Helminths

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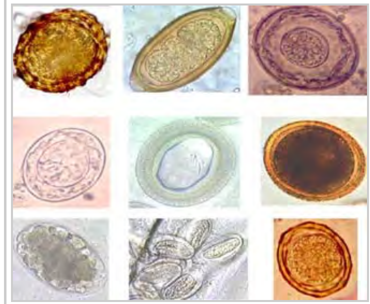

Helminth eggs of different helminth species, which are produced for reproduction of the worms.

Helminths (/ˈhɛlmɪnθs/), also commonly known as **parasitic worms**, are large multicellular organisms, which when mature can generally be seen with the naked eye. They are often referred to as **intestinal worms** even though not all helminths reside in the intestines; for example schistosomes are not intestinal worms, but rather reside in blood vessels.

There is no clear consensus on the taxonomy of helminths; it is more of a commonly used term to describe certain worms with superficial similarities. These are flatworms (platyhelminthes), namely cestodes (tapeworms) and trematodes (flukes), and roundworms or nemathelminths (nematodes) – both of these are parasitic worm types – and the annelida, which are not parasitic or at the most ectoparasites like the leeches.[1]

Many, but not all, of the worms referred to as helminths belong to the group of intestinal parasites. An infection by a helminth is known as helminthiasis, soil-transmitted helminthiasis, helminth infection or intestinal worm infection. The same naming convention applies to all helminths whereby the ending "-asis" (or in veterinary science the ending "-osis") at the end of the name of the worm is added to signify the infection with that particular worm, for example *Ascaris* is the name of a particular helminth, and ascariasis is the name of the infectious disease caused by this helminth.

Helminths are worm-like organisms living in and feeding on living hosts, receiving nourishment and protection while disrupting their hosts' nutrient absorption, causing weakness and disease. Those that live inside the digestive tract are called intestinal parasites. They can live inside humans and other animals. In their adult form, helminths cannot multiply in humans.[2] Helminths are able to survive in their mammalian hosts for many years due to their ability to manipulate the immune response by secreting immunomodulatory products.[3] Helminth ova (or eggs) have a strong shell that protects the eggs against a range of environmental conditions.

Helminthology is the study of parasitic worms and their effects on their hosts. The word helminth comes from Greek *hélmins*, a kind of worm.

Contents

Taxonomy

There is no real consensus on the taxonomy (or groupings) of the helminths, particularly with the nematodes.[4] The term "helminth" contains a number of phyla, many of which are completely unrelated. However, for practical considerations the term is still used nowadays to describe four groups with superficial similarities, the phyla Annelida, Platyhelminths, Nematoda and Acanthocephala.[4]

There is in fact no helminth classification; it is an "artificial" term.[5][6]

The most important helminths in the sanitation field are the human parasites, which is why most people relate the term helminth to them, where they are classified as nemathelminthes (nematodes) and platyhelminthes, depending on whether they possess a round or flat-shaped body respectively. The latter are further divided into cestodes and trematodes depending on whether or not they have a segmented body.[7]

Ringworm (dermatophytosis) is actually caused by various fungi and not by a parasitic worm.

Hookworms attached to the intestinal mucosa

Common characteristics

Helminths are a group of evolutionary unrelated organisms which share a similar form. Helminths include members of the following taxa: monogeneans, cestodes (tapeworms), nematodes (roundworms), and trematodes (flukes). The number of different helminth species is vast: it is estimated to be around one million species. The nematodes are the most diverse of all the helminths with the highest number of species.

Characteristics that are common for all helminths include:

Two pinworms

Life time:

- The life time of adult worms varies tremendously from one species to another but is generally in the range of 1 to 8 years (see following table). This life time of several years is a result of their ability to manipulate the immune response of their hosts by secreting immunomodulatory products.[3]
- Helminths can be either hermaphrodites (i.e. can have both sexes), like tapeworms and the flukes (except the blood fluke which is not a hermaphrodite), or have their sexes differentiated, like the roundworms.

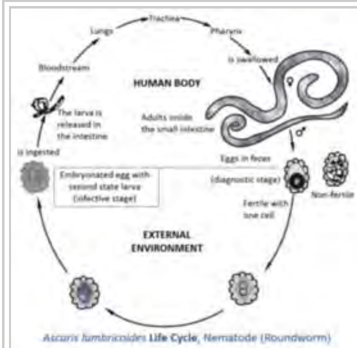

Image showing life cycle inside and outside of the human body of one fairly typical and well described helminth: Ascaris lumbricoides

Eggs:

- All helminths produce eggs (also called ova) for reproduction.
- Helminth eggs have a strong shell that protects them against a range of environmental conditions. This shell consists of three layers: a lipoidal inner layer, a chitinous middle layer and outer proteinic layer.[8]
- Generally thousands or even hundreds of thousands of eggs are produced each time the female worm deposits its eggs - a process called ovoposition. The following table shows a large variation in the amount of eggs produced by the different worms in one event; it varies in the range of 3,000 to 700,000.
- The frequency of egg deposition from an adult helminth is generally daily, or up to six times per day for some *Taenia* species.
- Adult trematodes lay smaller numbers of eggs compared to cestodes or nematodes. However, the egg develops into a miracidia from which thousands of *cercariae*, swimming larvae, develop. This means that one egg may produce thousands of adult worms.[9]
- Helminth eggs remain viable for 1–2 months in crops and for many months in soil, fresh water and sewage, or even for several years in feces, fecal sludge (historically called night soil) and sewage sludge; a period that is much longer compared to other kind of microorganisms.[10][11]

Larvae:

- Larvae hatch from these eggs (if the eggs are viable), inside or outside the host, depending on the type of helminth. Life cycles of the helminths differ in this and other specific aspects. Eggs that are no longer viable do not produce any larvae.
- The larvae maturing in the host take from about two weeks up to four months depending on the helminth species.

The following table shows the principal morphological and reproductive distinctions for three helminth groups:

		Tapeworms (Cestodes)		**Flukes (Trematodes)**	**Roundworms (Nematodes)**			
Species (examples)		*Taenia solium*, *Taenia saginata*, *Hymenolepis* spp., *Echinococcus granulosus*, *Multiceps multiceps*		*Schistosoma mansoni*, *Schistosoma japonicum*, *Fasciola hepatica*	*Ascaris*, *Onchocerca*, *Rhabditis*, *Trichuris*, *Necator americanus*, *Anchylostoma duodenale*			
Example diseases in humans		Tapeworm infection		Schistosomiasis, swimmer's itch	Ascariasis, dracunculiasis (guinea worm), elephantiasis, enterobiasis (pinworm), filariasis, hookworm infection (includes Necatoriasis and *Ancylostoma duodenale* infection), onchocerciasis, trichinosis, trichuriasis (whipworm)			
Shape		Segmented plane		Unsegmented plane	Cylindrical			
Body cavity		No		no	Present			
Body covering		Tegument		Tegument	Cuticle			
Digestive tube		No		Ends in cecum	Ends in anus			
Sex		Hermaphroditic		Hermaphroditic, except schistosomes which are dioecious	Dioecious			
Attachment organs		Sucker or bothridia, and rostellum with hooks		Oral sucker and ventral sucker or acetabulum	Lips, teeth, filariform extremities, and dentary plates			
Number of species		6000[12]		Estimated > 15,000[13] and 9,000[14] registered	800,000 to 1,000,000 estimated 25,000 registered[13]			
Number of species known to infect humans		40[12]		16[13]	> 12,000[13]			
Species		*Hymenolepis nana*	*Taenia solium /Taenia saginata*	*Fasciola hepatica*	*Ascaris lumbricoides*	Hookworm	*Trichuris trichiura*	*Toxocara*
Lifetime	Larvae formation		some days (eggs can survive for months)[15]	9–15 days[12]	18 days to several weeks[16]	1–2 days[17]	15–30 days[18]	
	Larvae growth		After hatching the larvae move to develop into cysticercoid, which can survive for years in an animal[15]	5–7 weeks as *cercariae* in snails and longer periods in wet environments as encysted *metacercariae*[9]	10–14 days[16]	5–10 days (after maturing can survive for weeks outside the host)[17]	60–70 days (from hatching to mature state)[18]	5–6 days[12]

	Larvae maturing (in host)		2 months (form cysticercoid to adult)[15]	3–4 months[9]	2–3 months[16]	2–8 weeks[12] (can become dormant for months)		
	Adult worm	4–6 weeks	Several years[15]	8–10 years[12]	1–2 years[16]	Several years[17]	1 year[18]	
Eggs laid per day		250,000[2] to 700,000[12]		3,000 to 25,000[13]	3,000[2] to 250,000[12]			
Egg deposition	Frequency		up to 6 times a day[15]		daily[16]	daily[17]	daily[18]	
	Number of eggs per event		50,000-100,000[15]		200,000[16][19] to 250,000 or more[12]	5,000-10,000[12]	3,000-20,000[18]	
Larvae per egg		1	1	300 *cercariae* (*Schistosoma*), 250,000 *metacercariae* (*Fasciola*)[13]	1	1	1	1

Draft genomes for all categories of helminth have been sequenced in recent years and are available through the ParaSite sub-portal of WormBase.[20]

Use in medicine

Parasitic worms have been used as a medical treatment for various diseases, particularly those involving an overactive immune response.[21] As humans have evolved with parasitic worms, proponents argue they are needed for a healthy immune system.[21] Scientists are looking for a connection between the prevention and control of parasitic worms and the increase in allergies such as hay-fever in developed countries.[21] Parasitic worms may be able to damp down the immune system of their host, making it easier for them to live in the intestine without coming under attack.[21] This may be one mechanism for their proposed medicinal effect.

One study suggests a link between the rising rates of metabolic syndrome in the developed worlds and the largely successful efforts of Westerners to eliminate intestinal parasites. The work suggests eosinophils (a type of white blood cell) in fat tissue play an important role in preventing insulin resistance by secreting interleukin 4, which in turn switches macrophages into "alternative activation". Alternatively-activated macrophages are important to maintaining glucose homeostasis (i.e., blood sugar regulation). Helminth infection causes an increase in eosinophils. In the study, the authors fed rodents a high-fat diet to induce metabolic syndrome, and then injected them with helminths. Helminth infestation improved the rodents' metabolism.[22] The authors concluded:

> Although sparse in blood of persons in developed countries, eosinophils are often elevated in individuals in rural developing countries where intestinal parasitism is prevalent and metabolic syndrome rare. We speculate that eosinophils may have evolved to optimize metabolic homeostasis during chronic infections by ubiquitous intestinal parasites….[22]

Eggs

In the environment

Eggs can reach the soil when polluted wastewater, sewage sludge or human excreta are used as fertilizer. Such soil is often characterized by moist and warm conditions. Therefore, the risk of using contaminated wastewater and sludge in agricultural fields is a real problem, especially in poor countries, where this practice is prevalent.[8][23] Helminth eggs are regarded as the main biological health risk when applying sewage sludge, fecal sludge or fecal matter on agricultural soils.[10] The eggs are the infective stage of the helminths' life cycle for causing the disease helminthiasis.


Analysing for helminth eggs in samples of feces from a dry toilet in Kenya

Helminth eggs are resistant to various environmental conditions due to the composition of the egg shell. Each helminth egg species has 3 to 4 layers with different physical and chemical characteristics: a) the 1 to 2 outer layers are formed of mucopolysaccharides and proteins, b) the middle layers consist of chitinous material and serve to give structure and mechanical resistance to the eggs, and c) the inner layer is composed of lipids and proteins and is useful to protect eggs from desiccation, strong acid and bases, oxidants and reductive agents as well as detergent and proteolytic compounds.[8][24][25][26]

Due to this strong shell, helminth eggs or ova remain viable in soil, fresh water and sewage for many months. In feces, fecal sludge and sewage sludge they can even remain viable for several years.[10][11] Helminth eggs of concern in wastewater used for irrigation have a size between 20 and 90 μm and a relative density of 1.06–1.23.[8] It is very difficult to inactivate helminth eggs, unless temperature is increased above 40 °C or moisture is reduced to less than 5%.[8]

Levels of infectiousness


Processed helminth eggs samples from a dry toilet in Kenya

Helminth eggs contained in wastewater, sewage sludge or human excreta are not always infectious, i.e. able to cause the disease helminthiasis. Fertilized eggs and unfertilized eggs can exist side by side. Unfertilized eggs are identifiable under the microscope by their elongated shape. No larvae can hatch from these kinds of eggs. Therefore, unfertilized eggs do not pose a danger to human health.

In the case of *Ascaris lumbricoides* (giant roundworm), which has been considered the most resistant and common helminth type, fertilized eggs deposited in soil are resistant to desiccation but are, at this stage of development, very sensitive to environmental temperatures: The reproduction of a fertilized egg within the eggshell develops at an environmental soil temperature about 25 °C which is lower than the body temperature of the host (i.e., 37 °C for humans).[19]

However, development of the larvae in the egg stops at temperatures below 15.5 °C, and eggs cannot survive temperatures much above 38 °C. If the temperature is around 25 °C, the infectiousness occurs after nearly 10 days of incubation.[7][27][28] Finally, after 2 to 4 weeks in moist soil at optimal temperature and oxygen levels, the embryo develops into an infective larva, named "second-stage larva". This larva has the ability to get out of the egg, hatch in the small intestine and migrate to different organs. These infective larvae (or "infective eggs") may remain viable in soil for two years or longer.[19]

Removal versus inactivation in wastewater and sludge treatment

In order to physically remove (but not inactivate) helminth eggs from wastewater, processes that remove particles, such as sedimentation, filtration or coagulation-flocculation are employed.[29][30] Therefore, waste stabilization ponds (lagoons), storage bassins, constructed wetlands, rapid filtration or upflow anaerobic sludge blanket (UASB) reactors can be used. These conventional wastewater treatment processes do not inactivate the helminth ova but only removes them from the wastewater and moves them to the sewage sludge.

Helminth ova cannot be inactivated with chlorine, UV light or ozone (in the latter case at least not with economical doses because >36 mg/L ozone are needed with 1 hour contact time).

Inactivation of helminth ova can be achieved in sewage sludge treatment where the temperature is increased over 40 °C or moisture is reduced to less than 5%.[8] Best results can be obtained when both of these conditions are combined for an extended period of time.[31] Details about the contact time under these conditions and other related environmental factors are generally not well-defined for every type of helminth egg species.[7] Helminth eggs are considered highly resistant biological structures.[8]

Indicator organism

Helminth eggs (or ova) are a good indicator organism to assess the safety of sanitation and reuse systems because they are the most environmentally resistant pathogens of all pathogens (viruses, bacteria, protozoa and helminths) and can in extreme cases survive for several years in soil.[10] Therefore, the presence or absence of viable helminth eggs ("viable helminth egg" means that a larva would be able to hatch from the egg) in a sample of dried fecal matter, compost or fecal sludge is often used as an indicator to assess the efficiency of diverse wastewater and sludge treatment processes in terms of pathogen removal. In particular, the number of viable Ascaris eggs is often taken as an indicator organism for all helminth eggs in treatment processes as they are very common in many parts of the world and relatively easy to identify under the microscope. However, the exact inactivation characteristics may vary for different types of helminth eggs.[7]

Measurement techniques

Environmental samples

For the purpose of setting treatment standards and reuse legislation, it is important to be able to determine the amount of helminth eggs in an environmental sample with some accuracy. The detection of viable helminth eggs in samples of wastewater, sludge or fresh feces (as a diagnostic tool for the infection helminthiasis) is not straight forward. In fact, many laboratories in developing countries lack the right equipment or skilled staff required to do so. An important step in the analytical methods is usually the concentration of the eggs in the sample, especially in the case of wastewater samples. A concentration step may not be required in samples of dried feces, e.g. samples collected from urine-diverting dry toilets.

Human stool samples

For medical purposes, the exact number of helminth eggs is less important and therefore most diagnoses are made simply by identifying the appearance of the worm or eggs in feces. Due to the large quantity of eggs laid, physicians can diagnose using only one or two fecal smears. The Kato technique (also called the Kato-Katz technique) is a laboratory method for preparing human stool samples prior to searching for parasite eggs. Eggs per gram is a laboratory test that determines the number of eggs per gram of feces in patients suspected of having a parasitological infection, such as schistosomiasis.

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Further reading

- Dickson Despommier, *People, Parasites, and Plowshares: Learning from Our Body's Most Terrifying Invaders*, Columbia University Press, 2016 (ISBN 978-0231161954).

External links

- Parasitic Roundworm Diseases (https://www.niaid.nih.gov/factsheets/roundwor.htm)
- World Health Organisation (WHO) topic page on helminthiasis (http://www.who.int/topics/helminthiasis/en/)

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