Nematodes: General Features

Nematodes are said to be the most worm-like of all helminths. This is because they generally resemble in appearance the commom earth worm, which is considered to be the prototype of 'worms'. However, taxonomically earthworms are not nematodes as they are segmented worms of the Phylum Annelida.

Nematodes are elongated, cylindrical, unsegmented worms with tapering ends.The name 'nematode' means'thread-like', from *nema*, thread. They are bilaterally symmetrical, with a secondary triradiate symmetry at the anterior end. The adults vary greatly in size, from about a millimetre to a metre in length.

The body is covered with a tough cuticle, which may be smooth, striated, bossed or spiny. They move by sinuous flexion of the body. The body cavity is a pseudocoele in which all the viscera are suspended.

The digestive system consists of the anteriorly placed mouth, leading to the oesophagus which characteristically varies in shape and structure in different groups. The intestine is lined with a single layer of columnar cells and leads to the rectum, opening through the anus. In the male, the rectum and the ejaculatory duct open into the cloaca. Nematodes have simple excretory and nervous systems. The sexes are separate. The male reproductive system consists of a single delicate tubule differentiated into testis, vas deferens, seminal vesicle and ejaculatory duct which opens into the cloaca. The female reproductive system consists of the ovary, oviduct, seminal receptacle, uterus and vagina. Nematodes may produce eggs (*oviparous*) or larvae (*viviparous*).

Some lay eggs containing larvae which immediately hatch out (*ovoviviparous*). The life cycle consists typically of four larval stages and the adult form. The cuticle is shed in passing from one stage to another. Unlike trematodes and cestodes, all of which are parasitic, most nematodes are free-living forms found in soil and water. Several species are parasites of plants, of great economic importance. Many nematodes parasitise invertebrate and vertebrate animals. The largest number of helminthic parasites of humans belong to the class of nematodes. There are an estimated 500,000 species of nematodes.

CLASSIFICATION

Nematode parasites may be classified in various ways.

A. Location of Adult in the Body

1. Intestinal Nematodes

a. Small intestine: Ascaris, Ancylostoma, Necator, Strongyloides,Trichinella.

b. Large intestine: Enterobius, Trichuris.

2. Tissue Nematodes
a. Lymphatic: Wuchereria, Brugia.
b. Subcutaneous: Loa loa. Onchocerca, Dracunculus
c. Mesentery: Mansonella
d. Conjunctiva: Loa loa.

B. Mode of Infection

1. *By Ingestion:*
a. Eggs: Ascaris, Enterobius. Trichuris.
b. Larvae within intermediate host: Dracunculus.
c. Encysted larvae in muscle: Trichinella.
2. *By Penetration of Skin:* Ancylostoma, Necator, Strongyloides.
3. *By Blood Sucking Insects:* Filariae.
4. *By Inhalation of Dust Containing Eggs:* Ascaris, Enterobius.

C. Based on Whether they Lay Eggs or Larvae

1. *Oviparous* -Laying eggs:
a. Unsegmented eggs: Ascaris. Trichuris.
b. Segmented eggs: Ancylostoma, Necator.
c. Eggs containing larvae: Enterobius.
2. *Viviparous*—Producing larvae:
Trichinella, Wuchereria, Brugia, Dracunculus.
3. *Ovoviviparous*-Laying eggs containing fully formed larvae which hatch out immediately: Strongyloides.

D. Zoological Classification

A simplified zoological classification of nematodes parasitic for man is given below:

PHYLUM NEMATHELMINTHES

Class Nematoda

Nematodes are divided into 2 subclasses based on the absence or presence of ’Phasmids’ which are caudal chemoreceptors. The 2 subclasses were called Aphasmidia and Phasmidia, now renamed Adenophorea and Secernentea respectively.

Subclass Adenophorea (Aphasmidia)

(No phasmids; no caudal papillae in male; eggs usually unsegmented with polar plugs, or hatching in uterus).
Order Enoplida
Superfamily Trichuroidea (Anterior part of body narrower than posterior) Trichuris,

Trichinelia, Capillaria.

Subclass Secernentea (Phasmidia)

(Phasmids present; numerous caudal papillae).

Order Rhabditida

Superfamily Rhabdisoidea (alternation of free-living and parasitic generations; parasitic females parthenogenetic).

Strongyloides

Order Strongyloida

Superfamily Ancylostomatoidea (Prominent buccal capsule with teeth or cutting plates)

Ancylostoma, Necator

Superfamily Metastrongyloidea (Tissue parasites; inconspicuous buccal capsule; have intermediate hosts).

Angiostrongylus

Order Ascaridida

Stiperfamily Ascaridoidea (Large worms of gut lumen. Mouth has 3 lips)—

Ascaris, Toxocara, Anisakis.

Order Oxyurida

Stiperfamily Oxyuroidea (Male has no caudal bursa; short stout body; oesophagus has prominent bulb; eggs planoconvex embryonate in uterus).

Enterobius

Order Spirudida

Stiperfamily Filarioidea (tissue parasites; viviparous; insect vector) *Wuchereria, Brugia, Onchocerca, Loa, Mansonelia, Dirofilaria.*

Superfamily Dracunculoidea (Very long female and small male; viviparous; larvae escape from ruptured uterus).

Dracunculus

Superfamily Gnathostomatoidea (Spiny body with bulbous head).

Gnathostoma

R o u n d w o r m

ASCARIS LUMBRICOIDES

History and Distribution

The roundworm, Ascaris lumbricoides is the largest nematode parasite in the human intestine. It had been observed and described from very ancient times, when it was sometimes confused with the earthworm. Its specific name lumbricoides is derived from this resemblance (Lumbricus, meaning earthworm in Latin). It is the most common of human helminths and is distributed worldwide. A billion people are estimated to be infected with roundworms. The individual worm burden could be very high, even up to over a thousand. An editorial in the Lancet in 1989 observed that if all the roundworms in all the people worldwide were placed end-to-end they would encircle the world 50 times.

Morphology and Life Cycle

The adult worms live in the small intestines of infected persons. They are large cylindrical worms, with tapering ends, the anterior end being more pointed than the posterior. They are pale pink or flesh coloured when freshly passed in stools, but become white outside the body. The mouth at the anterior end has three finely denticulated lips, one dorsal and two ventro-lateral.

The male measures 15 to 30 cm in length and 2 to 4 mm in thickness. Its posterior end is curved ventrally to form a hook and carries two copulatory spicules. The female is larger, 20 to 40 cm long and 3 to 6 mm thick. Its posterior extremity is straight and conical. The vulva is situated mid-ventrally, near the junction of the anterior and middle thirds of the body. A distinct groove is often seen surrounding the worm at the level of the vulvar opening. This is called the vulvar waist or genital girdle and is believed to facilitate mating (Fig. 17.1). The vulva leads to a single vagina, which branches into a pair of genital tubules that lie convoluted through much of the posterior two thirds of the body. The genital tubules of the gravid worm contain an enormous number of eggs as many as 27 million at a time. A single worm lays up to 200,000 eggs per day. The eggs are passed in faeces.

Two types of eggs are passed by the worms. The fertilised eggs, laid by females inseminated by mating with a male, are embryonated and develop into the infective eggs. The uninseminated female also lays eggs, but these are non-embryonated and cannot become infective. These are called *unfertilised eggs*.

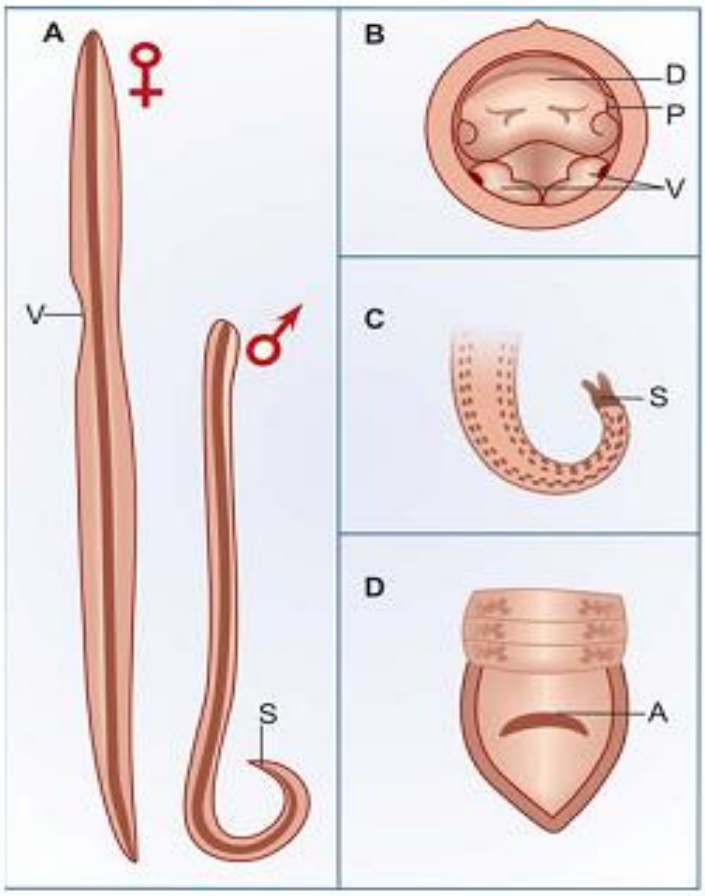

FIGURE 17.1: Ascaris lumbricoides. A. Adult male and female worms. Note the vulvar waist (v) in the female and the ventrally curved posterior end in the male with copulatory spicules(s). B. Anterior end of worm. head-on view, showing one dorsal (D) and two ventral. (V) lips, with papillae (P). C. Posterior end of male, showing two protruding copulatory spicules(s). D. Posterior end of female, showing anal opening (A) a little above the conical tip

The fertilised ascaris egg is spherical or ovoid, bile stained to a golden brown colour and measures 60 to 75 μm in length and 40 to 50 μm in breadth. It is enclosed in a stout translucent shell consisting of three layers, the outer coarsely mamillated albuminoid coat a thick transparent middle layer and the inner lipoidal vitelline membrane. Some eggs are found in feces without the outer mamillated coat. They are called the decorticated eggs. In the middle of the egg is a large unsegmented ovum, containing a mass of coarse lecithin granules. It nearly fills the egg, except for a clear crescentic area at either pole.

The unfertilised egg is longer, up to 90 μm, and more elliptical. The shell is thinner with the outer mamillary coat scanty and irregular. The ovum is atrophic and contains numerous disorganised, highly refractile granules of various sizes. The unfertilized egg is relatively heavy and does not float in saturated salt solution used for concentration by salt floatation while the fertilised eggs float. Stool samples may show both fertilised and unfertilised eggs, or either type alone (Fig. 17.2).

The fertilised egg passed in feces, is not immediately infective. It has to undergo a period of incubation in soil before acquiring infectivity .The eggs are resistant to adverse conditions and can survive for several years.

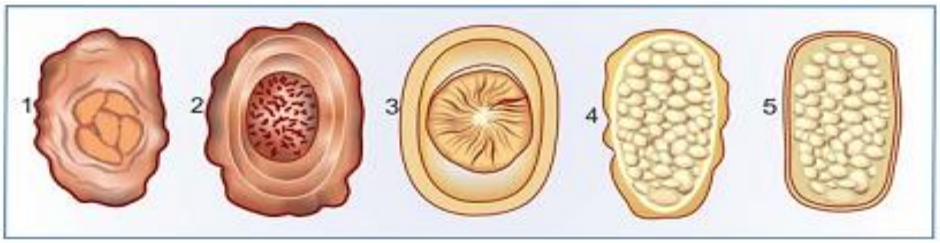

FIGURE 17.2: Types of ascaris eggs found in stools. 1. Fertilised egg surface focus. showing outer mamillary coat. 2. Fertilised egg. median focus. Showing unsegmented ovum surrounded by three layers of coats. 3. Decorticated fertilized egg. The mamillary coat is absent. 4. Unfertilised egg. Elongated, with atrophic ovum. 5. Decorticated unfertilised egg

The development of the egg in soil depends on the nature of the soil and various environmental factors. A heavy clayey soil and moist shady location, with temperature between 20° and 30°C are optimal for rapid development of the embryo. The development usually takes from 10 to 40 days, during which time the embryo moults twice and becomes the infective rhabditiform larva, coiled up within the egg.

Infection occurs when the egg containing the infective rhabditiform larva is swallowed. A frequent mode of transmission is through fresh vegetables grown in fields manured with human feces (‘night soil’). Infection may be transmitted through contaminated drinking water. Children playing about in mud can transmit eggs to their mouth through dirty fingers. Where soil contamination is heavy due to indiscriminate defecation, the eggs sometimes get airborne along with windswept dust and inhaled. The inhaled eggs get swallowed.

When the swallowed eggs reach the duodenum, the larvae hatch out. The rhabditiform larvae, about 250 μm in length and 14 μm in diameter, are actively motile. They penetrate the intestinal mucosa, enter the portal vessels and are carried to the liver. They then pass via the hepatic vein, inferior vena cava and the right heart, and in about four days reach the lungs, where they grow and moult twice. After development in the lungs, in about 10 to 15 days, the larvae pierce the lung capillaries and reach the alveoli. Then they crawl up or are carried up the respiratory passage to the throat and are swallowed. The larvae moult and develop into adults in the upper part of the small intestine. They become sexually mature in about 6 to 12 weeks and the gravid females start laying eggs. to repeat the cycle. The adult worm has a lifespan of 12 to 20 months (Fig. 17.3)

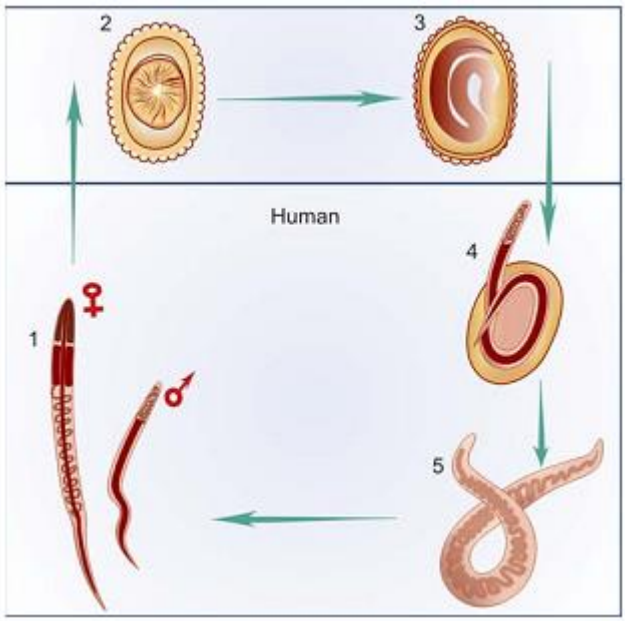

FIGURE 17.3: Life cycle of Ascaris lumbricoides. 1. Adult worms in small intestine of man. 2. Egg passed in feces reaches soil. 3. Mature egg containing larva— infective for humans. 4. When swallowed, larva hatches out in duodenum. 5. Rhabditiform larva penetrates gut wall, circulates in blood stream, moults in lung, reaches pharynx and is swallowed to develop into the adult in intestine

Pathogenesis and Clinical Features

Clinical manifestations in ascariasis can be caused by either the migrating larvae or the adult worms.

The pathogenic effects of larval migration are due to allergic reaction and not the presence of larvae as such. Therefore, the initial exposure to larvae is usually asymptomatic, except when the larval load is very heavy .But when reinfection occurs subsequently there may be intense cellular reaction to the migrating larvae in the lungs, with infiltration of eosinophils, macrophages and epithelioid cells. This ascaris pneumonia is characterised by low grade fever, dry cough, asthmatic wheezing, urticaria, eosinophilia and mottled lung infiltration in the chest radiograph. The sputum may contain Charcot-Leyden crystals. The larvae may occasionally be found in the sputum, but are seen more often in gastric washings. This condition is called *Loeffler's syndrome*. The clinical features generally clear in one or two weeks, though it may sometimes be severe and rarely even fatal. Loeffler's syndrome can also be caused by hypersensitivity to other agents, both living and non-living. Allergic inflammatory

reaction to migrating larvae may involve other organs such as the kidney or liver. Very rarely the larvae may occlude a small vessel in the heart or brain.

Clinical manifestations due to adult worm vary from asymptomatic infection to severe and even fatal consequences. It is not unusual to find children apparently unaffected in spite of heavy infestation with the worms. The pathological effects, when present, are caused by (i) Spoliative action, (ii) Toxic action, and (iii) Mechanical effects.

i. The *spoliative* or *nutritional* effects are usually seen when the worm burden is heavy.The worms may be present in enormous numbers, sometimes exceeding 500, in small children, occupying a large part of the intestinal tract. This interferes with proper digestion and absorption of food. Ascariasis may contribute to protein-energy malnutrition and vitamin A deficiency. Patients have loss of appetite and are often listless. Abnormalities of the jejunal mucosa are often present, including broadening and shortening of villi, elongation of crypts and round cell infiltration of lamina propria. These changes are reversed when the worms are eliminated.

ii. The so called *toxic* effects are due to hypersensitivity to the worm antigens and may be manifested as fever, urticaria, angioneurotic oedema, wheezing and conjunctivitis. These are more often seen in persons who come into contact with the worm occupationally, as in laboratory technicians and abattoir workers (who become sensitive to the pig ascarid *A. suum*), than in children having intestinal infestation.

iii. The mechanical effects are the most important manifestations of ascariasis. Mechanical effects can be due to masses of worms causing luminal occlusion or even a single worm infiltrating into a vital area. The adult worms live in the upper part of the small intestine, where they maintain their position due to their body muscle tone, spanning the lumen.

They may stimulate reflex peristalsis, causing recurrent and often severe colicky pain in the abdomen. The worms may be clumped together into a mass, filling the lumen, leading to volvulus, intussusception or intestinal obstruction.

The worms are restless wanderers apparently showing great inquisitiveness, in that they tend to probe and insinuate themselves into any aperture they find on the way. The wandering is enhanced when the host is ill, particularly when febrile, with temperature above 39°C. The male worm is more responsive to illness of the host, than the female. The worm may wander up or down along the gut. Going

up, it may enter the opening of the biliary or pancreatic duct causing acute biliary obstruction or pancreatitis. It may enter the liver parenchyma, where it may lead to abscesses. The worm may go up the oesophagus and come out through the mouth or nose. It may crawl into the trachea and the lung causing respiratory obstruction or lung abscesses. Migrating downwards, the worm may cause obstructive appendicitis. It may lead to peritonitis when it perforates the intestine, generally at weak spots such as typhoid or tuberculous ulcers or through suture lines. This tendency makes preoperative deworming necessary before gastrointestinal surgery in endemic areas. The wandering worm may reach the kidneys, lungs or other organs and cause ectopic lesions.

Diagnosis

In the early stages of infection, when migrating larvae cause Loeffler's syndrome, the diagnosis may be made by demonstrating the larvae in sputum, or more often in gastric washings. Presence of Charcot-Leyden crystals in sputum and an attendant eosinophilia support the diagnosis. At this stage no eggs are seen in feces.

The most important method for the diagnosis of ascariasis is the demonstration of eggs in feces. Ascarides are prolific egg layers. A single female may account for about 3 eggs per mg of feces. At this concentration, the eggs can be readily seen by microscopic examination of a saline emulsion of feces. Both fertilised and unfertilised eggs are usually present. Occasionally only one type is seen. The fertilised eggs may sometimes appear decorticated. Rarely, when the infestation is light, eggs are demonstrable only by concentration methods. The unfertilized eggs are not detectable by salt floatation. Eggs may not be seen if only male worms are present, as may occasionally be the case. Fecal films often contain many artefacts resembling ascaris eggs and care must be taken to differentiate them.

Sometimes the diagnosis becomes evident when the worm is passed either through the anus, or through the mouth or nose.

A skin test with ascaris antigen gives a positive result, but is unreliable and not used for diagnosis. Serological tests are not useful in diagnosis.

Diagnosis may often be made by barium contrast radiography of the abdomen.

Treatment

Several safe and effective drugs are now available.These include pyrantel pamoate, albendazole, mebendazole and piperazine citrate.

Prevention

Ascariasis can be eliminated only if fecal contamination of soil can be prevented. The ascaris egg is highly resistant. Therefore the use of night soil as manure will lead to spread of the infection unless destruction of the eggs is ensured by proper composting. Treatment of vegetables and other garden crops with water containing iodine 200 ppm for 15 minutes kills the eggs and larvae of ascaris and other helminths.

OTHER ROUNDWORMS

TOXOCARIASIS

Toxocara canis and *T. cati*, natural parasites of dogs and cats respectively can cause aberrant infection in humans leading to *visceral larva migrans* (VLM). Infection is acquired in pups by transmission of larvae transplacentally or lactogenically (through breast milk), but in kittens, only lactogenic transmission is recorded. Older animals are infected by ingestion of mature eggs in soil or of larva by eating infected rodents, birds or other paratenic hosts. Eggs are shed in feces and become infective in 2-3 weeks.

Human infection is by ingestion of eggs. Larvae hatch out in the small intestine, penetrate the mucosa and reach the liver, lungs or other viscera. They do not develop any further. Most infections are asymptomatic, but in some, particularly in young children VLM develops, characterised by fever, hepatomegaly, cough, pulmonary infiltrates, high eosinophilia and hyperglobulinaemia. In some, the eye is affected (*ophthalmic larva migrans*—OLM).

Baylisascaris procyonis, an ascarid parasite of raccoons in North America is known to cause serious zoonotic infections leading to VLM, OLM and *neural larva migrans* (NLM). Complications include blindness and central nervous system lesions ranging from minor neuropsychiatric conditions to seizure, coma and death.

GEOHELMINTHS

Soil-transmitted intestinal nematodes are called Geohelminths. In all of them eggs passed in feces undergo maturation in soil. They are classified into three categories based on their life cycle.

1. *Direct*: Ingested infective eggs directly develop into adults in the intestine, e.g. whipworms.

2. *Modified direct*: Larvae from ingested eggs penetrate intestinal mucosa enter blood stream and through the liver, heart, lungs, bronchus and oesophagus, reach the gut to develop into adults, e.g. roundworms.
3. *Skin penetrating*: Infective larvae in soil penetrate host skin, reach the lung and proceed to the gut as in the modified direct method, e.g. hookworms.

Geohelminths pose a serious health problem in poor countries, particularly among children. Their control requires general measures such as personal hygeine, sanitation and health education, besides provision of diagnostic and treatment facilities.