Scheme based on the Experience of the U.S. Public Health Service

General Measures	Survey	(a) Plague laboratory	Examination of rodents. Examination of human plague suspects.
		(b) Delineation of infected areas	Rodent examination. Epidemiology of human cases. 'Sentinel' guinea-pigs.
	Eradicative	Rodent destruction	Trapping. Poisoning. Miscellaneous.
		Rat-proofing	Protection of food supply. Elimination of harbourage.
	Restrictive	Fumigation SO_2, CO, HCN	Ships. Cargo or railway freight. Baggage.
		Rat proofing	Railway carriages. Railway stations and freight warehouses.
Special measures (applied to foci)		Evacuation Intensive rodent destruction	Fumigation HCN, SO_2. Immediate removal of harbourage.
		Flea destruction	Fumigation. Coal-oil emulsion. General cleanliness. Attention to household pets (cats and dogs).

INSECTS AND THEIR RELATION TO SOME DISEASES OF STOCK

LECTURE TO MEMBERS. BY R. E. MONTGOMERY

When I accepted the invitation of our energetic Secretary to offer for discussion before the Society a paper on Insects and their Relation to some Diseases of Stock, I did not quite realise the enormity of the task imposed.

Many people, when they see or hear of natural history, are inclined to look back on the time when the collection of mutilated butterflies, the hatching of some chrysalises surreptitiously saved from the gardener's wrath, or the blowing of birds' eggs, were the ideals of this hobby; for at that stage in our lives it could not be called science. A few years later, the school society fell into one's black books partly because it entailed—rather like the music-master—the sacrifice of a few precious hours a week: more often because it was surrounded by an aroma of servitude, and its members, headed by a quasi scientific master, did not usually include the most interesting boys; nor were the subjects chosen for discussion often of the same material value as those regarding the present position of Surrey and Yorkshire, or the standing of one's favourite football club.

So in later life the mention of natural history recalls at once birds and butterflies; but with all respect to ornithologists and lepidopterists this branch of nature does not end there. These enthusiasts will be the first to admit that; and when each one of us realises this fundamental truth, we shall find that both youth and adult will see in all nature something that will take us from our every-day worries, will give us a truer insight into sociological and economic problems of the world; and, if our careers are so destined, a hobby that shall be our work and a work that will be our hobby.

No section of any community is without interest in natural history—*Mammalia* are eagerly studied after death by the Kavirondo and during life by the Masai. *Aves* form the subject of many bitter disputes between Kikuyu and mistress, both as to the price to be paid per fowl, and often as to the original ownership of the parents of those eggs now offered for sale. *Pisces* delight the soul of the Swahili as well as the Goanese cook; and, in the form of the esculent herring with its long, long trail, has been known to be of frequent service to many essayists and budding politicians even in this new country.

Lower down the scale of animal life the phylum *Mollusca* furnishes the Cockney with his winkle, the Head of Department with his Zanzibar oyster, and the wife of the East African stock-owner with her pearls.

But of all natural orders commend us to the Arthropoda, a phylum containing jointed-limbed species of such diversity as *Crustacea*, represented here by the crayfish and prawn, which sometimes graces the Nairobi epicure's table: as *Insecta*, with its orders *Diptera* or flies, into which fall, in addition to the common fly, the mosquito and the tsetse: *Syphonoptera* or fleas, *Hemiptera* or bugs, and *Anoplura* or lice—in all of which the housewife of Nairobi, the man in the trenches, and even the Medical Officer of Health join issue in wondering why they should not possess a more interesting relationship to their second cousin the lobster than that afforded by natural history alone.

To the third great class of the Arthropoda, known as *Arachnida*, belong not only the two first cousins—the mites of cheese and the parasites of mange and scab—but also the family of *Ixodidae* or ticks, concerning which more hot air has filtered over East Africa than over the Sahara, and which has provided more grounds for thoughts and thoughtlessness, more excuse for the exhaustion of the limited supply of stationery than would be worthy of the largest animals—elephants, ichthyosauri, or even the modern tank.

The subject of the present paper deals largely with this family of Arthropoda, whose members are the carriers or the hosts of the diseases we shall discuss; but let it be understood at once they are not themselves the causes. We speak of tick fever, of sand-fly fever, of tsetse-fly disease: yet, strictly, these terms are wrong. Many ticks and all tsetse-flies are born clean and harmless to both man and beast: it is only after it has acquired infection by feeding upon a being which is or may have been sick that the real causal entity becomes acquired, and under certain defined conditions becomes elaborated to such a state that a succeeding bite by fly or tick will give the disease to the new animal.

In some cases the fly is merely a mechanical carrier or vector of the noxious disease-producing factor—as, for example, the common house-fly, *Musca domestica*, in its relation to typhoid and cholera of man; but, with certain exceptions, the conditions we shall discuss here are those in which the fly and the tick play a real live part in the multiplication of the causal germ: so live a part, indeed, that in a great many instances the disease could not exist, much less be propagated, but for the mediation of these so-called insects.

Let just one instance, known to all of you, suffice to make this point clear. A mosquito at birth is clean and harmless as a disease-producer, although some of us may fully appreciate the irritation and annoyance of its bite; but after it has fed upon a man suffering from fever, or in whose blood the lingering remnants of a previous attack are to be found, that mosquito, provided it be of a species capable of acquiring infection, becomes a breeding-place for the germs of malaria.

Among the germs taken in with the blood into the stomach of the mosquito, are some which have already undergone vital changes and have acquired sexual characters. Conjugation of the two sexual elements is effected, and the so-formed cell, having burrowed into the wall of the stomach, proceeds to divide and subdivide within the little cyst it has made. The contents eventually become so numerous and bulky that the cyst wall breaks, and the vast number of daughter cells are liberated into the body cavity, from which they wander to reach the salivary glands. From this destination they may pass down the proboscis at each subsequent bite of the mosquito, being aided by the discharge of saliva—an act natural to many animals at the thoughts of food.

These young cells, or sporozoits, injected into man will again reproduce, and with the culmination of each generation the patient suffers from the rigor of a malarial attack.

Here, then, is an instance in which an actual multiplication of the germs takes place within the insect: an instance where the mosquito is the true host of the disease, which it can convey at every succeeding bite, until the supply of sporozoits within the salivary glands becomes exhausted.

Analogous (though naturally with modifications adapted to the natural or life history of the respective participants) is the relationship between the tsetse-fly and the germ of fly disease or sleeping sickness, between the blue-tick and Redwater, the dog-tick and tick fever, the human-tick and recurrent or relapsing fever, and the brown-tick and East Coast fever. In each case the arthropod carrier is the true host, and the germ which it conveys belongs to the lowest form of animal life, the last zoological phylum it is necessary to mention —the family Protozoa.

When one speaks of disease-producing germs, one refers to microbes of three known categories :—

1. *Bacteria,* which include the causes of typhoid, tuberculosis, anthrax, and many others, all of which are classed as vegetable and represent the lowest form of plant life. Usually they do not possess any complex life history, but multiply by simple fission, and, in some cases only, form a resistant spore, by means of which adverse conditions, fatal to the vegetable cell itself, can be resisted and life maintained.

2. *Protozoa,* in the lower forms of which multiplication is by simple fission, but in the higher we find the very complicated sexual and asexual cycles analogous to that indicated for the parasite of malaria. Many disease-producing forms of Protozoa—such as malaria, East Coast fever, and tick fever of animals—require the intermediation of an insect host in which the sexual cycle is completed ; others—such as the amoeba of dysentery and the coccidia, which cause gastroenteritis in cattle—do not require an intermediary host ; and in the case of coccidia the later stages of the sexual cycle are undergone on the ground.

3. Thirdly, there exists a group of germs—if they can be so called—so small as to be invisible to the strongest microscope. Their presence in cases of disease can be proved by experiment, and it can further be shown that these invisible organisms are of different sizes, because some will readily pass through filter candles of very fine porosity, while others, though capable of passing through coarser candles, will be withheld by these. The ordinary filter-candle used for domestic water-supply will permit the passage of all germs of this category, yet they retain even very small bacteria.

In view of their minute size and invisibility, it is readily understandable that discussion has ensued as to the nature of these so-called ultravisible viruses ; but since with some of them it has been proved that development takes place within an insect host, which is the natural transmitting agent, the weight of opinion is in favour of considering them as a special group of the Protozoa, or animal, rather than vegetable, cells.

To this group belong the viruses of horse-sickness, heart-water, gastro-enteritis of sheep, and several others of very considerable importance to mankind and his property.

Our present discussion will, then, resolve itself into one concerning the Arthropoda and the Protozoa—both families of the Animal Kingdom, and therefore worthy of attention by zoologists and other workers in natural history. If I can induce some stock-owners to see the affinity between natural history and the very tangible interests of their pockets, then I feel certain this Society will materially benefit by their membership, and thereby from the encouragement which they will give to the study of such families as ticks and the various biting-flies—a study which will be to the mutual advantage of all members.

The phylum *Arthropoda* is divided into five classes: Crustacea, or lobsters and crabs; *Insecta,* or six-legged arthropods, including flies; *Arachnida,* including spiders, ticks, and mites; *Myriapoda,* or centipedes and millipedes; and *Protracheata,* a group of animals of interest chiefly because they constitute a missing link between the earth-worm and leech family and the *Arthropoda.*

Of these five classes, two only—the *Insecta* and the *Arachnida*—include forms which in virtue of their habits of sucking mammalian blood may be the true hosts of their diseases.

The class *Insecta* is subdivided into a very large number of orders, including the locust and mantis; the white ant and thrips; beetles; ants and bees; butterflies and moths, &c. But those of interest to us to-night are the *Diptera* or flies, *Syphonoptera* or fleas, *Hemiptera* or bugs, and *Anoplura* or lice. All known biting *Insecta* belong to one or other of these four orders; and though fleas, bugs, and lice are known to be carriers of such human diseases as plague, Kala Azar, and typhus fever (not typhoid), they have not yet been proved to be responsible for carrying any disease in stock, although the effects of the local irritation produced by lice and fleas are well known to both horse- and dog-owners.

The number of species of lice and fleas is considerable in this country; and although each species of domestic animal is commonly affected with its own species, there are some which will pass at least a temporary existence upon another host.

We all know how differently a flea-bite may affect any two individuals. It is of interest to realise that some species of flea have their own especial poison, and that a man by constant bites acquires a tolerance or an immunity to a given flea. But let that man be bitten by a species to which he has not acquired a tolerance, and he will respond and react as readily as any other person. When I tell you that in Nairobi alone there are four species of flea very common upon dogs, and at least an equal number on cats and other animals (domestic and otherwise) which frequent a house, you may realise why, even after long resistance, you sometimes feel the effect of a bite.

Bugs, in virtue of their essentially domestic habits, do not enter into the veterinary field, so far as is yet known; but it is quite conceivable that subsequent research may demonstrate both lice and fleas to be of pathological importance as carriers of disease; and I suggest these two orders to the members of this Society for study, both from a classification point of view and from that of their life histories.

Among the flies or *Diptera*, we find several species of extreme importance as hosts and as carriers of disease in man and animals. Even those which do not suck blood may be incriminated; for no one now disputes the rôle played by the common house-fly as a mechanical carrier of the typhoid and cholera microbes. Cases of anthrax in man have also been ascribed to their agency; and when it is known that the legs and wings of flies, which have walked over the skinned body of an animal dead of this disease, can carry the germs for twenty days, and, should those flies have fed upon the meat, their excreta contain the organisms for at least the same time, the justification for this belief is obvious. Should a house-fly—and with it may be grouped those flesh- or meat-flies so common in some neighbourhoods—die from any cause shortly after having fed upon an anthrax carcass, it has been demonstrated that their bodies can contain the anthrax organism for upwards of three years at least. Flies, too, which hatch out from maggots that fed upon diseased meat, contain the anthrax microbe in their bodies and may infect through their excreta.

But our subject lies more with those *Diptera* which possess biting mouth-parts and actually suck blood. Such insects must be more dangerous than non-biting flies, since they can deposit the disease-germs beneath the skin, and actually into the blood-circulation, through the agency of the bite; whilst the others merely deposit them upon the surface.

We have all heard of the accidents which may occur to man or animal through the use of a hypodermic syringe that is not clean and sterile. The mouth-parts of a biting fly may be likened to this contaminated syringe-needle. By a previous bite it has acquired an infection transmissible at a second or subsequent feed. If it be at an immediate second feed, which takes place within a short time, and if the germ involved does not require to undergo any developmental processes in the fly body, the infection is said to be mechanical. For such mechanical transmission it is theoretically conceivable for any biting fly, whose proboscis is like the syringe-needle, to acquire and to give any infection of a microbe present in the blood or on the skin of the bitten patient. Tsetse, mosquito, sand-fly, horse-fly, and so on, may be culpable; but, fortunately, a limitation to this transmission is enforced by Nature, which has endowed these several species of flies with certain habits of life. Some will not enter a stable; others a room. A few bite only at night; others only by day. One must live near the water in which it breeds; a second requires almost desert dryness. Unless we play into Nature's hands, and expose our animals or our men to the ideal conditions of transmission, these mechanical carriers are easily evaded; for in them the germs do not usually live long, and a second bite at several days' interval from the infecting bite will be harmless.

In opposition to the mechanical transference of disease is that known as vital or cyclical. In this, the germ, having entered a suitable biting fly with the blood it has ingested, commences a specific development, and converts the host fly into a breeding-place and reservoir for the disease. After the lapse of time necessary for the germ to undergo its full development, the fly can infect not only at a succeeding feed, but at every subsequent bite. So far as diseases of animals are concerned, the outstanding example of this is that of trypanosomiasis or tsetse-fly disease; in man, we have malaria, elephantiasis, and sleeping sickness—which last-named is essentially tsetse-fly disease.

There is a group of disease, both in man and animals, which is believed to be conveyed by *Diptera*; but research is not quite sufficiently advanced (chiefly owing to present inability to identify the microbe) to dogmatise as to whether transmission is mechanical or cyclical. Three days' sickness of cattle is presumed to be carried by midges. Horse-sickness may perhaps be conveyed by midges, gnats, or mosquitoes. Sand-fly fever of man, and yellow fever of the same subject, are instances of this class; and blue-tongue in sheep—a disease with marked affinity to horse-sickness—is a further example of a condition believed to be insect-borne.

In some cases the connection between the insect and disease is proved, e.g. yellow fewer; in others—as, for example, horse-sickness—it is largely circumstantial. It is known that the stabling of sick and healthy horses together is harmless, that the disease is not infectious; and by a process of elimination one is reduced to apparently incontestible evidence that some nocturnal flying 'dudu' is the responsible carrier.

Hundreds of thousands of pounds have been expended upon the inquiry into the nature and identity of this 'dudu.' At the Pretoria Veterinary Laboratory very extensive experiments have been conducted for several years past. Probably every known mosquito in South Africa has been collected, is being bred under natural conditions, and is fed upon sick and healthy horses, so far—I am given to believe—without any positive result.

Fly disease, or trypanosomiasis, is the condition of animals which offers the best example of *Diptera* as carriers of disease.

The actual germ, or trypanosome, belongs to one of the classes of the Protozoa, and it is characterised by certain anatomical features. All trypanosomes are not disease-producing. One, *Tr. Lewisi*, is very common in wild rats—even in Nairobi itself—and is carried from rat to rat by fleas in which a cyclical development is undergone. Many fish, reptiles, birds, and small wild mammals harbour trypanosomes without apparent injury; and there is one quite common in cattle of this Protectorate, as well as in England, that does not appear to produce any symptoms, and which will not affect any species of animal but cattle.

The first disease-producing, or pathogenic, trypanosome was found in India in 1880. In forwarding the discoverer's report to the Government of India, the Lieutenant-Governor of the Punjab wrote that although this discovery might be of some interest, and of possible importance, he regretted that Veterinary Colonel Evans had not discovered a cure. Thirty-seven years later the same regret can be expressed, although the number of pathogenic trypanosomes now known in domestic animals and man exceeds twenty.

The geographical distribution of these trypanosomes, and the diseases they give rise to, is wide: Persia, India, Malay States, and the Philippine Islands in Asia; Paraguay, Uruguay, Brazil, Guiana, and the Panama Canal Zone in America. In Africa they extend from Zululand to the Mediterranean. Australia is free, except for cases imported from India. Europe's only form of disease-trypanosome, is one that is not normally transmitted by a biting fly, but occurs chiefly in stallions and mares on stud farms.

Compare this distribution with that of the tsetse-flies, which, with one insignificant exception, are localised to Africa. In this continent, people are accustomed to think that the tsetse-fly alone is the carrier of the disease: they pooh-pooh the idea that any of the many other species of biting fly can be a responsible agent, forgetting or being ignorant of the fact that in America and Asia there *must* be other means of transmission.

On those continents it has been demonstrated that the family of horse-flies—*Tabanus* and *Haematopoda* or blind-fly, and the genus *Stomoxys* or 'stinging house-fly'—may carry infection by mechanical means from one animal to another. The proboscis of these flies is sharp, and is provided with a number of irregular teeth, in the shelter of which trypanosomes, acquired from the sick animal's blood, may lodge, to be conveyed to a new animal at the next bite. Fortunately, we know that trypanosomes do not live for long outside the body, and therefore should the contaminated fly not require another meal, or should he fail to obtain one, the infection will die within a few hours. Usually, a sick animal is dull and lethargic or unable to disturb the feeding fly, which therefore obtains a full meal, and, when replete, does not require another bite. As a result, the infection of the proboscis dies out and the fly becomes harmless. But were it to be disturbed in the middle of its feed, it will immediately seek to finish the course; and under the conditions of close contact occurring in a span of oxen, or among cattle put up in the evening into a boma, or yard, there is every chance of a new beast being selected at once, and the dirty proboscis will at entry promptly transmit infection.

This mechanical transmission is not localised to Asia and America. Morocco, Algeria, Tunis, and Egypt suffer severely from trypanosomiasis, and yet there are no tsetse-flies. Reduced to smaller areas, there is evidence that outbreaks of the disease occur from time to time in places where no tsetse can be detected, and these outbreaks occur in such a progressive manner that it is obvious some local agent is responsible. Remove or destroy the affected animals, and the epidemic will cease—sure proof that the transmitting fly is not a true host or reservoir, in which case it would still be capable of reviving the disease.

An outbreak which occurred two years ago on many farms in the Fort Hall District is an example of mechanical infection extending from cattle that had in all probability acquired the disease through the agency of tsetse-flies.

Among *Diptera*, cyclical transmission of trypanosomes has only been proved to take place in the tsetse-flies or *Glossinae*. Such has been searched for by numerous workers with *Tabanus* and *Stomoxys*, but without result; and although it should not be argued that vital development cannot take place in other biting flies it certainly appears that the *Glossina* is the true and natural host of the trypanosome in Africa.

From the dawn of European colonisation native stock-owners have ascribed a poisonous influence upon their cattle to the tsetse: the earliest explorers confirmed that belief; and in 1894, Bruce, by a series of brilliant experiments, proved that the tsetse-fly of Zululand carried a disease, and that this disease was due to a trypanosome very similar to that found by Evans, in India, fourteen years before.

Early in the present century, sleeping sickness of man—a disease considered to have been existent for many years in West Africa—occurred in Uganda, and within a very short time assumed most alarming proportions.

Investigations showed that a trypanosome, first seen by Dutton in the Gambia in 1902, was the cause, and subsequent work proved that transmission was being effected by one of the tsetse-flies—*Glossina palpalis*.

Until 1909, however, proof was wanting that *Gl. palpalis* conveyed in any way but mechanical. It was realised that simple mechanical transmission alone did not explain the rapidity of spread of the disease, and its continued existence in places whence all known sources of infection had been removed; but attempts to demonstrate a cycle within the fly had failed. In that year Kleine, working on Lake Tanganyika, discovered the secret, which has since been confirmed from every part of Africa, and has been shown to exist for nearly all well-known species of trypanosome occurring in tsetse-fly countries, and with all the common species of *Glossina*.

The tsetse-fly is born clean; and should it feed only upon blood in which no trypanosomes occur, it will remain clean and harmless, despite the severity of its bite, and the avidity with which it will follow an animal in search of a meal. But let that fly once feed upon a beast—whether wild or domestic—or a man, in whose blood trypanosomes exist, a developmental cycle promptly commences, and, being completed about a fortnight later, that fly is capable of infecting a susceptible animal at each succeeding bite, practically speaking, for so long as it lives.

The developmental cycle can be traced within the body of the fly; and it is interesting to note that even such a low animal as a trypanosome can select the special part of a fly's body in which the development can proceed. A group of trypanosomes, of which *Tr. gambiense*—the cause of sleeping sickness—may be taken as a type, develop in the intestinal tract, and finally invade the salivary glands: they do *not* develop in the proboscis. A second group develop in the intestinal tract *and* the proboscis, and do *not* invade the salivary glands. To this group belong those forms commonly found in stock, and which are capable of infecting cattle, horses, dogs, and small animals of the laboratory—such as rats and rabbits.

A third group develop *only* in the proboscis, *never* in the intestinal tract. The trypanosomes of this group are peculiar not only in this mode of development, but also in their microscopical appearance in the blood of infected animals, and from the fact that they will not affect dogs, rats, and rabbits, and are primarily disease-producers in cattle, much more rarely of horses.

By the dissection and examination of wild tsetse-flies, therefore, it is possible to form an idea of the class of trypanosome to be encountered in a given locality, and an indication of the practical application of this is offered by the recent operations in German East Africa. Had a pre-war survey been possible, enormous saving of animal life might have been effected.

It must not be forgotten, however, that a tsetse-fly may become infected with more than one species of trypanosome—a fact that would complicate the diagnosis by dissection alone, but which also finally dispels the view that one species of fly carries only one species of trypanosome.

In this Protectorate we have found about ten species of trypanosome, the identification of which is made on the main grounds of (1) microscopical appearance, and (2) effect upon animals.

By the microscopical appearance, we can readily distinguish a small form of only 10 to 15 micron from a giant form of 50 to 70. Some trypanosomes possess a long free flagellum; in others this is absent. In some the undulating membrane is much better developed than in others; and in one species a small and characteristic nuclear body, which occurs in all others, is missing.

So by the effect upon animals. There is a group which will not infect dogs and laboratory animals—*e.g.* rats, guinea-pigs, and rabbits; and of this group, most of which can affect cattle and sheep, are species which will not produce disease in horses and mules. There is one, however, which we obtained from Voi, which did not affect any inoculated animal except mules and donkeys. Oxen, sheep, dogs, rats, guinea-pigs, and rabbits were not susceptible; yet the trypanosome was so virulent as to kill mules and donkeys within six days of inoculation, and to reproduce most exaggerated symptoms like those of horse-sickness.

Opposed to this group, the majority of trypanosomes will affect both domestic and laboratory animals—usually, however, with variations in course, or symptoms which can be employed as bases for classification. Thus, one of the most common and serious infections of horses in German East Africa does not kill cattle, although these animals may harbour the trypanosome for years and therefore act as reservoirs. Another form, which killed many cattle in the Fort Hall epidemic of two years ago, is much less pathogenic to horses; for although one or two died of an acute disease, the majority recovered spontaneously, and are still alive and well over two years after infection.

It will be clear to you now that tsetse-fly disease is not due to the fly, but to the particular species of trypanosome conveyed; and with this knowledge it will be understandable how diverse the experience of different men will be. The one may lose all cattle; another all horses. A third will assure you that he has an absolute cure or preventive, because he did not lose his horse or his ox when a fourth owner did. These results are due to nature: due to the species of trypanosome involved, and rarely to any intervention; for we must still regret with the Lieut.-Governor of the Punjab in 1880, that a cure has not yet been found.

The time at my disposal is too short to enter into the vexed question of game and its relation to the *Glossinae*, and I give the Hon. Secretary the free tip that Mr. Percival be asked to afford the Society the benefit of his large experience on this point. But I have said enough to prove to you that the tsetse must acquire the trypanosome infection before it becomes harmful; and we know that many varieties of game can harbour trypanosomes in their blood and serve as reservoirs for these diseases.

I have not enumerated the different species of *Glossina* occurring in this Protectorate, or attempted to describe the particular habits of life of each. As carriers or hosts of trypanosomes, they are all one; though the severity of disease will be modified by habits, just as was the case with mechanical transmission by *Stomoxys* and *Tabanus*. A tsetse which prefers a desert and comparatively game-free country will naturally be less prone to infection than one which lives in a bush and densely game-packed district. The chief carrier of sleeping sickness is *Gl. palpalis*—a fly that will not live away from certain types of river banks. Such an insect must eventually be more dangerous to people who day by day have to go to the river for water or fishing, than one like *Gl. morsitans*, which will live many miles from water and has a wide range of flight. The odds against any one man coming in contact with the same fly at a future time are much less in the case of the restricted and somewhat domesticated *palpalis* than in the disseminated *morsitans*, which studiously avoids habitations.

Let us now turn to the second class of Arthropoda, which we said sucked blood, and were of importance as disease producers—the *Arachnidae*.

Of the five principal orders into which the *Arachnidae* are divided, and which include such forms as spiders and scorpions, only one, the *Acarina*, is relative to our present subject.

The *Acarina* themselves are divided into a number of families, of which the *Ixodidae*, or ticks, and the *Sarcoptidae*, or mites and mange parasites, are the only ones of immediate interest.

The diseases produced in animals by the *Sarcoptidae* are in great measure comparable to those due to lice and fleas: they are, fundamentally, of an external and irritating character, and due to the mechanical annoyance of this parasite itself rather than to any specific micro-organism conveyed. Itch in man, mange in dog and horse, and scab in sheep, are the principal conditions: each is due to distinct and specific forms, which only exceptionally pass from one species of animal to another. Although known as mange in each case, there are species of three distinct genera which may cause the disease—the type and severity of which varies according to the particular parasite involved, and the treatment to be effective must be accordingly modified.

Investigation into the life history of *Sarcoptes Scabei*, the cause of sheep scab, has enabled sheep-owners to check the disease very materially, as it has revealed the weakest point for attack by the dipping-fluids and the interval between dipping that is best for this attack. As this disease is estimated to cause a loss of five million pounds sterling per annum to flock-masters of the British Empire, the importance of this insignificant parasite is apparent.

As with the scab parasite, so also with ticks: the mechanical inconvenience caused by these pests is enormous. Have we not sometimes seen a dog whose body is literally covered with ticks, of all ages and sizes? In some countries of the world, cattle and horses may be seen similarly covered; and you can then well believe that the milk-yield of a cow so attacked may be reduced 40 per cent., and that calves reared under these conditions are stunted and take much longer to come to maturity. In this country it is fortunate that we are not quite so bad as others; but even here our collective losses from mechanical annoyance by ticks must be very great.

Much greater, however, are those due to the tick as a disease-carrier. Relapsing fever of man has caused serious losses among the troops in German East Africa: Redwater, anaplasmosis, and East Coast fever of cattle are a constant drain upon this country's resources, and tick fever of dogs has caused many of us to lose a cherished pet.

In order to appreciate the way in which these diseases are carried, we must be familiar with the life history and habits of the tick; and here at once we find two definite plans, each followed by the members of the two main divisions into which the *Ixodidae* are divided.

The so-called human-tick of Uganda, German East Africa, and the Northern Frontier, and the fowl-tick which occurs at Mombasa, are representatives of the one group, or *Argasidae*, the members of which live in cracks of the walls or floors in buildings, under stones and other sheltered places of camping-grounds, and only come out to feed especially at night. A few minutes suffice for the meal, and they then retire to their seclusion to digest the meal, and in the case of the female to lay a few eggs. This programme may be repeated whenever opportunity offers, for these ticks may live for two or three years.

The disease-germs which these *Argasidae* can carry are of a particular genus known as *Spirillum*, or *Spirochaeta* ; and not only is the tick, once infected, capable of giving the disease at succeeding bites, but the young, born of an infected mother, are also infective. Spirillum or relapsing fever of man, and spirillum disease of fowls, are the only two conditions in this country caused by the *Argasidae* with which I am familiar.

The second group, or *Ixodidae*, is that in which the popularly called tick falls. The adults of this group remain on an animal for many days, during which time blood is being ingested. When replete, the female drops to the ground, and under a tuft of grass or other shelter proceeds to lay her eggs to the number of several thousand, and then dies. She does not, as is the case with the *Argasidae*, return to the attack, and she is therefore incapable of spreading disease directly from one animal to another.

From the egg a minute larva or seed-tick hatches, in one to two months, and these larvae climb up a blade of grass and there await the arrival of a passing animal, to which they attach themselves. In a few days they become engorged with blood, and, according to the species of tick, either fall to the ground in order to moult into a nymph, or undergo that change on the host's body.

If they fall to the ground, they seek a sheltered spot again, and in one to two months the emerged nymph is once more awaiting a passing animal.

The nymph feeds upon the host for some days, and when engorged once more requires to moult—an operation which takes place on the animal or on the ground, depending again upon the species concerned. One to two months after the repletion of the nymph, the fully mature and sexually perfect adult or imago, which results from the moult, is ready to feed again. Copulation is effected; the fecundated female when replete falls off the animal, and shortly after commences ovipositing, and we have therefore a complete metamorphosis with larval, nymphal, and adult stage passed upon an animal host.

The blue-tick of Redwater and Anaplasmosis (*Boophilus annulatus*) passes all three stages and effects both moults on the one host. The red-legged-tick of horse-biliary fever (*Rhipicephalus evertsi*) passes the larval and nymphal stages on one host, and moults from nymph to adult on the ground. The brown-tick of East Coast fever, and sheep gastro-enteritis (*Rh. appendiculatus*), the bont-tick of Heartwater (*Amblyomma variegatum*), and the dog-tick of tick fever (*Haemaphysalis Leachii*) require three hosts, moulting from larva to nymph, and from nymph to adult, on the ground.

With the exceptions of the viruses of sheep gastro-enteritis and of Heartwater, which belong to the ultravisible class, the organisms conveyed by the above-mentioned ticks belong to the Protozoa; but, unlike trypanosomes, which swim about in the blood, these are non-motile, and are found within the red blood corpuscles. From the pear-shaped body of the first-discovered member they are termed *Piroplasma*.

Although it is known that these *Piroplasma* must undergo some developmental cycle in the ticks, research has not yet clearly demonstrated it; but experimental evidence shows that for each disease, the cause of which is distinct, a cycle different or modified is undergone.

It is by this knowledge of transmission that stock-owners are enabled to circumvent disease: either by destroying all ticks or, failing this, those forms or stages which acquire or which give infection.

We have emphasised that the *Ixodidae* do not directly pass from one animal to another; and in the case of the blue-tick of Redwater it was stated that all stages, from larva to adult, were spent on a single host. It might therefore be asked how such a tick could carry disease. Experiments show that the young larvae, born of a parent that fed upon an ox in which the Redwater parasites are present, will convey the disease when they first attach themselves to a host.

It has also been shown that even though these larvae feed upon a horse or other animal which is not susceptible to the bovine Redwater parasite, and reaching maturity eventually give rise to a second generation of larvae, these, too, are still infective and capable of giving rise to the disease. Infection then passes through the egg.

The parasite of dog-tick fever (*Piroplasma canis*) also passes through the egg, having been acquired by the adult female feeding upon a parasite-containing dog; but in this case the infection is not given to the dog upon which the larvae feed, nor to that on which the nymphs feed. The infection lies dormant through these two stages, and is only transmitted by the bite of the young adult tick.

In East Coast fever the infection is acquired at the larval feed and conveyed as a nymph; or acquired as a nymph and given as an adult. The parasite cannot lie dormant through the nymphal stage, nor does it pass through the egg.

Biliary fever of the horse is acquired during the larval or nymphal stage, which in the case of *Rh. evertsi* are passed on the same host, and given by the young adult.

Heartwater infection is acquired at either the larval or the nymphal stage, and given at the succeeding one, as is the case with East Coast fever: but here the infection may lie dormant through the nymphal stage should this be passed on an unsusceptible animal, and be transmitted as an adult. It does not pass through the egg.

Gastro-enteritis in sheep can be transmitted by an adult *Rh. appendiculatus*, the brown-tick, which fed as a nymph on a sick sheep. Up to now, we have been unable to incriminate any other stages.

In addition to the above-mentioned ticks there are four other species fairly common in certain parts of the Protectorate, which we have not yet been able to rear successfully under experimental conditions, and they have, therefore, not yet been proved carriers of any disease. But there is no doubt that subsequent research will show them capable of transmitting some infection either known or new.

The importance of being able to breed and rear ticks is obvious in view of what was said regarding their destruction at different stages. A knowledge of the length of time any particular stage remains on an animal is imperative, otherwise the dipping-fluid may be applied at such an interval that the tick had been on the animal, conveyed, or taken infection, and left before the next application.

The blue-tick, which passes all stages on the one host, and stays there about a month, is naturally more easily dealt with than the brown-tick, which in its dangerous larval and nymphal stages may only remain on an animal for as short a period as three days, and a dipping-bath efficacious against the first would be practically useless against the second.

The time various stages of tick remain on the ground is equally important. They do not live for ever; and it has been shown that by destocking pastures for eighteen months all *Ixodidae* will have been starved out. This is not always possible; but destocking of portions of the land may also be employed. Suppose, for instance, an owner has several cases of East Coast fever in cattle grazing on a portion of his land. If he so kraals those animals that the infective larvae or nymphae fall on a restricted area, he may with confidence move the clean balance of his herd to the uninfected lands. These larvae and nymphs will take at least a month to moult and become infective, by which time the stock has been moved out of their range.

Such are the methods for circumvention of disease, which are only possible when full knowledge of parasite and insect has been acquired. The study is as yet in its infancy; but even this infant has effected savings of millions of pounds. How much more will the grown-up be capable of?

To reach the grown-up stage quickly there must be more workers following upon organised lines. If I have set your cerebral cells moving in this direction and obtained one disciple to the view that my subject is natural history in the real meaning of the term, I am satisfied; for I know this Society will foster that disciple, and one can reasonably look to the day when it will have achieved even greater celebrity as an organisation competent, qualified, and willing to consider the vast economic problems which lie even within the least of the lesser animals.