Carriers of Human Diseases

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Through the centuries people have been plagued by insects and have died by the millions from diseases carried by them. Man is gradually gaining mastery over them, but the battle is long and expensive, the burden is too heavy for the poor in many parts of the world, and we still have much to learn about these agents of death.

Probably 10,000 kinds of mites, ticks, and insects infect man directly or indirectly with disease. Most of them are only occasional and accidental carriers. Many spread diseases among livestock and wildlife and carry them from the animal reservoirs of infections back to persons.

**INSECTS TRANSMIT DISEASE** in many complex ways.

First, their mere presence or attack, without the transfer of germs, may produce a disease or harmful condition. Itch mites and screw-worms that invade the tissues are of this type. Some insects cause accidental injury to sense organs. Others produce intense itching and allergies, such as are caused by body lice, bee stings, and bites of chiggers and ticks. Some persons have idiosyncrasies that intensify their reaction to such attacks.

A fly or other insect that walks over and feeds on filth and then deposits the germ-laden contaminants on food by crawling over it, vomiting on it, or defecating on it is spoken of as a mechanical carrier. An insect, such as a house fly, is also a mechanical carrier when it picks up germs by biting a diseased animal or person and then carries the germ on its beak until it bites a healthy individual.

More complex is the relationship among insect, disease, and man when the disease germ multiplies in the insect but does not change greatly in form. That occurs in fleas when they ingest plague organisms with the blood of a plague-stricken rat.

The most complex relationship is illustrated by anopheline mosquitoes in transmitting malaria. The malaria organisms in the blood of man at times produce male and female cells. The mosquito ingests the cells when it bites. The cells mate in the mosquito's stomach and develop into active ookinetes, which penetrate the stomach wall of the mosquito and thereon form cysts. Cell division takes place in the cysts, and hundreds of small, spindle-shaped sporozoites are formed.

The greatly enlarged oocyst then bursts open within the insect's body cavity. The active sporozoites swarm out, soon reach and penetrate the salivary glands, and are ready to pass into the blood stream of the next person the mosquito bites. This cycle, which takes 7 to 10 days, is called the essential or sexual cycle. Upon entering the blood stream, the minute malaria organisms—the sporozoites—enter such organs as the liver. In a few days they attack the red blood cells, in which they go through another cycle of growth and multiplication. Some ultimately become sexually mature, ready for other mosquitoes to ingest, and so repeat the sexual cycle in the insect.

Many variations occur in this method of disease transmission, which is called obligatory or cyclic because the disease organism is dependent on an insect for its continued natural transmission.

**INSECTS CARRY DISEASE ORGANISMS** of many types, among them microscopic viruses, bacteria, and protozoa and the larger roundworms and tape-worms. Ways by which disease organisms are kept alive in higher animals and insects and are passed from one generation to another frequently are very complex. Unraveling them has often required great scientific imagina-
tion and patient skill. We give some examples later. Sometimes disease organisms are carried from one stage of an insect host to another, with the intermediate stage or stages not transmitting infection or even living as parasites. In many instances the disease agents pass through the egg from one host generation to the next.

The disease cycle can be broken by destroying the insect vector, by using drugs to kill or suppress the disease organisms in the human host, or by immunization. Most successful usually is a combination of the three, plus isolation of infected persons (to prevent the insect vector from acquiring the disease organism) and such sanitary measures as screening to protect healthy persons.

Does the disease make the insect sick or kill it? Sometimes the infected insect is not injured in any way—apparently it has become tolerant. Sometimes its life span may be shortened. Occasionally it may be killed—when that happens, that particular kind of insect is not a usual or well-adapted carrier of those particular disease germs.

**INSECTS OF THE ORDER DIPTERA,** or two-winged flies, perhaps are responsible for more human illness and death than any other group. They may rank with the world's top killers of man. Mosquitoes inhabit practically all parts of the earth except the polar regions. They alone carry malaria, yellow fever, dengue, and bancroftian and malayan filariasis. They also carry certain types of encephalitis and may be involved occasionally in the mechanical transfer of tularemia and anthrax.

Malaria, the great disabler, prevails throughout the Tropics and much of the temperate regions. Outbreaks have occurred in Canada and as far north as Archangel in Soviet Russia. Species of dapple-winged *Anopheles* mosquitoes are the carriers of human malaria.

Large areas of the United States once were malarious, but as the swamps were drained and the land tilled and people got into screened houses, the malady was pushed southward. There the mild climate and abundant water areas gave opportunity for mosquitoes to breed in numbers during the long summer. The malaria parasites also developed in the mosquitoes and people were more exposed, because they spent more time outside during the warm evenings. Poorly built and unscreened houses sometimes permitted infection to occur even indoors. Since 1943 the disease has been further reduced by the use of DDT. There is little malaria now in the United States.

About a dozen species of *Anopheles* mosquitoes occur in the United States, but only one in the Eastern and Southern States has been important in transmitting malaria. Likewise in the Pacific States a single species, but a different one, is the natural carrier. Scores of different kinds of *Anopheles* exist in various parts of the world. Their varying breeding and biting habits determine which control measures are instituted in any area. Some carry malaria. Others have no part in infecting man.

Yellow fever, or yellow jack, periodically put terror in the hearts of our people, especially in the South in the early days. When Reed, Carroll, Lazear, and Agramonte proved in 1901 that a semidomestic mosquito, now known as the yellow-fever mosquito, was the vector, some of the terror disappeared. But although we know how to control or eradicate the mosquito, and although a protective vaccine has been developed, the disease is still regarded as a serious threat to this country and to many other warmer parts of the world. A deadly virus disease, it still lurks in the jungles of South America and Africa. To start serious trouble, the virus needs only to be transferred by jungle species of mosquitoes from an infected monkey to a man, who in turn may infect the yellow-fever mosquito in a populous area. Indeed, this insidious disease has suddenly flared up since 1950 in the jungles of Panama and Costa Rica, where it was thought
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to be stamped out, resulting in somewhat hysterical, unfounded reports even in Mexico.

The yellow-fever mosquito lives close to humans. It breeds in water in old tin cans, flower vases, and discarded tires. It is seldom found more than a quarter of a mile from a house. Only female mosquitoes bite. Females of the yellow-fever species slip out of hiding places at twilight, find exposed ankles or arms, and dart away at the slightest motion.

The Nobel Prize in Medicine for 1951 was awarded Max Theiler for development of a vaccine of living, attenuated virus, which has not only protected thousands of exposed civilians and troops but has undoubtedly been instrumental in keeping this dread disease out of the Far East, despite the increase in travel by air.

Dengue, or breakbone fever, also carried by the yellow-fever mosquito, is a painful and debilitating but not fatal virus disease that strikes occasionally. In an epidemic in 1922, Texas had more than a half million cases. For short periods it incapacitated large numbers of our troops on Guam and other Pacific islands during the Second World War.

Encephalitis, caused by several kinds of viruses that attack the central nervous systems of vertebrates, is transmitted by several species of mosquitoes. One species may be a vector of one virus strain and not of another. An outbreak of the so-called St. Louis type of encephalitis in 1933 is thought to have been carried by the northern house mosquito. A strain of the disease that has caused several hundred cases of human encephalitis each year is carried primarily by Culex tarsalis. Several species of mosquitoes can transmit the serious "Japanese B" encephalitis, which has caused serious epidemics in Japan and adjacent areas. Two types of equine sleeping sickness that have killed thousands of horses in the United States also cause illness in man and are probably transferred by a number of our common species of mosquitoes. Some infected parasitic bugs and bird mites have been found in the wild.

Elephantiasis, a disfiguring malady of people in the Tropics and subtropics, is carried by mosquitoes. The extremities and genitals often become greatly swollen because of small roundworms that establish themselves in the lymph glands. Into the blood stream the worms discharge eggs, which, after developing to active embryos known as microfilariae, are picked up by mosquitoes when biting. Some strains of the young worms swarm in the blood near the surface of the body at the time of the day or night when the favored species of mosquito is likely to bite.

Upon reaching the stomach of the mosquito, the young worms wiggle out of their saclike sheaths in an hour or so. They work through the stomach wall and into the thoracic muscles. There they grow for 2 or 3 weeks. Then they migrate to the beak of the mosquito, curl up, and await a chance to gain entrance to the skin of a person when the mosquito again bites. The worms, about one-twentieth inch long, burrow into the skin, reach the capillaries, and are carried in the blood stream to a lymph gland, where they develop to maturity. The female worms are 3 to 4 inches long. The males are about half that size. The cycle is complete when mating takes place and production of microfilariae begins.

Elephantiasis does not necessarily follow infestation from an infected mosquito bite, but skin irritation and fever are often manifest. Infection by these little worms is called filariasis. The malady occurred a number of years in the vicinity of Charleston, S. C., but it appears to have died out. No other endemic foci are known in the United States, although the carrier, the southern house mosquito, is widely distributed in the South.

The development and use of various ways to control mosquitoes are discussed on page 476.
Indians gave the name no-see-ums to the tiny mottled winged gnats that can readily crawl through a fine screen. They are also called punkies or sand flies (although they are not the same as Phlebotomus, discussed later), and are known scientifically as Culicoides. Their bites can be extremely irritating. Often they produce delayed reactions. The 20 species in North America differ greatly in breeding habits, but all develop in water or moist places. The larvae of the most troublesome kinds develop in the mud on salt marshes and in rot holes in trees where decaying leaves and water are held. The insects, however annoying, are not known to carry human disease in this country. They were mistakenly accused of causing "sand-fly fever" in American troops in New Guinea. They are an intermediate host of certain roundworms (nematodes) in Africa and elsewhere in the Tropics. These roundworms in the blood of man apparently do not cause illness.

Installing dikes and tide gates to protect salt-marsh areas, clearing and deepening the margins of ponds and streams, and filling tree holes are steps that reduce breeding. Insecticidal sprays and fogs protect communities against the adults. Painting screens with 5 percent DDT in kerosene, the use of close-woven bed nets, and the application of repellents to exposed parts of the body give some relief.

Black flies, of the family Simuliidae, are annoying pests to lumbermen, campers, fishermen, and others in the north woods. These rather small, hump-backed gnats are not confined to the north country, however. Some 75 species exist in the United States. Many others occur in other countries. All breed in flowing water. Some kinds live only in fast mountain streams. They lay their eggs on sticks and rocks projecting from the water. The larvae cling to objects in the water, from which they gather food with a set of motile brushes around the mouth. They spin weblike pockets under the water and pupate in them.

As carriers of human diseases, black flies are not serious in this country, although many persons get severe dermatitis or allergic reactions from the bites. In Mexico, Central America, South America, and Africa, some species are hosts for early stages of a roundworm, which they transfer from one person to another. The worms form nodules under the skin, principally on the head and upper part of the body which cause so-called onchoceriasis. Some get into the eyes and may produce blindness.

The larvae of black flies can be killed by adding small amounts of DDT to the infested stream. Dosages required to control larvae will not injure fish, but care should be taken not to apply excessive amounts, which will kill fish. DDT fogs applied from the air or ground help to destroy these gnats. Damming streams to eliminate rapids has some merit. Repellents are not entirely satisfactory.

Sand flies are annoying blood-suckers and carriers of at least two serious diseases, although none of the half dozen species of this group (Phlebotomus) that occur uncommonly in this country is a disease carrier. The dangerous verruga or Oroya fever, which occurs in Peru, Ecuador, Bolivia, and other South American countries, is carried by sand flies. They also transmit pappataci, sand-fly, or 8-day fever of the Mediterranean region, Near East, southern China, Ceylon, and India. It is a mild febrile disease of man. Kala azar, a leishmaniasis endemic in the Mediterranean area, Iraq, southern Russia, India, and China, is carried by sand flies, as is a repulsive skin disease, Oriental sore, in that general area.

The insects breed in damp animal and vegetable wastes and in crevices in rocks and walls. A spray of DDT in kerosene in corners of sleeping quarters, around the base of houses, and their other breeding and resting places controls the sand flies and stops infections.
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Close relatives of sand flies are other moth flies that have no thirst for blood. Some of them breed in sewage filters. Often they emerge from the sewer beds in large numbers and invade nearby houses. They are not attracted to food, but occasionally get on it or on dishes and utensils, which they undoubtedly contaminate. The larvae on the stones in the filter beds require much oxygen and may be killed simply by flooding the beds with a few inches of quiet water or sewage. Insecticides (such as DDT emulsions) are also effective but may destroy other organisms that aid in keeping the filters open.

Horse flies and deer flies are serious pests of livestock but usually are less troublesome to man. These aggressive bloodsuckers will also attack man. Their bites are painful. Bathers and picnickers on beaches near salt marshes along the Atlantic seaboard are often driven away by attacks of "greenhead" horse flies. Outdoorsmen in the north woods are familiar with swarms of the flies.

Deer flies often attack man. In the summer of 1935, 170 young men of the Civilian Conservation Corps were preparing a game refuge on salt marshes near Bear Lake, Utah. The deer flies were very annoying; 30 men contracted tularemia, or rabbit fever, in 2 weeks, and the camp had to be closed.

The flies carry tularemia on their beaks. Occasionally anthrax germs also are carried in that way by horse flies and deer flies between diseased and healthy animals and sometimes to man.

In tropical West Africa, deer flies of two or more species are hosts of the filarial parasite (Loa loa) of man. The parasitic lodges in the connective tissues under the skin and often invades the eyes.

One can combat horse flies and deer flies in several ways. Drainage of marshy breeding areas is frequently impractical. Spraying in early summer with DDT solution of marshes and swamps where the flies breed has some value. Because of the danger of injuring wildlife, the use of insecticides should be under the direction of an experienced person. Repellents to protect livestock have so far not proved very practical.

Tsetse flies carry African sleeping sickness, a deadly disease caused by minute, single-cell organisms, the trypanosomes. One form, Gambian sleeping sickness, is carried mainly by a fly, Glossina palpalis, which resembles the stable fly. Another kind, which brings death more rapidly, is Rhodesian sleeping sickness. It is carried principally by G. morsitans. Besides these diseases of humans, tsetse flies carry several related diseases of livestock and wildlife. The disease organisms are taken up by the fly in the blood meal, pass through developmental stages, and multiply in the digestive tract. They invade the salivary glands when mature and at a subsequent feeding of the fly they gain entrance to another animal host.

These dangerous flies are confined to tropical and subtropical Africa, where they hinder settlement and development.
Tsetse flies live 3 to 6 months. They can travel considerable distances, although *G. palpalis* stays close to the banks of lakes or the timber along streams. The insects differ from most flies in that the eggs hatch and the larvae develop in a uterine pouch within the body of the mother fly. One larva develops at a time. When it is full-grown, it is dropped in the shade and near water. There it burrows into the soil and in 3 weeks to 2 months changes into a fly.

**The House Fly** has shared man’s food and developed in his wastes and those of his domestic animals since the world was young.

The house fly may lay 21 batches of eggs, live 5 months, and complete a generation every 2 weeks.

House flies breed in fermenting vegetable and animal matter and other filth, without which they cannot exist, despite a high reproductive capacity.

Its ability to travel at least 13 miles, its filthy habits, and its greedy appetite make the house fly a formidable germ carrier, but many of the germs it carries to our food do not cause disease. When disease organisms are in the wastes, however, the house fly carries them. In earlier days, many cases of typhoid were clearly chargeable to it and some still are. Dysentery, diarrhea, and other digestive troubles are often due to contamination of foods and utensils by flies. House flies are believed to have a part in spreading the germs of cholera, yaws, trachoma, and tuberculosis. They also transport certain parasitic worms.

After the Second World War, DDT—applied as a residual or long-lasting spray to walls and ceilings of buildings—made the house fly almost a rarity for a time. But in line with nature’s defenses to perpetuate a species regardless of man’s wishes, strains of flies resistant to the effects of DDT began to appear in 1947 in various parts of the world; those strains became more resistant and widespread in the next years.

Other insecticides, somewhat like DDT chemically, were found to have the same residual killing effect, but were less persistent. Among them were benzene hexachloride, lindane, methoxychlor, TDE, chlordane, toxaphene and dieldrin. No doubt others will be discovered, but the house fly has demonstrated its ability to develop resistance to each of the materials after a number of generations have been exposed to them. To help meet the situation, the old and safe pyrethrum has been brought back more fully into use, alone and in mixtures. Unlike DDT, it is a quick killer.

Screens and other means of excluding flies from buildings and food are of great value and will undoubtedly continue to be necessary for protection against the house fly, mosquitoes, and other troublesome and dangerous insects. Sticky fly paper, traps, and electrocuting devices are also useful in destroying flies that breed despite rigid sanitation.

**Blow Flies**, often called green bottle flies and blue bottle flies, are of many kinds. They have life cycles and habits somewhat like those of the house fly, but they breed mainly in carcasses of dead animals and in meat in garbage. They are seldom so numerous as house flies but carry many of the same disease-producing organisms.

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The true parasites may suck blood, as the human-infesting Congo floor maggot does, or they may invade wounds or inflamed nasal passages, as the screw-worm does. Screw-worms, if not promptly killed and removed, may destroy enough tissue to produce disfigurement or death of the victim.

Some other insects that customarily live as parasites in livestock occasionally attack man. The sheep bot fly sometimes darts at the eye of a person and deposits in it a droplet containing a number of minute, active, spiny larvae. The larvae crawl over the eyeball and cause inflammation. Shepherds in North Africa are said to be blinded by repeated attacks. Horse bot flies and cattle grubs in the first stage of their development occasionally get into the skin of people working around livestock. The horse bots burrow about in the skin, producing what is likened to creeping eruption. The cattle grubs penetrate deeper and usually work upward as they do in cattle. Often they come to the surface on the neck or head and produce a boil-like swelling, from which they can be removed. They sometimes cause severe illness.

*Dermatobia* is a fly that produces serious losses to livestock in the tropical Americas. Often it infests man and has therefore been called the human bot fly. The larvae develop in pockets beneath the skin and maintain an opening through which to get air. To get its larvae to a suitable host, the fly catches a mosquito or other bloodsucking insect, attaches eggs to its body, and then releases it. When the mosquito bites a warm-blooded animal, the little maggots pop out of the eggs and burrow into the skin.

**Fleas**, like the biting flies, are among the higher insects that have complete metamorphosis. They have developed highly specialized parasitic habits in the adult stage only. The wingless adults have laterally compressed bodies and strong, spiny legs, which help them move rapidly among the hairs or feathers of their hosts. Their mouth parts are fitted for piercing and sucking. All species, as far as we know, are parasites of higher vertebrates. Fleas have astonishing strength in proportion to their small size. The human flea can jump 13 inches.

Some persons attract fleas more than do others under the same exposure. In one person, an area of inflammation immediately surrounds the bite; in others, a delayed irritation occurs. *Pulex irritans* is thus an appropriate name for the human flea, which has adapted itself to residence in folds of man’s clothing as a substitute for the fur of the lower animals. Their eggs are dropped promiscuously and are not fastened to clothing or hair as are those of lice. The maggotlike larvae live on organic waste about the premises.

Other species that may become annoying in human abodes are the rat, cat, and dog fleas, which do not have so restricted a host preference as do some of their cousins on various rodents in the field.

The chigoe is an especially irritating kind of flea to man and animals in the Tropics. The females bury themselves in the skin, particularly of the feet, and cause persistent, ulcerlike craters, from which the fleas have to be removed before the wound can heal. This flea is not a known disease carrier.

Of greater concern are the species that carry the serious and widely occurring rodent infections, bubonic plague and murine typhus, to man. They live everywhere in warm climates. One of the authors during the Second World War watched the pests jump in all directions from the wrinkles in the pantaloons of Arabs while he was studying the effects of DDT in Egypt; boil up into his clothes from the straw in abandoned pillboxes and from cave floors occupied by refugees in Sicily, where he was investigating mosquitoes and sand flies; and emerge by thousands from the ground litter of a small, abandoned native village along a mountain stream in the Philippines. Regardless of locality, race and color, they were after human blood.
Bubonic plague is by all odds the most serious of the human diseases attributed to the flea. Think of the ravages of the Black Death in the Middle Ages, particularly among the populations of port cities. Plague still stalks the earth. In military operations in the Tropics we may have unavoidably spread the disease to new areas through beachhead or landing operations when it was not possible to use safeguards, like collared anchor cables and inspection, which are observed in peacetime to restrict the emigration of rats and their rat fleas into new ports and settled areas.

One of us lived in 1930 in a West African port city where people regarded the annual human death rate of about 600 as not unusual. The disease waxes and wanes in the Tropics, but the antibiotics developed since 1940 give promise of relief if they are available. No one now need die of this once dreaded disease if diagnosis is made early enough and suitable drugs are available. Experimental data indicate that a combination of streptomycin and aureomycin is the treatment of choice.

The ecology of the so-called “sylvatic plague” in the western half of the United States has been quite obscure. There the infection continues to wipe out whole populations of field rodents locally with only an occasional human case. The disease has not affected rats in cities to any great extent. The special fleas of the affected ground squirrels, prairie dogs, and rabbits are less prone to bite human beings than are the oriental and the northern rat fleas.

Murine typhus, or endemic typhus, is much like the louse-borne type, which in numbers of cases, but not in virulence, outweighs plague as a worldwide human disease. The spread of murine typhus from man to man by lice, after establishment from fleas, has been reported in Mexico and Manchuria. New laboratory techniques and careful diagnosis are required to verify such reports.

Murine typhus occurs widely in tropical and temperate climates. Treatment with antibiotics has been effective, but preventive measures are still the most important. Constant vigilance is required against the spread of rat fleas by domestic rats from foreign ports. In endemic localities DDT or other toxicants are used in rat runways to reduce existing flea populations on rats. Another weapon is rat poisons, which have been spectacularly improved in recent years; one of them is the comparatively safe warfarin.

Almost everyone has been stung by bees, wasps, and ants. Some have suffered the more painful sting of a velvet ant, the “cow-killer.” All these insects use their stings merely in self-defense, but the pain is none the less severe. The effects generally do not last long, but some persons who are allergic to the poison that the insect injects may be seriously affected or even killed, particularly when they get many stings.

The material that causes the pain and the stinging mechanism vary among the different insects. The venom is usually a complex protein material. Among ants, formic acid is partly responsible for the pain of the bite or sting. Most insects can sting more than once, but a honey bee loses its life when it stings. The barbed sting holds fast in the flesh, and the tip of the abdomen and the two poison glands are torn off: The muscles that operate the stinging organ keep contracting for a few minutes, force the sting deeper into the skin, and pump the venom into the wound. The sting therefore should be removed quickly. That is best done by scraping the sting off with a knife or the fingernail; pulling it out with the fingers might squeeze more venom in.

Caterpillars do not carry human diseases, but often they cause painful injuries. The hairs or spines on the bodies of the larvae are mainly responsible. The hollow spines, connected at their bases with poison glands, contain poisonous materials. They are
broken off in the skin of man when a sensitive part of the body comes in contact with the caterpillar or its shed skin. The spines help protect the caterpillar against its predatory enemies, but they do not prevent its destruction by parasitic flies and wasps, which kill a high percentage of them.

Several species in seven or eight families of moths can sting in that way. Some of the worst, such as the puss caterpillar, look quite innocent, but many ugly and dangerous-looking caterpillars, such as the hickory horned devil, are harmless.

Some urticating caterpillars are crop or forest pests, such as the brown-tail moth in New England, the flannel moth of the Northern States, the io moth, the saddleback caterpillar, and the puss caterpillar. The last named occasionally strips the leaves from elms, hackberries, and other shade trees in the South.

The hairs of the brown-tail moth retain their poison for a long time and, when the insects are numerous, may irritate the skin and eyes of many people. The sting of most of the species, although painful, does not last long. The puss caterpillar can have a more lasting, severe sting, which can give persons the symptoms of paralysis.

Before they reach full growth, the caterpillars can be controlled by spraying the infested shade trees or shrubbery with arsenate of lead or DDT. The likelihood of a person coming in contact with them is increased when the caterpillars are crawling around seeking a place to pupate. There is no specific remedy for the sting, although packs of bicarbonate of soda and cooling lotions are advised.

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Beetles of the family Meloidae have in their body fluids a poisonous substance, cantharidin, which blisters the skin. The beetles are collected and dried and the cantharidin is extracted and sold as a drug. Of the many species of blister beetles, one is widely known in this country as the old-fashioned potato beetle.

To the entomologist the term "bug" refers specifically to an order of insects, the Hemiptera, which includes the wingless bed bugs of various species, and the winged, biting, or blood-sucking insects known as "kissing bugs," assassin bugs, conenoses, and their relatives.

Few insects have been more often maligned and less confirmed as carriers of disease than the bed bug or its close relative in the Tropics and sub-tropics, the Indian bed bug. Some other species of the bed bug family that are customary parasites of poultry, swallows, or bats may invade houses on occasion but cause little complaint among human inhabitants. An infestation of bed bugs is considered a sign of filth and uncleanliness in houses and hotels, but the bugs are seen sometimes in public conveyances so that any person might take one home. A few persons are sensitive to their bites and may develop a temporary rash, local swelling, or irritation following such attacks. The bugs are nocturnal. In daytime they retreat into mattresses, joints of wooden bedsteads, cracks, and other hideouts in bedrooms. Their flat bodies can edge into tight crevices. They have a distinctive, pungent odor. All active stages are parasitic from the time they hatch from eggs, which are laid in their hiding places. Adults can live a year without a meal of blood but will usually migrate during such a starvation period.

No one so far has proved that bed bugs are the actual, natural vectors of any important human disease. The causative agents of several diseases,
including those of kala azar of Asia, Chagas' disease of South America, relapsing fever, infectious jaundice, lymphocytic choriomeningitis, tularemia, and also plague, have been shown experimentally to persist some times in the bodies of the bugs. They also have been reported as vectors of Rocky Mountain spotted fever in Brazil. From earlier experimental work in Poland similar conclusions were drawn, but such experimental results have not been found by other investigators.

Certain of the conenoses, sometimes called kissing bugs, of the family Triatomidae have been shown to be the natural carriers of trypanosomiasis in the American Tropics and even in temperate parts of South America. Chagas' disease, named for a Brazilian investigator, causes high mortality among children in some localities. The disease is caused by minute organisms, trypanosomes, which multiply in human organs and pass through a definite developmental cycle in bugs that have fed on persons having them in their blood. Some 40 species of the triatomids have been found naturally infected, but fewer than 12 are of any importance in human transmission. Several species habitually pass excrement while biting or soon thereafter. Transmission probably occurs through fecal contamination of the bite wounds and other abrasions or of the mucous membranes of the victim, rather than through direct inoculation by the mouth parts of the feeding bug. A number of native and domestic animals are reported to be reservoirs.

Several species of the bugs occur in various parts of the Southern States, where they infest rodent nests and other animal habitations. They may invade human dwellings or camps and attack man himself. Natural infection of trypanosomes in wood rats, and in their parasites, *Triatoma protracta* or *T. uhleri*, has been reported in a few localities. Human infection in this country has been suspected only on serological evidence. Triatomids were found naturally infected with western equine encephalomyelitis virus in Kansas, but it is doubtful whether they are of importance in either human or equine transmission.

Assassin bugs prey on other insects but are not parasitic on animals. If annoyed or accidentally touched, some species can inflict severe and painful "stings" with their beaks.

Bed bugs are controlled with preparations of DDT. The conenoses are susceptible to the new insecticides, but the delayed action of DDT and their ability to fly and quickly reinfest premises complicate the problem of control. DDT can be applied as a 10-percent dust or a 5-percent solution in deodorized kerosene to the hiding places of the bugs.

**Cockroaches** are the only members of the grasshopper group (order Orthoptera) that are involved in the contamination of food. Crickets often enter houses and occasionally eat holes in clothing but are not attracted to food.

Of the many species of cockroaches, only five are common house inhabitors. They are the large American, oriental, and Australian cockroaches and the smaller German cockroach, or "water bug," and the brown-banded roach. Their habits are similar. They prefer secluded, warm, damp places, as behind sinks, around drain pipes, and in furnace rooms. They lay their eggs inside a pod. The German cockroach carries the egg capsule attached to the tip of the abdomen until a day or two before the eggs hatch. The young insects resemble the adults except in size and lack of wings. Cockroaches grow slowly. The American cockroach usually takes a full year to develop from egg to adult. Then and later the filthy pest at night or on dark days busily runs about, sampling filth and foods and imparting to infested areas his fetid, roachy smell.

People have long assumed that cockroaches must be carriers of various enteric diseases and tuberculosis. Now we know that certain disease organisms
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(Salmonella) were still alive when passed 10 to 20 days after being fed to three common kinds of household roaches. The germs remained infective in the fecal pellets for more than 199 days afterward. These insects furnish one of the important sources for spread of intercurrent salmonellosis in laboratory animals.

Cockroaches can be controlled by thorough sanitation, elimination of breeding and hiding places, and insecticides. Sodium fluoride dust (at least 50 percent) has been used in this way. Chlordane, applied as a 2-percent spray or a 5-percent powder to restricted areas where the insects hide has given good results. A 5 percent DDT spray or 10 percent DDT powder is also recommended but is less effective than chlordane. Pyrethrum sprays are recommended in situations where foods might be contaminated with chlordane or DDT. Pyrethrum must be reapplied frequently because it loses its effectiveness in a few days.

Of the two kinds of lice, we are concerned here with the sucking lice (Anoplura). The biting lice (Mallophaga) are chiefly parasites of birds.

Three kinds of sucking lice commonly infest man, the head, body, and crab lice.

Crab lice, also called pubic lice, prefer hairy parts of the human body in the pubic region and armpits. In severe infestations they may be found in the eyebrows and lashes. They may cause intense itching but have no known effect on the health of the host.

The other lice have greatly influenced human history. They have affected the outcome of many military campaigns because they spread epidemic typhus. This disease, the "red death" of the Middle Ages, has been the scourge of soldiers and displaced peoples during times of their greatest misery, when they were least able to exercise customary habits of sanitation.

No insect has shown greater adaptation to the habits of its human host than has the body louse. It alone of all the members of its order has forsaken the fur of its host and found refuge in man's inner garments, on which its eggs are fastened and to which it clings except while feeding. An adult may feed as often as six times a day. The longer the garments are worn next to the skin, the better the body louse thrives.

The head louse is related to the body louse, but it is slightly smaller and darker in color and is found only among hairs of the head. The more luxuriant the head adornment of natives, the greater opportunity is provided for lice to develop.

Adult lice may survive up to 5 days without a meal of blood. The younger stages must feed oftener than once a day to stay healthy. A person's first exposure means little or no discomfort, but a sensitivity occurs after a week or 10 days, when the average person develops an intense itching from the feeding of the lice. A tolerance is later developed by constantly infested peoples, who take little notice of their presence. Infestations of head lice are not uncommon in the United States; occasionally they occur among school children.

Louse-borne typhus, like plague, has been one of the historic scourges of vermin-infested mankind. Like malaria, on the other hand, it is one of the few serious insect-transmitted diseases in which man himself serves as the so-called animal reservoir; there is no known cycle in some lower animal. Epidemics, heretofore, have followed in the wake of war as certainly as death and taxes, simply because habitual sanitation and segregation, which prevent the spread of lice, could not be constantly maintained among the soldiers or civilians. At the beginning of the First World War as many as 2,500 new cases a day were hospitalized with typhus in the Serbian Army; among civilians the number was said to be three times greater. The outbreak temporarily checked the impending invasion of the Austrian Army at the Serbian borders more effectively than any
military strategy. Napoleon's retreat from Moscow is believed to have been due more to typhus than to cold weather.

Trench fever, another disease of soldiers, is also louse-borne. It occurred in the First World War and also in the Second World War on the Russian-German front. The causative agent is thought to be related to typhus fever. It does not kill, but it can be a debilitating epidemic disease among louse-infested troops.

Relapsing fever, also transmitted by the body louse, is caused by a spirochete, an organism entirely different from the one that causes typhus. The disease is most prevalent in parts of North Africa and Asia. Here again the louse-man-louse cycle is all that is needed to maintain the infection. How louse-borne relapsing fever and typhus are maintained between epidemics is a mystery, because transmission through the egg from one generation of lice to the next seldom occurs, if ever.

Lice can be controlled easily with 10 percent DDT powder. In 1944 a simple method was devised to apply DDT powder by blowing it into the openings of the clothing while on the person. Thousands of individuals living under refugee conditions in Naples were so treated and a threatened outbreak of typhus was averted. However, the finding of DDT-resistant lice during the Korean conflict has made it necessary to use pyrethrum or lindane instead of DDT.

Tick and mite. Scabies of man is a condition caused by the itch mite, which burrows in the skin, where it lays its eggs. The mite causes intense itching and irritation. In aggravated cases, an extensive crusting and scabbing results, particularly over the arms and hands. The offenders are never seen except by careful dissection under a good lens. Observations in England during the war demonstrated that the major source of new cases was provided by actual body contact rather than through towels, bed clothing, and wearing apparel used by infested people.

Grocer's itch and harvester's rash—transient but often annoying—are the result of exposure to mites that ordinarily infest grain and stored-food products.

The tropical rat mite and a less common but also widely spread house-mouse-infesting mite, *Allodermanyssus sanguineus*, occasionally cause complaints through infestation of houses invaded by their rat or mouse hosts. The first species has been accused of acting as a vector of murine typhus and of plague, but experimental evidence has been conflicting, and its importance in this regard remains doubtful. But it can transmit rickettsialpox, the most recently discovered of the typhuslike diseases, which has occurred in some mouse-infested premises in New York and Boston. *A. sanguineus* is the natural transmitter of rickettsialpox in New York suburban settlements. Some of these mites have also been reported as transmitting tularemia in Russia.

Chicken mites and related species occasionally annoy man by their bloodsucking habit but do not remain on him long.

Chiggers belong to another group of mites of the family Trombiculidae. Only the first or larval stage is parasitic on vertebrates and must have a blood meal for further development. Chiggers are so minute that they are seldom seen by man even though the numerous sites of attachment such as the belt line are evident. In eastern and southern areas of the United States where...
chiggers are most prevalent, they are not known to carry any disease, but their attack produces severe itching, which may result in secondary infections. This type of attack in the southwest Pacific area is known as scrub itch.

Scrub typhus, a serious malady in the Far East, is called tsutsugamushi disease in Japan, where it was first recognized. It is carried by certain species of the chiggers. The disease agent, related to the typhus group, is passed from one generation of mites to the next through the egg.

The chiggers usually parasitize rats and other rodents, but certain species will attack man. The mortality from scrub typhus can be extremely high—more than 60 percent of cases in some parts of Japan, or as low as 0.6 percent among Americans in an epidemic in the Schouten Islands, where 1,469 cases occurred in 6 months. Even with this low death rate, the situation is serious when incapacitation averages 2 months or more. Chloromycetin and aureomycin, however, are markedly reducing hospitalization and will aid in progress against this dread disease.

More people have an acquaintance with ticks than with mites. Yet many do not know that there is one family, the Argasidae, or soft ticks, which feed on man rather rapidly like bed bugs and do not remain attached.

The notorious relapsing-fever tick of tropical Africa has become almost completely domesticated, and natives sleeping on the floors of their huts pay little attention to it. A number of related species in various parts of the world, including the United States, have since been found to cause human cases of relapsing fever. These are mostly species that rodents bring into living quarters, mountain cabins, native huts, and the like. Several similar forms of relapsing fever are carried by different species of these soft ticks.

Another group of ticks, the hard ticks, of the family Ixodidae, customarily require several days to complete engorgement after attachment. In temperate climates where cold seasons intervene, some species may require 2 years to complete a generation. The Rocky Mountain wood tick is an example. The adults have been known to survive three winters when kept outside. Many ticks have simple eyes with which they can discern the passing shadow of a potential victim. Others have no eyes. Special sense organs enable them to detect animals 25 feet or more away, so that an unwitting camper may attract ticks from a considerable area. Many ticks are thus able to select favorable sites—game trails, for instance—for seeking their host.

Ticks have numerous progeny and few enemies, are not greatly affected by weather conditions, can feed upon various kinds of animals, and permit the passage of disease organisms from stage to stage as well as from one generation to another through the egg. Instances of secondary infection at the point of tick attack occur often.

"Spring-summer" encephalitis in Soviet Russia and Siberia is the most important of the filterable viruses carried by several Russian species. Another tick-borne virus is the rather mild, nonfatal Colorado tick fever of our Rocky Mountain region.

Tick-borne typhuslike diseases are assuming increasing importance in various parts of the world. These include American or Rocky Mountain spotted fever in various countries of the New World, and a group of usually less severe diseases in Europe, Africa, Asia, and probably Australia, related to boutonneuse fever, which was first recognized in the Mediterranean region. The latter group of diseases includes South African tick-bite fever, Kenya typhus, and Siberian, Indian, and probably Queensland tick typhuses. In the United States, the Rocky Mountain wood tick in the West, the American dog tick in the East and South, and probably the lone star tick in the South are the chief criminals in human infection with spotted fever.

Q fever is a peculiar, recently recognized disease due to a typhuslike agent
which is being discovered in many parts of the world. Ticks have been found naturally infected in North America, Australia, Spain, and parts of North Africa, but only in Australia have they shown any importance in relation to human infection.

Tularemia, an important bacterial disease affecting man, occasionally is transmitted by ticks.

Tick paralysis of man and animals is due to a presumed toxin secreted in the saliva of ticks. Though more frequently observed in tick-infested animals, a number of human cases have been reported in the United States, Canada, and Australia. The ascending paralysis is caused by a rapidly engorging female tick attached to the base of the head, where the hair may hide its presence for longer periods. Complete recovery has followed within 24 to 48 hours of removal of the offending tick. Death occurs if the ascending paralysis reaches the respiratory centers of the human or animal victim before the tick has dropped off or has been removed.

The Acarina are more difficult than insects to control because they are more resistant to insecticides. Benzyl benzoate ointment is one of the best materials for the control of scabies. This acaricide in combination with dibutyl phthalate is an excellent clothing impregnant against chiggers and is more durable than many chemicals previously tried. Chiggers can be controlled in infested areas by applying 1 to 2 pounds of chlordane or toxaphene or one-fourth pound of lindane per acre, employing dusts or sprays. Such mixtures are being constantly improved.

Several substances effective against ticks have been discovered. The control of livestock and wild animals upon which ticks feed reduces the number of these pests. Many of the ticks in infested ground areas can be destroyed by spraying with a 5 percent DDT emulsion. Certain ticks congregate near roads and trails and an insecticide should be applied especially on those areas. Clearing of brush and close cutting of grass is a material aid in tick control.

The best way to remove ticks that are attached to persons is to pull them out. Some ticks have long beaks and their removal may require a needle or knife.

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