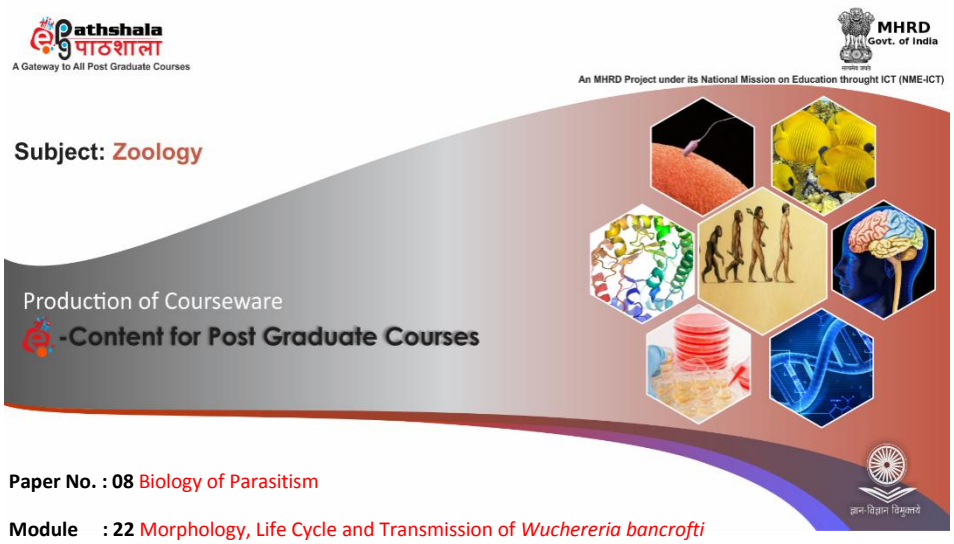

Paper No. : 08 Biology of Parasitism

Module : 22 Morphology, Life Cycle and Transmission of *Wuchereria bancrofti*

Development Team

Principal Investigator:	**Prof. Neeta Sehgal** **Head, Department of Zoology, University of Delhi**
Paper Coordinator:	**Dr. Pawan Malhotra** **ICGEB, New Delhi**
Content Writer:	**Dr. Sarita Kumar** **Acharya Narendra Dev College, University of**
Content Reviewer:	**Prof. Virender Kumar Bhasin** **Department of Zoology, University of Delhi**

Description of Module	
Subject Name	ZOOLOGY
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Contents

1. Learning Outcomes

After studying this Unit, you will be able to

- realize the medical importance of *Wuchereria bancrofti*
- identify the parasite from its morphological features
- distinguish between male and female *Wuchereria bancrofti*
- recognize the digenetic nature of parasite and comprehend its life cycle in two hosts
- understand the factors affecting its transmission

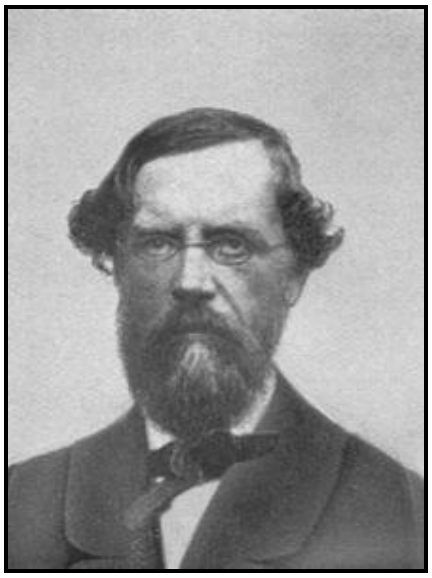
2. Introduction

Wuchereria bancrofti, also known as *Filaria bancrofti* is a thread-like parasitic nematode of human beings. It is commonly known as **human Filarial Worm** and is well known as the causative worm of **lymphatic Filariasis/bancroftian Filariasis** or **elephantiasis** in which the lymphatic and genital organs get disabled either temporarily or permanently. It is extremely painful and disfiguring disease, the infection of which is generally attained during childhood, but visible manifestations occur later in life.

3. Discovery of *Wuchereria bancrofti*

Wuchereria bancrofti has been named after its discoverers - Brazilian Physician **Otto Edward Henry Wucherer** (7 July 1820 – 7 May 1873) and British Parasitologist **Joseph Bancroft** (21 February 1836 – 16 June 1894). Both scientists are considered pioneers in studying filarial infections (Fig. 1 a; b).

Dr. Wucherer, after whom the worm has been named, was a medico at Bahia, Brazil. He discovered the larvae of *Wuchereria*, the prime cause of the disease. Dr. Bancroft, a surgeon at Queensland, discovered the mature Filarial worm and was one of the first ones to suggest that it was borne by mosquitoes.



(a) **(b)**

Fig. 1: (a) Otto Edward Henry Wucherer; (b) Joseph Bancroft

Source: http://en.wikipedia.org/wiki/O._E._H._Wucherer; http://en.wikipedia.org/wiki/Joseph_Bancroft

The parasitic effects of *W. bancrofti* have been acknowledged early in prehistoric texts. Greek and Roman writers established the similarities between the symptoms of the disease with the features of elephant; such as enlarged limbs and the cracked and dry skin of infected individuals. Since then, this parasitic condition has been commonly known as **elephantiasis**, though this is a misnomer, as it factually interprets "a disease caused by elephants".

In India, description of a filariasis-like disease has been documented in 6th century BC in Chapter XII of the '**Susruta Samhita**'. Later, the signs and symptoms of this disease were described in 7th century AD by Madhavakara in Chapter 39 of his treatise '**Madhava Nidhana**'. In 1709, Clarke named elephantoid legs as **Malabar legs** in Cochin and the microfilariae(Immature worms)were discovered for the first time in the peripheral blood by **Lewis** in 1872 in Kolkata.

Filariasis is considered as a disease mostly of the poor and is most commonly found in individuals inhabiting areas with poor sanitation and hygiene. It has resulted in its inclusion on the neglected tropical diseases listed by World Health Organization (http://www.who.int/neglected_diseases/diseases/en/). It is known to have caused significant economic and psychosocial impacts wherever it is endemic; disfiguring and/or incapacitating more than 40 million individuals, their families, and the endemic communities.

4. Geographical Distribution of *Wuchereria bancrofti*

Wuchereria bancrofti is largely confined to the tropical and sub-tropical regions of the world. According to the WHO reports, 73 countries are affected with the parasite. Some of these countries include India, West Indies, South America, West and Central Africa, Southern China, Japan, Pacific Islands and Korea (Fig. 2). Approximately 120 million people are believed to have filarial infection out of which 25 million men suffer from genital disease while almost 15 million, mostly women, have developed elephantiasis of the leg. Approximately 66% of those at risk of infection are reported to live in the South-East Asia Region and 33% in the African Region.

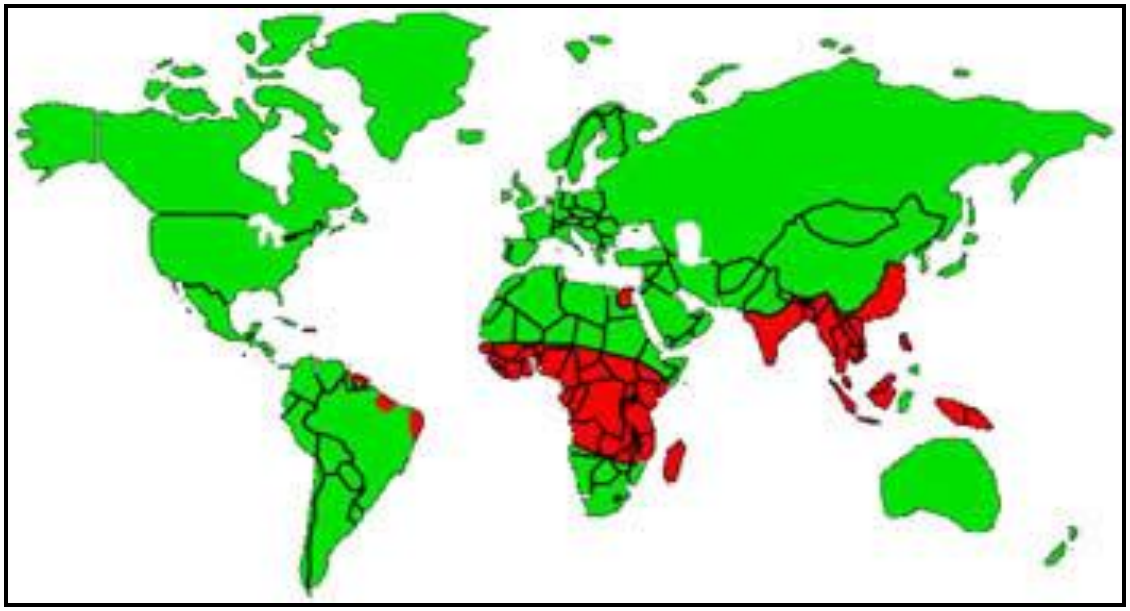


Fig. 2: Prevalence of *Wuchereria bancrofti* in the world
The areas in red indicate the geographical distribution of the parasite
Source: http://www.cdc.gov/parasites/lymphaticfilariasis/epi.html

Interestingly, the parasite is reported to be completely absent from Europe, North America and Polar Regions. In USA, the infection disappeared early in the 20th century where only four countries are currently known to be endemic: Brazil, Haiti, Guyana and the Dominican Republic. The regions of Charleston, South Carolina, were the last known places in USA with lymphatic Filariasis. It is contemplated that the filarial worm disease has been brought to the New World by the slave trade after the introduction of which, the disease persisted throughout the areas surrounding Charleston, South Carolina until its sudden disappearance in the 1920s.

In India, the *Wuchereria bancrofti* is primarily distributed in the Southern regions especially along the sea coast affecting more than hundred million people. Native cases have been reported from about 250

districts in 20 states and Union Territories. Major cases have been recorded from Pondicherry, Andaman & Nicobar Islands, Lakshadweep, Daman & Diu, Dadra & Nagar Haveli and Goa (Fig. 3).

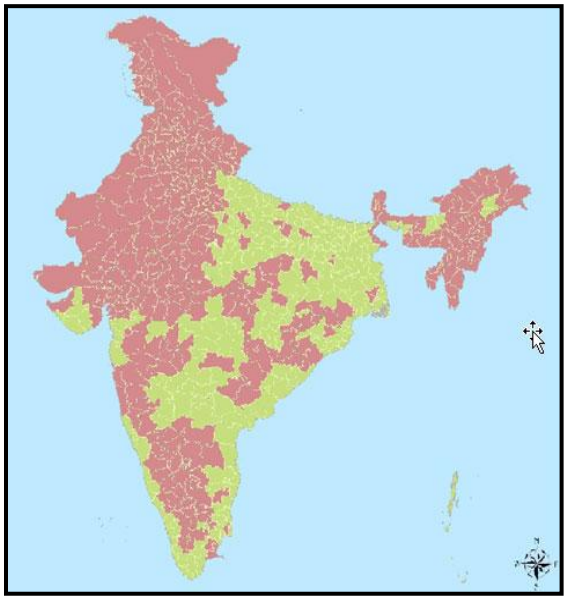


Fig. 3: Districts with endemic *Wuchereria bancrofti* in India
Source: http://nvbdcp.gov.in/fil-map.html

On the other hand, North-Eastern States; namely Sikkim, Arunachal Pradesh, Tripura, Mizoram, Meghalaya, Nagaland and Manipur are known to be free from indigenously acquired filarial infection (Fig. 4; Table 1).

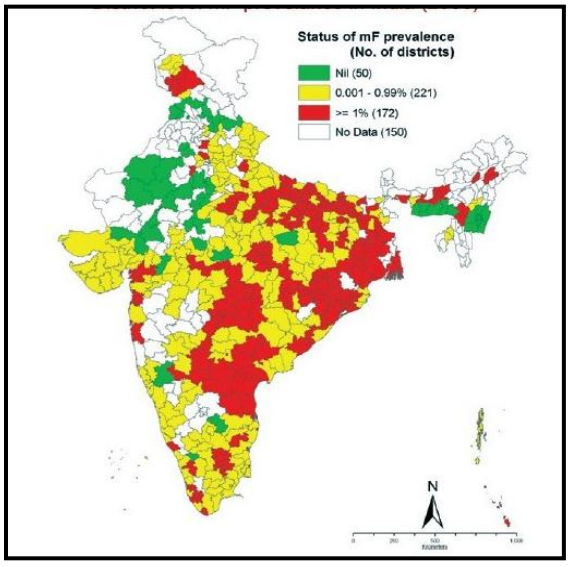


Fig. 4: Status of Filariasis prevalence in various districts of India
Source: http://www.jpgmonline.com/viewimage.asp?img=jpgm_2010_56_3_232_68650_f1.jpg

Table 1: Trend of Average Microfilaria rates (%) in the State since 2004

S. No.	States/UTs	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	Andhra Pradesh	1.36	0.74	0.69	0.26	0.38	0.45	0.35	0.21	0.20	0.22
2	Assam	ND	0.04	0.19	1.46	0.88	0.81	1.06	0.17	0.19	0.15
3	Bihar	1.50	2.15	1.38	0.68	ND	1.07	0.94	ND	1.15	ND
4	Chhattisgarh	ND	1.96	ND	0.61	0.45	0.54	0.40	0.10	0.10	0.08
5	Goa	0.11	0.04	0.02	0.08	0.01	0.00	0.01	0.00	MDA stopped	MDA stopped
6	Gujarat	0.22	0.84	0.84	0.42	0.83	0.92	0.46	0.52	0.24	0.31
7	Jharkhand	ND	0.84	1.40	1.34	1.10	1.11	0.82	0.63	NR	ND
8	Karnataka	1.87	0.84	0.69	1.15	1.07	0.93	0.89	0.83	0.65	0.60
9	Kerala	0.68	0.50	0.67	0.65	0.29	0.39	0.17	0.14	0.21	0.15
10	Madhya Pradesh	0.83	0.40	0.38	0.70	0.36	0.40	0.19	0.23	0.09	ND
11	Maharashtra	1.13	1.45	1.13	0.83	0.35	0.46	0.53	0.51	0.43	0.46
12	Orissa	2.60	2.37	1.11	0.99	0.74	0.69	0.40	0.43	0.34	0.34
13	Tamil Nadu	0.04	0.38	0.39	0.29	0.15	0.12	0.07	0.09	0.17	ND
14	Uttar Pradesh	1.77	1.01	0.81	0.32	0.41	ND	0.28	0.24	0.38	0.17
15	West Bengal	4.74	4.10	2.72	2.83	0.89	0.48	0.44	0.55	0.70	ND
16	A&N Islands	1.4	0.09	0.15	0.34	0.19	0.46	0.10	0.12	0.17	0.14
17	D & N Haveli	1.96	2.01	2.91	3.47	1.82	1.23	0.95	1.79	0.71	0.54
18	Daman & Diu	0.47	0.14	0.27	0.09	0.07	0.07	0.06	0.07	MDA stopped	MDA stopped
19	Lakshadweep	1.19	0.09	0.07	0.02	0.27	0.00	0.00	ND	ND	ND
20	Pondicherry	0.42	0.50	0.15	0.06	0.03	0.00	0.00	0.00	MDA stopped	MDA stopped
	National Average	**1.24**	**1.02**	**0.98**	**0.64**	**0.53**	**0.65**	**0.41**	**0.37**	**0.41**	**0.29**

ND: Not Done || **NR**: Not Reported

Source: http://nvbdcp.gov.in/fil-rate.html

5. Characteristic Features of *Wuchereria bancrofti*

Wuchereria bancrofti is a pseudocoelomate (coelomic cavity is not surrounded by mesoderm) cylindrical, thread-like nematode. The body is covered with a thick cuticle with syncytial (multinucleated) epidermis.

The systematic position of *Wuchereria bancrofti*is as under:

Phylum : Nematoda
Class : Phasmidia
Genus : *Wuchereria*
Species : *bancrofti*

5.1 Habit and Habitat of Wuchereria bancrofti:

Adult *Wuchereria bancrofti*is an endoparasite of human beings. It is not a zoonotic parasite and thus, is not found in any other mammal. In humans, it can be located in the lymphatic vessels and lymph nodes of the body, particularly in the groin regions (Fig. 5).

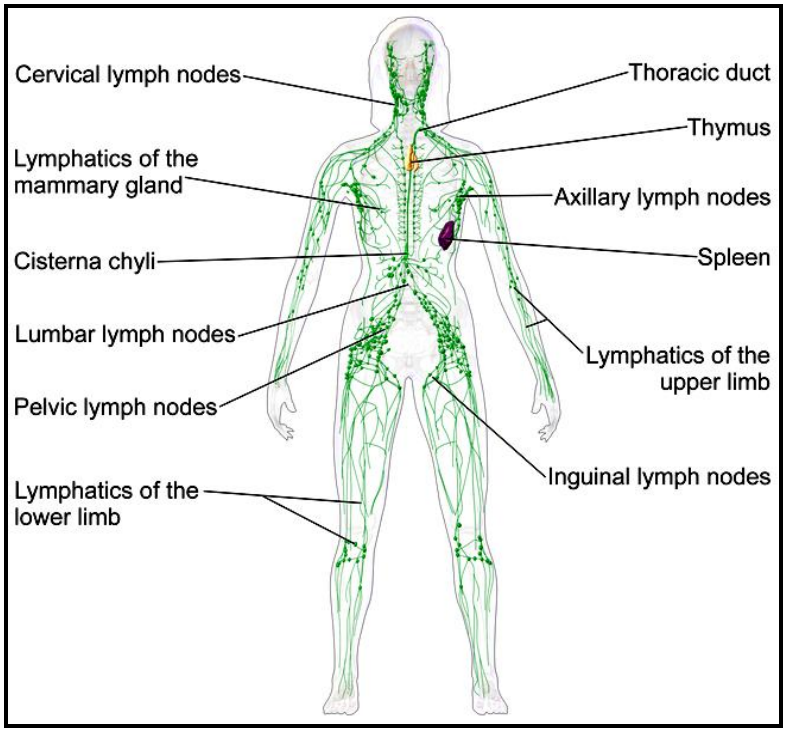


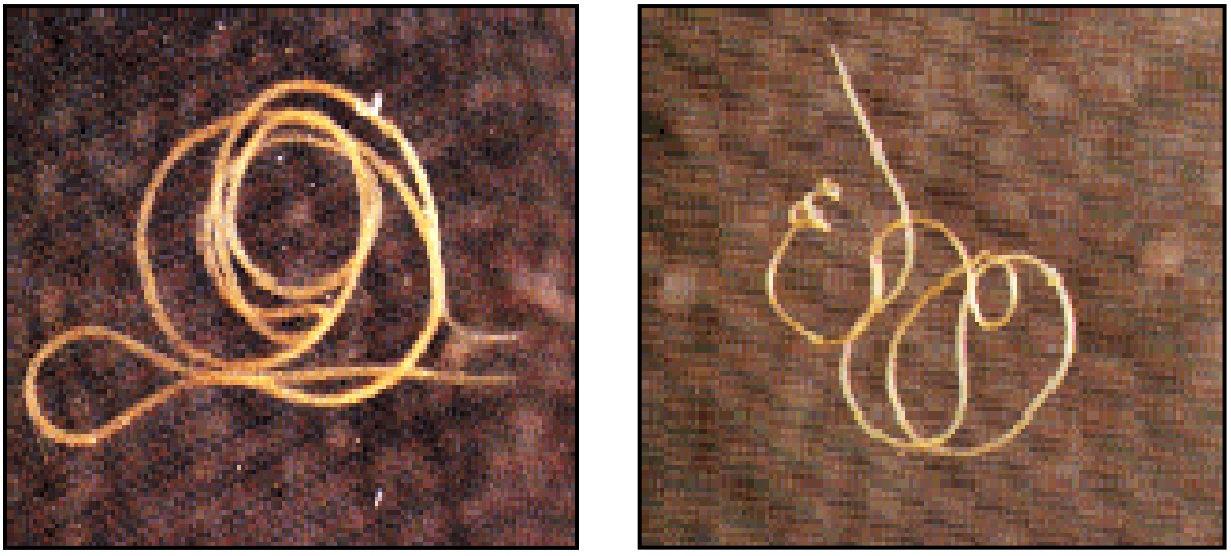
Fig. 5: Human Lymphatic System
Source: http://commons.wikimedia.org/wiki/File:Blausen_0623_LymphaticSystem_Female.png

5.2 Morphological Features of Adult Wuchereria bancrofti

Adult *Wuchereria bancrofti* worms are elongated, cylindrical, hair-like and slender worms. The body is slightly curved with rounded ends. They are often creamy-white in colour, though occasionally their body looks transparent. The body has numerous nuclei dispersed throughout their body cavity which appear as dark spots on the outer covering. The mouth is very small and is devoid of buccal capsule. Male and female *Wuchereria bancrofti* are separate and exhibit distinct sexual dimorphism (Fig. 6 a; b).

Head End: The head or cephalic end of both males and females is slightly enlarged and terminates in a slightly round swelling. It has two circles of distinct papillae and is connected to the main body by a short and constricted **neck**.

Tail End: The tail end of the worms lacks any nucleus. Male adults have a ventrally curved tail with 15 pairs of minute caudal papillae at the tip of the tail which are sensory in nature. Out of these 11 pairs of papillae are present (in front of anus and are called **pre-anal papillae** while 4 pairs are located behind the anus and are named as **post-anal papillae**. On the other hand, the tail end of female worms gradually tapers, is rounded at the tip and lack any papillae. There are no additional sensory structures.



(a) **(b)**

Fig. 6: Outline structure of adult *Wuchereria bancrofti* (a) Female; (b) Male
Source: http://xyala.cap.ed.ac.uk/research/nematodes/fgn/pnb/wuchban.html

Also, as in other nematodes, the digestive system and reproductive system of female adults open separately, *via* **anus** and **gonopore**; whereas, males *Wuchereria* have single opening for the both the systems, called **cloaca**.

The summary of the differences in the characteristic features of male and female *Wuchereria bancrofti* are presented in Table 2.

Table 2: Difference between Male and Female *Wuchereria bancrofti*

Characteristic Features	Male *Wuchereria*	Female *Wuchereria*
Shape	Smaller and thinner than female adult	Longer and stouter than male adult
Length	Range between 2.5 - 4.0 cm	Range between 5 - 10 cm
Width	100 µm approx.	200 - 300 µm approx.
Posterior End	Sharply curved ventrally	Narrow, tapers gradually with rounded tip
Opening at posterior end	Cloaca (Common opening of digestive and reproductive system)	Anus (Opening of digestive system). Reproductive system opens separately
Reproductive opening (Gonopore)	Opens in cloaca	Vulva opens ventrally at anterior one-third of the body
Penial/Copulatory spicules	One pair of unequal length	Absent
Genital papillae	Present at the anal end	Absent
Sensory Papillae	15 pairs at the anal end: 11 pairs pre-anal and 4 pairs post-anal	Absent

6. *Wuchereria bancrofti* - Digenetic Parasite

Wuchereria bancrofti is a **digenetic parasite.** It completes its asexual and sexual life cycle in two hosts.

(a) Primary/Definitive Host: A Primary host is the organism where the adult stage completes its reproduction and thus sexual part of its life cycle. *Wuchereria bancrofti* can reproduce only in the body of human beings. Thus, man is the **only definitive host** of filarial worms. However, certain reports of filarial infection in monkeys, though, have been cited but these infections have been carried out artificially and do not occur in nature.

(b) Secondary/Intermediate Host: An intermediate host is a transitory organism which is essential for the asexual reproduction of parasite, completion of its larval stage and for transmission to the definitive host. A large number of mosquito species belonging to the genus, *Culex*, *Aedes* and *Anopheles*; act as **secondary hosts** and are responsible for the transmission of *Wuchereria* to healthy human beings. However, the transmission by different species of mosquitoes varies in different regions depending upon the prevalence of a particular species in a region.

The transmission by -

- *Culex* mosquito is widespread across urban and semi-urban areas of tropical countries (Fig. 7a),
- *Anopheles* mainly takes place in rural areas of tropical countries (Fig. 7b), and
- *Aedes* primarily occurs in endemic islands in the Pacific (Fig. 7c).

(a) (b) (c)

Fig. 7: Intermediate hosts of *Wuchereria bancrofti*;
(a) *Culex* mosquito; (b) *Anopheles* mosquito and (c) *Aedes* mosquito

Sources: (a) http://cdn2-b.examiner.com/sites/default/files/styles/image_content_width/hash/d7/18/1343162393_2483_CulexNil.jpg?itok=bwAGsu8g
(b) http://www.jyi.org/wp-content/uploads//3029599900_306c972145.jpg
(c) http://farm1.staticflickr.com/50/152742527_e7335f5819_o.jpg

In India, *Culex pipiens fatigans* is the principal intermediate host.

Culex is the domestic mosquito which breeds in association with human habitations. It prefers polluted waters, such as sewage, drains and septic tanks; however, they can breed in clean water also, such as ponds. The mosquito lays eggs are laid in rafts, each of which contains 250-300 eggs; depending on the quality and quantity of blood meal. At the optimum temperature of 25 °C – 30 °C, the eggs hatch within 24 to 48 hours. The life cycle includes four instars which may take 10-12 days for development. The fourth instars transform to comma-shaped pupae, which after 24-48 hours emerge into an adult mosquitoes. The entire cycle from egg to emergence of adult is completed in 10-14 days.

7. Life Cycle and Development of *Wuchereria bancrofti*

7.1 Copulation

The adult *Wuchereria bancrofti* resides in the lymphatics of the human host (Fig. 8). Male and female parasites live together; coiled with each other so strongly that it becomes very difficult to separate them. Copulation between male and female adults takes place in the lymph glands of human beings.

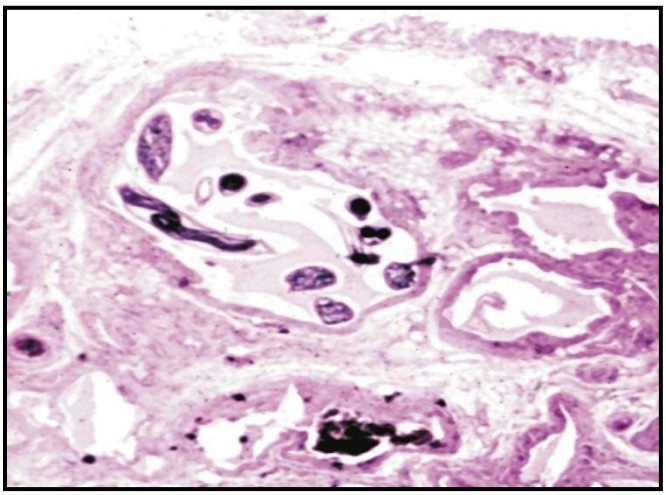


Fig. 8: Adult *Wuchereria* in lymphatic vessel

Source: http://www.microbeworld.org/images/stories/twip/wuchereria_adults_lymph.jpg

During copulation, male adults of *Wuchereria bancrofti* grasp females with the help of coiled tail region. The sensillae and copulatory spicules located around the cloacal region of males help them to open the vulva and vagina of females and transfer the sperms. Reports are available which evidently prove the involvement of sex pheromones in attracting mates. In addition, evidences suggest that males possess a chemosensory apparatus required for recognition of such signals (Nisbet *et al*., 2004; Nutman and Scott, 2000).

7.2 Release of Microfilariae

The females of *Wuchereria bancrofti* are **ovo-viviparous.** Thus, instead of laying eggs like many other nematodes, they liberate numerous active embryos, called **juveniles** or **microfilariae** in the lymphatic channels (Fig. 9).

Fig. 9: Microfilaria in the human blood

Source: http://www.microbeworld.org/images/stories/twip/wuchereria_microfilaria.jpg

7.3 Structure of Embryos or Microfilariae

Microfilariae are very active in habit and are microscopic. The peculiar morphological characteristics of the larvae are presented in Fig. 10 and Table 3.

Table 3: Characteristic Features of *Microfilaria bancrofti*

Characteristic Features	*Microfilaria bancrofti*
Shape	Elongated, filiform with blunt head and pointed tail (Fig. 10)
Length	200 to 300 µm approx.
Width	6 to 7 µm wide
Colour	Colourless or transparent
Covering	A hyaline/transparent sheath

Fig. 10: Photomicrograph showing a microfilaria of *Wuchereria bancrofti* with a rounded anterior and tapered posterior end. (MGG 40×)
Source: http://labmed.ascpjournals.org/content/40/11/683/F2.expansion.html

The detailed features of microfilariae can be observed after staining with Romanowsky's stain (Fig. 11).

Fig. 11: Microfilaria in the human blood stained with Romanowsky's stain
Source: http://microwikiwau.wikispaces.com/Wuchereria+bancrofti

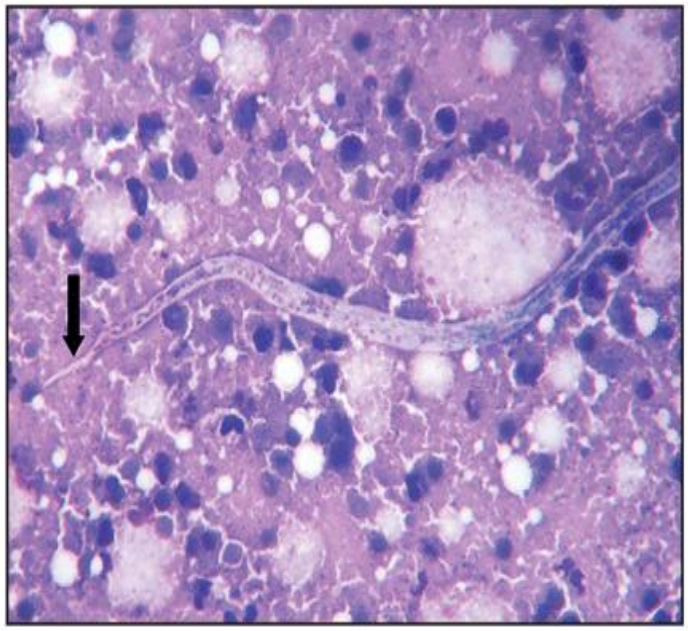


Fig. 12: Photomicrograph of the microfilaria of *Wuchereria bancrofti* with a clear space free of nuclei at the caudal end (arrow). (MGG 40×)
Source: http://labmed.ascpjournals.org/content/40/11/683/F3.expansion.html

Fig. 13: Microfilariae in human blood
Source: http://en.wikipedia.org/wiki/Wuchereria_bancrofti

The detailed stained structure of the microfilaria shows the following features:

(a) Hyaline sheath:

The body of microfilariae is covered with a transparent sac called **hyaline sheath.** It is made up of flattened epithelial cells. The sheath being 359 µm long, is larger than the size of microfilariae (Fig. 12). The ends of the sheath project beyond the ends of the embryo so that they can move easily within it.

(b) Subcuticular cells:

Cuticula is lined by special cells, called subcuticular cells which are visible only when stained with vital stains.

(c) Nuclei:

Another diagnostic feature of microfilariae is the presence of numerous nuclei in their cytoplasm. These nuclei appear as **granules** and are clearly visible after staining (Fig. 13). However certain areas lack these nuclei which serve as the distinguishing feature of microfilariae.

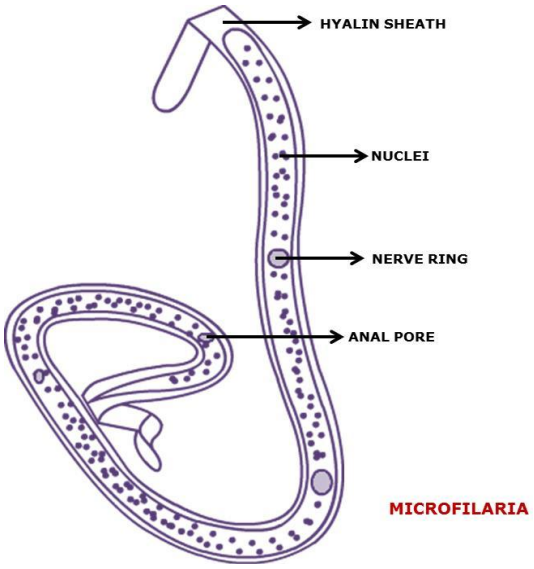


Fig. 14: Diagrammatic structure of microfilaria
Source: http://vle.du.ac.in/

These areas signify the following regions of microfilariae (Fig. 14):
(i) Anterior end, called cephalic space
(ii) Tail end, called anal space (terminal 5%)

Further, granules are broken at definite places, which help in the identification of species. These are:
(i) Nerve ring – visible as oblique space
(ii) Excretory system – Anterior V-spot representing the rudimentary excretory system
(iii) Anus or cloaca – Posterior V-spot representing the opening of digestive system

7.4 Circulation of Microfilariae in Human beings

The microfilariae released by adult *Wuchereria bancrofti* into the lymph vessels are very active and quickly enter the main lymphatic trunks. Eventually, they find their way into the circulating blood (Fig. 15). Though, generally, they move with the blood stream, but they are capable of moving against the blood stream too. Ultimately, microfilariae migrate to deeper blood vessel and stay there for further development.

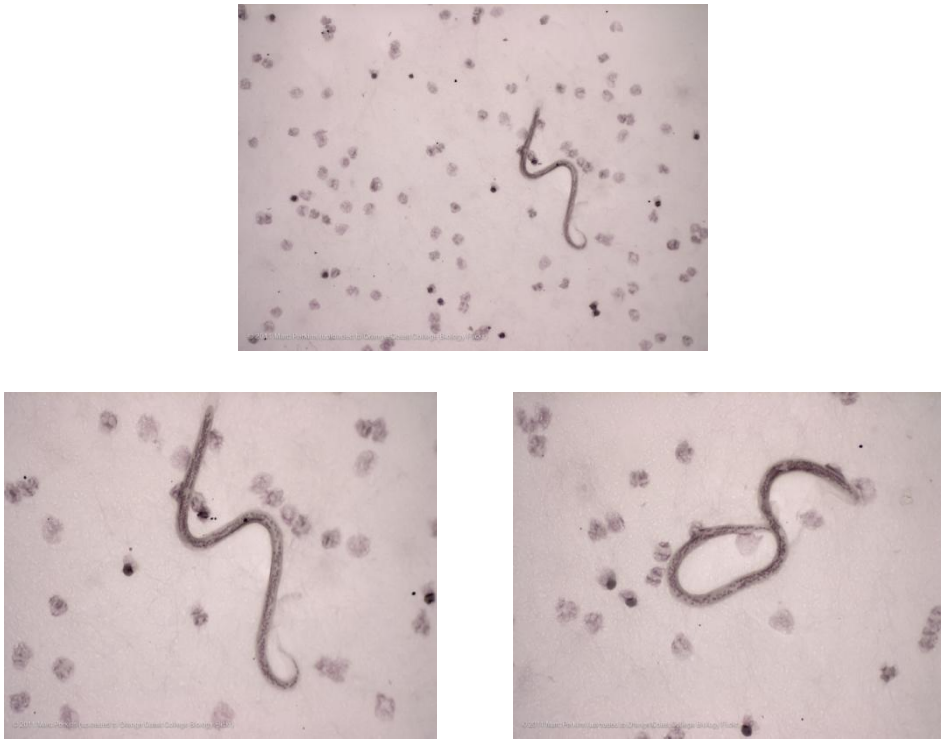


Fig. 15: Migration of microfilaria through blood stream (Credit: Marc Perkins)
Sources: https://www.flickr.com/photos/occbio/6414495735/; https://www.flickr.com/photos/occbio/6414494361/; https://www.flickr.com/photos/occbio/6414497563/

The microfilariae need a lower temperature for their further development and thus, they stay in human beings as newly emerged larvae. The average life span of microfilariae in human body is approximately 70 days. For further development, the larvae need their intermediate host, i.e. *Culex* mosquito. If they are not sucked by these mosquitoes, they die and disintegrate in the human body.

7.5 Nocturnal Periodicity of Microfilaria bancrofti:

As we have discussed earlier, the microfilariae reside in the deeper blood vessels. Thus, they cannot be sucked by mosquitoes unless; they migrate to superficial blood vessels. In India, *Culex pipiens fatigans* is the principal intermediate host which is a nocturnal feeder. Consequently, the microfilariae exhibit certain periodicity and move to superficial vessels in order to be sucked by mosquitoes.

Thus, during day time the microfilariae reside in the large and deeper blood vessels of various organs, such as lungs, kidneys, heart and large arteries. However, during night, they appear in the peripheral blood vessels, especially between 10 pm to 4 am, to be sucked by *Culex*. This is called **nocturnal periodicity**. Similarly, in Pacific islands, *Aedes polynesiensis* is the intermediate host of *Wuchereria*

bancrofti which can feed on human blood throughout the day and night. Thus, in those regions, the microfilariae do not exhibit any periodicity and are found in the peripheral blood throughout.

How does *Wuchereria* recognize its environment? It has been reported that *Wuchereria bancrofti* lacks visual abilities and depends on its sensory receptors to detect chemicals in its environment and pheromones released by other members of its species. Moreover, tactile papillae present on various parts of the body assist them for tactile communication with the environment and food. The periodicity of the worm is correlated with the lifestyle patterns of its human host. Through its chemosensory abilities, the worm detects the difference in oxygen levels between arterial and venous blood vessels which is indicative of decreased oxygen intake and lessened host activity. These conditions signify the night time and the feeding time of *Culex* mosquito. Thus, when *Wuchereria bancrofti* senses even a small difference in the oxygen content between venous and arterial blood vessels, it migrates to the peripheral circulation. It increases the chance of ingestion by *Culex* leading to dispersal to other hosts (Ash and Schacher, 1971; Cox and Chappell, 1993; Napier, 1994).

7.6 Development of Microfilariae in Culex Mosquito

When female *Culex* adults suck the blood of an infected individual, the sheathed microfilariae are also ingested with the blood. They reach the stomach of mosquito where they lose their sheaths. Within 1-2 hrs, the microfilariae (without any sheath) penetrate the wall of stomach and migrate to the muscles of thorax or wings for further development (Fig. 16).

Microfilaria in the mosquito body passes through three larval stages, which takes approximately 2 weeks (Table 4 and Fig. 17).

First stage larva: In the next 2 days of their migration to the thoracic muscles, the slender unsheathed microfilaria develops into first stage larva. It measures 124 to 250 µm in length, 10 to 17 µm in breadth and is much thicker, shorter and sausage-shaped with spiky tail.

Second stage larva: Within next 3-7 days, the first stage larva sheds its cuticle, thickens, enlarges and metamorphoses into second stage larva. It measures approximately 225 to 330 µm in length and 15 to 30 µm in breadth.

Third stage larva*:* The second stage larva enters into the third stage on 10-11th day of development. This is almost five times to that of second stage and measures about 1,500 to 2,000 µm in length and 18 to 23 µm in width. The spiky tail degenerates, while various organs; such as digestive and genital organs; and the body cavity are well developed.

The third stage larva is infective to man. On about 14th day, it migrates to the proboscis of the mosquito. It cannot develop further in the mosquito as it needs higher temperature for maturation into adult. The third stage larva waits for the new human host for its development.

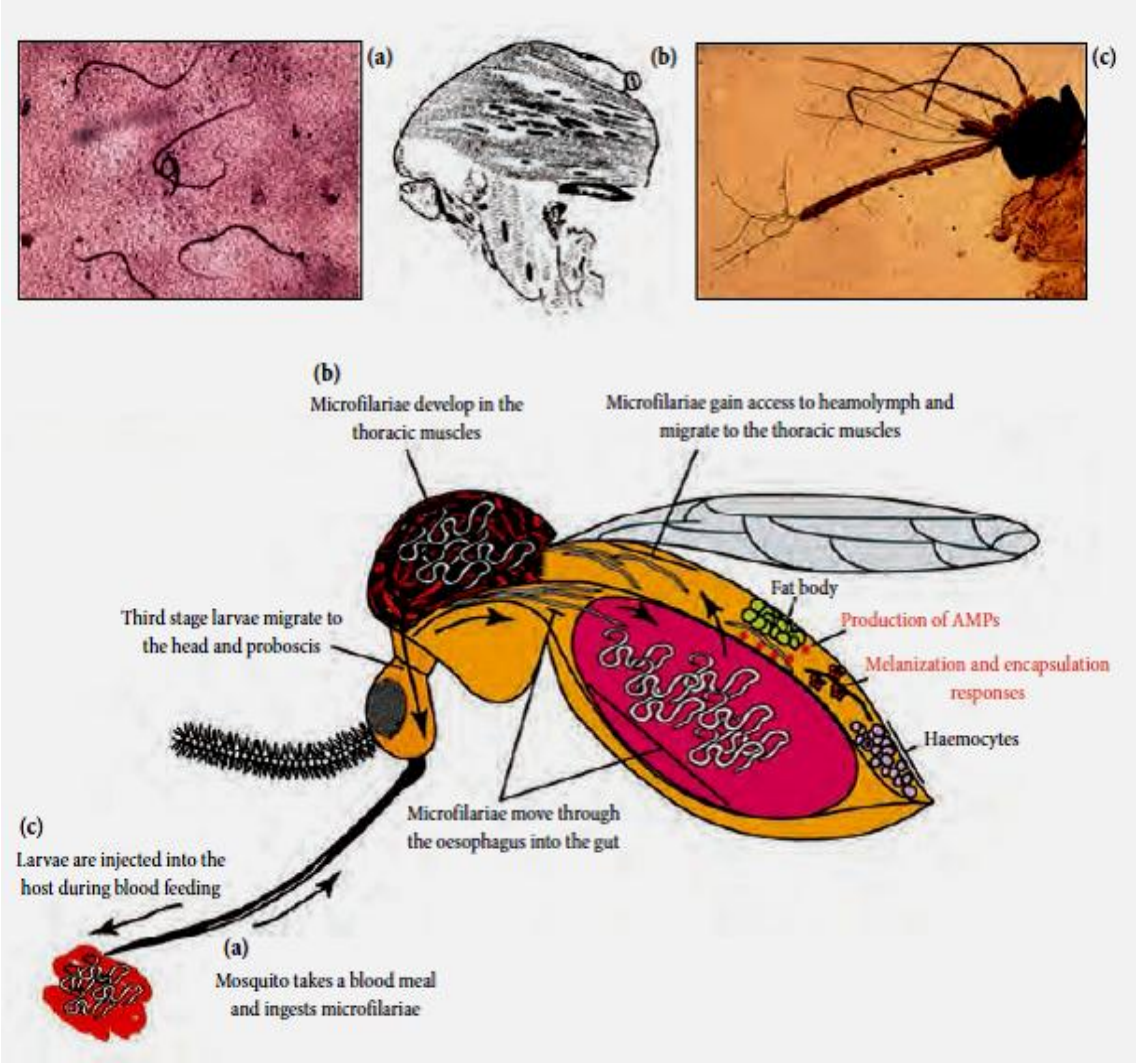


Fig. 16: Microfilariae of *Wuchereria bancrofti;*
(a) L1 in human blood; (b) L2 in the thoracic muscles of mosquito;
(c) L3 emerging from the proboscis of mosquito

Source: Lymphatic Filariasis: A Handbook of Practical Entomology For National Lymphatic Filariasis Elimination Programmes, World Health Organization, Italy, 2013

(a) (b)

(c)

Fig. 17: Photomicrograph of the different stages of microfilaria of *Wuchereria bancrofti*; (a) in a background containing thin serous fluid (MGG ×4); (b) sheathed microfilaria of *Wuchereria bancrofti* with a rounded anterior and tapered posterior end (MGG ×10); (c) showing clear space free of nuclei at the caudal end (MGG ×40)

Source: http://www.tropicalparasitology.org/viewimage.asp?img=TropParasitol_2012_2_1_77_97251_u1.jpg; http://www.tropicalparasitology.org/viewimage.asp?img=TropParasitol_2012_2_1_77_97251_u2.jpg; http://www.tropicalparasitology.org/viewimage.asp?img=TropParasitol_2012_2_1_77_97251_u3.jpg

The summary of larval stages is presented below in Fig. 18 and Table 4.

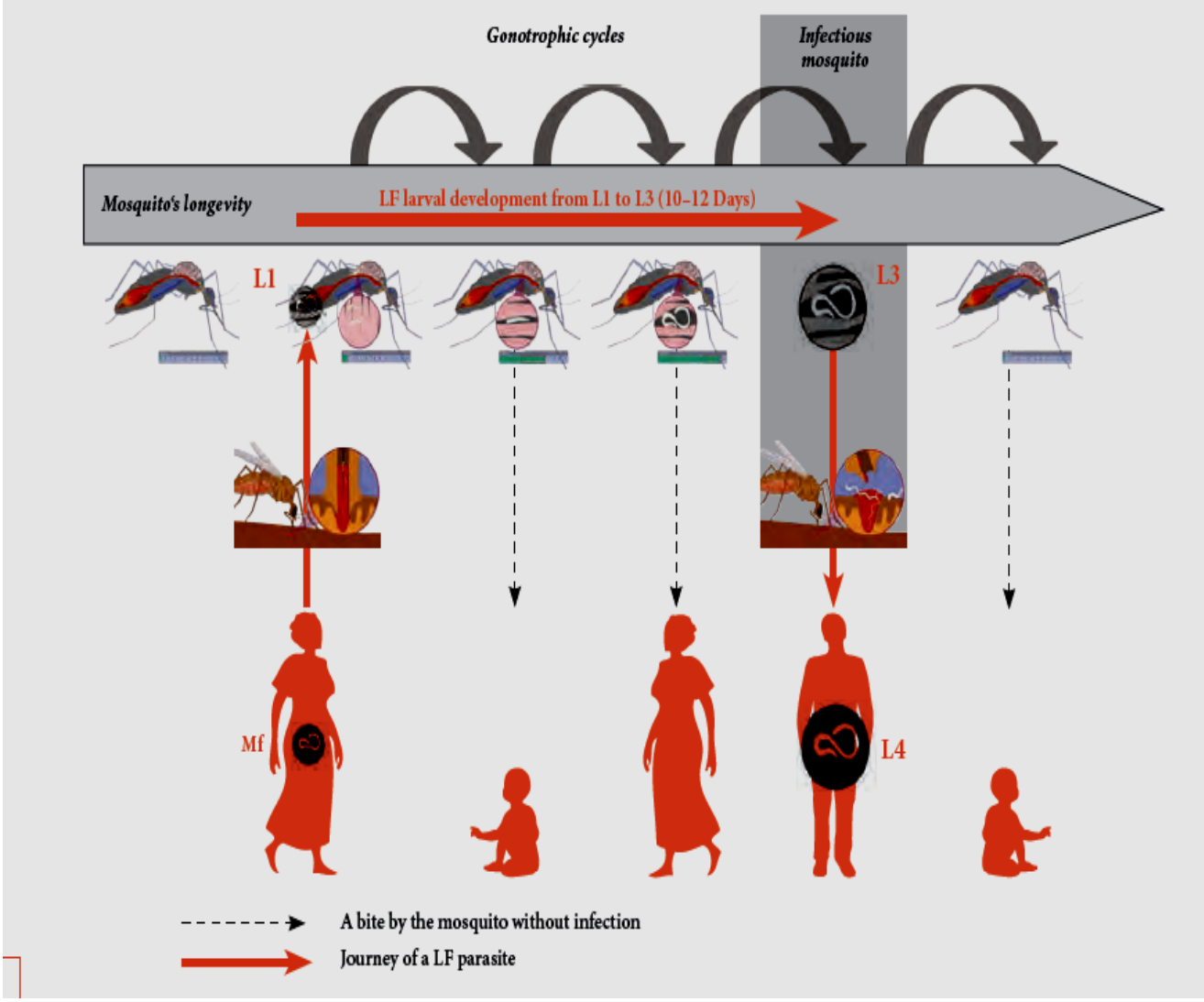


Fig. 18: Summary of development and life stages of *Wuchereria bancrofti* in a mosquito
Source: Lymphatic Filariasis: A Handbook of Practical Entomology For National Lymphatic Filariasis Elimination Programmes, World Health Organization, Italy, 2013

Table 4: Larval stages of *Wuchereria bancrofti* in mosquito body

Larval Stage	Duration of Development	Length	Width
First Stage	2 days	124 - 250 µm	10 - 17 µm
Second Stage	3-7 days	225 - 330 µm	15 - 30 µm
Third Stage	10-11 days	1,500 - 2,000 µm	18 - 23 µm

7.7. Maturation of Microfilaria into Adult

The infection of *Microfilaria bancrofti* takes place to a new human host when the infected *Culex* mosquito sucks the blood of a healthy human being. While sucking blood, the female *Culex* mosquito releases the third stage larva on the skin of the host near the site of puncture. The larvae get attracted by the warmth of human body and invade the skin either through the puncture or on their own. The larvae migrate through the subcutaneous tissues, reach the lymphatic vessels and accumulate at a particular lymphatic region; especially inguinal, scrotal and abdominal lymphatics. The larvae accumulated in the lymphatics go through two moults and begin to grow into mature adults. After approximately 5-18 months, they gain sexual maturity (Fig. 18). As described earlier, the male and female live together in coiled forms and undergo copulation. Female *Wuchereria bancrofti* gives birth to new generation of microfilariae and whole cycle repeats (Fig. 19).

The video depicting the entry of *Wuchereria bancrofti* microfilariae into the human body through a mosquito bite can be seen at http://www.youtube.com/watch?v=xfLZLQnCHyg

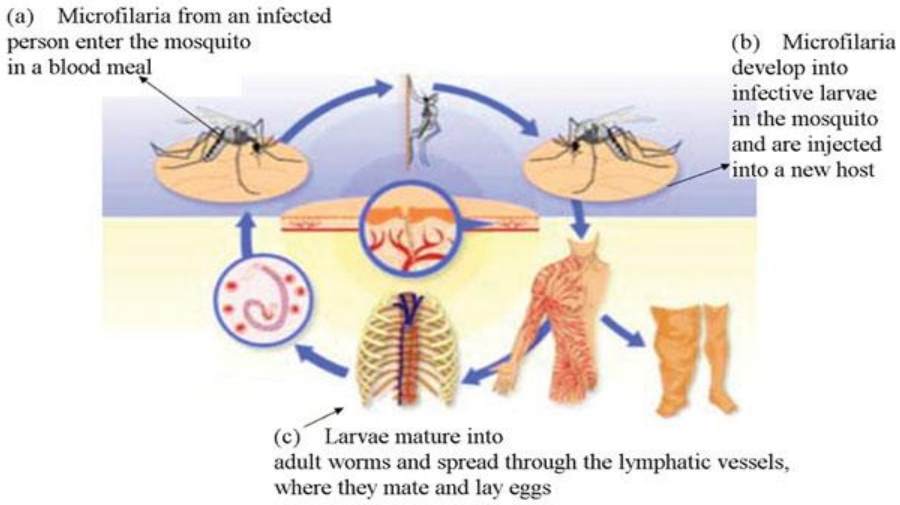


Fig. 18: A diagrammatic sketch of the life cycle of *Wuchereria bancrofti*
Source: http://www.who.int/lymphatic_filariasis/en/

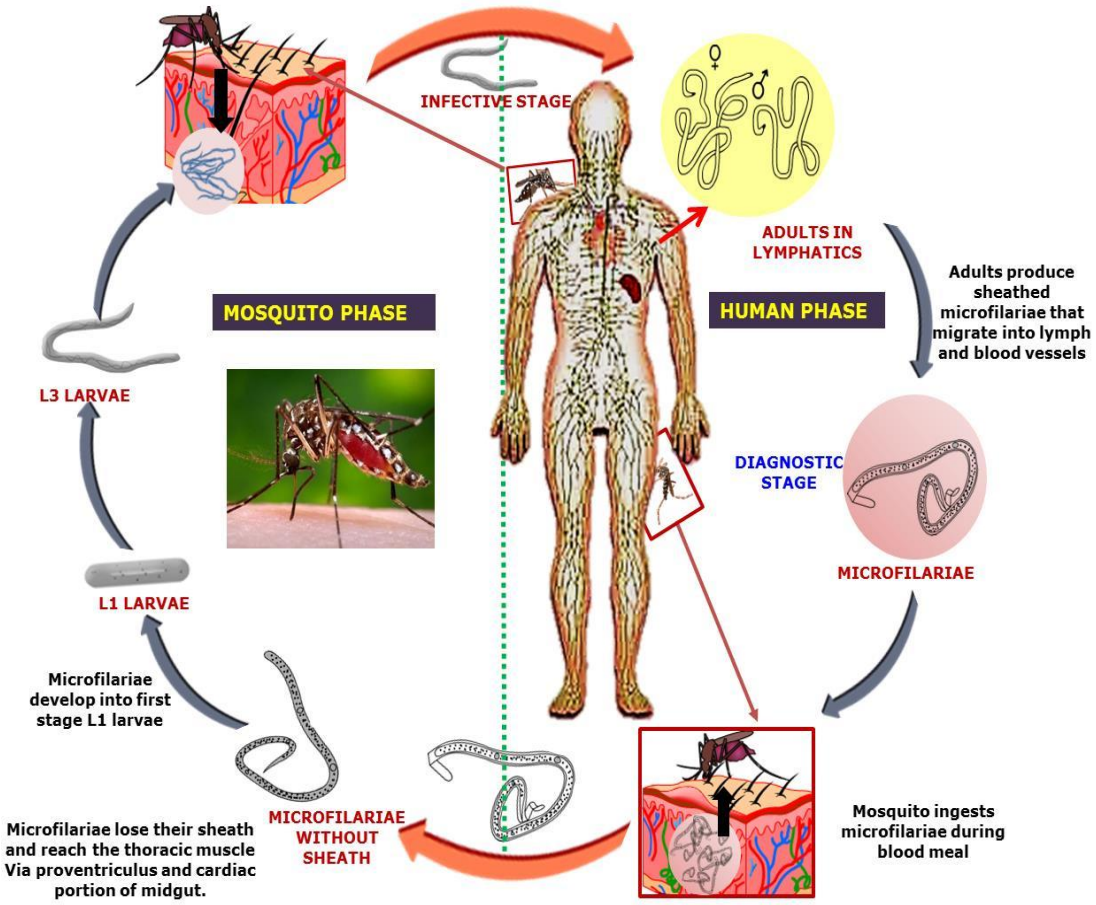


Fig. 19: Detailed Life cycle of *Wuchereria bancrofti*
Source: http://vle.du.ac.in/

8. Factors Affecting the Transmission of Filarial Worm

The transmission of *M. bancrofti* is considered to be less efficient than that of other vector-borne parasites, for example as compared to the transmission of malaria parasite and dengue virus. This is because of various factors that limit the transmission of filarial worm.

(a) Number of ingested microfilariae: The microfilariae do not multiply in the mosquito body. Therefore, the number of L3 which a mosquito has and can transmit is limited by the number of microfilariae ingested by mosquitoes.

(b) Longevity of mosquito: The development of microfilariae in the body of a mosquito takes about 12-14 days. Consequently, only those mosquito adults that have more than 15-20 days of longevity will

contribute to transmission of the parasites. The adults that die before the development of L3 cannot play a role in the transmission cycle.

(c) Release of microfilariae: As the mosquito does not inject L3 into the human body but deposit them on the skin near the puncture, the larvae cannot enter the human body until they find their way into the bite wound.

(d) Biting rate of the mosquito: The rate of transfer of microfilariae from a human host to a mosquito vector is proportional to the biting rate of the mosquito. The higher is the biting rate of mosquito; more is the probability of a mosquito picking up microfilariae leading to increased transmission.

(e) Prevalence of disease: The spread of the disease in a community depends upon the intensity of infection and the number of infectious hosts available who should have appreciable density of circulating microfilariae in their peripheral blood.

(f) Impact on mosquitoes: The filarial development in mosquitoes can result in their mortality, if the blood sucked by mosquitoes has large number of microfilariae, as they can cause considerable damage to the mosquito's gut and thoracic muscles. Moreover, the emergence of L3 from the flight muscles can result in irreparable damage to the muscles, hampering the mosquito from flying and causing its death.

(g) Environmental conditions: The transmission of the microfilariae also depends upon the local environmental conditions such as, rainfall, temperature, humidity and soil type which affect the breeding sites and the survival of adult mosquitoes.

It is clear from the above factors that the intensity of filarial worm transmission depends on the number of infectious hosts carrying microfilariae, biting rate of the mosquitoes and the proportion of surviving mosquitoes carrying L3 larvae. Thus, in order to disrupt filarial worm transmission and to ensure that no new infection occurs, the intensity of microfilariae or the vector density must be brought down below a threshold which varies because of the heterogeneity of the vector–parasite relationship.

The relationship between a host, vector and a parasite can be evaluated by following indices.

(a) **Transmission potential of a mosquito**: It is calculated as:
Mean number of infective larvae (L3) per infective mosquito X *The estimated biting rate of the vector for a given period.*
As transmission potential during a month varies seasonally with biting density, the annual transmission potential is a useful indicator of the risk for lymphatic Filariasis transmission.

(b) **Vector infection rate:** This is the percentage of mosquitoes infected with filarial worms and is calculated as follows:

$$\frac{\text{Number of mosquitoes with any stage of microfilariae}}{\text{Number of mosquitoes dissected}} \times 100$$

(c) **Vector infective rate:** The percent mosquitoes infected with L3 infective stage is calculated as follows:

$$\frac{\text{Number of mosquitoes with L3 stage of the worm}}{\text{Number of mosquitoes dissected}} \times 100$$

(d) **Monthly infective biting rate:** The estimated number of infective mosquitoes biting a human per month are:

Vector infective rate X *Monthly vector-biting rate*

(e) **Annual infective biting rate:** The estimated number of infective mosquitoes biting a human per year is calculated as

Vector infective rate X *Annual vector-biting rate*

(f) **Monthly transmission potential:** It indicates the infection risk per month and includes the number of infective larvae rather than the infective mosquitoes. It is calculated as:

$$\frac{\text{Total number of infective larvae (L3)} \times \text{Monthly vector-biting rate}}{\text{Number of mosquitoes dissected}}$$

(g) **Annual transmission potential**: It is indicative of the infection risk per year and is calculated from:

$$\frac{\text{Total number of infective larvae (L3)} \times \text{Monthly vector-biting rate}}{\text{Number of mosquitoes dissected}}$$

Table 4: Summary of Characteristic Features in the Life Cycle of *Wuchereria bancrofti*

Feature	Characteristic
Mode of infection	Through the bite of mosquitoes
Vector for transmission	Female mosquitoes; *Aedes*, *Culex* and *Anopheles* In India: *Culex pipiens fatigans*
Infective stage	Third stage larva of *Microfilaria bancrofti*
Portal of entry	Skin
Migration of larva	Peripheral blood vessels to deeper blood vessels in various organs
Site of localisation	Lymphatic system, most commonly inguinal region
Pathogenic stage	Adult *Wuchereria;* sometimes Microfilaria
Pathogenesis	Adult – Lymphangitis, lymphadenitis, enlargement of limbs due to blockage of lymph flow – elephantiasis, hydrocoele, chyluria Microfilaria – Eosinophilia, hepatosplenomegaly, enlargement of lymph nodes
Diagnostic stage	Microfilariae

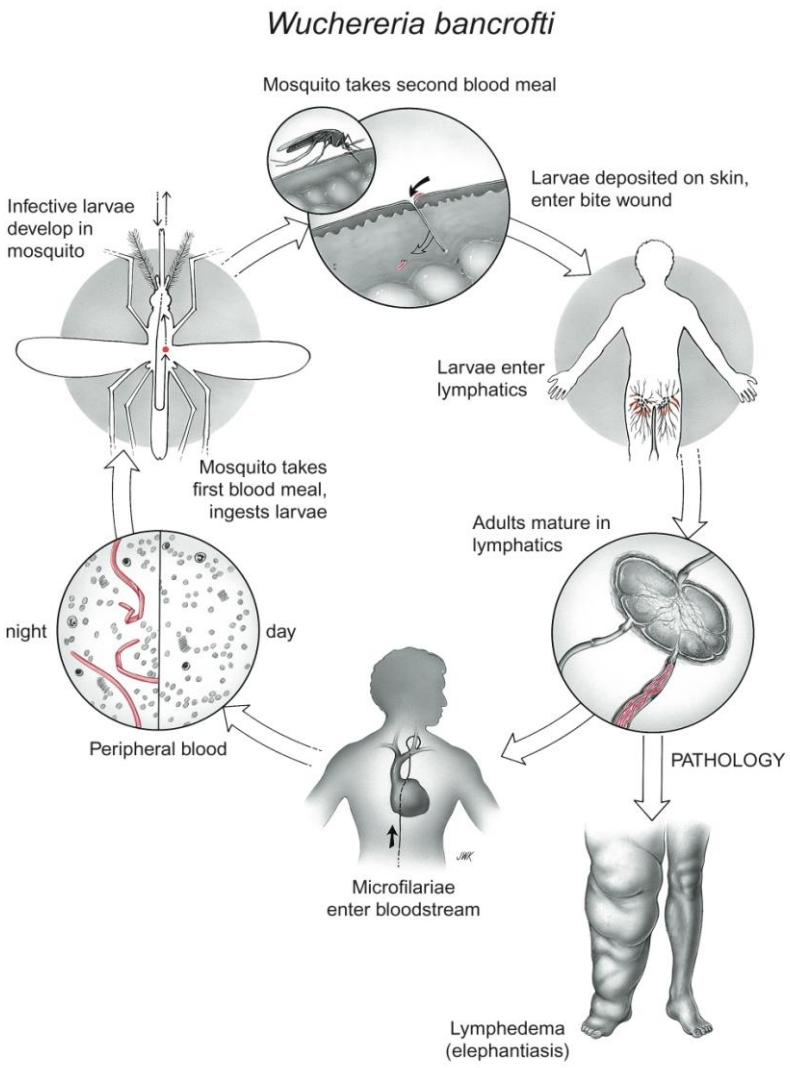


Fig. 20: Summarised life cycle of *Wuchereria bancrofti*
Source: http://www.microbeworld.org/images/stories/twip/wbancrofti_cycle.jpg

The summary of the life cycle of *Wuchereria bancrofti* can be visualized at: http://www.biomedcentral.com/content/supplementary/1475-2883-2-13-S1.swf

9. Summary

- *Wuchereria bancrofti* is one of the most dreadful nematodes largely confined to the tropical and sub-tropical regions of the world affecting more than 120 million people.
- It is an endoparasite and is commonly found in the lymphatic vessels and lymph nodes of human beings particularly in the groin regions.
- Male and female *Wuchereria* are separate and exhibit distinct sexual dimorphism.
- *Wuchereria bancrofti* is a digenetic parasite and requires two hosts to complete its life cycle. Man is the only primary host, while a large number of species of mosquito belonging to the genus; *Culex*, *Aedes* and *Anopheles* act as secondary hosts.
- In India, *Culex pipiens fatigans* is the principal intermediate host which is a nocturnal feeder.
- Copulation between male and female adults takes place in the lymph glands of man.
- The female *Wuchereria* are ovo-viviparous and liberate numerous microfilariae in her lifetime.
- The microfilariae are covered with a hyaline sheath and possess numerous nuclei which are absent from head, anal region, nerve ring and excretory pore of the body.
- The microfilariae enter the circulating blood and do not undergo any further development in the human beings as they need a lower temperature for their development.
- In India, microfilariae exhibit nocturnal periodicity as during night, they appear in the peripheral blood vessels, especially between 10 pm to 4 am, to be sucked by *Culex*; while during day time they reside in the large and deeper blood vessels of various organs.
- When mosquitoes suck the blood of an infected individual, the sheathed microfilariae are ingested with the blood and reach the stomach of mosquito.
- Within 1-2 hrs they lose their sheaths and penetrate the wall of stomach migrating to thoracic muscles or wing muscles for further development.
- Within next 14 days, the microfilariae pass through three larval stages, third larval stage being the only infective stage which migrates to the proboscis of mosquito.
- Infection to a new host takes place when the infected mosquito bites a human being.
- The larvae are deposited on the human skin from where they enter human body generally through the site of mosquito bite.
- The larvae accumulate in the lymph glands and attain sexual maturity within 5-18 months. The intensity of filarial worm transmission depends on the number of infectious hosts carrying microfilariae, biting rate of the mosquitoes and the proportion of surviving mosquitoes inhabiting L3 larvae.