**PHYLUM NEMATODE**

This phylum is usually ubiquitous. Nematodes are free-living in marine, freshwater and land habitats and parasitic in animals and plants. They are clearly of great economic importance as they exist in extraordinary numbers and play a significance role in the total matter and energy cycle of the biosphere. Nematodes are pseudocoelomate, bilaterally symmetrical, triploblastic, unsegmented, vermiform, organ-system grade of organization with complete digestive tube. The worms are enclosed in a tough but flexible cuticle, under which is a layer of muscle, longitudinal only. There is no blood or other circulatory system.

Distinguishing characteristics of this large group of animals are their cylindrical shape; their flexible, non-living cuticle; their lack of motile cilia or flagella; the muscles of their body wall, which have several unusual features, such as running in a longitudinal direction only, and eutely. Correlated with their lack of cilia, nematodes do not have protonephridia; their excretory system consists of one or more large gland cells, or both cells and canals together. Their pharynx is characteristically muscular with a triradiate lumen.

Body wall muscles of nematodes are very unusual. They lie beneath the hypodermis and contract longitudinal only. There are no circular muscles in the body wall. The muscles are arranged in four bands, separated by four hypodermal cords. The fluid-filled pseudocoel, in which the internal organs lie, constitutes a hydrostatic skeleton. The alimentary canal of nematodes consists of a mouth, a muscular pharynx, a long non-muscular intestine, a short rectum, and a terminal anus. A ring of nerve tissue and ganglia around the pharynx gives rise to small nerves to the anterior end and to two nerve cords, one dorsal and one ventral. Sensory papillae are concentrated around the head and tail. Most nematodes are dioecious. Males are smaller than females, and their posterior end usually bears a pair of copulatory spicules. Fertilization is internal.

The phylum is initially divided into two- the Aphasmidia and the phasmidia. These were later renamed Adenophorea (gland bearers) and Secernentea (secretors) respectively. The Secernentea share several characteristics, including the presence of phasmids, a pair of sensory organs located in the lateral posterior region, and this is uised as the basis for this classification. Most common nematodes belong to Secernentea. Examples are *Ascaris, Ancylostoma, Wuchereria bancrofti*.

***Ascaris*:** It is an endoparasite in the intestine of man. It is one of the most common nematode parasites of humans. It is cylindrical, and tapering at both ends. The sexes are separate and there is sexual dimorphism. The body is covered with a smooth, tough and elastic cuticle which is striated transversely and gives the pseudo-segmented appearance to the worm. The mouth is triradiate aperture with three lips, one dorsal and two ventro-lateral. The dorsal lip has double pair of papillae and ventro-lateral lips have a pair of papillae each. All the papillae are sensory in nature. The lips have teeth. The posterior end is a transverse anus with thick lips, but the male has a cloaca from which two equal chitinous spicules or penial setae. There are two distinct longitudinal lateral lines on the cuticle marking the position of the excretory canals. The body wall is made up of outer cuticle, middle epidermis and inner muscle layer.

**LOCOMOTION:** Movement is aided by the contraction of longitudinal muscles, which produce produces thrashing movements. The presence of a stiff cuticle and absence of circular muscles results in poor power of locomotion.

**NUTRTION:** It has a complete alimentary canal of mouth to anus. Its food comprises blood; tissue exudes and partly or fully digested food of the host. Food is digested extracellularly in its intestine. Intracellular digestion has been reported to occur in the cells of intestinal wall as they engulf solid particles to digest intracellularly. The undigested items are egested through the anus.

**RESPIRATION:** There are no respiratory organs, but it carries on anaerobic respiration as oxygen content in the intestine of host is very poor.

**EXCRETION:** The excretory system is made of some glandular structures and a system of canals. The glandular portion known as renette, opens into two major lateral ducts joined at the anterior region in an H-shaped fashion. The excretory pore is located ventrally to the mouth.

**NERVOUS SYSTEM:** The nervous system is well developed and complicated and like the excretory system, it is situated in the body wall. At the region of the pharynx is a nerve ring with two paired ganglia. There are two major fibres namely, a dorsal and a ventral nerves interconnected by transverse fibre.

**SENSE ORGANS:** Sense organs are very simple and they are either as minute elevations or pits in the cuticle of the body. They are the labial papillae, amphids, phasmids, cervical papillae, cephalic papillae and genital papillae.

**REPRODUCTION:** The sexes are separate and gonads are well developed. The gonads and their ducts form continuous tubes. It is monogenetic. In males, testes lead to vas deferens which leads to ejaculatory duct that opens out at the curved posterior end. In females, the ovary leads to the oviduct, then to the seminal receptacle and then to the uterus, which leads to the vagina that opens out at the anterior part of the body.

Fertilization through copulation leads to production of several eggs stored at uterus. The eggs are discharged into intestine of the host who expel them with faeces to the outside. A female *Ascaris* may lay 200,000 eggs a day, carried by the host’s faeces. Given suitable soil conditions, embryos develop into infective juveniles within two weeks. Direct sunlight and high temperatures are rapidly lethal, but the eggs have an amazing tolerance to other adverse conditions, such as desiccation or lack of oxygen. Shelled juveniles can remain viable for many months or even years in soil. The eggs are un-segmented when they leave the host. The larva develops within the eggs but does not hatch out until the mature egg is swallowed. The juvenile or rhabditiform larva moults to become the second stage juvenile or second stage rhabditoid. This is the infective stage. Transmission of infection is when a new host swallows the infective eggs under condition of poor sanitation usually by drinking contaminated water or eating contaminated vegetable matter. The larva is thus released when the infective eggs reach the small intestine of the host and the egg shells are dissolved by action of host’s digestive juices and develops into adult nematode. The larva does not develop in the intestine of host. Before the larva becomes adult, it undergoes a typical wandering tour. It bores through the intestine to the liver, the heart, the lungs, the trachea and eventually back into the intestine where another life cycle begins. Nematodes grow by moulting. In the alveoli of the lungs, the larva moults to become 3rd stage larva; in the intestine the fourth and final moulting takes place and it grows into adult and attains maturity.

The adverse effects of *Ascaris* can be grouped into two: the effects due to the adults and those due to the migrating larvae. The consumption of semi-digested food from the host may contribute to malnutrition and underdevelopment in children. Adult worms interfere with normal metabolism through blockage of the lumen, reducing the absorptive area; absorption of intestinal contents; ingestion of blood by destruction of intestinal mucosa; neutralizing pepsin and trypsin with an anti-enzyme, ascarase. All allergic responses to waste products of the parasites are evident in most patients. These present in form of abdominal pain, rashes, insomnia, restlessness etc. It can completely block the intestinal lumen with fatal consequences. Adult worms produce pathological effects when they wander into abnormal sites. Thus adult worms have been found clogging the appendix, bile and pancreatic ducts, trachea, Eustachian tube and urino-genital ducts with grave consequences. Worms can also produce bizarre effects when they migrate upwards to the stomach, the resulting nausea causing the host to vomit live worms through the mouth. They can also emerge involuntarily through the nose or anus to the chagrin and embarrassment of the unsuspecting host. Infection rates tend to be highest in children, and males tend to be more heavily infected than females, presumably because boys are more likely to ingest dirt.

 Life cycle of *Ascaris lumbricoides*, the cause of human ascariasis as shown in the diagram below:

Adult *Ascarislumbricoides* worms (1) live in the lumen of the small intestine. A female may produce 200,000 eggs each day, which are passed with the feces (2) of the host. Ingested unfertilized eggs are not infective, but fertile eggs begin to develop and become infective after 18 days to several weeks (3), depending on environmental conditions (an optimal environment being moist, warm, shaded soil). After infective eggs are swallowed (4), the larvae hatch (5), invade the intestinal mucosa, and are carried via first the portal and then the systemic circulation to the lungs (6). The larvae mature further in the lungs for 10 to 14 days, then penetrate the alveolar walls, ascend the bronchial tree to the throat, and are swallowed (7). Upon reaching the small intestine, they develop into adult worms (1). Between two and three months are required from ingestion of infective eggs to oviposition (egg-laying) by the adult female. Adult worms can live one to two years.

 

***Ancylostoma*:** This is the common hookworm man and it is so named because the anterior end curves dorsally suggesting a hook. It is a small and cylindrical in shape. Sexes are separate. The posterior of the female worm tapers bluntly in a short post-anal tail while that of the male ends in copulatory bursa that surrounds the cloaca and it has six muscular rays. The anterior end of both sexes is slightly bent dorsally and has a large buccal capsule that is lined with hard substance and is provided with six teeth. The body of hookworm is covered externally by cuticle. This is followed internally by the epidermis and the longitudinal musculature. It is pseudocoelomate.

The mode of respiration, excretory system, nervous system and receptors are like those of *Ascaris*.

**NUTRITION:** The alimentary canal is simple and complete. It has mouth, buccal capsule, muscular pharynx having a triradiate lumen lined by cuticle, oesophagus bulb, intestine, rectum and cloaca in male and anus in female. It feeds on intestinal mucous membrane and blood. It has oesophageal gland that secretes a ferment which prevent the clotting of blood when it feeds on the blood of the host.

 

Eggs are passed in the stool (1), and under favorable conditions (moisture, warmth, shade), larvae hatch in 1 to 2 days. The released rhabditiform larvae grow in the feces and/or the soil (2) and after 5 to 10 days (and two molts) they become become filiform (third-stage) larvae that are infective. (3) These infective larvae can survive 3 to 4 weeks in favorable environmental conditions. On contact with the human host, the larvae penetrate the skin and are carried through the veins to the heart and then to the lungs. They penetrate into the pulmonary alveoli, ascend the bronchial tree to the pharynx, and are swallowed. (4) The larvae reach the small intestine, where they reside and mature into adults. Adult worms live in the lumen of the small intestine, where they attach to the intestinal wall with resultant blood loss by the host (5). Most adult worms are eliminated in 1 to 2 years, but longevity records can reach several years.

**REPRODUCTION:** Sexes are separate and sexual dimorphism is well distinct. The male reproductive organs open into the cloaca while that of the female opens out by the gonophore situated at the junction of the posterior and the middle third of the body. Life cycle is monogenetic. No intermediate host. Copulation occurs in the intestine of the host and the fertilized eggs then pushed into the uteri for laying through vagina and gonopore into the intestine of the host. Eggs pass out with the host’s faeces and these eggs are not infective to man. The eggs hatch into rhabdiform larvae and moult twice to become the filiform larvae which are infective to man. The filiform larva penetrates the skin of the feet, hands, buttocks etc- areas which are in frequent contact with the soil. In the subcutaneous tissues, it enters the lymphatic and small venules. Then, it goes through the heart, lung, trachea, stomach and finally into the intestine. After the larval migration, the larvae undergo the final moult in the intestine to produce the adults. In few weeks, it becomes sexually mature and the cycle begins again.

The hallmark of hookworm disease is iron deficiency anaemia, a condition which should give no cause for concern when nutrition is adequate, or could be readily reversed by iron therapy. Morbidity in hookworm infections can be either acute or chronic; acute infection is due to activities of migrating larva and the adults recently reaching the intestine, while morbidity due to chronic infections arise from the activities of established adults in the intestine as well as the consequences of the physiological, biochemical, and haematological disturbances they cause. Penetrating larvae produce inflammation (dermatitis) which is intensified by secondary bacterial infection causing irritation of varying severity known as ground itch. On arriving in the intestine the worms cause severe abdominal pain, loss of appetite, nausea, and vomiting, flatulence, etc. associated with abdominal pain are indigestion and diarrhea produced on arrival of the fourth stage larva, and dysentery and constipation arising from the bloodsucking activities of adult worms in the intestine. The adult worms in the intestine cause anaemia and such chronic malnutrition, particularly in the young, often causes stunted growth and below-average intelligence. It also causes loss of energy in children. This can be removed by restoring the haematological level with iron therapy.

***Wuchereria bancrofti*:** This is the nematode found in the lymphatic systems (lymphatic vessels and lymph nodes) of man. Adult worms are long and slender, hair-like, transparent and often creamy-white in colour with a smooth cuticle and bluntly rounded ends. Their head is slightly swollen and bears two circles of well-defined papillae. Their mouth is small; a buccal capsule is lacking. Males are about 40 mm and 100 µm wide. Their tail is finger-like. Females are 6 cm to 10 cm long and 300 µm wide. Their vulva is near the level of the middle of their oesopgagus.

The adults live in the lymph glands of human where they form tight coils. The females are ovoviviparous, producing thousands of pre-larval stage called microfilariae which are ensheathed in egg membrane. The microfilariae pass into the blood stream through the thoracic duct. The microfilariae exhibit nocturnal periodicity in the peripheral blood: they accumulate in the peripheral circulation around the midnight (between the hours of 2200 and 0200), but remain in the deep circulation particularly in the pulmonary vessels of the lungs during the daytime. Concentration of microfilariae in the peripheral blood at night is correlated with the peak feeding period of the mosquito vector, but this does not explain why the microfilariae should migrate to the lungs in the day.

When a mosquito bites man, it sucks blood containing microfilariae, which lose their sheath in the stomach and migrate to the thoracic muscles within few hours. They undergo the first moult and become the second larva stage which is the characteristic sausage shape. Two weeks after , the second moult occurs producing the third stage (filiform) larva which is the infective stage. The larvae migrate to the proboscis sheath and when the mosquito bites man, the larva escape onto skin and gain entrance into the body through the bite wound. They migrate through the lymphatic system, finally settling in their definitive site where they become sexually mature in about 9 months.

 

During a blood meal, an infected mosquito introduces third-stage filarial larvae onto the skin of the human host, where they penetrate into the bite wound (1). They develop in adults that commonly reside in the lymphatics(2). The female worms measure 80 to 100 mm in length and 0.24 to 0.30 mm in diameter, while the males measure about 40 mm by .1 mm. Adults produce microfilariae measuring 244 to 296 μm by 7.5 to 10 μm, which are sheathed and have nocturnal periodicity, except the South Pacific microfilariae which have the absence of marked periodicity. The microfilariae migrate into lymph and blood channels moving actively through lymph and blood (3). A mosquito ingests the microfilariae during a blood meal (4). After ingestion, the microfilariae lose their sheaths and some of them work their way through the wall of the proventriculus and cardiac portion of the mosquito's midgut and reach the thoracic muscles (5). There the microfilariae develop into first-stage larvae (6) and subsequently into third-stage infective larvae (7). The third-stage infective larvae migrate through the hemocoel to the mosquito's prosbocis(8) and can infect another human when the mosquito takes a blood meal (1).

Before microlariae appear in the blood, the infection is symptomless. Then follows the acute stage marked by acute inflammation of various parts of lymphatic system which become swollen and painful, accompanied by headache, nausea, elephantoid or filarial fever with high temperature and sweating. The initial inflammatory stage is characterized by swelling granulomatous lesions, swelling, and impaired circulation. Adult worms in lymph cause dilation of the channels and interfere with lymph flow, resulting in lymphedema. Patients with lymphedema have periodic attacks of adenolymphangitis (inflammation of lymph channels) and lymphadenitis (inflammation of lymph nodes). This stage is followed by enlargement of the lymph nodes and dilation of the lymph channels, which, over the years, harden and become infiltrated and clogged with fibrous tissues elements, resulting in some of the untreated cases in the condition known as elephantiasis, which is typically associated with the gross expansion of the tissues of the lower limbs, vulva, breasts, arm and scrotum which become swollen.