Carriers of Animal Diseases

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Flies, ticks, and other arthropods spread and perpetuate many livestock diseases. Most are of comparatively minor concern as direct causes of injury or annoyance but, like the fever ticks of cattle, are important as reservoirs and vectors of disease-causing organisms. Some, like the tsetse flies in Africa, are of no consequence as pests, yet are a limiting factor in the production of livestock.

The remarkable ways of insects and their allies in transmitting diseases are as varied and spectacular as the diseases themselves and the vectors that transmit them. Common house flies, however benign and unspectacular they may seem, often carry on their feet and mouth parts or in their bodies the contaminating germs of everyday skin and generalized infections and sometimes even the dreaded bacilli of anthrax or the fatal toxin of botulism. Other insects, mites, and bugs of various kinds transmit the infective stages of numerous parasites, final infection usually resulting from accidental swallowing of the infected vector by a susceptible animal. Disease caused by tropical warble flies, which are next in importance to the cattle fever tick among the external parasites of livestock in Latin America and analogous to the better known warble flies of Temperate Zones, is essentially insect-borne—the flies attach their eggs to captured mosquitoes (Psorophora), which in turn transport the infection to cattle and other animals.

The afore-mentioned examples are illustrative only of the ways in which insects carry diseases. With the notable exceptions of tick-borne fever of cattle and tsetse fly disease, they are scarcely typical of the principal arthropod-borne diseases of livestock. As might be suspected, the chief vectors are predominantly bloodsucking species, and the diseases transmitted by them are essentially blood infections. Those vectors ordinarily spread and propagate disease in two ways. One, mechanical transmission, is the direct transfer (or its equivalent) of infective blood from diseased to healthy animals. The other, biological transmission, represents a specialized and complex relationship among vector, organism, and host, which is characterized by reproduction and structural change of the disease-causing organism within the body of the vector. Some biting flies function naturally in both ways. For a short period, probably not more than 2 hours, after feeding on the blood of a diseased animal, the dangerous organisms may be carried to healthy, susceptible animals on which the fly may chance to feed. For a longer period thereafter, from a few days to several weeks, the fly is incapable of transmitting the infection. Then it may again become infective in consequence of a biological reconstitution of the organism, culminating in the production of new infective stages in its salivary glands or other tissues.

The arthropod-borne diseases of domestic animals are of two main kinds: Those caused by plant microorganisms and those caused by animal micro-organisms. The former comprise bacteria, spirochetes (Borrelia), Rickettsiae, (Coxiella), and viruses. The latter, in part, are pathogenic protozoa, including piroplasms (Babesia), Theileria, the trypanosomes, Leishmaniae, Leucocytozoa, and a species of Haemoproteus. Animals that recover from disease caused by some of these organisms may remain carriers, or apparently healthy animals that are dangerous seedbeds of infection, for long periods or for life.

The bacterial diseases that are sometimes carried by arthropods are
Anthrax, tularemia, swine erysipelas, and botulism (limber neck of birds). All are spread by other means, and the role of arthropods is accidental and mechanical.

Anthrax, an acute disease caused by *Bacillus anthracis*, affects all classes of mammals, including man. Infections in livestock are generally acquired during grazing. Incidence is especially high during the fly season, and outbreaks in cattle have been ascribed to fly transmission. The vectors are the black horse fly and other horse flies, the stable fly, mosquitoes (*Psorophora sayi* and *Aedes sylvestrus*), and several nonbiting species, including the house fly and blow flies (*Calliphora*). The ear tick and even ants also have been suspected.

Tularemia, caused by *Bacterium tularensis*, is primarily an infection of small wild animals, such as rabbits, squirrels, rats, mice, woodchucks, opossums, and grouse, but it can be transmitted to man, sheep, swine, dogs, and cats. The disease is transmitted commonly by contact, sometimes by the ingestion of contaminated food and water, and occasionally by the bites of ticks, flies, lice, and bed bugs.

Swine erysipelas is a prevalent infectious disease that biting flies may spread from pig to pig. We do not know the extent to which it is insect-borne, but such transmission has been demonstrated experimentally with the stable fly. The infectious organism, *Erysipelothrix rhusiopathiae*, is an invader of the blood, joint membranes, and other tissues. Death is uncommon, but condition and marketability are seriously affected.

Botulism, or limber neck of chickens, is a fatal condition induced by the potent toxin of *Clostridium botulinum*. Ordinarily it follows ingestion of canned vegetables that have become contaminated with the organism. At times chickens become ill and die from ingesting blow fly maggots that have developed in contaminated meat.

Spirochetes affect all animals and get from host to host in many ways. They are minute, spiral organisms, which show some affinities to the protozoa but are commonly regarded as bacteria. We mention two examples, both tick-borne.

*Borrelia theileri* is responsible in South Africa for a benign, febrile disease of cattle, sheep, and horses. It occurs in the blood stream and is transmitted biologically by one- and two-host ticks, *Boophilus decoloratus* and *Rhipicephalus evertsi*, and possibly by others.

*Borrelia anserina* causes relapsing fever, or spirochetosis, in chickens, turkeys, ducks, and geese. It occurs in Asia, Africa, South America, and elsewhere. It has been found in a few epizootics of turkeys in the United States. It causes a rapidly fatal blood infection. The fowl tick and probably the chicken mite are vectors. Mosquitoes also are suspected.

Rickettsiae, which are intermediate between bacteria and viruses, cause many serious diseases of man as well as animals. One of these, Q fever, caused by *Coxiella burnetii*, is a disease of man, but cattle probably are the source of most human infections. The disease is recognized now in many parts of the world, including the United States. Ticks carry the organisms, and natural infections have been found in numerous species (Rocky Mountain wood tick, Pacific Coast tick, lone star tick, brown dog tick, and others).

A few other rickettsial infections of livestock, such as heart water fever of ruminants, occur outside the United States. Ticks, as far as we know, are the only vectors.

Virus diseases are numerous, and many are mechanically transmitted, wholly or in part, by arthropods, particularly biting flies.

The ones transmitted mainly by these agents are equine infectious anemia, infectious equine encephalomyelitis, African horse sickness, Japanese B encephalitis, louping ill of sheep, Nairobi
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disease of sheep, blue tongue of sheep, and rift valley fever. At times arthropods are presumably instrumental also in the transmission of fowl pox, swine pox, myxomatosis of rabbits, and infectious enteritis of cats.

Equine infectious anemia, or swamp fever, occurs throughout the world. It destroys the working efficiency of thousands of horses, mules, and donkeys. Its natural spread is imperfectly understood, but the disease is readily produced experimentally in susceptible animals by injection of infectious material, such as blood or other tissue fluids from infected animals. Under experimental conditions, the virus has been transmitted by horse flies (Tabanus septentrionalis and T. sulcifrons), stable flies, mosquitoes (Psorophora columbae), and biting lice (Bovicola pilosa?). The probability that direct mechanical transmission by biting flies commonly occurs is emphasized both by the summer intensity of the disease and the persistence of the virus in the blood of infected hosts.

Infectious equine encephalomyelitis is caused by so-called Eastern, Western, and Venezuelan types of virus in North and South America and neighboring islands. Man is susceptible to all types. Natural reservoirs, particularly birds, are a probable source of infection to mosquitoes, which are the common vectors of the virus. The virus types have been recovered from or experimentally transmitted by a large number of arthropod species, among them the yellow-fever mosquito, salt-marsh mosquitoes (Aedes), other mosquitoes (Culex, Culiseta, and Mansonia), the bloodsucking conenose, the Rocky Mountain wood tick, the chicken mite, and chicken lice (Menopon pallidum and Eumenacanthus stramineus). In the tick, the virus is present at all stages of development, but scientists do not know yet whether the virus passes through the egg.

African horse sickness, an acute and virulent infection of equine species in central and southern Africa, is presumed to be transmitted by arthropods, mainly because of apparently convincing evidence that the disease does not pass directly from animal to animal. Mosquitoes, horse flies, midges, and other insects have been suspected as vectors.

Japanese B encephalitis, a fatal virus infection of man, is not a disease of domestic animals, but domestic animals, especially the horse, are dangerous reservoirs of the virus. It occurs in the Far East, where it is transmitted biologically by hibernating culicine mosquitoes (the southern house mosquito and others).

Several virus infections of sheep, all of which affect other animals in some degree and most of which are transmissible to man, are biologically and exclusively spread by arthropods. They are serious diseases in several parts of the world. Louping ill, transmitted by the castor bean tick (Ixodes ricinus), is prevalent in the British Isles. Rift valley fever, transmitted by mosquitoes (Eretmopodites), and Nairobi disease, carried by ticks (Rhipicephalus appendiculatus), occur in Kenya, British East Africa. Blue tongue, a more widespread disease, is carried by midges (Culicoides).

Fowl pox, a widespread and serious disease of chickens, turkeys, and pheasants, is often transmitted by the northern house mosquito and the yellow-fever mosquito, possibly, in some instances, by a biological mechanism. Ordinarily, however, it is passed directly from bird to bird. Swine pox, another virus disease, does not appear to be directly infectious but is probably transmitted mainly by the sucking lice of hogs (Haematopinus suis). Feline infectious enteritis is a common, fatal disease of kittens. The cat flea is presumed to be an important vector, although the disease is more commonly spread by direct contact with diseased animals or contaminated quarters. Myxomatosis, which occurs in California, is a fast-spreading, fatal disease of rabbits, that is carried both by contact and by mosquitoes (Culex annulirostris and Aedes theobaldi?).
Tick paralysis of cattle is actually caused, rather than carried, by ticks, yet it is a specific clinical entity characterized by complete paralysis in severe cases. Outbreaks in the Rocky Mountain States and British Columbia have resulted from infestation with the Rocky Mountain wood tick. Tick removal usually affords prompt relief. Other ticks (the American dog tick in the East and species of *Ixodes* in Australia and elsewhere) cause the condition. The symptoms are apparently due to the injection of toxin by female ticks at a particular stage in their sexual development.

Arthropod-borne, protozoan diseases of livestock, in contrast to most of the diseases already discussed, are distinct from those affecting man. The only exceptions, known technically as leishmaniasis and Chagas’ disease (*Trypanosoma cruzi* infection), are predominantly human afflictions, although they also occur naturally in dogs and some other animals. A disease of extreme importance in man and of even greater importance in livestock is sometimes referred to as African trypanosomiasis but the specific organisms that cause disease in animals are not infective to man. On the other hand, the species affecting man (*Trypanosoma gambiense* and *T. rhodesiense*), although experimentally transmissible, are diagnosable in animals only as *T. Brucei*, which is a most serious disease-causing species.

Poultry (chickens, turkeys, pigeons, ducks, and geese) are subject to two insect-borne diseases caused by related protozoan parasites, namely, *Haemoproteus columbae* and *Leucocytozoan smithi*. Both occur in the United States. The former is a parasite of pigeons, although this or related species also occur in other birds. Commonly referred to as pigeon malaria, the disease is carried by pigeon flies (*Lynchia maura* and *Pseudolynchia canariensis*). The latter, possibly comprising more than one species, affects other classes of poultry and is transmitted by black flies (*Simulium occidentale, S. venustum, S. nigroparum, S. slosonae, and S. jenningsi*) and perhaps by mosquitoes.

Anaplasmosis, caused by *Anaplasma marginale*, an organism of indefinite classification, clinically resembles cattle fever and was not recognized as a widespread disease in the United States until fever ticks were eradicated from a large part of the cattle fever area. Because the disease is coextensive with cattle fever, vectors of the latter are presumed to be transmitters of anaplasmosis. This incriminates the principal species of fever ticks (*Boophilus annulatus, B. microplus, and B. decoloratus*). However, the persistence of the disease, which is not contagious, in areas without fever ticks indicated clearly that there were other vectors. Much experimental work has revealed that other ticks (American dog tick, Rocky Mountain wood tick, Pacific Coast tick, brown dog tick, and possibly others) can transmit the disease, although we do not know their natural capacity to do so. Several species of horse flies and some mosquitoes have also been demonstrated to be potential mechanical vectors.

Aegyptianellosis, caused by *Aegyptianella pullorum*, another organism of uncertain zoological classification, affects chickens, ducks, and geese. It is transmitted by the fowl tick and occurs in Africa and in parts of Europe and Asia.

Piroplasmosis, one of the most devastating groups of diseases of domestic animals, affects cattle, horses, sheep, swine, and dogs.

The causative organisms, all biologically transmitted by ticks, are: In cattle, *Babesia bigemina, B. argentina, and B. bovis*; in horses, *B. equi* and *B. caballi*; in sheep, *B. motasi and B. ovis*; in swine, *B. traumanni and B. perroncitoi*; and in dogs, *B. canis* and *B. gibsoni*. These are microscopic, single-celled parasites that enter and destroy the red blood cells. When the disease is acute, or fulminating, the parasites multiply rapidly and cause
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dearth in most cases. The symptoms are
those associated with destruction of
red blood cells, namely, fever, anemia,
jaundice, thick bile, enlargement of
liver and spleen, and emaciation. Ticks
ingest the organisms during their en-
gorgement on infected animals. Car-
riers, rather than acutely ill animals,
are commonly the chief source of tick
infection. In ticks, the parasites mul-
tiply and invade all tissues, including
the salivary glands. The cattle tick, all
stages of which live on one animal,
transmits the parasites through its eggs
to the next generation of larvae, or
seed ticks, which carry the disease to a
new host.

CATTLE TICK FEVER, or bovine piro-
plasmosis, is prevalent throughout the
world. It causes incalculable losses. The
history of the disease in the United
States is a remarkable chapter of medi-
cal science. First came the demonstra-
tion in 1893 of tick transmission by
Theobald Smith and F. L. Kilborne,
of the Department of Agriculture—a
discovery of immense benefit because
it pointed the way to the solution of
other disease problems. Then came the
remarkable campaign, begun in 1906,
to eradicate the cattle tick, and with
it, cattle fever. The painstaking studies
that laid the groundwork for success
included researches into the habits and
distribution of cattle ticks, determina-
tions of their capacity to transmit cattle
fever, establishment of the northern
limits of the disease, the promulgation
and enforcement of quarantines gov-
erning the shipment of cattle, and the
critical evaluation of arsenical dips
against the cattle tick. When the pro-
gram of tick eradication was finally de-
vised, cattle fever was causing losses
exceeding 40 million dollars annually
in the South and Southwest. As of 1952,
and for more than a decade, the dis-
case and fever ticks have been all but
eradicated from the country. The fight
against this disease is the most exten-
sive campaign ever waged against par-
asitic disease in livestock. The total cost
amounted to scarcely more than the
toll that was formerly taken by the dis-
ease in a single year.

In the areas of their respective dis-
tributions, many ticks transmit the
three afore-mentioned species of Ba-essia among cattle. Chief among them
are Boophilus annulatus, B. microplus,
B. decoloratus, Rhipicephalus appen-
diculatus, R. evertsi, R. bursa, Ixodes
ricinus, I. persulcatus, and Haemaphy-
salis cinnabarina.

Tick fever of horses does not occur
in the United States but is a common
and serious disease throughout tropical
and temperate zones. The two species
of Babesia utilize tick vectors belonging
principally to the genera Rhipicepha-
lus, Hyalomma, and Dermacentor.
The story of the piroplasmoses af-
fecting other animals is similar, al-
though Babesia infections of sheep,
swine, and dogs are not of comparable
economic importance to those affect-
ing cattle and horses. Canine piroplas-
mosis occurs in the United States. It is
the only Babesia infection of domestic
animals that has been found in this
country since 1939. The brown dog
tick and probably other ticks (Dermacen-
tor reticulatus, D. andersoni, Haemaphy-
salis leachi, and H. bispinosa)
are vectors of the species of Babesia
affecting dogs.

Theileriasis principally affects cat-
tle in Africa, but it occurs in sheep,
goats, and dogs and on other contin-
ents. It is similar to piroplasmosis but
does not commonly cause jaundice,
hemoglobinuria (hemoglobin in the
urine), or anemia. Theileriae do not
multiply in and destroy red cells but
enter them only after multiplication in
the so-called endothelial tissues. The
causative organisms are: In cattle,
Theileria parva, T. annulata, and T.
mutans; in sheep and goats, T. ovis
and T. recondita; and in dogs, Ran-
gelia vitali. T. mutans is an essentially
harmless species. The species of Thei-
leria are transmitted by two- and three-
host ticks in contrast to the usual trans-
mission of Babesia of cattle fever by
one-host ticks. Associated with this dif-
ference in vectors are differences in the biology of transmission. Theileriae develop in successive stages of ticks and are not transmitted hereditarily, or through the eggs, to successive generations as in the case of Babesia. Ticks usually acquire the organisms during their larval stages and carry them to new hosts during succeeding nymphal stages.

**East Coast Fever**, caused by *Theileria parva*, is a fatal disease of cattle in South Africa. The chief vectors are species of *Rhipecephalus* (*R. appendiculatus*, *R. capensis*, *R. evertsi*, and *R. simus*). A milder form of bovine theileriosis, caused by *T. annulata*, is transmitted by *Hyalomma mauritanicum* in North Africa and by *H. dromedarii asiaticum* in Central Asia.

In sheep, goats, and dogs, theileriosis, although a serious infection, is not of comparable importance to the disease in cattle. Of interest is the fact that a soft, or argasid, tick (*Ornithodoros lahorensis*) is presumed on experimental grounds to be a vector of the disease among sheep and goats. All other ticks that transmit protozoan infections are hard, or ixodid, ticks.

**Trypanosomiasis** is a group name for several related diseases, each of which is caused by a specific trypanosome. It includes some of the worst illnesses of domestic animals and man. It is the only disease that by itself has denied vast areas of land to all domestic animals other than poultry. The areas of complete denial are all in Africa. One-fourth of Africa is controlled by tsetse flies (*Glossina*), which are principal vectors of trypanosomes. The disease is, however, a major livestock scourge in every continent except Australia. Moreover, the exclusive occurrence of tsetse flies in Africa makes it evident that other vectors and mechanisms are responsible for the spread of the disease outside of Africa and, indeed, that they are operative within the tsetse fly area.

Nine species of trypanosomes produce disease of livestock. Four (*Trypanosoma congolense*, *T. brucei*, *T. simiae*, and *T. uniforme*) are found only in the tsetse fly areas. Two others (*T. vivax* and *T. theileri*) exist therein but are also established in other areas, where they are mechanically transmitted by horse flies (*Tabanus*) and other biting flies, exclusive of tsetse. These are the half-dozen species responsible for nagana, the African animal trypanosomiasis. The three remaining species (*T. evansi*, *T. equinum*, and *T. equiperdum*) cause severe diseases in horses (surra, mal de caderas, and dourine). Mal de caderas occurs in South America. Surra and dourine occur worldwide. Both have occurred in the United States, but constant vigilance and prompt eradicative measures have kept them from becoming established. Surra and dourine also employ particularly interesting methods of transmission. The former is usually transmitted mechanically by horse flies and other biting insects. However, it is probably identical with murrina, an affliction of horses in Panama that has heretofore been ascribed to *Trypanosoma hippicum* rather than *T. evansi*. This infection (murrina) incriminates the vampire bat (*Desmodus rotundus murinus*), this being the only instance of mammalian transmission of a protozoan disease. Dourine, on the other hand, is ordinarily transmitted during coitus, and is therefore frequently referred to as horse syphilis. It is consequently confined to horses and donkeys, occurring chiefly among breeding stock.

Eight (all but *T. equinum*) of the nine disease-causing trypanosomes of livestock are encountered in Africa; namely, the four afore-mentioned, indigenous species, two of cosmopolitan distribution that affect horses, and two extra-African species that also cause nagana. The latter, *T. vivax* and *T. theileri*, have outgrown their dependence on tsetse flies. In Africa, however, *T. vivax* is associated closely with *Glossina* and is as dependent as *T. congolense*. *T. vivax* is a cause of cattle tryp-
anosomiasis in South and Central America, where biting flies presumably transmit it. *T. theileri*, similarly spread, is of cosmopolitan distribution in cattle but only occasionally causes severe disease. It occurs in North America, where it is apparently noninjurious.

Nagana, or African trypanosomiasis of animals, caused by some six species, already named, affects all mammals. Economically it is the most important protozoan disease of livestock. In cattle the species responsible for the disease, in order of importance, are *T. congolense*, *T. vivax*, and *T. uniforme*. The first two account for most of the cases. *T. congolense* occurs throughout the tsetse fly areas and is the most virulent trypanosome affecting animals. The organisms are found only in the blood. In the case of *T. vivax*, organisms are not readily found in the blood stream but may generally be demonstrated in a gland smear.

A study of cattle losses in Nigeria revealed that 30 of every 100 deaths were due to nagana.

In horses, the principal species causing nagana are *T. brucei* and *T. congolense*. *T. vivax* sometimes infects horses but rarely causes symptoms. *T. brucei*, like *T. vivax*, is more readily found in glandular tissue than in blood. Horses infected with either *T. brucei* or *T. congolense* almost always die unless they are adequately treated.

In sheep and goats, nagana is caused by the same species that cause it in horses. *T. congolense* infections, in contrast to those associated with other trypanosomes, is characterized by a sameness of grave disease in cattle, horses, sheep, and goats.

In swine, the chief pathogen is *T. simiae*, which has been called the lightning destroyer of pigs. Swine are susceptible to infection with *T. brucei* and *T. congolense*, but these species rarely produce symptoms. *T. simiae* infection of pigs is extremely acute. Animals in apparently good health are taken ill overnight and die the next day.

Camels and dogs are notably susceptible to trypanosomiasis; in them, *T. evansi*, the cause of surra in horses, produces the same disease. Some authorities regard surra as a predominantly camel disease. Camels and dogs are also victims of severe and fatal disease caused by *T. congolense* and *T. brucei*. Camels, but not dogs, are subject to the same hyperacute disease caused by *T. simiae* that occurs in pigs. This species, as suggested by its name, also causes fatal illness in monkeys.

The transmission of nagana is both biological and mechanical. Tsetse flies are the only biological vectors, but they and other biting flies transmit the infections mechanically. The cyclical development of trypanosomes in tsetse flies is exceedingly complicated, since it varies with different species of trypanosomes and even with the same species in different tsetse fly species. In general, *T. congolense*, for example, initiates its development in the alimentary tract of the fly. Then elongated organisms move to the hypopharynx, where attached intermediate forms and free trypanosomes successively develop. In the case of *T. vivax*, all development takes place in the mouth parts of the fly. Usually from 2 to 4 weeks are required for multiplication and metamorphosis in the fly.

All forms of nagana are also spread by the interrupted feeding of biting flies, including tsetses, and this may be the normal method of transmission when outbreaks occur. Throughout the tsetse fly region of equatorial Africa, there exist numerous horse flies and other biting flies, notably *Chrysops* and *Haematopota*. With reference to these genera, probably all species act as mechanical vectors. Small flies are poorer vectors than large ones.

Extensive studies of nagana seem to warrant the general deduction that mechanical vectors have a large part in the spread of African trypanosomiasis but that cyclical development in tsetse flies is essential to the perpetuation of the diseases. Eradication of tsetse flies from any area has always eliminated nagana completely.

Tsetse flies, found only in Africa,
owe their importance entirely to the fact that they are vectors of trypanosomes. The principal species, about 20, vary considerably in size, abundance, distribution, habits, susceptibility to adverse environment, and economic importance. They are about the size of house flies. Low mean temperatures generally are unfavorable to them. They cannot endure dry heat or temperature above 106°F., even in areas of high humidity. Vegetation must be ample for the support of reservoir and other host animals, since blood is the sole food of tsetse, but treeless grassland, deciduous bushland, and woodlands with a thick underbrush are unfavorable. Rainfall or fresh-water streams must be abundant where the flies and their mammalian hosts reach maximum populations. Some tsetses in East Africa, however, are well adapted to comparatively arid districts. Because of this delicate environmental adjustment, tree clearance, burning of grass and brush, establishment of zones of vegetation-clearance, and like measures have been useful in controlling the flies. Seasonal changes and other natural factors cause expansion and contraction of fly belts.

Unlike mosquitoes, which are the only insects of greater medical importance than the tsetses, males as well as females are bloodsuckers. They feed mainly on large game and domestic animals. Native game, however, are comparatively resistant but serve as reservoirs of trypanosomes. Probably no trypanosome is pathogenic to its normal host. In any event, notwithstanding a complete dependence on large mammals, neither tsetse flies nor trypanosomes are especially host-specific. Some authorities also believe that any species of tsetse fly probably can transmit any species of pathogenic trypanosome with which it comes in common contact.

In addition to peculiar feeding habits and the comparative immunity of native game reservoirs, the method of reproduction of tsetse flies increases the difficulties of control. Females do not lay eggs like most insects. They give birth to live young and deposit the larvae in haunts that are peculiar to the individual species. Larvicides therefore are of no avail, and breeding places cannot be eradicated.

Adult tsetse flies probably do not live longer than 8 or 10 months. Their cycle of development is comparatively simple and direct. Females produce their first larvae about 3 or 4 weeks after mating. One large larva is produced at a time, but a new larva begins its development as soon as one is born. Successive larvae are produced every 9 to 14 days. The larvae pupate promptly in warm, loose soil of protected, shady areas. Pupation lasts 2 weeks to 4 months, and the adults rarely emerge unless the temperature is above 70° and below 87°.

The control of nagana—tsetse fly disease, or African animal trypanosomiasis—is much more than an entomological or veterinary problem. It is acutely beset with economic and sociological obstacles and with the basic agricultural problems of land usage and soil erosion. But such considerations do not lower the value of continued effort to achieve better control through therapy, prophylaxis, and immunization directed against the trypanosomes, through eradicative and limiting measures directed against tsetse flies, and through modifications of the environment to make it unfavorable for the continuance of trypanosomal diseases. Increased utilization of disease-resistant breeds of livestock, such as the West African Shorthorn cattle, for example, may also be a measure of great potential value.

The outlook for better control of insect-borne diseases is bright. The discoveries of new insecticides and the devising of effective formulations and methods of application have in large measure provided the means for a concerted attack upon the insect vectors. New chemicals for treatment of these diseases and methods of immunization against them are also available. Finally,
an ever-increasing knowledge of all aspects of insect-borne diseases has provided the foundations essential to the success of applied control measures. Seemingly the major limiting factor in the achievement of unprecedented, constructive victories is the modest economic burden that would be temporarily imposed.

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Insects and Helminths

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Many species of the helminths, or parasitic worms, of livestock and poultry can pass through certain of their early stages only within the body of an insect. These species are transmitted, in the true sense, by insects. Beetle mites or grass mites similarly transmit others. One species is transmitted by a tick as well as by insects. These particular species of worms are obligatory parasites of insects, or their allies, just as truly as they are obligatory parasites of farm animals or birds. For their continued existence and propagation, for their survival as species, they depend equally upon insect and upon avian or mammalian hosts.

The life cycle of a helminth of one of these species, like the life cycle of all other parasitic helminths, is initiated by the eggs or microscopic larvae produced by the mature female or hermaphroditic individual. But depending on its specific identity, its eggs or larvae are infectious only to an insect or a mite or perhaps a tick. If ingested by a suitable insect, for example, each egg or larva gives rise to a more advanced developmental stage of the parasite, which takes up its abode in some part of the insect's body. There, however, the development of the worm stops at a stage far short of reproductive maturity. Unless this arrested-developmental stage gains access to the body of a suitable vertebrate animal, the life cycle of the parasite cannot be completed. Obviously, therefore, any step that can be taken to destroy infected insects will aid in preventing the infection of livestock and poultry with worms that have this type of life cycle. The world-wide extermination of the insect vectors, were this possible, would