ingly typical small, bloody lesions and larger, older, dried ones. Only a tentative diagnosis is possible in such cases, unless other infested lesions are found on the same animal. Even if sections of worm-free lesions show microscopic tissue and cellular changes like the ones observed when this parasite is present, the diagnosis remains inconclusive because similar changes may be caused by other classes of parasitic organisms.

No specific drug treatment for this condition is known. Tartar emetic and antrypol (suramin) have been successfully used in India for the treatment of a related disease (hump sore, caused by Stephanofilaria assamensis).

Normally free-living, or saprophytic roundworms of the genus Rhabditis, occasionally infest bovine skin lesions, according to reports from California and other States. These worms are omnipresent in soil and moist, decaying, organic materials, including feces. They get on the skin of cattle by contact with such materials. They evidently become established only in already diseased skin areas. They apparently can cause extension of the sores and have been found associated with extensive dermatitis.

JOHN T. LUCKER is a parasitologist in the Animal Disease and Parasite Research Branch and leads a unit which investigates the helminthic parasites and diseases of cattle. He is a graduate of the University of Washington and the George Washington University. He has worked in the Department of Agriculture since 1930, and has carried out investigations on roundworm parasites of swine, horses, sheep, cattle, and other hosts.

Cattle Grubs

IRWIN H. ROBERTS AND ARTHUR W. LINDQUIST

NEARLY all cattlemen know the conspicuous swellings that appear in the backs of cattle in winter. The swellings contain grubs, which are the maggot stage of heelflies.

Of all the insect pests that prey on livestock, heelflies are among the hardest to control. They and the cattle grubs (which are known also as warbles and wolves) may be to blame for losses to producers, feeders, dairymen, packers, and tanners. The losses may nearly equal those caused by all other insect pests of cattle combined.

Two species of heelflies, or warbleflies, parasitize cattle in North America. The common heelfly, Hypoderma lineatum, and its larva, the common grub, exist in all parts of the United States and Canada. The northern species, Hypoderma bovis, is found in Canada and the northern half of the United States.

Heelflies are true flies of the order Diptera. They are closely related to other flies commonly encountered on farms, but look like small bumblebees—hairy, black, and striped with yellow. The common heelfly is nearly three times larger than the housefly.

The northern heelfly is much larger and stouter.

From the eggs that the flies lay on cattle emerge tiny, white larvae. The flies, their eggs, and the young maggots are seldom seen by casual observers. The young maggots penetrate the skin of the host animals, move through the
Cattle Grubs

body tissues, and eventually emerge—as the familiar cattle grub—in the backs. Mature grubs are black and may be an inch long. Heelflies develop from grubs that have dropped to the ground from the backs of cattle.

Common heelflies appear during the first warm days of spring. They have no mouth parts and do not bite or sting. They live only a few days, rarely as much as 2 weeks, but in that time they can deposit hundreds of eggs. The heelflies are active about 2 months. They lay their eggs in neat rows on hairs, usually low on the legs on and above the fetlock—hence the name "heelfly." If the animal is lying down, the eggs may be laid on the hairs closest to the ground.

The eggs hatch in 3 or 4 days. The minute, spiny maggots crawl down the hair and begin to burrow through the skin. Then they begin an amazing journey through the tissues of the body. They appear to limit their travels to the soft connective tissues between the muscles. Most of the larvae of the common heelfly congregate in the tissues of the gullet after about 5 months.

The larvae spend 3 months or so in the gullet. After that they begin their final migration, again through the connective tissues, to the region beneath the skin of the back. Almost immediately they make breathing holes in the skin.

In a very few days a pocket, or cyst, developed from the tissues of the host, surrounds each larva, and in this the grub remains for about 6 weeks. At all times during its stay in this swelling, the breathing hole is kept open. The tail end of the grub, with its two prominent breathing pores, lies just under this opening.

The grub molts twice in the cyst. When it is mature, it works out of the now enlarged hole in the skin. Once free of the animal, the grub seeks the protection of soil or trash. Its outer cuticle becomes hard and black. Within that protective or pupal case, in a month or so, the change from grub to fly takes place.

The fly emerges from its pupal case through a hinged cap at the upper forward end. It may crawl from the puparium in less than a minute, dry its wings, and be in the air within half an hour. Shortly thereafter, the flies mate, and if the weather is favorable, egglaying may begin on the same day the adults emerge.

Northern heelflies appear later in the season, after the egg-laying activities of the common species are well underway. The activities of the two flies overlap for a short time, and then, after the common fly has disappeared, the northern fly continues to plague cattle well into the summer months. The northern heelfly deposits its eggs at about the height of the hock, striking the animal a number of times in rapid succession and cementing an egg on a hair each time. Its eggs are deposited singly, but it can lay several hundred in its lifetime.

The young larvae penetrate the skin and travel through the soft tissues of the body (as do those of the common heelfly), but they congregate in the spinal canal instead of in the gullet on their way to the skin of the back. When fully developed, the grubs of the northern fly are larger than those of the common heelfly, but their appearance otherwise is much the same. By the time northern grubs reach the backs of cattle, the common grubs normally have been present for about 2 months, and most of them are ready to emerge from their cysts. The northern grubs are most abundant in the backs of cattle after the larvae of the common fly have practically disappeared. It is not unusual in Northern States to find a few of these grubs emerging from the backs of cattle as late as July.

In order to control cattle grubs effectively, it is particularly important to know when they are likely to be found in the backs of cattle, so that they may be attacked when they are most vulnerable.
Common grubs are said to appear as early as the first week in September in southern Texas. They appear progressively later as one goes northward. Common grubs may not appear until February or March in Montana, and the northern grub generally appears a month later.

Along the Gulf of Mexico and in southern Arizona and California, all grubs are likely to have matured and dropped from their cysts by the first days of March, at a time when the arrival of the grubs in North Dakota, Minnesota, and northern New York has scarcely begun.

In each section of the country, the appearance of grubs can be anticipated annually with some accuracy, but an allowance must be made for seasonal variations of approximately a month. In an average locality, grubs may show up in January one year, December the next, and in February the third year. Greater year-to-year variations than those have been known to occur, but are uncommon.

Heelflies and cattle grubs injure cattle in various ways.

One is the annoyance to cattle when the flies are laying eggs. The northern fly excites stock most. Heelflies cause no pain while depositing their eggs, but the reaction of cattle to them may be one of great fear. Animals attempting to escape them run with their tails held high in a characteristic manner. Occasionally they injure themselves in their wild flight from the flies. More often, however, they seek protection from the flies in shade or in water, and fail to graze for hours at a time. The fact that heelflies attack range cattle in early spring, when cows are poor and weak, with calves at their sides, intensifies the losses. Milk production of dairy cattle may drop 10 to 25 percent when heelflies are active.

The grubs migrating through the body tissues and the larvae boring into the backs of cattle cause injuries that one can appreciate but cannot assess easily. Losses after slaughter, however, are obvious. When hides are removed from grub-infested cattle, a mass of yellowish, gelatinous meat may be seen around the grub holes. It must be trimmed out as inedible. Fourteen million pounds of choice meat were wasted because of such trimming in 1948. Carcasses so trimmed are lowered a full grade, or loins may be so badly damaged that they must be boned.

The damage grubs do to hides is the easiest of all losses to evaluate. A third of all cattle hides produced in the United States in 1948 contained five or more grub holes and were sold at a discount of a cent a pound. Many grub holes impair the quality of the skin for leather. Occasionally 100 to 200 grub holes are found in a hide. Such hides are not worth tanning and are sold for use as byproducts.

Losses due to cattle grubs and heelflies in the United States have been set at 100 million to 300 million dollars a year.

An acceptable method of controlling heelflies and cattle grubs has been the object of a diligent search by many investigators since 1890. Attempts to destroy or repel the adult flies have not been successful. Efforts to destroy the eggs after they have been deposited on the hair coats of cattle or to keep the larvae from penetrating also have resulted in failure.

Research was begun in 1947 to find a drug which, given internally, would destroy the grubs after they reached the backs of cattle and would kill all the young larvae as they wandered through the tissues of the body. By 1955, several insecticides showed promise against grubs when injected into cattle or when administered in the feed or mineral-salt supplements. Among the most successful were lindane, aldrin, dieldrin, as well as some of the organic phosphorus compounds. Work on the internal administration of those and related insecticides had not advanced beyond the experimental stage in 1956. Additional research is un-
underway to determine their effectiveness and the hazards involved in their use.

A satisfactory method of attack is to destroy the grub after it has formed an opening in the skin of the backs of cattle. Killing the larvae at that stage interrupts the life cycle before a fly can be produced. Cattle thereby are spared the annoyance of attack by the heelfly and the hundreds of larvae that could hatch from the eggs produced by each female fly.

The larvae within the cysts of the skin can be killed in several ways. An early and simple method was the removal of the grub by pressing firmly with the fingers. That is a slow and laborious method, but many dairymen have used it.

Research workers the world over have experimented with hundreds of materials in the search for insecticides for the mass destruction of grubs, but few have proved effective.

The chlorinated hydrocarbon insecticides, among them DDT, lindane, chlordane, methoxychlor, and toxaphene, which are used against other insect pests, have little effect against cattle grubs when applied externally over the cyst openings.

A few of the organic phosphorus compounds, a group of insecticides developed during the Second World War, are highly lethal to grubs when applied in that way. They have been used experimentally but are not recommended for general use because they possibly may have toxic effects on the animals.

Benzol and carbon tetrachloride, injected into grub cyst openings with an oil can, will destroy grubs, but this method is not a great improvement over manual removal.

Rotenone remains the only effective toxicant that can be safely recommended for use by cattle owners. Rotenone occurs in tropical shrubs, especially *Derris eliptica* and *Lonchorpus nicou*. The finely ground roots of the plants are known as derris and cube powders. The powders, adjusted to contain about 5 percent of rotenone, can be applied to the backs of cattle in ointments, dusts, washes, dips, and sprays.

A rotenone ointment can be prepared by mixing 1 part of cube or derris powder with 10 parts of petroleum. The preparation is applied with the fingers directly over each grub opening. It is highly effective, but, like manual removal or the use of an oil can, it is designed only for dairy cattle or individual animals. Stockmen in the United States rarely use ointments.

Rotenone dusts are more practical for treating larger numbers of cattle. Such dusts can be formulated by mixing 1 part of cube or derris powder with 2 parts of dry vehicle or carrier, preferably a powdered mineral known as pyrophyllite. The dust is placed in a large shaker can, applied liberally to the backs of the cattle, and rubbed into the cyst openings with the fingers. Dusts are readily available for use. They are clean, quickly applied, and preferred by some stockmen who hesitate to chill their cattle with liquids in very cold weather.

Some farmers use washes to kill the grubs. Washes are made by mixing 12 ounces of cube or derris powder, one-half ounce of soapless detergent or 2 to 4 ounces of powdered soap, and 1 gallon of warm water. A pint or more of the thin, warm paste is poured on the back of each animal and brushed over the cyst openings with a stiff brush. A crew of 3 or 4 men can apply washes to several hundred head of cattle in a day. Groups of a thousand cattle or more have been treated periodically in South Dakota in this way by several stockmen working together. The washes, carefully applied, destroy a greater proportion of the larvae present at the time of treatment than any other large-scale method of grub control.

Dips may be used to treat large numbers of cattle quickly. Dipping vats are charged with from 7.5 to 10 pounds of cube or derris powder to each 100 gallons of water. Cattle are held in the vats for about 1 minute, with the backs submerged. Their backs also may be
brushed with long scrub brushes at this time. This procedure has been used chiefly in the Southwest, but it is expensive and has never been accepted generally.

Spraying is an easy, fast, and economical way to apply rotenone to the backs of cattle. Cattle can be treated with power-driven, high-pressure orchard spraying equipment almost as fast as they can be driven through chutes or pens. Cube or derris powder should be used in the proportion of 7.5 pounds for each 100 gallons of water in the sprayer tank. The tank should be equipped with a mechanical agitator, or else frequent stirring will be needed to prevent settling of the powder to the bottom.

The spray should be applied to the cattle at a gauge pressure of about 400 pounds to the square inch. A coarse, driving spray is directed upon the back of the animal. The nozzle of the gun should be held not more than 24 inches from the back. Catwalks, on which the operator can stand, should be placed high along the side of the chute or directly above the pen in which the cattle are restrained. From this elevated position, the operator can apply sprays with great efficiency at right angles to the backs of the animals.

To obtain maximum results from any control program, it is best that no larvae escape contact with the insecticide. Grubs spend 35 days or so in their cysts within the skin of the back and continue to appear for several months. A succession of treatments, about 30 days apart, therefore is necessary. The first treatment in any locality should be applied about 30 days after the first grubs make their holes in the skin and continue to appear for several months. A succession of treatments, about 30 days apart, therefore is necessary. The first treatment in any locality should be applied about 30 days after the first grubs make their holes in the skin and continue to appear for several months.

As many as four treatments may be required in localities where the two species of grubs exist.

Less involved schedules of treatment have been used in South Dakota and Montana. There it has been demonstrated that two accurately timed applications will destroy most of the grubs of both species and provide a satisfactory degree of control from year to year. The first treatment is applied just before the first of the common grubs commence to emerge from their cysts, when the great bulk of all common grubs are present in the backs of cattle at one time. That date usually follows the start of the grub season by about 60 days. The second treatment is administered when the northern grubs have reached their peak of abundance in the backs, at a time when the earliest of those common grubs which may have survived the first treatment begin to emerge. This second treatment should follow the first application by 40 to 60 days. Individual cattle owners must determine these dates by careful and frequent examination of their cattle.

Near Colorado Springs, Colo., where only the common grub was found to exist, a single application of washes, properly timed before the emergence of the first grubs, destroyed 90 to 100 percent of the grubs appearing in the treated cattle during the grub season.

The heelfly does not travel far—probably 3 miles or less from the point where it emerged from its pupal case. Nevertheless, because it can cross fences and travel to nearby herds, attempts to control grubs in an individual herd are relatively futile. Community action is essential if grub control is to be practiced on a sound basis.

The effectiveness of community efforts to control grubs has been demonstrated repeatedly in the United States, Canada, and Europe.

Two noteworthy community programs were completed successfully in South Dakota in 1953 under the direction of the Department of Agriculture and the South Dakota Agricultural Experiment Station. In one of them, involving 20 thousand head of cattle in an area of 430 square miles in Hughes and Hyde Counties, systematic efforts at grub destruction reduced the grub population by 93 percent in 5
years. At the end of the program, only 2 grubs an animal were found in herds at the center of the area, compared to an average of more than 30 in untreated animals in herds outside of the experimental area. The 175 cattlemen who participated used dusts, washes, and sprays. Each selected the method that suited his needs.

In the other campaign, in Meade and Pennington Counties, 10,000 head in 85 herds were treated in an area of about 375 square miles with equal success. An average of fewer than 2 grubs remained in animals in centrally located herds, compared to 30 in untreated animals in herds outside the area where grub control was practiced. High-pressure sprayers were used in this program.

Successful community battles against grubs also have been waged in Kittitas County, Wash., and in Chaves County, N. Mex.

Wherever grub populations are consistently high and so are an economic problem, such a program will pay for itself. Community control is most successful in regions where cattle are produced, rather than shipped in and fed, and where both cattle and grub populations are more or less constant from year to year.

A farm adviser or the county agent can give information about the importance of grubs in a county. Should a schedule of treatment be undertaken, the Extension Service representatives can offer technical assistance.

First one has to fix the boundaries of the area in which control measures are to be undertaken. The area should be reasonably large and should be as nearly square or circular as possible.

Community action in a small area would be no more successful than grub control in an individual herd. Even the limited flight of the heelfly is enough to permit flies from pastures on which untreated cattle are grazed to reinfect practically all cattle in an area of about 10 square miles. In a much larger area, however, flies from surrounding pastures cannot make their way to centrally located herds, and would normally reinfect only the cattle on farms at the edge of the territory. Not less than a township should be involved. An area of that size, in northern Illinois, say, might involve 100 dairymen and 4,000 head of cattle. From an administrative standpoint, it is a sizable undertaking. Elsewhere in the country, as in the North Central States, a program involving 8 or 10 townships, 100 farms and ranches, and perhaps 12,000 cattle, would not require much more effort. In the Southwest, as in New Mexico, grub populations in huge areas might be reduced materially through the cooperation of as few as 5 to 10 ranchers.

Wherever located, the area should be blocked out into a roughly square or circular shape, with as short a boundary line as possible.

Wherever the district in which grub control is to be undertaken is located, it is necessary to consider the existence of natural barriers against invasion by heelflies. The perfect place for a control project is an island. Heelflies apparently do not cross large bodies of water, and grub-free cattle on an island a mile or more from the mainland are not likely to be reinfested. In approximating such ideal conditions, it may be advisable to extend the territory up to the banks of a large lake or wide river. Mountains and woodland are similarly effective, and even croplands on which there are no cattle provide a barrier against heelflies. Every effort should be made to separate the district from nearby concentrations of untreated, grub-infested cattle and to make it difficult for heelflies to reenter.

The administrative aspects of a program can be worked out with the assistance of Extension Service advisers or instructors of vocational agriculture. Thereafter the participants will find it useful to select an executive or committee to be in charge. A county association of cattlemen or dairymen, or a similar group, may have to assume those duties if the undertaking is large.

All owners of cattle within the com-
munity should take part in the program, because any untreated cattle in the area will constitute a source of infestation for treated animals and will make control that much harder. Actually, if more than 80 percent of the cattle within the community can be treated systematically, the program will be worthwhile. Routemen should be appointed early to get in touch with all participants to outline the details of operation, and to discuss with the cattle owners the economic advantages to be gained and the methods of treatment.

Details that must be attended to are the purchase of enough cube or derris powder for treating all animals and arrangements for applying the insecticide. If hand treatment is to be employed, the distribution of the insecticide, properly mixed, weighed and sacked, will help expedite matters.

Spraying equipment will generally be required for large herds. Some associations of cattlemen have found it desirable to buy their own orchard sprayers. Other groups may obtain such equipment from the Extension Service office or may find it economical to contract with commercial pest control operators for the work. In still other instances, the cooperating members may own enough suitable equipment to provide facilities for all cattle owners in the community.

Usually systematic grub-control practices have to be continued for 3 years before appreciable results, in terms of reduced grub infestations and heelfly activity, will be obtained.

Often the establishment of a workable program requires able and persevering leadership during the first year, but once support and experience have been gained, a control schedule can be maintained for years with little effort. When grub populations have finally been reduced materially in a large area, only 1 or 2 applications of insecticide may be required each winter to keep the pests at a low level.

When all aspects of cattle grub control are considered, the problem may appear to be a formidable one, but is by no means insurmountable. Stockmen have demonstrated their ability to conduct successful control programs, despite the deep snows and the subzero temperatures encountered in Washington in midwinter, or the difficulties imposed by the repeated handling of cattle on the huge ranches of New Mexico. In any locality in which a majority of cattle owners are willing to expend the time and energy required, cattle grub infestations can be virtually eliminated, as in parts of South Dakota. It is a matter of record that community action against this pest is effective, practical, and rewarding.

Irwin H. Roberts is a veterinarian and parasitologist in the Animal Disease and Parasite Research Branch of the Department of Agriculture and has been stationed in Springfield, Ill., since 1953.

Arthur W. Lindquist, a graduate of Bethany College and Kansas State College, since 1931 has conducted and directed research on the biology and control of hornflies, tabanids, screwworms, blowflies, cattle grubs, mosquitoes, and other pests affecting man and livestock.

For further reading on cattle lice:
John G. Matthysse: Cattle Lice, Their Biology and Control, Cornell University Agricultural Experiment Station Bulletin 832, 67 pages. 1946.