ground animals which burrow in soil, or search the litter and perhaps the lower part of the tree trunks. The general character of the primary rain forest is the presence of the third dimension. The more the canopy closes in, the more distinctly does it support a bustle of life peculiar to itself. There is a striking contrast between the silent depths near the forest floor and the busy zone amongst the treetops in the sunshine.

In my working life I have come upon many exciting research projects carried out by various researchers seeking scientific knowledge. One of the most remarkable, but a very hazardous and dangerous one was that conducted by Dr. Elliot McClure of the US Army Medical Research Unit - Malaysia (USAMRU-M), attached to the Institute for Medical Research. In the Hulu Gombak Forest Reserve, approximately 40 km from Kuala Lumpur at 1,900 feet elevation he built a platform at a height of 140 feet with a vertical ladder to the platform on a large *Anisoptera laevis* tree (Fig. 2). The purpose of the project was to study the usage of flowers or fruits by birds and vertebrate animals. Rainfall in the canopy was measured weekly. The project began in September 1960 through April, 1965. From September 1960 till June, 1963, Dr McClure climbed the ladder alone once a week, and less regularly until April, 1965. He spent approximately six hours each time (sometimes longer) on the platform. The platform commanded a view of more than two square miles of climax hill dipterocarp forest. Sixty conspicuous trees in about four acres around the platform were identified and numbered. Figure 3 shows one of the four sections of the forest with the numbered trees. Dr McClure obtained numerous valuable data on the flowering and fruiting of the many species of rain forest trees over the years, and recorded the activities of the crown-dwelling birds and mammals. The prelimimary results of his study were published in McClure (1966). After his departure from Malaysia the study was continued by the Zoology and Botany Departments of the University of Malaya.

A less dangerous solution to the problem of climbing a tall tree was for the construction of an aerial transect through the forest canopy. Such a transect was constructed in the Bukit Lanjan Forest Reserve, some 50 km northeast of Kuala Lumpur, by the joint IMR - U.S. Army Medical Research Unit, using the aborigines (orang asli) under the supervision of Dr Lim Boo Liat. The walkway in the

Figure 2. Dr McClure's tree showing platform (Courtesy The Malayan Forester, 1966)

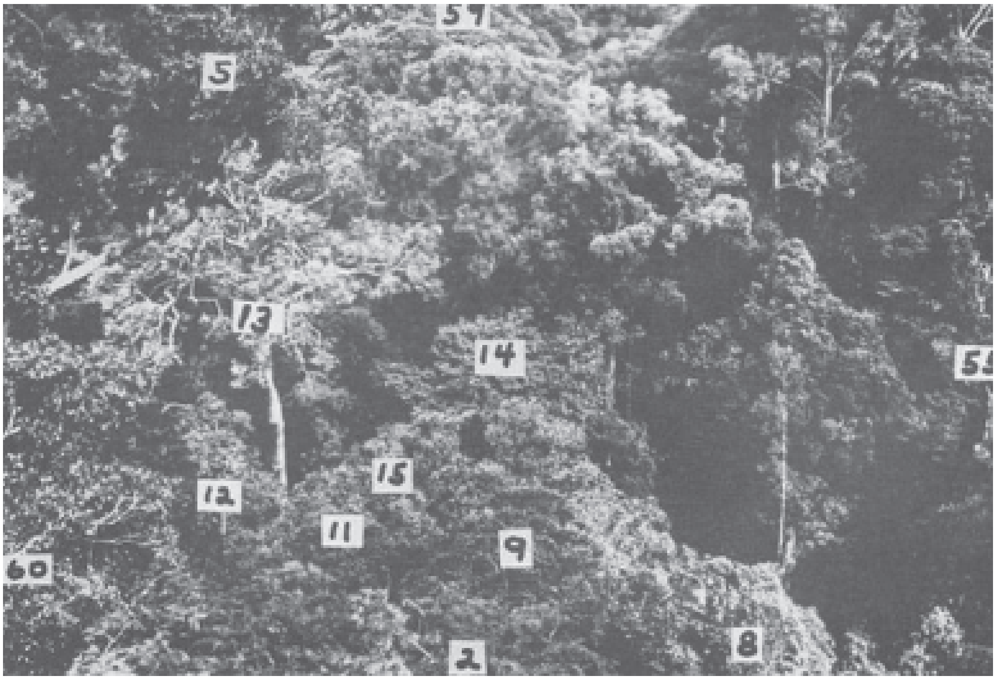


Figure 3. One of 3 sections of rain forest canopy seen from McClure's platform (Courtesy The Malayan Forester, 1966)

transect was constructed of horizontally placed sections of a light-weight aluminium ladder suspended by polyester robes. The aerial transect meandered through the forest at a height which varied from 6 m (20 ft) to over 30 m (100 ft.). The Medical Ecology Division of the IMR (Dr B.L. Lim) and the USAMRU (Dr Illar Muul) conducted a joint capture – mark – release study of small mammal in the 1970s. Animals were trapped with the traps set and placed in rattan baskets and placed on branches in amongst the leaves with a thin guide-line attached (Whittow, 1983).

Dr McClure, an ornithologist, on leaving Malaysia became actively engaged in studies of migratory birds with his headquarters in Bangkok. His well acknowledged work on migratory birds and parasites was published in 1971. The acarine parasites are included in this paper.

Many creatures live entirely in the canopy. When the canopies of the forest trees are cleared, sun and rain are let on to the soil. Many of the arboreal animals are locally doomed, deprived of their territorial niche where they bred and lived happily for generations on end. Examples of some of them are the apes (siamang and gibbons), leaf monkeys, flying lemur, flying foxes (Megachiroptera), that roost and breed on the branches or tree-holes of the upper storey of tall forest tree tops, many species of civet cats, flying squirrels and squirrels. Hornbills, barbets, woodpeckers and many other birds make their nests in tree holes of the mostly dipterocarp forest, not forgetting the myriad of insects and other arthropods that feed on tree-tops. The wildlife has to move to other places to start their life all over again when the canopy is cleared. Some creatures of the lower canopy and those that live on the ground can adapt themselves to the new conditions, while many others may actually find that the new ground conditions are a great improvement, so they increase in numbers.

The forest supports big animal wildlife (carnivores, elephants, tapirs, rhinoceros, cervids and bovids). Two species of wild pigs, *Sus scrofa* Linneaus and *Sus barbatus* Mueller, the principle hosts of the medically important

Dermacentor, *Haemaphysalis* and *Amblyomma* ticks, especially the adult ticks, are widely distributed. The pigs are inhabitants of all types of forest environment. Two species of monkeys (Long-tailed and Pig-tailed macaques) spend much time on the ground as does the Lesser mouse-deer, and have been infested with *Leptotrombidium* chiggers, the vectors of scrub typhus.

A study by Ratnam *et al*. (1991) listed 121 species of ground mammals in Peninsular Malaysia (Fig. 4). Most of them occur in primary lowland forest (75%), hill forest (48%) and swamp forest (31%), compared with mangrove forest (20%), cultivated areas (14%), and human habitats (6%). Of the 121 species 38 are considered endangered to threatened of which 34 species live in lowland forest, 12 in hill forest. Because small mammals are important hosts of parasites of zoonotic importance, it is necessary to be acquainted with the broad ecological distribution of the small mammalian fauna. As lowland forest has suffered the greatest loss to agriculture, industrial development and urbanization, species that depend on it for survival are at greatest risk. With increased development in highland areas, the montane species are also at risk. The small mammals inhabiting lowland and hill forests are the rodents (47.8%, and 34.5%). The species in mangrove and swamp forests are spill-overs from the adjacent lowland forests.

Most of the murids are forest ground dwellers. According to Corbet & Hill (1992) 12 species of insectivores, 25 species of tree squirrels and flying squirrels, and 13 species of Muridae are denizens of the rain forest, which excludes the commensals. The names of the murid species of the forest habitat are given here because of the major role they play in zoonotic infections. The species are: *Rattus annandalei*, *Lenothrix canus*, *Berylmys bowersi, Niviventer bukit (formerly N. fulvescens), Niviventer rapit, Niviventer cremoriventer, Leopoldmys sabanus,*

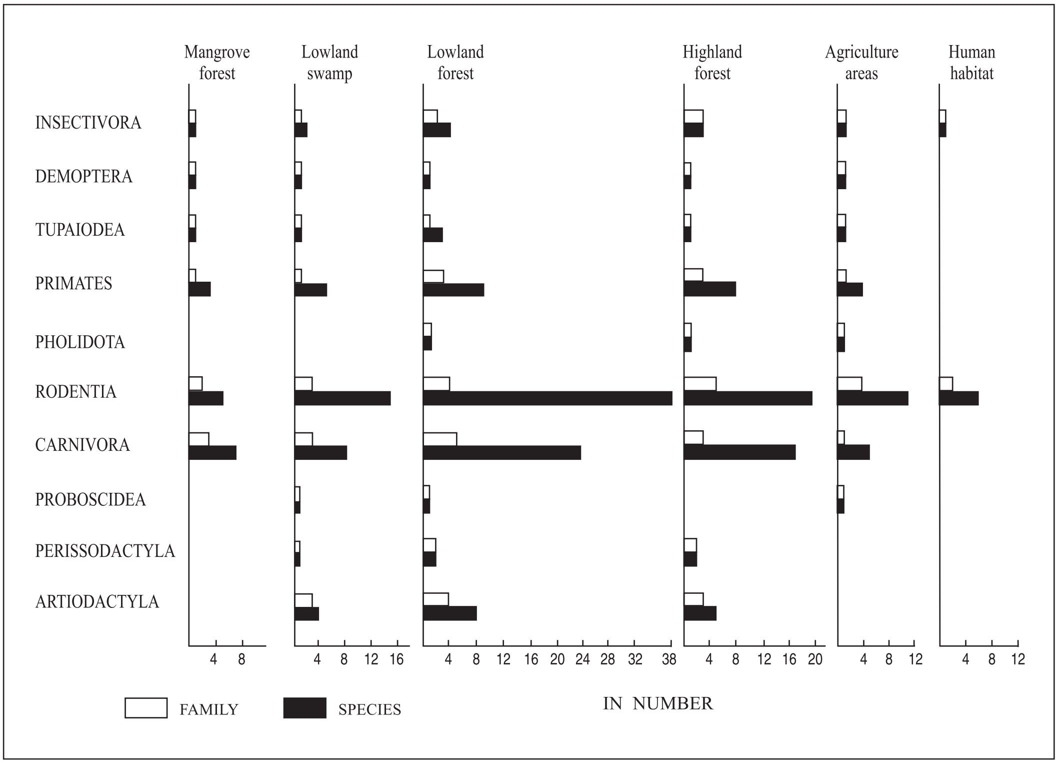


Figure 4. Distribution pattern of mammals by habitats
(Courtesy: Ratnam *et al.* and Malayan Nature Society)

Leopoldmys edwardsi, Maxomys rajah, Maxomys surifer, Maxomys. whiteheadi, Maxomys inas, and *Sundamys muelleri*. Their territorial behaviour also overlaps secondary and forest fringes. It is emphasized that all insectivores, sciurids, and murids serve as hosts to most ectoparasites, some of them of zoonotic importance. Deforestation of the stable environment creates conditions suitable for the introduction of grasses and other weeds that soon cover the ground cleared of forest, followed by herbaceous shrubs, so that the undergrowth becomes very dense and affords suitable cover for rodents and many species of scrub-nesting birds.

Secondary forest is a clearing caused through logging activities recognized by the absence of the tall forest trees with lofty crowns, and by the density of vegetation of the floor made up of saplings and introduced plant species. The jungle clearing offers two distinct sets of conditions – forest and introduced scrub vegetation side by side, and many creatures are confined to one or the other by their mode of life. This habitat is the **forest fringe-habitat** (Audy, 1949). This is an important habitat. That the mite population is high in this habitat has some experimental support. Trombiculid mites were collected by Audy in 1945 in transect through the edge of a gallery forest near Kanglatongbi, Imphal, Myanmar. A total of 145 rats were exposed in the scrub and within the strip of forest. Of these, 43 picked up a total of 186 trombiculid mites (chiggers) of 4 species, 17 (i.e. 11%) picking up 25 *Leptotrombidium deliense*, the vector of scrub typhus. A futher 60 rats were exposed at the same time in the narrow intermediate zone of scrub: 27 picked up a total of 173 chiggers while 20 of these picked up 142 *L. deliense*. Thus in this experiment, the rats exposed in the intermediate zone had roughly three times the chance of picking up *L. deliense* compared with rats placed outside this zone, while the total number of *L. deliense* picked up would be 10-15 times greater (Audy, *loc. cit*.).

Same results were found in similar habitats in Peninsular Malaysia, through numerous surveys conducted there. Some creatures are adaptable and can live in either type of habitat. Many find the accessibility of the two types - forest and scrub, much better than having to live in either. Some examples of host animals of importance to be found in the fringe habitat are *Rattus tiomanicus, Rattus exulans, Rattus annandalei, Maxomys whiteheadi, Leopoldmys sabanus, Sundamys muelleri, Callosciurus notatus, Sus scrofa* (wild pig), macaque monkeys and civet cats. Some tick species are *Haemaphysalis semermis* (Neumann) *Haemaphysalis nadchatrami* Hoogstraal, Trapido and Kohls. *Dermacentor atrosignatus* Neumann, *Dermacentor compactus* Neumann, *and Dermacentor steini* Schluze, *Ixodes granulatus* Supino, and *Amblyomma testudinarium* Koch. Some medically important chiggers are *Leptotrombidium deliense* (Walch), *Leptotrombidium bodense* (Gunther), and *Leptotrombidium keukenschrijveri* (Walch).

On this view, the appearance of scrub (*belukar* in Malay) formed mostly by weeds and introduced plants as mentioned above; chiefly the lalang, *Imperata cylindrica* is important because it is a most vigorous weed that generates quickly with repeated fires caused by friction of the blades of grass during the dry season. The tenacity of the rhizomes of the lalang grass is such that it sends up shoots progressively and eliminates most competitors, and it flourishes to become a semi-permanent feature, as can be seen as wide areas of grassland along the countryside. The fruit and seed-bearing plants in scrub habitats attract ground-dwelling small mammals, ground birds and shrub birds. This habitat next to the fringe-habitat, to secondary forest and finally to the great reservoir of the primary forest offers new opportunities and provides a great impetus to evolution in directions which otherwise may not have been exploited.

Plantations: Oil Palm, Rubber and Coconut plantations when fully developed, said to superficially resemble European woodlands, are grown in many parts of the country. When flying over Peninsular Malaysia, oil palm and rubber plantations can be seen to cover extensive areas of green. Rats and pigs are attracted to rubber in its early stages, especially in nurseries. The attraction is much less afterwards, for not only is there little food, but predatory birds and other predatory animals find the conditions to their liking. Oil Palms (Fig. 5) attracts rodents at all stages of their growth, because the trunks and tops support a large insect population living in the humus collected within the axils which cover the trunks from top to bottom. Over-grown or poorly maintained plantations were found to be important in the development of outbreaks of scrub typhus (Cadigan *et al.,* 1972), which in some places is as common as malaria. The most common rat species found in the oil palm plantation habitat is *R. tiomanicus,* the host for the scrub typhus vector species, *L. deliense;* the rat's favourite food is the palm fruit. In short, tree-plantations are characterized by uniformity, which may extend for many thouands of acres. As I write this paper much of the rain forest of Penisular Malaysia is seen to be giving way to plantation of oil palm, a valuable economic commodity. Coconut plantations do not provide so much attention until they bear fruit, which they do only in a small way in four or five years. Squirrels and rats are then greatly attracted. Husks and shells gnawed by squirrels litter the floor and provide a special habitat fostering not only rats and shrews, but breeding sites for mosquitos, e.g. *Aedes albopictus,* one of the dengue mosquitos. The plantations possess a tree-top zone; in the order: oil-palm, coconut, rubber and they support many animals.

Figure 5. Oil Palm Plantation
(endemic for scrub typhus)

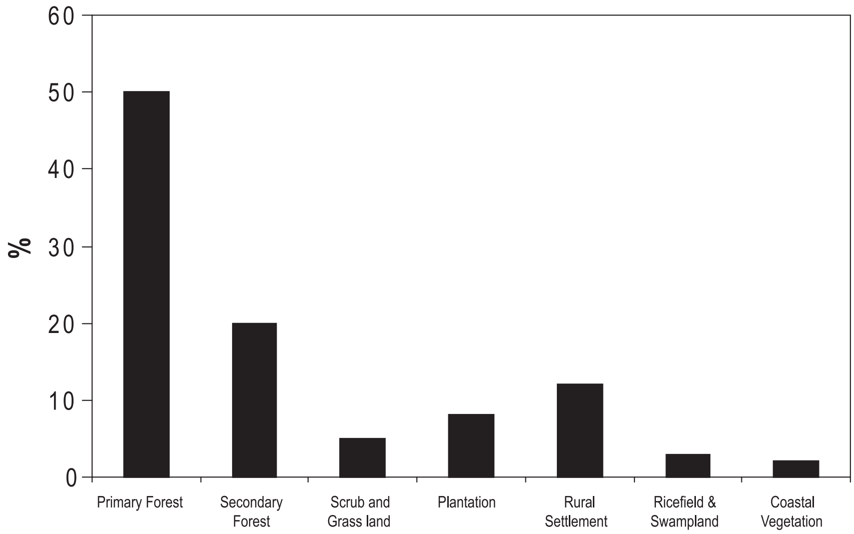


Figure 6. The changing environmental scene (approximate ecological distribution)

Standing crops such as pineapple, grains and tapioca lack the vertical dimension, but possess uniformity. They produce large quantities of different kinds of foodstuff. Pineapple and tapioca attract pigs, porcupines, civet cats, rats and squirrels. Rice and other grain crops attract rats and grain-eating birds. The standing crops offer few habitats and are mostly short-lived. However, the environmental scene is changing with regard to edible fruits trees. There are over a hundred species of edible fruits, and most of them grow naturally in the forest. Many of them are now being propagated by grafting or other horticultural methods, in human settlements (Chin & Yong, 1981).

Settlements or residential areas attract their own creatures: - the common house rat, *R. r. diardii*, *R. exulans,* the house mouse, *Mus musculus*, the common house shrew, *Suncus murinus*, house swifts, house sparrows, and a few fruit bats. The kampong (village) in a rural area, and the larger villages or the towns obviously differ considerably. Many different species of fruit trees are grown in rural kampongs, including the durian (*Durio zibethinus*), regarded as the king of fruits. bananas (*Musa*), papaya (*Carica papaya*), rambutans (*Nephelium lappaceum)* duku and langsat (*Lansium domesticum*) and mangoes (*Mangifera indica*). Unlike the papaya, banana, starfruit or carambola (*Averrhoa carambola*), ciku or sapodilla (*Manilkara achras*) that grow throughout the year, most local fruits are seasonal and appear about twice a year, as they are influenced by dry and wet seasons. Gardens and compounds of houses with fruit trees are attractive to squirrels (*Callosciurus notatus,* and *Callosciurus caniceps*), bats, house rats, monitor lizards (*Varanus* sp.), and insectivorous and fruitivorous animals which come to the fruits, waste food and other rubbish. More than a dozen species of birds frequent gardens, including sharmas, babblers, bul-buls, warblers and tailor-birds.

As will be seen, there is every possibility for the exchange or interchange of parasites from one zone to another. In some cases, as food becomes scarcer for animals that normally depend on forest resources, such as fruit, they range outside forest land into the domains of humans. Sometimes they may carry pathogens that can affect human health.

IMR animal trapping and collection sites

Most of the field collection of animals for some 20 years between 1948 and 1968 in Peninsular Malaysia was from scrub habitats for field rats, birds and their ectoparasites to investigate the ecology of scrub typhus, which was within 35 km of Kuala Lumpur. The wasteland or scrub was at Subang, Seaport Estate at Sungai Way, "West Folly" scrub bordering on the Lake Garden, villages around Sungai Buloh, and Hanson's disease settlement, and at Kuala Lumpur were sites of urban- suburban habitats. For forest animal and ectoparasite collection, routinely the major collecting areas were the Forest Reserves at Gombak, Bukit Lagong, Hulu Langat, and Bukit Lanjan (Sungai Buloh). These collecting areas were within a radius of 50 km of Kuala Lumpur. Occasional collecting trips were made to the highland forests at Fraser's Hill, Maxwell Hill (Bukit Larut), and Cameron Highlands to make collections for comparative studies with the host and parasite fauna of the lowlands. Almost all these collecting places have now transformed into highly populated areas, except for the forest reserves that are remaining, but thinned. The Subang Forest Reserve 40 km west of Kuala Lumpur used to be secondary forest in scattered patches throughout. The picture of scrub habitat (Fig. 1a) adjoins a gallery of secondary forest. It was in this forest where the picture of questing unfed chiggers (Fig. 21) was taken.

The zones of the changing environmental scene are approximately as figured in Figure 6. Though it is suggested that the primary rain forest is still some 50 percent of the total environment, it is quite possible that the percentage of primary and secondary forest is that much intermixed that the percentages of these habitats might differ.

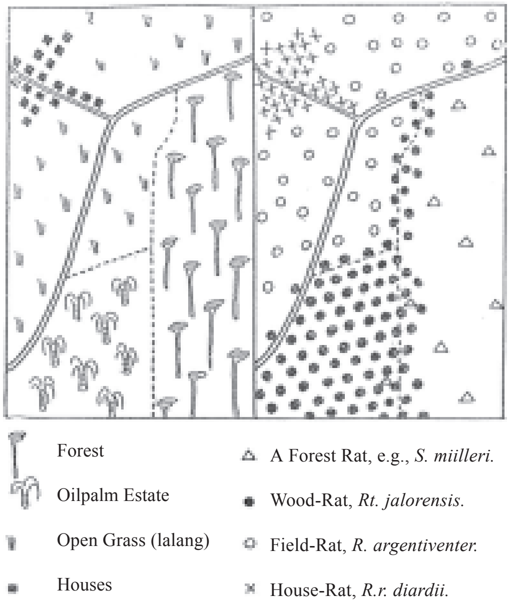


Figure 7. An Example of effects on deforestation and settlement (Peninsular Malaysia).

Degree of "herding" and contact between herds

"Herding" is used here to describe the patchy concentration in numbers of host and parasite in an altered environment. The effect on animals of deforestation and settlement is figured (Fig. 7). This imaginary spot-map (Audy, 1956a) indicates the distribution of a few animal species in common types of terrain in Malaysia. In the more simple cleared areas the distribution is patchy and concentrations of animals occur such as one does not meet in the forest. Only one of the species of forest rat (*S. muelleri*) is indicated here. There are several other genera and species of forest rats about as widely dispersed as *S. muelleri* in a forest habitat, depending on the topography of the countryside. In the simple, cleared areas the concentration of animals of a single species is unlike that seen in the forest, e. g. common house rat, *Rattus r. diardii,* in and around houses, *R. tiomanicus* in plantations and the field rat, *Rattus argentiventer,* in grass and scrubland.

Humans encourage dense populations of animals of a single species and their parasites in three different ways: (a) by encouraging patchy distribution by deforestation, and concentrations of animals occur such as one does not meet in the forest, or other destructive behaviour; one consequence is scrub typhus: scrub lalang habitat → *Rattus argentiventer* (host) → *Leptotrombidium fletcheri* (vector) thus giving rise to the development of typhus foci in scrub habitat; (b) covering large areas with single cultivation such as oil-palm or rubber, which encourages the plantation rat: so that we have oil-palm plantation → *Rattus tiomanicus* (host) → *Leptotrombidium deliense* (vector), or with poorly constructed buildings that encourage the house rat, *Rattus r. diardii,* thus setting the stage for the entry of murine typhus and even plague; (c) deliberately encouraging the raising of livestock and domestic animals close to human habitation (tick-caused Kysanur Forest Disease). Though not an Acari-borne zoonosis, a new virus, Nipah virus encephalitis in 1998-99, afflicted many pig farmers among which there were 105 human fatalities, because of the close proximity of domestic pigs to humans in Sungai Nipah, Negri Sembilan, Malaysia. The sources of the viral infection were bats (Microchiroptera) and flying foxes (Megachiroptera), but the natural history of the infection is not well known. It is believed that the degree of concentration of single species of plants and animals is one of the important factors in the epidemiology of diseases in general and acarine zoonoses in particular. Hoogstraal (1981) hypothesized that the epidemiology of tick-borne diseases began to change when human society progressed from primitive hunter-gathering activities to a more settled agricultural and forest-clearing stage of civilization centered in villages and towns. The introduction of large herds and flocks of domestic animals destroyed the natural environment. Relatively benign tick-borne infections of wildlife evolved into more or less serious infections of susceptible domestic animals and humans.

TICK-BORNE ZOONOSES, AN ECOLOGICAL PERSPECTIVE

Up-date of species status and distribution of Malaysian ticks

There have been two comprehensive studies on Malaysian ticks and both of which were published in the Malaysian Parasites series published by the Institute for Medical Research, based on collections made by the IMR. The ticks of Malaya and Borneo were reviewed by Kohls (1957) who discussed 23 species, and dealt with host distribution and taxonomic keys to the genera and species of Malayan ticks. The seven genera of Ixodidae found in Malaysia were treated. The second paper on Malaysian ticks was by Audy *et al.* (1960). This paper was on tick distribution by host species, with tabulated details of tick-infestation by larvae, nymphs and adults of 17,683 reptilian, avian and mammalian hosts examined in 1952-59 by the Medical Zoology Laboratory of the Institute for Medical Research. This work was based on the hosts and ticks collected exclusively in Peninsular Malaysia. New records were added to the ticks recorded for Malaya and Borneo by Kohls. The paper also recorded all the animals examined and those that were uninfested, which made it possible to judge the frequency of distribution of the various stages of ticks on the available hosts.

Subsequent to these studies in 1966, the genera *Haemaphysalis* and *Dermacentor* of Malaysia were jointly studied by Hoogstraal, Anastos, Lim and Nadchatram. The systematic aspects of the studies were conducted by Hoogstraal and Anastos. Field work on host distribution and breeding experiments were conducted by Lim and Nadchatram. The systematics and host distribution studies of *Dermacentor* ticks, with the taxonomy of the adult species are finally resolved. Nearly all the *Haemaphysalis* species occurring in Peninsular Malaysia are also known through a number of publications under the main heading of "Studies on Southeast Asian *Haemaphysalis* ticks" mostly by Hoogstraal.

For the purpose of this presentation, Audy *et al* (1960) will form the basis for discussion of subsequent authors on the systematics, geography and host distribution, until a comprehensive study is undertaken on the ticks of Malaysia.

Aside from Hoogstraal & Wassef (1984, 1985a & 1985b) and Wassef & Hoogstraal (1983, 1984a, 1984b, 1986 & 1988), there are four other excellent review publications on Southeast Asian ticks, which included the taxonomic status and distribution of Malaysian ticks, including *Dermacentor* by Petney and Keirans. The first of their four papers dealt with the genus *Ixodes* of Southeast Asia (Petney & Keirans, 1994). The second paper dealt with the genera *Amblyomma* and *Hyalomma* (Petney & Keirans (1995), the third paper was on the genera *Boophilus*, *Dermacentor, Nosomma* and *Rhipicephalus* (Petney & Keirans (1996a), and the fourth paper was on the genus *Aponomma* Petney & Keirans (1996b). The review papers relating only to Malaysia will be discussed here. However, the genus *Hyalomma* and *Nosomma* have not been recorded by Audy *et al,* neither were they recorded by Petney and Keirans.

In the genus *Ixodes* there are approximately 220 described species in the world. Of the 13 species known from Southeast Asia infesting, birds, bats and ground mammals, five species of *Ixodes* are known from Malaysia. Of these two species, *Ixodes kopsteini* Oudemans and *Ixodes simplex* Neumann are bat-specific. Of the ground mammal ticks, *I. granulatus* is the most commonly collected tick from a variety of rodents and shrews. Other less common species of *Ixode*s from rodents in Peninsular Malaysia are *Ixodes werneri* Kohls, and *Ixodes malayensis* Kohls, and they are also parasites of small mammals in all stages. This constitutes *I. werneri, I. malayensis, I. kopsteini*, and *I. simplex* as new records to Malaysia vide Audy *et al* (1960). The ecological and zoonotic importance of *Ixodes granulatus* is discussed elsewhere in this paper.

Thirteen species of *Amblyomma* are known to occur in Southeast Asia, and of these seven species are recorded in Peninsular Malaysia. *Amblyomma cyprium* originally recorded as occurring in Malaysia is absent in the records of Petney & Keirans (1995). It was originally included with reservation by Kohls (Audy *et al*, 1960). However, *Amb. crenatum* is recorded from the Sumatran rhinoceros, *Rhinoceros sondaicus* in Malaysia for the first time. *Amblyomma testudinarium* Koch, *Amblyomma geoemydae* (Cantor), and *Amblyomma cordiferum* Neumann are considered as of zoonotic importance in Malaysia as they parasitize a wide range of hosts from birds, reptiles to mammals.

Petney & Keiran (1995a) dealt with the genera *Boophilus, Dermacentor*, *Nosomma and Rhipicephalus*, all of which are recorded in Peninsular Malaysia, with the exception of *Nosomma*, which was originally classified as a *Hyalomma,* and occurs in the Indian subregion extending up to northern Thailand. The genus *Boophilus* is represented by a single species, *Boophilus microplus*, the common cattle tick in Malaysia; and *Rhipicephalus* has two species, *Rhipicephalus sanguineaus* and *Rhipicephalus haemaphysaloides* in Malaysia. The genus *Dermacentor* is discussed separately because of the zoonotic importance of all four species in the genus, which form the central base to my paper on zoonoses.

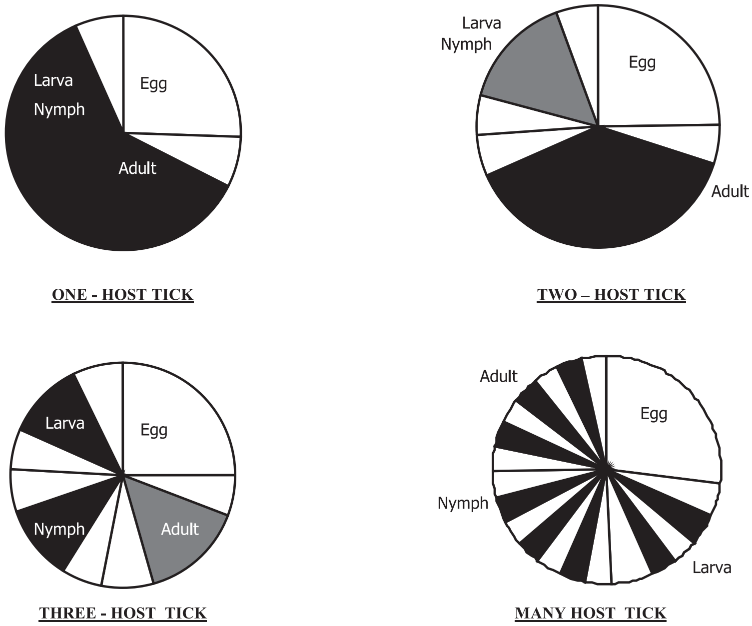
According to Petney & Keirans (1996a), the centers of diversity for *Dermacentor* are North, Central and South America (12 species) and Palearctic Region (16 species) while that of *Rhipicephalus* is Africa (about 54 species). Only 5 species of *Dermacentor* and 3 species of *Rhipicephalus* are found in Southeast Asia. The original area of distribution of *B. microplus* is thought to have originated in the Indian subregion and transported from there to other areas of tropical Asia and the South and Central America.

The genus *Aponomma* is a small genus with 24 described species, mostly from reptiles. Nine species are recorded in Southeast Asia. Two species occur in Peninsular Malaysia, *Aponomma fimbriatum* Koch, 1844 and *Aponomma varanensis* (Supino, 1897). The species *Aponomma lucasi* Warburton, 1910 listed in Audy *et al* is now established as a synonym of *Apo. varanensis* (Petney & Keirans, 1996b).

Barker & Murrell (2004) sank *Aponomma* and moved the known species to *Amblyomma*. They also regard *Boophilus* as a subgenus of *Rhipicephalus*. However, in this paper their systematic and evolutionary treatment though respected, is not taken into consideration as this study is not one of a taxonomic nature.

LIFE-CYCLE AND PATTERN OF PARASITIZATION OF TICKS

On a world-wide basis, ticks are regarded as among the most important of all arachnids, and their public health importance is considered as second only to mosquitoes. Ticks transmit numerous viral and rickettsial agents, bacteria and protozoa from animals to humans. The two families of ticks known in Southeast Asia are the hard ticks, Ixodidae, and the soft ticks, Argasidae. Based on their feeding behaviour, hard ticks are classified as **one-host**, **two-host**, **three-host**, and the soft ticks as **many-host** ticks (Figure 8). **One-host** ticks are host-specific, e.g. *B. microplus* (Canestrini), the common cattle tick. The tick remains on the host throughout its entire parasitic life, moulting to the nymph and adult on the host, and leaving the host as fully fed adult. In a **two-host** ticks the tick after attaching to the host as a larva, drops from the host as an engorged nymph. After moulting takes place, the adult attaches to another host, usually of the same kind. *Rhipicephalus sanguineus* (Latreille), the common dog tick, is usually a **two-host** tick, because the larva moults to a nymphal stage on the host, but may depending on environmental conditions, change to a **three-host** tick. *Rhipicephalus haemaphysalodies* was success-fully reared in the laboratory using forest rats to feed larvae and nymphs; adults were reared on rabbits (Salleh *et al*., 1982). The **three-host** ticks drop off following feeding to repletion in each



Tick-Host Associations: in one-host tick the fed female leaves the host, lays eggs in the soil, larva attaches to host, the larva and nymph moult on host, e. g. the common cattle tick, *Boophilus microplus*. Two-host tick is similar to one-host tick, but usually the larva moults on the host, e. g. the common dog tick, *Rhipicephalus sanguineus*, In three-host tick, in stage of life cycle, tick leaves the host after a blood meal, moults in nest or soil and the next stage attaches to another animal; usually the larva and nymph feed on small mammal and adult on large animals, e. g. *Haemaphysalis, Dermacentor, Amblyomma.* In many host tick, feeding on host takes place a number of times in each stage, e. g. the bat ticks *Argas, Ornithodoros.*

Figure 8. Tick-Host Associations

stage of its parasitic life, and attach to another host after moulting had taken place, away from the host in suitable soil or vegetation, e.g. *Ixodes, Haemaphysalis, Dermacentor, Amblyomma*. However, the adults of the three latter genera feed on large animals. **Many-host** ticks in Malaysia are soft ticks of the genera *Argas* and *Ornitho-doros* infesting bats and feed intermittently in each stage of the life-cycle, feed at frequent intervals for short periods (5 to 30 minutes at a time), in the larval, nymphal and adult stages and return to their nesting places or runways of their host. Some larval argasids remain attached and feed for periods up to several days.

The genus *Ixodes,* made up of **3-host** ticks, is the only Malaysian ground-dwelling tick genus that completes its entire cycle on small ground mammals, e.g. rodents. The only known exception is that the female *I. kopsteini* Oudemans, a bat-infesting tick in Malaysia and Indonesia, does not deposit her eggs in an external environment as do all other known species of *Ixodes* but rather retains the eggs within the body until hatching occurs. The mother's dead body serves as an egg-case and protects the developing eggs and the hatched larvae (Anastos *et al*., 1973). Among Ixodidae ticks it is the **3-host** tick which is mostly regarded as of zoonotic importance in Malaysia. The genera of ticks collected in the immature stages on wild rodents and shrews were *Ixodes, Haemaphysalis, Dermacentor* and *Amblyomma*.

HISTORICAL BACKGROUND ON STUDIES OF *DERMACENTOR* AT THE IMR

The IMR was involved in studies of all acarine parasites, including ticks since 1947. Because of the medical importance of ticks, it was necessary to study their taxonomy and distribution. This led to the publications by Kohls (1957) and Audy *et al*. (1960). In order to better understand the bionomics of Malaysian ticks a joint "Malayan Tick Survey" programme was initiated in 1967 with the IMR, in which Dr H. Hoogstraal of the U.S. Naval Medical Research Unit, Cairo; Professor G. Anastos of the University of Maryland, College Park, U.S.A.; Dr B. L. Lim of the Medical Ecology Division and M. Nadchatram of the Acarology Division, IMR were participants. The project received the approval and blessing of the then Director of IMR, the late Professor (Dr) Ungku Omar Ahmad. Nadchatram's role involved field studies and taxonomic screening of ticks collected, and rearing immature ticks to obtain correlated adults for taxonomic studies. Based on the life-history studies by Nadchatram, the taxonomic status of several species of ticks were clarified through successful rearing and obtaining correlated stages of their life cycle to aid in the taxonomic clarification of the Malaysian *Dermacentor* and *Haemaphysalis* species. The two forms referred to as "close-spur" and "wide-spur" *Dermacentor* "*auratus*" (Fig. 10) published by Hoogstraal *et al*. (1972) was resolved as valid species, *D. compactus* Schulze, *D. atrosignatus* Neumann, with *Dermacentor auratus* Supino as the least common of the 3 species. (In the midst of the Tick Project, Nadchatram was awarded a research fellowship to conduct taxonomic studies of the Trombiculid mites of the Asia-Pacific region supported by the U.S.P.H.S. National Institutes of Health Research Grant to the Department of Entomology, Bishop Museum, Honolulu, and he was away from Malaysia for approximately 30 months from August, 1968 to December, 1970). Dr B.L. Lim was assigned the field responsibility in the "Malayan Tick Survey" from then on.

Recent studies indicate that there are four species of *Dermacentor* in Peninsular Malaysia (Wassef & Hoogstraal,1988), based on extensive collections in the Asia-Pacific region. Based on taxonomic studies of the Malaysian *Dermacentor* species, the four species established are: *D. auratus* Supino, 1897; *D. compactus* Schluze, 1901; *D. atrosignatus* Neumann, 1906; and *D. steini* Schluze (1933). As can be seen from the dates of the original descriptions they were named and recognized from a long time ago, however, with the exception of *D. auratus,* the other species were treated as of doubtful status by Anastos (1950), Kohls (1957) and Arthur (1960). Taxonomic confusion with *Dermacentor* began in the 1950s. Kohls (1957) and Anastos (1950) recognized *Dermacentor* as representing a single species, *D. auratu*s, in Malaysia (Fig. 10). (The natural size of the engorged ticks in figure 10 varied between 12 and 20 mm in length). The work of Kohls and Anastos were the main source of reference at the IMR in the early years. However, in those early years of our studies the difference in the shape of coxal spur I at least was recognized, which from 1950s onwards was treated as a variation of *auratus* until the publication of Hoogstraal *et al*. (1972).

Dr Audy and others who had worked intensively with trombiculid mites and ticks in Malaysia in the 1950s, followed by others in the 1960s had recognized that some of the morphological differences did not subscribe to the published studies of ticks of Anastos (1950) and Kohls (1957) in that the descriptions and keys provided in these two manuals left many questions unanswered with regard to the identification of some of the species (mostly *Haemaphysalis*) collected routinely from animals by the IMR. Also because immatures were not identifiable to species, it was Dr Audy who initiated the rearing of immatures to obtain the adult stages of the ticks. In addition to the *Dermacentor "auratus*" complex, species of *Haemaphysalis* were also successfully reared from nymphs to adults. They are *Haemaphysalis doenitzi, H. semermis* and *H. nadchatrami* and correlated adults were obtained (IMR Report, 1970). *Amblyomma geoemydae* (Cantor), *A. cordiferum* and *R. haemaphysaloides* Supino were also reared to obtain all stages of the life-cycle. It is fair to state that the initiative of Dr Audy in 1950s was instrumental in the tick study programme to take a firm footing led by Drs H. Hoogstraal, G. Anastos and G. Kohls. Dr Audy was at that time very much involved in the taxonomical, ecological and evolutionary studies of trombiculid mites and vectors of scrub typhus with particular reference to the epidemiology of the disease, and had contributed immensely to this effort. As one who served as the late Dr. Audy's personal technical assistant, it is very satisfying that after some 40 years of studies of Malaysian ticks, in which the IMR played a useful contributory role, the taxonomic confusion of the *Dermacentor* ticks is finally resolved through the excellent studies of Hoogstraal & Wassef (1984, 1985a, 1985b) and Wassef & Hoogstraal (1983, 1984a, 1984b, 1986). (Figs. 10, 11, 12 13) It is hoped that studies of the immature stages will follow the excellent contributions to the taxonomical studies of the adults.

The study by Wassef & Hoogstraal (1986) showed that in Peninsular Malaysia, *D. steini* is one the commonest of the four species, on pigs and at least 3 species of *Dermacentor* have been found on a single wild pig. Both species of wild pigs, *Sus scrofa* and *S. barbatus* are reputed to be the most common hosts for all the *Dermacentor* species, thus reversing the long held belief that *D. atrosignatus* is the most abundant Malaysian species. All the 4 species have been collected on vegetation in large numbers, and their distribution on host and vegetation are recorded (Wassef & Hoogstraal, loc. cit.). *Dermacentor steini* being the most common species of the genus, a total of 3,444 males and 2,353 females were collected from 331 wild pigs from 61 different localities, and from vegetation in the same localities 5,454 males and 6,897 female ticks were recovered. They were also found either attached to or crawling on humans and were also found feeding on a variety of large and small mammals and reptiles.

Preliminary field studies were also conducted earlier at the IMR, prior to the taxonomic revisions by the above authors, to obtain data on the distribution of questing adult ticks in the natural vegetation. In the Bukit Lagong Forest Reserve, Kepong, Selangor, a 1.65km square plot was used to conduct the study. The field study was made by the I.M.R. (IMR Ann. Rep. 1969). Mark-release-recapture studies of adult *Dermacentor* ticks over a one year period showed that *D. compactus* (wide-spur) and *D. atrosignatus* (close-spur) were recaptured from one to seven times. The distance of movement was not notably marked averaging only 10 mm. More than 500 adult ticks of both species were collected from vegetation during the study period. The height of attachment on vegetation ranged from 10 mm to 210 mm (IMR Ann. Rep.1969). The comprehensive study of Hoogstraal *et al.* (1972) recorded altitudinal distribution, ticks, hosts and medical relationships. Both these studies have shown that the adults of these genera of ticks are found in vegetation along animal trails waiting to attach to a host that happens along. The latter study also included new distribution records of the tick species.

Based on experience of studies on geographic distribution and behaviour of immature and adult ticks, it is my opinion that the more important field-dwelling ticks of significant zoonotic importance in Malaysia would be *Haemaphysialis semermis* Neumann, *Haemaphysialis bispinosa* Neumann *H. nadchatrami;* the four species of *Dermacentor* - *atrosignatus, steini, compactus, auratus,* and three species of *Amblyomma – testudinarium, geoemydae* and *cordiferum.* The life-cycle of *A. cordiferum*, a parasite of snakes was raised in the laboratory on rats and guinea pigs and published by Ho & Salleh (1984). It is suspected that it would feed on hosts other than snakes in nature. With the exception of *A. cordiferum,* the other species of ticks which in the immature stages are mostly parasitic on small animals, on reaching adulthood have been found in low to medium height vegetation awaiting passively for a large animal to come along to attach to (Fig. 9). Questing ticks are attracted to carbon dioxide (Garcia, 1962). Studies to learn other chemical and physical factors of host-locating behaviour will contribute to knowledge of the medically important parasites. Lim (1972) studied seasonal distribution of immature *Dermacentor* and *Haemaphysalis* spp. *Dermacentor* (Fig. 15) and *Haemaphysalis* (Fig. 16). The study was conducted for a 2-year period in primary and mixed secondary rainforest in Sungei Buloh Forest Reserve, about 26 km northwest of Kuala Lumpur. In the mixed-secondary forest (= forest fringe-habitat) a seasonal peak occurred in July for *Dermacentor* spp. In the primary forest a seasonal peak occurred in August for *Haemaphysalis* spp. and an apparent peak occurred in November for *Dermacentor* species. The important 3-host tick of rodents, *I. granulatus* Supino is not yet considered as having the opportunity of coming in direct contact with humans at the present time, because it is essentially a nest-dwelling tick in forest rodent burrows in Malaysia, where the forest environment is somewhat still stable.

The late Dr Harry Hoogstraal's enormous contribution to the study of ticks on taxonomical, ecological distribution, and medical importance is world renowned. His important studies of the taxonomy of *Haemaphysalis* species of Malaysia, prior to the revisionary studies of the *Dermacentor* species, yielded many publications. Among his first papers on Malayan *Haemaphysalis* was Hoogstraal (1962). Some of the other studies published under the heading of "Studies on Southeast Asian *Haemaphysalis*" accessible to me are: Hoogstraal (1964), Hoogstraal & Trapido (1966), Hoogstraal *et al*. (1965), Hoogstraal *et al.* (1965), Hoogstraal *et al*. (1965), Hoogstraal *et al.* (1965), Hoogstraal (1966), Hoogstraal *et al*. (1966), Hoogstraal *et al.* (1966), Hoogstraal *et al.* (1971), Hoogstraal *et al.* (1971), Hoogstraal *et al.* (1971), Hoogstraal *et al.* (1973), Saito *et al.* (1971). Kohls (1949) published a paper on *Haemaphysalis* of birds in Malaya. These references that are related to Malaysian ticks are cited for the convenience of those interested in tick studies.

SIMPLE KEY TO MALAYSIAN *DERMACENTOR* SPECIES

This simple key should serve to recognize and separate the Malaysian *Dermacentor* species, all of which are of the subgenus *Indocentor*. It is not to be taken as a serious taxonomic key by any means. For detailed taxonomic treatment, see references cited.

All four Malaysian *Dermacentor* species have rectangular basis captituli, prominently ornamented and punctate scuta, with prominent pair of eyes. Hypostome with 3/3 dentition. The four *Dermacentor* species can be placed in two groups by virtue of coxa of leg I having spurs long and stout (*atrosignatus* and *steini)* and, spurs on coxa I distinctly short *(auratus* and *compactus)*.

The four Malaysian *Dermacentor* species are separable as follows:

1. Coxal I spurs long, prominent, closely spaced (figs. 11, 12) 2

   Coxal spurs short, spaced wide apart (fig. 13, 14) 3

2. Genital area of ♀ (fig. 11) broad, without V shape, pseudoscutum of ♂ not demarcated, contiguous (fig. 11) .... *D. astrosignatus*

   Genital area of ♀ distinctly V shaped (Fig. 12). Margins of ♀ scutum sinuous, outline of pseudoscutum of male demarcated (fig. 12) ....*D. steini*

3. Coxal spurs IV of ♂ two in number. ♂ pseudoscutum discontinuous posteriorly, not demarcated (fig. 13) .... *D. compactus*

   Coxal spurs IV of ♂ 3-6 in number. ♂ pseudoscutum, somewhat demarcated broader than long (fig. 14) .... *D. auratus*

Figure 9. A questing *Dermacentor* tick resting on the tip of a leaf in the forest (size 5 mm)

Figure 10. Five fed ♀ *Dermacentor* "*auratus*" and 1 ♀ *Amblyomma testudinarium* (size 15 to 20 mm)

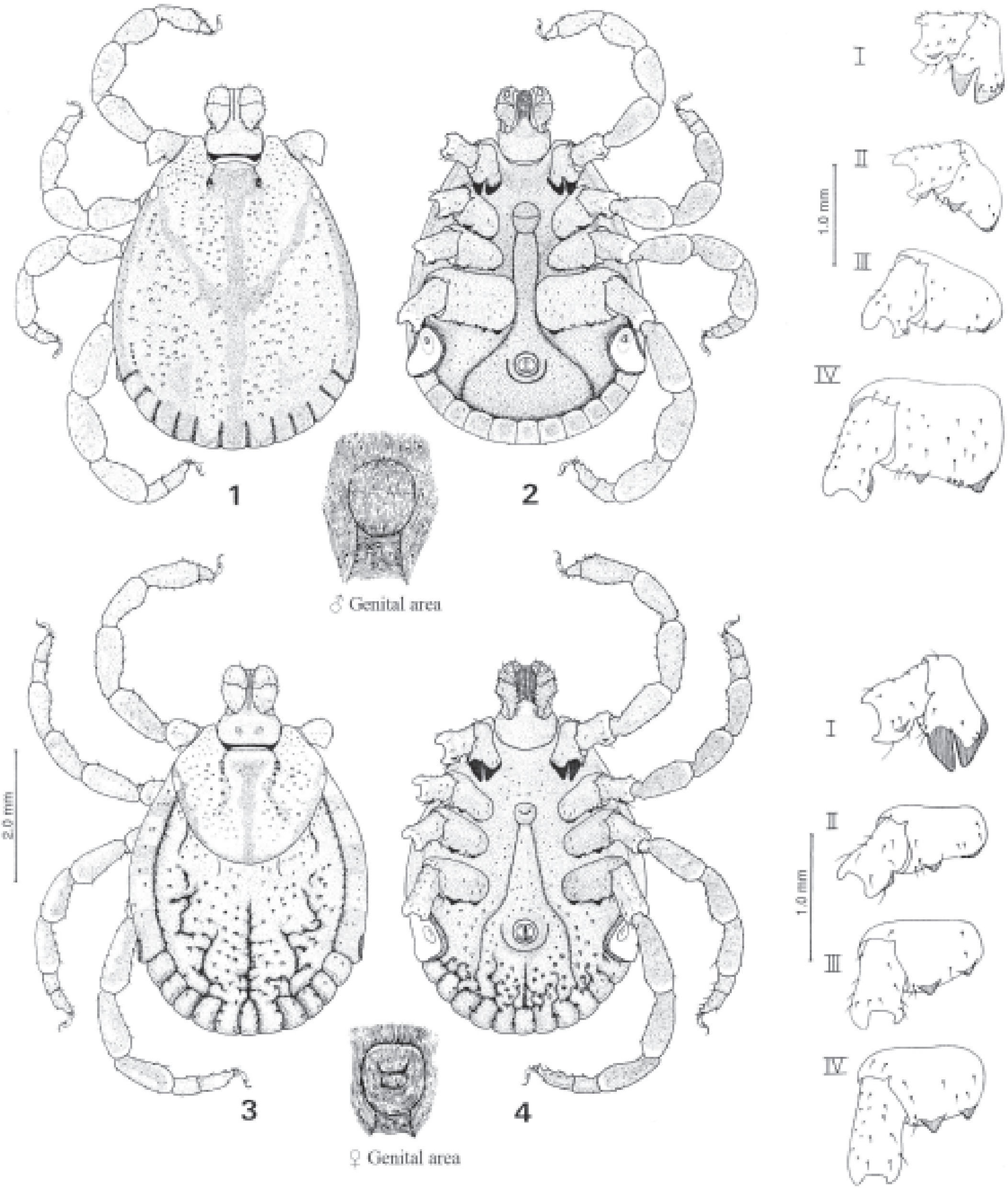


Figure 11. *Dermacetor atrosignatus*
(revised kind courtesy of Wassef & Hoogstraal, 1984)

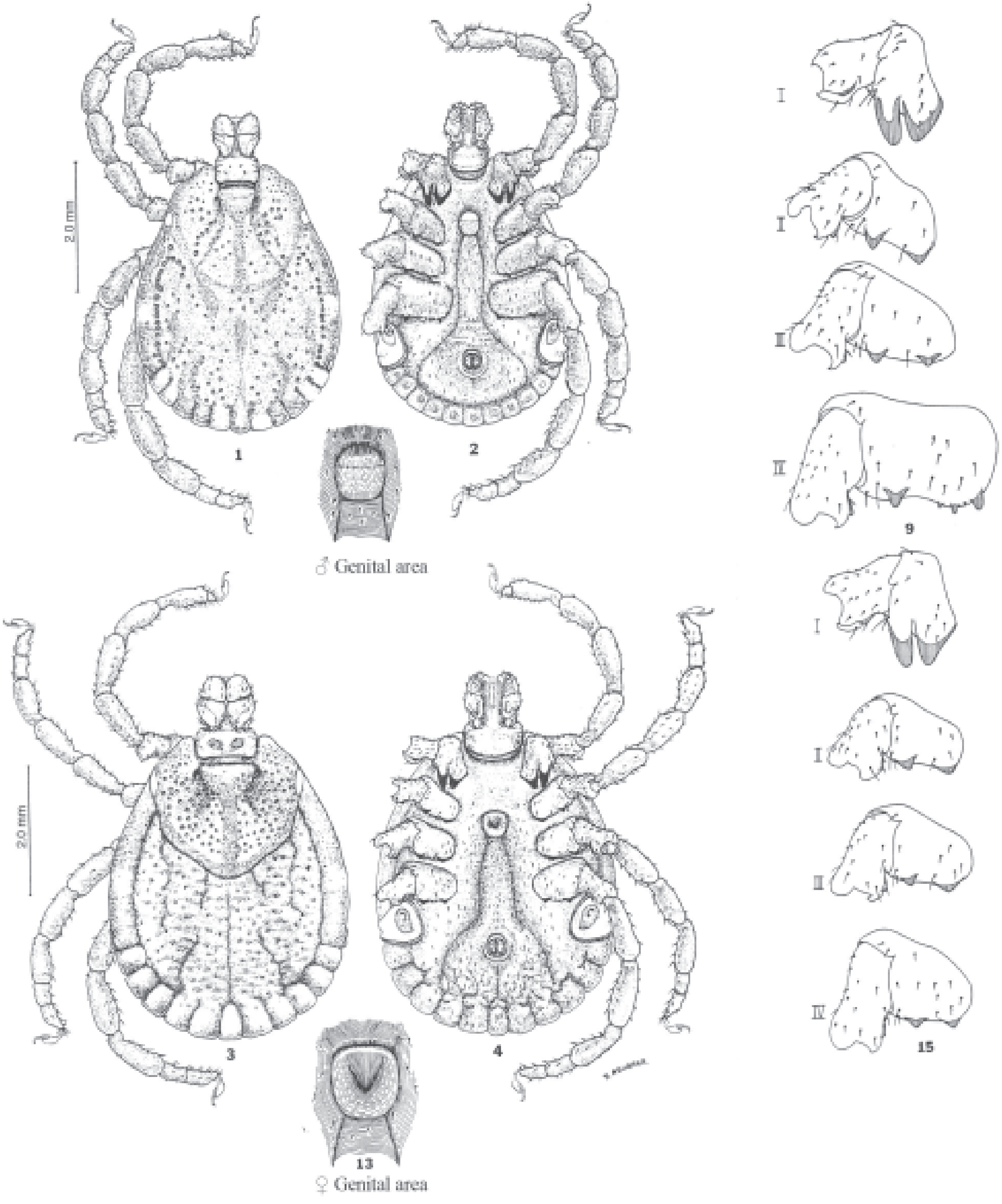


Figure 12. *Dermacentor steini*
(revised kind courtesy of Wassef & Hoogstraal, 1988)

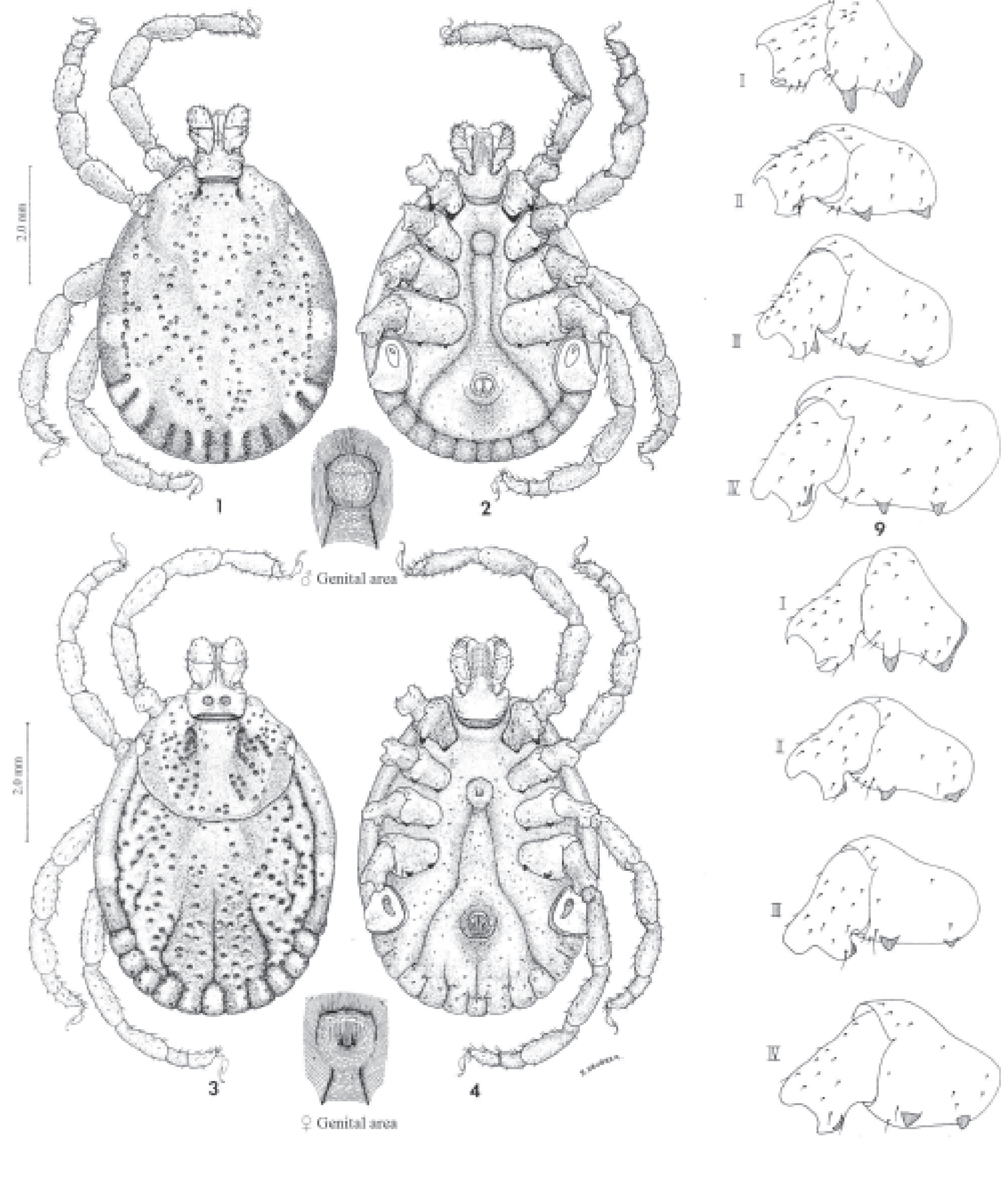


Figure 13. *Dermacentor compactus*
(revised kind courtesy of Wassef & Hoogstraal, 1983)

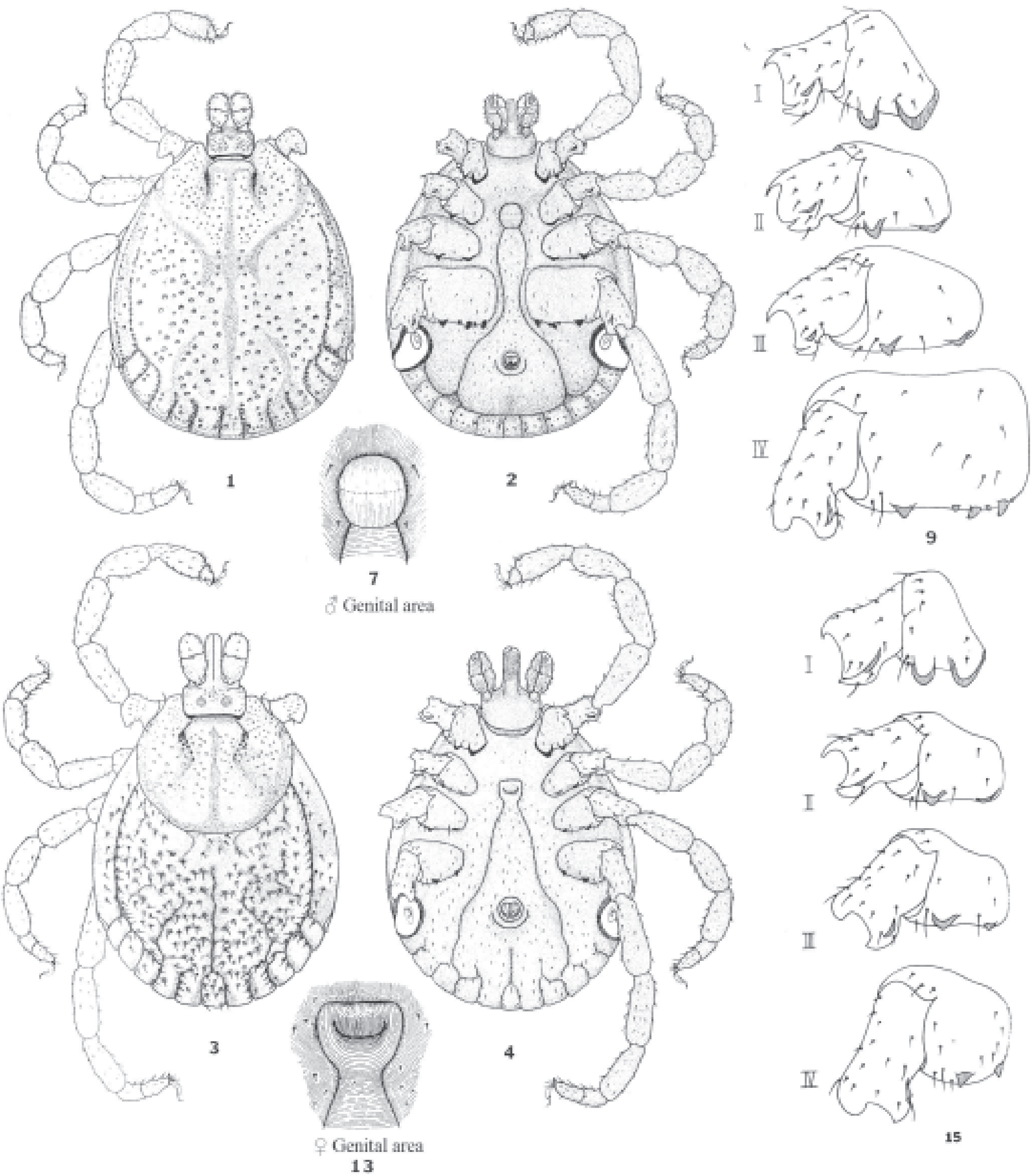


Figure 14. *Dermacentor auratus*
(revised kind courtesy of Wassef & Hoogstraal, 1984)

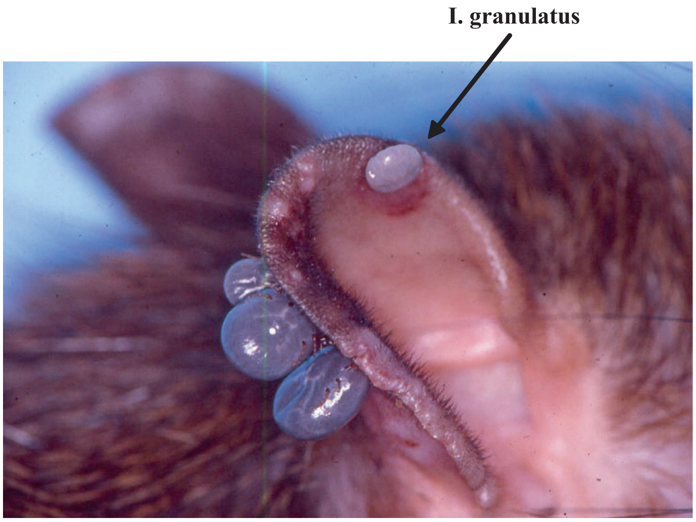


Figure 15. *Dermacentor* nymphs and 1♀ *Ixodes granulatus* feeding on ear of forest rat.

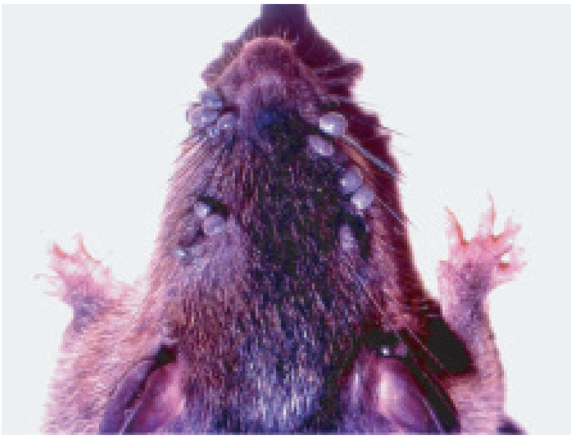


Figure 16. *Haemaphysalis* and *Dermacentor* nymphs on head region of a forest rat.

In this paper six classical zoonotic diseases or infections in which ticks and mites are involved in the tropics are briefly reviewed to illustrate the importance of Malaysian Acari-borne zoonoses. The tick-borne viral diseases and rickettsial diseases are discussed separately. A classical ecological and epidemiological study of a tick-borne viral zoonosis was that conducted in India. It is mentioned here as reference to better understand the natural history of the tick vectors.

TICK-BORNE VIRAL DISEASES

Kyasanur forest disease, India

The first tick-borne virus disease reported in the tropics occurred in India in 1957. Named Kyanasur Forest Disease (KFD), the viral agent is a member of the Russian Spring-Summer Encephalitis complex (RSSE). According to Hoogstraal (1966) the discovery of the basic cycle of the disease was the most dramatic epidemiological detective story up to that time. In 1957 the Poona Virus Research

Center in India received reports of two species of monkeys dying in the forest of Shimoga District, Karnataka (formerly Mysore). At first it was suspected that sylvan yellow fever had invaded India for the first time. On arrival at Shimoga the investigating scientists learned that a protracted febrile, often fatal illness was rampant among humans in villages near Kyasanur Forest where the monkeys were dying. Blood specimens from humans and monkeys yielded strains of virus. The strains from both sources were identical and found to represent a previously unknown virus of the RSSE complex. Three species of *Haemaphysalis* ticks collected from monkeys and other sources were also positive for the virus. The human incidence of KFD subsided after the first explosion in 1957, but it again increased in 1962 and 1963. Where forest primate infection has been demonstrated, human cases have almost always occurred. Since 1972, there have been new KFD outbreaks, within 80 km of the original focus. Early in the epidemiological survey investigators in the Virus Research Centre, Pune, India found ticks parasitizing humans in Shimoga forest, and also parasitizing monkeys, ground-feeding small mammals, birds, and cattle wandering through the forest. The ticks in the endemic areas were poorly known prior to the explosive outbreak of the disease. Systematic studies of the tick species in all their life stages took five years to complete. Out of the 14 *Haemaphysalis* species in Kyasanur Forest, over 500 isolations of KDF virus were made from 7 species. Trans-stadial transmission of KFD virus to new hosts during biting by each development stage of the tick was demonstrated for 4 species of *Haemaphysalis.* Up to 1978, KDF virus had been isolated from 8 species of *Haemaphysalis* and 5 other tick species. A variety of small rats, squirrels, and shrews were hosts for immature stages. The adults fed on large, wild, forest-inhabiting mammals and domestic cattle.

After a decade of field and laboratory research the collected data showed that the human population of Shimoga had more than doubled since 1951, and consequently alterations in the ecosystem had produced conditions favouring an enzootic process. Two factors appear to be epidemiologically most significant in the outbreak: (a) increased tick population densities in the forest and the increased human visits to the forest to gather fire-wood for sale and for household use, and thus the potential for man-tick contact was multiplied many fold; (b) tick numbers were much greater because the adults could feed on the numerous cattle brought to graze in and near the forest.

Langat virus, Malaysia

In Malaysia, a virus similar or close to those of the RSSE group was first recovered in 1956 from *Ixodes granulatus* infesting *Sundamys muelleri* and *Leopoldmys sabanus* from Hulu Langat Forest Reserve, Selangor, 22 km south of Kuala Lumpur (Smith, 1956). The localities, geography and vegetation of the collection areas are given by Audy & Harrison (1954) and Harrison (1957). Those interested in vertebrates and their ectoparasites will find these two publications useful. TP 21, as this virus was first called, was later named Langat virus or langat encephalitis and reported to be closely related to the tick-borne Kyasanur Forest virus (IMR Ann. Rep.,1960). While the natural history of langat virus remains to be studied, *I. granulatus* is also involved in the cycles of tick typhus (*Rickettsia* sp.) and Q fever (*Coxiella burneti*) in climax forest of Peninsular Malaysia (Marchette, 1965). Many subsequent isolations have been made from this tick. The tick *I. granulatus,* a common rodent parasite in Malaysia, has a distribution extending from Southeastern Asia to Eastern India and China. It parasitizes a variety of forest rats, squirrels, and shrews. Nadchatram (1971) recorded the nidicolous habitat of *I. granulatus*. According to Hoogstraal (1973), because of its ecological isolation, this species might not play an important role in the epidermiology of human diseases. However, many other tick species, including those that do contact humans, feed on the same hosts and may acquire pathogens circulated in the *granulatus* – rodent - *granulatus* cycle and consequently transmit these diseases to humans and other hosts when feeding in subsequent developmental stages. Neutralising antibodies to langat virus have been found in a few Malaysian aborigines who live in and around the forests. Experimental infection of cancer patients has shown that this virus is capable of causing encephalitis in humans. It has also been demonstrated that the virus can invade other species of ticks and that the infection is transstadially transmitted from larvae to nymphs and from nymphs to adults. It was also demonstrated that the virus can be transmitted to mice, rats and chicks by infected nymphs (Hoogstraal, 1966).

Lanjan virus (LJN), Malaysia
Another virus was isolated from a tick for the first time at the IMR by Tan *et al* (1967). It was the Lanjan virus isolated from *Dermacentor "auratus"* from the Bukit Lanjan Forest Reserve. Subsequently the virus was isolated from *I. granulatus* and *H. semermis* by Marchette. The ticks infest rodents, shrews, large mammals and even reptiles. Antibodies for LJN were detected in 3 sera from *L. sabanus* (1) and *M. surifer* (2) from Bukit Lanjan Forest Reserve and Hulu Langat F.R. The infected D. "auratus" group nymphs were probably *D. compactus* or *D. atrosignatus* (Hoogstraal & Wassef, 1984). However, recent study indicates the most common species to be *D. steini* (Wassef & Hoostraal, 1986 *loc cit*.). Regardless, all four questing adult species of *Dermacentor* are found to be abundant on vegetation, and are of zoonotic importance.

Other tick-borne viruses
Three other viruses have been isolated in Malaysia from ticks, vertebrates or both. Selatar virus was from the common cattle tick, *B. microplus;* Keterah virus from a common argasid bat tick, *Argas pusillus,* and an unnamed virus from *A. cordiferum*. In addition, viruses were isolated in the Asian region from a single species of argasid tick, *Argas robertsi*, a widely distributed bird parasite as follows: Nyamanini virus and Pathum Thani virus from Thailand and Sri Lanka; Kao Shuan virus from Taiwan, Indonesia and Australia. The involvement of these in human disease is unknown (IMR Ann. Rep. 1957; Hoogstraal, 1973; Varma & Converse, 1976). A follow up of the importance of these ticks and the viruses they harbour is worthy of medical research, and there is every likelihood that *A. robertsi* occurs in Malaysia.

ECOLOGY OF *IXODES GRANULATUS* SUPINO

There are approximately 40 species of hard and soft ticks in Malaysia. *Ixodes granulatus* is the commonest 3-host tick that completes the entire life cycle on rodents, shrews, and other small mammals in Malaysia (Audy *et al.1960.)* Parasites and their hosts are useful indicators for the assessment of the ecological well-being of the forest ecosystem. For example, the biotope of the tick, *I. granulatus* coupled with the host animals, is useful as an "ecological label" to monitor alterations in the natural environment, because it is a 3-host tick which lives, parasitizes and completes the entire life cycle on forest rodents and shrews in nests in forest ground burrows.

Keirans *et al* (1970) have described the male and immature stages of *I. werneri*. Studies over many years in Malaysia (unpublished) have shown that *I. granulatus* in all its stages continues to be one of the most common species of tick on rodents. However, based on published records (Audy *et al.,* 1960*)* and subsequent unpublished data, very few immature stages were found on the rodents, suggesting that feeding of the immatures may take place mostly in the nest of the rodents in ground burrows. A virus was first isolated from the genus *Ixodes,* infesting rodents, in Malaysia in 1956. Both *I. werneri* and *I. malayensis,* because they are uncommon could have been overlooked during routine identification. Between 1948 and the 1960s intensive as well as extensive collections of animals were made from a number of forest reserves, mostly in the state of Selangor (Audy & Harrison, 1954).

An average of 25 animals were routinely examined for ectoparasites and endoparasites for six days a week. From 1952 to 1959 alone 17,863 vertebrates of various species were processed for ectoparasites in the Medical Zoology Laboratory of the IMR. Because of the routine field work that continued, it is reasonable to assume that some 30,000 animals were brought to the laboratory and examined for parasites until 1970. Nadchatram for the most part and one other junior assistant were involved in body processing and parasite collection. Routine screening and identification of ticks, chiggers and other mites were done by Nadchatram and there is the likelihood of a species close to *I. granualtus* to be missed during routine screening. *Ixodes granulatus* was successfully reared in the laboratory and it took 185-271 days for it to complete its life cycle in the laboratory (Nadchatram, 1960). Under laboratory conditions the maximum survival time of the larva, nymph and adult were: 95, 160, 180 days, respectively. The developmental stages of the tick between feedings take place in the nests of ground burrows of various forest rodent species (Nadchatram 1970, 1971, 1972). The absence of natural infection of field workers and jungle trekkers by this species is perhaps due to it usually developing in the ground burrows of forest rats (*L. sabanus, L. edwardsi, S. muelleri, B. bowersi, M. whiteheadi, M. surifer, M. rajah* and 2 species of shrews). Ecological data on these small mammals is reported in IMR Ann. Rep. (1972). The cryptozoic habitat of *I. granulatus* was discovered by Nadchatram in the late 1960s, through investigations to determine the nest-dwelling behaviour of forest rodents with special reference to the ecology of trombiculid mites and the epidemiology of scrub typhus.

A virus was first isolated from the genus *Ixodes* in Malaysia in 1956, but manifestation of human infections was absent. It is highly probable that it is due to the tick being a nidicolous species in the Malaysian rain forest.

Ixodes species of medical importance in other developed countries are thought to have been originally nidicolous as *I. granulatus.* Changes in the environment of these countries would have resulted in many *Ixodes* species becoming field ticks in certain stages of the life-cycle. *Ixodes* species occurring in these countries, based on our experience with *I. granulatus* would seem to have adapted to the changes in the environment of the developed countries, resulting in many *Ixodes* species being able to come in close and direct contact with humans.

The following comparisons of *Ixodes* species in other countries is confined to ecological consideration only, related to the behaviour of the larval and nymphal stages. For example, *Ixodes ricinus* (Linn.), the sheep tick, one of the commonest British ixodid ticks is principally a parasite of sheep and cattle in its larval and nymphal stages as well as adults, but it has been reported from small mammals and birds (Lees, 1967). Though Evans *et al.* (1961) do not give the type of hosts for the immatures, they state that the female lays eggs in crevices in the soil and amongst the litter-mat. The hatched larvae ascend to the tips of herbage, and likewise the questing nymphs. The hosts of immatures are not given.

However, Nilsson (1988) stated the occurrence of *I. ricinus* on small mammals and vegetation in the immature stages and adults on sheep and deer in Sweden. This important 3-host tick is found throughout Europe. *Ixodes persulcatus* Schluze occurs mostly in Eastern Europe (Pomerantzev1959; Bolotin, 1982), Bolotins's study of the seasonal distribution of immature ticks indicates an increase of *I. persulcatus* with human activity. Its host preference is somewhat similar to that of *I. ricinus. Ixodes scapularis* Say, the deer tick in North America and *Ixodes holocyclus* Neumann in Australia in their immature stages also feed on small mammals, and adults feed on big animals. Humans may be exposed to the bite of both the immature stages and adults of these 3-host ticks, and therefore, these species in all stages of the life-cycle are of public health importance in the countries where they occur.

The point that is being made here is that in the event that the Malaysian natural environment is altered, it is speculated that *I. granulatus* would adapt to the altered environment and thrive to be of epidemiological importance as *Ixodes* in other developed countries. Studies made by the IMR represents the first record of *I. granulatus* living in all its stages in burrows of forest rats in Malaysia. However, the burrowing behaviour of *Ixodes trianguliceps* in rodents and insectivores of Europe, ranging from Ireland in the West to the vicinity of Lake Baikal, Eastern Europe is recorded by Katelina *et al.* (1971) and O'Donnel (1971).

TICK-BORNE RICKETTSIAE

Well known human rickettsial diseases transmitted by ticks from animals are Rocky Mountain spotted fever (RMSF), (*Rickettsia rickettsii);* Siberian tick typhus, (*Rickettsia siberica)*; boutonneuse fever or tick typhus (*Rickettsia conori)*; Queensland tick typhus (*Rickettsia australis),* and Q-fever, the agent of which is *Coxiella burneti*. Only Boutonneuse fever and Q-fever are discussed here. Though RMSF occurs only in North and South America and Canada, it deserves special mention here, because it is the best known of rickettsial diseases, and was the first to be scientifically investigated.

Rocky Mountain spotted fever

The disease was first recognized in the 1880-1890 period and it was a severe and fatal disease. The brilliant early research devoted to finding the pathogenic agent, the tick vectors and vertebrate hosts, and to elucidating the natural history of the disease is an epic of biomedical history. The early epidemiological research of RMSF provided the intellectual inspiration for the development of the renowned concept of the focality of vector-borne diseases by the Russian scientist, E.N. Pavlovskii. This concept was to guide Russian investigations of a remarkable number and variety of arthropod transmitted diseases in the Asiatic regions of Russia (Hoogstraal, 1978).

RMSF is vectored chiefly by *Dermacentor andersoni* Stiles and *D. variabilis* Say in North America. Several other species of hard ticks have also been incriminated. Several species of mammals, small and large, serve as natural hosts. The incidence of the disease in humans, who do not serve as reservoirs, depends largely on the behaviour of the vector ticks, their distribution and ecology, and either on the ticks encroachment into the human domain, or human's penetration of tick's natural habitat which is the wild domain. The complex inter-relationships of population densities and annual cycles of the abundance of ticks and their hosts were important factors in respect to human disease incidence. The undiminished virulence of *R. rickettsii* strains, passed transstadially and transovarially, through several generations of ticks served to maintain an infected focus. Several thousands of lives were lost to RMSF. Even now several cases are reported annually in America.

Boutonneuse fever or Indian tick typhus

In the tropics, including Malaysia, boutonneuse fever or Indian tick typhus, occurs in India, Myanmar (Burma), Malaysia, Thailand and Vietnam. Boutonneuse fever causes mild to severe disease and few fatalities. Numerous tick species in several genera have been incriminated as vectors. In Southeast Asia, investigations of tick-borne rickettsial agents commenced about 1950. Serological evidence and clinical diagnosis of mild human cases were reported from Vietnam. Tick-borne rickettsiae have been isolated from *Ixodes* and *Rhipicephalus* from rats in Thailand. Cases suspected of being boutonneuse fever were from Myanmar where *R. sanguineus* is common on dogs.

Human boutonneuse fever or tick typhus as it was then known was first detected in Malaysia in 1958. The following year additional human cases were found and the presence of antibodies in jungle vertebrates was established (IMR Ann. Rep., 1959). Stimulated by this finding an extensive survey and intensive study was undertaken in 1960s by Marchette (1965). He demonstrated that the basic cycle of tick typhus occurs in the mammals and ticks of the Malaysian rain forest. Six species of forest rodents and a species of tree shrew were sero-positive for tick typhus. *Ixodes granulatus* and at least 2 species of *Haemaphysalis* ticks were involved in the cycle. In agricultural lands presumptive isolations of the rickettsiae were made in 2 species of field rats, and the high prevalence of serological positives in urban areas indicated that a cycle also exists in these situations. At least 3 of the 6 species of forest rats were involved: *S. muelleri*, *M. whiteheadi* and *N. niviventer.* These rats are known to wander into scrub habitats fringing the forest, where they may come in contact with scrub rats, *R. tiomanicus* and *R.. argentiventer,* and exchange ectoparasites and rickettsiae. These in turn would come in contact with other small mammals of strictly man-dominated ecosystems, such as plantations and agricultural fields. Serological evidence indicated that ground or bush-dwelling birds such as the common bulbuls and babblers may become infected (IMR Ann Rep. 1959).

Occurance of Q-Fever in Malaysia

Q-fever is common in Australia, the U.S.A. and many Asian countries, as well as the Mediterranean and African savaanas. Modes of transmission are various and domestic animals are frequently involved. The limited knowledge of Q-fever in the tropics in general, and Southeast Asia in particular, is probably due to lack of survey rather than the lack of pathogenic agent. Not until after World War II was attention turned to the possibility of Q-fever occurring in the Asian region. Q-fever is now known to occur in China, India, Sri Lanka, Japan, Vietnam and Malaysia. Although there are no reported incidents of Q-fever in a number of countries in Asia, there is evidence that Q-fever is endemic in Southeast Asia (Marchette, 1965).

The presence of Q-fever in Malaysia was first recognized in 1951 (IMR Ann. Rep., 1951), when serological survey revealed complement-fixing antibody against *C. burneti* in man and domestic animals. By 1960 at least 12 human cases were diagnosed as Q-fever in the course of serodiagnostic investigations by the U.S Army Medical Research Unit attached to the Institute for Medical Research (IMR Ann. Rep 1958, 59, 60). All except one of the cases were either military or police personnel whose duties required that they go into the jungle. Subsequent studies showed that at least 3 species of small forest mammals (*S. muelleri, M. rajah* and *Tupaia glis*) and two species of *Haemaphysalis,* a single species of *Dermacentor* and *I. granulatus* were positive. The incidence of infection among the mammal species tested was low, but evidence of infection was found in widely separated and differing types of terrain throughout peninsular Malaysia (IMR Ann. Rep. 1959).

HUMAN TICK-CAUSED OTOACARIASIS

The above heading is proposed to specify ear-canal or intra-aural infestation by ticks on humans. Generally, otoacariasis is infestation of the ears of cats, dogs and other animals with mites of the species *Otodectes cynotis* (family Psoroptidae). Between 1947 and 1982 the ears and nasal passages of many thousands of rodents, other small mammals, reptiles and birds were examined for parasites and numerous species of chigger mites, adult and immature ticks, and other mites representing many families, genera, and species were recorded by Audy & Harrison (1954) and Nadchatram (2006). Some examples of other discoveries were psoroptid mites from the ear canal of proboscis monkey described by Fain & Nadchatram (1979) as *Nasaliages borneensis* gen. n. sp. n. and the species *Chelonotus selenirhynchus* Berlese 1893, the ear mite of squirrels, living naturally throughout its life on the outer ear lobe, within a dry, yellowish, nest-like mass of debris. They live protected from the elements of a tropical country. These mites have been found on many species of squirrels in Malaysia and other Southeast Asian countries throughout the years. Whenever these mites occur there is hardly any other parasitic mite to be found, because mites of the family Cheyletidae are predatory. Domrow (1960) has given a good account of the taxonomy of this cheyletid mite.

The common site of infestation for larval trombiculid mites of rats is in the inner and outer ear lobes and pinnae. Inside the ear pinnae of rats is the favourite site of attachment of chiggers throughout the world, where they feed to repletion and then leave the host. For many acarine parasites, the ear is the natural site for the entire life cycle of the organism.

Otoacariasis can have a different connotation if it is related to a disease manifestation. Human otoacariasis is not a natural happening, and human otoacariasis where ticks are involved is not a natural occurrence, but rather an accidental phenomenon when humans living in close contact with tick-infested animals, or living close to the environment where ticks naturally occur, get accidentally infested. It is suggestive of sub-standard living conditions, as in the eastern rural districts of the states of Kelantan, Terengganu and Pahang in peninsular Malaysia. In these areas the residents live in close contact and harmony with domestic animals. Based on my Malaysian experience, having worked on mites and ticks for many years, I suggest that the accidental invasion of the ear canal of children and elderly persons while sleeping on the floor is probably most often caused by the fed nymph of the common dog tick, *R. sanguineus,* detached from the host and looking for a suitable site to moult. Several occurances of infestation of houses by this species have been recorded in Australia (Roberts, 1970). The accidental invasion by the larvae of the common cattle tick, *B. microplus,* or the bat-infesting tick which lives in the attics and ceiling space of houses, *A. pusillus* Kohls are probabilities. Children playing or loitering in secondary forests or forest fringes may be affected by other species of ticks to be found in those habitats.

With the establishment of universities and medical faculties provided with medical specialists throughout Malaysia, the rural population now has access to medical attention, and ailments unheard of in the past are becoming known. During my active working days in the late 1950s and early 1960s there was only one university and medical faculty which was located in Kuala Lumpur, the University of Malaya.

There have been 2 papers published on tick-caused human otoacariasis in the state of Kelantan, Malaysia by Indudharan *et al*. The first one in 1995 reports on 2 cases of tick-caused otoacariasis – a seven year old child, and a 64 year-old woman. The child suffered intense pain in the left ear for 4 hours, before receiving medical attention. It was found that a tick had attached itself to the tympanic membrane. On first examination it was mistaken for a haemorrhagic bulla, which turned out to be an engorged tick; when it was removed with surgical forceps, the patient recovered soon after. The elderly woman complained of severe pain in the right ear, decreased hearing and giddiness for 2 weeks. Otoscopy revealed a red bullous lesion. A 4% lignocaine solution was instilled in the ear canal for 10 minutes and the "bulla" which was a replete tick was removed. The patient was relieved of pain and discharged, but the inflammatory reaction of the tympanic membrane took more than a month to resolve. The tick was identified as a *B. microplus,* but the general image in the photograph of the capitulum (mouthparts) does not look like that species. Moorhouse (1967) discusses and illustrates the pattern of attachment of female ixodid ticks to animals.

Indudharan *et al*. (1999) presented an overview of the incidence of otoacariasis in the state of Kelantan. Between 1990 and 1996, a total of 348 cases of aural foreign bodies were reported at the School of Medical Sciences, University Sains Malaysia. Of these 59 cases were by cockroaches and other insects, 43 were unidentified arthropods, and ticks made up 40 cases of animate foreign body. It usually took one to ten days for the affected individual to present for medical attention, at an average of 7 days. The age distribution of patients ranged from one to 65 years, 70% were less than 14 years old. Clinical manifestations were also presented. Nearly all the cases with tick-caused otoacariasis were from two rural villages in Kelantan state. Unfed larvae are not identified even to genus, and it is not established where the ticks were collected from.

Mariana *et al.* (1996) reported on a survey of two villages in Kelantan where tick-caused human otoacariasis was reported. Most of the houses in the village were of timber structure raised on stilts about a meter above the ground. The space beneath some of the houses was used to keep cattle and other domestic animals. Three species of adult and immature ticks were collected from domestic goats, sheep and cows from both villages. It is unfortunate that the *Haemaphysalis* nymphs and adults were not identified to species. From previously known host records they were probably *H. bispinosa.* The infestation of *B. microplus* on goats is unusual, because the species is usually considered host-specific to cattle. No ticks were found on rats trapped around the houses, nor were ticks found by flagging or examining leaf litter.

In the state of Pahang, in the Hospital Tengku Ampuan Afzan, Kuantan, Peninsular Malaysia, Mariana *et al* (pers. comm.) extracted records of 318 cases of tick-caused human otoacariasis for the period 2002 to 2006. A total of 329 ticks were recovered over the 5-year period. They were mostly *Dermacentor* spp. made up of 99.7 %, represented by one or more species of *D. atrosignatus, D. compactus*, and *D. steini*. Only a single tick of *Haemaphysalis* was found. All active stages, i.e. larva, nymph and adult were represented, 84. 4 % were nymphs. Usually one tick was found per case. In 7 cases, however, 2 or 3 ticks were extracted from a single ear. The ticks were found in the bony part of the auditory canal, followed by tympanic membrane and cartilage part of the ear canal. A few ticks were attached to the outer pinna. Though the attachment of ticks caused pain, no facial paralysis was recorded perhaps due to the short period of attachment. Throughout the study there were 6 repeat cases, 2 cases presented 3 times in a year. The afflicted individuals were mostly children (76.4%), nearly 69.0% were females. The dominant ethnic group was Malay (96.6%). The 3 states mentioned above are, unfortunately, not yet as well developed, socially and economically, as other states of Peninsular Malaysia, or the afflicted individuals lived in environmental conditions close to the habitat of the ticks. The states of Pahang, Terenggnau and Kelantan represent 51% of the land mass of Peninsula Malaysia and in line with the aspiration of bringing developed status for Malaysia by the year 2020, enormous amounts of money are to be invested to improve the economic status of the three states to bring them to par with other states of the peninsula.

In Sri Lanka, Dilrakshi *et al*. (2004) reported a retrospective study from January 2000 to December, 2001, in which intra-aural ticks were present in 870 (15.2%) of 5714 patients who reported with ear related complaints to the E.N.T. ward at Ratnapura Hospital, Sabaragamuwa Province. A review of 383 of these cases showed that the majority (70.8%) of surgically removed ticks were nymphal *Amblyomma integrum*, together with nymphal and adult *R. haemaphysaloides*, *R. sanguineus* and 2 species of *Hyalomma*. The genus *Hyalomma* does not occur in Malaysia. but is recorded in the drier area of Northern Myanmar (Petney & Keirans, 1995). More female than male patients are reported with otoacariasis, and more children (aged 0-10 years and adults over 21 years) were represented. The authors noted that this represented the most extensively reported case of human tick-caused otoacariasis and might be indicative of a wider, but little reported, human tick problem in Sri Lanka. Otoacariasis is also known in Chile and Spain. In Spain a soft tick is incriminated.

TICK PARALYSIS

It was reported by Indudharan *et al* in a letter to the Lancet (1996) that in the School of Medical Sciences, Universiti Sains Malaysia in the east coast of Malaysia, a 65-year old patient was admitted, experiencing increasing pain in her right ear and weakness on the right side of her face after a tick had entered the right ear 7 days earlier. The tick was identified as a *Dermacentor* species. On medical examination, she had a right-sided, isolated, complete, lower-motor-neuron facial palsy. In the light of available information on tick distribution, I have long suspected that tick paralysis occurs in Malaysia. It has been reported from many countries throughout the world. The disease in humans is caused by the introduction of a neurotoxin into a human during attachment and feeding by a female tick of a variety of species. In Australia, *I. holocyclus* is a medically important tick known as the paralysis tick. Found in a variety of habitats, it is mostly associated with wet forest and temperate rain forest. In the United States several species of the genera *Dermacentor, Amblyomma* and *Ixodes* are associated with tick paralysis. Onset of symptoms usually begins after a tick had fed for several days. If unrecognized, the paralysis can lead to respiratory failure. In the United States the disease is most often reported in children living in rural areas. It is a rare disease and is often confused with other acute neuorologic disorders.

In Malaysia, and other Southeast Asian countries awareness of the potential of tick paralysis needs to be fostered among medical practioners and those field workers, picnickers and campers in forest habitats who are likely to be exposed to ticks. Paralysis caused by a tick is usually resolved in 24 hours after its removal. It is ascending (starting from the lower body). An afflicted person experiences jerky body movements, and muscle weakness beginning in the lower extremities and progressing upwards. Breathing difficulties often occur. Typically, the site of attachment of the ticks are the hairline, the neck region below the hairline, or the back of the body. All the genera of ticks incriminated in causing tick paralysis in other countries also occur in Malaysia. The ecological distribution is somewhat similar and the behaviour of adult *Dermacentor* spp. in that they rest on vegetation awaiting a host to attach to as seen in fig. 9, are suitable situations for the attachment of the ticks on humans.

LYME DISEASE

In consideration of new emerging diseases with global distribution, mention must be made of another tick-borne zoonosis known as Lyme disease, which is not yet known in Malaysia. It was first described in the U.S.A. in the town of Old Lyme in Connecticut in 1975. The disease is now reported to occur in most of the United States, southern Canada, Europe and northern Asia. Symptoms initially are mild fever plus a localized rash in some patients. Later symptoms of Lyme disease may be quite serious, including arthritis, pain in peripheral nerves, palsy and disorders of central nervous system. Rodents and deer are the most commonly infected animals in North America and serve as hosts for the tick, while small mammals and birds are incriminated in Europe. A number of *Ixodes* species are vectors. The pathogen is a spirochete bacterium, *Borrelia burgdorferi.* Chiang *et al.* (1998) reported on the first case of Lyme disease in Taiwan, China. Several strains of *Borrelia* spirochetes had been isolated from rodents. Though *I. granulatus* and *Ixodes ovatus* were collected from rodents, the involvement of these ticks in the transmission of the zoonosis is still uncertain. However, in Zhonghua, the Chinese journal of internal medicine, there are many publications on Lyme disease in many parts of China and Mongolia. Isolations of *Borrelia* strains from *I. granulatus* in the Fujian Province is recorded. It appears that Lyme Disease is also spreading in forested areas in China and Japan in which *Ixodes* species are also vectors. Enzootic transmission cycles in birds are reported in Japan by Nakao *et al*. (1994).

Aside from Nipah Virus, in the past few decades new diseases have been emerging, either vectorborne or with other means of transmission, i.e. either direct contact, or with contact with birds and bats. A good example of the emergence of zoonotic diseases in Malaysia is Japanese encephalitis, a mosquito-borne arbovirus. After it appeared in Japan in 1870s, its introduction in Southeast Asia, including Malaysia is well documented by Solomon *et al.* (2003).

HUMAN TICK BITES WITHOUT CLINICAL MANIFESTATION

There have been numerous incidents or reports of dermatitis caused by tick bites in Malaysia. To those who ramble in forest clearings or forest fringes, larvae of *A. testudinarium,* are the causative agents when loitering in areas close to wild pig wallows. I have on many occasions been bitten by larval ticks of *A. testudinarium* attached to groin and scrotum and experienced itchiness for 4-5 days without other side effects. Larval *Dermacentor* species also may be involved. The adults of both species are common parasites of wild animals, especially the wild boar. In nature the larval ticks, on hatching, look for a rodent or any small mammal on which to attach and feed. Efforts were made a number of times to rear *A. testudinarium* from gravid adults obtained from a wild boar. Though the adult females laid eggs in the laboratory the eggs failed to hatch. One female with length equal to one diameter of a twenty cent coin or a U.S. quarter, laid some 8,000 eggs, but none hatched.

Other recorded incidents of ticks biting man were 5 larval *A. testudinarium* biting Professor Morrell, Singapore Island, 1953; *Amblyomma* sp. (immature) from a tiger in some numbers reported as biting man in Fraser's Hill Pahang (reported by Mr Hislop, a senior game ranger), *Amblyomma* larvae biting Dr Harrison after he handled a dead civet, *Viverra zibetha,* Kuala Kubu, Selangor, and Dr J.A. Reid bitten by *H. bispinosa* in Fraser's Hill. Adults of *H. bispinosa* have been recorded from goat, dog, wild boar, deer and cattle (IMR Ann. Rep. 1954; Audy *et al*., 1960). Larval ticks in particular may attack humans in considerable numbers and cause severe irritation. They have been confused with chiggers which cause scrub-itch. Many ticks are potential vectors of a surprising variety of infectious organisms, as stated earlier. It is important to know which species bite, and in what stage of the life-cycle they do so. It is reasonable to assume that unrecorded incidents of humans being bitten occur when exposed to tick-infested country. *Haemaphysalis bispinosa* that parasitized a goat in a residential area caused serious problems to humans living in a house that had a large neglected compound, near the Royal Selangor Golf Club in Kuala Lumpur.

Reports were received of the nuisance caused by larval soft tick, *A. pusillus* Koch that parasitizes bats roosting in the ceiling space or attic of houses. One complaint was received from the District Health Officer of Kuala Pilah, Negri Sembilan in 1979, that residents of a nurses hostel had complained of bats living in the attic of the building and that the residents suffered from bites caused by little insects. It was found that the bites causing irritation were *A. pusillus* that were natural parasites of the bat *Tadarida plicata.* A total of 75 bats of a single species were trapped in one day. (IMR Ann. Rep. 1979). Two species of ticks infesting bats were found, *A. pusillus* and *I. simplex.* In Singapore in 1986, bats identified as *Scotophilis kuhlii* were collected from the attic of the residence of Professor Chen of the National University Singapore who had complained of itchiness suffered by family members. Larvae, nymphs, and adults of *A. pusillus* were obtained (Fig. 17).

Species of ticks collected by sweeping vegetation

Valuable studies of ticks under the "Malaysian Tick Survey" initiated at the IMR in the 1960s, contributed to a wealth of knowledge, also of the distribution of ticks parasitic on wildlife

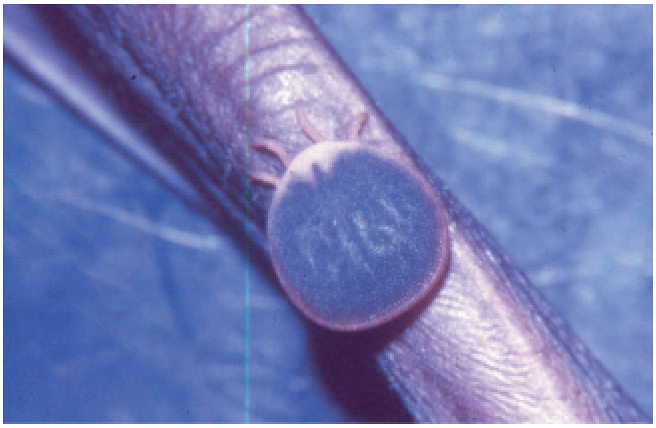


Figure 17. *Argas pusillus* crawling on humerus of bat.

and the forest vegetation which served as the launching pad for the hungry, questing adults of various species of ticks to attach themselves to a host that happens along. Todate a total of 14 species were collected from vegetation, as listed below, and as seen in Fig. 9. In addition to a number of species biting humans, many species of ticks have been collected by sweeping the vegetation in primary, fringe, and secondary forest habitats in 5 different forest reserves in Peninsular Malaysia (Hoogstraal *et al.,* 1972; Hoogstraal & Wassef, 1985a,b; and Wassef & Hoostraal, 1988). Many thousands of questing male and female ticks and occasionally nymphs were collected from vegetation of the following species: *Dermacentor steini D. atrosignatus, D. compactus, D. auratus*, *H. semermis, H. nadchatrami and Haemaphysalis koningsbergeri* were among the most common species of both sexes collected. Occasional collections were made of adult *H. cornigera, Haemaphysalis calvus, Haemaphysalis obesa, Haemaphysalis hylobatis, Haemaphysalis traubi, Haemaphysalis lagrangei, Haemaphysalis traguli and Amblyomma* sp. prob. *testudinarium.* These questing ticks wait on tips of vegetation for a suitable host to come along to attach to (Fig. 9), as they respond to carbon dioxide and movement of the prospective host. The waiting period may last days, and all of them being ticks that feed on mammalian hosts, have the opportunity of attaching to humans.

SCRUB TYPHUS
(Tsutsugamushi Disease)

The name scrub typhus had been coined by the then Director of the Institute for Medical Research, Kuala Lumpur, Dr W. Fletcher in 1927. (IMR,1951 p.198). He was one of the first medical scientists to be involved in scrub typhus research in the IMR, which means that the IMR has been involved in scrub typhus investigations in one form or another for 80 years. Other prewar medical scientists who worked on scrub typhus at the IMR were Drs R. Lewthwaite (1929-1946), J.W. Field (1931-1949), J. Lessler (1918-1921) and S.R. Savoor (1927-1955). In 1924-25 a few cases were diagnosed as tropical typhus and later found to be a disease occurring in Japan and known by the name of tsutsugamushi disease.

Dr Fletcher named scrub typhus to stress the association of the disease with scrub and wasteland. During World War II, the name scrub typhus became fully established by usage, and being easy to pronounce, as well as having a clear meaning in English, this name has undoubtedly come to stay. It is however, acknowledged that tsutsugamushi disease is the older name, which has been the topic of research in Japanese medicine since 1877 (Audy, 1968). A more recent comprehensive study on tsutsugamushi disease was that of Kawamura, Tanaka & Tamura (1995). In 1974, the name chigger-borne rickettsiosis was proposed by Traub and Wissman, but the name tsutsugamushi disease is the senior valid name. Scrub typhus is the name with which the IMR is intimately associated and the literature is replete with references to this name. As will be seen scrub typhus is a zoonosis with a colourful biomedical history, similar to that of Rocky Mountain Spotted Fever. It is a febrile illness caused by infection with *Orientia (=Rickettsia) tsutsugamushi*, the vectors of which are certain species of larval mites (chiggers) of the family Trombiculidae. The disease, first reported in Japan in 1910, is widespread in the Asia-Pacific region (Audy, *loc.cit*.). The disease was dreaded by field and plantation workers. Only those who were exposed to scrub grassland and poorly maintained plantations (oil palm, rubber) where field rats and infected vector mites lived came down with the disease.

Historical brief on scrub typhus

Recent history of scrub typhus research began in IMR in 1947 with the establishment of the Scrub Typhus Research Unit led by Dr. J. R. Audy. Dr Audy, a Lt. Colonel in the British Army Medical Corps was engaged in studies of scrub typhus in the Indo-Burma front during WW II. In 1948, the U.S. Army Scrub Typhus Research Team led by Dr Joseph E. Smadel came to the IMR with antibiotic derived from a mould isolated from Venezuelan soil, a crystalline substance prepared as a natural extract in the laboratories of Parke, Davis and Co., and produced synthetically in 1948, to conduct field trials of the antibiotic Chloromycetin (chloramphenicol) against scrub typhus. Many laboratory studies were conducted by Smadel and his associates in the U.S.A. before the field trials were conducted in Malaysia (IMR Jubliee Issue, 1951). The move to conduct the medical trials with the scientific staff of the IMR in 1948 was initiated by the Director of IMR, Dr R. Lewthwaite. Dr Lewthwaite, who was a medical scientist at the IMR before WW II, returned after the war and assumed the directorship of the Institute. The dynamic research investigations and medical trials led to the speedy and most successful results. Human volunteers exposed as guinea pigs in an endemic scrub typhus area in Seaport Estate, Subang and who contracted the infection were treated with chloromycetin with 100% success, and the bogey of scrub typhus was laid to rest (Fig. 18). The cartoon produced in good humour by A. Dorall, personal assistant to the Director, Dr R. Lewthwaite did not give prominence in the clinical experiments to Drs Audy, Harrison and Cockings of the IMR Scrub Typhus Research Unit, but not in the celebration. (The first Malaysian international airport was sited in Subang in the general area which was highly endemic for scrub typhus and in the vicinity where the successful trials were conducted).

Further work in the Institute and elsewhere has shown that the value of chloromycetin is not restricted to scrub typhus, for the drug is also active against a wide range of bacterial diseases. The classical example of unselfish scientific research for the benefit of mankind is well described in IMR Jubliee publication (1951). The successful medical trials led to the discovery of a wonder drug against scrub typhus. "Overnight as it were a once severe and often mortal disease, centuries old, much feared by planter and serving soldier alike, had become trivial."

Scrub typhus has been a disease as common as malaria in new settlements in Malaysia (Cadigan *et al*., 1972). The U.S. Army Medical Research-M to which Col. Cadigan belonged was comprised of many other scientists who served with the U.S. Army Unit during their attachment to the IMR from 1947 until 1988. Over some 50 years of their association with the IMR, several hundred scientists from the Walter Reed Army Institute of Reseach, Washington, D.C. attached to the IMR as the USAMRU-M worked cordially with the staff of IMR, and their programmes included research not only on scrub typhus, but complemented research with IMR staff on other lesser known infectious diseases. It is only fitting that their contributions to Malaysia is recognized. Among those who had made a major impact on biomedical research with

AMONG THOSE PRESENT ...

WOODWARD (US) COCKINGS PHILIP (US)
TRAUB (US) LEY (US) SAVOOR LEWTHWAITC
AUDY SMADEL (US) HARRISON

Figure 18. Laying of the boguy of scrub typus to rest.

particular reference to scrub typhus and with whom I was associated in research were Robert Traub, Bennet Elisberg, Garrison Rapmund, Alexander Hubert, Eliot McClure, James Gentry, Robert Upham, Francis Cardigan, Alexander Dohany, Illar Muul, David Huxsoll and Akira Shirai. Oaks *et al.* (1983) somewhat summarized the research activities of USAMRU-M.

It is equally important to recognize the significant contributions of the Hooper Foundation, which was established at the IMR in 1960. Dr J. R. Audy, who was formerly the Head of the Division of Virus Research and Medical Zoology, IMR until 1959, on retirement from the Malayan Government assumed the directorship of the Hooper Foundation, University of California Medical Center, San Francisco, California. On the realization that a vacuum had been created in the IMR with the exodus of the experienced British expatriate scientists following the attainment of independence, Dr Audy established the Hooper Foundation research programme sponsored by the U.S. National Institutes of Health through the University of California International Center for Medical Research, with the blessing of the Malaysian Government. The Hooper Foundation was established at the IMR in 1960 and ceased operations in 1980. During this period a total of approximately 125 UC ICMR scientists have worked in the IMR, and collectively they have contributed well over 1,000 research publications of public health importance to Malaysia, mainly in the fields of arborvirus, medical ecology, parasitology, blood genetics, and community health in collaboration with Malaysian scientists. Acarological studies were supplemented by the Hooper Foundation with logistic and technical support from Dr Audy himself. Among some of the prominent scientists of the Hooper Foundation with whom I was closely associated were Professors Lie Kian Joe, Fred Dunn, Donald Heyneman, Al Rudnick, Nyven Marchette and Paul Basch.

Scrub typhus gained military importance among both allied and Japanese forces during World War II. An estimated 30,000 individuals in the military were afflicted by the disease, with a fatality rate of 35% in American troops alone. Fatality rate in the Japanese army is unknown, but it is said that a truce was declared to evacuate afflicted soldiers from both sides out of the war zone for specialized treatment. All the known vectors of scrub typhus wherever they occurred have been species of the genus and subgenus *Leptotrombidium.* A more recent review of the natural history of *Leptotrombidium* is that of Nadchatram (1984) where it is stated that of the seven proven vectors of scrub typhus of the 258 species known at that time, at least three of them were proven vectors in Malaysia. It will be noted that Nadchatram & Dohany (1974: p. 3) treated *L. (L.) fletcheri* as a synonym of *Leptotrombidium akamushi* and gave sufficient evidence for the synonymy based on review of literature by prominent acarologists. In actual fact, Womersley & Heaslip (1943) created *fletcheri* as a new species, but in his monographic work on chiggers of the Asiatic-Pacific Region, Womersley (1952) synonymized *fletcheri* with *akamushi* noting that there was considerable variation in the number of dorsal setae, also noted by Nadchatram & Dohany (*loc. cit*.). However, Vercammen-Grandjean (1976) again elevated *fletcheri* from synonymy. According to him *akamushi* is confined only to Japan, Korea and eastern Manchuria).

The well documented Malaysian vector species, therefore, are: *L.* (*L.*) *fletcheri* (Womersley & Heaslip), *L. deliense* (Walch), *Leptotrombidium arenicola* Traub, and a species introduced by migratory thrushes, probably from Japan *Leptotrombidium.(L.) scutellare*) (IMR Ann. Rep. 1960). The latter species is well established on forest rodents in the highlands of Peninsular Malaysia. However, a few more species have been found to be sero-positive for the agent in Malaysia (Shirai *et al,* 1981). Two of the Malaysian species are *Leptotrombidium. (L). vivericola* Vercammen-Grandjean, 1976 and *Leptotrombidium. (L.) umbricola* Nadchatram & Dohany, 1980. Kawamura *et al.* (1995) have recorded additional species of *Leptotrombidium* and *Neoschoengastia* positive for *Rickettsia tustsugamushi* by the indirect immuno-flourescence (iFA) technique from Korea and Primorye. Species of the genus *Helenicula* possess attributes regarding habitats, major hosts, bionomics and behaviour that are suggestive of the known vectors of scrub typhus, and thereby merit investigation (Nadchatram & Traub, 1971). *Helenicula lanius* (Radford,1946) the type species of the genus is of seasonal occurance, and orange coloured. According to Harrison & Audy (1951) the infestation of rats trapped at Kanglatongbi, near Imphal, Myanmar, in 1945-46, where in September-October, during the hot wet season, 80% bore *L. fletcheri,* the well-known vector of scrub typhus and none bore *H. lanius*, while in January-February, when the weather was cool and dry, 10% bore *L. fletcheri* and over 80% bore *H. lanius*. This suggests that the seasonal records, i.e. wet and dry weather, for the distribution of the known vectors and potential vectors are important. Vercammen-Grandjean & Langston (1976) in their monograph "Chigger mites of the world, Volume III" reviewed the taxonomy of *Leptotrombidium* and created many new species. However, it is felt that a few new species of *Leptotrombidium* they established in Malaysia will prove to be synonymous with known species.

Migratory and resident birds are now known to carry trombiculid mites within the country and from one country to another. McClure's many years of bird banding investigations in Malaysia and other Southeast Asian countries has contributed immensely to our understanding of the role that birds play in distributing parasites in the region (McClure, 1974). The table given below lists the chigger mites found on birds from 1963 to 1971 in Southeast Asia.

Nine species of migratory birds were found to be infested by one of the common vectors of scrub typhus, *L. scutellare* in Japan, since its first discovery in Cameron Highlands, Malaysia by Nadchatram and McClure during a bird-banding project in November, 1960. In

Japan, unfed larvae of *L. scutellare* were collected by the plate method in Chiba Prefecture, and the larvae were placed on human skin. Of 336 chiggers in a glass ring cover, 64 (17.5 %) bit the skin. According to Kawamura *et al* (1995), the biting of *L. scutellare* on human skin was more precisely confirmed by exposing 35 volunteers to mites by having them sit on the ground in a chigger habitat on Hachijo Island for one hour. Twenty hours later the skin was examined for chiggers, and 100 were recovered from 21 persons. The chiggers were all *L. scutellare.* Nine species of birds infested with *L. deliense* were collected from birds in Southeast Asia by McClure's team. *Helenicula* species based on known records are suspected to be vectors. It would be highly exciting to learn more of the migratory bionomics of the birds. Some of the species are established vectors of scrub typhus, while a few others cause scrub itch in humans, e.g. *Odontocarus audyi, Eutrombicula wichmanni*, *Siseca rara* and *Blankaartia acuscutellaris*. *Neoschoengastia* and *Toritrombicula* species are more host associated with birds. At least five species of *Leptotrombidium* are confirmed or suspected vectors of scrub typhus in China.

Geographic distribution of chiggers of zoonotic or potential zoonotic importance on birds of Southeast Asia (McClure et al, 1971) (This excellent report covered the period 1963 to July, 1971. Since the date of publication is not given, it is assumed that it was published in 1971.)

(Scientific names were revised and common names added based on King et al, 1976)

Brachypteryx leucophrys (Lesser Shortwing babbler)		
Neochoengastia sp. (ch)	Thailand	
Neochoengastia solitus (ch)	Thailand	
Copsychus malabaricus (White-rumped sharma)		
Toritrombicula densipiliata (ch)	Thailand	
Siseca rara (ch.)	Thailand	
Leptotrombidium deliense (ch)	Thailand	Malaysia
Copsychus saularis (Magpie Robin)		
Leptotrombidium sp.	Thailand	
Erithacus calliope (Siberian Rubythroat Thrush)		
Leptotrombidium deliense	Thailand	
Leptotrombidium elisbergi	Thailand	
Leptotrombidium scutellare	Thailand	
Eutrombicula wichmanni	Thailand	
Neoschoengastia longipes	Thailand	
Helenicula simena	Thailand	
Erithacua cynae (Siberian Blue Robin)		
Odontocarus audyi	Thailand	Malaysia
Leptotrombidium deliense	Thailand	Malaysia
Leptotrombidium arvina	Thailand	
Leptotrombidium lanceolata		Malaysia
Toritrombicula densipiliata	Thailand	
Neoschoengastia sp.	Thailand	

Hodgsonius phaenicuroides (White-bellied Redstart Thrush)		
Leptotrombidium scutellare	Thailand	
Monticola solitarius (Blue Rock-Thrush)		
Leptotrombidium scutellare	Thailand	
Locustella certhiola **(**Palla's Grasshopper Warbler)		
Blankaartia acuscutellaris		
Cinclidium leucurum (= *Micomela leucura*) (White-tailed robin)		
Leptotrombidium scutellare	Thailand	
Leptotrombidium deliense	Thailand	
Neoschoengastia solitus	Thailand	
Neoschoengastia sp.	Thailand	
Myophonus coeruleus (Blue Whistling Thrush)		
Leptotrombidium deliense	Thailand	
Leptotrombidium sp.	Thailand	
Saxicola ferrea (Grey Bushcat)		
Leptotrombidium scutellare	Thailand	
Tarsiger cyanurus (Orange-Flanked Bush-Robin)		
Leptotrombidium scutellare	Thailand	
Turdus obscurus (Eye-brown Thrush)		
Leptotrombidium scutellare	Thailand	Malaysia
Leptotrombidium deliense		Malaysia
Leptotrombidium keukenschrijveri		Malaysia
Leptotrombidium fletcheri		Malaysia
Neoschoengastia longipes	Thailand	
Zoothera citrina (Orange-headed Thrush)		
Odontacarus audyi	Thailand	Malaysia
Leptotrombidium deliense	Thailand	Malaysia
Toritrombicula densipiliata	Thailand	
Toritrombicula vorca		Malaysia
Neoschoengastia solitus	Thailand	
Zoothera dauma (Scaly Thrush)		
Leptotrombidium scutellare	Thailand	
Helenicula simena	Thailand	
Zoothera sibirica (Siberian Thrush)		
Leptotrombidium deliense	Thailand	

Gallus gallus (Red Jungle Fowl)	
Helenicula scanloni	Thailand
Leptotrombidium deliense	Thailand
Leptotrombidium scutellare	Thailand
Blankaartia acuscutellaris	Thailand
Jynx torquilla **(**Wryneck)	
Ascoschoengastia indica	Thailand
Garrulax strepitans *(*White-necked Laughing thrush)	
Leptotrombidium rapmundi	Thailand
Leptotrombidium scutellare	Thailand
Helenicula scanloni	Thailand
Odontacarus audyi	Thailand

Biotope of the vector species and transmission of disease

Only the larval stage of the trombiculid mite (chigger) is parasitic, whereas the post-larval stages (nymph and adult) are free-living predators. In the infected mite, the infection is passed on transstadially (TS) from the fed larva to nymph to adult, and transovarially (TO) from a fertilized adult female to eggs; the infection is passed on to the newly hatched larvae (Fig. 19).

On finding a host it feeds to repletion. As the mite lives as a parasite only once in its lifetime, usually on a rodent, the infected larval trombiculid mite is able to transmit the infection to a human who is an accidental host, whereas with ticks there may be 3 opportunities – in larval, nymphal and adult stages, all of which are parasitic. The maintaining hosts of the *Leptotrombidium* vectors are mostly field and plantation rats of the genus *Rattus* (*R. argentiventer* in scrub, grassland, and ricefields, and *R. tiomanicus* in plantations). Also, Macaque monkeys and mouse-deer serve as hosts to *Leptotrombidium* species in forest fringe and secondary forest habitats. It is still a big question mark as to the origin of the rickettsial organism and how the infection is acquired. Is it by the larval mite from an infected rat, or is it acquired by the adult feeding on other arthropods, or their eggs or from substances in the soil? It is felt and laboratory evidence supports the proposal that the mite itself may act as a reservoir of the disease (Traub & Wisseman, 1974). The disease may be maintained in the adult and not actually acquired from the infected rodent. Laboratory studies have shown that the infection can be maintained within the colony for more than 20 generations based on IMR studies. The original belief was that the infection was acquired by the larval mite feeding on an infected rat. With the present understanding, it is believed that the rodents only serve as maintaining hosts of the vector mites. Intensive research had been in progress in Malaysia, mostly by the U.S. Army Medical Research Unit attached to the IMR, since 1947 on all aspects of the disease, both epidemiology of scrub typhus and the ecology of the chiggers, with the ultimate aim to produce an effective vaccine, which unfortunately has not been successful, despite 40 years of intensive field and laboratory studies, probably because of the presence of many strains of the infection.

Detailed studies on scrub typhus were made to elucidate ecological factors contributing to the human infection, the great variation in disease severity, and improved methods of clinical diagnosis. It is a matter for concern that with the rapid national development taking place in Southeast Asian countries, especially in land development and the resettlement of non-immune communities to areas newly cleared of forest, more and

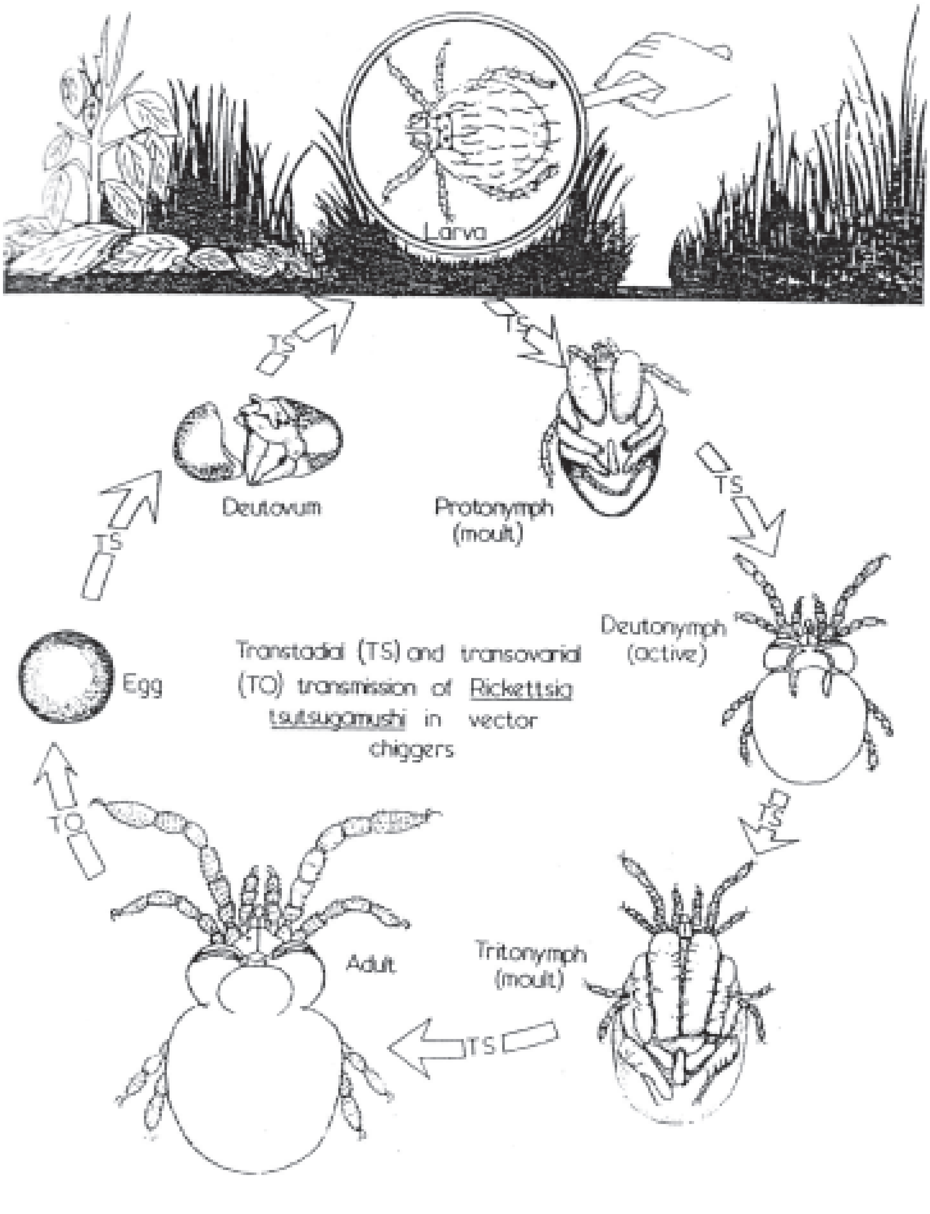


Figure 19. Life- cycle of chiggers (Trombiculidae)
(Courtesy A.L. Dohany and Nadchatram)

more susceptible individuals are being exposed to infection created by ecosystems encouraging rats and chigger mites with vector potential to thrive.

The life-history of chiggers is somewhat complicated (Fig. 20). Eggs are laid singly in suitable soil, debris or in nests of birds and small mammals depending on the habitat of the species. They go through a developmental stage called the deutovum or prelarva, after which the parasitic 6-legged larva emerges. Fig. 21 shows live unfed chiggers on a dead leaf. An unfed chigger on a mounted slide is shown as seen under a low-power objective of a compound microscope (Fig. 27).

The only exception to the life-cycle of the familyTrombiculidae is found in the species *Vatacarus ipoides*. In the life-cycle of this species, two stages are bypassed – the nymphophane and the active nymph. The fully

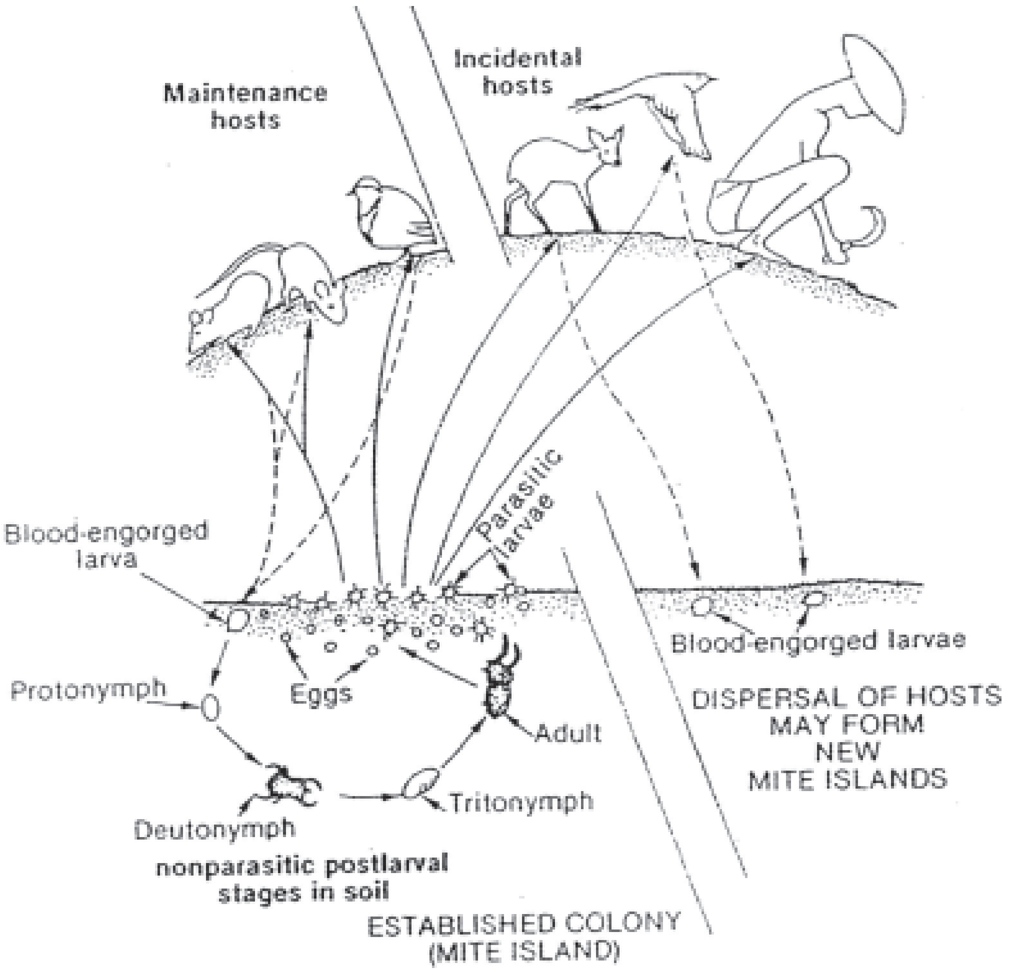


Figure 20. Life-cycle of *Leptotrombidium* species, the vectors of scrub typhus. (Modified from Audy, 1968)

engorged or neosomatic larvae gave rise to mature male and female adults (Nadchatram, 2006). The study was based on larvae recovered from the trachea of amphibious sea snake, *Laticauda colubrina* collected from Pulau Sudong, Singapore. A new locality for *L. colubrina* is Pulau Kalampunian Damit in Sabah (Borneo). The island is rocky, providing ideal resting and mating place for the snake. Damit, meaning a small island in Brunei, is visited by at least 600 snakes to mate, rest and digest their food (Nais & Ali, 1991). For anyone interested to study the natural habitat of the mite, this would prove to be a good location. Interested readers are referred to Audy, 1956b, and Nadchatram, 1970 for a complete account of the biology and life-cycle studies of chiggers in general, based on Malaysian studies.

The questing parasitic larva responds to carbon dioxide (Fig. 21). The larva of a vector species attaches and feeds on an animal, and feeds continuously for 2 to3 days. Fig. 22 shows chiggers attached to the pinna of ear.

The common sites of attachment are in the inner and outer ear lobe, outside of ears, axillae and corresponding fold of hind legs; heavy infestation results in the infestation in the perianal region of rats.

The chiggers feed on lysed epidermal tissue fluids by means of a sucking tube produced from its saliva, called a stylosome

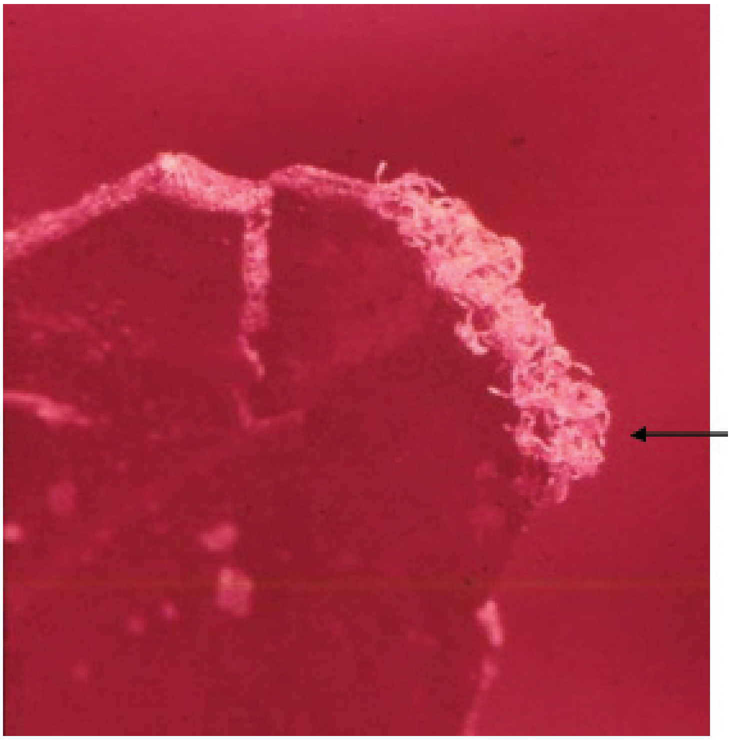


Figure 21. Questing
Leptotrombidium deliense seen on dead leaf on the ground
(Newly hatched, questing chiggers of *L. deliense* clustered in a colony on a dead rotten leaf on the forest floor. At least 25 chiggers seen in the colony, natural size of chigger 220 µm)

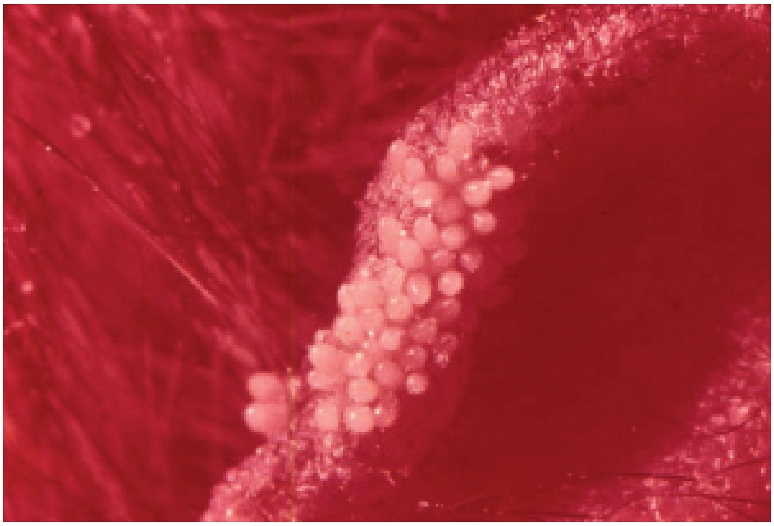


Figure 22. Larvae of trombiculid mites, chiggers (*L. deliense*)
feeding on pinna of rat ear

(Fig. 23). Stylostome formation by larval *L. akamushi* in Japan is assumed to be the cause of the "ira" sensation in humans after 10-20 hours of the bite (Kawamura *et al.,* 1995). The skin manifestation in humans caused by the bite applies to all *Leptotrombidium* species. After repletion the chiggers drop off the host (Fig. 24) and go through a moulting stage (protonymph- Fig. 25) and develops into an active 8-legged nymph (Fig. 26).

After a few days of another moulting stage (teliophane) the active adult emerges. Fertilization is indirect, in that the male deposits spermatophore (Fig. 28) in the soil which the female takes in through the genitalia. Nymph and adult have four pairs of legs and are of similar shape (Fig. 29). Shaped like a figure of 8 and hairy, hence described as velvet mites.

The parasitic larvae are 6-legged (Fig. 35), with fewer body setae.

The active nymph and adult are non-parasitic, live in the soil and are predacious on other arthropods or their eggs. The life-cycle of the vector species and the common scrub-itch chiggers are completed in approximately 60 days. Adults of *B. acuscutellaris* (Fig. 29), the larvae of which are scrub-itch chiggers, and adults of *L. deliense,* the larvae of which are vectors of scrub typhus (Fig. 30). Fertilization in the family Trombiculidae is achieved by an indirect way and not through copulation. From a few observations made in the laboratory the male adult deposits sperm sacs in the presence of a female. The spermatophore in a capsule is held on a stalk (Fig. 28) deposited by the male which is then taken up by the female through her genitalia for fertilization to happen. This unique method of insemination was described by Lipovsky *et al.* (1957). Trombiculid mites (chiggers) are parasitic only once in their lifetime, in the larval stage. Maintaining hosts are mostly rats. Birds, mouse-deer, and ground frequenting monkeys, *Macaca fascularis* and *Macaca nemestrina*, and other animals disperse the chiggers to other new locations to form new islands (Fig. 20). Man is an incidental host. There are many publications on prevention and control (Audy 1968), and other workers. A more recent summary was given by Nadchatram (1983).

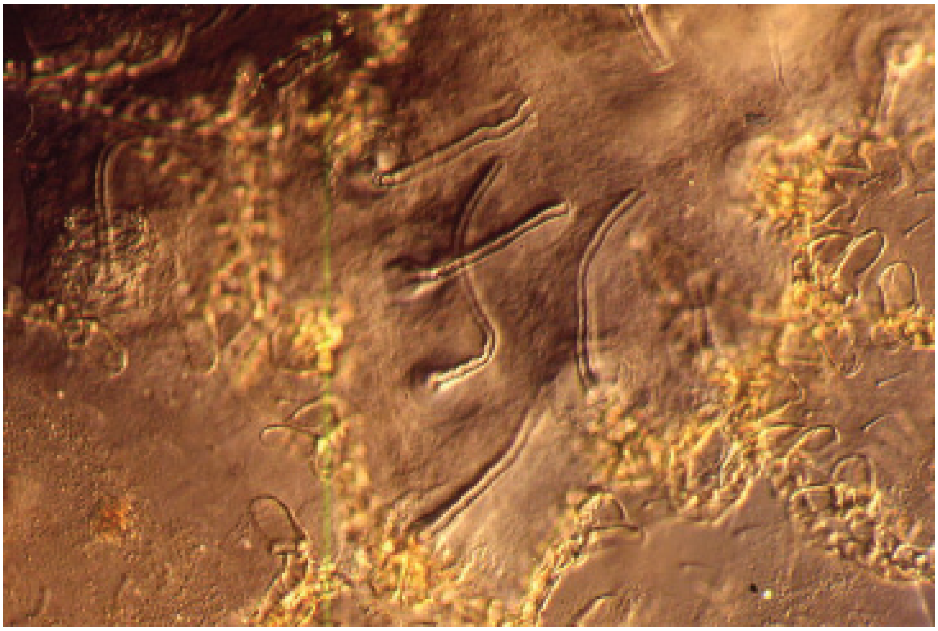


Figure 23. Squash preparation on mounted slide showing feeding tube or stylostome, (each tube belongs to a single chigger, 6 tubes are clearly seen)

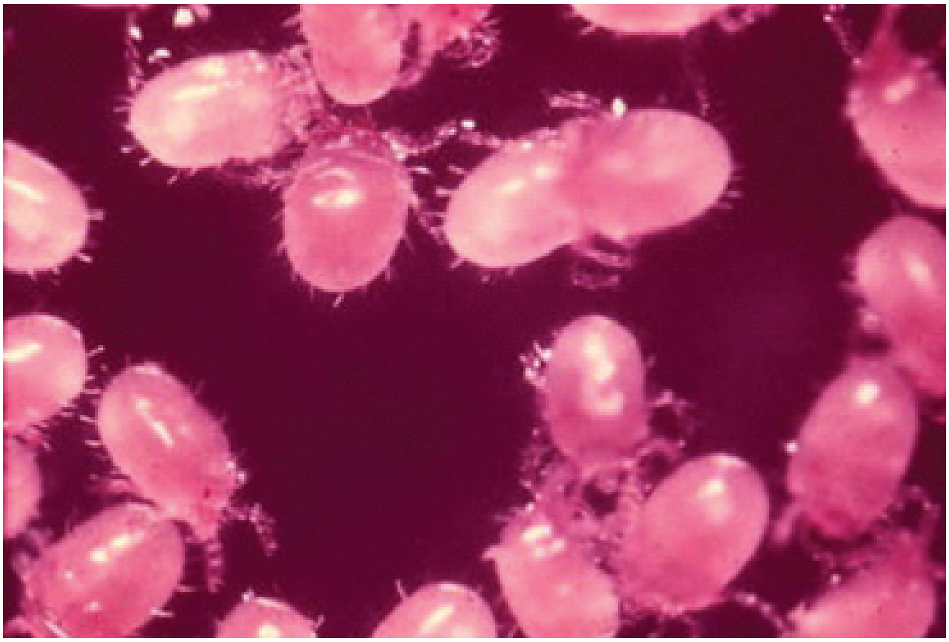


Figure 24. Fed chiggers, *L. deliense* dropped from rat

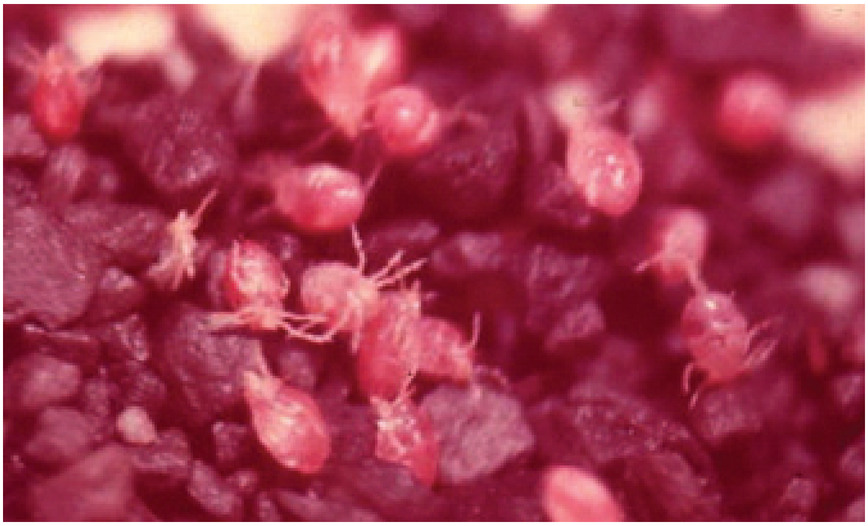


Figure 25. Nymphophanes of trombiculid mites, shedding of larval pelts seen

Figure 26. Unfed 8-legged nymph of trombiculid mite mounted on slide (3-4 mm)
Figure 27. An unfed larva of *Leptotrombidium* sp. mounted on slide (220 µm)

Figure 28. Spermatophore of *Blankaartia acuscutellaris* deposited by male on soil. (ca 40 µm)

Figure 29. *Blankaartia acuscutellaris* adults of scrub-itch chiggers (eggs laid in soil, 3-5 mm)

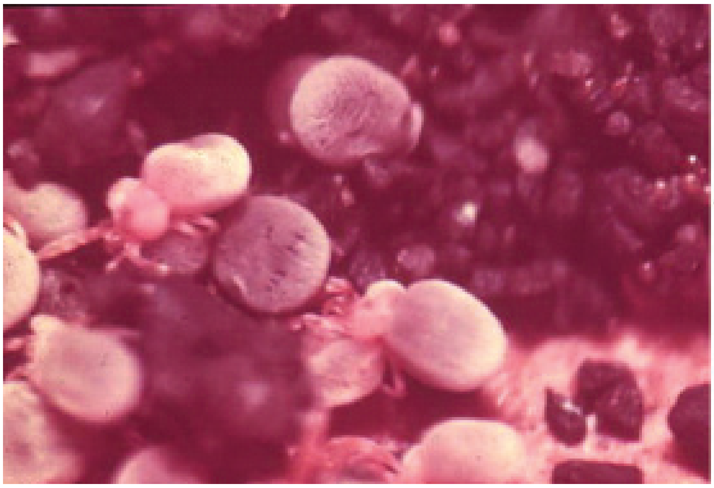


Figure 30. Adults of *Leptotrombidium deliense* and eggs (the larvae are vectors of scrub typhus (4-5 mm)

The size and shape of the spermatophore is believed to vary from species to species. In *L. deliense* the sperm sac is elongated.

The larvae of *B. acuscutellaris* with *E. wichmanni* are the common scrub-itch chiggers in Malaysia and are easily reared in the laboratory. The latter is common on reptiles, birds and occasionally on *R. tiomanicus*. Unfed larvae are very active. *B. acuscutellaris* are bright scarlet, and the brightest coloured mites in Malaysia.They feed on field rats and were found in ricefields and disused mining ponds covered in water hyacinth. They are mostly to be found on water birds.

Leptotrombidium deliense is an important vector of scrub typhus. The other better known species are *L. fletcheri* and *L. arenicola*. *Leptotrombidium deliense* (Fig. 35), as other species of *Leptotrombidium,* is very successfully reared under laboratory conditions. One colony was reared for over 30 generations. Like all larval trombiculid mites the newly hatched larvae crawl up the clay pot and form clusters on the underside of the glass cover. They will remain there for weeks. Unfed larvae are 220 x 150 and fed larvae grow to 560x400µm. The larvae are pale orange, and adults somewhat greyish as seen in fig. 30. Life-cycle takes about 8 weeks. Larval feeding time is 2-3 days.

Unfed questing larvae of the vector species of *Leptotrombidium (Leptotrombidium*) were found in colonies on the tips of dead dried leaves fallen on the floor of secondary forest as seen with *L. (L.) deliense* (Fig. 21). They are activated by carbon dioxide as can be seen by their out-stretched legs.

In the lallang grassland of scrub habitat the questing larvae of mostly *L. (L.) fletcheri* rest on dried, over-hanging blades of grass ca. 6 to 10 mm above the ground floor and attach usually by dropping on to a rodent or ground bird, e.g. a quail as the potential host comes along. In the vector species and the scrub-itch chiggers no blood is taken (Audy, 1951; Wharton & Fuller, 1952).

Studies of populations of both species of questing larvae were conducted along the transects in the grassland and forest habitat using black formica plates as the tool of measurement for a period of 67 weeks. The chiggers of both *L. fletcheri* and *L. deliense* were found to be abundant and easily collected during periods of rainfall and difficult or impossible to collect during dry periods (Gentry *et al*., 1977). On rodents several hundred mites in colonies were collected from a single *R.. argentiventer* in the ears, axillae and corresponding fold of hind legs; generally scattered with heavy infestation; often mixed with a few *L. deliense.* On a single quail in a scrub habitat more than 5,000 *L. fletcheri* were collected (Audy, 1956b). In the lallang habitat, the soil at base of the grass affords suitable sheltered cracks and crevices in the soil and spaces for fed *Leptotrombidium* larvae to drop off the rat to continue with the progression of the life-cycle until the emergence of the questing larvae of the next generation in the next 2 months or so.

The behaviour of field-dwelling chiggers is quite unlike that of pallid chiggers which are nest-dwelling in ground burrows of forest rodents. (See ecological grouping below). It is noteworthy that in 1948 during the anti-scrub typhus drug trials almost a hundred adult *L. fletcheri* were collected on a single day from the top layer of soil, nearby a stream, in the highly endemic scrub habitat of what was once the Seaport Estate in Subang, by the flotation technique. Buckets were filled with water and the top soil was scattered in the water, and the floating adults were picked up. K.L. Cockings, the biologist with the Scrub Typhus Research Unit, and two assistants (Nadchatram and Mr Aman) helped in the field work.

Ecological grouping of chiggers and epidemiological importance

Through intensive ecological investigations conducted in Malaysia and the discovery of questing larvae of pallid chiggers in ground holes (Kundin *et al.* 1966), it was possible to better understand the natural history of the pallid chiggers infesting forest rodents. The chigger mites have been classified into seven ecological groups on the basis of the ecology of the chiggers to determine their epidemiological importance. On the basis of host-parasite relationship, microhabitat of newly hatched larvae, their tolerance to changing environmental conditions based on breeding experiments in the laboratory, and the colour of the chigger mites, Nadchatram (1970) developed an ecological classification as summarized (Fig. 31).

Morphological and taxonomical characters were supplemented to the criteria of Nadchatram (1970), and the classification of the ecological groups was revised. The palpal tarsus formula (PTF), i.e. the number and type of setae on palpal tarsus, in particular, is related to the behaviour and biotope of the chiggers (Nadchatram, 2006). The palpal tarsus formula is explained in Nadchatram & Dohany, (1974) and Vercammen-Grandjean & Langston (1976). It will be observed that the number of palpal tarsal setae is directly related to the chiggers' microhabitat, so that ground surface dwelling chiggers bear 7 branched seate (7B) or 7 branched setae and a nude subterminala (7BS) whereas cryptozoic ones have fewer setae on palpal tarsus, 3, 4, 5 or 6

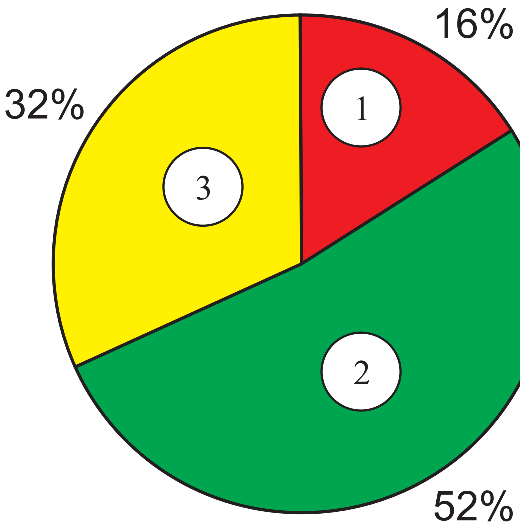


Figure 31. Ecological classification of the 158 species of chiggers from P. Malaysia. (1) orange to red chiggers found on ground surface and tolerant to changing environment conditions (16%); (2) pallid chiggers, nest-dwelling in rat burrows in the ground and very sensitive to fluctuating environmental conditions (52%); (3) yellow and pink chiggers, nest-dwelling and closely associated with their hosts (i.e. exhibit ecological specificity) somewhat sensitive to changing environmental conditions (32%).

branched setae, and mostly lack the nude subterminala. The criteria of the seven ecological groups are as follows: **Ecological Group I:** Orange to red chiggers, living on ground surface, relatively highly adaptable to fluctuating environmental conditions, parasitic on ground-dwelling small mammals, birds and reptiles. Having palpal tarsus with 7B or 7BS PTF formula (shown red in fig. 31). *Leptotrombidium* species that are vectors or potential vectors of scrub typhus have 7B, a somewhat rectangular scuta, filiform sensillae that have short barbs on their distal half. **Ecological group II:** White to yellow chiggers, nidicolous in forest ground burrows of ground dwelling rodents of variable forest species, sensitive to fluctuating environmental conditions, naturally feeding on rodents and shrews. PTF 3B or 4B, mostly with expanded, club-shaped sensillae: (shown green in fig. 31). **Ecological Group III:** White, pink, orange or red chiggers, arboreal habitat, nidicolous on tress and presumably in tree holes, parasitize arboreal rats, squirrels and flying lizards, less adaptable to fluctuating environmental conditions. PTF 4B, 4BS or 5B, either with filamentous or expanded sensillae. **Ecological Group IV:** Strictly bird-infesting; orange chiggers burrow or ground surface habitat, burrows usually in banks of streams and forest paths, less adaptable to fluctuating environmental conditions. 5B or 6B, with filamentous or expanded sensillae. **Ecological Group V:** Strictly bat-infesting, yellow to orange chiggers, live in crevices of bat cave roofs, walls and tree holes is the resting habitat of hosts, sensitive to fluctuating environmental conditions. PTF 5 B or 6B, with mostly filamentous or expanded sensillae. **Ecological Group VI:** Hypodermal in frogs or endoparasitic in amphibious sea-snakes, orange chiggers, nidicolous habitat. Chiggers from sea-snakes able to complete life-cycle in laboratory conditions. PTF 7B or 7BS. **Ecological Group VII:** Infesting scorpions or pill-millipedes, pallid chiggers, in ground holes or under dead logs, concurrent microhabitat-specificity of host and parasite, less tolerant to changing environmental conditions. PTF usually 7B. The genera of chiggers of the seven ecological groups are tabulated. The major attributes of this classification are an ecological framework within which the Malaysian chiggers may be classified, and that their epidemiological importance as vectors may be evaluated by their distribution in nature. Group III to VII combined is shown yellow in Figure 31. The 158 species of Malaysian chiggers in 35 genera were classified into seven groups and the genera of the chiggers are tabulated in Fig. 32.

On the basis of (a) their breadth of host range; (b) ability to tolerate changing environmental conditions; (c) the ground surface biotope of larval mites prior to attachment to a host; (d) taxonomic characteristics of the species, and (e) the fact that they were coloured orange to red, only 26 species or 16 % were placed in Ecological Group I of the 7 groups proposed. This group, the epidemiologically important one, includes the known vectors, potential vectors, and a few other species which are established agents of scrub-itch. In a serological study by Shirai *et al.* (1981), it was demonstrated that 7 other *Leptotrombidium* species (including 3 non-*Leptotrombidium* species) belonging to the same ecological group as the proven vectors were also positive for *O.* (=*Rickettsia) tsutsugamushi*, the pathogenic agent of scrub typhus. This strongly suggests that there are other species that are likely to be vectors in nature, but are undocumented in biomedical literature. Because of the medical importance the family Trombiculidae is among the most studied with some 3,000 species described worldwide.

Investigations on scrub typhus during WW II in the Asia-Pacific region have shown that the tropics are very rich in species of trombiculid mites, the larvae (chiggers) of which are among the most numerous of all external parasites of birds, reptiles and mammals. While the vectors of scrub typhus are confined to the Asia-Pacific region, scrub-itch mites are represented in every continent. All chiggers that are known to bite humans produce mild to severe itching. The vectors of scrub typhus produce some form of irritation following attachment due, perhaps, to the formation of the stylostome. Although it is often difficult to distinguish scrub typhus clinically from other causes of febrile illness, there are several features which, if present, are characteristic. The primary lesion or eschar develops at the site of the bite of the infected chigger. When seen on a fair skin it may be easy to recognize, with its black scab. On dark skins it may not be noticeable. It may easily be overlooked during a cursory examination, often located near the groin, axilla, or buttocks (Brown, 1976).

SCRUB-ITCH OR TROMBIDIOSIS

But the bite of scrub-itch mites causes a reaction to the salivary secretion of the mite in humans. The reaction is partly allergic. In a few cases only the chelicerae penetrate the skin. Following the penetration of the chelicerae a straw-like feeding tube or stylostome is slowly formed through which the chigger sucks digested host tissue and lymph (Fig. 23). This alone cannot be the cause of the specific reaction, for the vectors of scrub typhus also produce such sucking-tubes while causing a non-specific reaction. All *Schoengatia* and *Acomatacarus* species have the chelicerae armed with rows of ventral or dorsal teeth that are probably responsible for the pricking, sensitive sensation. Following the lodging of the serrated chelicerae on the skin, a reaction would happen causing irritation. It is a delayed reaction which produces the irritating bumps on the skin, in the centre of which the living larval mite may be seen as a tiny scarlet speck partly embedded in the swelling tissue. From our Malaysian experience, only those reptile and bird infesting chiggers have been known to bite man. This wide host-range gives the scrub-itch chiggers a powerful advantage in survival (Audy, 1968).

The important scrub-itch or dermatitis-producing species are of the genera *Schoengastia, Eutrombicula, Neotrombicula,*

	ECOLOGICAL GROUPS						
GENERA OF CHIGGERS	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Odontacarus	1	–	–	–	–	–	–
Whartonia	–	–	–	–	4	–	–
Trombicula	–	–	–	–	6	–	–
Microtrombicula	–	–	2	–	2	–	–
Sasatrombicula	–	–	–	–	1	–	–
Eltonella	–	–	1	–	–	–	1
Vercammenia	–	–	–	–	–	1	–
Eutrombicula	2	–	–	–	–	–	–
Siseca	1	–	1	–	–	–	1
Fonsecia	2	–	–	–	–	–	–
Babiangia	2	–	–	–	–	–	–
Vatacarus	–	–	–	–	–	1	–
Blankaartia	1	–	–	–	–	–	–
Heaslipia	1	–	–	–	–	–	–
Leptotrombidium (Leptotrombidium)	6	15	–	–	–	–	–
Leptotrombidium (Trombiculindus)	–	9	–	2	–	–	–
Toritrombicula	2	–	–	–	–	–	–
Myotromicula	–	–	–	–	2	–	–
Chiroptella	–	–	–	–	3	–	–
Trombigastia	–	–	–	–	3		–
Reidlinia	–	–	–	–	1	–	–
Rudnicula	–	–	–	–	1	–	–
Schoengastia	2	1	–	–	–	–	–
Neoschoengastia	1	–	1	5	–	–	–
Walchiella	1	5	1	–	–	–	–
Herpetacarus	–	2	–	–	–	–	–
Ascoschoengastia	1	5	10	–	–	–	–
Kayella	–	1	–	–	–	–	–
Helenicula	1	–	–	–	–	–	–
Cheladonta (Susa)	–	2	–	–	–	–	–
Doloisia	–	10	–	–	–	–	–
Schoutedenichia	–	3	–	–	–	–	–
Gahrliepia (Gahrliepia)	–	12	–	–	–	–	–
Gahrliepia (Schoengastiella)	–	3	–	–	1	–	–
Gahrliepia (Walchia)	1	14	–	–	–	–	–
TOTAL	25	82	16	7	24	2	2

Figure 32. Distribution of Malaysian genera of chiggers by Ecological Groups I – VII

Acomatacarus and *Odontocarus*. In the Americas and Europe a few of the notorious scrub-itch species are *Eutrombicula alfreddugesi* (Oudemans)*, Eutrombicula batatas (*Linnaeus), *Eutrombicula splendens* (Ewing), *Neotrombicula autumnalis (*Shaw). In the Asia-Pacific region, species of *Acomatacarus, Eutrombicula, Blankaartia*, and *Schoengastia* are responsible for scrub-itch. *Acomatacarus australiensis* (Hirst) occurs in Australia along with *Eutrombicula samboni* (Womersley), *Eutrombicula hirsti* (Sambon), and *Eutrombicula sarcina* (Womersley). Scrub-itch chiggers are parasites of birds, reptiles and mammals and belong in Ecological Group I. They have a palpal tarsus formula 7BS, including the *Schoengastia* species. Of the 25 species plus 4 more species added to the list of *Schoengastia* of Nadchatram *et al.* (1980) at least 6 species have been recorded as biting humans in New Guinea, North and South Sumatera, Philippines and Japan (Nadchatram *et al,* 1980; Goff, 1981). Six species of *Schoengastia - vandersandei* (Oudemans), *taylori* (Gunther), *whartoni* Womersley, *diannae* Goff, *loomisi* Goff and *nadchatrami* Goff have long, sword-like, serrated chelicerae, relative to the size of chigger. The chelicerae are 50 to 70 µm long; the average length in other species is approximately 30 µm. Wherever these scrub-itch chiggers occur they have been known to come in contact with humans when exposed to them. The habitats of the *Schoengastia* species are scrub and open grassland. I had the experience of being attacked in the thighs, axillae and scrotum by many individuals of *Schoengastia schuffneri* in the Brown River area, near Port Moresby, Papua New Guinea. It was also collected by exposing black plates on the ground in the scrub habitat. Soldiers during the war were often attacked, and the orange mites were observed on their boots.

Scrub-itch chiggers and potentials in Malaysia

In peninsular Malaysia scrub-itch is known to be caused by at least 3 species, but more species are suspected. The known scrub-itch chiggers are *E. wichmanni* (Oudemans), *B. (B.) acuscutellaris* (Walch) and *Schoengastia psorakari* Nadchatram & Gentry. Recently, *B. acuscutellaris* was recorded biting humans in Hungary (Ripka *et al*., 2006). A few mites were found on the scalp and scrotum of a young boy who suffered erythema and itchiness. *Heaslipia gateri* (Womersley & Heaslip), PTF with 7BS was discovered by Vercammen-Grandjean in Africa. Two species were found, and one of them was indistinguishable from *H. gateri* (Audy, 1956b), and in a comprehensive review of the genus *Heaslipia* by Vercammen-Grandjean & Audy (1957), *H. gateri* is revised with descriptions of the nymph, and description of a new species, *Heaslipia weberi* from the host *Capella media* from Lake Kivu, 100 km from Bukavu, Belgian Congo, (now the Democratic Republic of Congo), Africa. In Peninsular Malaysia, *H. gateri* is widely distributed on birds and field rats, *R. argentiventer* frequenting padi-fields and other swampy areas in Sungei Petani (sungei = river), in the state of Kedah, Taiping in Perak, and from a bittern, *Oxobrychus eurythmus,* in a swamp along Sungei Buloh in Selangor. This further suggests the importance of migratory birds in the dispersal of important parasites from one continent to another. Another species, *Blankaartia (Megaciella*) *dohanyi* Nadchatram & Goff 1980 was described from the plumed egret, *Egretta intermedia* from Irian Barat, New Guinea. The host is distributed in Africa and the Asia-Pacific region. Because it shares a similar habitat to *B. acuscutellaris* and has wide geographic distribution, the species is strongly suspected as having the ability to come in contact with humans.

There have been numerous reports of human attacks by these mites, known as "tungau" among the rural Malay folks. *Eutrombicula wichmanni* is recorded from birds, reptiles and mammals and *B. acuscutellaris* from birds frequenting swamps, other wet land, and field rats. The natural hosts of *Schoengastia psoakari* is not known, but birds and reptiles are strongly suspected. The local residents living in Sungei Dungun area often suffered from severe skin reaction usually below the waist, especially in the groin, legs and in the axillary region after visiting or camping on the sandy bank of the fresh water river, usually at night. The area surveyed was the right bank of Sungei Dungun at Padang Pulut, approximately 16 km upstream from the township of Dungun, east Malaysia. The questing larvae were collected on black formica plates exposed on the sandy beach. A total of 119 chiggers were collected in 30 minutes. No mites were collected during periods of sunshine, but they appeared immediately once it became cloudy. This is the first and only record. It is suspected that they will be found in other places of similar habitat. Other species that are suspected to come in contact with humans and cause scrub-itch are *Eutrombicula fieldi* Audy, *H. gateri* (Womersley & Heaslip), *O. audyi* (Radford), *S. rara* (Walch), *Babangia booliati* Audy, *Walchiella oudemansi* (Walch) and *Helenicula mutabilis* (Gater), the latter is only species of the genus found in Peninsular Malaysia. All these species have either a broad host range or are tolerant to fluctuating environmental conditions.

ASTIGMATID MITES OF ZOONOTIC IMPORTANCE

Scabies and *Sarcoptes scabiei* (Degeer)

There are many species of mites in many suborders of acarines that are of veterinary importance worldwide. In this section only Astigmatid mites that are known to come in contact with humans are discussed.

Human scabies is also called the 7-year itch. Scabies caused by infestation with the itch mite, *Sarcoptes scabiei* (Fig. 33) is a widespread disease of humans and other animals. The species is of the family Sarcoptidae of the suborder Astigmata.

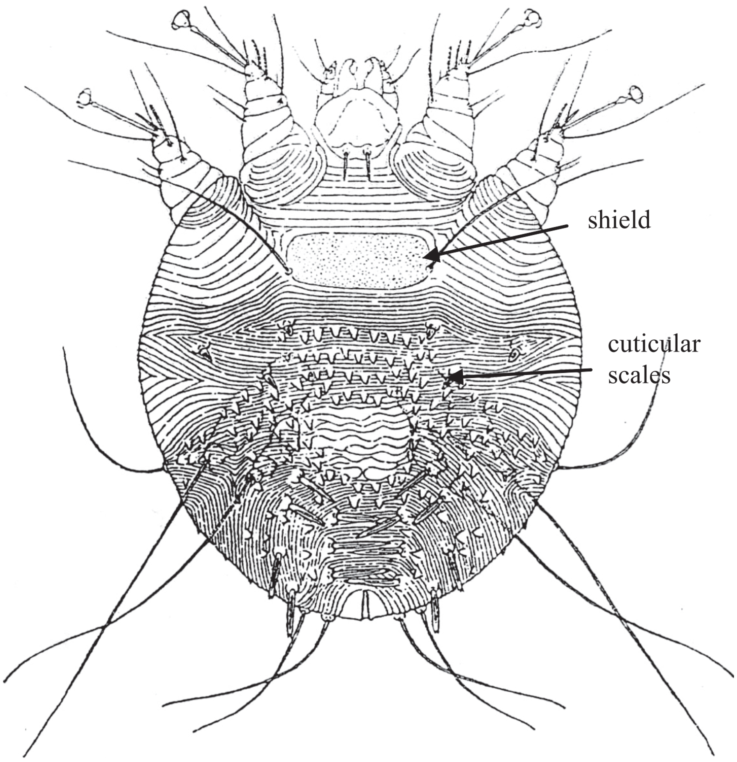


Figure 33. *Sarcoptes scabiei*, scabies mite

It is now known that scabies can sometimes be a zoonosis. Human infestations with *Sarcoptes* of animal origin are common (Fain, 1978, 1983). The mite is found in a variety of animals in most countries. In Malaysia it has been found deep in the ears of a domestic pig and goats (M.N.). From the ears of a single live pig over a thousand mites were collected; and all stages of the cycle were recovered. An undetermined number of *S. scabiei* mites were found in two live domestic goats. The species has been recorded from dogs and cats in Ipoh and Kuala Lumpur, Malaysia (Normaznah, 1995). Scabies in humans has a long and interesting history throughout the world, following the discovery of the scabies mite by Degeer in 1778. It caused great havoc to humans during two world wars. However, it was found to be a zoonosis only in later years. Itch mite infestation in groups of closely related persons, especially primary school children is well documented in Malaysia. In 1970 and 1979 104,233 and 97,828 cases, respectively, were recorded by the Government Medical and Health Services, Malaysia (Normaznah, 1995). Cases occur most commonly where standards of hygiene are low, as in poorly developed regions. It is often associated with those practicing poor sanitary habits. Scabies is a problem in Malaysia for the above reason, and also, among workers from countries seeking greener pastures in Malaysia. There are over one million foreign workers, nearly half of whom come here as domestic maids who may, if infested, pass on the infestation to children of their employers, because of the highly contagious nature of the infestation. They come from countries of low economic levels where proper hygiene is often not practiced. Scabies is spread through close bodily contact. Sleeping in the same bed is one of the common ways for the transfer of the mites.

Though *S. scabiei* has so far been found in the ears of goats, pigs, dogs, and cats, there is no record of direct animal to man transmission reported in Malaysia. Yet cross infestation is highly suspected. Normaznah *et al*. (1996) found that the *orang asli* or aborigines of Peninsular Malaysia are known to have close association with dogs. An ELISA study was done to detect anti-*Sarcoptes scabiei* var. c*anis* in the aborigine community, as a measure of exposure to the mite. Of 312 orang asli tested 24.7 % were positive for polyvalent anti-*sarcoptes* antibodies. Human infestation with *Sarcoptes* of animal origin is common in many other countries, (Hoogstraal, 1976; Fain, 1978; Arlian 1989); Burroughs & Elston, 2003). Burroughs & Elston, (*loc. cit*.) showed that a study of US Air Force bases revealed *S. scabiei* var *canis* being among the five most common zoonotic threats to humans. These infestations are generally considered as self-limiting, but in some cases the lesions may continue for several weeks, and even persist until treatment is begun. The non-human strain of *Sarcoptes* which infest man is most frequently from the dog, but strains from many other species of animals have been reported. The mites from dogs may cause severe pruritis and prolonged papular eruption, whereas those from cats do not establish themselves successfully in humans.

In humans, the mite burrows into the horny layers of the skin going no deeper. Severe pruritis occurs before papular eruptions form. The fertilized female causes most of the trouble, tunneling beneath the surface, laying eggs as she progresses. The burrowing is largely responsible for the itching, which is often complicated by scratching, secondary infection, or irritation due to reaction to treatments. It has been shown that itching begins about 4 weeks after a primary infestation, and during this early period symptoms are mild or absent, which would explain how scabies epidemics occur. The mites are also found on hair follicles and skin surface, but reaction is mild. The stages in the life-cycle are egg, larva, nymph, male adult, and immature and mature female adult. The transformation from immature to mature female is believed to take place after fertilization. The fertilized females begin laying eggs within a few hours. The cycle from egg to egg-laying female takes from 10 to 14 days. Less than 10% of eggs mature into adults (Baker *et al.,* 1956; Mellanby, 1972). It is now known that with those afflicted with AIDS, the immune system may not develop antibodies to the mites and may develop Norwegian scabies.

The Division of Rural Health, I.M.R conducted a scabies study in Jengka, Pahang in 1977, because of an epidemic which occurred where the entire population of Jengka, which was a new Government sponsored human settlement, was affected. The Division of Acarology (Nadchatram) also participated in the control programme. Not always easy to detect, the incriminating mites were found on three of the afflicted individuals. The mites were found in tiny burrows under the skin. The entire populations of some 150 individuals were bathed in water containing 1% Gammexene. The treatment was successful, and the residents were relieved of itching following the entire programme in which every household member participated. A few dead *S. scabei* were found in two of the patients, following the treatment.

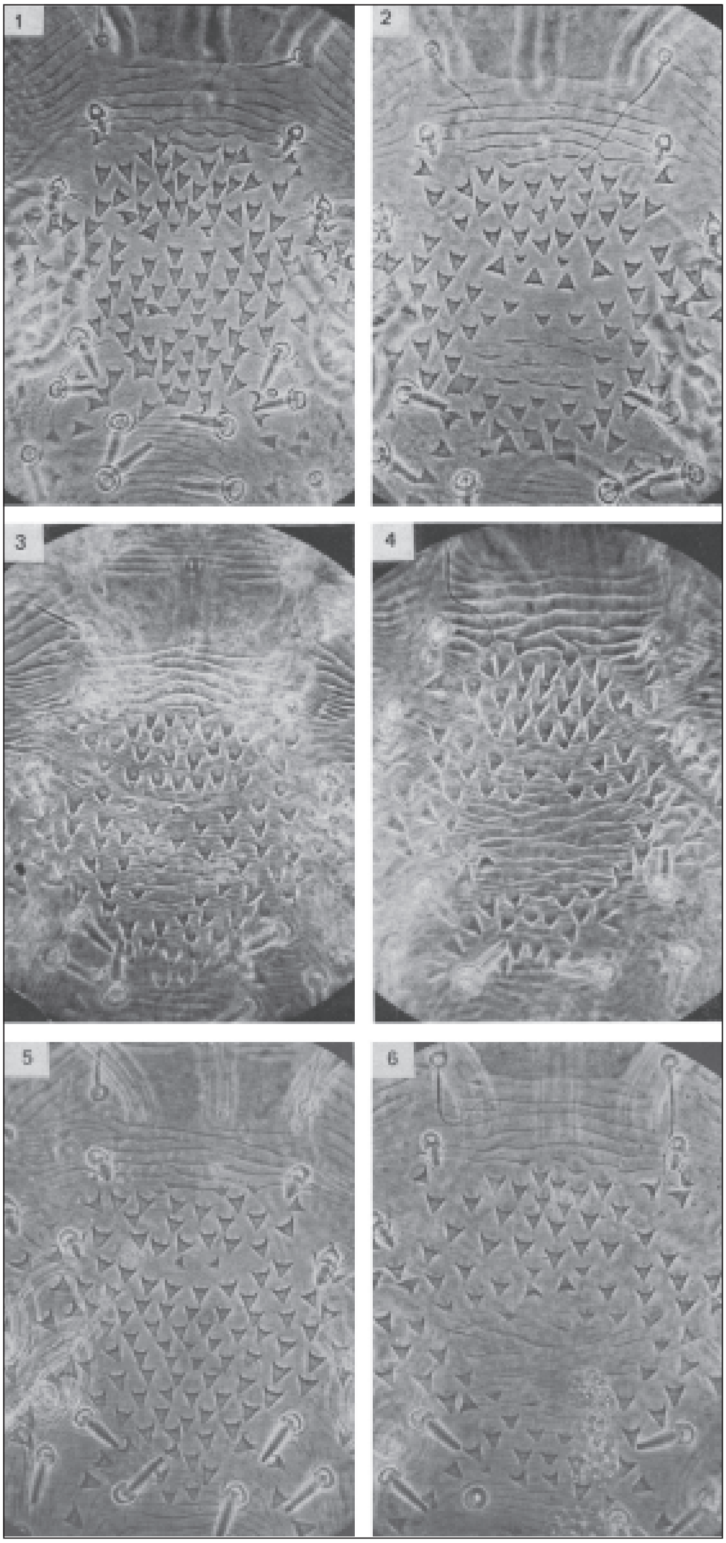
Are human and animal scabies mites separate species?

This short discussion is not so much about scabies, but more to provide a reason to consider that the scabies mites infesting humans and animals are species separate from each other. After considerable work done by many workers elsewhere Fain (1978) considered that the genus *Sarcoptes* consists of only one valid, but variable species.

At present it is thought that mammalian hosts have their own race of *S. scabies*. Humans can be infested with races from domestic animals. However, a study done in Australia showed that dog-derived and human-derived *S. scabiei* are genetically distinct, suggesting that human-derived and dog-derived *S. scabiei* are different species (Walton *et al*., 1999). In the light of this new information, a review of the status of the taxonomy of *S. scabiei* is felt appropriate. The excellent study of the eminent scientist, Fain (loc. cit.) noted that 30 species and 15 varieties had been described in the genus *Sarcoptes* and suggested that it was based on variable morphologic characteristics without taxonomic value. To come to that conclusion, Fain had examined series of scabies mites of almost all those described "species" and had documented the morphological differences as seen in (Fig. 34). However, the fact that scabies is now recognized as a zoonotic disease, the need has arisen to carefully re-examine the mite from different hosts to determine if the systematic differences in the number and size of the cuticular scales and their arrangement on the dorsal and lateral regions, the shape and size of the dorsal shield or scutum, the length of dorsal setae, and the absence or presence of the bare area without dorsal scales, and other features of a taxonomic nature are constant for the mite from different species of hosts, to recognize if animal scabies mites are separate species from those infesting humans.

For example, in the family Trombiculidae the number and arrangement of idiosomal setae are among the characters that are regarded as of value to separate species. The taxonomic classification of the family Trombiculidae of the suborder Prostigmata is based on the larval stage of the mite or chigger and is accepted (Vercammen-Grandjean, 1969). The dorsal scutum, its shape and size, the structure of the chelicerae, the setation of the palps in texture and number, the number of sensory setae of legs and, number and type of dorsal and ventral setae of the idiosome and their pattern of arrangement, are regarded as important taxonomic characters. The arrangement of dorsal setae on *L. deliense* is 2.8.6.6.4.2 as seen in Fig. 35. Approximately 3,000 species in many genera have been described based on these characters.

It is, therefore, not impossible that for *S. scabiei* the differences in the shape and size of the dorsal shield or scutum, number and type of dorsal scales, number of idiosomal setae and the presence or absence of dorsal spurs in the mid region of the dorsum of idiosome as shown in Figure 34, would prove to be of taxonomic value to treat scabies mites



(Reproduced from Fain 1978, with kind courtesy of the author)

Figure 34. Cuticular setae on dorsum of *S. scabiei*

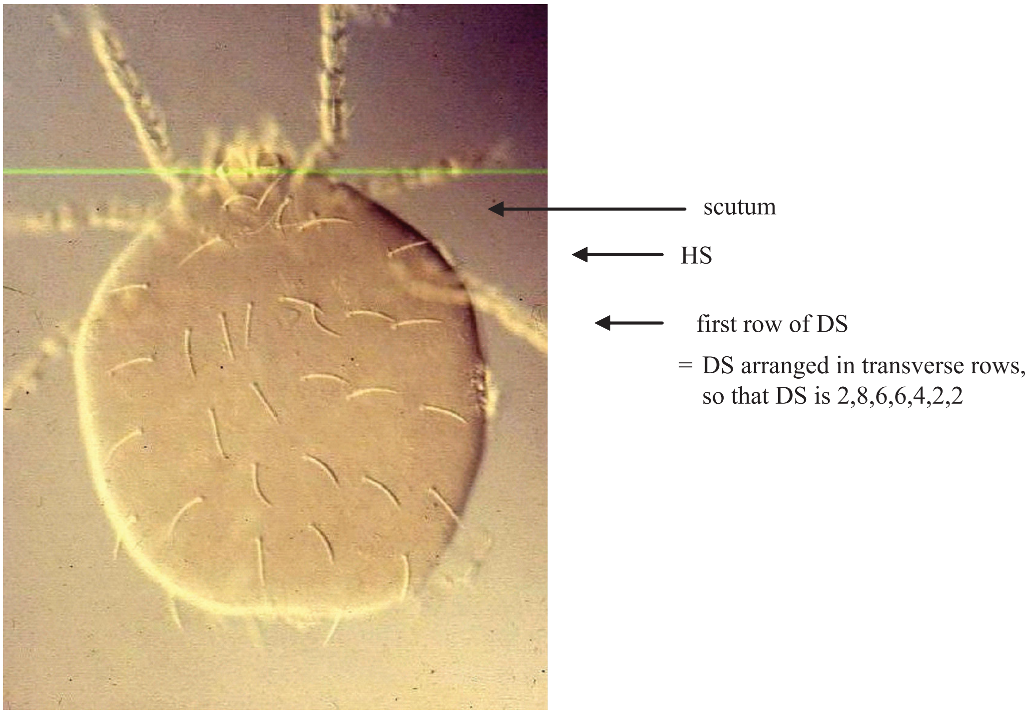


Figure 35. *Leptotrombium deliense* shows DS arrangement

of humans and other animals as valid separate species. Also other species of astigmatid mites of veterinary importance are classified for the separation of genera and species based on patterns of idiosomal striations and the setae.

Mange mites of the genus *Knemidocoptes*

In the genus *Knemidocoptes* of the family Knemidocoptidae, a family of the suborder Astigmata, the two species *Knemidocoptes mutans* and *Knemidocoptes pilae* are separated by the pattern of dorsal striae (Fig. 36). However, the genus *Neocnemidocoptes* is separated by the fact that the dorsal striae are unbroken and the mid-portion is not scale-like (Fig. 37).

This sarcoptid mite, *K. mutans* (Robin and Lanquetin, 1859) causes scaly legs in chickens and variety of other birds, including caged birds. This group of mites is not very well known, and it is suspected that other species may be found if careful taxonomic examination is undertaken. Scaly legs is very contagious. The mites become embedded beneath the scales of the birds' feet and legs. It has been suggested by Baker *et al* (1956) that *mutans* is probably confined to the feet and legs, but other species may infest other parts of the bird. With *K. mutans* 2 other species are known. *K. pilae* and *Neocnemidocoptes laevis gallinae.* A member of the Zoology Department of the University of Singapore and his wife suffered from severe allergic dermatitis due to an infested caged bird they kept in the house.

Another mite close to *K. mutans* is *N. laevis gallinae* (Railliet, 1887). This mite is also a parasite of birds, but they attack the skin of chickens at the base of the feathers, on the back, top of the wing, around the vent and on the breast and thighs. It has also been found on pigions, pheasants and geese. The life-cycle of both these species is similar to *S. scabiei.*

Mange caused by *Notoedres cati* (Hering)

These are mite parasites of birds, dogs, cats, rabbits and guinea pigs (Baker *et al*. 1956). Current knowledge pertaining to their biology

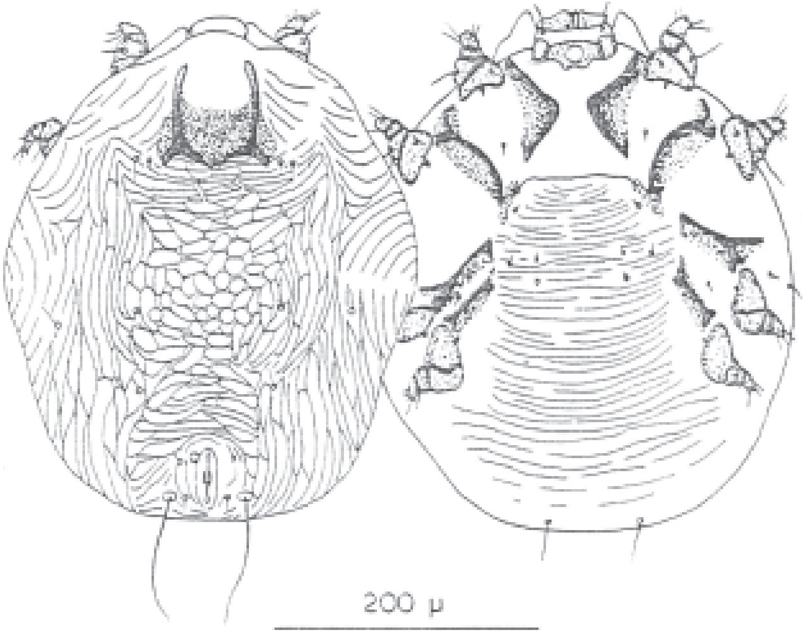


Figure 36. *Knemidocoptes mutans* ♀, the scaly leg mite of domestic and wild birds (courtesy Spence, 1983)

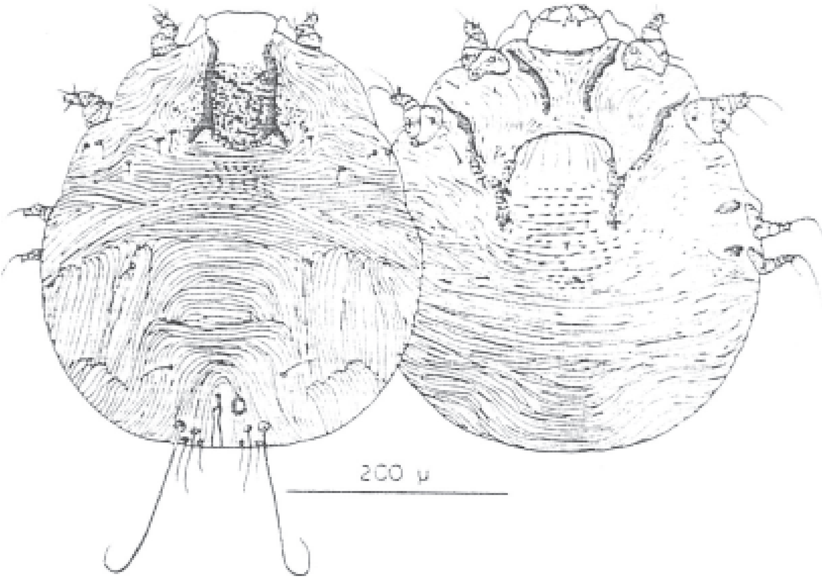
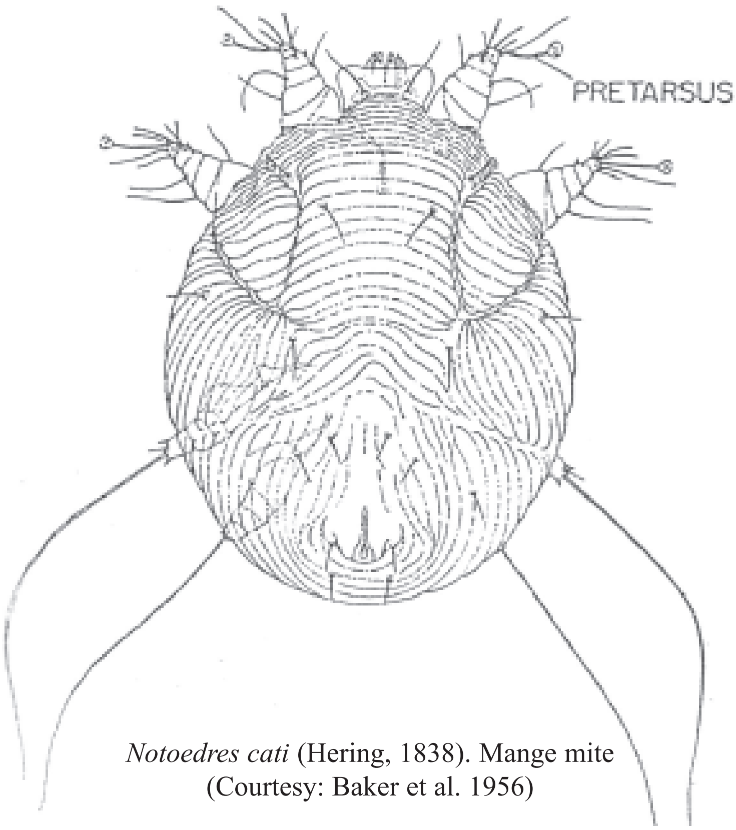


Figure 37. *Neocnemidocoptes laevis,* depluming itch mites of poultry (courtesy Spence, 1983)



Notoedres cati (Hering, 1838). Mange mite
(Courtesy: Baker et al. 1956)

Figure 38. *Notoedres cati* (Hering)

and taxonomy would be essential so that control measures can be sought. For this reason it is believed that information of the mite is appropriate.

The mite of veterinary importance that humans encounter and are afflicted with is the mange mite, *Notoedres cati* (Hering), a highly contagious mite which can infest cats, humans, rabbits and dogs. (Fig. 38).

Almost all the human cases, 5 to 7, reported to IMR involved this mite. There have been several reports received from pet owners because of dermatitis caused to the owners and their pets (Babjee, 1968). The life cycle of the mite is similar to that of *S. scabiei*. *Notoedres* is of the family Sarcoptidae. A number of other mites are reported to cause ectoparasitic mange in humans elsewhere, but have not yet been recorded in Malaysia.

Klompen et al. (1983) did a review of the genus *Notoedres* from East Asian hosts. Of a total of 11 species, eight of them were collected, described and redescribed from Peninsular Malaysia from bats and rodents, four of the eight were new species. A key to the male and female species is given to the 15 species of *Notoedres* known, including *Notoedres cati* and *Notoedres rajamanickami* Lavoipierre, 1968 among others. The new species described are *Notoedres pahangi* ex *Rattus tiomanicus jalorensis, Notoedres dohanyi* ex *Tadarida mops*, *Notoedres ismaili* (named for Salleh Ismail) ex *T. plicata*, and *Notoedres dewitti* ex *T. plicata*. The latter 3 hosts are free-tailed bats. This is a straight forward taxonomic paper and does not discuss medical importance. Many species of astigmatid mites are of verterninary importance (Nutting, 1983).

MITES OF THE SUBORDER MESOSTIGMATA

Macronyssid mites biting humans

There have been several unauthenticated reports of acarines other than trombiculids, ticks and astigmatid mites biting humans. However in Malaysia, there are three recorded cases of mites of the family Macronyssidae biting man and causing itchiness and swelling.

Ornithonyssus bacoti (Hirst)

In 1974 it was reported that mites were found biting Professor S. Ramalingam in the neck and chest region and causing painful irritation which persisted for about 8 days. The causative agents were apparently mites dropping from the ceiling of his office directly above his table at the University Of Malaysia Department Of Parasitology. Several mites were collected and identified as the cosmopolitan species *Ornithonyssus bacoti* (Hirst) (Fig. 40), (Nadchatram & Ramalingam, 1974). The house rat, *R. r. diardii* that was nesting in the ceiling space was the natural host. After control measures were taken there were no further reports of the occurrence of the mite. *O.bacoti* was found on many other species of rodents in Malaysia. The life-cycle of *O. bacoti* consists of egg, non-feeding larva, feeding protonymph, non-feeding deutonymph, and active feeding adult. The life-cycle from egg to adult takes about 20 days. According to Strandtmann & Wharton (1958), rickettsialpox is beyond a doubt transmitted from animal to animal and to man through the house mouse mite, *Allodermanyssus sanguineus*. The same reference cites a mite (*O. bacoti*) to be as an intermediate host of a parasitic nematode.

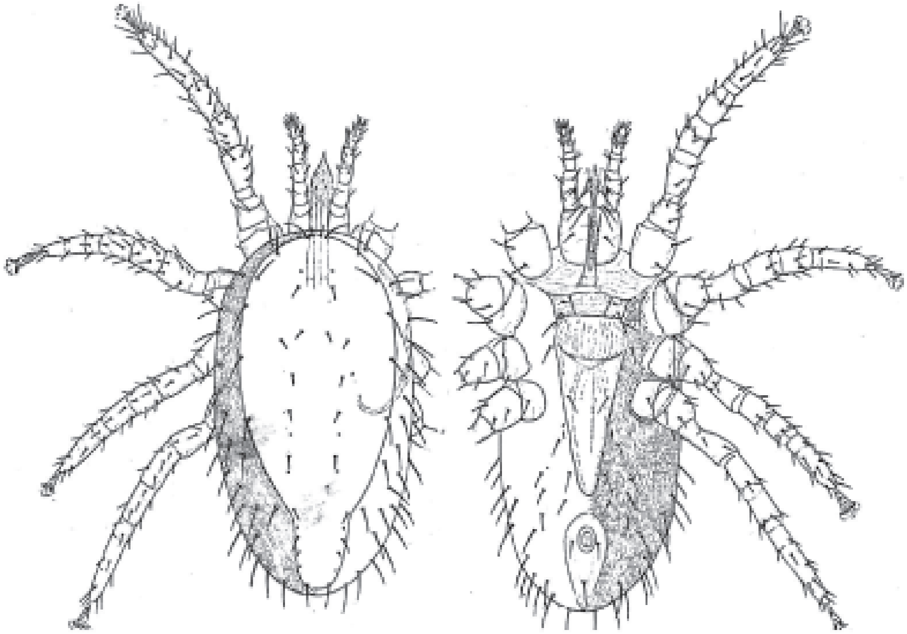
***Ornithonyssus sylviarum* (Canestrini & Fanzago, 1877) –** Northern fowl mite

Ornithonyssus sylviarum (Fig. 39) is also known to bite and cause dermatitis in humans (Radovsky, 1967). Though it is not represented in the records of IMR, it was found infesting 35 different species of birds in Asia, in the course of studies of bird migration (McClure *et al*, 1971), as shown below. The geographical distribution of many of the bird species covers Southeast Asia, including Malaysia. This species is most common in North Temperate Zones where it feeds on blood of a variety of wild and domestic birds. It is also found in Australia and New Zealand. The species is not recorded in Malaysia due to lack of intensive survey. However, the presence of the mite species on some 35 species of Southeast Asian birds listed below, denotes its occurrence in Malaysia. The entire life cycle can be completed on the host otherwise it is quite similar to that of *Ornithonyssus bursa*. Experimental transmission of Western Equine Encephalitis and St. Louis Encephalitis was done, and the viruses have been isolated from the mite. However, these were accidental infections, and the mites do not play a role in the natural transmission (Southcott, 1983). According to Fain (1983) this mite may cause itching in humans.

Alcedo atthis (Common kingfisher)
Buceros bicornis (great hornbill)
Picus chlorolophus (Lesser yellownape woodpecker)
Hirundo rustica (Barn Swallow)
Parus palustris (Marsh Tit)
Timaliidae (Babblers) 6 species
Turdidae (Thrushes) 7 species
Sylviidae (Warblers) 2 species
Muscicapidae (Flycatchers) 5 species
Lanius cristatus (Brown Shrike)
Fringillidae (Finches and Buntings) 8 species
Passer montanus (Eurasian Tree-Sparrow)

***Ornithonyssus bursa* Berlese 1888, Tropical Fowl Mite**

In the mid 1960s, Tuan Haji Amran Daran reported of an entire village at the 5th mile Hulu Gombak, approximately 8 km from Kuala Lumpur, complaining of itchiness and



Ornithonyssus sylviarum (C. and F., 1877).
Left dorsal and right, ventral view of female

Figure 39. *Ornithonyssus sylviarum*

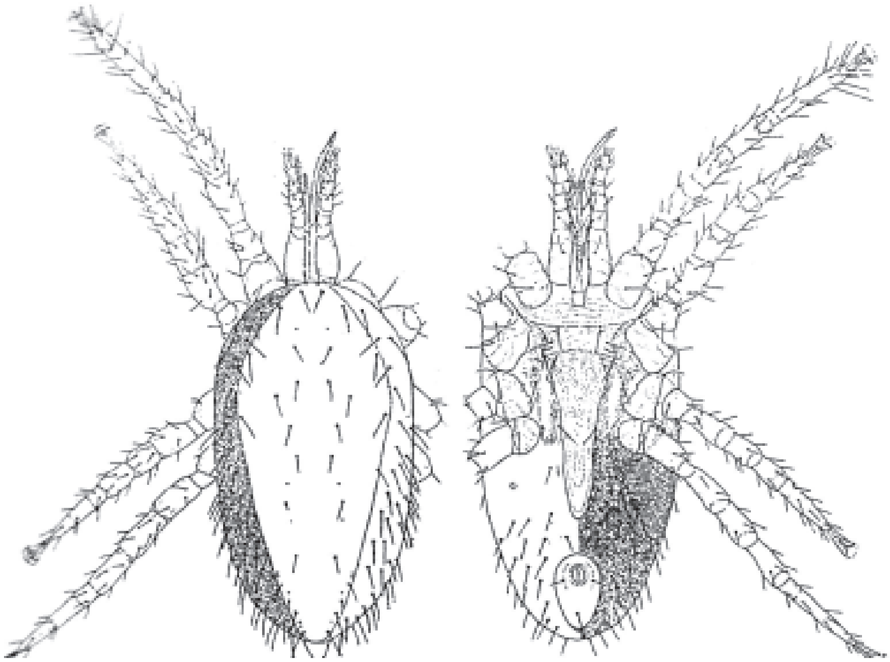
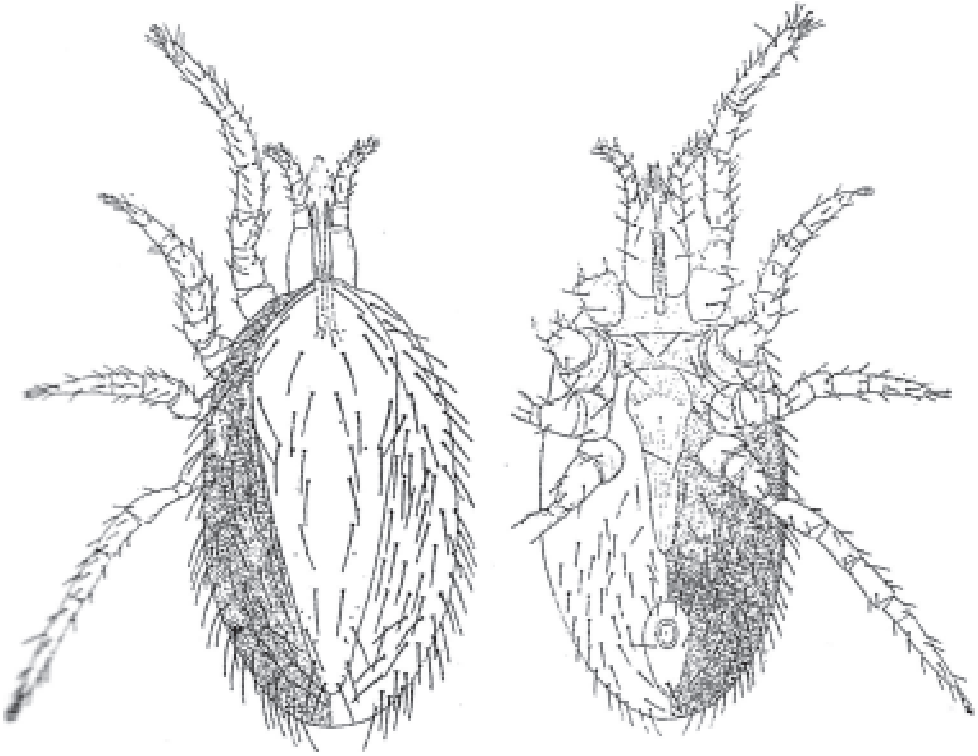


Figure 40. *Orthonyssus bacoti* (Hirst, 1913), Tropical rat mite.
(Courtesy: Baker et al, 1956)



Orthonyssus bursa (Berlese), Left, dorsal view of female.
Right, ventral view of female (Courtesy: Baker et al, 1956)

Figure 41. *Ornithonysus bursa*, the tropical fowl mite

swelling among the villagers. On a visit to the village, domestic fowl were seen grazing around the houses, and the birds were nesting in the backyards of the houses. We collected debris from one of the nests and found numerous live mites of the species *O. bursa* (Berlese) (Fig. 41).

More samples were collected and almost all of them were of the same species. Amran Daran, who lived in the same village and worked at the IMR, said that the incidence of dermatitis was either seasonal or occasional. More recently *O. bursa* was reported to bite IMR staff in the toilet at the Division of Haematology. The source of the infestation was traced to a nest of birds on the other side of the toilet wall (IMR centenary celebration, p.8). Several species of birds (little spider-hunter, blue and gold flycatcher, streaked bul-bul, spotted munia, scops owl, golden-throated barbet, and other species of birds) were found infested. *Ornithonyssus bursa* has been reported as completing its life cycle in a week (Desch, 1983). Both these species of *Ornithonyssus* are frequently reported producing dermatitis in humans in tropical and subtropical countries generally. Humans inadvertently may encounter an ongoing biocenose (= living together) involving mite, vertebrate host and pathogenic bacteria or virus. The very short life cycle of the mite, e.g. *O. bursa,* and seasonal dynamic changes that influence large populations of mites to happen are factors to be seriously considered before control measures are to taken.

Host distribution of mites of the family Laelapidae

In some 30 years of taxonomic studies of acari, approximately 100 species of Mesostigmatid mites in various families were recorded in Malaysia, but are yet to be published. Many species of mesostigmatid mites are reported to come in contact with humans, but there are no authenticated reports of the mites serving as vectors of infections to humans. However, because they are parasites of wild rodents of the rain forest, and their territorial behaviour overlaps host species of different kinds of rodents that share the hosts of other ectoparasitic arthropods, there is likely to be exchange processes to develop and maintain enzoonotic cycles of possible infections. Mesostigmatid mites also lend themselves to be useful "ecological labels" that would help to better understand the distribution and behaviour of the host animals (Nadchatram & Rohani, 1977). The intranasal mites of birds and other endoparasitc mites of reptiles and mammals have been reviewed (Nadchatram, 2006). Most Mesostigmatid species are ectoparasitic nidicoles that reproduce in the nests of their hosts (some of them are *Laelaps, Haemolaelaps, Longolaelaps, Echinonyssus*, and *Ornithonyssus* species). Two common Laelapid mite species that are known to have universal distribution are *Laelaps echidnanus* and *Laelaps nuttalli*, and they are illustrated here.

Laelaps echidnanus (Berlese, 1887) (Fig. 42)

This species is as common as *L nuttalli*, but less common on the *Rattus* species, but was found to be very common on a forest rat, *Sundamys muelleri*. This rat is host for a number of protozoan and helminthic parasites, and the mite is suspected to be involved as a possible intermediate vector from animal to human of Schistosomiasis (IMR. Ann. Rep.1981).

Laelaps nuttalli Hirst, 1915 (Fig. 43)

This is a common species with a wide distribution in Asia and South America in temperate and tropical areas of the world. The common hosts of the species are urban and field rats of the *Rattus* species in Malaysia. But many years of studies of host distribution show that *L. nuttalli* is found to be common on *L. sabanus,* a giant forest rat. Though the species is incriminated as an agent of pathogens, we do not have any evidence to suggest this at the present time in Malaysia for lack of studies on the medical importance of this mite. It was, however, suspected that it might be involved in the rat to rat transmission of bubonic plague and murine typhus (Audy, 1956a).

As far as we know from studies made in Malaysia, mites of the suborder Mesostigmata live in the nests of their hosts, breed in the nest and feed intermittently on the host. Approximately 12 families of Mesostigmatid mites have been recorded from reptiles, birds, bats and other ground dwelling mammals, especially from shrews and rodents in Peninsular Malaysia. Our long-term studies of Mesostigmatid mites of the family Laelapidae from rodents have shown that like most species of chiggers, they have a somewhat low specificity to a host. Because the pattern of parasitization is largely decided by their behaviour and habitat, it gives us clues to the behaviour and habitat of the host. Species of rats that have spiny fur (*Maxomys* spp. and *Niviventer* spp.) harbour many more mites, in numbers and species, than those species without spines. With 673 specimens of *M. rajah* group infested with a total 24,100 mites, a mean value of 35.8 mites was obtained. Of 41 *N. rapit* infested, a mean of 32.4 mites was obtained. *Maxomys rajah* and *M. surifer* roam on the forest floor and live in burrows, and repeated live trappings showed effective lifetime range to be 260 to 280 metres (Medway, *loc. cit.*).

Between early 1950s and mid 1970s approximately 30,000 reptiles, birds, and small mammals were examined for all mite parasites. Figure (44) lists 12 species of rodent hosts and the distribution of 16 species of mites on the host animals. It will be seen that *Laelaps turkestanicus* is one of the predominant mite species on *Hapolomys*

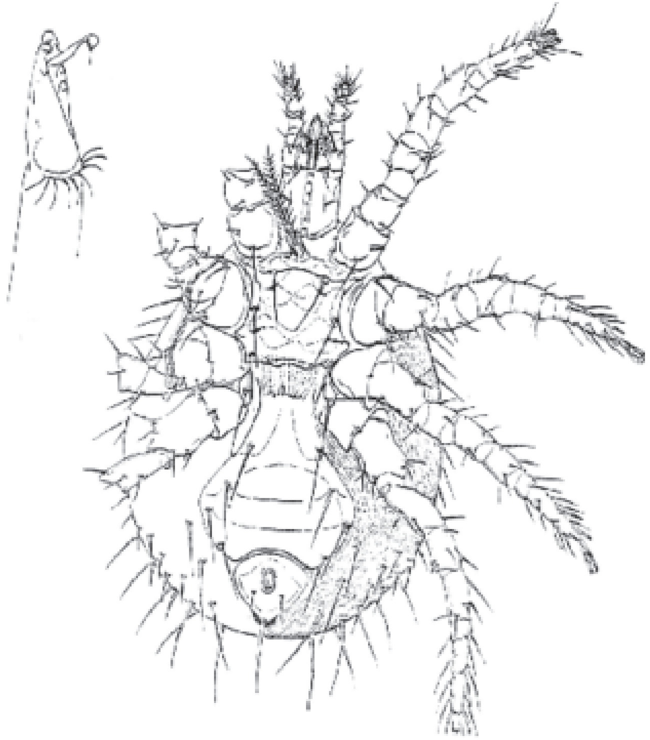


Figure 42. *Laelaps echidnanus* @ & common hard mite of forest rats
(Courtesy Baker et al. 1956)

Figure 43. *Lealaps nuttalli,* common hard mite of house and field rats, Rattus species. (Courtesy Baker *et al*. 1956)

Host / Mite	Lae. nut.	Lae. ech.	Lae. scu.	Lae. ain.	Lae. san.	Lae. tur	Lae. tra	Lae. ins	Lae. 'A'	Lon. Ion	Hae. aud	Hae nad.	Hae 'A'	Hae 'B'	Hae 'C'	Hae tra.	His cal
Rattus t. jalorensis	+++	+				+				+							
Rattus annandalai		+				+++											
Sundamys muelleri		+++															
Leopoldmys sabanus	+++	+	+	+				++									
Maxomys whiteheadi			+++							++							
Maxomys rajah gr				+++	++												
Niviventer cremoriventer		++		+		+++											
Niviventer rapit						+++	+++										
Hapolomys longicaudatus						+++			++								
Callosciurus notatus	+					++				+		+				+	+
Sundasciurus hippurus											+++	++			+		
Hylopetus lepidus (flying squirrel)											+	+	+++	++			

Lae.nut = *Lealaps nuttalli* Hirst; *Lae.ech* = *Laelaps echidninus* (Berlese); *Lae.scu.*=*L. sculpturatus* (Vitzthum); *Lae.ain.*= *L. aingworthae* Strandtmann & Mitchell; *Lae.san.*=*L. sanguisugus* (Vitzthum); *Lae.tur* = *L. turkestanicus* Lange; *Lae.ins* = *L. insignus* Delfinado; *Lae. A* = *Laelaps sp "A"*; *Lon. Ion* = *Longolaelaps longulus* Vitzthum; *Hae. aud.* = *Haemolaelaps audyi* Baker, Traub and Evans; *Hae. nad.* = *H. nadchatrami* Baker *et al.*; *Hae. tra* = *Haemolaelaps traubi* Strandtmann; *His. cal.* = *Hirstionyssus callosciurius* Bregetova & Grobkovsky.
(Symbols: +++ = common ++ = moderate + = occasional)

Figure 44. Distribution of Mesostigmatid mites on forest rats, squirrels and a flying squirrel
(*Niviventer rapit* was *N. fulvescens* prior to Corbet & Hill (1992)

longicaudatus, a true arboreal rat. Since this mite is also the major parasite of *R. annandalei¸ N. rapit* (previously *N. fulvescens*) and *N. cremoriventer,* it proves that there is similarity in the nesting behaviour of all four species, i.e. arboreal. As stated earlier, all species of murids were treated as of the genus *Rattus* prior to Musser (1981) and the nesting habits of the hosts not well known. Long-term studies have also shown that nearly every forest rodent has usually one, sometimes two species of primary laelapid parasites and a number of secondary parasites varying from three to 12 species. However, the primary parasite of one species of murid host is a secondary parasite of a number of other host species. As will be seen from the table, *L. nuttalli* was found to be very common on *R. tiomanicus* and *L. sabanus* and less so on other species of hosts examined. The commonest mite on *S. muelleri* was *L. echidnanus*. The Whitehead's rat, *M. whiteheadi* had the most number of *Laelaps sculpturatus* and moderate numbers of it were found on *C. notatus*. The Plantain Squirrel, *C. notatus* a squirrel with an arboreal habitat of scrub and plantations, also ranges freely into forest habitats, both primary and secondary. It was trapped on many occasions in traps set on the ground. The distribution of the mite species indicates that the squirrel would venture into the nests of other small mammals. *Sundasciurus hippurus*, the Horse-tailed Squirrel is confined to tall forest and the common mite found on 26 host specimens was *Haemolaelaps audyi*. The most common mite infesting the Flying Squirrel, *Hylopetes lepidus* was *Haemolaelaps* species "A", and in moderate numbers *H*. sp. "B". A total of 115 flying squirrels were infested.

The photograph of the flying squirrel (Fig. 45) taken by Ogilve in 1951 and reproduced through the courtesy of the Malayan Nature Journal was identified as *Hylopetes sagitta* by Ogilve. In the distribution table of Mesostigmata of rats, squirrels and a flying squirrel in Figure 44 in this paper, the species originally listed as *Hylopetes spadiceus* for the flying squirrel has been revised as *H. lepidus* (Red-cheeked flying squirrel) vide Boonsong & McNeely (1977). Both *H. sagitta* and *H. lepidus* are treated as synonyms of *H. lepidus* (Horsfield, 1822), based also on skull characters by the above authors. According to Muul and Lim (1971), this species in Peninsular Malaysia is common in primary forest up to 1,000m. They are scarce in kampongs (villages), plantations and in trees along roadways. However, *Hylopetes platyurus,* another species of common flying squirrel was not found in primary forest in P. Malaysia, but they found this species to be common in kampong, estates, forest edges, and in trees along roads and near villages.

Heamolaelaps sp. A was also found in moderate numbers on *S. hippurus*. (The Bishop Museum Department of Entomology was a participating institution with the IMR Acarology Division on taxonomic studies of specialized group of mites. The *Haemolaelaps* "A", "B" and "C" along with 3 or 4 other species of the genus were sent as slide preparations to the Bishop Museum (attention Dr JoAnn Tenerio) for study in the late 1970s. I have not kept track of the fate of the material after my retirement). All correspondence related to this and other matters are not traceable.

DISCUSSION AND CONCLUSION

Ecologically trained parasitologists as well as medico-veterinary epidemiologists have the same goal with respect to zoonoses and communicable diseases. However, mindful that the theme of this report is acarine zoonoses in relation to the rain forest ecosystem, an attempt is made to identify some of the factors affecting the environment in respect of ecological deviation in consideraion of climate change and global warming. It is vital that our natural forest is preserved to suppress or control the carbon dioxide to reduce greenhouse gases in the atmosphere.

There is no doubt that ticks and mites are important vectors and causal agents of

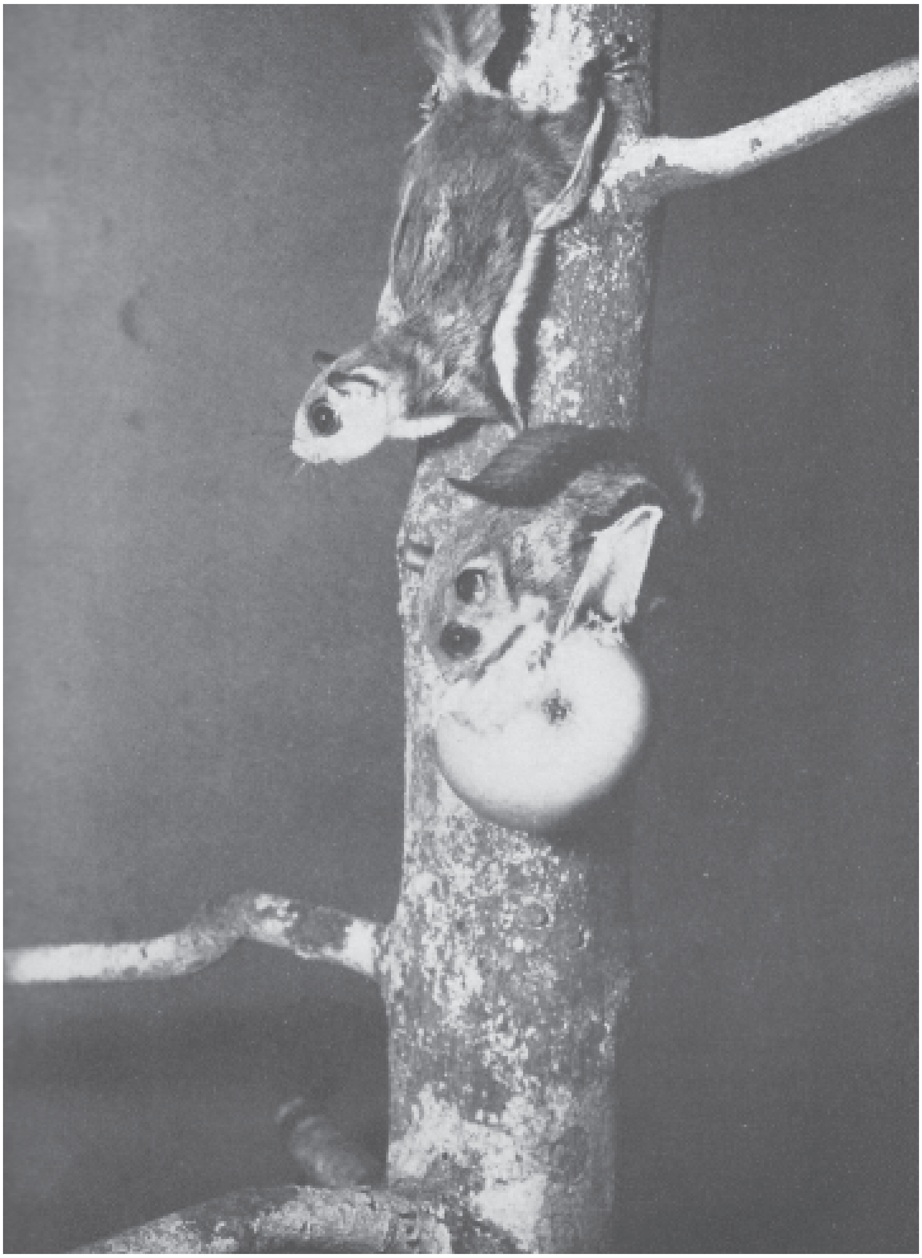


Figure 45. Picture of *Hylopetes lepidus*
(Courtesy: Ogilvie and Malayan Nature Journal, 1958)

zoonotic diseases. Also in the opinion of this author, zoonotic infections are caused through artificial habitats created in the natural environment. Classical examples are given of the natural history of some vector-borne zoonoses. Some of them are significant and others less so. It would seem that Acari-borne zoonoses do not give cause for alarm in the Southeast Asian region at the present time when compared with mosquito-borne diseases, e.g. malaria, filariasis and dengue. However, it does show that ecological changes through deforestation and other environmental effects can cause health problems. (Leptospirosis has a similar epidemiological distribution in Malaysia as scrub typhus. It affects army personal, rural populations, their animals and those who indulge in out-door activities). Awareness of ubiquitous "fevers of unknown origin" and the variety of factors that may incriminate ticks and mites suggest unlimited opportunities for zoonotic research where ticks and mites are concerned. Q fever that is recorded in Malaysia and many Asian countries is believed to have originated in Australia and the Americas, boutonneuse fever or Indian tick typhus is distributed throughout Asia. It is now suspected that tick paralysis and lyme disease either occur or have every likelihood of invading Malaysia. The tick genera incriminated elsewhere for the above infections are native to Malaysia and share behavioural patterns similar to those genera of vectors in western countries.

Importance of migratory birds in dispersion of parasites

Furthermore, the important role that migratory birds play in conveying a parasite from one country to another is of significance. A vector species of scrub typhus was collected from two migratory thrushes flying through the Japanese islands where the species is a common vector of scrub typhus. It is also known that the species is well established on several species of rodents in Cameron Highlands where *L. scutellare* (Nagayo *et al*) was first discovered on the two species of migratory thrush, the Siberian Thrush, *Zoothera sibirica* and the Grey Head Thrush, *Turdus o. obscurus*. During the extensive banding of birds through the Migratory Animals Pathological Survey between 1963 and 1971 (McClure *et al.*, 1971) ectoparasites were collected from 743 species of birds in Asia, including Malaysia. A total of 34 species in 11 families of migratory birds yielded 136 collections of chiggers. Collections made from migratory birds in Malaysia were *L. deliense, L.scutellare, L. akamushi, L. keukenschrijveri, Toritrombicula vorca* and *Odontacarus audyi.* Five species of migratory birds, including the *Turdus* species from which I made the first collection in Gunong Brinchang in 1960, yielded the chiggers. Three of them are established vectors and the other three are also of Ecological Group I of Nadchatram (1970 loc. cit.). Our limited knowledge of Acari-borne diseases in Southeast Asia is due largely to lack of survey rather than the lack of pathogenic agents. Progressive changes in the ecology affecting the country landscape has also affected the distribution of parasites. To describe the changes in the environment, it is noteworthy that *Schoengastia vieta* Gater, 1932 and *Gahrliepia fletcheri* Gater, 1932 were described from *R. r. diardii,* an urban rat, in the town of Kuala Lumpur in 1929 and 1930 (Gater, 1932). These 2 species are now found mostly in secondary forest and forest fringe habitats many kilometres away and have not been recorded in house rats in Kuala Lumpur since. Subsequent studies show that *S. vieta* is widely distributed in Malaysia and infests birds, reptiles and small mammals (Nadchatram *et al*., 1980).

A few decades ago, Russian (Soviet) scientists discovered numerous viral and rickettsial infections in Asiatic U.S.S.R. in which Acari or Dipterans were vectors. Many species of migratory birds and bats are involved in the cycles of these infections. Birds can maintain and transport pathogens for long periods and over long distances. In turn, ticks and chiggers are also capable of carrying the infections for generations by transstadial and transovarian transmission. Migratory birds which breed in cooler climates, including Siberia, winter in Southeast Asia (McClure, 1974). The photograph seen here is of Dr. Eliot McClure with his assistants, and the mobile bird banding laboratory in the highlands in Malaysia (Fig. 46).

Dr McClure has made significant contributions on studies of bird migration and the parasites they transport from one country to another. IMR records as well as McClure *et al.* (1971) show that migratory birds play an important role in the transportation of acarine ectoparsites from country to country. If a species of acarine found on a bird in one country was not recorded in another country,

Figure 46. Dr H. Eliot McClure, in his bird migratory mobile laboratory

it does not mean that the said species does not happen there. The Migratory Animals Pathological Survey was initiated to determine the origins and movements of migratory bird population in Southeast Asia to serve as background information for epidemiological studies of zoonoses. In the study, Acari made up for the greatest number of parasites. Of the 26 families and 120 genera, 62 genera were represented by 194 species. Among the ticks, six genera and 16 species of Argasidae and Ixodidae were recorded. Next in line of importance are the family Trombiculidae and 44 species in 17 genera were recorded. The species of chiggers of zoonotic importance have been mentioned above. In the mesostigmatid suborder, two species of Dermanyssidae in two genera were recorded. Macronyssidae was represented by two genera and five species, and Laelapidae was represented by four genera and eight species, thus illustrating the ability of birds in the dispersal of Acari parasites. Distribution of parasites on migratory birds is important and useful to accrue general information concerning the ecology of birds and their parasites.

The recovery in the Cameron Highlands of Peninsular Malaysia of *L. scutellare* on migratory thrush for the first time in 1960 reveals some interesting observations. The following information was obtained from McClure (1974). Migratory birds fly non-stop to cross the sea. The birds usually perform a circular ascending flight (soaring) using rising warm air currents or thermals generated by the hot sun on mountain or lowland areas. After soaring to a considerable height, they will glide or cruise long distances to the next destination along the migration route. The soaring and gliding technique is repeated many times until the birds reach their final destination over many days, depending on the weather. The chigger species were collected in late November on two species of thrushes, mentioned above. Three species, *L. scutellare,* Japanese *L. akamushi* and *L. keukenschrijveri,* a local species were found. The feeding time of *L. scutellare* is about 2 or 3 days on attachment to a host. Since the chigger species was fully engorged when collected from the birds, it would seem that the chiggers attached to the bird approximately three days prior to its collection in Malaysia. Noteworthy is the fact that the migratory birds took three days to fly from a point on a Japanese island to pick the questing chiggers and arrive in Cameron Highlands, Malaysia if it had happened to have flown directly. The question now is whether the bird flew directly from a

Japanese location or picked the chiggers up along the route enroute to the Malaysian Highlands from Siberia. The critical phase, for epidemiological consideration, is the feeding period that the vector chiggers take to attach and feed on a host. All chiggers of ecological group I feed to repletion in 2-3 days. This includes the vector species and scrub itch chiggers. But all species of Ecological group II take 10 days or more to complete feeding. Those of Ecological Group III to VII are also slow feeders varying for a week or longer. For the Peninsular Malaysia genera of chiggers by Ecological Groups see fig. 32.

Dispersal of parasites by bats

Bats (Chiroptera) number approximately 100 species in Malaysia, made up of the suborder Megachiroptera and Microchiroptera. On feeding behaviour, the bats are separated as fruit bats and insect-eating bats. They are hosts to hundreds of species of acarine parasites. Bats are considered of zoonotic importance because their homing range extends over many countries. They are infested with a vast variety of ticks and mites representing at least four suborders of the subclass of Acari. Radovsky (1967) treated 86 species in 15 genera of the families Macronyssidae and Laelapidae of the suborder Mesostigmata and provided valuable taxonomic data on the bat parasites. The mites were found on representatives of each superfamily and all common families occur throughout the geographic range of the Chiroptera. Anciaux de Faveaux (1971 to 1985) compiled all the acarine parasites of bats and published 10 catalogues running to 1128 pages. These valuable publications on host-parasite association of bats are a monumental contribution. Beck (1971) did a 2-year survey of bats and ectoparasites of Malaysia. In his prelimary survey, 7000 bats of 40 species led to the discovery of 12 families of acarines (Spinturnicidae, Macronyssidae, Laelapidae, Argasidae, Demodicidae, Myobiidae, Psorergatidae, Trombiculidae, Listrophoridae, Teinocoptidae, Bakerocoptidae, and Sarcoptidae) without realizing that the IMR has long been one of the principle investigation institutions in Malaysia on the systematics and host distribution of acarines in Malaysia. The registry of records in the Division of Medical Zoology show that collection of bats were made throughout the country and, at least, the acarine parasites were examined, and those that the IMR did not have the competency to identify were sent to collaborating institutions to study. It was found that the host-specific mites of the family Spinturnicidae were the most common on bats, and at least 12 species were recorded, the commonest species being *Ancystropus zeleborii, Ancystropus eonyteris, Para-periglischus rhinolophinus* were a few of them. Other Mesostigmatid mites found on bats were *L. echidnanus, Longolaelaps whartoni, Longolaelaps longulus, Histrichonyssus turneri, Macronyssus radovskyi,* and *Nakhoda lineartis.* Two species of soft ticks and many Astimatid mites were also recorded from bats by the IMR. The trombiculid mites of bats were represented by 10 genera and 24 species (Nadchatram, 1970).

The importance of systematics and ecology of the acari

There is no disease so perfectly described that we can say it is completely understood. At the Institute for Medical Research where I worked, through the foresight of pioneer scientists, research on parasitic arthropods was undertaken without definite knowledge of the ability of the arthropods to transmit diseases. Because of this, we obtained a better understanding of the systematics, ecology and distribution of vectors and related species causing malaria, filariasis, dengue, scrub typhus and other vector-borne diseases. The foresight of the earlier researchers of the pre-war and early post-war years have contributed much to the present knowledge of the natural history of tropical diseases. The study of the historical relationships of groups of biological organisms and recognition to understanding the biodiversity is defined as systematics, of which taxonomy is a part. Systematics differs from ecology in that the latter is concerned with the interactions of taxa, while the former is concerned with the relationships of hierarchic lineages. Systematic research is important to be able to discover organisms created by nature, regardless of their role as useful or harmful to humankind. It is, in actual fact, to understand their relationship with other organisms which share our environment. Ecological research is essential to understanding the workings of the environment. However, systematic science does not exist because of ecology's requirement. Each discipline provides information essential to the other.

Terry Erwin of the American National Museum of Natural History in 1982 stated in a news article, that in the tropical rain forests alone there may be 30 million species of living creatures, including arthropods and other invertebrates. Of the approximately 1.4 million known living things, including plants, animals and other micro- and macro-organisms, only a small fraction have been studied as to biology, ecology and interrelationships with the climate and soil. Because of the wealth of arthropod fauna in the rain forest, there have been studies conducted in Malaysia by foreign investigators and collections have been made here and studied in their respective countries.

One such programme was initiated by Japanese scientists. Under the heading of *Nature* and *Life in Southeast Asia* the joint Malaysia/Japan/ UK Research project was carried out from 1970 to 1974, within the framework of the International Biological Programme. There are 7 volumes altogether. The greater part of the material was obtained from Pasoh Forest Reserve, a lowland rain forest in Negri Sembilan. I have had access to 2 publications of the last volume, No. 7, which is almost completely devoted to the taxonomical study of soil fauna of Southeast Asian rain forest, which also includes titles of taxonomic papers on Tarsonemini, Acaridae, and Oribatid mites. Of the 2 publications, one is on the taxonomy of free-living soil Prostigmata (Shiba, 1976) and the other on the taxonomy of free-living soil Mesostigmata (Ishikawa, 1976). Though these papers are not related to my study, the references are recorded here in the event of future needs. Shiba's paper covered 58 new species, 24 newly recorded, and 5 known species of Prostigmata from the IBP study area in the Pasoh Forest Reserve, in the north eastern part of Negri Sembilan. Ishikawa's publication covers 18 species of Mesostigmata belonging to 4 families and 11 genera of soil fauna also from Pasoh Forest Reserve. However, my review paper is related to the known association of ticks and mites with animals and humans.

The resplendent Malaysian rain forest

Ripley (1965), a naturalist of the Darwinean school, in his deep and intimate book on the Land and Wildlife of Tropical Asia, described the forest of Southeast Asia with passionate feeling. In the three major areas of tropical rain forest on earth, i.e. in South America, in Africa and in Southeast Asia, the high and even temperatures, high humidity and high rainfall being equal the flora and fauna is peculiarly their own, and this is true of Southeast Asia which is rich in trees, both in numbers and species. My colleague, Alexander Hubert of USAMRU-M and I spent two nights with the orang asli (aborigines) in a small holding made up of three or four pondoks (huts) in the Hulu Langat Forest Reserve, about 22 km from Kuala Lumpur, in 1967 and enjoyed their hospitality. It was delightful to ramble in the park-like primary forest interspaced with tall trees forming the canopy high above. The forest showed considerable uniformity over a very large tract, the forest floor carpeted with dead fallen leaves, and without undergrowth. The atmosphere was tranquil. Though having enjoyed living in tents for days and weeks in the forests in Malaysia and other Asia-Pacific countries on collecting trips on many occasions, this 2-day visit to Langat registered in me, a somewhat memorable and happy disposition. However, it is quite unlikely if this forest will remain preserved 40 year later, because of commercial timber-felling activities.

In the early 1950s Peninsular Malaysia was covered by at least 75% forest, either virgin or secondary (Audy & Harrison, 1954). In 2006, 59% of Malaysia's land surface is still covered by forest according to the Honourable Minister of Natural Resources and Environment (Malaysian Naturalist, 2006). The Ministry of Natural Resources and Environment is serious in carrying out conservation of the forests, rivers and wildlife. Careful logging is practiced to preserve the environment. Many vast areas have been declared permanent forest reserves, Endau-Rompin Forest Reserve, Belum–Temengor Natural Park are new additions to the many others. The Taman Negara (or National Park) is the oldest and biggest reserve. It is 4,300 square kilometers encompassing lowland, hill and montane rain forest (Rubeli, 1986). Rubeli's publication also prides in excellent photographs of plants and animals. The Endau-Rompin and Belum natural parks are smaller nature reserves. The Belum-Temengor comprising 117,500 hectares was on 3rd May, 2007 gazetted as a permament forest reserve, and to be known as the Royal Belum State Park (Malaysian Naturalist, 2007).

According to Rubeli most of the mature forests of Southeast Asia are not virgin in the strict sense, but rather old forests that have reached a fairly stable equilibrium of ecological succession. Collections of small mammals have been made in these reserves in search of parasites from time to time. However, the Hulu Langat F.R., about 200 square kilometers in area, along the main range was one of our three major long-term collecting sites for small mammals in the state of Selangor for many years, and it is pleasing to note that this forest is now a declared nature reserve. Comparative studies of animals and ectoparasites would be useful to assess ecological changes in the bionomics of the fauna. Throughout the country there are many forests declared as reserves, and there is promise of the *status quo* being maintained for a very long time. Despite the years spent on gathering data, we need to remind ourselves that we know very little of the biology and inter-relationships of these arthropods with other organisms and their importance to mankind. To monitor the ecological well-being of the rain forest ecosystem, not only in the field of acarology, but parasitology as a whole is biologically necessary. In contrast, Western countries are usually advanced in systematic and biological research.

Population growth and climate change

Zechariah (1973) recalled the demographic history of mankind. "From figures used by the United Nations, it required perhaps 200,000 years for the human race to number 1,000 million by 1830, while it only took another 100 years to add the second 1,000 million, 30 years to add the third 1,000 million and the fourth 1,000 million is coming at a rate of 70 million a year, a mere 14 years time". She continued by stating that Malaysia's own population in 1970 was 10.5 million, and with the present rate of 3% the population will be increased by three million. The 2% birthrate target set by the Government, if unchanged from 1985, it will be sufficient to double the 13 million by the turn of the century. Zechariah's forecast was accurate to the last million.

According to the 2006 Malaysian Government statistics the population of Malaysia is 27.2 million, with approximately 2.5 million in Sarawak and 3.2 million in Sabah (Borneo). If compared with the population of 21.5 million in Peninsular Malaysia in 2006, the population was close to 5 million in 1948. In 1957, the year Malaysia attained independence, the population of Peninsular Malaysia was 6.5 million. The human population of the world in 2006 was in the region of 6.5 billion as compared to 1974 when the population was 4 billion, a demographic increase in global population growth by 2.5 billion in 33 years! (It was a remarkable co-incidence that the announcement of the world population reaching the 4 billion mark, was made at the graduate course I attended in international health at the University of Hawaii, in July, 1974). The rapid increase in human population will have serious effects on the world's environment with gradual depletion of the natural resources. The human population is expected to reach 9.1 billion in 2050 (Gore, 2007).

Some 50 years ago Malaysia was reputed to be one of the cleanest and safest countries for drinking water, where the quality of water allowed one to drink directly by opening any water tap anywhere in the country. But, now the water in rivers and streams are coffee black or coffee white but never crystal clear as it used to be. Nowadays, even the household water comes rusty black. This we all can see to experience, but how about the air we breathe, the polluted air that we cannot see.

In the story of early Kuala Lumpur (Gullick, 1956) Chinese tin miners set off from what was then Port Klang to sail to the interior of Selangor. Upstream they poled their boats along the silent empty reaches of the winding Klang River, which during the early days of settlement since 1857 was the only mode of transportation. On either side of the river, jungle and swamp came down the water edge. A mixture of small stones and pebbles of the river bottom showed clear through the green water. However, a study done 2 decades ago revealed that the same Klang River flowing through the city of Kuala Lumpur is so polluted that it has almost zero oxygen content. Timber felling activities affected the waterways from tributaries to streams and finally to the rivers. Soil erosion of the forest land deposited as a sediment causing the waterways to be clogged and chocked up with silt, resulting in the Klang River to be heavily polluted. Having stated this fact, it is heartening that positive efforts are being made by the Government to improve the quality of the waterways. Measures are being taken to stop development projects that would affect natural water catchments. Measures to counter climatic change, Kuala Lumpur hosted a regional meeting to prepare Asean countries for the UN climate convention in Bali, Indonesia in December, 2007. It is good that the Asean region is seriously thinking of climate change issues. It is a start to the many things that need to be done. Meaningful education is vital at schools on the importance of preserving the environment through tree-planting programmes, and bring to their attention to other related causes affecting the environment so as to improve the quality of the air we breathe.

Environmental education should be made an official part of the school curriculum. In other words, it is desired that basic environmental knowledge is passed on to every school-going child. Children must be taught basic things such as the three Rs so that it becomes second nature to them. All schools must be made environmentally friendly. Allowing periods for recreational activities to screen documentary films on environment such as 'Planet in Peril' produced by CNN would be useful.

Global warming is very real. We already know some of the impacts, e.g. melting of polar ice caps, rising oceans, severe droughts, massive flooding, surging storms, spread of diseases. We in Southeast-Asian countries are exposed to the effects of climate change, unless efforts are taken to encounter the problem. The release of carbon dioxide into the atmosphere is one of the main contributors. Appreciation of this and conserving our natural resource, the rain forest, would be one effort in the right direction to help contribute to unpredictable changing climate and also help to reduce greenhouse emissions. In a passionate, inspirational and educational documentary entitled *"An inconvenient truth"* published in 2007, the author Al Gore looks at climate change and global warming as a serious climatic crisis, and explains the issue with clarity. The documentary film under the same title is also available on DVD. It covers a broad range of subjects related to global warming, including the movement of disease producing organisms.

It will be good if nature study is introduced in the early years, because it is vital to maintain the equilibrium between forces that counter each other.

Effects of global warming

Man-made climate change and global warming is a very real thing going by recent reports of heavy rainfall causing serious floods in India, China, Pakistan, Bangladesh and some Southeast Asian countries. Western countries are also affected by climate change. The Katrina hurricane ravaged the Gulf Coast area of New Orleans causing untold misery in 2006. Some regions of the world are becoming drier. Very recently southern California was swept by uncontrollable fire which contributed much destruction. On the other hand, for the first time in the history of Mexico heavy rains led to flooding in a state in the southern part of Mexico. The area the size of Belgium suffered property losses and human misery. Green house gases comprise carbon dioxide, methane halocarbons, ozone and nitrous oxide which can accumulate in the atmosphere. As these gases accumulate and form a layer around the atmosphere, more and more heat gets trapped in Earth. Trapped heat causes the temperature to rise – thus known as Global warming. Global warming can then influence change in temperature, rainfall and wind patterns. Malaysia is experiencing frequent thunder and lightening followed by heavy rainfall; the days are hotter, the temperature reaching 95ºF or 35ºC. Because of the vital importance of saving the environment, the Nobel Peace prize for 2007 was awarded to those who have drawn the attention of the world to the consequences of global warming and environmental deterioration. Hurricanes and tornadoes in the Americas, typhoons and cyclones in Asia are causes of concern to mankind. The cyclone in Myanmar in 2008 caused human losses and sufferings to thousands.

To protect and conserve the rain forest of the Asean region we need to be conscious of the ruinous damage that has been caused to the Amazon rain forest in South America by human interference and exploitation. It is vital to ensure that the rain forest of our region does not give in to the sort of human activities that destroyed the ecological balance of the environment that prevailed in the Amazonian rain forest. Earthquakes happen as we never heard of before. Three years ago Pakistan suffered a massive quake, and this year (2008) China was struck by another massive quake. The bottom line is that global warming can cause earthquakes and cause open earth fractures. Only by education of the more relevant situations of life, including the preservation of the good health of human and animal welfare, sex education, population education and understanding of the environment that can contribute to a healthy, peaceful and harmonious civilization in the rain forest environment that we are fortunate to live in.

In a paper published, courtesy of the Rainforest Medical Foundation, Wong *et al*. (2001) justify the reason for protecting the rain forests for health. They said that though timber is often taken from a forest, resource managers would be wiser to consider how the forest can be managed with minimum degradation and maximum benefit. The Rainforest Medical Foundation had highlighted two important perspectives. The first being that rain forests hold species that yield valuable biochemical substances, and the second being that undue disturbances of the forest ecosystem results in health consequences. The paper discussed the consequences of deforestation in Africa, South America and Asia and the wealth of natural pharmacies affected by it, both western and native medicinal knowledge. Plants of medicinal value in a rain forest can be gathered in a sustainable way and income can be generated, making medicinal plants an economically viable alternative to logging, looking into cultivation and protecting plant resources, improve sustainable harvesting, and showing that long-term profits from pharmaceutical products exceed those from logging.

Herbal medicine or botantical medicine using plant seeds, berries, roots, leaves, barks or flowers is said to becoming more mainstream as up-to-date analysis and research show their value in the treatment and prevention of diseases. Malaysia is well placed to become a fore-runner in the popular alternative medical industry that has a global market exceeding RM200 billion (quoted by The Honourable Prime Minister of Malaysia in Sunday Star of 28.10.07). It is safe to assume that Malaysia is still in an ecologically sound position if considered with environmental devastations experienced by other countries.

Emerging diseases

In the past two decades Malaysia has experienced the introduction of new diseases or infections. Nipah virus, a Hendra-like paramyxovirus was originally suspected as JE. Confirmed as a virus, by CDC Fort Collins/ Atlanta it caused 105 human fatalities and 1.1 million pigs were culled in 1999. Bird flu or avian influenza (HS N1) afflicted a number of states of Malaysia. Many human lives were lost and millions of poultry were culled. Severe acute respiratory syndrome (SARS) is another emerging disease. It is highly suspected that bats are the origin of this air-borne virus. The natural history of these syndromes is unknown and will take a long time to resolve. Though these diseases are not vector-borne, their introduction to Malaysia suggests the multifactorial causes resulting from the imbalance in the natural environment. In such circumstances, it is probable that favourable climatic conditions as well as the rapidly increasing environmental changes caused by land development for economic growth will result in increased human-parasite as well as human-Acari contact, and the possible threat of zoonotic outbreaks.

It is, therefore, important to continue investigations to understand the natural history of animal host-parasite relationshp in order to bring speedy remedial measures in the event of a zoonotic epidemic. When a forest tree is felled it destroys all other vegetation around it. The canopy is broken allowing sunlight to enter. This contributes to changes to take place in the rainforest environment. Machinery used in logging activities causes much damage to the soil, creating deep depressions in the undulated soil affected by the fallen tree. In due course weeds, grass, and plants of various introduced species become established. Rain water fills the deep holes caused by the fallen log or caused by the machinery to remove the timber tree, providing breeding places for mosquitos and other water-borne organisms that cause human diseases such as malaria, filaraisis, schistosomiasis, and chikungunya virus fever. Every tree felled creates new environments and artificial ecosystems within the rain forest. Of course, natural interruptions may also occur in the forest from time to time such as when a large tree falls. The primary rain forest that was once a stable environment is exploited through introduced vegetation and animals mostly by man-made activities. Ultimately, it is the rain forest that is blamed for the proliferation of disease producing pathogens. Most zoonotic diseases occur when new environments are created in an otherwise stable structure. In the Amazonia and Indonesia humans who venture into these man-made habitats in the forest, picked up the infection. In the case of malaria not only the infection, but the vectors are introduced to human settlements, and the vector-borne disease gains and establishes a stronghold. However, the Malaysian Government, in a conscious effort, is doing all it can to protect the natural heritage of the Malaysian countryside with the lessons learnt from past experiences.

Importance of fundamental scientific research

Wise development of natural resources can only take place if it is based on sound knowledge of the consequences of environmental degradation. Research in biomedical science can play a major role in an era of comparative biology in Malaysia. It is neglected however, but much needed. The new generation of Malaysian scientists needs to be trained to contribute to natural science and hence the welfare of the nation

(Nadchatram, 2004). The rich biodiversity of flora and fauna of the rain forest ecosystem is being taken for granted, but the younger generation of Malaysian scientists is following the western world in resorting to more glamorous, advanced areas of study, mindless of the importance of the wealth of biological information fundamental to life, that is available at their door-step and that could be tapped, and linked to molecular and genetic information to bring about a complete story to the benefit of science and mankind. Millions of Malaysian ringgit was spent to send a Malaysian to space, which, no doubt, is a great tribute to Malaysia. As stated earlier, however, some 30 million species of living creatures live on planet earth, and of these only 1.4 million known living creatures have been even be named, and very few of them studied as to their ecology and interrelationship with the climate and soil.

The Malaysian rain forest is also rich in bio-diversity of life, and the promotion of fundamental research to learn of the creatures of the soil and their life-style is necessary to sustain the good image of the country. It is also important to consolidate valuable taxonomic information if serious research is to continue, regardless of the discipline. Some unfinished projects have taken many years to gather the systematic data by many scientists, prior to 1980. For example, in the field of acarology the vectors of scrub typhus and related trombiculid mites or chiggers number some 158 known species have not been brought to completion. Though ecological knowledge of these mites is somewhat clarified (Nadchatram, 1970), the systematic study remains to be worked out. The tick fauna of Malaysia of zoonotic importance, only second in importance to mosquitoes, had taken some 30 or 40 years to resolve the taxonomic confusion of some genera; the ticks of medical and veterinary potential number some 40 species. Mites of the suborder Mesostigmata of Malaysia which number some 14 families, useful for the determination of environmental changes in the rain forest number close to 100 species; and the house dust mites number over 50 species. There are also several parasitic astigmatid and prostigmatid mites that have been recorded in Malaysia, mostly by the IMR. The failure to make use of good analytical results in research will prove to be wasteful repetition when new projects of a similar nature are conducted. It is necessary to catalogue the data that had taken many long years of dedicated toil and much expense to compile. My health willing, I will help in any way possible to realize some of the outstanding commitments.

EARLIER ACCOUNTS

This review report covers the known association of ticks and mites with humans, by or through animal hosts, and the effects of environmental alterations on the ecology of zoonoses. Emphasis is also placed on the benefits to be derived from preserving our rain forest through research studies on vector-borne diseases that help to recognize ecological changes affecting the rain forest. The work is to compensate for a vacuum created in our understanding of Acari-borne diseases, due to change of direction of research activities through retirement of experienced staff from the Acarology Division of the Institute for Medical Research from which I retired 26 years ago. In those days, because acarology was a new scientific discipline, much of the time was devoted to discoveries of new taxa and to gain field experience in their basic ecology. The medical research aspects were referred to the bacteriologists, virologists and other relevant departments of the Institute.

The division, because of the knowledge of systematics and full-time involvement in the studies of Acari, was once a renowned reference center for acarology in the Asia-Pacific region, and a depository for type material of acarines of the region. The recruitment of new staff in the unit will need guidance in research. It would be of interest to recall the reorganizations that had taken place at the IMR from time to time. Before the formal recognition of the Division of Acarology, IMR in 1967, the Division was one of the laboratories of the Division of Virus Research and Medical Zoology (IMR Ann. Rep., 1953). Due to expansion of activities, the Division of Virus Research became independent in 1962, leaving the Division of Medical Zoology on its own. While the Head of Division of Medical Zoology changed from time to time for many years, Lim Boo Liat and M. Nadchatram remained as senior laboratory technologists, and later both of them were promoted as the first 2 experimental officers at the IMR. In 1967 four new divisions were created during the Directorship of the late Professor (Dr) Ungku Omar Ahamd - the Division of Medical Zoology and the Division of Acarology are two of them. However, under a major organizational schedule that happened some 10 years ago the Divisions of Acarology, Entomology and Parasitology were brought together with the Bacteriology and Virus Divisions as Units to form the Infectious Diseases Research Centre. This is a very natural grouping making it possible for closer integration with the Units that provide microbiological diagonostic services to offer impetus for collaborative research, somewhat like it used to be in 1953. Suprisingly, there is no unit in the new system for medical zoology. From 1953 onwards, the Division of Medical Zoology served as an anchor for parasitological and acarological zoonoses research. It is respectfully requested that the importance of medical zoology be recognized, and it be resurrected and belong in the Infectious Diseases Research Centre. Nevertheless, my studies on investigations of taxonomy and ecology under the system that existed then, was accomplished with satisfaction and pleasure, and it is hoped that the results will prove to be useful to all concerned.

Acknowledgements. The production of this swan-song publication was made neither with promise nor expectation of monetary assistance; instead I utilized my own funds in the process of producing this work over a period of three years. That the completion of this manuscript conjoins the 50^{th} year anniversary of the independence of Malaysia is a special blessing for me. The ultimate reason is to acknowledge the help I have received from so many well-wishers of international fame in their respective fields, many of whom are no longer with us. This publication is in honour of all of them, and I want to pay tribute in the best way I know to fulfill this ambition.

I gratefully express my thanks to the Directorate, Institute for Medical Research, Kuala Lumpur for the many years I enjoyed working there under very encouraging Directors (among whom were Prof. (Dr) A.A. Sandosham, Prof. (Dr) Ungku Omar Ahmad, Drs Bhagwan Singh and George de Witt). A former IMR Director, Datuk (Dr) Mani Jegathesan, in recognition of my experience and unique skills invited me to rejoin the Institute sometime in 1990 after my return from Singapore, but was uable to accept the invitation due to poor health. I wish to express my very grateful thanks to Dr Frank J. Radovsky, Oregon State University, Corvallis, Oregon, renowned acarologist and formerly Chairman, Department of Entomology, B.P. Bishop Museum, Honolulu, Hawaii and retired editor-in-chief, Journal of Medical Entomology for his review of the manuscript. I am especially indebted to Dr Radovsky for writing the foreword to this report. Frank is my respected friend and senior colleague. Dr Indra Vythilingam, Parasitology Unit, extended many courtesies which is gratefully acknowledged. I am indebted to Ms Marini Ismail, University Hospital, Petaling Jaya for her valuable services to format this manuscript with her intimate knowledge in computer technology application. Mr Lee Woon Kai assisted in scanning my colour transparency images, and I thank him. Dr Dora C.G. Tan of the then Virus Research and Medical Zoology, IMR was committed to virus investigations of arthropod-borne infections with Dr J.R. Audy and Dr C.E. Gordon-Smith, and is credited for being among the first to isolate TP 21 or Langat virus from *Ixodes granulatus* in 1956, and Lanjan virus in 1967. Dr W.W. Macdonald, an entomologist whose specialty

was arborviruses and ecology of culicine mosquitoes, was acting head of the division on Dr Audy's retirement, and he fully encouraged my studies of acarines. Acknowledgement is also made to Mrs P. Thanalukshmi, a senior laboratory technologist, sponsored by the Hooper Foundation, and one of my dedicated assistants whose valuable assistance was partly responsible for maintaining the systematic organization of the Acarology Division, and screening of trombiculid mites. She is the daughter of the late Mr. A. Ganapathypillai who assisted Dr. B.A.R. Gater with the preparation of the trombiculid material which led to the publication of Gater (1932).

One more enthusiastic assistant was Mrs. Rohani Abu Hassan, an IMR laboratory technologist, who conscientiously participated in the study of Acari parasites and in the preparation and screening of mites of the suborder Mesostigmata. In the 34 years I served the IMR I have had the pleasure of working with many technical staff who were friendly and cooperative. There were disagreements now and then, but as a team we worked together. The other senior team members in acarology during the many years I worked there were Harun Peral, the late R.S. Ratnam, Salleh Ismail (now the Head of the School of Medical Laboratory Technology), Kulaimi Bujang, the late Veer Jung Bharat, the late Amran Daran, Geraldine Lopez followed by Kum Lim Poh as Illustrators, Wong Ah Leng, Heah Sock Kiang and Vasantha Nair. Each of them had their own duties. Their contributions were helpful and recognized. The Divisions of Acarology and Medical Zoology, though moved apart administratively, the staff of both divisions worked closely, and grateful thanks are extended to Dr Lim Boo Liat, a close friend of almost 60 years duration for his kind cooperation.

This is also to pay tribute to the late Professor (Dr) Ungku Omar Ahmad who passed away suddenly following a massive heart attack in the very bloom of life at age 37 years, in February 1969. In the few precious years that he was with us he left behind a wonderful heritage for all Malaysians and his international colleagues to be proud of. Most important of all he left a legacy for Malaysia. He was appointed Director, IMR in 1965, which was immediately marked by increased research activities and creation of new divisions in keeping with the rapid growth of medical sciences he introduced. His academic brilliance earned him several fellowships in the U.K. and the U.S.A. In 1965 he obtained his Ph.D from the University of London. He was an author of numerous scientific and medical publications in his short life. The late Professor Ungku Omar Ahmad was indeed a devout and patriotic son of the nation and an individual par excellence. He endeared himself to everyone regardless of class or creed. I am one of those who had utmost respect for him for his recognition of my contributions to biomedical science when I served on the laboratory technical staff at the IMR. Professor Ungku Omar despite his hectic travel schedule to attend international meetings, stopped over in Honolulu in 1969 to visit the Department of Entomology, Bishop Museum where I was attached as a research fellow in acarology in the Department during the chairmanship of Dr J.L. Gressitt, a globally renowned scientist and entomologist.

The Prime Minister of Malaysia, the Honourable Tungku Abdul Rahman Putra in his obituary said, "…his passing was all the sadder to me personally because just before his untimely end I had been discussing and had agreed on his promotion in the service, which was due to take effect very soon". Professor Donald Heyneman, who knew Professor Ungku Omar when he served as resident coordinator of the Hooper Foundation for a few years, and later from the University of California, in his message said "I have never known anyone, anywhere, who had made such a profound and admirable contribution to so many in so short a time. He achieved this by a combination of intellect, energy, and personal character. He seemed to draw people together and bring out the best in each of them."

I also wish to take this opportunity to pay tribute and my respects to the many renowned scientists who have contributed in

one form or another to the study of animal hosts, vectors and Acari-borne diseases, and whom I have personally known and with some of whom I worked, and/or whose valuable work I have made reference to in this paper, but who are no longer with us, namely, Professors J.Ralph Audy (IMR), J.L. Harrison (IMR), J. A. Reid (IMR) and C.E. Gordon Smith (IMR), A.A. Sandosham (IMR), Ungku Omar Ahmad (IMR), Robert Traub, E. W. Baker, N.J. Marchette, H. Hoogstraal, R.V. Southcott, P.H.Vercammen-Grandjean, A.L. Gentry, H.E. McClure, G. M. Kohls, James Brennan, Eliot McClare, H. Womersley, R.W. Strandtmann and Dr J. Linsley Gressitt. The late Dr Gressitt who retired as Chairman of the Department of Entomology, Bishop Museum was not only a renowned scientist, but was solely responsible for the development of the Entomology Department as the premier center for systematic studies of insects and other arthropods of the Asia-Pacific region. He also founded the Journal of Medical Entomolgy and Pacific Insects (later the International Journal of Entomology). Dr Gressitt's offer to me of a permanent position as acarologist in his department in 1968 was converted to a research fellowship for a period of 30 months at the request of the then Director of IMR, Dr Ungku Omar Ahmad. I feel blessed to have known this very dynamic and illustrious scientist of international fame during his working lifetime. Radovsky (1983) presented a tributary admiration of Dr J. Linsley Gressitt.

Through my revered guru, Dr J. Ralph Audy, arrangement was made for me to visit many scientists and their respective institutions to receive education in acarology: H. Hoogstraal, NAMRU-3 in Cairo, G. Owen-Evans, The British Museum (Natural History), London; Edward W. Baker, U.S. Department Agriculture, Washington, D.C.; G.W. Wharton, R.W. Strandtmann, Joseph Camin, George Anastos, Alex Fain and Don Johnston in the Institute of Acarology, Maryland, U.S.A., 1961; Glen Kohls and Jim Brennan, Rocky Mountain Laboratory, Hamilton, Montana, and Manabu Sasa, University of Tokyo, Japan, The cordial cooperation of Sam Kadarsan formerly Director, Bogor Museum and Botanical Gardens, Indonesia is also acknowledged. Also acknowledged is David C. Lee of the South Australian Museum, Adelaide.

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I want to pay tribute to Professor (Dr) Robert M. Worth, Epidemiologist, School of Public Health, University of Hawaii, Honolulu. The late Professor Worth, who was my major professor, was a students's friend, teacher, philosopher and renowned medical epidemiologist. Among many of his achievements and contributions, he was Coordinator and Director of the Nepal Health Survey (supported by the Thomas A Dooley Foundation) from 1965 to1966, in which medical and paramedical personnel, mostly from the U.S.A. volunteered their services. I had the pleasure of participating in the health survey by invitation from the Bishop Museum. The purpose of the survey was to provide a concise, quantitative picture of the important health problems in Nepal. Dr Worth, a specialist in Hanson's disease, was also

instrumental in having the century old Hanson's disease quarantine lifted in Kalaupapa, Hawaii in 1969. I am one of the many Asian students who benefited from his painstaking tutorial assistance in graduate school. Another academic staff of the School of Public Health, and Department of Tropical Medicine and Medical Microbiology, University of Hawaii, Honolulu, Professor (Dr) Robert S. Desowitz died on 24th March, 2008. Professor Desowitz whom I had known from the University of Malaya (Singapore) in the 1960s, was a Faculty Member when I was a graduate student in the University of Hawaii in 1974–75. His loss is deeply felt by many in the world, including the Malaysian Society of Parasitology and Tropical Medicine which he founded and was its Honorary Member.

My warm and grateful thanks are also extended to Professor Duane J. Gubler, an eminent virologist and the late Professor Nyven Marchette, a dedicated rickettsiologist, who were members of the medical faculty of the University of Hawaii, and also my professors. Another motivator was Professor R. W. Armstrong of the School of Public Health, University of Hawaii.

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Aged 80 years, I am thankful to God Almighty for having made it this far. The fact that I have come this far is largely due to the good medical care I continue to receive gratuitously throughout my life as a Government pensioner, mostly from the University Hospital, Petaling Jaya, Selangor. Though treatment received for health care may be taken for granted, I am grateful for the health care provided by many. I want to thank all the medical officers, and I deem it necessary to express my gratitude to a few medical specialist friends by name for their care following a few major health episodes that had taken place in my life in recent years. Dr Kuppusamy Iyavoo, a respiratory disease specialist helped to control my chronic obstructive pulmonary disease and offered treatment to cease my smoking habit of 60 years duration. Dr Hardeep Singh, a leading eye specialist in private practice, for the advanced laser treatment of glaucoma and cataract which he provided and which also relieved me of mild macular degeneration, free of specialist fees. Another friend, Dr Harjit Singh, a private practitioner, who responded to a telephone call one night 12 years ago, and traveled some distance from his residence to mine to attend to me upon my being seized by a transient ischemic attack. His presence and bedside manner, before my being transported by ambulance and attended to by a specialist neurologist in a private hospital, led to immediate treatment and prevention of permanent paralytic disability. To all of them, and to my loving wife, Maheswari and my loving daughter Indra, for their support and encouragement I express my heartfelt thanks.

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