

Subject: Zoology

Production of Courseware
-Content for Post Graduate Courses



Paper : 08 Biology of Parasitism
Module : 27 Morphology, Life Cycle, Pathogenicity and Prophylaxis of *Dracunculus medinensis*



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Description of Module	
Subject Name	ZOOLOGY
Paper Name	Biology of Parasitism- ZOOL OO8
Module Name/Title	Morphology, Life Cycle, Pathogenicity and Prophylaxis of <i>Dracunculus medinensis</i>
Module Id	27; Morphology, Life Cycle, Pathogenicity and Prophylaxis
Keywords	Fiery serpent, <i>Mesocyclops leuekarti</i> , Dracontiasis, Gubernaculum, Rhabditoid larva, Blister formation, Morphine-6-glucoronide

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1. Learning Outcomes

After studying this unit you will be able to:

- Understand the medical importance of *Dracunculus medinensis*
- Identify the female worm from its morphological characteristics
- Explain the importance of two hosts in the life cycle of *Dracunculus medinensis*
- Highlight the symptoms of the disease caused by the parasite
- Suggest various methods for the prevention and control of the parasite

2. Introduction

Dracunculus is called “FIERY SERPENT” in the bible. The Greeks and the Romans called it as “little snakes”. Colloquially it is named as Guinea worm (so called because it was discovered in Guinea in West Africa), Medina worm (Commonly found in Medina and hence the name), Dragon worm and Serpent worm (Figure 1). *Dracunculus* have also been reported in the Egyptian mummies. There are basically two important species of *Dracunculus* viz *Dracunculus medinensis* and *Dracunculus insignis*. *D. medinensis* is the parasite found in the subcutaneous tissues of man, dogs, cattle, horses and foxes. However, *D. insignis* infects wild carnivores, dogs and cats. *D. insignis* so far has been reported from America.



Figure 1: *Dracunculus* : “ The FIERY SERPENT”

Source: <http://ianimal.ru/topics/rishta>

3. Discovery of *Dracunculus medinensis*

It was **Carlus Linnaeus** in 1758 who first suggested that *Dracunculus* were worms. Russian naturalist, **Alexei Fedchenko** in 1870 studied the life cycle of the parasite *Dracunculus* and found that the parasite was a digenetic nematode (Figure 2). He discovered that the larvae emerging from the protruding female worm in the infected limbs of a person further developed in another host: the *cyclops*, a fresh water crustacean.

The fiery serpent causes the disease dracontiasis. The name dracontiasis was given by **Galen** (in Greek: draco means dragon or serpent) Figure 3. The disease is caused by the female worm.



Figure 2: Alexei Fedchenko

Source: http://en.wikipedia.org/wiki/Alexei_Fedchenko



Figure 3: Claudius Galen

Source: <http://famousbiologists.org/galen/>

4. Classification of *Dracunculus medinensis*

PHYLUM:	Nematoda
CLASS:	Secernentea
ORDER:	Spirurida
FAMILY:	Dracunculidae
GENUS:	<i>Dracunculus</i>

5. Geographical Distribution of *Dracunculus medinensis*

It was widely distributed right from India, Pakistan, Burma, Saudi Arabia, Iraq, Iran, Soviet Union, Africa to West Indies. In India it was reported from Punjab, Rajasthan, Gujarat, Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka and Madhya Pradesh. *Dracunculus medinensis* has been eradicated from several countries in Africa, Asia (has been totally eradicated from India) and Middle East (WHO report). It is now found only in some of the African states (Figure 4). It has been found that the worm prefers drier location. Areas of abundant rainfall are free from the worm.

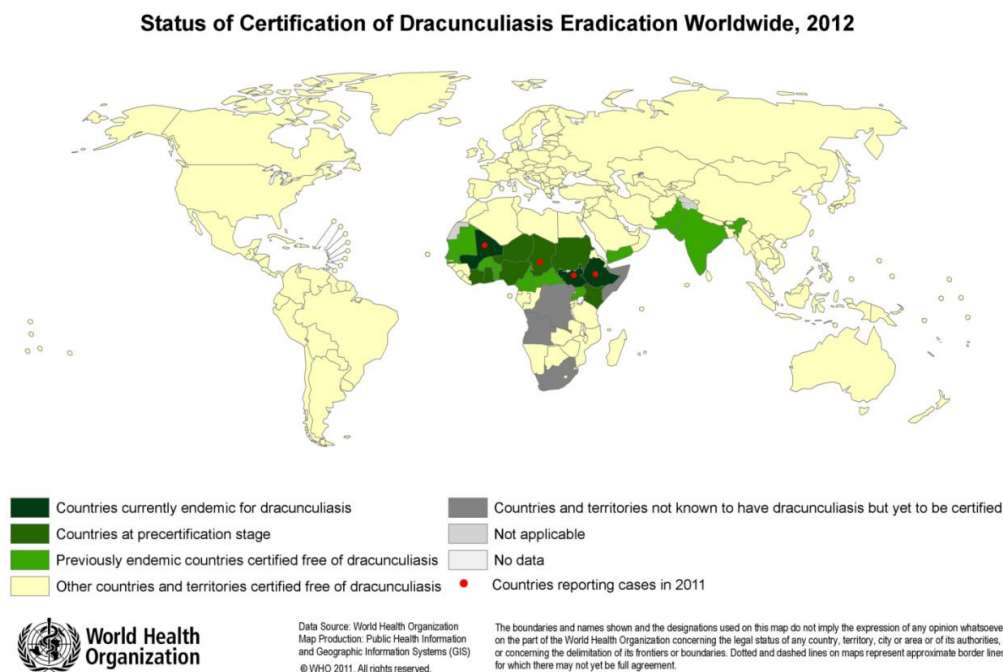


Figure 4: Prevalence of *Dracunculus medinensis* in the world
 Source: courses.bio.unc.edu/2012spring/.../FrankMu_Dracunculiasis.pptx

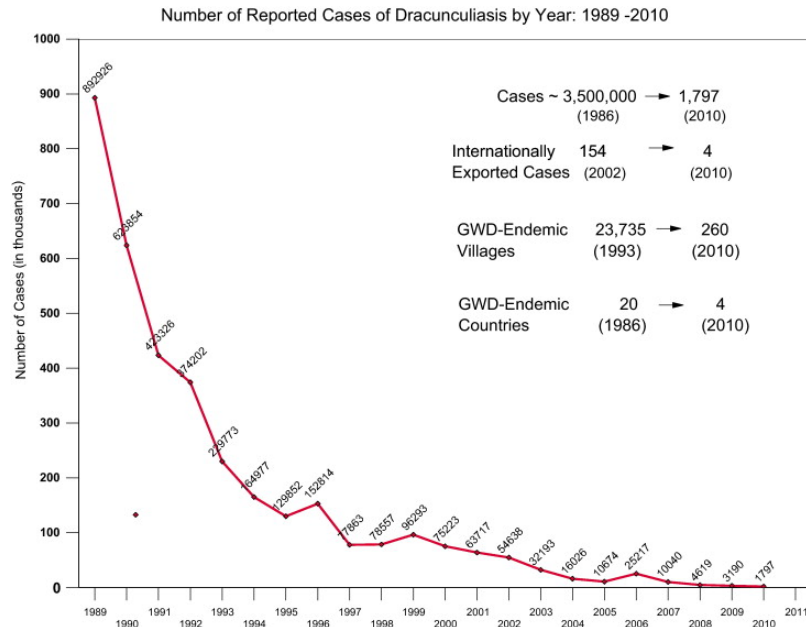
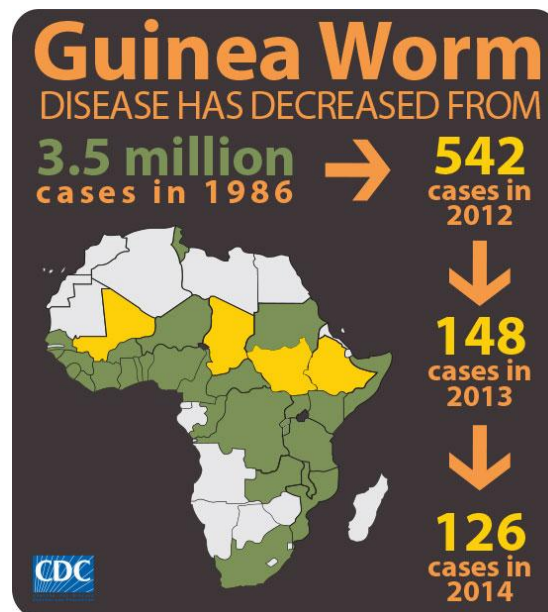


Figure 5: Number of reported cases of *Dracunculus* by year 1989-2010
Source: courses.bio.unc.edu/2012spring/.../FrankMu_Dracunculiasis.pptx



Source: <http://www.cdc.gov/parasites/guineaworm/>

The Guinea worm eradication program has drastically reduced the dracunculiasis cases from 3.5 million (reported from Asia and Africa) in 1986 to just 126 cases in 2014 (Figure 5).

The day is not far off when Guinea worm disease will be globally eradicated.

6. Habit and Habitat of *Dracunculus medinensis*

Parasite lives in the subcutaneous tissues of humans and other vertebrates especially just under skin of legs, ankles, arms, and neck and can migrate from one site to another.

7. Host: Digenetic

Definitive host: Humans, dogs, cats and other wild animals.

Intermediate host: *Cyclops* (Figure 6).



Figure 6: *Cyclops*

Source: <http://www.britannica.com/EBchecked/media/158679/Water-fleas-carry-the-guinea-worm?topicId=170708>

Table 1: Important features of *Cyclops*

- *Cyclops* are microscopic crustaceans about 0.5-3mm in length
- Both male and the female *Cyclops* of any age can be an intermediate host and transmit the disease
- Breeds in fresh water
- It lives along the margins of stagnant and slow flowing water bodies that are covered with plants
- Predominantly carnivorous, feeds on small fragments of plant material, small animals, larvae of fishes and other animals. They can even feed on dead and decaying flesh of animals(**carrion**)
- Swims with jerky movements
- *Cyclops* covers itself with slime in order to survive unsuitable conditions
- *Cyclops* density is high in water bodies during summer months. Low temperature reduces its reproductive activity and also results in high mortality of *Cyclops*
- Average life span of a normal *Cyclops* is 3 months

8. Reservoir

Humans are the only reservoir of infection. Many animals such as dogs, cats and foxes are found to be naturally infected with *Dracunculus*, however these animals do not constitute any reservoir of infection to humans.

9. Morphology

Body is cylindrical, smooth and milky white in color. Head bears a chitinous shield on which six papillae are present. Adults also possess six conspicuous labial papillae and eight external papillae. Papillae are sensory structures. *Dracunculus* shows sexual dimorphism (Figure 7).

Female: Female worm is one of the largest nematode known to cause infection to humans. The adult female is a slender, long, milky white worm measuring 60cm -120cm (about a metre) in length and 1.5-1.7mm in thickness, resembling a piece of long white twine thread. It has a blunt anterior end and a tapering posterior end which is bent to form a chitinous hook (Figure 7; Figure 8a). Female is didelphic. Gravid female has two uteri full of embryos; all other organs including the alimentary canal, gets atrophied (Figure 7). Roughly about 3 million embryos may be found in the uterus of a gravid female. Worm is viviparous and discharges embryos in successive batches for about 3 weeks. By this time the uterus gets emptied.

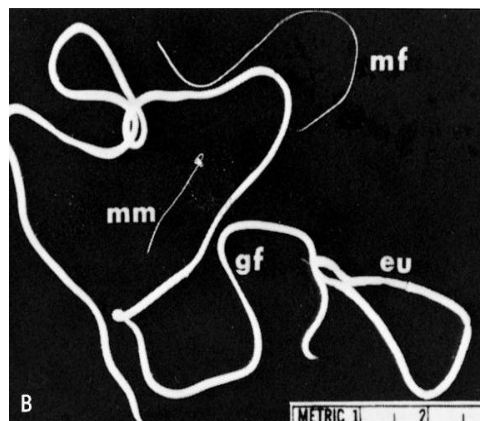


Figure 7: Showing---mm: Mature male, mf: Mature female, gf: Gravid female and eu: Gravid female showing extruded uterus Source: course1.winona.edu/kbates/Parasitology/.../Dracunculusmedinensis2.ppt

Male: Males are much smaller than females, measuring 12-30 mm in length; 0.4mm in width (Figure 7; Figure 8a). Posterior end of male is conical; bears 10 pairs of genital papillae: 4 Pairs of preanal and 6 pairs of post anal. Males possess spicules of unequal length and gubernaculum which help them in opening the vulva of the female during copulation.

Gubernaculum: It is a sclerotized thickening of the cuticle formed from spicule pouch; lies on dorsal side of cloaca and probably help to guide the spicules in opening the vulva of the female worm thereby help in mating.

The males die after copulation and they have not been reported from man (except for one case in India). Males have only been recovered from experimental animals.

As in other nematodes, the male *Dracunculus* has a common opening for the anus and the genital aperture called the **cloaca** present at the posterior end a little in front of the tail end. However, in case of the female *Dracunculus* anus is present at the posterior end while the genital aperture/gonopore is present in the middle one third region of the body.

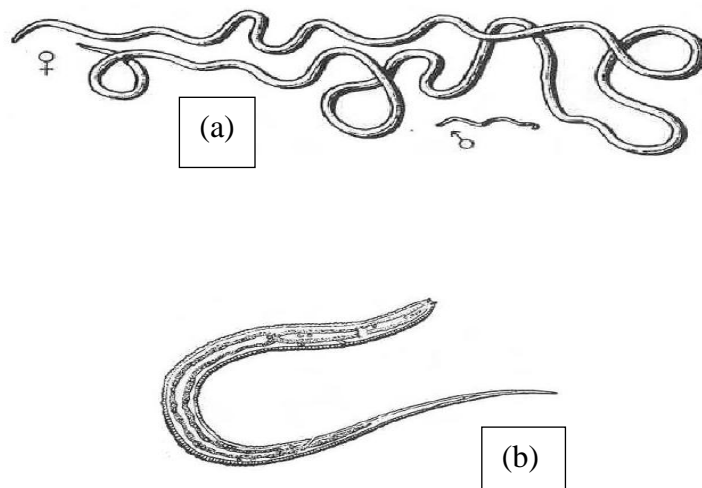


Figure 8: (a) Male and Female Adult *Dracunculus* (b) Rhabditiform larva

Source: <http://armymedical.tpub.com/MD0842/MD08420201.htm>

Table 2: Difference between Male and Female *Dracunculus medinensis*

Characteristic Features	Male <i>Dracunculus</i>	Female <i>Dracunculus</i>
Shape	Adult male is smaller than the female	Longer and stouter than adult male
Length	12-30 mm	60cm -120cm (about a meter)
Width	Approximately 0.4mm	1.5-1.7mm
Posterior End	Sharply curved	Has a blunt anterior end and a tapering posterior end which is bent to form a chitinous hook
Opening at posterior end	Cloaca (anus and the male genital aperture both open into the cloaca)	The digestive system opening—anus is present at the posterior end, a little in front of the tail end
Reproductive opening (Gonopore)	Opens in cloaca	Vulva opens ventrally at anterior one-third of the body
Spicules	One pair of unequal length	Absent
Gubernaculum	Present	Absent
Genital Papillae	10 pairs of genital papillae: 4 Pairs of ofpreanal and 6 pairs of post anal	Absent

10. Copulation

Copulation takes place in deeper connective tissue

During copulation, the male orients itself in such a manner that the male gonopore coincides with the female gonopore. Spicules, gubernaculum and genital papillae help the male in opening the vulva of the female during copulation and in the transfer of the sperms.

11. Life Cycle of *Dracunculus medinensis*

It is a digenetic parasite requiring two hosts to complete its life cycle.

Definitive host: Humans, dogs, cats and other wild animals.

Intermediate host: *Cyclops-Mesocyclops leuekarti* (A fresh water crustacean)

Life span of female is 1 year and that of male is 6 months.

Males are short lived. They die soon after copulation.

Female *Dracunculus* is viviparous

Life cycle starts with the development of young worms within the body of the female. When the young are ready to emerge from the uterus, the female comes beneath the skin surface of the host in

order to release them in water. The female worm produces a toxin that forms a blister in the host skin which regularly comes in contact with water e.g. hands, soles of feet, arms and legs of washer man, backs of water carrier (Bhistis) etc. (Figure 13). Eventually the blister bursts and a small ulcer is formed. When the host's skin comes in contact with water as when bathing and washing clothes, uterus of the female worm is projected out of the ulcer cavity and milky fluid containing myriads of coiled young worms are released into the water (Figure 14; Figure 15). **Contact with water stimulates the worm to release coiled embryos in water.** This process continues for 2 -3 weeks till all young ones are released into the water. When the host leaves water, the exposed end of the uterus dries and shrivels and blocks further release of larvae.

The larva called **rhabditoid larva**, has a long coiled body with rounded head and long slender tapering tail, measures 650 -750um in length and 17 -20 um in width (Figure 8b; Figure 9).



Figure 9: Rhabditoid larva

Source: <http://xyala.cap.ed.ac.uk/research/nematodes/fgn/pnb/dracmed.html>

It moves about briskly in water in search of a suitable **intermediate host** (*Cyclops*-these are small fresh water crustaceans), coiling and uncoiling the body. Further development takes place in suitable *Cyclops* species (Figure 10). As they swim some of them may be eaten by *Cyclops*. Unless taken up by *Cyclops*, the rhabditoid larva can live only for a short period of 4 -7 days. Each *Cyclops* can ingest 15 – 20 larvae of the guinea worm. The infected *Cyclops* can live for about a month or so. They usually die in about 40 days. However, it has been found that with heavy infestation, the *Cyclops* do not survive for more than 15 days (NORMAL LIFE SPAN OF *CYCLOPS* IS ABOUT 3 MONTHS).

Within the crustacean, the young guinea worm break through the mid-intestine wall within 1-6 hours after ingestion, migrate to the haemocoel (body cavity of the *Cyclops*), undergo two molts and become **infective third instar larva** in 10-20 days.



Figure 10: *Cyclops*

Source: <http://www.britannica.com/EBchecked/media/158679/Water-fleas-carry-the-guinea-worm?topicId=170708>

Man acquires the infection by ingesting *Cyclops* containing third instar infective larva in drinking water

Cyclops is digested by host's gastric juices in the stomach. Under the influence of digestive juices the larvae become active and penetrate the gut wall. They then migrate through the host's intestinal wall into the deeper connective tissue/retroperitoneal connective tissue where they molt twice to attain maturity in 3 – 4 months. The worm is guided towards their final destination purely by physical factors (sense organs –both visual as well as auditory are absent in them). Fertilization takes place here. Males die after copulation and are absorbed by the host and disappear within six months of infection. Growth and development of female is slow and it takes 6 months to 1 year for the female to mature and select proper site (only those parts of the skin liable to come in contact with water) for discharging the embryos in water. A local inflammatory reaction is then produced by the female.

The entire life cycle is completed in about a year.

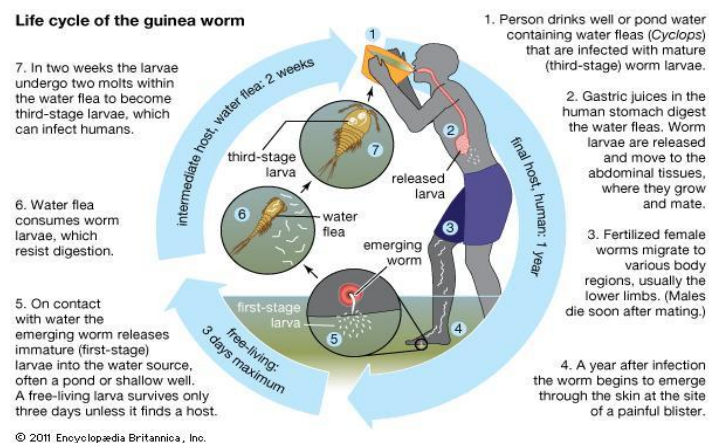


Figure 11: Life cycle of guinea worm

Source: <http://www.britannica.com/EBchecked/media/158064/Life-cycle-of-the-guinea-worm?topicId=170708>

12. Genomics of *Dracunculus medinensis*

Not much molecular work has been done on the endoparasitic *Dracunculus*. Bimi L, Freeman AR, Eberhard ML, Ruiz-Tiben E, Pieniazek NJ have shown that the *D. medinensis* 18S-rRNA sequences are 1819 bases long. Another species of *Dracunculus*, *D. insignis* 18S-rRNA sequences are 1821 bases long and differed from *D. medinensis* 18S-rRNA sequences at eight positions which amounts to a difference of only 0.44%. (Source: <http://www.ncbi.nlm.nih.gov/pubmed/16004710>; Ann Trop Med Parasitol. 2005 Jul;99(5):511-7)

Phylogenetic position of *Dracunculus* too has been studied by comparing the 18S-rRNA sequences of various nematodes. Of the various spirurids studied, *Dracunculus* have a close relationship with *Philometra ob turans* while the other spirurids like *Wuchereria bancrofti* and *Brugia malayi* are more close to the Rhigonematida. Ivashkin et al. 1971 had also showed that *Dracunculus* and *Philometra* morphologically shared a close resemblance (Figure 12).

Source: Martina Wijova' & František Moravec & Ales' Hora'k David Modry' & Julius Lukes Parasitol Res (2005) 96: 133–135: DOI 10.1007/s00436-005-1330-x

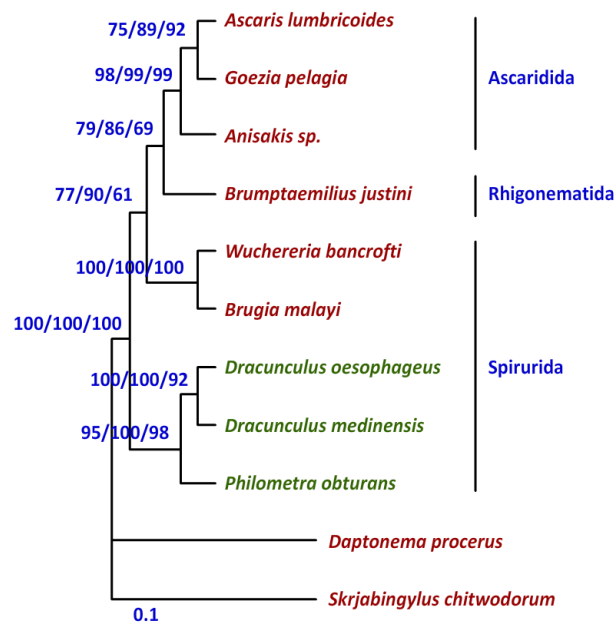


Figure 12: Phylogenetic position of *Dracunculus*

Source: www.researchgate.net/.../7923087_Phylogenetic_position_of_Dracunculus...

13. Pathogenicity of *Dracunculus medinensis*

Guinea worm disease is known as **dracunculosis** or **dracunculiasis** or **dracontiasis**.

D. medinensis infection in humans is asymptomatic until the female worm reaches the surface of the skin and is ready to discharge the larva. Third instar larvae are not pathogenic. They essentially do not produce any pathological lesion in humans either after they are released from *Cyclops* in the stomach or during penetration of intestinal mucosa and migration in the viscera and deep somatic tissues.

Only the female adult worm is pathogenic

Symptoms of Dracunculosis are absent until a skin sore begins to form. Then nausea, diarrhea, giddiness, skin rash, itching, or asthma may occur. These symptoms are because of toxins produced by the parasite. Allergic reactions may also be caused by the toxins.

Blister formation: It appears whenever the gravid female worm makes an attempt to come to the surface of the body, purely guided by instinct and pierces through the skin to discharge its embryos. The worm secretes an irritant (histamine like substance) that produces a small red spot which gradually becomes a small bleb or blister (Figure 13). Blister formation is accompanied by intense burning pain. Over the next few days blister vesiculates (fluid appears in the blister). Fluid in the blister is bacteriologically sterile and yellow in color and contains many monocytes, eosinophils, neutrophil, polymorphonuclear leucocytes and granulocytes. Many embryos remain coiled up in this fluid. Finally, blister ruptures exposing a small superficial erosion. A small round hole may be seen at the center of the erosion (Figure 14). This hole leads to a tunnel in the subcutaneous tissue where the gravid female worm lies. Now, the gravid female worm protrudes its head through this hole whenever it comes in contact with water and discharges larvae. Discharge of larva is intermittent (Figure 15). Sore is not usually more than 5mm in diameter but can become larger and sometimes becomes secondarily infected with bacteria. Sore is usually on feet, legs or arms but occasionally on other exposed part of the body also. During next few weeks, worm dies and is slowly absorbed in the tissue after which the ulcer heals.



Figure 13: A mature blister

Source: <http://www.dpd.cdc.gov/dpdx/HTML/Dracunculiasis.htm>



Figure 14: A ruptured blister—gravid female worm can be seen emerging out

Source: <http://www.dpd.cdc.gov/dpdx/HTML/Dracunculiasis.htm>



Figure 15: Dracunculiasis

Source: <http://masterroshsi.blogspot.in/2012/08/dracunculus-medinensis.html>

Once the embryos have been discharged by the gravid female, the local discomfort diminishes. The problem now is to remove the dead worms because these worms may cause arthritis and paralysis of spinal cord if they get lodged in the joints or get calcified in the soft tissues (Figure 16; Figure 17).

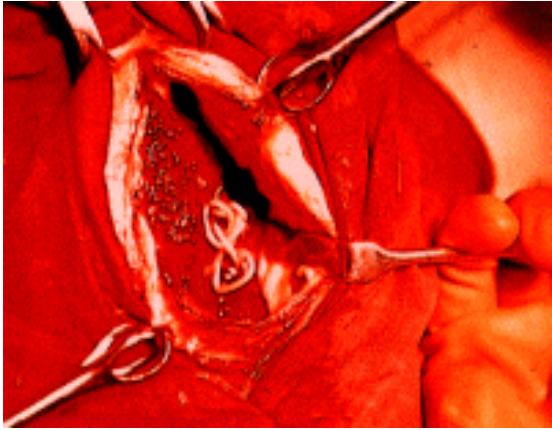


Figure 16: Adult in joints

Source: course1.winona.edu/kbates/Parasitology/.../Dracunculus medinensis2.ppt



Figure 17: Calcified lesion in soft tissues

However, if they are near the surface of the skin, they can easily be removed by carefully twisting around a stick (Figure 18). This method of extracting the worm may take some days or even weeks. Care should be taken that the worm does not break off in between as that might lead to complications because of the release of certain chemicals.

Secondary bacterial infection is quite common, sometimes even leading to tetanus.



Figure 18: *D. medinensis* being extracted out on a stick

Source: <http://ianimal.ru/topics/rishta>

This technique of extracting out the worm on a stick was for the first time devised by **Moses** and is still in practice in some of the endemic areas.

Table 3: Clinical symptoms of *Dracunculus* diseases

Symptoms due to migrating gravid female *Dracunculus*

- + Papule
- + Blister
- + Ulcer
- + Burning sensation
- + Secondary bacterial infection

Allergic symptoms

- + Nausea
- + Giddiness
- + Skin rash/urticaria
- + Itching
- + Asthma/dyspnea

Symptoms due to calcified female worms or if the female worm gets lodged in the joints

- + Arthritis
- + Compression or even paralysis of spinal cord
- + Fibrous joints

Symptoms due to injured or broken worm

- + Secondary bacterial infection, sometimes leading to tetanus
- + Painful, swollen and inflamed part

14. Host Parasite Relationship: Antibody Response

The host remains unaware of the presence of the parasite until the female worm comes up to the surface of the skin of the exposed parts like ankle to release the larvae. This is when the host's immune system starts to respond.

There are evidences to show that the parasite tries to evade the host's immune system. It is believed that the worm secretes opioids (Morphine-6-glucoronide) that suppresses the immune response of the body. It is also believed that the worm coats themselves with proteins that identify them as part of the host and therefore go unnoticed(SOURCE: END THE OF HORROR WORM: *Dracunculus medinensis*. Farhan A. Yusuf, School of Pharmacy, B.Pharm IV the Dar-es-salaam Medical Students' Journal - DMSJ October 2011)

15. Epidemiology

The disease is prevalent in areas where people do not have safe drinking water. There is **no vaccine** till day to prevent dracontiasis. Also, there are chances of re-infection as there is **noprotective immunity/acquired immunity** against Guinea worm. **There is no drug treatment for the fiery serpent**(Source: <http://www.cdc.gov/parasites/guineaworm/>)

16. Diagnosis

- **Adult:** Possible when female worm comes up to the surface of skin to release embryos.
- **Embryo:** Affected part through which head of the worm is protruding may be bathed with water in order to stimulate the discharge of embryos from the uterus which can then be examined under the microscope.
- **Blood examination:** Reveals eosinophilia.
- **Skiagraphy:** Worms in deeper tissues after death either become calcified or absorbed. Skiagraphy reveals calcified worms.
- **Intradermal test:** Intradermal injection of *Dracunculus* antigen in patients suffering from dracontiasis causes a wheal to appear in about 24 hours. Recently, Falcon assay screening test-enzyme linked immunosorbent assay (FAST-ELISA) and enzyme linked immune-electro transfer blot (EITB) TECHNIQUES are used to test human sera with *D. medinensis* adult worm antigen.

17. Prophylaxis

- Eradicate the intermediate host, *Cyclops* by encouraging *Cyclops* eating fishes in ponds and streams used by people, or by chemical treatment of water.
- Drink clean, filtered, water. Boiled water is always safe to drink.

- Keep away people with sores from contaminating wells, laundry and bathing water.

18. Treatment

Antihistaminic and steroids help in the initial stages of allergic reactions.

Drug therapy has no lethal effect on the worm but helps to reduce the swelling and also in removing the worm easily by surgical method.

Table 4: Summary of Characteristic Features in the Life Cycle of *Dracunculus medinensis*

Feature	Characteristic
Mode of infection/ Port of entry	Oral, contaminated water
Source of infection	Infected <i>Cyclops</i> , <i>MESOCYCLOPS LEUEKARTI</i> (a fresh water crustacean)
Infective stage	<i>Cyclops</i> containing third instar larva
Digestion of <i>Cyclops</i> and migration of the 3rd instar larva in the body of definitive host	<i>Cyclops</i> is digested by host's gastric juices in the stomach. Under the influence of digestive juices the larvae become active and penetrate the gut wall migrate through the host's intestinal wall into the deeper connective tissue/retroperitoneal connective tissue attain maturity in 3 – 4 months
Site of localization	Subcutaneous tissues of exposed parts, like, legs, back, arms, and ankles
Pathogenic stage	Adult female <i>Dracunculus</i>
Incubation period	8-12 months
Pre-patent period	10-14 months (Period between infection and the emergence of the female parasite in the blister)
Pathogenesis	Disease caused: dracunculosis or dracunculiasis or dracontiasis Nausea, diarrhoea, giddiness, skin rash, itching, or asthma may occur. These symptoms are because of toxins produced by the parasite. Allergic reactions may also be caused by the toxins. Secondary infection by bacteria, sometimes leading to tetanus. The dead worms that get lodged in the joints or get calcified in the soft tissues may cause arthritis and paralysis of spinal cord
Pathogenic stage	Adult female <i>Dracunculus</i>

19. Summary

- *Dracunculus medinensis* is a somatic nematode which requires two hosts to complete its life cycle: **Definitive host:** Human and an **Intermediate host:** *Cyclops*
- It is a viviparous parasite

- Infective stage is the *Cyclops* containing the third instar rhabditiform larva
- Humans get the infection by drinking contaminated water containing the infected *Cyclops*
- Larva are digested out of the *Cyclops* by the acidic juices of the stomach
- The larva migrates through the intestinal wall and reach the retro-peritoneal connective tissue where they grow and attain maturity
- The male *Dracunculus* resides in the retroperitoneal connective tissues and dies shortly after copulation
- Female *Dracunculus* is the largest nematode and is found in the subcutaneous tissues in the legs, arms and back
- Causes Dracunculiasis
- Clinical manifestations are because of the female emergence through the skin
- Its body fluid is toxic and blister appears as the female worm makes an attempt to pierce the skin in order to discharge the embryos
- Secondary bacterial infection is quite common in persons infected with *Dracunculus*
- Dracunculiasis is a water borne disease
- Safe drinking water, not allowing infected persons from entering water bodies like ponds, step wells etc and removal of *Cyclops* from the water bodies can help in prevention of the disease

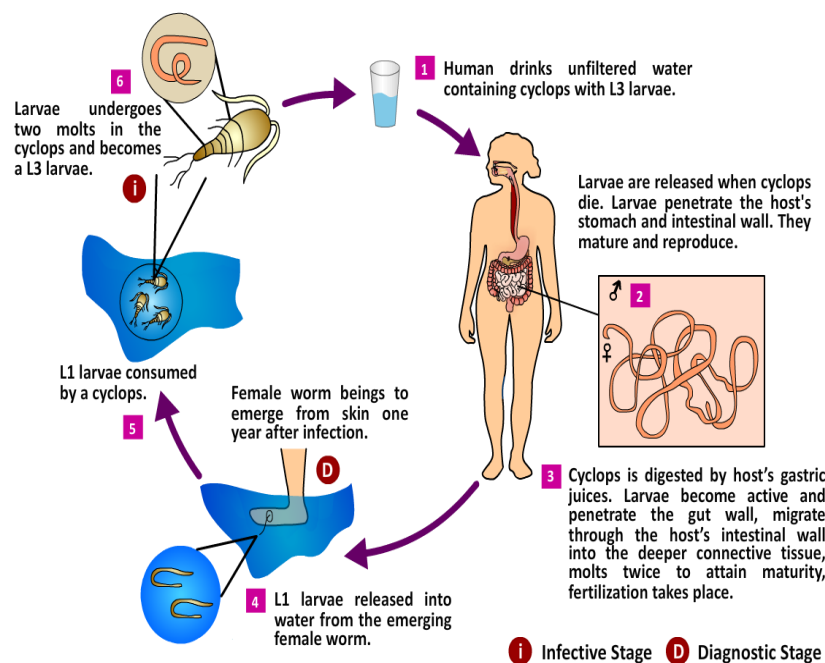
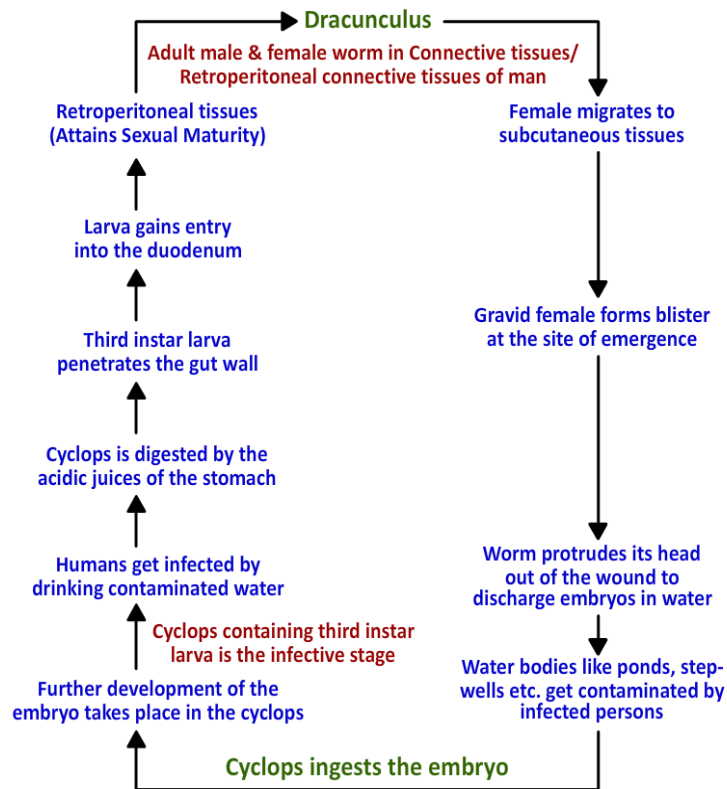


Figure 19: Summarized Life cycle of *Dracunculus medinensis*



Diagrammatic representation of the life cycle of *D. medinensis*