No specific chemical treatment of proved reliability is available for coccidiosis of sheep and goats. Sulfonamides, especially sulfaguanidine, sulfamethazine, and sulfasuxidine, have been used advantageously in several instances. At the proper time and in proper amounts, they may destroy some of the intestinal stages, reduce the production of oöcysts, and help the animal withstand the injurious effects of the parasites. Since the developing stages of coccidia injure the lining of the intestine and make it easier for bacteria to invade the intestinal wall, these drugs may be of help in stopping invasions by certain bacteria.

Fly strike is favored by the watery feces of coccidial scouring, which keeps the wool on the hind parts moist. The odor of the feces attracts blowflies, and they lay tremendous numbers of eggs on the soiled wool. The larva, or maggots, that hatch from the eggs live close to the skin and attack the tissues of the living animal. Severe infestations of the larva may cause death unless they are detected early and proper treatment is given.

Treatment consists in removing the soiled wool and applying a medicated smear or ointment to destroy the maggots and to promote the healing of lesions. Commercial screwworm remedies are recommended for this purpose.

Control of coccidiosis of sheep and goats rests largely on the use of management practices that help to keep the animals from contaminating their feed and water with droppings, which may contain oöcysts. That, in turn, helps keep the animals from swallowing large numbers of oöcysts at one time and thus prevent severe cases.

Some suggestions:
Clean pens often and keep them dry. Ordinary disinfectants have little or no effect on oöcysts. Washing pens with disinfectants may be of little value against coccidiosis, but may help to control bacterial diseases.

Crowding animals together in close quarters favors coccidiosis. With increased use of improved pastures and more intensive farming, there is an increasing tendency to keep larger numbers of sheep and goats in small areas. Pastures should not be overstocked. A plan of pasture rotation should be followed.

Feed good diets and use prescribed medicines in recommended ways to help prevent severe infections, especially when animals are crowded. Sulfur mixed in the feed of lambs kept in feed lots is reported to have given good results against coccidiosis.

John C. Lotze, a parasitologist in the Animal Disease and Parasite Research Branch, has done research on protozoan diseases of livestock at the Agricultural Research Center since 1938.
More than twenty-four species of roundworms occur in the digestive tract of sheep and goats in the United States. The worms are tiny, cylindrical, threadlike parasites. Some are hard to see with the unaided eye.

The common and scientific names of roundworms that occur more or less frequently in sheep and goats in this country are given in the list that follows. (When more than one species is listed under one common name, the first species named is usually the most important one. Practically all species listed occur in sheep and goats, but some are commoner in sheep than in goats, and vice versa. Some species normally are parasites of cattle but have been reported also in sheep and goats. In fact, about half of these species have been found in cattle and several kinds of wild ruminants.)

**IN ESOPHAGUS AND RUMEN—gullet worms:** Gongylonema species.

**IN FOURTH STOMACH (abomasum)—** large stomach worm: Haemonchus contortus; medium stomach worms: Ostertagia circumcincta, O. trifurcata, O. occidentalis, Marshallagia marshalli, Pseudostertagia hullosa; stomach hairworm: Trichostrongylus axei.


**IN LARGE INTESTINE and blind gut, or cecum—nodular worms:** Oesophagostomum columbianum O. venulosum; whipworms: Trichuris ovis, T. globulosa, T. discolor; large-mouthed bowel worm: Chabertia ovina; pinworm: Skrjabinema ovis.

Parasitic gastroenteritis, a term that means irritation or inflammation of the stomach and intestines caused by parasites, usually roundworms, often is applied to a disease caused by several kinds of roundworms. It is not always possible to separate the effects of one kind of parasite from the effects caused by others.

The term “parasitic gastritis” is used when only the stomach is involved. “Parasitic enteritis” is used when only the intestines are involved. Sometimes more specific terms derived from the common or the scientific names of the parasites are applied when only one kind of roundworm is concerned in disease. For example, “haemonchosis” refers to infections with the large stomach worm, “ostertagiasis” to medium stomach worms, “trichostrongylosis” to hairworms, “hookworm disease” or “bunostomiasis” to the hookworm, “strongyloidiasis” to the threadworm, and so on.

The injurious effects of roundworms on sheep and goats are many and varied according to the species, numbers of parasites present, the age and nutritional status of the animals, and other factors.

Some kinds of roundworms are well tolerated by their hosts or seldom occur in numbers large enough to produce perceptible effects.

Some of the clinical symptoms of roundworm infections are diarrhea (scours), anemia (reduced number of red blood cells and quantity of their contained red pigment), edema (swelling caused by excess fluid in the tissues), emaciation (unthriftiness from failure to gain or from loss of weight), loss of appetite, and physical weakness. The acute effects of roundworms, or less severe chronic effects of long duration, may cause death of the host.

Both immature and adult roundworms may injure the tissues of the digestive tract. For example, larvae of the nodular worm stimulate the formation of pea-sized nodules in the wall of the small and large intestines. Medium stomach worms and cooperias cause the formation of very small
nodules in the wall of the stomach and small intestine, respectively. The large stomach worms, the hookworms, and large-mouthed bowel worms cut or pierce the inner lining of the part of the digestive tract in which they live with special mouth structures, at the same time ingesting blood, lymph, and cells from the gut wall.

Additional blood is lost from such small cuts or abrasions by seepage into the cavity of the digestive tract, from which it is eliminated in the droppings. When the worms make many small perforations of the gut lining, the total daily loss of blood may be greater than the animal can replace, and anemia ensues.

Hairworms, thread-necked worms, and threadworms do not usually inflict discrete, visible injuries to the tissues of the gut or cause anemia but cause diffuse damage to the gut lining, often to the extent that it may be partly destroyed.

Affected animals refuse food. Fluid may be lost from the body from a diarrhea and excessive urination. Normal digestion and absorption of nutrients are interrupted.

The life histories of these roundworms are called direct, as transmission from host to host occurs without intervention of an intermediate host, such as an insect, mite, or snail. The gullet worms are exceptions; their larvae develop in dung beetles.

Adult worms of both sexes live in the digestive tract. (The threadworm is an exception; only its females are known.)

Females deposit eggs in the cavity of the gut after fertilization by the males. The eggs are very small, usually contain one to many cells or a small larva, and are eliminated from the host in the droppings. On pasture under favorable conditions, the free-living development takes place. Small, active larvae, infective to sheep and goats, develop in a few days from the eggs. When a film of moisture is present on vegetation, they move onto the plants.

Infective larvae, after being swallowed by the host, develop to maturity in the digestive tract in 1 to 5 weeks, depending on the species. The young worms penetrate into the lining of the gut of the host, or are lodged between the small, fingerlike projections (villi), and usually cause damage to the tissues. As the worms mature, they usually, but not always, move to the cavity of the gut and spend their adult lives there.

Some variations of this typical life history occur in some species of roundworms. Knowing what they are helps one to understand the damage done and the symptoms.

Infective larvae of the hookworm and threadworm, which likewise can produce infection after being swallowed, also can enter the animal's body through the skin.

Many larvae penetrate the small blood vessels of the skin and are carried by the blood to the lungs. In the lungs they migrate from the small blood vessels through the lung tissue to the small air sacs. Infective larvae of these roundworms when swallowed may also penetrate the gut tissues, much as they penetrate the skin, and may be carried to the lungs by the blood. When the larvae reach the air passages in the lungs, they migrate up the windpipe or are coughed up and swallowed. Development to maturity takes place when they again reach the small intestine.

An interesting variation from the typical life history occurs in the threadworm, besides the fact that only females are known in the parasitic phase. Some of the small larvae, which are in the eggs when deposited on pasture, may develop directly into infective larvae. Others, however, may develop into adult, free-living males and females that differ in structure from the parasitic females. These in turn give rise to a much larger number of infective larvae than would develop directly from eggs deposited on the pasture.

In the following more detailed ac-
count of these parasites, emphasis is placed on the roundworms that cause the greatest losses to farmers. No further mention will be made of the gullet worms, which seldom occur in large numbers in sheep and goats. Therefore, the following discussion concerns the roundworms of the abomasum (hereafter referred to as "stomach"), the small intestine, and large intestine, including the blind gut, or cecum.

IN THE TRUE STOMACH of sheep and goats are three important kinds of roundworms, the large stomach worm, several species of medium stomach worms, and one species of hairworm. These are the common roundworms found in the stomach of these hosts, but occasionally some of the species that normally live in the small intestine are found in the stomach, and vice versa.

When small numbers of stomach worms are recovered from the intestines after death, it is usually thought these worms are being eliminated from the host. The stomach not only performs important digestive functions; it also insures the regular passage of food materials into the small intestine in the proper form and quantity for further digestion. Therefore, when the stomach cannot function normally because of the injurious effects of roundworms in it, the digestive processes, appetites, and general health of the parasitized animals are seriously impaired.

The large stomach worm is the main roundworm of sheep and goats in most of the United States. Its life history is direct. Heavy infections and clinical disease, called haemonchosis, are more common in localities with long summers and moderate to heavy rainfall or where pastures are irrigated than in cold, arid localities. The reasons are that infective larvae develop best during warm, wet weather, and the free-living stages are killed by relatively short exposure to drying and subfreezing temperatures. When arid land in warm localities is irrigated and made into productive pasture, it becomes ideal for the development of the larvae of large stomach worms and other roundworms. Heavy infections are rapidly acquired by stock under such conditions, and losses are serious. This roundworm is also common in cattle and wild ruminants throughout the country, and its injurious effects on these animals are much the same as for sheep and goats. This parasite is such a common cause of losses that sheepmen and goat raisers routinely take measures to prevent haemonchosis from developing in their flocks and herds.

Haemonchosis is a serious disease. Its most important symptom is anemia. Infective larvae of the large stomach worm develop into adult worms in the stomach in 2 to 3 weeks. The males are one-half to three-fourths inch long. The females may be more than 1 inch long and look like pieces of coarse thread. The worms are very vigorous. Each has a small, sharp tooth on the upper surface of a small mouth cavity, by which small cuts are made in the wall of the stomach. Blood seeps into the cavity of the stomach from the cuts. More blood is sucked from the stomach wall by the worms. The intestines of living worms are usually filled with blood and are deeper red than the light-pink body of the worms. The whitish reproductive organs of the female are wrapped around its intestine; the names "twisted stomach worm" and "barber-pole worm" therefore are often applied to the parasite. The stomach of an animal that dies of haemonchosis usually contains much chocolate-colored material, which is blood altered by chemical action in the stomach.

Animals seriously ill of haemonchosis may seem to be in good health and flesh, except when the infection is of long duration or other parasites are involved, which often is the case. When the anemia is severe, the whites of the eyes and skin are pale, there may be a swelling under the jaw (bottle jaw), and the animals are incapable of much
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exertion because of the lack of red blood cells to carry oxygen to the tissues of the body.

Normally there are 10 million or more red blood cells in 1 cubic millimeter of blood in healthy sheep and goats. When the number is reduced to 3 million or below, animals may die suddenly. The number of red blood cells may be reduced in acute haemorrhage to a fatal low level in just a few weeks.

Medium stomach worms are about one-half inch long. The males are smaller than the females. They occur in sheep and goats throughout the country, but they cause clinical disease in the Western States oftener than in other parts of the country.

Five species of medium stomach worms occur more or less commonly in sheep and goats in this country, but only *O. circumcincta* and *O. trifurcata* are of much importance. Three other species occur in restricted localities in small numbers.

The life histories are direct. Their early parasitic development takes place in the lining of the stomach, where they form small, red, elevated spots or, at times, larger, flattened nodules. The mature worms usually move out of the tissues and live close to the inner surface of the stomach wall. When large numbers of young and adult worms are present, they irritate the stomach and generally interfere with digestion. Heavily infected animals may lose weight, scour, and become anemic.

The stomach hairworm is only about one-fourth inch long. It is like a short piece of fine thread. It is the smallest roundworm of sheep and goats and cannot be seen without a microscope when the stomach of an infected animal is opened for inspection. The stomach contents and scrapings of the lining must be washed thoroughly so that the worms are obtained relatively free of debris before they can be seen. This worm is unusual in that it infects cattle, horses, and various wild animals, besides sheep and goats. It has been reported only once in a wild rab-

bit, but domesticated rabbits, guinea pigs, and hamsters have been infected with it experimentally.

Its life history is direct. Infective larvae after ingestion develop into mature worms in the stomach in about 2 or 3 weeks. Young worms penetrate deep into the glands of the stomach, but most of the adults live near the inner surface or in the crevices of its lining.

The stomach hairworm severely injures all its hosts, particularly sheep and goats. Because the worms live in the rear part of the stomach near the valve between the stomach and small intestine, they can exert great effect on digestion and the movement of food and fluids to the small intestine.

In heavily infected animals the lining of the rear of the stomach, the pyloric valve, and the first few inches of the small intestine are acutely irritated, inflamed, and swollen. Affected animals refuse feed and water, lose weight, and become diarrheic, with copious watery feces. Many die, after experiencing acute symptoms for a week or more.

In chronic infections of long duration, especially when the animals are poorly nourished, the failure to gain weight is a common symptom and a nutritional anemia may develop. Small ringwormlike ulcers may also form in the stomach in chronic infections. In acute infections, however, the opposite of anemia may occur—an increase in concentration of red blood cells, brought about by excessive fluid loss from the body.

In the small intestine of sheep and goats several different kinds of roundworms may be found—intestinal hairworms, the hookworm, thread-necked worms, the threadworm, cooperias, and capillarids. All (except possibly the capillarids) can injure their hosts. (In addition to these worms, the larvae of the common nodular worm produces nodules in the small intestine, as well as in the large intestine and the cecum.)
All these roundworms have direct life histories. Infections are acquired by sheep and goats by swallowing infective larvae. The larvae of the hookworm and threadworm may also penetrate the skin.

Intestinal hairworms are only slightly larger than the stomach hairworm and usually must be recovered from the small intestine after death by special techniques and identified by a microscopic examination. They are found in the first one-third of the small intestine. Their injurious effects on the small intestine are like those produced by the stomach hairworm. Their general effect on sheep and goats also is much the same.

The disease caused by stomach and intestinal hairworms is called trichostrongylosis. In Australia it is commonly known as “black scour,” because in affected sheep the wool around the anus usually is soiled by fluid feces. Actually, fluid feces in acute cases of pure hairworm infections is usually light brown or medium brown, but when considerable blood is lost into the cavity of the gut because of concurrent infections of large stomach worms or hookworms, decomposed blood blackens the fluid feces.

Trichostrongylosis is a serious disease, whether caused by hairworm species in the stomach, in the small intestine, or both. When sheep and goats are scouring, thin, and emaciated and poor feed is not entirely to blame, hairworms are often found to be the cause of their poor condition, although certain other kinds of roundworms may produce similar symptoms.

The characteristic symptoms of hairworm infections are loss of appetite, scouring, and loss of weight or failure to make normal gains. Scouring is often absent, however, unless the infection is overwhelming. When trichostrongylosis is made worse by haemonchosis or hookworm disease, the affected animals may scour and be anemic at the same time.

The hookworm is one of the large roundworms. The females are about an inch long. The males are slightly smaller. They are stout, muscular worms of a light-pink color. They live in the middle part of the small intestine. Their front ends are slightly bent, somewhat like a hook. Usually they are not encountered in as large numbers in sheep and goats as are large stomach worms, but several investigators have found several hundred worms in an animal.

The hookworm is potentially a dangerous parasite, particularly in localities with long periods of warm weather and high rainfall or on irrigated pastures in warm climates. Its life history is direct, but infective larvae may enter the hosts either by mouth with feed or through the skin.

Hookworms feed upon blood and cells while attached to the lining of the small intestine. They may move from one spot to another, making small punctures in the lining from which blood oozes into the cavity of the gut. Surrounding the mouth of the hookworm is a hard structure, called a buccal capsule, which contains cutting plates and a large tooth. Its esophagus is very muscular, and it can suck blood from the host’s intestinal tissues.

The effects of heavy hookworm infections on sheep and goats are nearly the same as those produced by large stomach worms. The same kind of anemia occurs in hookworm disease as in haemonchosis, even though the loss of blood occurs in one case in the small intestine and in the other in the stomach. Other side effects of the two roundworm diseases also are similar. Hookworm disease is less common than haemonchosis in goats and sheep.

Thread-necked worms inhabit the first third of the small intestine. They cause nematodiroisis. They are common in sheep and goats, particularly in localities of low average temperatures, as their pasture stages survive exposure to cold weather very well.

The females are about an inch long. The males are three-fourths inch long. All are threadlike. The hind half of the female is fairly broad and contains
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unusually large eggs. The front end of the body tapers toward the mouth and is quite narrow. Living, adult worms are light pink and sluggish in their movements. Immature worms are vigorous. When the small intestine of an infected animal is cut open, the adult worms can be seen tightly coiled in masses in the cavity of the intestine. Immature worms are hard to see, as they are smaller than adults and often are in the spaces between the intestinal villi.

Like the hairworms, thread-necked worms injure the lining of the small intestine and cause loss of appetite, a diarrhea, poor gains, and a loss of weight.

The threadworm causes strongyloidiasis in sheep and goats. Closely related species cause a similar disease in cattle, swine, dogs, monkeys, certain other animals, and man.

This roundworm is common in lambs and kids, but heavy infections may also occur in adult animals. Only females are known in the parasitic phase of the life history. They inhabit the first part of the small intestine, where they are found with their front ends deep in the spaces between the villi. Threadworms are about as long as hairworms, a quarter of an inch or less. They are slender and transparent and are hard to see with the unaided eye.

Strongyloidiasis is usually a disease of young animals. Injury to lambs and kids may be done in three ways. A skin irritation, or dermatitis, may occur when the larvae are penetrating the skin. The lungs may be affected. Bleeding may occur from the lung capillaries when larvae are passing through these organs on their way to the small intestine. Adult female parasites may injure the lining of the small intestine, causing an enteritis and symptoms similar to those associated with infections of hairworms and thread-necked worms.

Cooperias are small roundworms, one-fourth to one-half inch long. They inhabit the middle part of the small intestine. They can be distinguished from other kinds of small roundworms only with the aid of a microscope. Cooperias are common in all parts of the United States. Their life histories are direct.

*Cooperia curticei* is the most common one in sheep and goats. Its injurious effects are less severe than those we described for intestinal hairworms and thread-necked worms. They cause some irritation to the lining of the intestine. In chronic cases, small nodules form around immature worms in the tissues of the gut. Some of the other species of cooperias listed are known to cause more severe effects in cattle, but usually do not occur in large numbers in sheep and goats. Like most of the injurious roundworms, the cooperias, when present in large numbers, adversely affect the utilization of feed and rate of gain of lambs or kids.

Capillarids are slender roundworms, about one-half to three-fourths inch long, and are more closely related to whipworms than other kinds of roundworms of sheep and goats. They inhabit the small intestine. They seldom occur in large numbers and are not known to be injurious.

The large intestine and cecum of sheep and goats commonly harbor several kinds of roundworms, nodular worms, whipworms, the large-mouthed bowel worm, and the pinworm. Nodular worms, which are discussed in another chapter (page 399), are by far the most injurious roundworms found in the large intestine of these hosts in this country. The others may cause some trouble.

The whipworms look like the whipworms of other animals and man. Females may be 3 inches long. The males are slightly shorter. The front part of the body is slender and usually is embedded in the lining of the cecum, or upper part of the large intestine. The rest of the body is broader, contains the reproductive organs, and lies free against the lining. The life history is direct. Infection takes place when the
host swallows eggs that contain small larvae.

As far as we know, no serious injurious effects have been ascribed to whipworms of sheep and goats, but in heavy infections (which are rare) the lining of the large intestine and cecum probably suffers some irritation from their presence.

The large-mouthed bowel worm is about the same size as the two species of nodular worms, about an inch in maximum length, and resembles them superficially. At the head end is a large, cup-shaped buccal capsule, which has no teeth. This roundworm is much less common than some others. It has a direct life cycle. It is attached to the lining of the coiled parts of the large intestine by its buccal capsule, which is like a small suction cup. Damage is caused to the lining in a manner similar to that of the hookworm. This roundworm may cause diarrhea, bloody feces, loss of weight, and moderate anemia in heavy infections.

A species of pinworm, related to the pinworms that infect horses and man, is harbored by sheep and goats in some localities. It is found in the large intestine and usually is more common in goats than in sheep. Females are about one-fourth inch long. Males are about half as large. The life history is probably direct, but it has not been investigated thoroughly. Whether this roundworm is injurious to its hosts has not been determined.

Diagnosis of roundworm infections of the digestive tract of sheep and goats is done by one or more of three methods: Microscopic fecal examinations for roundworm eggs; postmortem examinations to recover adult and immature worms; and observations of clinical symptoms displayed by affected animals.

The eggs of roundworms passed in the droppings are too small to be seen with the unaided eye. They are thoroughly mixed with the manure when they are voided by the animal. The eggs therefore must be concentrated, partially cleared from the fecal debris, and studied with a microscope. That is done by a simple technique. Fecal preparations for microscopic examination are made by mixing a small amount of feces, usually a half or quarter of a pellet or the equivalent in mushy or fluid manure, with a solution of higher specific gravity than the eggs, which will float the eggs to the surface. The usual flotation solutions used are saturated solution of common salt in water, a concentrated solution of sugar (about 1 pound of sugar to 12 ounces of water), or a 33-percent solution of zinc sulphate in water.

The fecal sample and the solution can be mixed in a small vial. Flotation of the eggs can be accomplished in a few minutes by gravity, or the mixture can be placed in a small centrifuge tube and centrifuged for about a minute or two at moderate speed. The eggs that float to the surface of the solution are removed to a glass slide and examined microscopically. This technique is very useful, as the number and kinds of eggs in the feces are often roughly proportional to the number and kinds of roundworms in the animal. (Infrequently, however, when an animal has a heavy infection of immature roundworms, a fecal examination will not reveal any eggs.) This technique has a further advantage in that it can be used with living animals.

Research workers in Australia have devised a special slide for flotation and counting of helminth eggs in feces, known as the McMaster egg-counting slide. This slide, when used with a special technique, has been found to be efficient for processing large numbers of fecal specimens in the minimum of time. Also, some diagnosticians prefer the fecal-culture method of diagnosis. Small quantities of feces are cultured in small bottles, and larvae of the roundworms are subsequently obtained therefrom for examination and identification.

Postmortem examinations for parasites are performed in order to estab-
lish a diagnosis based upon the presence of adult or immature roundworms in the digestive tract. The abdominal cavity is opened, and the digestive tract is removed and opened for examination. Large roundworms are easily seen and can be removed for study, but the small and immature worms of all kinds must be separated by special techniques from the food material and studied microscopically. Direct total counts of the large roundworms usually can be made, but when large numbers are present or the worms are small, those in a small sample or samples are counted and the total number is calculated.

The clinical symptoms we described as associated with roundworm infections often are helpful in making a diagnosis, but one cannot rely entirely on them because other diseases and conditions often cause similar effects. In sheep and goats, however, when such symptoms as diarrhea, anemia, emaciation, edema, loss of appetite, poor weight gains on good feed and forage, weight loss, and physical weakness are seen, roundworm parasites of the digestive tract are often involved.

The effects of poor or inadequate nutrition are often associated with the effects of parasitism, and the two factors are difficult to separate.

CONTROL OF ROUNDWORMS of the digestive tract of sheep and goats is of utmost importance if one is to raise the animals profitably. Parasite-free, or relatively parasite-free, animals make better weight gains and are more productive than animals with moderate to heavy parasitism.

It is not practicable now to raise parasite-free sheep and goats on the farm, although under experimental conditions that goal has been approached. It is possible, however, to control roundworms in sheep and goats so their effects are small or insignificant. This objective can be accomplished by the use of proper management procedures that check the transmission of roundworms from animal to animal and by judicious use of medication.

Sheep and goats acquire infections by grazing on pastures contaminated with larval stages of the parasites. All practices designed to reduce the numbers of the infective larvae aid in control. The numbers of infective larvae on pastures may be reduced to low levels if strict attention is given to three practices:

First, resting pastures, to take full advantage of the killing effect of adverse climatic conditions on larvae,

Second, maintaining animals on a high level of nutrition, to develop maximum resistance to roundworm infections and to their injurious effects, and

Third, reducing the numbers of adult egg-producing worms in grazing animals by medication. The drug most effective in removing roundworms of sheep and goats, phenothiazine, also has important secondary effects of inhibiting egg production of female worms not removed from the hosts and preventing the development of infective larvae from eggs deposited in manure on pastures.

Most of the larval stages of many kinds of roundworms are killed by exposures of a few weeks to 2 months of drought in the summer or by subfreezing weather in winter. Most larvae will survive best during periods of high rainfall and moderate temperatures. Irrigation probably lengthens the survival time of larvae. The killing effect of subfreezing weather on roundworm larvae is minimal in the Southern States. Larvae of a few kinds of roundworms are resistant to adverse effects of certain weather conditions. Significant numbers of larvae of medium stomach worms and thread-necked worms survive over winter even in the coldest parts of the country. Most other kinds of roundworms are primarily carried over winter in the breeding stock. Knowledge of the lethal effects of climatic conditions on free-living stages of roundworms is helpful in planning a pasture rotation program for parasite control.
Roundworms are easier to control if sheep and goats are fed well. A well-fed, healthy animal generally withstands the injurious effects of roundworms better and tends to have fewer worms than a poorly nourished one.

Animals subjected to massive invasions of large stomach worms, hookworms, and other roundworms that can produce anemia, need a high intake of iron, protein, and other nutrient elements (including carbohydrates and minerals) to replenish the blood lost as the result of infection. In some localities forage may not contain all the nutrients needed to maintain a high level of nutrition, and dietary supplements, including minerals, are helpful in maintaining nutrient levels and lessening the effects of parasitism.

A number of chemicals or combinations of chemicals are in use against roundworms in sheep and goats. In order of their usefulness they are:

- Phenothiazine, copper sulphate and nicotine sulphate, copper sulphate, carbon tetrachloride, tetrachlorehylene, hexachloroethane, copper sulphate and sodium arsenite, and copper sulphate and arsenic pentoxide. These chemicals are of little or no value in treating some kinds of roundworm infections.

Phenothiazine is the most useful drug for removing and controlling roundworms of the digestive tract of sheep and goats and is used more widely in the United States than any other. It is particularly effective against large stomach worms, the medium stomach worms, hookworms, liverworms, large-mouthed bowel worms, and nodular worms. Phenothiazine is less effective, but still useful, against cooperias, thread-necked worms, and the whipworms. Phenothiazine has been found so useful in control of so many kinds of roundworms of sheep, goats, and cattle that several million pounds are used annually in this country.

Phenothiazine is remarkable in its action against many kinds of adult roundworms of sheep and goats, but it cannot be relied upon to remove immature roundworms from the digestive tract.

Phenothiazine may be administered in capsule, bolus, and tablet form and as a drench. It may be mixed in feed. The dose of the drug is usually 1 ounce (25 grams) for adult sheep and goats and about three-fifths ounce (15 grams) for lambs and kids under 60 pounds. Doses for adult animals may be safely varied from 20 to 40 grams, and about one-half those amounts for lambs and kids. The lower dose range is adequate for removing large stomach worms and nodular worms, but the higher dose range is needed when hairworms and thread-necked worms are the main roundworms present.

It is helpful to give treatments to breeding stock in the late fall or early winter, or a month before lambing and kidding time, and to treat again before they are put out to pasture in the spring. Because many kinds of roundworms are carried over the winter primarily in breeding animals, the spring treatment is helpful in preventing early contamination of pastures and early exposure of lambs and kids to infective larvae.

Phenothiazine also may be used preventively by a free-choice method of administration. Phenothiazine may be mixed with loose salt or suitable mineral mix in the proportion of 1 part by weight of the drug to 9 to 14 parts by weight of salt or minerals. This mixture is made available to the animals in a suitable container that protects the mixture from rain.

Sheep and goats should get about one-half gram of phenothiazine a day. That amount has the effect of preventing to a considerable extent the development of roundworm larvae in the droppings. The free-choice method may be used continuously and combined with therapeutic treatments when needed. If animals eat less of the medicated salt or supplement than is desirable, a small amount of grain may be added to make it more palatable.

Salt blocks medicated with phenothiazine have also been used in some
localities, but it is not certain that they are economical or efficient.

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Nodular Worms of Sheep and Goats

REX W. ALLEN

SHEEP and goats harbor two species of nodular worms, the common nodular worm (Oesophagostomum columbianum) and the lesser nodular worm (O. venulosum).

The adult stages of both species live in the lower part of the digestive tract. They are whitish and about one-half inch long and one-fiftieth inch wide.

The common nodular worm causes the condition known as pimply gut, or knotty gut, in which growths—nodules—occur in the walls of the intestines.

Intestines of sheep are used in the meatpacking industry chiefly as casings for sausage and as material for surgical sutures. Intestines containing nodules are unsuitable for those uses.

The developmental cycle of the common nodular worm begins with the eggs that are produced by the adult female worms. The eggs pass out of infected animals in the manure. After a period of development, a small, immature worm—a first-stage larva—hatches from each egg. The larva grows into a second-stage and finally a third-stage larva.

The third stage is the infective stage. It is about one thirty-second inch long.

It can develop further only in a susceptible animal, such as a sheep or goat. Development from the egg stage to the infective stage takes 6 or 7 days if the weather is favorable. Lower temperatures prolong the time or prevent development entirely.

In experiments conducted at Beltsville, Md., in 1945, A. G. Dinaburg found that mean air temperatures of 65° F. or above are necessary for their development. That means that in most parts of the United States little development takes place during winter.

The infective larvae are swallowed with feed or water. They penetrate the intestinal wall, usually in the lower part of the small intestine. After about 5 days, the larvae have attained a length of about one-twelfth inch. Now they migrate out of the wall into the lumen, the hollow part of the intestine, where growth to the adult stage takes place. Infective larvae usually reach the adult stage in 4 to 8 weeks.

The lesser nodular worm develops in much the same way.

Nodules, which often are as big as a pea, form as a direct result of penetration of the intestinal wall by the larval worms. Nodules are sites where