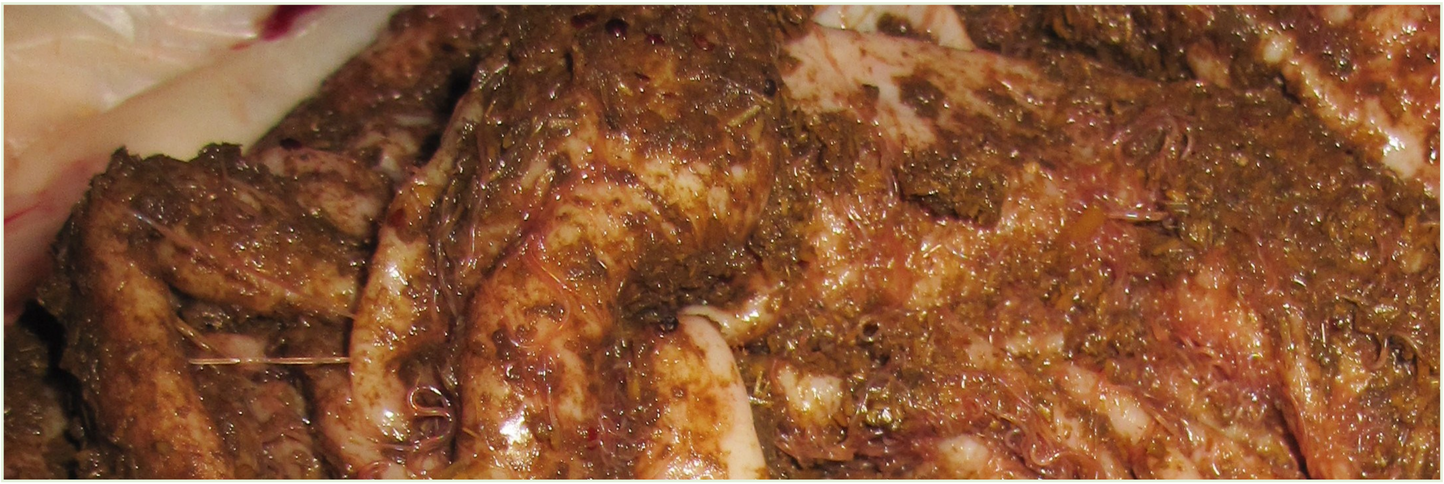
UNDERSTANDING THE BIOLOGY



Heavy infection with *Haemonchus contortus* in the abomasum of a sheep. Some individual worms can be seen, but all the reddish material present is clumps of parasites. Image by Anne Zajac

Sheep, goats, and camelids in the US and around the world are infected with a broad range of internal and external parasites. In many regions of the world, the most important parasites are the gastrointestinal nematode worms (GIN) that are able to cause substantial production loss and even death.

All grazing sheep and goats and camelids are infected with a community of GIN that can contribute to disease and production losses. With the development of modern dewormers beginning in the 1960's, control programs based on frequent deworming of all animals in a flock or herd reduced the ability of these parasites to affect animal health and production. However, these programs led to the rapid development of significant drug resistance. Adequate control of these parasites now requires integrated parasite management programs that are most effective when they are based on a basic knowledge of the biology of the parasites.

Although all grazing small ruminants are infected with GIN, low worm numbers will usually have little impact on animal health. However, as worm numbers increase, decreased appetite and reduced weight gain may occur. With even heavier worm burdens, clinical signs including weight loss, diarrhea, anemia, and bottle jaw may develop. Camelids (llamas and alpacas) can also be infected with these parasites and suffer the same signs of disease when parasite numbers are high. Adult cattle and horses, however, usually do not become infected with sheep and goat GIN and usually kill these parasites if they ingest them.

As a consequence of these host preferences, cattle and horses can be used to help decrease the level of infective parasite larvae on sheep/goat pastures (an exception to this general rule is that calves can be infected with *Haemonchus contortus* and should probably not be placed on heavily infected pasture). This can be accomplished either by grazing horses or cattle with sheep/goats or placing horses or cattle on pasture after it has been grazed by sheep/goats. If the latter strategy is used, it is important to leave the horses/cattle long enough to allow all the eggs of the small ruminant parasites to hatch and develop to the infective stage.

While all GIN can contribute to disease in sheep and goats, there is one worm that dominates in importance throughout the Eastern and Midwestern

US and also in many other countries around the world. This parasite is *Haemonchus contortus*, also known as the barber (or barber's) pole worm or wireworm. The details of the life cycle of almost all other related GIN parasites like *Teladorsagia* and *Trichostrongylus* are very similar to those of *H. contortus,* and the same life cycle based strategies can be used in parasite management.

HAEMONCHUS CONTORTUS

Haemonchus contortus adults are found in the abomasum, or true stomach, of small ruminants. In camelids, the parasites are found in C3, the camelid equivalent of the abomasum. One of the reasons that *H. contortus* is such an important parasite is its mode of feeding. Unlike most GIN that feed on intestinal tissue or fluids, the barber pole worm feeds directly on host blood. The parasite has a small "tooth" that is used to lacerate the stomach wall and cause surface bleeding, with the worm ingesting released blood.

When large numbers of parasites are present, significant loss of red blood cells and blood proteins occurs, resulting in anemia and bottle jaw, which can be fatal. Severe infections are most likely to occur in young animals before immunity has developed. Long term infection with moderate numbers of *H. contortus* may lead to reduced growth and less severe anemia. This is especially likely to occur in animals on a nutritionally inadequate diet or with other chronic disease conditions.

BIOLOGY AND LIFE CYCLE

When barber pole worm larvae infect a host, they must first complete their development to the adult stage (figure 1). This process takes from two to three weeks and once male and female worms are mature, they mate and females begin to produce eggs. Barber pole worms are remarkably prolific and each female worm can produce up to 10,000 eggs/day. It is not unusual for sheep or goats to be infected with hundreds or thousands of parasites that could daily produce millions of eggs. Individual adult worms have a limited life span and usually survive for only a few months.

Eggs of *H. contortus* and other GIN are shed in the manure of infected animals. Development of the eggs

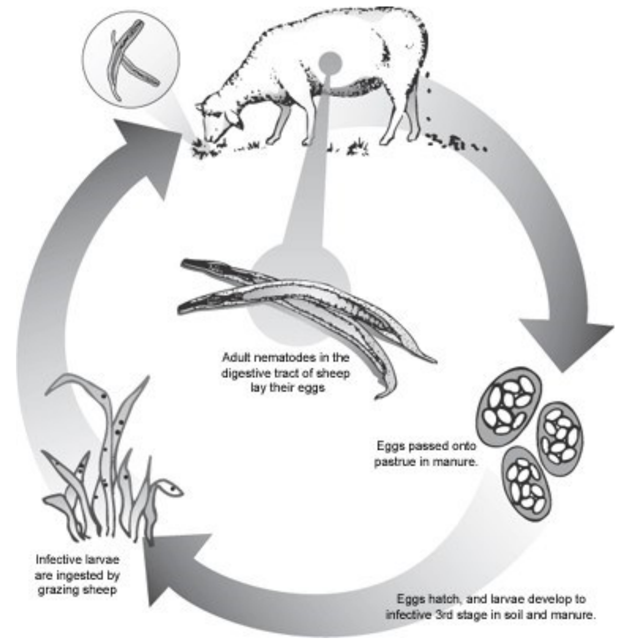


Figure 1. Life cycle of *trichostrongyle* parasites.

Figure from Whittier et al. *2009*. Control of Internal Parasites of Sheep. Virginia Cooperative Extension, Virginia Tech.

occurs in the manure which provides some protection from environmental conditions. The cells inside the egg form a larva (first stage or L1) that hatches out of the egg. After hatching, larvae feed on bacteria and go through two more molts to reach the infective third larval stage (L3). These third-stage larvae make their way out of the fecal material and onto the forage where they are ingested by sheep and goats. This process is dependent on environmental conditions and can take days to months.

The success of GIN egg and larva development and survival in the environment has an enormous influence on the number of parasites that will eventually infect small ruminants. In general, development of GIN eggs and larvae occurs in a temperature range of approximately 50°F to 96°F. *Haemonchus contortus* is so important in small ruminants in the US because the climate in much of the country is favorable for the development and survival of its infective larvae. *Haemonchus contortus* develops most successfully in warm, wet climates; eggs and larvae do not tolerate cold temperatures well. The southeastern US in particular, with its hot, humid summers and long grazing season, is very well suited for *H. contortus*. In many other states, summer grazing season conditions provide an appropriate environment for *H. contortus* development. The parasite is very important in these areas as well, although the period of active transmission is shorter than in southern states.

In studies done some years ago, scientists found that optimum conditions for transmission of *H. contortus* were present from May through September in Urbana, Illinois, whereas in Columbus, Georgia optimum conditions occurred from mid-March to mid -October. Work by members of the American Consortium for Parasite Control (ACSRPC) has shown that, even in New England, *H. contortus* is the predominant parasite identified in fecal samples in the summer grazing season. As far north as Canada, Scotland and Sweden, *H. contortus* can be successfully transmitted for long enough during the grazing season that disease may develop in vulnerable animals.

In western states with cold winters and dry summers, *H. contortus* becomes less important. However, *Haemonchus* can become an important parasite in dry regions if irrigation is practiced. In a study comparing irrigated with non-irrigated pasture in Utah, conditions were suitable for transmission of *Haemonchus* on irrigated pasture during 5 of the 6 months of the experiment. In contrast, conditions were never suitable for transmission on the non-irrigated pasture during the study.

The length of time required for development of the egg to the L3 stage has an impact on the design of pasture rotation systems. The minimum length of time required for the development of *H. contortus* larvae is about 3 to 4 days, and numbers of infective larvae can build up quickly in hot summer weather. The activity of dung beetles and earthworms breaks up fecal material and reduces the number of larvae by exposing developing stages to desiccation and ultraviolet light. If eggs are deposited in manure in cool spring weather it may take several months for the L3 larvae to be produced. As a result, larval numbers on cool spring pastures in more northern states may not significantly increase until late spring or early summer.

Because larvae develop within the fecal pellets, frequent removal of feces provides excellent control of GIN. Unfortunately, manure removal is seldom practical with sheep and goats, because of the small size and random distribution of fecal pellets on pasture. With camelids, however, manure removal is a very useful strategy for parasite control. Llamas and alpacas typically use communal dung piles that can be easily removed to extensively limit contamination of pasture with infective larvae. If the minimum time for development of eggs to the infective stage is considered (3 to 4 days), then removal of manure piles at least twice a week will be highly effective.

***Haemonchus contortus* adults removed from the stomach of a sheep. Adult females reach a maximum size of about 1 inch in length.**
Image by Anne Zajac

Once infective larvae have formed, they must leave the fecal pellet and migrate onto the pasture. Rain is important in releasing larvae from the manure. During dry weather, larvae will be retained in the manure pellets. With the next rain, there will be a burst of larval release. Producers may see an outbreak of parasitic disease a few weeks after the end of a period of drought when animals are exposed to large numbers of newly available infective larvae. Larvae of *H. contortus* and most other GIN do not survive well on surfaces other than grass pasture and little transmission occurs in housing or on dry lots. However, even the smallest tufts of grass can support larval survival and significant infection can occur in animals kept in dirt paddocks with small grass areas or where animals can graze through fences.

Parasite larvae can migrate laterally and vertically in films of moisture on grass and other plants. The ability of larvae to migrate is affected by air temperature, soil moisture, and relative humidity.

If pastures can be maintained to preserve a forage height of 4 to 6 inches, exposure to parasites can be reduced.

Vertical migration of most larvae is limited to about 4 to 6 inches from the ground. *Haemonchus contortus* larvae stay within a 12 inch radius after migrating out of manure, although some could move up to 36 inches. If pastures can be maintained to preserve a forage height of 4 to 6 inches, exposure to parasites can be reduced. Additionally, when animals are allowed to browse on bushes and other taller plants, infection will be reduced. Goats are browsers by nature and provision of browse plants in goat pastures is strongly recommended in parasite control programs.

The length of time that infective larvae can survive on the pasture is important for pasture management programs that aim to control parasitism. Nematodes are covered by a tough semi-permeable outer layer called the cuticle. The cuticle is replaced with each molt, but the infective L3 larva retains the cuticle of the second-stage larva as a sheath. While the sheath gives these larvae greater resistance to environmental conditions, it also prevents them from feeding. Once an L3 utilizes its stored metabolic reserves, it will die. Consequently, cool, moist conditions best support survival of the infective larvae because they will deplete their metabolic reserves slowly.

In hot weather, L3 use their reserves rapidly and survive for much shorter periods. In the temperate portions of the US, a pasture that has been grazed by sheep or goats must be rested for 6 months during cool weather to be considered safe. In the hot summer grazing season, numbers of larvae are usually significantly reduced after a rest period of 2 to 3 months. Parasite larvae will die more quickly if pasture regrowth is used for hay or the pasture is plowed and reseeded. When utilizing pasture rest or rotation as a method of parasite control, these time periods need to be considered.

HYPOBIOSIS

The epidemiology of important species of GIN is also strongly influenced by aspects of host/parasite biology after infection occurs. Larvae of important GIN are able to undergo a period of arrested development (hypobiosis) in the host. Following infection, larvae may become metabolically inactive for a period that may last several months and before resuming development. The greatest proportion of incoming larvae will become arrested at times of the year when conditions in the environment are least favorable for development and survival of eggs and larvae. In areas with cold winters, *Haemonchus* survives the winter months primarily as arrested larvae. When worm populations in the gastrointestinal tracts of sheep were examined in several eastern states, more than 80% of *Haemonchus* and some other GIN were present as arrested larvae in winter.

Even without anthelmintic treatment (deworming), in states with cold winters, *Haemonchus* problems usually resolve at the end of the grazing season. This is because most newly ingested larvae will become arrested in the host and eggs that are shed at the end of the grazing season are unlikely to develop or develop very slowly, preventing further buildup of infective larvae on pasture. Where winters are very mild, hypobiosis appears to be less important in the epidemiology of parasite transmission. In Louisiana, for example, levels of hypobiotic larvae in the GI tract were never substantial in lambs followed throughout the year, although the highest proportion of hypobiotic larvae tended to be in the fall.

In areas where seasonal arrest of parasite larvae occurs, emergence and development of adult worms in late winter and spring are followed by an increase in fecal eggs counts. The rise in egg counts is magnified in ewes and does in late pregnancy and early lactation by a relaxation of immunity that increases survival and egg production in existing parasites and also increases susceptibility to further infection. This relaxation in immunity typically begins 2 to 4 weeks prior to and peaks around 2 to 4 weeks post kidding/lambing. The periparturient egg rise (PPR) can make an important contribution to L3 populations on pastures as young, susceptible animals begin grazing.

SUMMARY

Several elements of the biology of *Haemonchus contortus* and GIN can be used in designing integrated parasite control programs (see table).

Understanding important aspects of the biology and life cycle of *Haemonchus* and other GIN provides opportunities for decreasing or interrupting successful parasite transmission, thereby reducing parasite loads in animals. Similarly, understanding important aspects of the response of small ruminants to parasite infection provides additional opportunities for successful control including use of the FAMACHA© selective deworming system, nutritional management, and breeding for parasite resistance. These essential strategies are discussed in other fact sheets in this series.

Integrated parasite control

1. Mixed or alternate grazing with horses or cattle helps reduce levels of infective larvae because each animal host has its own species of parasites (an exception is that young cattle can be infected with *H. contortus*).

2. Because infective larvae usually don't migrate higher than 4 to 6 inches on grass, managing pastures to minimize grazing below that level can reduce exposure to larvae. Similarly, allowing goats to utilize browse plants will reduce parasite exposure.

3. If using strip grazing for parasite control, move animals every 3 days so no eggs have a chance to develop to the infective stage.

4. Significant numbers of infective larvae can be removed from pasture by allowing a period of pasture rest of at least 2 months in the grazing season, or by using the pasture regrowth of a grazed pasture for hay or plowing and reseeding pasture.

5. Utilize knowledge of parasite biology in managing the periparturient egg rise. Birthing in dry lot or during times of year when parasite larvae do not develop or survive well on pasture can substantially reduce initial parasite infection of lambs and kids when they begin grazing.

Cattle and horses can be used to help decrease the level of infective parasite larvae on sheep/goat pastures.

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