Parasites and Insects Affecting Livestock

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HERE is a general survey of the more important types of internal parasites and insects that attack livestock, telling what they are and how they affect animals and outlining the methods commonly used to control them.

Parasites that attack livestock and poultry may live on the skin or in its layers (external parasites) or in the digestive tract, the liver, the lungs, the kidneys, and elsewhere in the body (internal parasites). With few exceptions, the external parasites are insects or forms related to insects. Most of the internal parasites are either microscopic organisms known as protozoa or belong to a group of larger parasites known collectively as worms.

Although the direct injuries produced by external parasites are confined for the most part to the skin, some of them have a profound effect on the general health. In addition to causing serious annoyance, some of the bloodsucking insects and related forms such as ticks introduce the germs of diseases.

Internal parasites seriously injure the parts of the body in which they become localized, their presence in large numbers frequently resulting in stunting, unthriftiness, wasting, and death.

In this article the more important external and internal parasites that are common to different kinds of domestic animals and poultry are discussed.

INTERNAL PARASITES AND THE DISEASES THEY CAUSE

The parasites affecting the various domestic animals are more or less related. Those that affect horses and mules in the United States,
however, with only a few exceptions, are not closely related to those affecting cattle, sheep, and goats. Since the domestic ruminants are closely related to one another, it is not surprising that they harbor the same or closely related species of parasites, which produce similar diseases. Parasitic diseases more or less like those occurring in domestic ruminants are known to affect swine also. The domestic ruminants and swine are therefore more often common hosts of certain groups of parasites and associated diseases than are domestic ruminants and horses, or horses and swine, or all of these animals together. The parasites and parasitic diseases of dogs and cats discussed in this article, though related to some of those affecting farm animals, are not transmissible to them.

The parasitic diseases of domestic birds, with the exception of coccidiosis, which affects poultry as well as food animals and pet animals, are caused by organisms most of which are not closely related to those that cause disease in livestock, and they are not discussed in this article.

The severity of the parasitic diseases depends in general on the number of parasites present in the affected host animal. As a rule the presence of relatively small numbers of parasites produces no noticeable symptoms or only slight ones; moderate numbers produce symptoms that are more or less pronounced; and large numbers usually cause severe symptoms. It must be borne in mind, however, that light or moderate symptoms may later become pronounced or even severe. Such an increase in the severity of symptoms in parasitic infections is an outward expression of increasing damage sustained by the host, resulting as a rule from an increase in the number of causative organisms present. In coccidiosis this increase results partly from the multiplication of coccidia within the host and partly from the intake of additional infective organisms from the outside. In the other diseases discussed, the increase in the number of offending organisms results solely from the continued intake of infection.

Coccidiosis

Coccidiosis, a disease affecting cattle, sheep, goats, swine, pet stock, and poultry, is caused by protozoan organisms known as coccidia, which live in the cells of the intestinal lining. The infective microorganisms gain entrance into an animal by being swallowed with feed or water that is contaminated with the droppings of animals already infected.

Coccidia are unusual among the parasites affecting domestic animals and poultry in that each of their various species is strictly specific to one species of animal, except as noted below. Coccidia of chickens and other poultry do not appear to be transmissible from one species of bird to another, and bird coccidia are not known to be transmissible to livestock, or vice versa. Each class of livestock, with the possible exception of sheep and goats, harbors its own species of coccidia. Coccidia of sheep are identical with those in goats, as far as can be judged from the structure of the organisms occurring in these two hosts, but conclusive proof of cross transmission from sheep to goats, or the reverse, is still lacking.
The life history of coccidia, beginning with the infective organism outside the host, is as follows:

An infected animal or bird may eliminate thousands of oöcysts (coccidia organisms in the resistant stage) daily with its droppings. Under favorable conditions of temperature and in the presence of moisture, each normal oöcyst develops until, in a few days, through successive division, it contains eight sausage-shaped infective bodies known as sporozoites. Susceptible animals grazing on pastures contaminated with the droppings of infected hosts or animals and birds swallowing feed or water so contaminated ingest the oöcysts. In the host's intestine, the outer membrane of the oöcyst, acted on by the digestive juices, ruptures or softens, and the sporozoites within, activated by the warmth and other conditions in the intestine, escape into the lumen (cavity) of the gut. Each sporozoite is able to attack an epithelial, or membrane, cell, penetrate it, grow at its expense, and ultimately destroy it. Before the cell has been destroyed, however, the parasite has divided into a number of new infecting bodies, which escape from the parasitized host cell when it disintegrates. Each of the new infective bodies repeats the process of cell penetration, growth, multiple division, and cell destruction. As a result, the intestinal lining becomes rapidly denuded of many of its cells, and the finer blood vessels are exposed and ruptured, producing hemorrhage into the intestinal lumen.

Sooner or later, a more complicated method of reproduction takes place, resembling in many respects the fertilization of the egg by the sperm in higher animals. The coccidial cell that has become fertilized secretes a membrane around itself and is eliminated from the intestine with the droppings. In this last stage it is known as an oöcyst. The oöcyst lives and develops in the open, as previously noted, and serves to propagate coccidiosis from host to host.

A severe infection with coccidia produces diarrhea and the liquid feces may become mixed with blood. Bloody diarrhea is characteristic of coccidiosis of poultry and cattle and occurs in other affected animals. Hosts that recover from coccidiosis continue discharging oöcysts for a long time. Livestock and pets, except in very severe infections, usually make a recovery, and chickens also recover, though less often. Susceptible young animals and birds occupying quarters with those that are or were affected are thus exposed to infection.

**Diseases Caused by Nematodes in the Alimentary Canal**

Of the worm parasites affecting the alimentary canal, the following, all nematodes, are among the most injurious to farm animals: (1) Stomach and intestinal threadworms, known collectively as trichostrongyles; (2) hookworms; (3) nodular worms; and (4) large roundworms, or ascarids. Under certain conditions each of these kinds of worms is capable of injuring the wall of the alimentary canal and producing more or less serious injuries elsewhere in the body, making the affected host animal definitely sick. Hookworms and ascarids also affect dogs and cats, producing diseases similar to those caused by related parasites in livestock.
Threadworms as a Cause of Gastroenteritis

Threadworms, or trichostrongyles, which occur in different classes of domestic animals, are especially abundant in cattle, sheep, goats, and related wild ruminants. In domestic ruminants the different parasites concerned become localized in the fourth stomach or in the small intestine; some species become localized in both places.

The threadworms are from about a fifth of an inch to an inch long and very slender. Some species, the common stomach worms (*Haemonchus contortus*), for instance, live in the stomach. Others, like the bankrupt worm (*Trichostrongylus* species), which gets its common name from the saying that stockmen whose animals are heavily parasitized are headed for bankruptcy, occur mostly in the intestine, though one species becomes localized in the stomach. A few, particularly those belonging to the genus *Nematodirus*, occur only in the intestine. The activities of these worms cause an inflammation of the stomach and intestinal wall known as gastroenteritis.

The common stomach worm occurs in all domestic ruminants, as do several other species of threadworms. Certain other species, however, occur only in cattle. Some occur only in sheep and goats.

Swine harbor in the stomach a trichostrongyle known as *Hyostrongylus rubidus*, and one of the trichostrongyles of ruminants, *Trichostrongylus axei*, occurs also in the stomach of equines.

The cycle of infection of host animals with trichostrongyles is as follows.

Microscopic eggs are discharged by the female worms into the lumen of the host's alimentary canal and are eliminated from the body with the droppings. During warm weather the eggs in the droppings develop and hatch in a few days. The larvae feed on the manure and are transformed into the infective stage in about a week, meanwhile passing through two successive molts. Cold weather retards the development of eggs and first-stage larvae and may even kill them, but infective larvae are resistant to cold and some other hazards. The infective larvae migrate upward on grass and other vegetation after rain, fog, or dew, when a film of moisture on the plants provides favorable conditions for them. Cattle, sheep, and goats grazing on pastures at such times may swallow dozens of larvae with almost every mouthful of forage.

Once in the host's alimentary canal, the larvae are localized in the stomach or intestine, depending on the species. Usually they penetrate the mucosa (mucous membrane), where they undergo at least part of their development, finally returning to its surface, on which, in most cases, they live as adults. After the mating of the sexually mature worms, the females begin to discharge eggs, which, as already noted, are eliminated with the droppings.

Trichostrongyles in the digestive tract of ruminants are capable of producing severe injuries. Some injuries are brought about by the penetration of the larvae into the mucous lining of the stomach or intestine, which destroys its integrity. Some of the worms suck blood and thus produce minute lacerations of the stomach or intestinal wall, from which blood oozes and may continue to ooze for a time.
after the worms have completed their meal. It is possible also that as a result of their life processes the parasites liberate toxic substances that are absorbed by the host. When the worms are abundant, the parasitized host becomes anemic, shows evidence of malnutrition even though adequate feed is available, suffers from digestive disturbances of various kinds, as evidenced by diarrhea or in some cases constipation, and is adversely affected in other ways.

The sum total of the injuries produced results in a condition designated by stockmen as unthriftiness. Marked unthriftiness leads to wasting and death. Losses among calves, lambs, and kids all over the United States, particularly in farm flocks and herds rather than on the open range, are due to a considerable extent to the effects of trichostrongyle infection, as is also much of the unthriftiness among cattle, sheep, and goats.

Trichostrongyles in swine and horses are known to produce local injury to the stomach wall. The precise effect of these nematodes on the health of their hosts has not been adequately investigated.

**Hookworm Disease**

Hookworm disease, characterized principally by anemia, is produced by a group of nematodes that occur in the small intestine of domestic ruminants, swine, dogs, and cats. Hookworms of the smallest species are somewhat longer than most trichostrongyles, and all are much stouter. Hookworms are included among the strongyles, which are related to the trichostrongyles but differ from them in a number of ways. The principal difference is that a strongyle has a relatively large cup-shaped mouth, which is missing in the trichostrongyles. The mouth of the hookworm is provided with teeth, cutting plates, or both. The hookworm attaches itself to the intestinal wall, sucks a piece of the intestinal-wall lining into its cup-shaped mouth, and lacerates the finer blood vessels with the teeth or cutting plates, thus obtaining blood.

The available evidence indicates that hookworms of cattle, sheep, and swine are specific to their respective hosts and are not transmissible from one kind of animal to another. The hookworms of sheep and goats belong to the same species and can presumably be transmitted from one of these animals to the other. Hookworms of dogs and cats also are specifically identical and are transmissible from one to the other but not to domestic ruminants or swine.

Hookworms are acquired by susceptible hosts either through the swallowing of the larvae that hatch on the ground and develop in a week or so to the infective stage or through the penetration of the infective larvae through the host’s skin. When the larvae are swallowed, they reach their preferred location in the host’s intestine and develop to maturity as do the trichostrongyles. When hookworm larvae have penetrated the skin, they enter the blood vessels and are carried by the blood to the heart and thence to the lungs. Here they escape from the finer blood vessels by rupturing their walls, which brings them into the air spaces of the lungs. By upward migration they reach the branches of the windpipe known as the
bronchi, pass through the windpipe proper, and arrive at the back of the mouth. On being swallowed, they get into the intestine, where they develop to sexual maturity and the female worms produce eggs, which are eliminated with the host’s droppings.

The penetration of the infective larvae through the skin may produce inflammation and even more serious lesions. In addition, injury to the skin in any animal is fraught with more or less danger. A broken skin opens the way for micro-organisms, some of which may be capable of doing serious harm. Although the migration of hookworm larvae through the host’s lungs apparently does not produce the severe injury that follows a similar migration of ascarid larvae, hookworm larvae rupture the blood vessels in the lungs and produce more or less hemorrhage. The chief injury to the host, however, is inflicted by the adult worm in the intestine. As previously stated, the parasites attach themselves to the intestinal lining and extract blood. The wounds produced by the laceration of the intestinal mucosa continue to bleed for a time after the worms detach themselves. The parasites find a new location on the intestinal wall, attach themselves, obtain blood, and seek another spot probably many times in the course of a day. When many worms are present, the bites and subsequent hemorrhages result in numerous small bleeding wounds on the intestinal wall. Marked anemia, swellings of the pendent portions of the body, weakness, and emaciation may follow. Other aggravating symptoms are digestive disturbances, including diarrhea or constipation.

**Nodular Disease**

Nodular disease occurs in cattle, sheep, goats, and swine. It derives its name from the lesions produced by the immature worms, which occur in small circumscribed areas, known as nodules, raised above the surface of the intestinal lining. The adult worms occur in the lumen of the large intestine. Nodular worms bear a marked resemblance to hookworms, their size range being from about half an inch to about an inch in length by about one-fiftieth of an inch in width. Their close relation to hookworms may be judged from the fact that, like hookworms, they are strongyles and possess a more or less cup-shaped mouth, which, however, is not armed with teeth or cutting plates.

Each of the susceptible domestic animals harbors its own kind of nodular worms, which so far as is known, are not transmissible from one to another except for those of sheep and goats.

Nodular disease affects sheep primarily and may lead to serious consequences in these animals if the nodules are numerous. In the other farm animals affected, the infection is more or less mild, so far as available evidence shows. Not all the pertinent facts concerning nodular disease in farm animals have been ascertained, however, and it is possible that further investigation may reveal that many species not now suspected of being particularly injurious are able to do considerable harm.

Infection with nodular worms, like that with hookworms and the trichostrongyles, results from swallowing the infective larvae with
feed or water. These larvae have passed through two successive molts since they were hatched from eggs discharged with the droppings of host animals. Under favorable conditions of temperature and moisture such as prevail during the late spring, summer, and early fall in all but the dry sections of the United States, the entire development on the ground or on a pasture, beginning with the egg and terminating with the infective larva, requires about a week.

On entering the body of its host the larva penetrates into the intestinal lining, undergoes its early development there, and returns to the lumen of the intestine to complete its growth and development to sexual maturity. After mating, the females begin to discharge eggs, thus starting the cycle all over again. Some larvae become trapped within the nodules and may remain there for months or die without getting out.

The penetration of the larvae into the intestinal mucosa produces an inflammatory reaction. Wandering cells from various parts of the body, especially from the blood, are attracted to the place of irritation. The accumulation of these cells around the larvae produces the solid swelling, or nodule, that becomes raised above the surface of the intestinal lining. At the apex of the nodule there is an opening for the escape of the larva and for the discharge of pus. Nodules of the common nodular worm of swine are of pinhead size, but other species parasitizing swine create nodules that are much larger and sometimes greatly inflamed. Occasionally such nodules become greatly enlarged and are filled with pus, which gives them the appearance of abscesses. In sheep the nodules are conspicuous, particularly after they have become filled with a cheesy mass resulting from the disintegration of various cellular elements within them. This soft mass becomes hardened, or calcified. Sheep guts containing calcified nodules are spoken of as knotty guts.

Although much still remains to be determined concerning nodular disease of domestic animals, there is no doubt concerning its seriousness in sheep. In severe cases, sheep suffer from diarrhea and from disturbance of the slow, rhythmic intestinal movements known as peristalsis, and this interferes with the digestion and absorption of food. There is also a possibility that the absorption of disintegrating products within the nodules produces more or less poisoning, which, together with other effects, results in emaciation.

**Ascariasis**

Ascariasis designates the injuries produced by the large intestinal roundworms, or ascarids. They are the largest known nematodes affecting livestock, the average size of the adults being that of an ordinary lead pencil. Some ascarids are even larger, reaching a length of 1 foot and sometimes more. Those that occur in dogs and cats are much smaller, their maximum length being about 5 to 6 inches. In their adult state, ascarids occur in the lumen of the small intestine. The larvae, however, migrate extensively in the body of their host before settling down in the small intestine.
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Horses, cattle, and swine harbor species of ascarids peculiar to them. The pig ascarid \((Ascaris suis)\) is also found occasionally in sheep and goats and more rarely in cattle. The true bovine ascarid \((Ascaris vitulorum)\) occurs in domestic cattle, the zebu, and the Indian buffalo; so far as is known, it is rare in the United States, having been found in only a few instances in cattle in the South. The horse ascarid \((Ascaris equorum)\) occurs in horses, mules, and zebras. Of the ascarids that parasitize pet animals, \(Toxocara leonina\) occurs in dogs and cats, \(Toxocara cati\) only in cats, and \(Toxocara canis\) only in dogs.

Hosts acquire ascarids through swallowing the microscopic infective eggs of these parasites with forage, dry feed, soil, or water. The eggs, which are discharged with the host's droppings, are relatively thick-shelled and highly resistant to various factors deleterious to most of the eggs of the other parasites previously discussed. Ascarid eggs develop on the ground slowly, even under favorable conditions, 2 to 3 weeks being required, as a rule, for development to the infective stage. An infective egg contains an immature coiled worm known as an embryo. When the worm escapes from the egg it is known as a larva.

When ascarid eggs reach the intestine of the host the shell is affected by the digestive juices and ruptures as a result of the vigorous movements of the embryos within. The immature worms or larvae thus get into the lumen of the gut and attack its lining. After penetrating the intestinal wall, the larvae get into the blood stream and are carried to the liver and thence to the lungs. There they leave the capillaries and get into the air spaces. From this point their migration is similar to that of hookworms. The ascarid larvae get to the back of the mouth and are swallowed. On reaching the intestine again after their roundabout journey through the host, they settle down and develop to maturity in about 2 months. Following the mating of the sexes the females begin to discharge eggs.

The injuries produced by ascarids include those that are inflicted by the larvae in the course of their migrations as well as those caused by the adult worms in the intestine. The larvae do some damage in the liver and much more in the lungs, where they cause pin-point hemorrhages resulting from the rupture of the capillary blood vessels. When many larvae go through the lungs at the same time, the small hemorrhages become numerous and are more or less serious. Furthermore, the passage at about the same time of many larvae through the lungs of a young animal produces irritation and disturbs respiration, as evidenced by rapid breathing and a cough, symptoms of profound injuries to the lungs. In heavy invasions of the lungs by migrating larvae, the animal develops a bronchopneumonia with more or less fever. The injuries produced by the migrating larvae are especially severe in pigs, which remain more or less stunted even after recovery.

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\(^2\) Commonly referred to in scientific literature as \(Ascaris lumbricoides\), the species occurring in man; in this article \(Ascaris suis\) is used largely for convenience.

\(^3\) Regarded by some scientists as constituting a distinct genus and designated as \(Neascaris vitulorum\).

\(^4\) Regarded by some scientists as constituting a distinct genus and designated as \(Parascarisa equorum\).
The adult worms in the intestine rob the host of essential food, this being, perhaps, the slightest of the injuries inflicted. Ascarids are provided with strong lips that bear numerous minute denticles, and they can abrade and otherwise injure the intestinal lining. When they are numerous, they tend to become entangled with one another, forming a mass of coiled worms large enough to produce intestinal obstruction, which may have serious and sometimes fatal consequences. In their wanderings the adult worms sometimes enter the bile duct and reach the liver, obstructing the flow of bile and producing jaundice. The worms may get into the stomach, migrate up the gullet, and enter the windpipe, where they can cause strangulation. They may even perforate the intestines and produce inflammation of the lining of the abdominal cavity, a condition known as peritonitis. Moreover, ascarids produce intestinal disturbances, characterized by constipation or diarrhea. If one or more worms die in the intestine and because of constipation are not eliminated quickly, their disintegration within the host may result in the liberation of toxic substances. This evidently occurs in bovines that harbor the true cattle ascarid. The injuries already enumerated and others not mentioned interfere with the growth of young host animals, producing more or less permanent stunting, marked un thriftiness evidenced by emaciation, a rough coat, and even death when the worms invade vital organs.

**Lungworm Disease**

Lungworm disease of domestic animals, known also as verminous bronchitis, is caused by nematodes living in the lungs and known, therefore, as lungworms. These parasites belong to a group of nematodes called metastrongyles, which are related to the strongyles and trichostrongyles, previously discussed. Aside from their localization in the lungs, metastrongyles differ from the two other groups in certain fundamental anatomical characters.

Horses, cattle, sheep, swine, dogs, and cats all harbor lungworms that are not transmissible from one kind of host to another, except that those occurring in sheep are also known to parasitize goats and to occur also in certain wild ruminants.

Depending on the species of lungworm concerned, the life history is either direct or indirect. In both cases, the eggs hatch in the lungs, and the larvae are coughed up and swallowed. On reaching the outside with the host's droppings, the larvae of species having a direct life history develop into the infective stage after two molts, as do those of the strongyles and trichostrongyles. The infective larvae are taken into the host's body with forage, contaminated dry feed, or water. The common lungworms (*Dictyocaulus*) of horses, cattle, sheep, and goats are acquired in this way. In the indirect life cycle, the larvae eliminated with the droppings do not develop unless they reach suitable intermediate hosts. The larvae of swine lungworms (*Metastrongylus* and *Choerodrstrongylus*) develop to the infective stage in various earthworms; those of the hair lungworms of sheep and goats (*Proostrongylus* and *Muellerius*) develop in
snails, as do also those of cats. The life history of the dog lungworm (*Oslerus*) has not yet been ascertained. The larvae of the cat lungworm, a species occurring in pulmonary blood vessels, may be acquired by snails as a result of active penetration into the soft parts of these intermediate hosts.

The details of the life histories of lungworms have not been ascertained in all cases. So far as the facts are known, the course of events is briefly as follows: Regardless of whether the infection is acquired directly or through intermediate hosts, the infective larvae, on getting into the host animals, reach the lungs by way of the lymph and blood. (Lymph is a body fluid that permeates all the cells and collects in lymph vessels, in which it moves toward the heart; it differs from blood in that it has no red blood cells.) Lymph moving in its vessels finally gets into large lymph vessels, one of the principal ones being known as the thoracic duct. Through this duct the lymph and any lungworm larvae it happens to contain get into large veins that empty into the heart. From the heart the larvae get to the lungs through the pulmonary arteries. In the lungs they escape from the capillary vessels into the air spaces, from which, by active migration, they reach the bronchioles and other parts of the air system of the lungs. There, in their preferred location, lungworms develop to sexual maturity and mate, and the females discharge the eggs, thus starting the life cycle all over again.

Lungworm disease is characterized by a cough, rapid respiration, weakness, emaciation, and sometimes anemia. Diarrhea may be present also, especially in calves. Lungworms appear to produce more serious disturbances in domestic ruminants than in pigs, although young pigs may suffer severely from lungworm infection and it retards their growth. Little is known about lungworm disease in horses. In farm animals that are heavily parasitized by lungworms, solidified areas, sometimes involving almost an entire lobe, may be present in the lungs. Other lung areas may become emphysematous (permanently distended with air) and cease to function.

**Liver Fluke Disease**

Liver fluke disease, as it occurs in domestic ruminants in the United States and Territories, is caused by three species of trematodes, of which the common liver fluke is the most important. This fluke, known to zoologists as *Fasciola hepatica*, is about an inch long by about half an inch wide. A closely related species, the giant liver fluke (*Fasciola gigantica*), about 1 to 3 inches long by about half an inch wide, is the liver fluke of cattle in the Hawaiian Islands, where the common liver fluke does not occur. A third species, the large American liver fluke (*Fascioloides magna*), reaches a size up to 4 inches long by about 1 inch wide.

The common and giant liver flukes occur in the bile ducts and the large American liver fluke in the liver substances. All three species occur in cattle, sheep, and goats. Liver flukes occur also in wild ruminants and other animals, including horses and swine. Liver fluke disease affects principally cattle and sheep among domestic animals, sheep suffering more severe effects than cattle.
Infected hosts eliminate the microscopic fluke eggs with the droppings. The eggs develop in wet or swampy pastures after a period that varies with the species as well as with the temperature; cold weather retards development, and warm weather accelerates it. The larva that hatches from the egg is provided with cilia (hairlike processes) that enable the immature worm, known as a miracidium, to swim. Unless the miracidium finds a suitable snail host within a few hours, it dies.

Snails become infected by the penetration into their soft parts of one or more miracidia. Within the snail the miracidium undergoes a marked transformation, giving rise to several generations of larvae, those of the final generation being known as cercariae. The cercariae, of which several hundred may be produced from a single miracidium, leave the snail and swim about in water for a time. Sooner or later each cercaria secretes a protective membrane, or cyst, about itself. The encysted cercariae lodge on vegetation or float on the surface of water.

Cattle, sheep, goats, and other susceptible hosts, grazing on wet pastures infested with cercariae, swallow them with forage or water. After reaching the intestine of the final host, the cercariae escape from the cysts and bore through the intestinal wall, getting into the body cavity, where they migrate for a time. Within a few days they enter the liver by perforating its capsule. After wandering in the liver substance, the young of the common and giant liver flukes enter the bile ducts, in which they become mature in about 3 months. The large American liver flukes wander in the liver of cattle, in which they become encapsulated, or surrounded by a tough wall, before attaining maturity. In sheep, these parasites do not become encapsulated, the sheep liver apparently offering little resistance to their migrations; hence in sheep, even a small number may practically destroy the entire liver and cause death. Mature liver flukes discharge eggs which reach the intestine with the bile and are then eliminated with the droppings.

The common liver fluke has been studied more extensively, with regard to both its life cycle and the injuries it produces, than the other two flukes, and hence more is known about the disease it produces. In the discussion that follows, the facts have been ascertained by investigations on the common liver fluke and apply for the most part to it.

Liver flukes are bloodsuckers, their bloodsucking activities beginning shortly after they enter the host. The flukes possess muscular suckers with which they can attach themselves to almost any tissue, and the mouth sucker exerts enough pressure on delicate linings to rupture the fine blood vessels underneath. If many flukes pierce the liver capsule at the same time or in rapid succession, more or less extensive hemorrhage into the abdominal cavity may follow. In the bile ducts, the flukes continue to suck blood as long as they remain. Because of their spiny surface, they irritate the delicate lining of the bile ducts and when present in large numbers obstruct the flow of bile. The anemia produced by the bloodsucking activities of the worms is evi-
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denced in the host animal by the appearance of dropsy, especially a swelling of the lower jaw called bottle jaw by stockmen.

In many parts of the world, including certain sections of the United States, liver flukes are the most serious cause of sickness and mortality among sheep. In the past, the flocks of certain countries have been drastically reduced by the ravages of the common liver fluke.

In cattle, digestive disturbances, especially constipation, are symptoms of liver fluke disease. Other evidences of illness observed in these animals are weakness and, in the advanced stages, prostration. As a rule, only calves show marked symptoms, dying in extreme cases, whereas adult cattle are rather resistant to the effects of flukes. Rather serious losses result from the condemnation of cattle livers affected with flukes under Federal and other competent meat inspection. Considering the fact that liver flukes are prevalent in some of the most important areas where beef cattle are raised, namely, the South and Southwest (particularly the Gulf coast region) and the Rocky Mountain and Pacific Coast States, it is evident that the losses resulting from condemnation of calf and cattle livers are a serious financial drain on the meat industry. The financial losses involved are borne, at least in part, by the beef producers.

CONTROL OF INTERNAL PARASITES

Reduced to the simplest terms, the most effective control of the parasites discussed in this article involves systems of management that would entirely preclude the acquisition by domestic animals and pet stock of parasite eggs and larvae from contaminated ground and pastures. Unfortunately, no system of management has yet been devised that will accomplish this. As previously emphasized, parasitized animals eliminate parasite eggs and larvae with their droppings, which are deposited on the ground and on pastures from which the animals obtain their feed. In short, host animals contaminate their own table.

Although complete control by management alone is impossible in the light of present knowledge, much can be done to reduce the intensity of parasitic infection by sanitation practices designed to cut down the intake of excessive numbers of parasite eggs and larvae by grazing animals. Among the practices that experience has shown to be effective are rotation of pastures and of stock, sanitation in animal shelters, a clean water supply, and similar measures that will tend as much as possible to cut down excessive contamination of forage, dry feed, and water with droppings of parasitized host animals.

Since the parasites of horses are in general not transmissible to ruminants, it is safe to rotate equines with ruminants. One of the stomach worms of horses, however, occurs also in ruminants, and when this worm is abundant in either ruminants or equines rotation of these two classes of livestock should be avoided. It is safe to rotate equines with swine and swine with ruminants, but one kind of ruminant should not be rotated with another, because, as has been mentioned, some of the injurious parasites of cattle, sheep, and goats are specifically identical and cross-transmissible. Where there
is sufficient pasture land, it is a sound procedure to move animals from one pasture to another as often as available pastures permit, because of the excessive numbers of parasite eggs and larvae that accumulate during the late spring, summer, and early fall when the same pasture is used continuously.

Special measures designed to reduce or even destroy the snail population are necessary for the control of liver flukes. Draining wet, swampy, and boggy land and broadcasting bluestone or copper sulfate are known to destroy aquatic snails, which constitute an essential link in the life cycle of the fluke. When such measures cannot be carried out, it is advisable to fence off wet areas on pastures so that cattle, sheep, goats, and other susceptible livestock will not have access to them.

Stables, barns, and other animal shelters, as well as paddocks, yards, and corrals, should be kept as clean as possible. This necessitates the frequent removal of manure, which should not be spread on pastures to which the domestic animals will have access during the same season but should be utilized as fertilizer on fields sown to crops other than forage crops. Spreading manure on pastures disseminates gross parasitism in stock, and the practice should be discontinued in the interest of sound husbandry.

Grain fed in barns and other animal shelters should be placed in boxes well above the ground, and hay should be placed in overhead racks to prevent contamination of the feed with manure that may be teeming with eggs and larvae of parasites. Other measures, especially adequate feeding and the supplying of necessary minerals that promote the health and tend to build up the resistance of animals, tend to prevent the inroads and depredations of parasites.

Young animals of all kinds appear to be far more susceptible to the acquisition of parasites and to the effects of parasitic infections than are older animals. Special attention should be paid, therefore, to young stock, which should be kept away, as far as possible, from pastures contaminated with the droppings of older stock and from association with older animals that may harbor parasites without showing clinical symptoms.

**Treatment for the Removal of Parasites**

Drugs used for the destruction of parasites and their subsequent removal from hosts are known as parasiticides. Those used specifically for removing worms are anthelmintics. There is no medicinal treatment for coccidiosis, and since all other diseases discussed in this article are caused by worms, the treatments recommended are anthelmintics.

Anthelmintic medication must be based on sound knowledge of the parasites present in the host, the anatomy and physiology of the animals to be treated, the physiological action of the drug or drugs to be used, judgment in the selection of a specific treatment where more than one drug is available, appraisal of the condition of the subject to be treated to discover indications against any specific treatment or all possible treatments, and skill in administering drugs. Medicinal treatment for the destruction of parasites is the
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business of the veterinarian, just as prevention of parasitic infection by sanitation and other methods is the business of stockmen and farmers.

Treatments administered to kill and expel worms from livestock and poultry have one of the following main objectives: (1) To give parasitized animals that are obviously sick or definitely unthrifty relief from the drain of parasites; or (2) to treat flocks and herds in which parasites are present or suspected, but are not yet sufficiently numerous to cause alarming symptoms, in order to prevent the development of parasitic diseases to a point where marked unthriftiness and death will occur. The former is curative treatment; the latter is largely prophylactic (preventive) treatment. In either case, a sound diagnosis must be established to determine the kinds of parasites present.

For certain species of parasites there are specific treatments; for others there are more general treatments, effective for more than one species. The diagnosis, which must be made before treatment is undertaken, should be based on (1) microscopic examination of the host’s droppings to determine the kinds of parasite eggs or larvae present, or the examination of blood smears for larvae in cases of infection involving this type of parasitism; or (2) post mortem examination of one or more animals that have died from parasitism or of one or more unthrifty animals that have been slaughtered, with particular attention to the tissues and cavities where parasites commonly occur. Either procedure involves technical knowledge and skill not possessed by most stockmen. Unthriftiness and other symptoms of parasitism are useful aids in diagnosis. Some symptoms similar to those due to parasitism may be the result of faulty feeding, or inherent in poor breeding, or caused by other conditions. When unthriftiness and the related symptoms previously enumerated are present in animals of good breeding that are being fed an adequate diet, a presumptive diagnosis of parasitism is warranted in most cases. A conclusive diagnosis should be based on post mortem findings or microscopic evidence of such parasitism in the droppings.

In general, all drugs used for killing parasites are more or less toxic; ordinarily, only a toxic agent can destroy parasites, which are living creatures, leading their normal lives within a host. Since anthelmintics may be more or less toxic to the host, the doses administered must be so standardized in relation to the weight of the host animal as to cause the maximum injury to the parasites and the minimum injury to the host.

Some anthelmintics still in use were developed many years ago. Most of those used in treating livestock, pet stock, and poultry, however, have been developed during the last 2 or 3 decades by rigorous, painstaking scientific research. Much of this research was conducted by parasitologists of the Bureau of Animal Industry. In this research dozens of drugs have, in some cases, been tested on animals and birds before a useful one was discovered.

It is not the purpose here to give specific treatments for the removal of the various internal parasites discussed. Such information is given in the various articles dealing with the specific parasites and
associated diseases of farm animals, pet stock, and poultry. A few drugs more or less widely used as anthelmintics are mentioned, however, for purposes of illustration.

Carbon bisulfide is used for the removal of ascarids from horses; oil of chenopodium is used for the removal of palisade or red worms from horses and ascarids from swine, dogs, and cats. Dilute solutions of copper sulfate (bluestone), with or without nicotine sulfate, are used in the form of a drench for the removal of stomach worms from cattle, sheep, and goats. Carbon tetrachloride is used for removing liver flukes from sheep, and the same drug or tetrachloroethylene, in capsules, for the removal of stomach worms and other trichostrongyles from domestic ruminants and of ascarids and hookworms from dogs and cats. There are no known anthelmintics effective for the removal of lungworms.

The ideal anthelmintic would have no injurious action whatsoever on the host and yet would kill all or practically all the parasites harbored by the animal. Such a drug has not yet been discovered. The nearest approach to it is phenothiazine, developed by the United States Bureau of Animal Industry during the last 3 years, which appears to be the most useful anthelmintic yet discovered.

This drug, administered in proper therapeutic doses in a capsule, in a drench, or in feed, is efficacious for removing stomach worms and related trichostrongyles, as well as hookworms and nodular worms, from cattle, sheep, and goats, palisade or red worms and related strongyles from horses, and nodular worms from swine. No other known anthelmintic removes so many different kinds of parasites from the host animals mentioned as does phenothiazine.

**INSECTS AFFECTING LIVESTOCK**

The relationship of insects to animals is one of considerable complexity. Some insects are injurious to animals in many different ways, whereas some are actually beneficial. Some carry disease germs on their beaks, hairy bodies, and feet, or even within their bodies, and transfer them mechanically and more or less accidentally; others serve as necessary hosts of disease germs or of higher forms of life such as parasitic worms; that is, the disease-producing organism must spend some stage of its life within the insect's body. Some insects injure livestock by biting—sometimes drawing considerable quantities of blood—and by crawling and scratching. Some live within the digestive tract, causing irritation and interfering with the digestion and absorption of food. Some burrow in the tissues, which become inflamed or are actually destroyed.

Many insects are more or less specific to a host—that is, they limit their attack to one or a few kinds of livestock—whereas others attack many or all kinds.

The North American cattle tick, for example, attacks cattle, horses, mules, and sometimes sheep, but it is only to bovines that it transmits cattle tick fever, the deadly disease which gives it its principal importance. The American dog tick and the Rocky Mountain spotted fever tick attack bovines and rarely transmit any disease to them, but they do transmit a deadly disease to man. On the other hand.
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the screwworm attacks practically all kinds of domestic animals and many wild animals and though it does not transmit any disease, it is injurious and may be deadly to any animal it attacks.

It is thus impossible to combine in a convenient list insects having the same characteristics, habits, and methods of injuring livestock. The principal kinds of insects affecting animals may be broadly grouped, however, as follows:

(1) **Mites.** The mites that attack livestock and poultry breed exclusively on the bodies of their hosts. Injury is caused by blood-sucking and the formation of scabs and other skin affections. Considerable damage to hides intended for leather and to the wool of sheep and mohair of goats sometimes results. Mites can be controlled by dipping infested animals in insecticidal solutions or applying insecticides by hand.

(2) **Ticks** (including, among others, the North American cattle fever tick, the Gulf coast tick, the spinose ear tick, the fowl tick, the brown dog tick, the tropical cattle fever tick, the lone star tick, the Rocky Mountain spotted fever tick, and the American dog tick). In general, ticks breed on animals but pass part of their lives in pastures or in close proximity to other places frequented by the hosts. Injury consists for the most part in the weakening of the host by the drawing of blood or in the transmission of disease. General methods of control include the application of insecticidal solutions, usually by dipping, or the application of insecticides to the breeding places; in the case of cattle ticks, also removal of host animals from the infested areas until the ticks starve to death.

(3) **Flies** (including various species of mosquitoes; cattle grubs, or heel flies; the screwworm fly; the stablefly; the horn fly; horse bots; the sheep head bot; the so-called sheep tick; the pigeon fly; horseflies; and the buffalo gnat). Flies breed in various situations. The nature of their injury to animals is extremely varied. It may consist in loss of blood and irritation due to biting (the latter sometimes resulting in violent and injurious reactions on the part of the animal), in the transmission of disease, or in the feeding of the insect larva on the vital tissues of the host. It is usually necessary to use specific control measures for each species of fly. Some species can be controlled by treatment of the breeding place or by the use of insecticidal sprays at the time the insect is making its attack on the animal. In other cases it is necessary to apply insecticidal ointments or washes to the body of the host. A fumigant introduced into the stomach of the host is used, among other things, for the control of horse bots.

(4) **Lice.** Lice breed only on the host. Injury consists in lowered vitality of the animal and reduction in the quantity and quality of animal products. Control is effected by the application of insecticides, either dry or in solution. They may be applied by dipping or with spraying or dusting apparatus.

(5) **Fleas.** Fleas breed in debris, bedding, and dirt in places frequented by their animal hosts. Their bloodsucking and irritating propensities make them especially injurious to poultry. Their attacks may cause the death of young chickens. Egg production is
interfered with seriously. Dog and cat fleas transmit the dog tape-worm to these animals. Fleas also seriously annoy human beings and carry bubonic plague and endemic typhus. They can be controlled by cleaning up and treating infested premises and by applying insecticides to the host.

**CAUSES OF INSECT ABUNDANCE**

A distinction should be made between the causes of insect abundance and the causes of insect attacks on animals. Conditions for which man is responsible often favor insect breeding, and as a result the insects become so abundant that they are a scourge to livestock. In other cases the breeding of large insect populations is a natural phenomenon and cannot be charged directly to man's interference with nature. Man does not directly cause insect attacks on animals. The attacks are caused by natural forces—primarily hunger or the biological urge to perpetuate the species.

Any large-scale interference with nature is likely to produce far-reaching and sometimes unforeseen consequences. In general, nature tends to maintain a working balance between insects and their animal hosts whereby both may live a normal existence and neither can exterminate the other. There is no record of extensive insect deprivations on the buffalo that once ranged over a wide area in the western part of our country, but since that region has been brought directly under human management, insect attacks on livestock have become a serious problem.

Grouping and holding livestock in barns and small enclosures disturbs the balance of nature. When barns and barnyards are allowed to become insanitary there is a further disturbance. Accumulations of manure mixed with straw and uneaten feed and trampled into a mire furnish breeding places for such insect pests as stableflies, houseflies, and fleas. Neglected pigpens and runs may be expected to produce houseflies and fleas, and a dirty chicken house is an ideal place for the breeding of sticktight fleas and other pests of poultry.

Insanitary household premises may also provide insect breeding places. In some parts of the country, houses are raised above the ground, and dogs, cats, and rodents run freely underneath them, creating a condition favorable to the breeding of fleas. Anything that will hold water, such as tin cans or old automobile tires scattered about the yard, is a potential breeding place for mosquitoes.

In farm fields it is not unusual to find old neglected strawstacks. The parts that become wet breed stableflies (dog flies) by the thousands. Where peanuts are grown, the same thing occurs if the trash and litter from the crop is left in piles on the field.

On irrigated farms and ranches the faulty or careless handling of water is often responsible for veritable plagues of insects. Slight leaks in the main canals form pools of standing water in which mosquitoes breed. Holding water on the fields for an unnecessarily long period produces the same result on an even larger scale, and poor drainage is likely to cause swamp conditions conducive to the continuous breeding of both horseflies and mosquitoes.
Where livestock are subject to attack by the screwworm, certain farm and ranch practices have a great influence on the breeding of this pest in destructive numbers. Any flow of blood, however slight, on an animal predisposes it to screwworm attack. Among the practices that may be expected to contribute to an abundance of screwworms are the use of excessive amounts of barbed wire; neglect of projecting nails and jagged boards or poles in corrals, pens, and barns; performing surgical operations on animals in seasons of the year when screwworms are active; faulty regulation of breeding, resulting in the dropping of young when screwworms are abundant; carelessness in shearing, resulting in cuts in the animal's skin; and the use of dogs to catch animals, resulting in wounds that attract the screwworm fly. Wounds caused by fighting between animals, the scratching of needlegrass or pricklypear in pastures, and the attacks of other species of parasites, such as horn flies, horseflies, and ticks, also favor infestation by screwworms.

In the case of such pests as lice and mange mites, it seems apparent that poor condition, for which the owner is presumably responsible, predisposes the animal to attack. Dairymen and stockmen sometimes claim that animals in poor condition are more heavily infested with cattle grubs than fat ones, but there is no conclusive evidence that this is a fact. It seems certain, however, that the attacks of internal or external parasites in considerable numbers reduce the vitality and condition of an animal.

**Prevention and Treatment of Insect Attacks**

Obviously, the first line of defense against insects should be to eliminate breeding sources, so far as possible, and to avoid conditions that predispose animals to attack. When such measures are only partly successful, direct action must be taken against the insects.

The diversity of the habits and life histories of insects makes it necessary to use many different control methods. Seldom can a method of control be set up that is applicable to more than one species. Dipping vats installed for the control of cattle ticks may be used to control cattle lice or mange mites and for dipping sheep and goats for lice and scab, but for most of the insect pests of livestock individual methods of treatment are necessary.

In determining a suitable method of control it is necessary for the investigator to know the life history of the insect in detail. Most insects undergo radical changes in form in the course of their life cycle, the usual stages being egg, larva, pupa, and adult. At each stage the insect is likely to be subject to different environmental influences, and its ability to fend for itself and ward off danger is likely to be different. One of the fundamental principles of insect control is that, to be effective and easy to apply, it must be directed at the weakest or most susceptible stage in the insect's life. In some cases this is the adult stage and in others one of the immature stages. Sometimes, however, control measures may profitably be directed against more than one stage. In the case of the housefly, for instance, it is obviously the larval stage that offers the best chance for the
effective use of control measures, but since considerable numbers of larvae succeed in reaching the adult stage in spite of the measures taken to destroy them, it is advantageous also to use fly traps and sprays for the control of adult flies. Likewise, in the case of the stablefly the principal control measures are directed against the larvae, which breed in massed wet straw, seaweed, and vegetable litter of various kinds; but it is impossible to locate all the breeding places, and some adults are usually present to pester livestock, so that an effective fly spray is also distinctly useful.

The horn fly, practically a specific pest of cattle, is best controlled in the adult stage by contact sprays or by cattle fly traps, which are reasonably effective. In small pastures it is possible to destroy the larvae by hauling a brush drag over the fresh droppings to break them up and allow them to dry quickly. The breeding of houseflies is also prevented by regularly removing manure from barn lots and pens and scattering it on fields soon to be plowed.

Specific treatments adapted to each of many types of insects affecting livestock are described in other articles in this volume.