Introduction
Gastrointestinal parasitism remains a significant health problem in horses, although the nature of the problem has changed in the past 20 years. It is probably fair to state that ivermectin revolutionized control of gastrointestinal parasites of horses, but the use of ivermectin, or any other anthelmintic, did not eliminate equine gastrointestinal parasites. When administered at recommended intervals, the use of ivermectin did eliminate the devastating clinical disorders associated with *Strongylus vulgaris* (thrombo-embolism, verminous arteritis). Subsequently, clinical problems attributable to other endoparasites (small strongyles, tapeworms, roundworms) have become more notable. Reliance on anthelmintics to control endoparasites has led to the emergence of resistance to many anthelmintics, especially among the small strongyles, and this will require a more targeted approach to the management of parasites, under the supervision of a veterinarian.

Important Equine Endoparasites
This paper is not intended to be a thorough review of parasitic disorders in the horse. The most frequent disorders caused by endoparasites in foals and horses are related to infections with *Parascaris equorum*, the many species of cyathostomes (small strongyles), the large strongyles (primarily *Strongylus vulgaris*), and *Anoplocephala* species. Infection with *Gasterophilus* sp. is usually benign, but heavy can cause clinical problems. In certain environments, infection of foals with *Strongyloides westeri* is a clinical problem.

*Parascaris equorum* -
Roundworms are of particular concern in foals, because innate control of roundworm infection relies upon the acquisition of an immune response to the parasite. Infection with *Parascaris equorum* can develop in older horses, and not just those that are immuno-suppressed. The author has diagnosed primary ascariasis in horses 2 to 4 years of age. Nonetheless, the problem is most widespread in foals. Ascariasis is associated with poor weight gain, increased total body water content, respiratory disease (due to larval migration), and colic, which can be secondary to enteritis, impaction, or intussusception. Foals less than 6 months old are most susceptible to infection and are the source of the greatest egg production. Immunity is induced by exposure to infective eggs and antigens expressed by migrating larvae. Generally, after 6 months of age the foal’s immune system limits migration of larval stages, although this can be associated with a more severe inflammatory response and clinical signs of respiratory disease.

Eggs become infective within 2 to 4 weeks after passage in the feces. Larvae can migrate into the liver within 1 day of ingestion of infective eggs. Within 2 weeks larvae are migrating through the lungs, which can result in clinical respiratory disease. Larvae are coughed up and swallowed, and they moult to mature, egg-laying, worms in the small intestine. Female ascarids are highly prolific, and total fecal egg output can be several million. The eggs are extremely resistant to even the harshest environmental conditions and disinfectants, and eggs can persist and accumulate in the environment over several years. Infective eggs can accumulate in pastures, stalls, run-in sheds, etc.

*Cyathostomes* -
There are many species of cyathostomes infecting the horse, and they have become notable not only for their affect on the health of horses but because of their development of resistance to a broad range of anthelmintics. Their impact relates to their ability to remain encysted within the large intestine for several weeks to months, where they are largely protected against the effects of anthelmintics. Clinical disease can result from inflammation associated with acute larval migration into the mucosa of the large intestine or large-scale emergence of encysted larvae. Clinical syndromes include mild to severe forms of colic.
and diarrhea, although with the exception of severe cases it is unknown to what degree small strongyle infection contributes to disorders of the cecum and large colon. In many cases, histologic findings from horses with no signs of gastrointestinal disease reveal mucosal stages and encysted small strongyle larvae with an attendant inflammatory response. Apparently, in these horses there were no clinical problems associated with small strongyle infection. Other horses, though, may not tolerate a moderate infection and may exhibit clinical signs. With a moderate to heavy burden of encysted larvae, synchronous emergence of larvae from the mucosa can result in substantial inflammation and clinical disease.

There are 13 genera of cyathostomes and more than 50 species, but fewer than 12 species are commonly seen and five species account for 80 - 90% of the cyathostomes found in horses. The adult worms live in the cecum and the colon, attached to the intestinal mucosa. They are 5 - 10 mm long. The number of adults is less than 10% the number of larvae. When the climatic conditions are favorable (humidity about 80%, temperature between 12º and 30ºC with an optimum of 25ºC), the eggs that were passed in the manure develop to L1 larvae within a few days. These larvae subsequently moult to the L2 stage and then to the L3 infective stage, retaining the egg envelope; this development can be as short as 2 - 3 days during the summer in temperate zones. The horse ingests the L3 larvae during grazing. They shed their envelope in the small intestine and come to lie in the crypts of Lieberkühn in the colon and the cecum. They then migrate into the intestinal mucosa and sub-mucosa. Some species (Clylicyclus, Gyalocephalus) penetrate as far as the smooth muscle of the intestine. The L3 that have newly moved into the intestinal wall are considered as being at the beginning of their development within the host and are known as early L3 larvae (EL3). The EL3 larvae encyst in the mucosa or sub-mucosa of the intestine. Subsequent development can continue in one of two ways:

- The EL3 enter hypobiosis (becoming inhibited L3 or IL3) and they can remain in this state for several months or years. The hypobiotic, encysted larval stages can contain more than 50% of the total larval population. In northern temperate climates of the northern hemisphere, hypobiosis is a phenomenon that predominates during the winter, while in southern temperate climates with hot summers and mild winters hypobiosis predominates in the summer. Following hypobiosis, the larvae recommence their development to late L3 (LL3) larvae.
- Alternatively, the larvae develop directly over a period of 8 - 10 weeks to late L3 (LL3), followed by a moult to early L4 (EL4), and continued development to late L4 (LL4) when they emerge from the cysts.

Development re-commences with the emergence of the encysted larvae (in the spring in northern temperate climates and autumn in southern temperate climates of the northern hemisphere) and this seems to be at least partly controlled by the number of adult worms present in the gut lumen. The administration of anthelmintics that are active against adult small strongyles induces the LL3 larvae to emerge from hypobiosis and to resume their development to LL3 and L4, eventually producing a new generation of adult worms in the intestine. This anthelmintic effect is independent of seasonality.

The pre-patent period averages 6 - 14 weeks for the direct cycle without hypobiosis. With re-infection a greater proportion of infecting larvae are found in the mucosal stages and in hypobiosis. In cyathostome-naïve foals, initial infection results in the majority of the larvae completing development to adults, whereas in adult horses that have been frequently exposed naturally to cyathostomes most worms are in arrested development in the mucosa (Baudena et al. 2003).

Strongyle egg counts in adult horses throughout the northern hemisphere show a distinct seasonal pattern. In northern temperate climates (northern U.S., northern Europe) they begin to rise in March, peak anywhere from July to October, and decline over winter to a low level in February and March before beginning to rise again. Conversely, in the southern temperate climates of the northern hemisphere egg counts rise in the autumn and can peak in the winter. The rise in strongyle egg counts in grazing horses in spring comes primarily from larval cyathostomes that survived winter as hypobiotic EL3s in the intestinal mucosa and resumed their development to adults in late winter and early spring. As environmental temperatures rise these eggs hatch and develop rapidly to infective L3s providing a source for constant re-infection of grazing horses and, more importantly, infections of newly weaned foals in spring and early summer.

Large strongyles -
The three species of large strongyles infecting horses are Strongylus vulgaris, Strongylus edentatus and Strongylus equinus. Adult worms are destructive feeders on the mucosa of the cecum and colon, and parasitic larvae undergo extensive migrations in their equine hosts causing significant damage to organs during their migrations. Once an important cause of colic, particularly thromboembolic colic and verminous arteritis (S. vulgaris), the medical consequences of large strongyles have been largely mitigated by the use of macrocyclic lactone anthelmintics (ivermectin, moxidectin).

Strongylus vulgaris is clinically the most important and best studied large strongyle. After ingestion of infective larvae, S.
vulgaris L3s exsheath in the small intestine, penetrate the intestinal mucosa and moult to L4s by 7 days after infection. These L4s penetrate submucosal arteries and migrate along the endothelium to the cecal and colic arteries (by 14 days post infection) and then to the root of the cranial mesenteric artery and its main branches, which they reach by day 21 after infection. After a period of development of 3 to 4 months, the larvae return to the intestinal wall via the lumen of arteries. Nodules are formed around the L5s mainly in the wall of the cecum and colon. Subsequent rupture of these nodules releases the young adult parasites into the lumen of the intestine where they mature in another 6 to 8 weeks. The pre-patent period is 6 to 7 months, which is sufficiently long to be vulnerable to most routine anthelmintic administration programs. Larvae of S. edentatus invade the gut wall, penetrate blood vessels and migrate to the liver via the hepatic portal vein, where they traverse for approximately 6 weeks. Larvae leave the liver via the hepatic ligament and underneath the parietal peritoneum to the right flank. Here they molt to immature adults between 13 and 15 weeks after infection and finally return to the large intestine where they form mucosal nodules. Maturation takes place in the large intestine and the pre-patent period is approximately 11 months. Larvae of S. equinus invade the wall of the small intestine, cecum and colon. Thereafter they migrate to the liver, and they return to the GI tract via the pancreas. L5s penetrate the gut wall and enter the lumen of the large intestine via the formation of nodules. The pre-patent period is approximately 9 months.

**Tapeworms -**

There are three species of equine tapeworms: Anoplocephala perfoliata, Anoplocephaloides mamillana, and Anoplocephala magna. *Anoplocephala perfoliata* is associated with most tapeworm-related pathologic changes in horses, which result from the predilection of these parasites to the mucosa at the ileo-cecal orifice. This orifice is rather narrow normally, and with a large infection and its attendant mucosal inflammation, passage of ingesta can be delayed or obstructed. Secondary to inflammation at the ileo-cecal orifice, ileal hypertrophy or intussusception can occur. Less often, inflammation is so severe that ulceration and even perforation of the cecum occurs. It has been reported that the severity of pathology is directly proportional to parasite infection intensity.

The prevalence of tapeworms varies by location, but in temperate climates as many as 90% of horses are seropositive for antibodies to tapeworms (Reinemeyer et al 2003). There does not appear to be an acquired or age resistance to this parasite in horses because all ages, including older ones, can be infected. Infection occurs by ingestion of the oribatid mites that harbor the infective cysticercoid. These mites are normal soil mites, and there can be thousands per square foot of pasture. Live mites also can be found in hay and processed forage. Grazing horses inadvertently eat mites with almost every mouthful. Tapeworm segments (proglottids) contain both male and female organs. Proglottids progress through development from immature, to mature, and to gravid. This last segment contains fertile eggs, sloughs off, disintegrates in the large intestine, and eggs are passed in the manure. Eggs present in the feces are the result of a ruptured proglottid. Oribatid mites eat the tapeworm eggs, which undergo a period of development of 2 to 4 months inside the mite before reaching the infective or cysticercoid stage. For a horse to become infected with a tapeworm, it must, as it grazes, ingest mites containing the cysticercoid stage of the parasite. The parasite attaches to the intestinal mucosa of the ileocecal junction with suckers on the scolex and develops there into an adult worm in 5 - 6 weeks.

Until recently, *A. perfoliata* infection was thought to be of little clinical significance to the horse. Infection was difficult to detect, and heavily parasitized horses went undiagnosed unless they went to surgery or post-mortem examination. Diagnosis by fecal examination often yields negative results, or few eggs are noted. In one report, fecal examinations were negative for tapeworm eggs unless there were at least 40 tapeworms in the horse. When viewed with the microscope, the eggs of *A. perfoliata* have a "D" shaped characteristic appearance, a thick refractile shell, and an internal oncosphere and pyriform apparatus. The coprologic diagnosis lacks sensitivity, which is primarily due to the small number of eggs present in the feces of infected horses and the high specific gravity of the eggs that makes flotation difficult.

**Treatment of Endoparasites**

**General Considerations -**

Several chemical compounds are available for the control of equine internal parasites. Those products in most widespread use fall into three major categories: benzimidazoles (fenbendazole, oxibendazole, mebendazole) tetrahydropyrimidines (pyrantel pamoate, pyrantel tartrate), and the macrocyclic lactones (ivermectin, moxidectin). The label indications for each product can vary by country within Europe, particularly for small strongyles and roundworms.

Treatment of intestinal parasites in horses is often just considered in the context of anthelmintic use: which drug to use, how often to de-worm, which rotation program to use. Because of the effectiveness of modern anthelmintics, particularly the macrocyclic lactones, little regard is given, in many cases, to other considerations beside the use of drugs to control parasites. In particular, the practices of monitoring fecal egg counts and directing treatment to when parasite burdens are anticipated to be greatest are often neglected. Monitoring fecal egg counts provides valuable information on the individual animal, but also provides vital information on the parasite status of the herd, with regards to both anthelmintic efficacy and parasite exposure.
to the herd. Also, treatment can be coordinated with environmental conditions that are unfavorable for parasite survival to enhance reduction of environmental contamination. These strategies can be used to effectively time the administration of anthelmintics, and many parasitologists advise that these strategies are the best tools available in managing the emergence of resistance.

Many species of equine parasites, particularly the small strongyles, have already demonstrated resistance to several anthelmintics. In a parasite population, resistance is defined as failure of a medication to kill a very high proportion (> 90%) of a defined population for a specific parasite species or type when that same medication was previously effective. Developed anthelmintic resistance should be carefully contrasted with inefficacy, which may be innate (was never effective), dose-related (animal under-dosed), caused by inactivation or improper administration of the drug, or related to management and environmental conditions.

There are several methods for monitoring anthelmintic efficacy, but the most widely used and practical is the fecal egg count reduction test. This method requires a quantitative fecal egg count method (such as McMaster), and fecal sampling pre-treatment and 14 days post-treatment.

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\text{FECR} = \frac{\text{pre-treatment FEC} - \text{post-treatment FEC}}{\text{pre-treatment FEC}} \times 100\% = \% \text{FECR}
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Of the three major classes of anthelmintics, resistance to benzimidazoles is the most prevalent and widespread, with reports from 21 countries documenting resistance. Resistance to one member of the benzimidazoles class confers resistance to other similar compounds. Pyrantel-resistant nematodes have been reported in several countries but are most prevalent in the US where use of daily pyrantel tetractate is most common, and in a recent study in the southeastern United States, there was evidence of increasingly widespread resistance to pyrantel among the strongylid nematodes on several horse farms (Kaplan et al, 2003). To date, resistance to macrocyclic lactones (ivermectin, moxidectin) has not been documented for equine nematodes. Minimizing the problem of anthelmintic resistance in horses is complex. There are three areas to be considered: drug selection, treatment schedule, and animal management. Selecting a drug that is effective and administering the proper dose for the body weight of the horse are crucial. In addition, programs should be designed that will provide optimal parasite control with the least number of treatments per year. Pasture rotation may be beneficial in reducing worm numbers, as may regular removal of feces from the environment.

Frequency of treatment is regarded as a major factor in selection for resistance. The more frequently a compound is used, the more likely resistance may occur. Deworming compounds that interfere with energy metabolism (benzimidazoles) are more prone to result in parasite resistance when compared to those that disrupt neuromuscular activity (ivermectin). Parasites with shorter life cycles are generally expected to manifest drug resistance sooner than those with long life cycles, because recombination of alleles occurs with greater frequency in these species. Also, drugs that persist for extended periods (including at sub-therapeutic levels) may select for resistance alleles.

Whereas the practice is widely recommended, here is little evidence to support the value of alternating or rotating anthelmintics to slow the development of resistance and many parasitologists now discount this practice. Frequent rotation may even accelerate the development of multiple resistance, as each generation of worms is exposed to several different classes of drug.

**Treatments for specific equine endoparasites**

*Parascaris equorum*

Several anthelmintics have efficacy against this parasite, including ivermectin, moxidectin, fenbendazole, and pyrantel. Products containing these compounds all have a claim for activity against adults and L4 stages, although only ivermectin has a claim for L3 stages (in most countries in Europe). This parasite is considered to be dose limiting for the macrocyclic lactones. The dose limiting parasite for an anthelmintic is the species requiring the highest dosage to achieve > 90% reduction in numbers of worms. Even when the proper dose of macrocyclic lactone is given, the ability of female ascarids to produce millions of eggs can create a situation of apparent inefficacy. If > 90% of the female roundworms are killed, a sufficient number of these highly fecund parasites can remain such that fecal egg counts may remain high. In such cases, apparently poor efficacy, as determined by FECR, is not the result of resistance (an acquired development), but rather the dose limiting effect on this parasite.

Ascarid control should be focused on foals and timed for when larval migration is anticipated. Once fecal monitoring detects high levels of fecal *ascarid ova*, larval migration and associated tissue inflammation have already occurred. One
recommendation by parasitologists is to administer an anthelmintic at 2 months of age and perform a fecal egg count 2 months later. If *ascarid ova* are still present, deworm again.

**Large strongyles** -  
Efficacy against the luminal stages of large strongyles is excellent across the three classes of anthelmintics (benzimidazoles, pyrantel, macrocyclic lactones). Only the macrocyclic lactones and fenbendazole at 2X for 5 days are effective against migrating larvae. Resistance to the three classes of anthelmintics has not been demonstrated by large strongyles.

**Small strongyles (Cyathostomes)** -  
The relatively short pre-patent period, and the large reserve of mucosal stages of larvae that can be shielded from lethal doses of anthelmintic, make this class of parasites particularly adapted for resistance development. Resistance to drugs in the benzimidazole class has been recognized for more than 35 years, and resistance to pyrantel is becoming more prevalent and widespread. Recently, resistance has been identified among small strongyles to treatment with 5 days of 2X fenbendazole, a regime that has been recommended to remove mucosal stages of cyathostomes. The macrocyclic lactones (ivermectin, moxidectin) are effective against adult and L4 stages of cyathostomes, although registered claims for larval stages vary by country. Moxidectin carries a label claim for encysted mucosal stages of small strongyle larvae.

**Tapeworms** -  
For several years, pyrantel products have been used at a 2X dose to treat for tapeworms in horses. Recently, praziquantel has been approved for use in treating tapeworms in horses in Europe, the United States, and other countries. Praziquantel is highly effective (> 98%) in killing tapeworms at dosages ranging from 1.0 mg/kg to 2.5 mg/kg. Traditional recommendations have been to treat for tapeworms in the spring and the fall, to correspond with expected periods of high exposure to the mites harboring the infective cysticercoid stage of the parasite. This recommendation has not been critically examined, and under some conditions, substantial exposure to mites may occur at other times of the year. It is more difficult, though, to use fecal egg counts to monitor for tapeworm infection than for small strongyles, and the use of new serum antibody tests may prove useful in the management of anthelmintic administration for tapeworms.

**Conclusion**  
It is generally agreed among parasitologists that the objective of parasite control programs is to keep the parasite burden in horses at a low level, rather than to eliminate parasites entirely. To a large extent, the horse’s immune system accomplishes much of this objective. An exception to this is young foals, which are fully susceptible to infection by ascarids and other helminths until they develop immunity after exposure. It is important to choose and administer an anthelmintic based on these features:

- It is effective against the parasites of concern.
- Timing of anthelmintic administration is based on likely periods of high exposure or crucial stages of a parasite’s life cycle.
- Timing of anthelmintic administration considers environmental conditions to optimize reduction of larval burden on pastures.
- Fecal egg count monitoring is performed to determine effectiveness of treatment and management to reduce the parasite burden.

**References**


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