Economic Zoology, Animal

Protozoan Parasites of Man and Animals

Protozoan parasites are microscopic unicellular organisms. They are found in different places and in different kinds of habitats. A large number of protozoans are parasitic in nature. Majority of the parasitic protozoans do not cause diseases in their hosts. They only produce minor symptoms. But a few parasitic protozoans are pathogenic to human beings and other animals. They cause important diseases in their hosts. The following are the significant pathogenic protozoans of man and animals.

1.1 *ENTAMOEBA*

Phylum: Protozoa
Class: Rhizopodea
Order: Amoebida
Genus: *Entamoeba*

The *Entamoeba* is a genus found as internal parasites or commensals of animals. This is an unicellular animal that exists as *Entamoeba* cell. They are quite small, 20–35 µm with a single nucleus and typically a single lobose pseudopod. They primarily feed on bacteria. The *Entamoeba* divides by a simple binary fission to produce two smaller daughter cells.

They have a simple life cycle that consists of an infective cyst stage (transmission stage) and a multiplying trophozoite stage (feeding–dividing stage). Transmission of the infection occurs by ingesting the cysts that contaminate food or water supplies. The cysts are transmitted through the faecal material of infected animals.

The entamoebae are categorised along with the cyst producing organisms. The different species of entamoebae are identified on the basis of the variable size of the cysts and the number of nuclei present in them. The cysts may have one, four or eight nuclei. A few species, e.g., *E. gingivalis*, do not produce cysts.

Out of several species at least six inhabit humans. *E. histolytica* causes amoebiasis, *E. gingivalis* causes periodontal disease and gingivitis, *E. coli* (not to be confused with *E. coli*) inhabits human large intestine as a commensal, and hence, harmless. *E. dispar* is another harmless species.

Almost all *Entamoeba* species are found in the intestines of the animals they infect. The exceptions are *E. gingivalis*, which lives in the mouth, and *E. moshkovskii*, which has been reported from river and lake sediments.

1.1.1 *Entamoeba histolytica*

Entamoeba histolytica is a small unicellular microscopic protozoan averaging about 25 µm in size which lives as a pathogenic parasite in the large intestine of man. It is more commonly present in warmer regions of the world. It has a crystal clear ectoplasm and moves actively.

The life cycle does not involve any intermediate host. The amoebae (trophozoites) inhabit large intestine (Figure 1.1 (a) and (b)). They change into smaller minute forms and encyst to form tetra nucleate cysts (Figure 1.2). Transmission of parasite from person to person takes place through these cysts. The cysts are passed with the faeces and contaminate food and water and spread into new hosts. Houseflies help in its rapid spread.

On ingestion by man, excystment occurs in the small intestine. Each tetra nucleate amoeba produces eight uninucleate amoebae by a process

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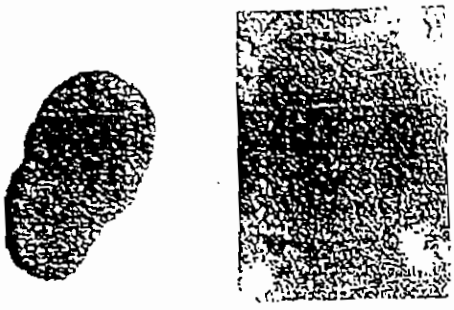


(a) (b)

Figure 1.1 *Entamoeba histolytica:* (a) Image of an adult trophozoite stained. (b) An image of trophozoite with a progressive pseudopod. (*Courtesy:* CDC, Atlanta, USA.)

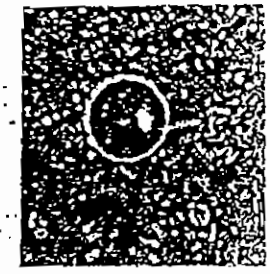


Figure 1.2 *Entamoeba histolytica* cyst showing a chromatoid body with bluntly rounded ends. (*Courtesy:* CDC, Atlanta, USA.)

of division. The amoebae may either invade the mucous membrane of the colon and caecum or multiply, or may remain in the intestinal lumen (Figure 1.3 Life cycle).

Entamoeba histolytica usually causes amoebiasis in infected individuals, but when individuals infected with entamoebae show no symptoms of disease, the disease is referred to as lumenal amoebiasis. On the other hand, trophozoites, which become magna trophozoites, may invade the intestinal tissues and feed on blood, forming abscesses in the mucosa and submucosa. These abscesses burst leading to the discharge of blood and mucus into the intestine. The discharged materials finally pass with stool. This is referred to as invasive amoebiasis or amoebic dysentery. This is evidenced by the presence of haematophagous trophozoites [trophozoites containing red blood cells (RBCs)] (Figure 1.4). In most cases, the infection is harmless because the host serves as a symptomless carrier. The presence of cysts in faeces is the only evidence of infection. Sometimes, the abscesses are formed in the vital organs like brain, lung, liver, spleen and gonads, which are painful and prove to be fatal. This pathological condition is known as amoebic hepatitis.

Contamination of food and water with cysts should be avoided to prevent the spread of the disease. Metronidazole, emetine, erythromycin, aureomycin and fumagillin provide relief in cases of amoebiasis. Fumagillin is a complex biomolecule mainly used as an antimicrobial agent. It was isolated in 1949 from the microbial organism (fungus) *Aspergillus fumigates.*

1.1.2 *Entamoeba gingivalis*

Entamoeba gingivalis is a common parasite of human mouth and is the smallest species of *Entamoeba.* The trophozoites live in the oral cavity of humans, residing in the gingival pockets near the base of the teeth (Figure 1.5). The ideal surfaces of location, therefore, are the spaces between the teeth and soft pits of the gums. This is because in these sites bacteria and detritus are richly present. It has crystal clear cytoplasm and moves actively. They feed on bacteria and other debris. The food vacuoles are usually numerous and contain bacteria, leucocytes and occasionally red cells.

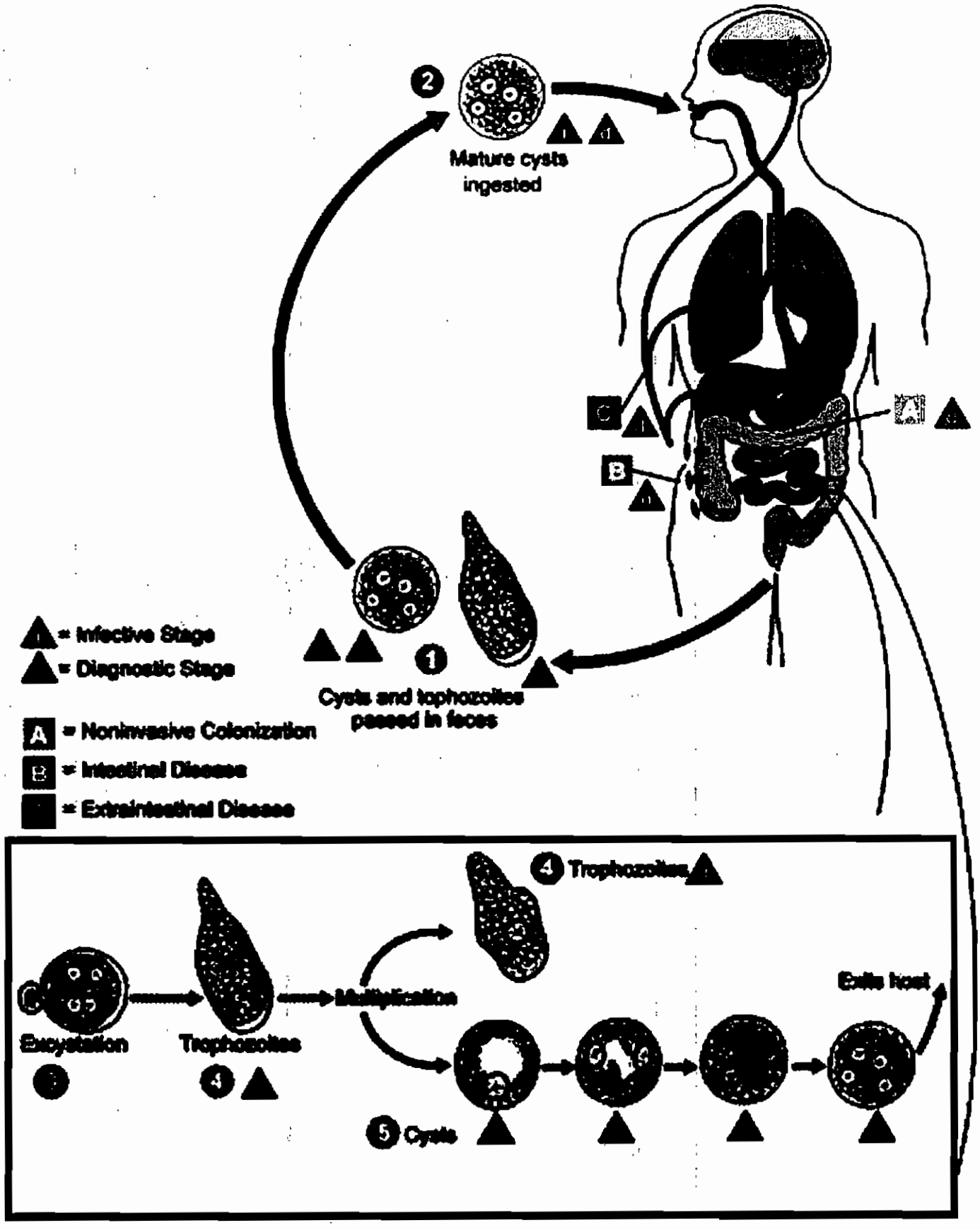
Entamoeba gingivalis is regarded to be nonpathogenic. This species prepares the teeth for pyorrhoea or Riggs' disease. Riggs' disease causes progressive decay of the alveoli and looseness of the teeth. The teeth become very loose and fall out of the sockets. The infection is transmitted by the transfer of trophozoite from one person to another by kissing and by sharing same food and water. There is no known cyst stage for *E. gingivalis* (Figure 1.6 Life cycle).

Entamoeba gingivalis is morphologically similar to *E. histolytica* except that it does not form cysts.

1.1.3 *Entamoeba coli*

Entamoeba coli has world-wide distribution. Trophozoites of *Entamoeba coli* usually range 15–50 µm in size. They have single nucleus, granular and vacuolated cytoplasm with peripheral chromatin. There is a characteristic large, eccentric karyosome. Pseudopodia are short and blunt. The trophozoites show non-directional movement. It

Life Cycle


2
Mature cysts ingested
C
A
B
= Infective Stage
= Diagnostic Stage
1
Cysts and trophozoites passed in feces
A = Noninvasive Colonization
B = Intestinal Disease
= Extraintestinal Disease
4 Trophozoites
Multiplication
Enters host
Excystation
3
Trophozoites
4
5 Cysts

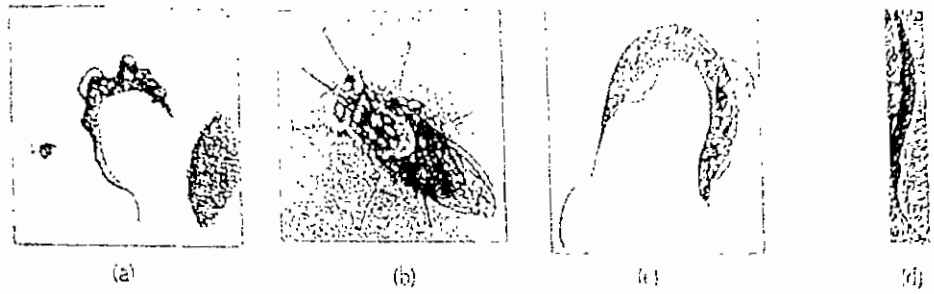


Figure 1.19 Images: (a) *Trypanosoma brucei* in thin blood smears stained with Giemsa (b) A close up of a tsetse fly Illustrations: (c) *Trypanosoma brucei*, (d) *Trypanosoma cruzi*. (Courtesy: CDC., USA)

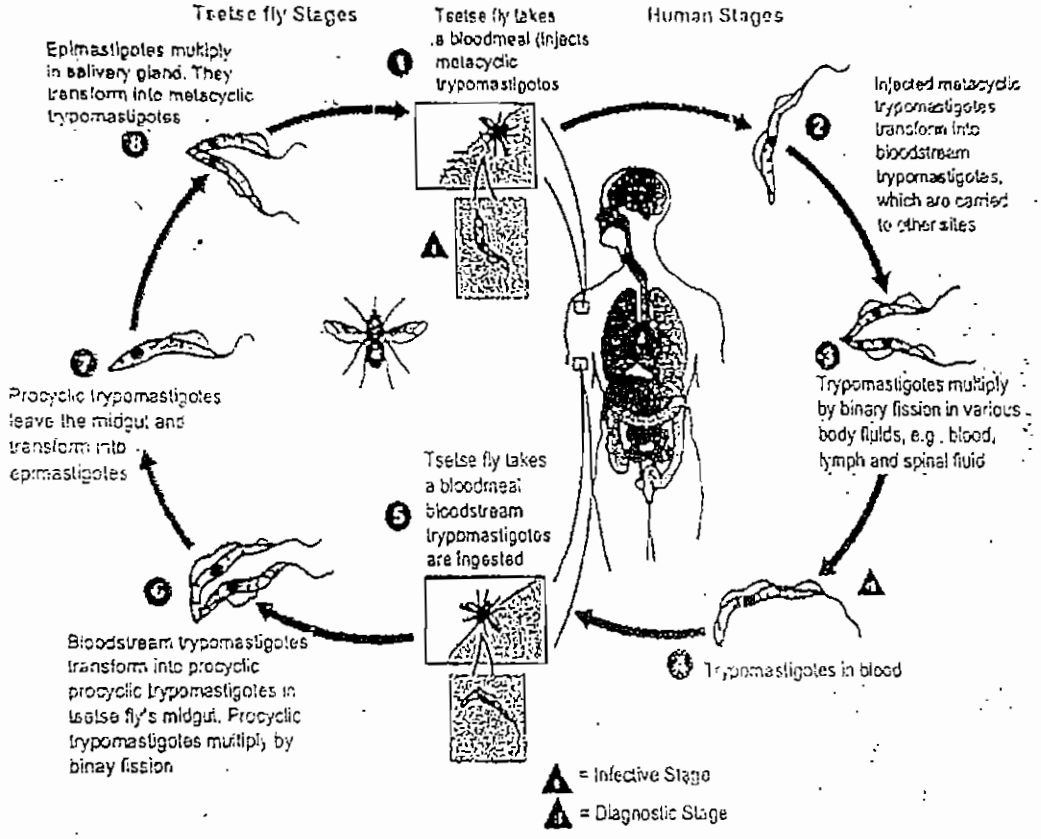


Figure 1.20 Life cycle of *Trypanosoma brucei*. (Courtesy: CDC.)

differences. It is distributed in West Africa. It is transmitted by the tsetse fly *Glossina palpalis*.

The pathology is same for both the species. When the tsetse fly bites, the trypanosomes are deposited in the dermal connective tissue. This induces a local inflammatory reaction. In case of *T. brucei rhodesiense* this results in the development of red-spots which is rare in *T. brucei gambiense*. Now, they migrate to the lymphatics and hence, into the blood stream. Here, they multiply fast by binary fission with a doubling time of 6 hours. Then, they penetrate the blood and lymph capillaries and enter into the connective tissue. After about 30 days they enter the brain and cerebrospinal fluid (CSF) by crossing the choroid plexus. The invasion of the nervous system results in sleeping sickness, characterised by a general physical and mental depression and a desire to sleep.

The two species differ nosologically (i.e., the type of disease they produce). *T. brucei gambiense* produces 'Gambian sleeping sickness', which is a chronic disease that may last for several years before ending in death. In contrast, the disease 'Rhodesian sleeping sickness' produced by

T. brucei rhodesiense is an acute disease that runs an acute course for about 6 months before terminating fatally.

Protecting humans from the bites of the tsetse fly, quarantine of persons coming from infected to uninfected territory, destruction of resting and breeding grounds of tsetse fly, and use of curative and prophylactic drugs are some of the important control measures.

1.6.4 *T. cruzi* and Chagas' disease

This organism causes a disease known as **Chagas' disease**, named after Carlos Chagas who first described it in Brazil in 1909. It is distributed in Central and South America especially Brazil, Argentina and Mexico. The disease is also known as **American trypanosomiasis**. *T. cruzi* is monomorphic, 20 µm in length and characteristically curved. The flagellum is of medium length. It is transmitted by brightly coloured bugs (family Reduviidae, subfamily Triatominae). All the stages larva, nymph and imago of the vector are susceptible to infection. Transmission occurs through bug's faeces. The faeces contain the parasite which penetrates man's skin. The eyes and lips are particularly affected (Figure 1.21 Life cycle).

Infants and children are most frequently infected. Swellings and inflammation take place in acute Chagas' disease resulting due to inoculation of infective metacyclics. The initial swelling is known as the primary **chagoma**. If the ocular mucosa is inoculated, a characteristic unilateral conjunctivitis and oedema of the eyelids may occur. This is known as **Romana's sign**. Penetration of the heart by the *Trypanosoma* results in chronic Chagas' disease involving heart failure and breathing difficulties.

The control measures are the same as for sleeping sickness.

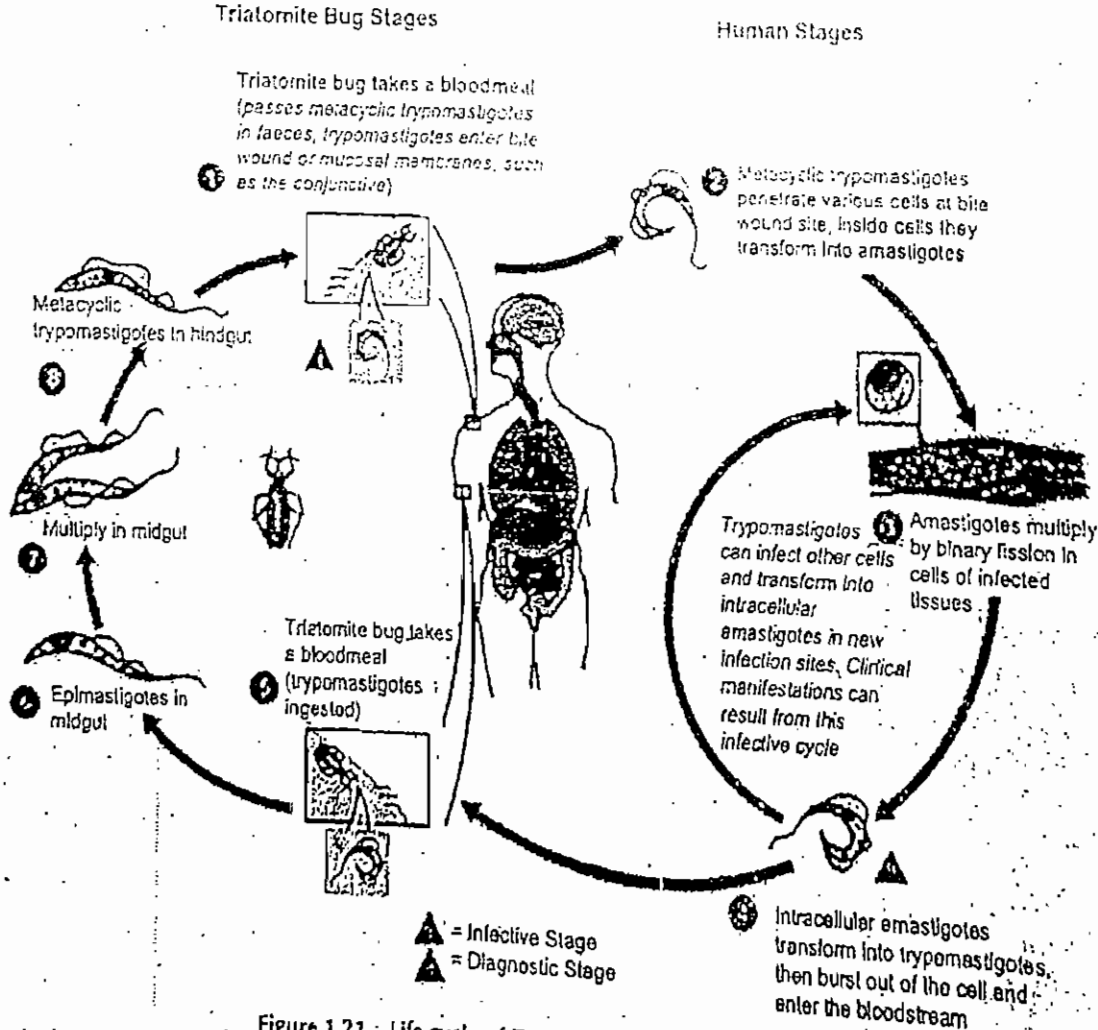
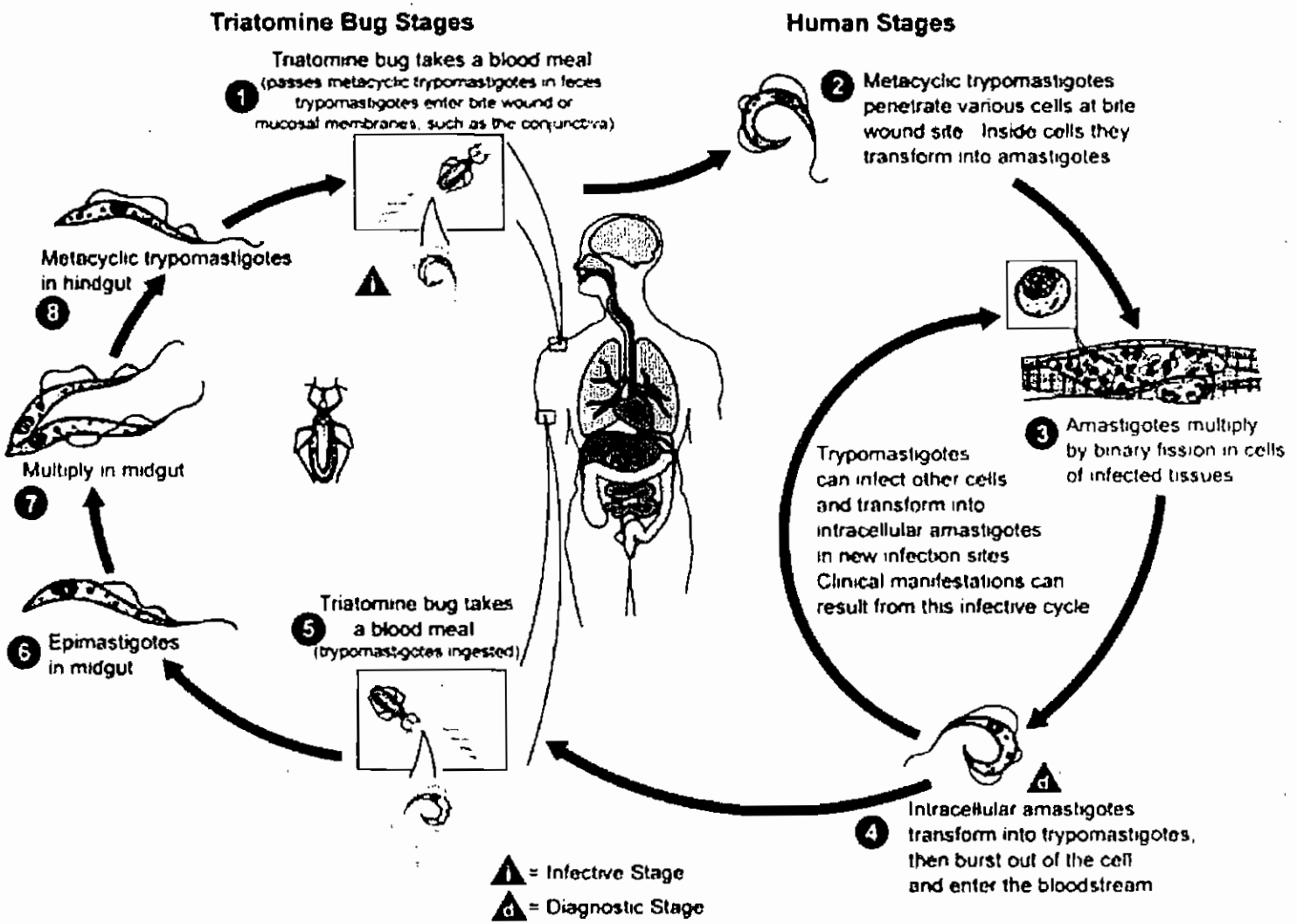


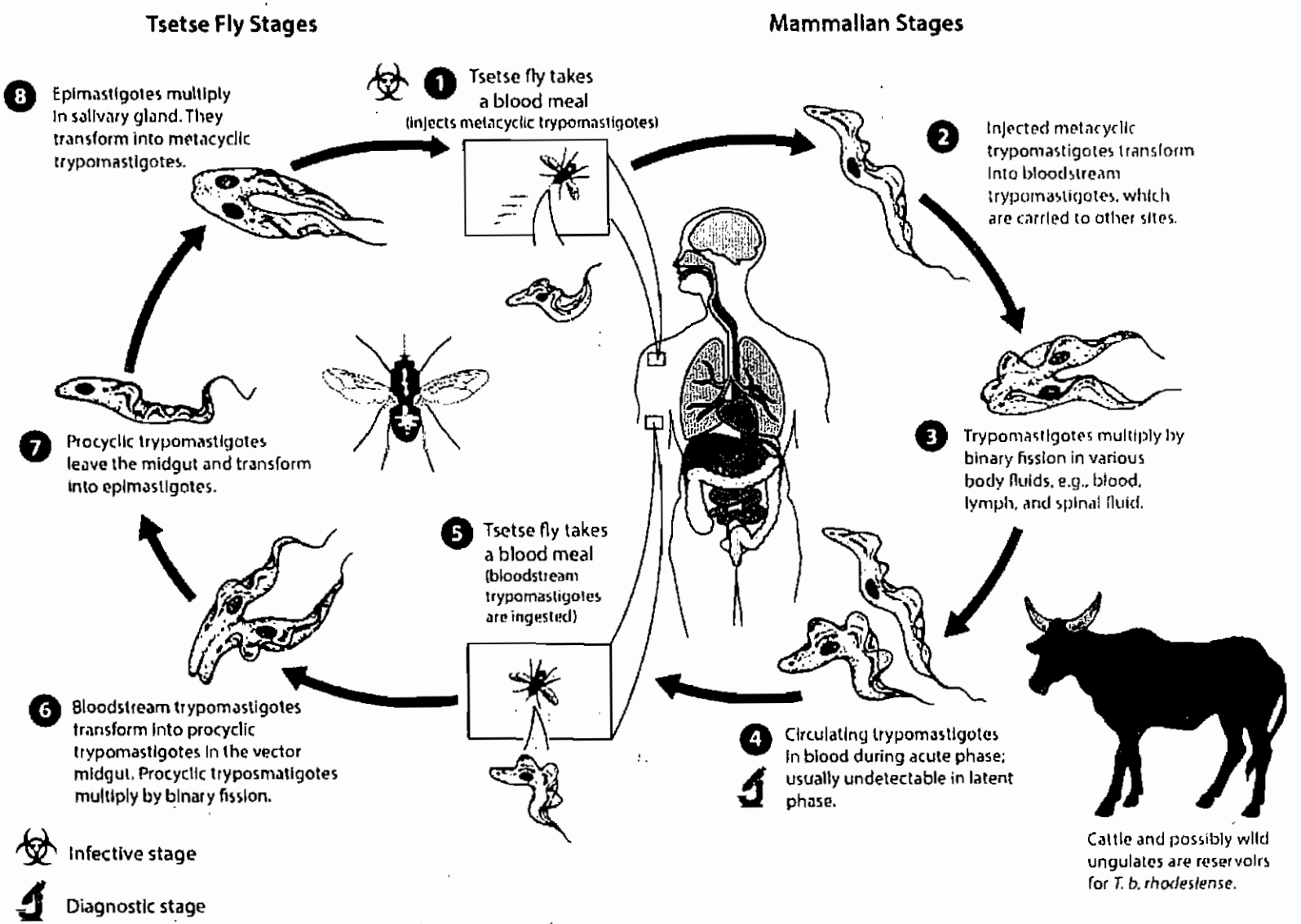
Figure 1.21 : Life cycle of *Trypanosoma cruzi*.(Courtesy: CDC.)

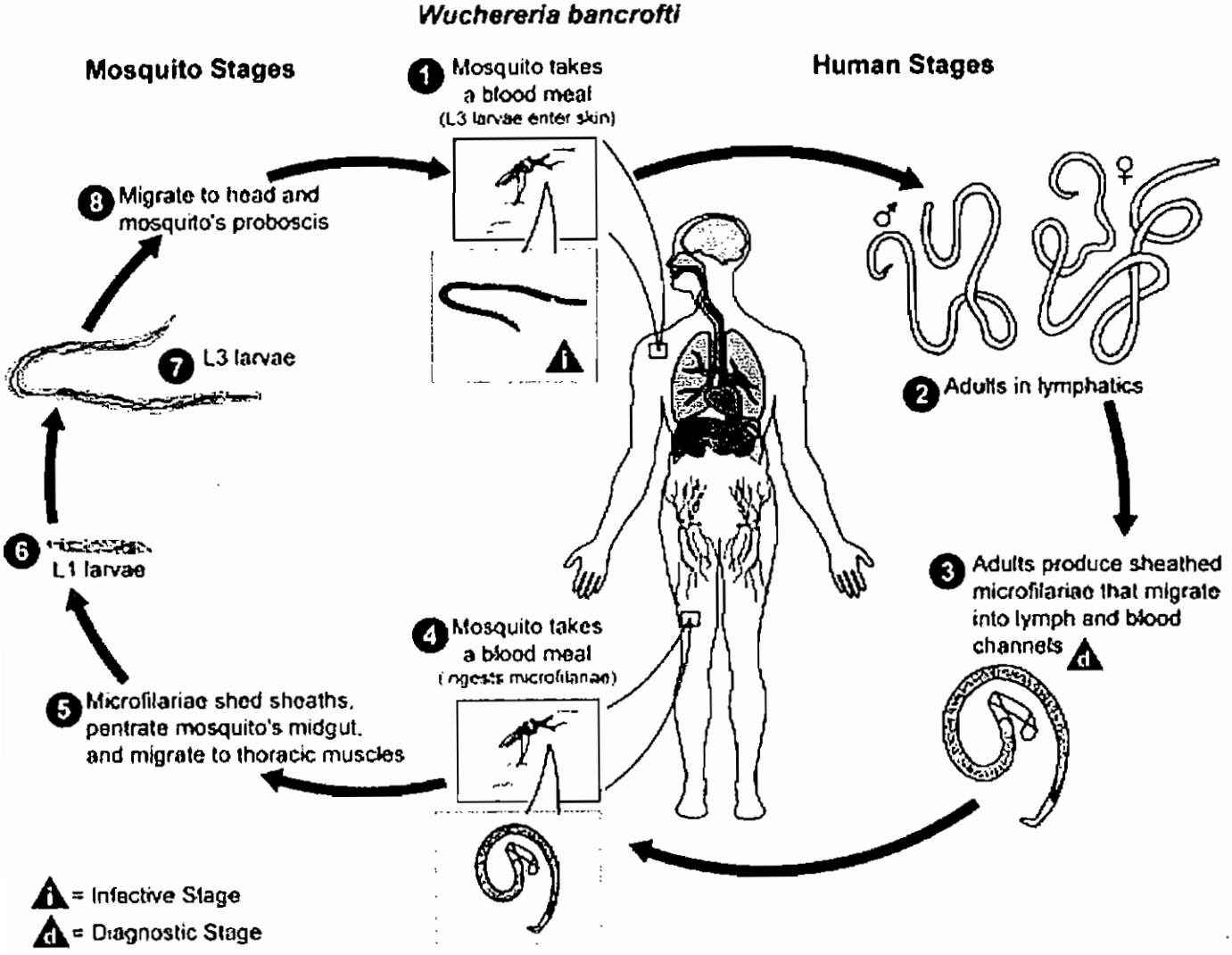
Life Cycle: *T. cruzi*



African Trypanosomiasis

Trypanosoma brucei gambiense & Trypanosoma brucei rhodesiense




Wuchereria bancrofti
Mosquito Stages
Human Stages
1 Mosquito takes a blood meal
(L3 larvae enter skin)
2 Adults in lymphatics
3 Adults produce sheathed microfilariae that migrate into lymph and blood channels
4 Mosquito takes a blood meal
(ingests microfilariae)
5 Microfilariae shed sheaths, penetrate mosquito's midgut, and migrate to thoracic muscles
6 L1 larvae
7 L3 larvae
8 Migrate to head and mosquito's proboscis
♂
♀
i = Infective Stage
d = Diagnostic Stage

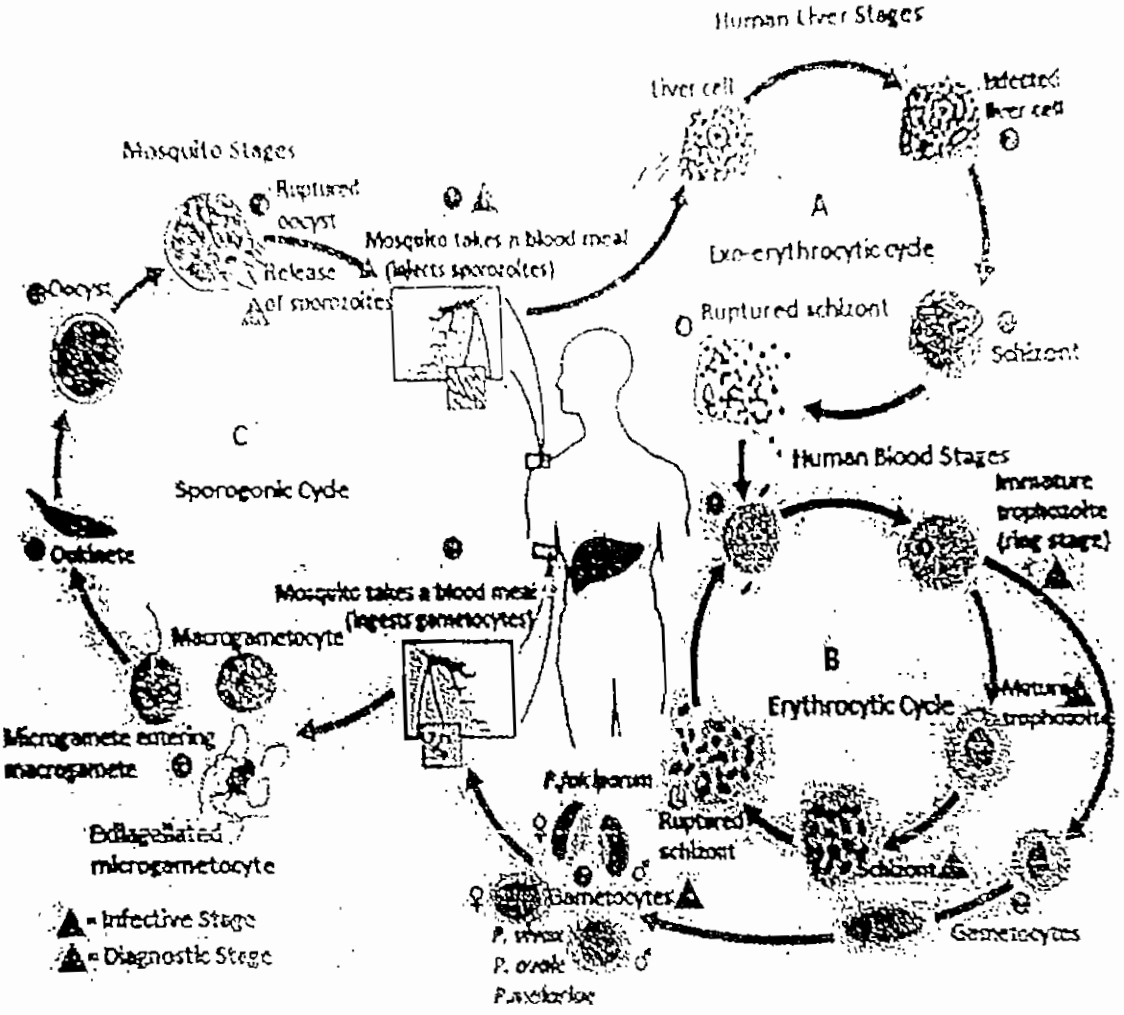


Figure 1.17 Life Cycle of *Plasmodium falciparum*. (Courtesy: CDC.)

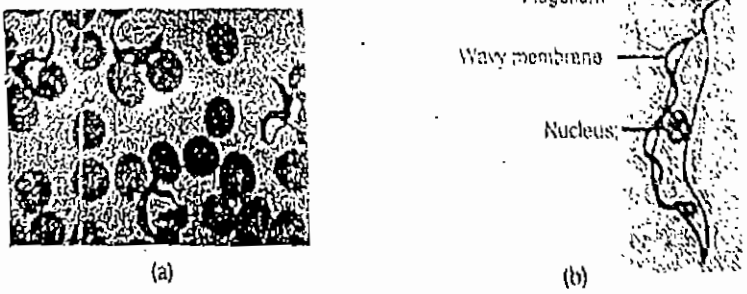


Figure 1.18 (a) *Trypanosoma* sp. among red blood cells. (b) Illustration of Trypanosoma. (Courtesy: Dr. Myron G. Schultz, CDC, USA.)

gambiense. The transmission of both of them takes place by the tsetse fly. All these forms are morphologically indistinguishable (Figure 1.20).

1.6.2 *Trypanosoma brucei rhodesiense*

Trypanosoma brucei rhodesiense is a flagellate parasite of blood (in vertebrate host) and gut (in invertebrate host). The organism has spindle-shaped body with central nucleus and rod-shaped flagella. It is distributed in East Africa. It is transmitted by the tsetse fly *Glossina palpalis*.

1.6.3 *Trypanosoma brucei gambiense*

Trypanosoma brucei gambiense is somewhat similar to *T. brucei rhodesiense* with minor external

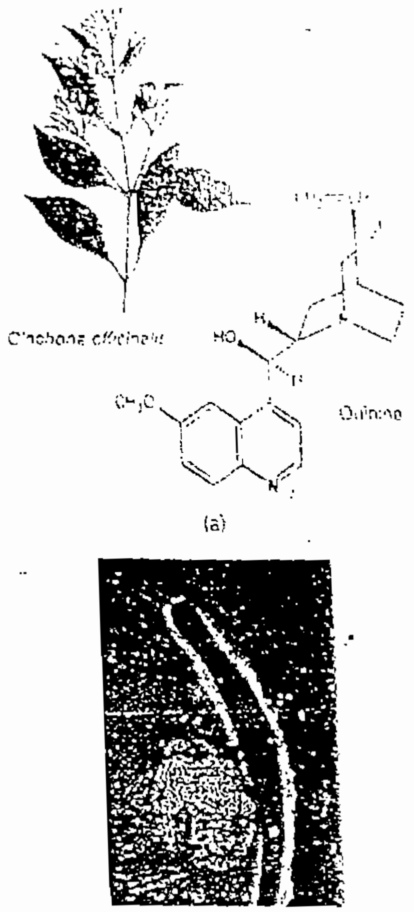


Figure 1.16 (a) Source and structure of quinine biomolecule. (b) Image of a malarial sporozoite stage of *Plasmodium falciparum* in an infected epithelial cell. (Courtesy: Ute Freven, Public Library of Science.)

When such a mosquito bites a person, sporozoites are transferred and life-cycle is completed (Figure 1.17 Life cycle).

The disease is characterised by the periodic attacks of fever. Malarial fever occurs when schizonts in RBCs burst and release their contained merozoites together with a pigment and other waste products. The malarial pigment called **haemozoin** is toxic and therefore causes high fever and shivering. The period of recurrence of fever is different for different species. The period of recurrence of fever is 48 hours (tertian malaria) in *P. vivax*, *P. ovale* and *P. falciparum*, and is 72 hours (quartan malaria) in *P. malariae*. Other symptoms are reduction of RBCs, loss of plasma, anaemia and decrease in circulating blood volume.

(2) ... by means of drugs like quinine, paludrine, proquanil, etc. cures the disease successfully.

1.6 *TRYPANOSOMA*

Phylum: Protozoa
Class: Zoomastigophorea
Order: Kinetoplastida
Genus: *Trypanosoma*

Trypanosoma occurs in the blood and some tissues of the majority of vertebrate animals, both warm and cold blooded (Figure 1.18). There is an intermediate host, usually an insect, in the life cycle. A great majority of trypanosomes are non-pathogenic but many others are pathogenic. The disease produced by *Trypanosoma* is termed as **trypanosomiasis**.

There are two main diseases of man caused by the species of *Trypanosoma*:

(1) **Sleeping sickness or African trypanosomiasis**: This disease is caused by *T. brucei gambience* and *T. brucei rhodesiense*. It occurs in tropical Africa. The vectors for the disease are tsetse flies of the genus *Glossina*.
(2) **Chagas' disease or American trypanosomiasis**: This disease is caused by *T. cruzi*. It occurs in Central and South America. The vectors for the disease are bugs of the family Reduviidae.

1.6.1 *Trypanosoma brucei* and Sleeping Sickness

Trypanosoma brucei has three forms. The non-human-infective form is assigned to the subspecies *T. brucei brucei* (Figure 1.19). The human-infecting form of the species causes **sleeping sickness**. The form which causes an acute form of the disease in East Africa is known as *T. brucei rhodesiense*. The other form, which causes the chronic form of the disease in West Africa is known as *T. brucei*

Parasitic Worms

Helminths are elongated and crawling animals, commonly referred to as **worms**. They have been classified and grouped into two Phyla, viz., **Platyhelminthes** (flat worms) and **Nematoda** (Non-segmented round worms, threadworms or pinworms). Trematodes and cestodes are two groups of parasitic animals under Platyhelminthes whereas nematodes are group of animals under Nematoda. Thus, helminths are divided into three groups of parasitic animals, viz., Trematoda, Cestoda and Nematoda. A large number of helminths are parasitic worms. They are endoparasites of vertebrates found generally in the gut and blood of humans and other animals. They cause diseases, collectively called helminthiasis. On the basis of the type of helminth parasite causing the disease, helminthiasis can be distinguished into three forms: trematodiasis, cestodiasis and nematodiasis.

2.1 TREMATODES

The diseases caused by the trematode worms belonging to the class Trematoda, are collectively known as trematodiasis. Some common trematode worms causing diseases to human beings and other animals are discussed below.

2.1.1 *Schistosoma*

Phylum: Platyhelminthes
Class: Trematoda
Order: Digenea
Genus: *Schistosoma*

The worm *Schistosoma* is known as blood fluke because it lives in the blood of humans throughout the world. The female is longer and slender in shape but the male is shorter and broader. Unlike the flukes, adult schistosomes have the sexes separate, with the female residing in a gynaecophoral canal within the male. Male worms are robust, tuberculate and measure 6–12 mm in length. Females are longer, 7–17 mm in length and slender. Adult *S. mansoni* reside in the venous plexuses of the colon and lower ileum and in the portal system of the liver of their host. The female and the male both have ventral and oral suckers (Figure 2.1 and Figure 2.2). *Schistosoma* has three species—*Schistosoma mansoni, S. japonicum* and *S. haematobium* which attack humans.

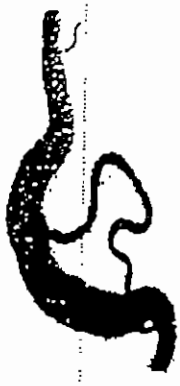


Figure 2.1 Adults of *S. mansoni*. The thin female resides in the gynaecophoric canal of the thicker male. (*Courtesy:* CDC, USA.)

Life cycle is digenetic with man as primary host and an intermediate snail host. The female is permanently lodged in the gynaecophoric canal of the male and the paired worms move against the blood stream in a state of permanent copulation. Fertilization takes place in the oviduct. After fertilization, the female leaves the male's body and

Eggs → miracidia larva → sporocyst larvae → cercaria larvae → metacercaria larvae

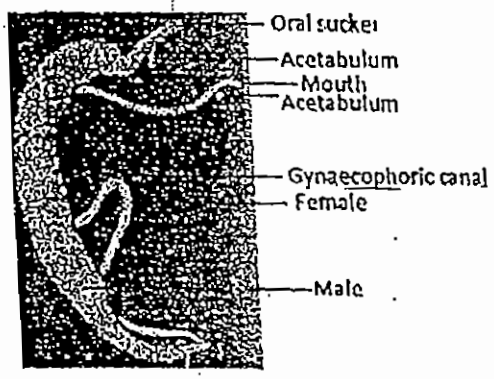


Figure 2.2 *Schistosoma mansoni*. The tuberculate exterior of the male. (Courtesy: CDC, USA.)

lay enormous number of eggs in blood stream from where they find their way either into intestine (*S. mansoni, S. japonicum*) or urinary bladder (*S. haematobium*) and are ejected in faeces or urine. Eggs contain motile miracidia larvae which are short, pear-shaped and tapering at the posterior end. The larvae hatch out of the eggs, when in contact with water and bore into the body(foot) of snails and enter the lymphatic system. Here, these develop first, into sporocyst stage and finally into cercaria larvae, which leave the snail, swim freely in water and penetrate the skin of man. As soon as they reach vascular system, they lose their tail and are now called metacercaria larvae. Through blood circulation metacercaria larvae reach lungs to become adult worms which finally enter into blood stream via liver and hepatic portal system (Figure 2.3).

Schistosoma is different from all other trematodes. First, they are dioecious, the male bearing the female in a ventral canal, the gynaecophoric canal, and secondly, they live in the blood stream of warm blooded hosts, being the only trematode to do so. In mammals, the portal blood vascular system, which carries intestinal break-down products from the duodenum, is rich in glucose and amino acids, so that together with the protein available in the plasma and blood cells, it would represent an environment capable of satisfying the metabolic

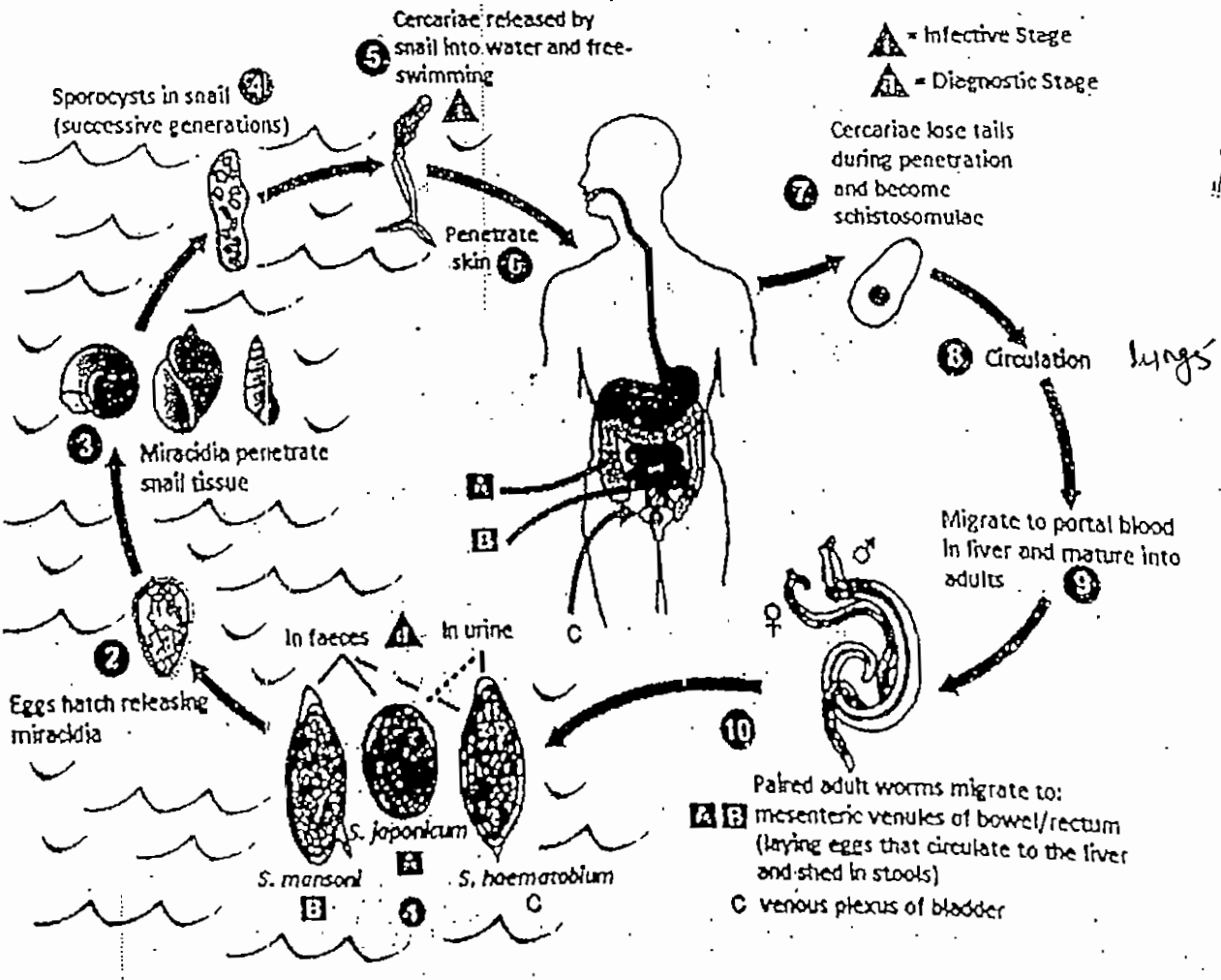


Figure 2.3 Life cycle of *Schistosoma* (Courtesy: CDC's Division of Parasitic Diseases, USA.)

2.2 CESTOIDES

The diseases caused by the tapeworms, belonging to the class Cestoda, are collectively referred to as cestodiasis. The tapeworms, also called cestode worms, with a few exceptions, have an elongated tape-like body. They lack an alimentary canal. Taeniasis is the infection of humans with the cestodes *Taenia saginata* (beef tapeworm),

T. solium – located in small intestine

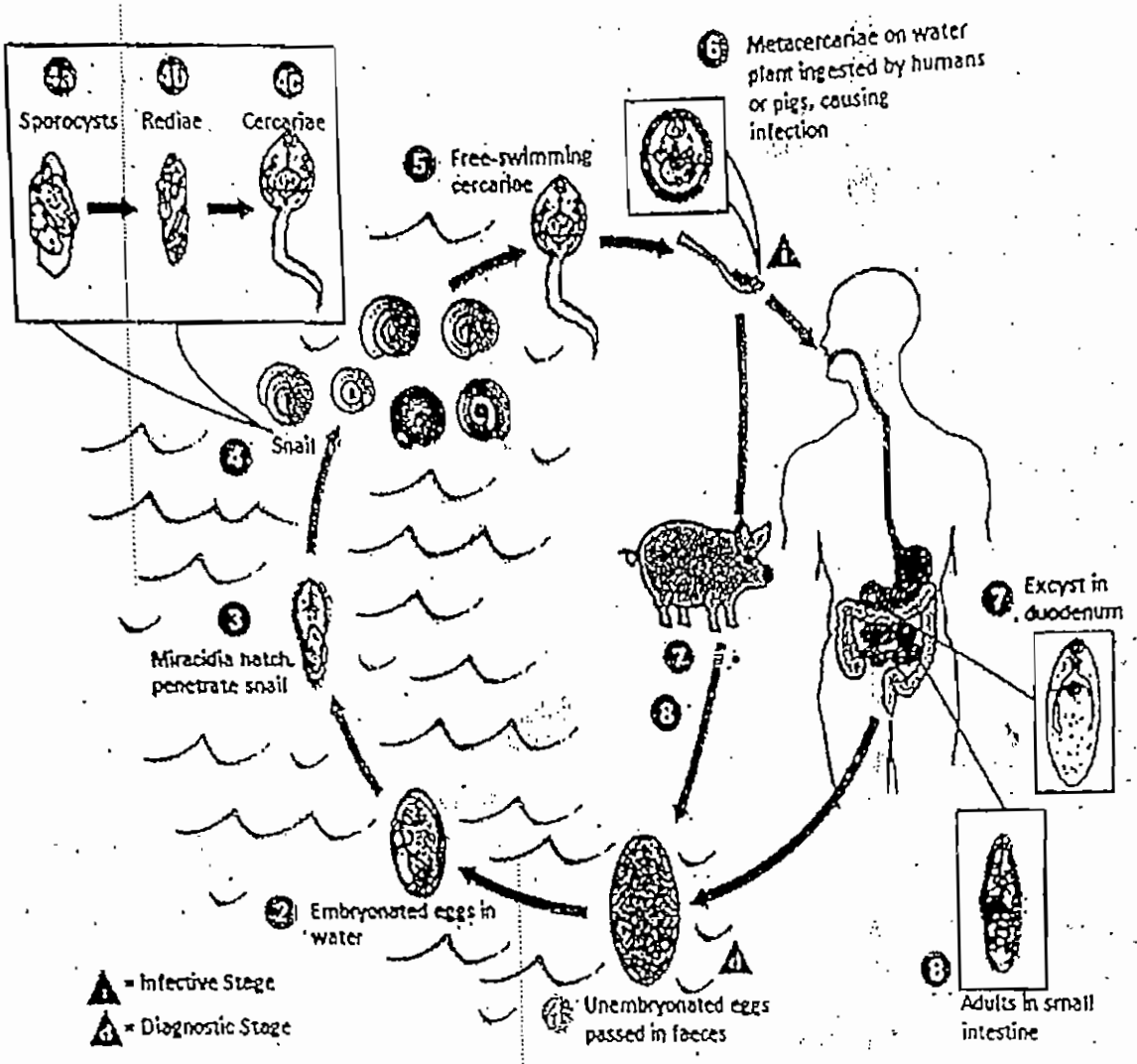


Figure 2.12 Life cycle of *Fasciolopsis buski* (Courtesy: CDC's Division of Parasitic Diseases, USA.)

T. solium (pork tapeworm) and *T. asiatica* (Asian tapeworm). *Taenia solium* can also cause cysticercosis. Humans are the only definitive hosts for these three species. Cattle (*T. saginata*) and pigs (*T. solium* and *T. asiatica*) are intermediate hosts. Adults of *Taenia* spp. can reach a length of 2–8 m, but the scolex is only 1–2 mm in diameter. The scolex of *T. solium* contains four large suckers and a rostellum containing two rows of large and small hooks. There are usually 13 hooks of each size. The scolex of *T. saginata* has four large suckers but lacks the rostellum and rostellar hooks. The scolex of *T. asiatica* possesses rudimentary hooklets in a wart-like formation.

Some common cestode worms causing diseases to humans and other animals are detailed here.

2.2.1 *Taenia solium*

Phylum: Platyhelminthes
Class: Cestoda
Order: Cyclophyllidea (Taenioidea)
Genus: *Taenia*
Species: *solium*

Taenia solium is commonly known as pork tapeworm. The body is usually 1–5 m long and opaque white in colour. The elongated body gradually broadens towards the posterior end. It is located in the small intestine of man. It is widely distributed in the world. The body is differentiated into scolex, neck and strobila. The scolex is the anterior end of body. With the help of its hooks and suckers, the scolex lies buried in the host's intestinal mucosa and serves as an organ of attachment. Strobila consists of similar parts called proglottids, usually 800–1000 in number. The proglottids are budded off in the neck region and pushed backwards. Each proglottid is hermaphrodite (Figures 2.13 and 2.14).

T. solium – contains – four large suckers & rostellum containing two rows large sucker – 13 hooks each size
T. saginata – foure large suckers lacks rostellum & rostellar hook.

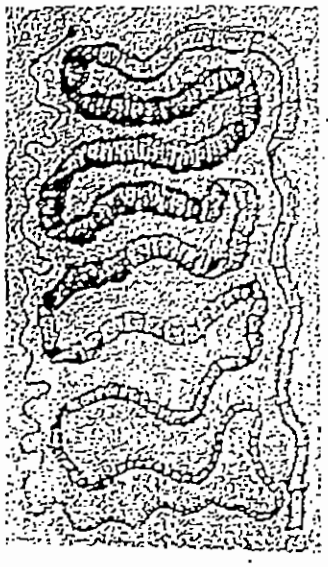


Figure 2.13 *Taenia solium*. Adult.

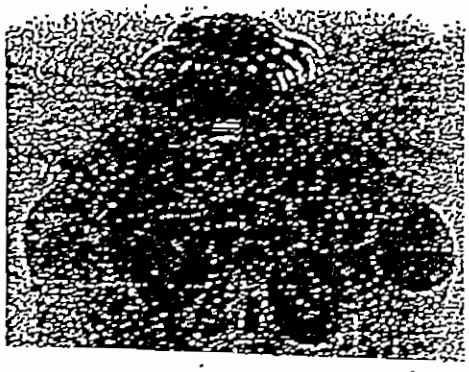


Figure 2.14 Scolex of *T. solium* with four large suckers and rostellum containing two rows of hooks. (*Courtesy:* S.J. Upton.)

Life cycle involves a primary host man and an intermediate host pig. Life history begins with the self-fertilization within the same proglottid. The ripe proglottids containing fertilized eggs are shed from the body of the tapeworm and come out with human faeces. These eggs now reach pig's intestine along with the faeces. Now they hatch into hooked embryos which penetrate pig's intestine and reach the muscles through the blood flow. In the muscles embryos develop into cysticercus larvae. Man acquires infection by eating raw or undercooked pork that contain the cysticerci. In the intestine of man, cysticerci develop into adult tapeworms which absorb nutrients through general body surface by diffusion (Figure 2.15).

The disease caused by the worm is referred to as taeniasis. Taeniasis causes gastrointestinal disorders, hunger, pain, anaemia and nausea. In cysticercosis, cysticerci can occur anywhere in the body, the eye commonly being infected. Cysticerci under the skin form visible subcutaneous nodules, which are largely asymptomatic. However, cerebral cysticercosis is the most commonly occurring infection.

Prophylactic measure requires eating of thoroughly cooked pork. The disease can be cured by the use of drugs such as atabrine and quinacrine hydrochloride.

2.2.2 *Taenia saginata*

Phylum: Platyhelminthes
Class: Cestoda
Order: Cyclophyllidea
Genus: *Taenia*
Species: *saginata*

Taenia saginata is commonly known as beef tapeworm. It has a cosmopolitan distributiuon, but is more common in developing countries, where hygiene may be poor and where the people eat raw or insufficiently cooked meat. It is comparatively bigger in size and has about 2000 proglottids. The scolex is without a rostellum and hooks but has four suckers (Figure 2.16).

Man acts as the definite host. It is located in the intestine of humans. Life history starts with the discharge of ripe proglottids containing self-fertilized eggs from worm's body present in the intestine of man. These pass out of the host's body with the faeces. Cattle are the normal intermediate hosts. On ingestion by cattle, the fertilized egg releases oncosphere in the duodenum. The onchosphere releases histolytic secretions which help the embryo to enter the mucosa and into the general circulation. In the muscles embryos develop into cysticircus larvae. Man acquires infection by eating raw or undercooked beef that contain the cysticerci. In the intestine of man cysticerci develop into adult tapeworms (Figure 2.17).

An infection due to an adult *Taenia*, in man or animals, is referred to as taeniasis and that due to the larval stage as cysticercosis. In man when the brain is invaded, the resulting disease is referred to as neurocysticercosis.

The most noticeable symptom is the spontaneous discharge of one or several proglottids, which often show individual muscular activity. These may creep out of the anus onto the perianal skin and may even migrate over the clothes or on the ground, shedding eggs as they go. Other symptoms recorded are abdominal pains, headache and increased appetite.

1st host = man
Intermedi- pig

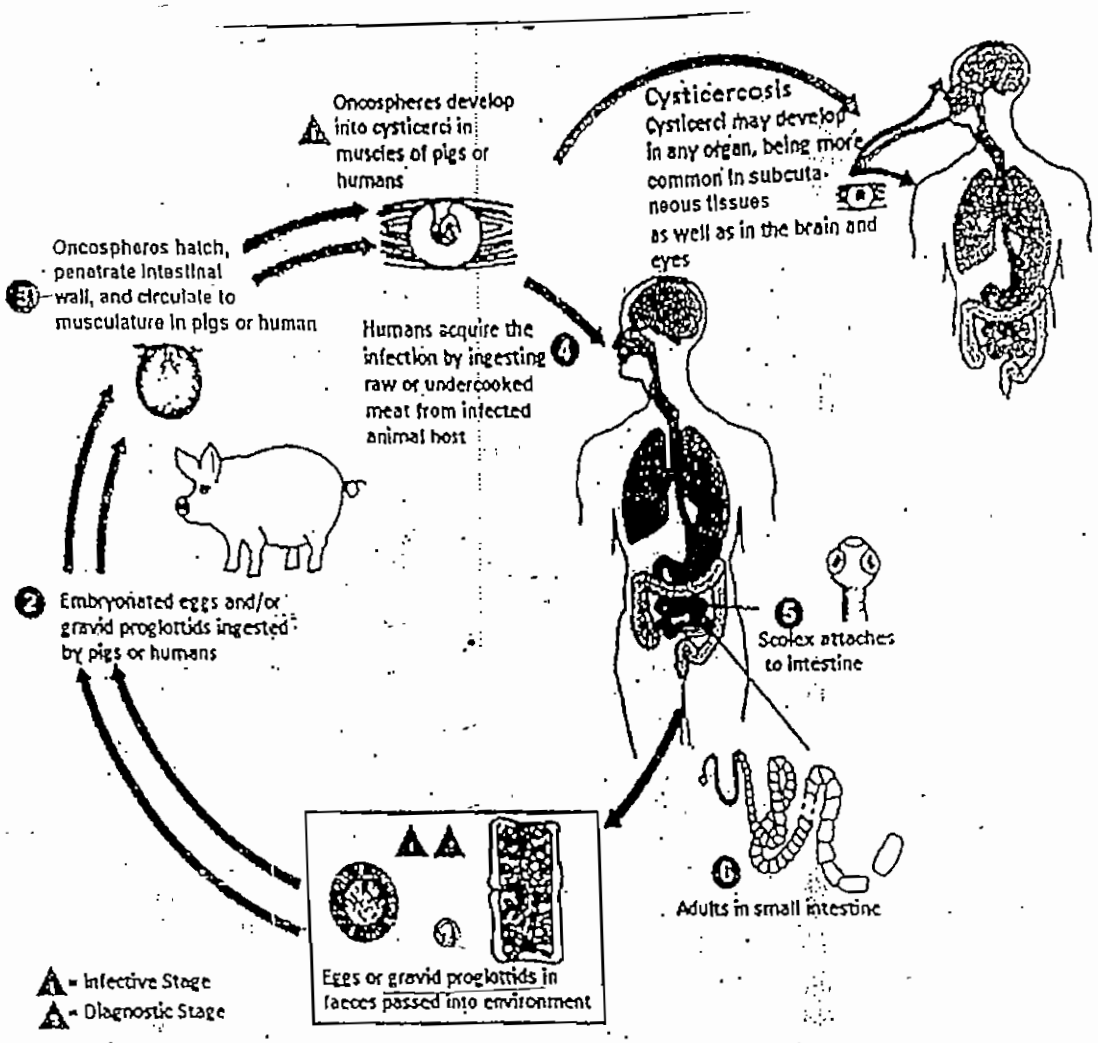


Figure 2.15 Life cycle of *Taenia solium* (Courtesy: CDC's Division of Parasitic Diseases, USA.)

(a) (b)

Figure 2.16 (a) *Taenia saginata*. Adult image. The adult in figure is approximately 4 m in length (Courtesy: CDC, USA.) (b) Scolex of *T. saginata*. Note the four large suckers and lack of rostellum and rostellar hooks. (Courtesy: S.J. Upton.)

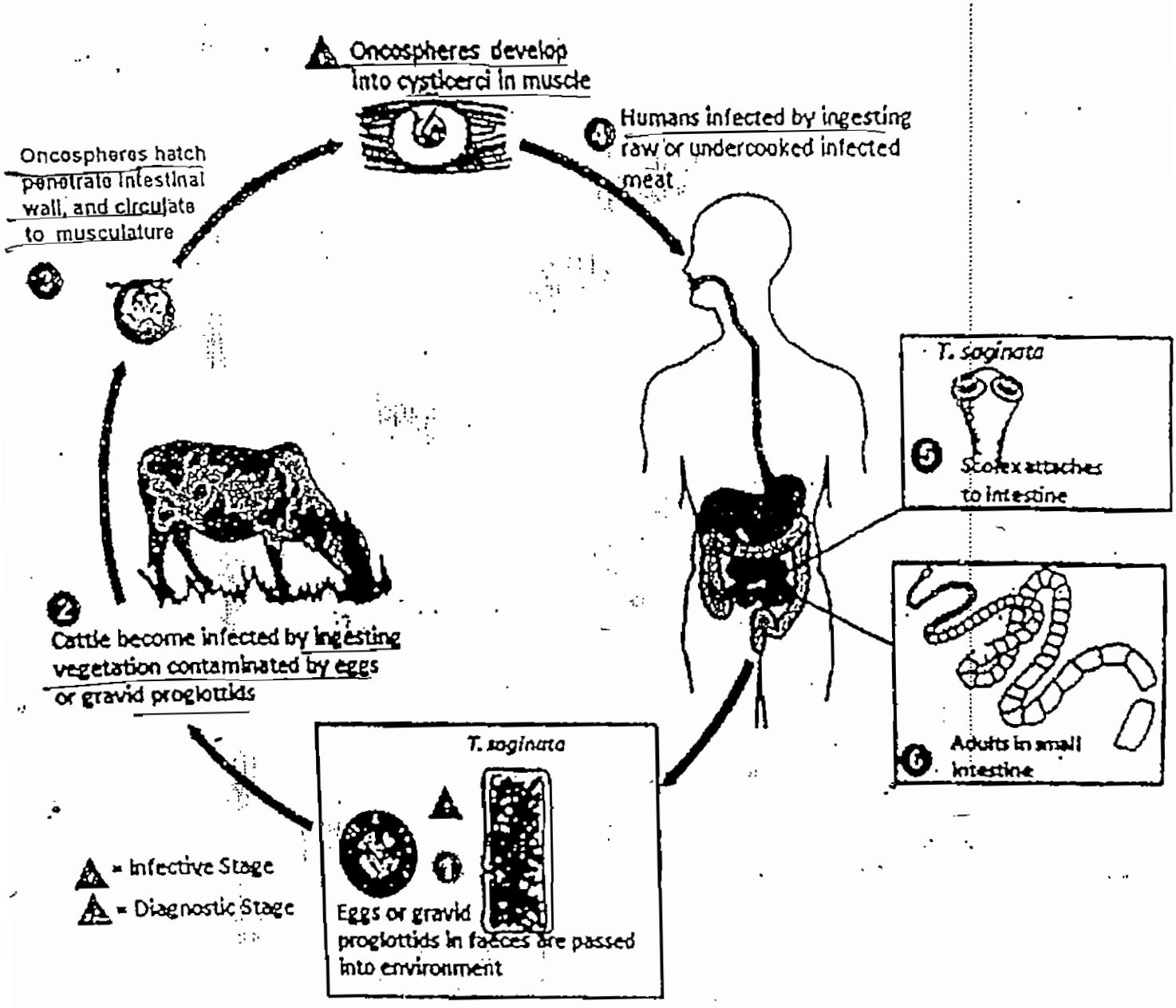


Figure 2.17 Life cycle of *Taenia saginata*. (*Courtesy: CDC's Division of Parasitic Diseases, USA*).

Taenia saginata host cattle (beef worm)
Taenia solium host pig. (Pork tapeworm)
Taenia asiatica host pig (Asian tapeworm)
definite host is man. or mammals.

23 NEMATODES

The diseases caused by the roundworms, belonging to the phylum Nematoda, are collectively referred to as **nematodiasis**. The nematodes or round worms are unisexual, worm-like, pseudocoelomate and cylindrical animals with unsegmented body. They have simple and tubular alimentary canal. Some common nematode worms causing diseases to human beings and other animals are discussed below.

:atch the anal region, so that the eggs
: lodged under the finger nails and
e mouth. The eggs, in the duodenum,
a rhabditoid larva. The larvae reach
intestine, moult twice, reach the large
and develop into adult worms. The adult
'e in the caecum. After a period of about
th, the adult worms come out with the
The infection with this nematode worm
iar in the sense that the eggs are rarely
n the faeces. Sometimes eggs hatch in the
:gion but the larvae migrate and mature in
ecum. This mode of infection is referred to
trofection (Figure 2.27).
he disease caused by the worm is referred to
iterobiasis. The symptoms of the disease are
of appetite, restlessness, profound hysteria,
vousness and inflammation of mucus membrane
colon, caecum and appendix. Control measures
clude good sanitary habits. Treatment can be
me by using drugs like pyrantel, mebendazole,
iperazine, etc.

2.3.3 Wuchereria bancrofti

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

The common name of this nematode worm is filaria worm of man. It is distributed in the tropical, sub-tropical and temperate countries, mainly in Asia, Africa, America and the Pacific. It is found in the major lymphatic ducts in the form of tightly coiled nodular masses and also in the tissues of the lymphatic glands and muscular tissues of man. They are creamy-white, cylindrical and filiform with blunt ends. Females measure 65–100 mm in length while males 40 mm (Figure 2.28 and 2.29).

The life cycle involves an intermediate host which acts as vector. The most important vectors of *W. bancrofti* are various species of mosquitoes. The most important vectors are members of the *Culex pipiens*, *Culex fatigans*, species of *Anopheles*, *Aedes*, and more rarely *Mansonia*. Copulation occurs when the adult worms of both the sexes are present in the lymphatic ducts. The female after fertilization gives birth to a number of larvae known as microfilariae, which are ensheathed in their egg membrane. The appearance of microfilariae in the peripheral blood shows nocturnal periodicity. The larvae reach their maximum concentration in the blood about midnight whereas during the day time they are concentrated in the lungs. On ingestion by the mosquito host, the sheath is lost and the microfilariae migrate to the thoracic muscles. In the muscles they grow and differentiate into sausage-shaped infective stage larvae. Thus, the

Worm – filaria - 65-100 mm (female), 40 mm (male)
Intermediate vector – Mosquitoes

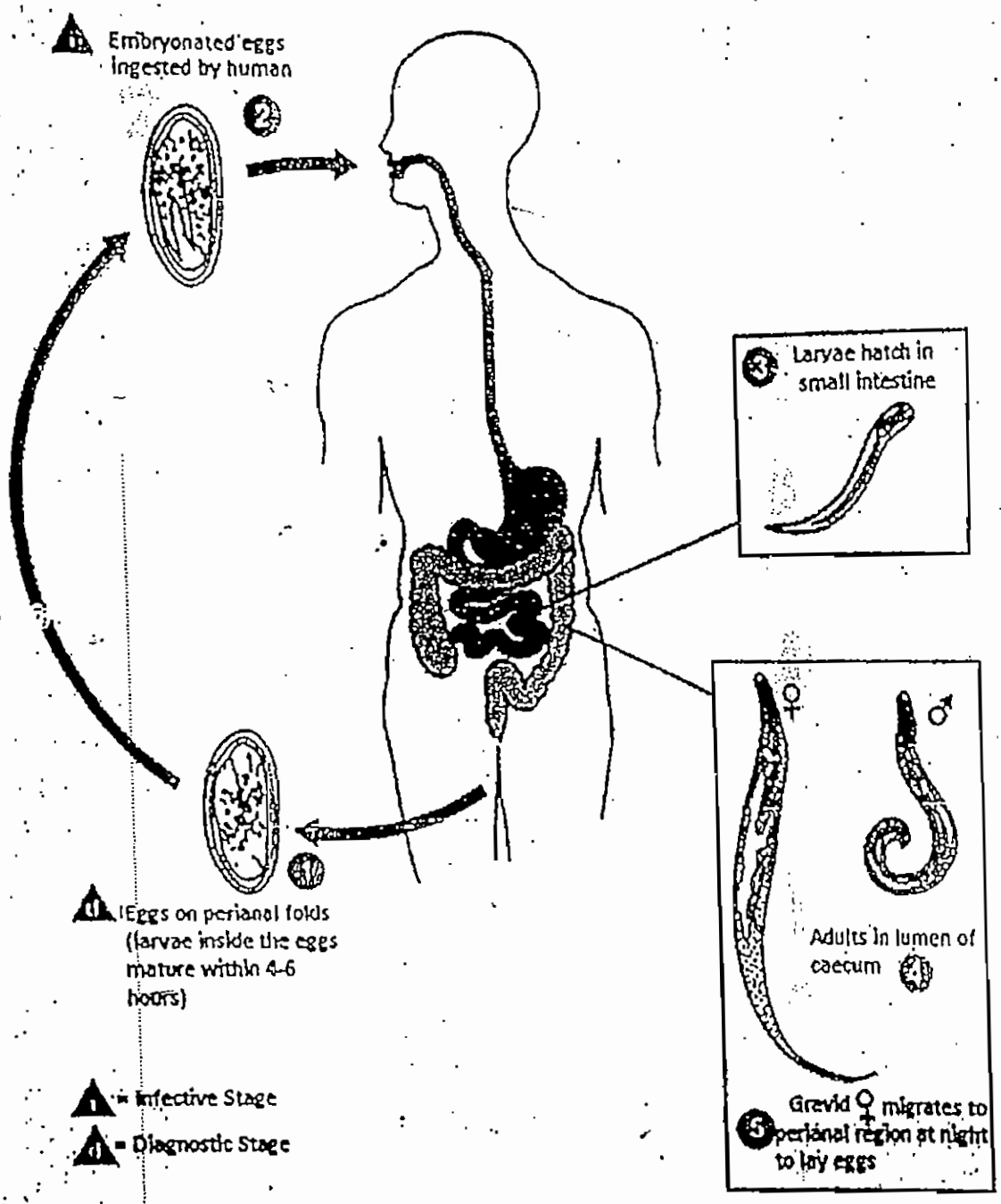


Figure 2.27. Life cycle of *Enterobius vermicularis*. (Courtesy: CDC's Division of Parasitic Disea es, USA.)

mosquitoes incubate the larvae and become vectors or carriers of the disease. The infective stage larvae migrate into the proboscis. When such a mosquito bites a person, numerous microfilariae are injected into the blood. They develop to adult stage after undergoing two moultings. Maturation to a sexually mature worm requires about nine months (Figure 2.30).

This species causes bancroftian filariasis, resulting into elephantiasis in man, causing swellings often in the legs and genital system. Swelling occurs due to blockage of lymphatic system by the worms. The lymph which cannot get back into the circulatory system accumulates in the organs and causes them to swell to greater proportions. The disease also causes filarial fever, mental depression and headache.

The preventive measures largely depend on the elimination of mosquito breeding sites. Mass chemotherapy has long involved the use of diethylcarbamazine (DEC). This can be mixed with salt. Recent results suggest that ivermectin, which is very effective against the microfilariae, can replace DEC. Unfortunately, it does not kill the adult worms. This fact severely limits its value in the eradication of the disease.

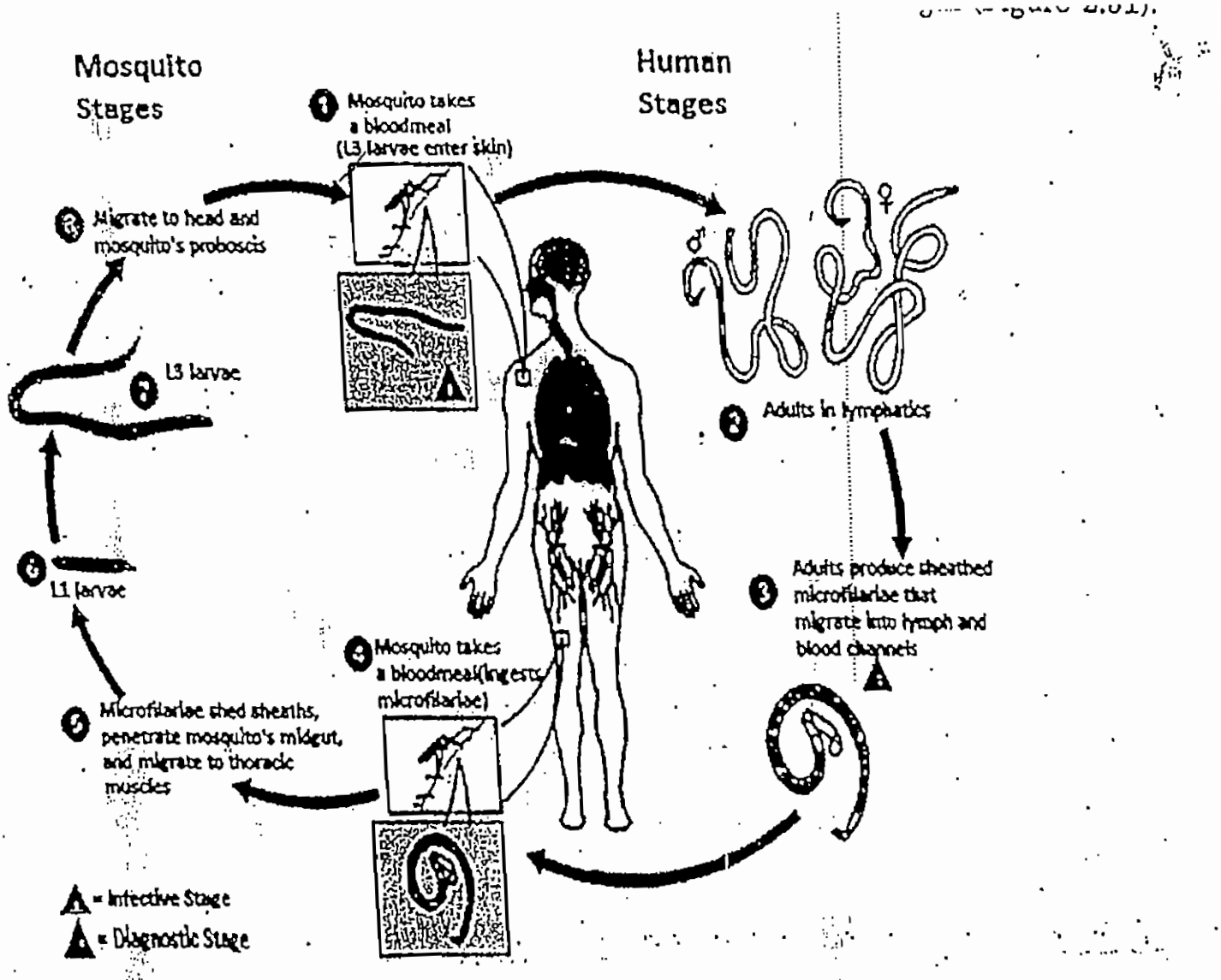
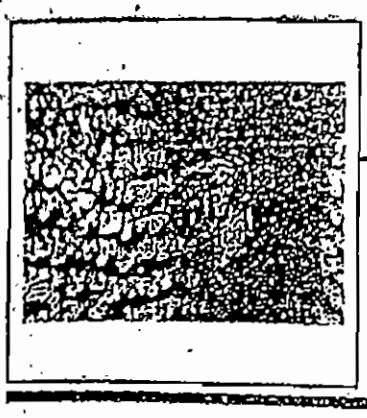


Figure 2.30 Life cycle of *Wuchereria bancrofti*. (Courtesy: CDC's Division of Parasitic Diseases, USA).



Chapter 10

Apiculture

A Temporary Honey Bee Swarm
(Courtesy: Karen Ridenour.)

Bees are wonderful insects because they pollinate our flowering plants. Our beautiful gardens and flower beds depend on bees. They also make delicious honey that adds a natural sweet flavour to many of our favourite foods. However, when bees swarm together or make a hive, they can become dangerous or even deadly. The most dangerous bees are the African Bees, commonly named "killer bees". (Arbor Pest, 2011).

APICULTURE is a scientific system of bee-keeping for the commercial production of honey and other useful products. In this system honeybees are reared, cared and managed as a profit making venture.

Man, because of his intelligence and superior skill, has been making use of animals and their products since long back. One of the best illustrations in this respect is our knowledge regarding the procurement of honey collected by bees. Before man learned to manufacture sugar, he depended for his sweets largely upon honey, which formed an important element in human diet. Honey has been under use by man since ancient time as referred in our religious scriptures like Vedas, Purranas, Ramayana, Mahabharata and Charak Samhita. Honey has medicinal and food value.

Honeybees have been most intimately associated with mankind, since very ancient times, and have reached the highest degree of domestication. Bee-keeping, therefore, is one of the oldest agricultural pursuits of man. Though bee-keeping has been in practice in India since time immemorial, scientific bee-keeping referred to as apiculture is a new venture.

10.1 TYPES OF BEES

Bees are arthropod insects which have been grouped in the order Hymenoptera. There are a number of species of bees. Most of them are solitary, but some species are social, living together in colonies with a division of labour among the individuals. All bees are important pollinating agents due to their habit of visiting flowers. All bees gather nectar and pollen from flowers, but only a few of the social bees store the nectar as honey. Of the bees that store honey, there are even fewer species that store it in sufficient quantity to make the effort of harvesting the honey worthwhile. In tropical regions, some species of stingless bees—notably *Trigona* and *Melipona*—are robbed of their honey. All of these bees build their nests inside cavities. Even though these do not sting, they defend their colony by biting the intruder.

Some secrete irritating substances along with the bite. Low yields make the keeping of these bees economically feasible only for home honey consumption. Although some stingless bees are robbed of their honey in tropical regions, bees

of the genus *Apis*, the true honeybees, are the major producers of honey and other hive products. *Apis mellifera*, the western honeybee, has been introduced into most regions of the world for use in bee-keeping.

10.1.1 The True Honey Bee (*Apis*)

The true honeybee is an example of colonial insect (others are ants and termites) having great economic importance, not for its honey, but for the role it plays in pollinating important agricultural crops. The genus *Apis* has four species—three, which are native to Asia and one, which is native to the Euro-African region. Though they have differences in size and colour, all of these are similar in appearance. Moreover, all these four species make two-cell thick vertical combs.

The giant or rock honeybee (Apis dorsata)

The species *Apis dorsata* is the biggest of the honeybees of the world and is found in Asia. The average size is about 2 mm in length. This gives highest honey yield to the tune of 18–36 litres of honey per colony per year depending upon the size of the colony. It constructs a single large comb which may measure 1–1.5 m long. The size of the colony may exceed 1,25,000 bees. The combs are located up to the height of 3,500 ft above sea level on inaccessible branches of trees, under caves, overhanging precipitous rocks or under roofs of high buildings. The species shows migratory habit and are ferocious in nature. During the month of June and July they swarm to the hills, but in winter they come back to the plains. There is a tendency to make unprovoked, sometimes fatal, mass attack on persons, who approach the hive. Its vicious temperament and migratory habit make it quite unfit for domestication.

The little honeybee (Apis florea)

The species *Apis florea* is the smallest species of honeybee. The yield is very little to the tune of few ounces per colony per year. It constructs tiny single comb which may measure about 15 cm across. This small-sized honeybee is a plain species, found rarely about 1,000 ft above sea level on twigs and branches of trees, in bushes, or under the wall and crevices of buildings, etc. This species is also unfit for domestication in view of its poor honey gathering capacity and migratory habit.

The eastern or Indian honeybee (Apis cerana, formerly A. indica)

This honeybee is native to Asia. This is a smaller-sized honeybee and is very common on the plains and forest of India. This species is fit for domestication in view of its mild temper and non-migratory habit. Since it can be easily hived in man-made containers, bee-keeping with this bee has been developed in different regions of Asia. The Indian honeybee *Apis cerana* is hived and reared in especially designed hives for its honey. Honey yields of up to 15–20 kg per year are obtained in some areas, but the average is much lower approximately 3–5 kg per colony per year. The techniques of bee-keeping with this bee are similar to those used with the western honeybee, though the hives used are smaller. The species has three regional strains. The lighter strain is a plain strain. It constructs several parallel combs about 30 cm across. The combs are located upto an altitude of 1,500 ft in protected places like inside cavities generally in hollow trees, caves, in rocks, etc. This strain is the best to be hived in artificial Indian conditions. The *Picea* strain is a hill strain found in hills at an altitude of 7,000 ft. The Pironi strain is a transitional strain found between an altitude of 3,000–4,000 ft.

Development of small-scale bee-keeping with the eastern honeybee deserves attention in its native area. Although yields are considerably lower than with the western honeybee, this bee has the advantage of being well adapted to the area. It is more resistant to some of the disease and pest problems found in the area. Therefore, it is better able to survive under the minimal management conditions which often characterise bee-keeping at the small-farmer level.

In recent years, there has been an effort in Asia to replace the eastern honeybee with European races of the western honeybee. This has been successful only in temperate regions and only for large-scale, capital-intensive operations where the technology is available to control disease and parasite problems of the European races. For a small-scale development effort in this area, it is advisable to consider the likely bee-keeping conditions in choosing a species. The importation of bees is often fraught with problems. Importing bees for a small-scale project often makes the people psychologically dependent upon the outside source. They neither realize that there is a locally available bee resource nor are

they motivated to make use of it. Imported bees often are not adapted to the areas into which they are introduced. This is especially true of temperate European races introduced into tropical areas. Importing bees also risks the introduction of exotic bee diseases and parasites. Tragic cases of this have occurred in recent years in Europe and South America with the introduction of *Varroa*, a mite parasite of the honeybee.

The most notable problem of the unguarded importation of bees occurred in Brazil in 1956. A bee-keeping industry based on European races of the western honeybee was well established in many areas of temperate South America. African bees were imported into Brazil in an attempt to establish an industry in some of the more tropical regions. Some of these bees accidently escaped and became established. They have continued to expand their range in the tropical lowlands, and in most cases they have actually supplanted the existing European bees. The establishment of African bees in tropical America has caused a great disruption of the bee-keeping industry. The African bee is noted for its defensiveness and unpredictability. These are characteristics considered undesirable from a bee-keeper's point of view. In some cases, nearby persons and farm animals have been stung to death. Adjusting to the increased number of stinging incidents and to the difficulty of managing this bee has been difficult for bee-keepers.

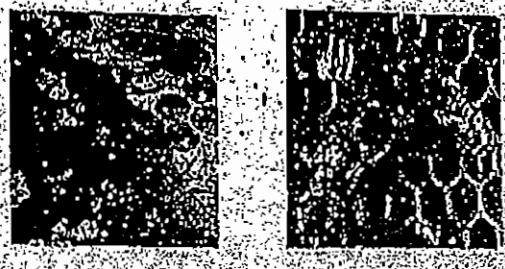
The western honeybee (Apis mellifera)

This honeybee is native to western Asia, Europe and Africa. This species resembles Indian honeybee in the nature, size and the location of the combs. It builds multicomb nests in enclosed cavities. These bees can be kept in hives. There is tremendous variation in this bee across its range, and at least 20 different sub-species or races are recognized, broadly divided into European and African groups. Several races of this bee are considered especially desirable for bee-keeping. European races of the western honeybee have been introduced into most parts of the world including the America, Australia and Asia. This bee has been studied intensely from both a strict biological and a bee-keeping viewpoint. Under good conditions, desirable races build large colonies and produce large surpluses of honey. Yields of 100 kg/year or better are possible under optimum conditions. The western honeybee offers a great potential for bee-keeping development. In addition to high yields, its ability to survive under a wide range of conditions and its availability due to past introductions or to native populations are characteristics, which have made this bee popular for bee-keeping. This is common in Europe and of many varieties, the Italian variety is considered to be the best. It gives a yield of about 100–400 lbs of honey per colony per year. This is the most commercial species of the world. This species was introduced in India in the year 1960 and at present is being reared in J&K, Punjab, Haryana, Himachal Pradesh, U.P., Bihar and West Bengal. Due to its high yield and friendly nature, it is now being preferred over Indian honey-bee by Indian bee-keepers.

In any small-scale bee-keeping development effort, the existing bee resource of the area should be used. Importing bees for such a project is far riskier than it is worth.

10.2 THE CASTES

The honeybee is a colonial insect. They do not survive individually, but rather as part of the colony. Reproduction is also accomplished at the colony level. Colonies are often referred to as super organisms. The house of the honeybee is called bee-nest, bee-hive or bee-comb. On an average a mature colony has 50,000 individuals. There are three different types of individuals or castes in the colony—queens (fertile female bees), drones (fertile male bees) and workers (sterile female bees), which depend on each other for their existence. Each caste has its special function in the colony. Due to the presence of three different castes of different morphological forms, honeybees are referred to as trimorphic species. Each caste has a different developmental time and is reared in a distinct type of cell (Figure 10.1).



(a) (b)

Figure 10.1 Queen, drones and workers in a bee-hive: (a) Queen surrounded by workers; (b) Drones

10.2.1 Queen

Normally, there is only one queen per colony, though sometimes two queens are present when the old queen is being superseded (replaced).

The queen is a diploid fertile female honeybee, biggest than the other castes. She is distinguished by her long, slender appearance, due to the full development of the ovaries in her abdomen. She has a sting without barbs and mandibular gland for secreting queen substance but lacks salivary and wax gland. It releases queen substance which inhibits sexual development of worker bees. The queer is the mother of the colony whose only function is laying of eggs. The queen lays both fertilized and unfertilized eggs. The fertilized eggs develop into female bees and unfertilized eggs develop into male bees. The grubs that hatch out from fertilized eggs and fed with royal jelly throughout develop into queens. However, only one queen reigns the colony. Extra queens are either go away, driven away or killed.

The developmental time of the queen is 16 days which is the shortest (Table 10.1). The developing queen larva is always surrounded by royal jelly, a special, highly-nutritious food produced by head glands of the workers. This feeding scheme, called massive provisioning, is unique to the queen and continues throughout her entire developmental period. The queen is the only female that is completely developed sexually. This is a result of a total diet of royal jelly during the developmental period. She is reared in a specially constructed royal or queen cell. Queen cells are downward-pointing, peanut-shaped cells which hang from the surface of the comb and in which the egg adheres to the ceiling. These cells are filled with royal jelly to keep the larvae from falling and to feed them. They can be located along the edges of the comb or within the comb area. The colony constructs queen cells when there is a need to rear queens, though cells are sometimes started and then abandoned. These are called false queen cups.

The longevity of the queen is three years and she lays about 15 lakh eggs in her whole life span. The queen can live for up to four years, but in the tropics, where the yearly laying period is longer, the queen does not live as long. Older queens do not have the laying capacity of younger queens, therefore young, vigorous queens are preferred by bee-keepers. In intensive bee-keeping, queens are replaced about every two years.

Approximately five days after emerging from her cell, the virgin queen begins to take mating flight, also called **marriage flight** or **nuptial flight**. She may take a number of such flights over a period of two to three days, and may mate with ten or more different drones. The sperm is stored in a special organ, the spermatheca, and the queen never mates again after this period. About five days after taking her mating flights, the queen begins to lay. During favourable periods a good queen can lay more than 1,500 eggs per day [Figure 10.2(a)].

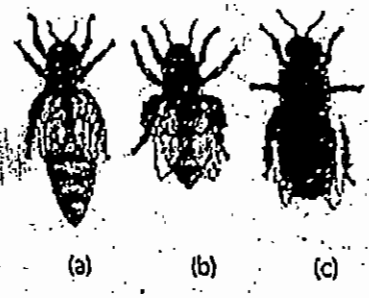


Figure 10.2 Castes of the honeybee. There is only one queen: (a) In a honeybee colony. She is the dominant reproductive female and can live up to 3–5 years. The worker, (b) is a facultative sterile female with a typical lifespan of 4–6 weeks. A colony normally consists of 10,000–30,000 worker bees. The male caste, or drone, (c) is only raised under favourable conditions when there may be 300–3000 drones present in the society. Few drones survive more than 4–5 weeks.

10.2.2 Workers

The workers are innumerable in number and constitute the majority of the bees in the colony. They are smallest in size. They are **diploid sterile females** which do not have functional sex organs. Worker bees are raised in the multi-purpose, horizontally arranged cells of the comb. Workers are reared in the same type of cell that is used to store honey and pollen. This type of cell makes up the majority of the comb in the colony. The adult worker emerges from the cell 21 days after the egg is laid. Majority of grubs that hatch out from fertilized eggs are fed with royal jelly first and with bee bread afterwards. The adult bees reared and developed in this manner become workers. Workers have special structures and organs which are associated with the duties they perform. During the active periods, about three weeks are spent as a hive bee and the remainder three weeks as a forager. For the first 3 weeks

of her life, therefore, she stays within or close to the hive and performs indoor functions of the hive. The following are the some of the indoor functions performed by the workers.

1. Cleaning cells for reuse.
2. Nursing the grubs—At first she feeds them brood food. When her glands stop producing this, she feeds them honey and beebread instead.
3. Building and repairing of combs—The wax glands on the ventral side of the last four abdominal segments begin to secrete beeswax. The worker uses her mandibles to mould them into new cells for the comb.
4. Receiving nectar, which the foragers bring back, and converting it into honey—This involves evaporating water from the nectar and digesting the sucrose into glucose and fructose.
5. Cooling and maintaining temperature of the hive—Cooling the hive if it gets too hot. To do this, she receives water from foragers, spreads it on the surface of the combs, and evaporated it by fanning it with her wings.
6. Keeping the hive clean by removing any debris (including dead workers), and
7. Defending combs—They perform patrolling in front of the hive, ready to sting any intruders.

It has been observed that the young workers actually spend only about 40 per cent of their time on these activities. The rest of the time is spent simply standing around in the hive ready to engage in any of these activities as the need arises.

After three weeks the workers serve as foragers of nectar and pollen. Nectar is collected in a special chamber of the digestive tract, the *honey sac*, and brought back to the hive to be converted into honey. Pollen is brought back in the *pollen baskets* of the metathoracic (hind) legs. It is moistened with honey to form bee bread.

DNA chip analysis reveals that this shift coincides with a change in gene activity of over 2000 different genes represented by up or down in m-RNA levels in the brain. One of these whose activity goes up is called Amfor (Apis mellifera foraging gene).

Tools of the worker honeybee

The worker honeybees perform their specialized functions with the aid of the following tools:

(1) It has long been known to bee-keepers that honeybees respond better to flowers moving in the breeze and with complex petals. The honeybee eye can detect all colours (except red) and also ultraviolet. So the only red flowers that are normally pollinated by bees are those that radiate ultraviolet as well. The antennae contain odour receptors responsible for the bee's ability to detect and discriminate among odours.

(2) Their body is densely covered with hair like bristles to which the pollen grains stick. The workers bees have certain special structures such as *antenna cleaners* on forelegs, *pollen combs* on hind legs and *pollen brushes* on all legs to remove the pollen grains from the worker's body. The collected pollen grains are stored in a pollen basket situated on hind legs (Figure 10.3).

Figure 10.3 European honeybee, *Apis mellifera*, flying back to its hive carrying pollen in a pollen basket. Pictured in Dar es Salaam, Tanzania on a private facility. (Courtesy: Muhammad Mahdi Karim, 2009.)

(3) The worker bees collect nectar and water from plants with the help of sucking mouthparts which are modifications of the maxillae and labium (Figures 10.4 and 10.5).

Figure 10.4 Mouth parts of honeybee. (Courtesy: John W. Kimball; from Kimball's Biology Pages, 1994).

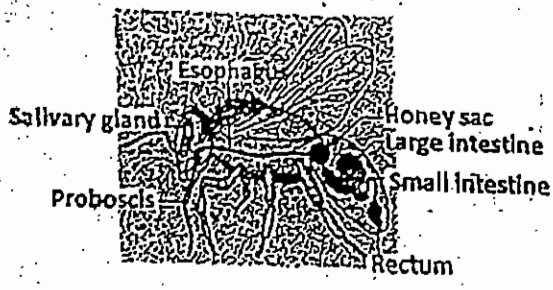


Figure 10.5 Honey sac of honeybee. (Courtesy: John W. Kimball; from Kimball's Biology Pages, 1994).

(4) The ovipositor is specialized as a stinging apparatus instead of being an egg-laying organ. The tip of the abdomen is provided by a sting. There is a poison storage sac connected to the base of the sting. The poison is formed by the mixing of the secretions from one alkaline and two acidic glands. The venom is used in colony defense. When the sting is withdrawn from the prey's body, the entire poison apparatus along with the sting are left behind in the victim leading to the death of the bee. This is an illustration of altruistic self sacrifice. The workers, thus, sting once in their life. The salivary and wax glands are present.

The various functions of workers are age-related. For the first 3 days, the worker bees clean walls and floors of empty cells of the hive for the reuse. Such worker bees are referred to as sanitary bees or cleaner bees. From 4th to 10th day, the worker bees feed the newly hatched larvae with highly nutritious royal jelly (bee milk) secreted by their pharyngeal glands which open in the buccal cavity. Such workers which perform the act of feeding larvae are referred to as feeder bees or nurse bees. They also perform the act of receiving nectar from the foragers, depositing the nectar in cells and converting the nectar to honey. From 11th to 15th day, the workers build the comb by wax secreted by four pairs of abdominal wax glands. These workers are called builder bees. From 16th to 20th day, the workers receive pollen loads from the foragers (workers) returning to the hive and store the pollens into the pollen cells of the hive. Such workers are referred to as off-loader bees. The workers which are at their 20th day of life span sit at the entrance of the hive and defend the colony from intruders by stinging them to death and pushing them out of the hive. Such worker bees are referred to as guard bees or sentinel. From 21st day of their life span, the workers start performing outdoor activities like finding out new sources of food, the nectar, pollen and water and collect them. In search of food, they have to make multiple visits. The forelegs and hind legs of the workers are adapted for pollen collection. The mouthparts are modified for collecting the nectar and the pollen. The bee is capable of carrying pollen loads of 26–35 per cent of its body weight. Such workers are referred to as foragers, field bees or scout bees.

The life span of worker adults varies greatly with the time of year. During periods when the colony is relatively inactive (dearth periods), workers may live three months or more, but when the colony is active, they live for about six weeks only. The life span of workers of tropical races of the western honeybee and the eastern honeybee is shorter (Figure 10.2).

It has been observed that when a colony has become queenless and there are no young larvae or female eggs from which to rear a new queen, laying workers can develop. The ovaries of some workers in the colony develop because of the absence of queen substance, and they start to lay eggs. Since workers do not have the body structure or behaviour necessary to be fertilized, all of the eggs are unfertilized and thus produce drones. Laying workers can be suspected in a colony if there are an excessive number of drones present.

10.2.3 Drones (300) – Haploid fertile males.

A strong colony can have about 300 drones. But during periods when resources are scarce, the workers run the drones out of the colony. They die as they cannot feed for themselves. The number of drones is less than the workers.

They are medium in size. The body of the drone is larger than that of the worker or queen. The eyes are large and cover practically the whole head. The end of the abdomen is blunt and is covered with a tuft of small hairs.

They are noisy and have no sting, salivary and wax gland. As the sting is a modified structure of the female genitalia, drones do not have stings and hence cannot sting. They also do not have any of the structures necessary to collect nectar and pollen.

Drones, the males of the colony, are produced from unfertilized eggs and hence are *haploid fertile males*. The queen can control whether or not the egg is fertilized as she lays it. The grubs that hatch out from unfertilized eggs and fed with brood food first and with bee bread afterwards become drones. They are well fed during the breeding season but are neglected during the non-breeding season. The developmental period of drones is 24 days. Drones are reared in cells of the same shape as worker cells but are larger in size. Their only function is to mate with the queen. The mating of honeybees takes place in the air away from the colony. When the weather is good, mature drones leave the colony during the afternoon and congregate in certain areas where they wait for virgin queens to fly by. Drones sometimes return to colonies that have a virgin queen. Such colonies will accept drones from other colonies and will tolerate a large drone population while the queen is a virgin. However, after a queen mates, the workers run many of the drones out of the colony. Their survival is 60 days at the most (Figure 10.2).

10.3 LIFE CYCLE OF THE HONEYBEE

The honeybee is an insect with complete metamorphosis. This means that there are four distinct stages in the life cycle—egg, larva, pupa, and adult (Figures 10.6 and 10.7). The first three stages develop in cells in the comb, and are collectively referred to as the brood. Eggs and larvae are in open cells and are cared for by adult workers. These stages are called the open or unsealed brood. Once the egg hatches, the workers continually feed the developing larva.

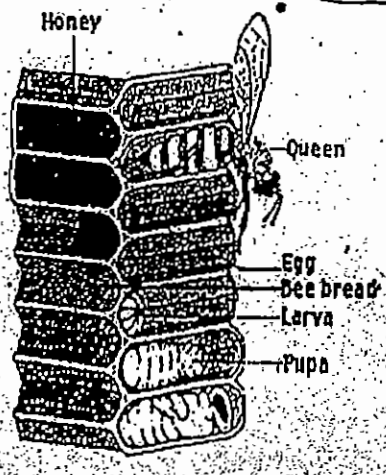


Figure 10.6 Stages of honeybee (*Courtesy:* John W. Kimball; from Kimball's Biology Pages, 1994).

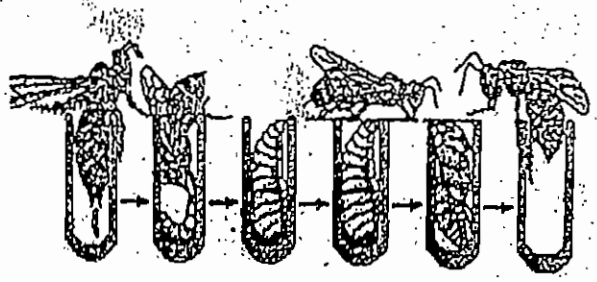


Figure 10.7 Life cycle of honeybee: Queen lays egg in wax cell, worker feeds hatched larva, larva reaches full growth, worker seals cell, larva becomes a pupa, adult bee leaves cell. (*Courtesy:* Gold city pest services, 2010).

When the larva nears the end of the larval period, it engorges on food provided by the workers, and the workers seal the cell. This is known as the capped or sealed brood. After the cell is sealed, the larva changes into the pupal stage. There is no feeding during this period. The pupa develops into the adult form, which emerges on its own from the cell.

The life of the honeybee colony, i.e., the life cycle revolves around the activities of its single queen. When food is abundant she spends most of her time laying eggs in the wax cells of the honeycomb. Winter season is the season of breeding. Before a new queen emerges, the old queen leaves the hive, taking a substantial fraction of the workers with her. This is called swarming. After a few days, the new queen leaves the hive to mate while flying high in the air with the fastest of the drones chasing her. This is mating flight, also called marriage flight or nuptial flight. The drone gives up his life as he succeeds. The queen receives the sperms or spermatophores from the drone and stores in her storage sacs or sperm receptacles called spermatheca. She may repeat the process 10–30 times, thus ensuring a genetically diverse collection of sperms. This is important as colonies with a single father rather than multiple fathers are less resistant to disease, bring less food back to the hive, build new comb more slowly and raise fewer young. After first stinging to death any other developing queens (unless the hive is so crowded that additional swarms are called for), she begins egg-laying. The inseminated queen lays both fertilized and unfertilized eggs singly in the hexagonal cells of the comb attached to the bottom wall @ 1 egg per minute/1500 eggs per day/1.5 million eggs during life span of 3–5 years. The queen has voluntary control over the process of egg laying. The laying of two types of eggs is possible

because the queen has system for regulating the release of sperms from her spermatheca. In 3 days of mating the young queen begins to oviposit. The fertilized and unfertilized eggs are laid in different cells. The fertilized (diploid) eggs develop into female bees (queen/workers) whereas unfertilized (haploid) eggs develop into male bees (drones). This type of reproduction is called arrhenotokous reproduction.

These eggs hatch into larvae (grubs) after 3 days. This is known as incubation period. Now the feeding begins. The larvae are tended and fed for a total period of about six days. For the first three days all the larvae are tended and fed by workers with a protein-rich secretion called brood food, also called bee milk or royal jelly. Then after three days of common feeding change in diet begins for the next three days. Generally one of the females going to become the *queen* is continued to be fed on royal jelly. The other female bees going to become the *workers* and the male bees or *drones* are switched over to a kind of coarser food called **bee bread**, a pollen/honey mixture. Because of its crucial role in converting grubs into queens instead of workers, brood food is also known as royal jelly.

Differential food types result into difference in size of the developing larvae. The larvae grow and moult several times. On 9th day, the cells containing larvae are sealed with wax-cap and the larvae undergo metamorphosis. A pupal stage is passed within the sealed chamber during which the larva secretes a thin, silky cocoon around it. During pupal stage changes take place and finally the adult honeybee comes out by cutting the cocoon wall and breaking the waxcap. While all the eggs hatch on the third day, it takes the queen about 16 days, the worker 21 days and the drone 24 days to complete metamorphosis and emerge out as adult. During winter season bees undergo rest and consume the stored honey and pollen. As soon as the spring season follows activities are resumed and new queens and drones are raised up. This is how life cycle continues (Figure 10.7).

Why the worker bees are sterile? Two reasons are given for this. One explains by saying that differential food type results into degeneration of body size and reproductive organs. The other explains by saying that a queen substance containing 9 oxodetrons-2-enoic acid secreted from the mandibular gland of the queen is sprayed on her whole body by the queen herself. The workers lick this substance from queen's body. This results in the retardation of ovary and hence sterility of worker bees. It has been observed that when the workers are isolated from queen, their ovaries ripen. This fact supports the second view.

Table 10.1 Developmental events (in days). The figures given can vary a day or so, depending on the type (species and/or race) of honeybee, the weather conditions, or the time of year.

	Queen (Days)	*Worker (Days)*	*Drone (Days)*
Egg hatches after	3	3	3
Cell is sealed after	8	9	10
Adult emerges after	16	21	24

All young larvae of about three days old are fed with royal jelly by the massive provisioning scheme. After the third day, worker larvae are gradually switched to a progressive feeding scheme where they are fed with a mixture of royal jelly, honey and pollen. With progressive feeding, the larvae are fed periodically, thus food is not always available to them. The different feeding schemes determine the caste of the adult bee. The feeding scheme for drones is similar to workers, but they are produced from unfertilized eggs.

10.4 CERTAIN IMPORTANT EVENTS IN THE LIFE CYCLE OF HONEYBEE

10.4.1 Swarming

The swarming is an act of migration of honeybees in group consisting of an old queen, a few drones, and a large number of workers from an old hive to a new place for the purpose of establishing a new hive. The driving force behind the act of swarming is the much more increase in the number of individuals in the colony. There are following advantages of swarming:

(1) Swarming in bees relieves the hive from overcrowding.
(2) Swarming helps in the perpetuation of the species.
(3) Swarming helps in dividing the parent colony into two or more new young colonies.

(2) Wasps *like Palarus orientalis, Vespa cincta* and *V. tropica* var. *haemotoides* damage the colony.
(3) Louse like *Braula caeca* sucks the blood of queen and disturbs the whole colony.
(4) Wax Beetle like *Platybolium alvearium* produces unhygienic condition inside hive.
(5) Bug like *Acanthaspis siva*, the black ant *Camponotus compressus*, the leafcutter bee *Megachile disjuncta*, the death's head moth *Acherontia styx*, birds—like drongo *Dicrurus ater* and bee—eater *Merops viridis*, the arachnid *Ellingsenius indicus*, lizards, toads, snails and termites attack bees and bee-hives.

10.7 ECONOMIC IMPORTANCE: THE PRODUCTS OF THE HIVE

Honeybees are the source of honey, beeswax, propolis, royal jelly, pollen and honeybee venom. Not only this, their role in pollination is equally important.

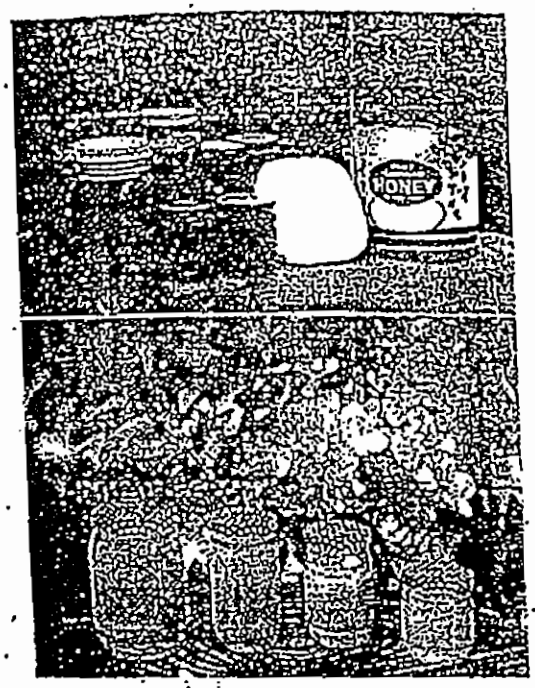
10.7.1 Honey

Fresh honey is an edible, sweet, colourless, viscous fluid made by honeybees from nectar collected by workers (foragers or field honeybees) from flowers. The collection of nectar is a hard work. Field honeybees collect flower nectar in the honey sac, which is an enlargement of the oesophagus. In the crop or honey-sac of the worker bee the nectar mixes with salivary enzyme which converts its complex cane-sugar into simple invert-sugars dextrose and levulose. On entering the hive with a full honey sac, the field bee regurgitates the contents into the mouth of a young worker, called the house, or nurse, bee. The house bee deposits the nectar in a cell and carries out the tasks necessary to convert the nectar to honey. After losing a certain amount of water this changed nectar becomes honey. The fresh honey is used as food for the developing bees. The surplus honey is stored for future use. When the surplus honey is fully ripened, the cell is sealed with an airtight wax capping. Both old and young workers are required to store the winter supplies of honey.

Honey is a complex biological mixture substance which has antibacterial and antifungal properties inhibiting the growth of many bacteria and fungi and will not rot or ferment when stored under normal conditions. However, honey will crystallize with time. Crystallized honey is not damaged or defective in any way, for human use, but bees will automatically remove crystallized honey from their hive and discard it, since they can only use liquid honey. The honey contains 17 per cent water, 78 per cent sugar, minerals, enzymes and about eight components of vitamin B complex. The colour, flavour and odour of honey depend on flowers from which nectar is collected. One gram of honey contains 3.2 calories of energy. It is an energy rich food and is therefore given to men, women and children. It is a good energy provider and immune builder. As it is a natural antiseptic and contains valuable nutrients, it has medicinal importance too. Honey is beneficial in cuts and burns and cough and cold.

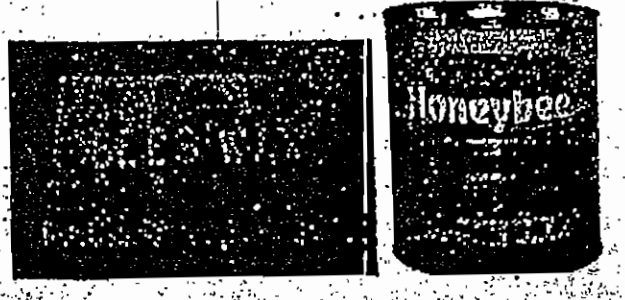
The flight radius of Indian honeybees is about 1 mile. For collecting one pound of nectar, honey bees make about 40000 trips and cover a distance of about double the circumference of the earth.

The inhibine or inhibiter effect of honey is due to small amounts of hydrogen peroxide in dynamic equilibrium in honey solutions. The hydrogen peroxide is due to the interaction between an acid and an enzyme namely, gluconic acid and glucose oxidase, respectively. Due to the acidic ph (average 3.9) and the moisture absorbing property the honey prevents the growth of microbes. When applied over cuts and wounds it absorbs and removes moisture from the injured area thereby discouraging microbial growth. As far back as the Crimean War honey was successfully used for dressing and treating wounds. Much work has been undertaken in recent years in New Zealand with Manuka honey, which has developed a reputation as a great healer, but whether it is better than other honies remains to be seen as research continues in this country and other parts of the world. There are reports of cases of even leg ulcers that have responded well to dressing with liquid honey when other treatments failed. Certainly it would seem that anyone could use it, to advantage, on a septic wound without medical advice irrespective of the level of antibacterial activity in the honey concerned.



10.7.2 Bees Wax

It is a fine wax with unusual qualities. Worker bees of a certain age will secrete bees wax from a series of wax glands on their abdomen. They use the wax to form the walls and caps of the comb, i.e., in the construction of hive. It is a hard and waterproof material with high melting point of about 140°F. When honey is harvested, the wax can be gathered to be used by human beings in various wax products like candles, ointments, cosmetics, polishes, lubricants, seals, etc. By using bees wax, an ointment called 'Bee Balm' has been formulated. This recipe can be used to heal small sores particularly on the mouth, open wounds, minor cuts and scratches and patches of dry skin. Daily use of balm on hands and feet keeps skin in good condition.



10.7.3 Propolis

Propolis is a resinous mixture that honeybees collect from tree buds, sap flows, or other botanical sources. It is a gummy substance made from plant sap. It is used as a sealant for unwanted open spaces in the hive. Propolis also has antibacterial properties. These properties are put to good use by the bees primarily to varnish the brood cells before they are reoccupied. When the cells are cleaned after use, the varnishing is part of the disinfecting process thereby keeping the brood nest clean and wholesome. Propolis is harvested commercially, refined and used medicinally for a whole variety of ailments such as gumboils, drying up cuts, cold sores on the lips and sore throats. Propolis is marketed for its alleged health benefits, but may cause severe allergic reactions in some individuals.

Propolis was first used seriously in Russia by veterinary surgeons for the treatment of animal complaints. Propolis is now being investigated throughout the world for the treatment of human complaints. There has been a report about the treatment of stomach ulcers at a London teaching hospital. A group of patients were treated with ½ pint of milk morning and evening with two or three drops of tincture of propolis added to the milk. After three months a high percentage of the group were completely cured while the rest showed a marked improvement. Tincture of propolis is an alcohol solution saturated with propolis.

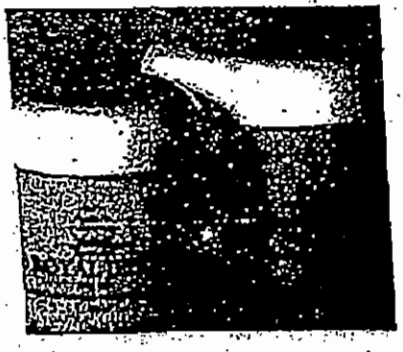
10.7.4 Royal Jelly

Royal jelly is a honeybee secretion that is used in the nutrition of the larvae. It is marketed for its alleged health benefits, but may cause severe allergic reactions in some individuals.

Queen bees are made, not born, and their feeding with royal jelly is the key to that process. Without this special food, queen bees would fail to develop properly. Royal jelly is a thick, extremely nutritious, milky white, creamy liquid secreted

by the hypopharyngeal glands of the worker bees (nurse bees) in the hive. It is so named because it serves as the sole food for the queen bee. Queen bees live exclusively on royal jelly and it accounts for their incredible size and longevity. They average 42 per cent larger and weigh 60 per cent more than the worker bee. Amazingly, they live 40 times longer than worker bees, seven years as compared to seven weeks.

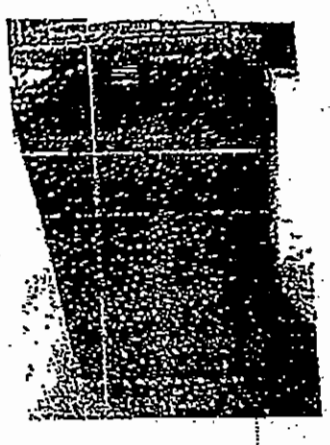
Royal jelly is an excellent source of nutrients. It promotes youthfulness, skin beauty and more. Biochemically speaking, royal jelly is very complex. It is a very rich source of proteins and contains eight essential amino acids, important fatty acids, sugars, sterols and phosphorous compounds as well as acetylcholine. Acetylcholine is needed to transmit nerve messages from cell to cell. Too little of this compound makes individuals prone to Alzheimer's disease. It contains gamma globulin, known to stimulate the immune system and fight off infections. Royal jelly contains vitamins A, B-complex, C, D and E. It is particularly useful for its B-complex contents, including B1, B2, B6, B12, biotin, folic acid, and inositol. Royal jelly is high in the B vitamin pantothenic acid, recognized for its ability to reduce stress levels. It also supplies the minerals, calcium, copper, iron, phosphorous, potassium, silicon and sulphur.



Although royal jelly has been traditionally known to prolong youthfulness and improve the skin beauty, evidence indicates that this substance increases energy, alleviates anxiety, sleeplessness, moodiness, memory loss, and bolsters the immune system. Researchers have found that royal jelly contains a complex compound that stimulates glands and normalizes the reproductive systems of both men and women and acts as a natural hormone. It is an aphrodisiac and mood enhancer. It enhances mood and bolsters and invigorates sexual vitality. Royal jelly is also rich in nucleic acids, RNA and DNA. Gelatin, another significant component, is one of the precursors of collagen, which is another component of royal jelly. Collagen is an anti-aging element that keeps the skin looking smooth and youthful. Adenosine triphosphate (ATP), adenosine diphosphate (ADP) and adenosine monophosphate (AMP) are also found in Royal Jelly.

10.7.5 Pollen

Field bees collect pollen in the pollen basket present on their hind legs and carry it to the nest or hive and place directly in the cells. In the hive, pollen is used as a protein source necessary during brood rearing. Pollen supplies protein and fat for bee brood to grow. In certain environments, excess pollen can be collected from the hives. It is often eaten as a health supplement.



10.7.6 Venom

Honeybee venom is extracted for the production of antivenom therapy and is being investigated as a treatment for several serious diseases of the muscles, connective tissue, and immune system, including multiple sclerosis and arthritis.

10.7.7 Pollination

Honeybees are good pollinator of plants. Setting of fruits and increase in crop yields need no citation to highlight the parts played by the bees. The utilization of bees for pollination in cotton has been explored with much success in India. Thus, they play a good role in agriculture and horticulture.

The pollen of a given load is derived mostly from plants of one species, which accounts for the honeybee's outstanding role as pollinator. If it flew from one flower species to another, it would not be effective in the transfer of pollen, but by confining

its visits on a given trip to the blossoms of a single species, it provides the cross-pollination required in many varieties of plants (Figure 10.14).

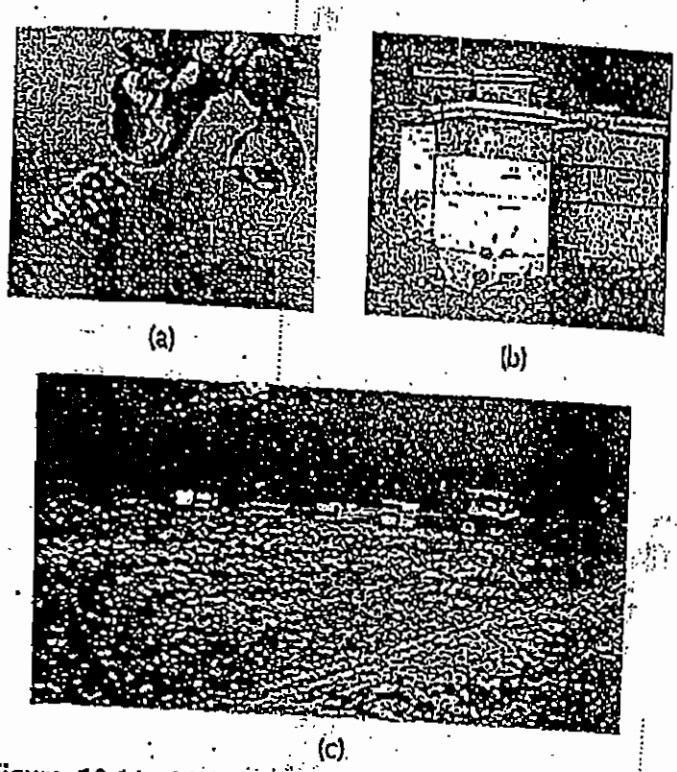


Figure 10.14 (a) Pollination by a honeybee. (b) Painted wooden beehives with active honeybees. (c) Bee-hives setup for pumpkin pollination (*Courtesy:* Jonathunder, 2010.)

10.8 APICULTURE—THE COMMERCIAL BEE-KEEPING

Bee-keeping in India is one of the successful cottage industries. The Indian bee *Apis indica* and the European bee *Apis mellifera* are the two very commonly hived species. Apiculture is practiced with the help of artificial bee-hives and other equipments.

10.8.1 Artificial Bee Hive

Artificial bee-hives serve two purposes: production of honey and pollination of nearby crops. Artificial hives are commonly transported so that bees can pollinate crops in other areas. A number of patents have been issued for beehive designs.

Traditional artificial hives

Traditional bee-hives simply provided an enclosure for the bee colony. Because no internal structures were provided for the bees, the bees created their own honeycomb within the hives. The comb is often cross-attached and cannot be moved without destroying it. This is sometimes called a fixed-frame hive to differentiate it from the modern movable frame hives. Harvest generally destroyed the hives. Honey from traditional hives was typically extracted by pressing–crushing the wax honeycomb to squeeze out the honey. Due to this harvesting, traditional bee-hives typically provided more beeswax, but far less honey, than a modern hive. There are three basic styles of traditional bee-hive; mud hives, clay/tile hives, skeps and bee gums. Mud hives are still used in Egypt. These are long cylinders made from a mixture of unbaked mud, straw, and dung. Clay tiles were the customary homes of domesticated bees in the eastern end of the Mediterranean. Long cylinders of baked clay were used in ancient Egypt, the Middle East and to some extent in Greece, Italy and Malta. They sometimes were used singly, but more often stacked in rows to provide some shade, at least for those not on top. Keepers would smoke one end to drive the bees to the other end while they harvested honey. Skeps, which are baskets placed open-end-down, have been used for about 2000 years.

Modern artificial hives

The modern artificial bee-hive, also known as bee box, is a movable frame hive. It is made up of wooden box. The different types of hives are in use in different parts of the world. Their models differ in their size and number of frames used. The box is made up of single or double walls. The double walled hives provide better insulation that keeps the hives cool in winter and warm in summer (Figures 10.15, 10.16 and 10.17).

There are two basic types of modern or movable hive in common use, the **Langstroth hive**, which has enclosed frames to hold the comb and the **top-bar hive**, which has only a top-bar to support the comb. These hives are typified by removable frames which allow the apiarist to inspect for diseases and parasites. Movable frames also allow a bee-keeper to more easily split the hive to make new colonies.

The **Langstroth bee-hive**, patented in October, 1852, is the standard bee-hive used in many parts of the world for bee-keeping. The advantage of this hive is that the bees build honeycomb into frames, which can be moved with ease. The frames are

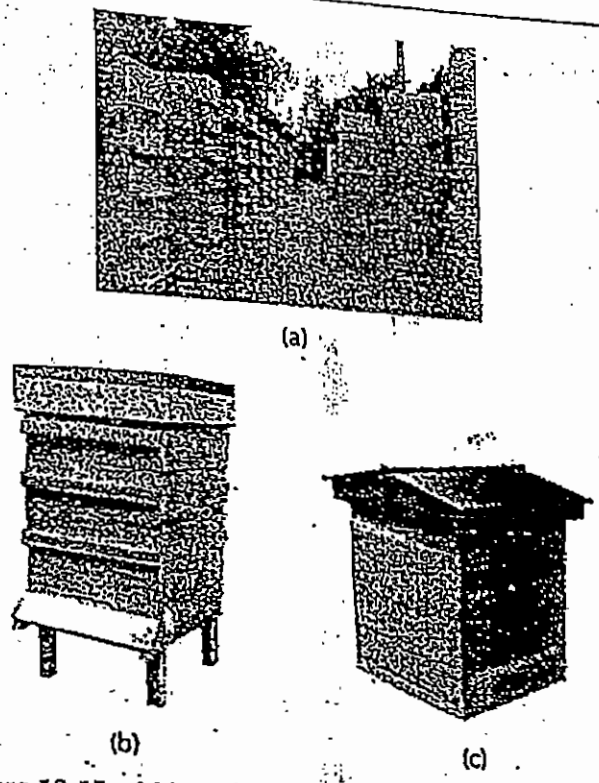


Figure 10.15 (a) Wooden Bee-hives, (b) Langstroth hive, (c) National hive. (Courtesy: ANP, Delhi; Bee-hive Maker, UK.)

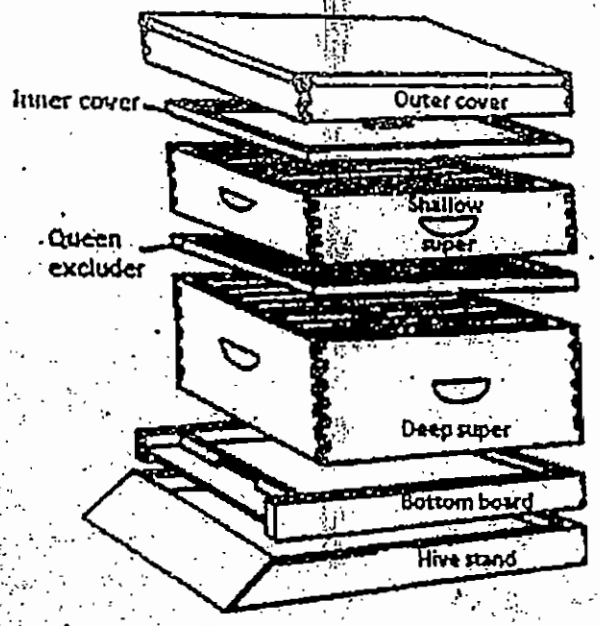


Figure 10.16 Artificial beehive (Langstroth bee box) with its components for bee keeping industry.

designed to prevent bees from attaching honeycombs where they would either connect adjacent frames, or connect frames to the walls of the hive. The movable frames allow the bee-keeper to manage the bees in a way which was formerly impossible.

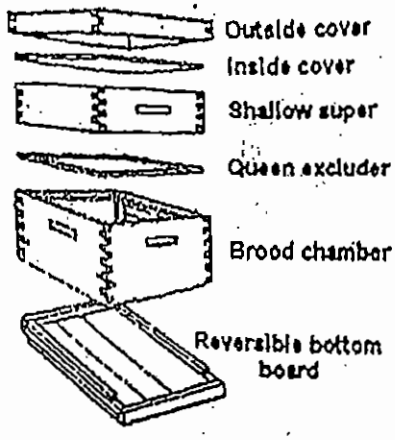


Figure 10.17 Artificial bee-hive loosened to reveal its structure. (Courtesy: The University of Georgia, College of Agricultural and Environmental Sciences.)

The National hive is the most widely used hive in the United Kingdom. It is a square hive, with rebates (grooves) that serve as hand grips. The frames are smaller than standard Langstroth and Commercial hives and have longer hand grips (or lugs).

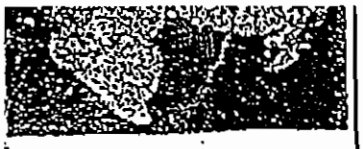
The Commercial hives are exactly the same external dimensions as a National hive, but instead of having a rebate the hive is a simple cuboid. Because of this the frames are larger and have shorter handles or lugs.

One new hive with bees and basic equipment costs about $150. The modern hive has following parts that can be assembled as well as separated (Figures 10.16 and 10.17).

Hive stand: It is a wooden stand on which the upper hive components rest. It protects the Bottom Board from rot and cold transfer. It supports the hive in slanting position so that the rain water flows down easily.

Bottom board: It is a basal plate, which is placed over the stand. It forms the base of the hive. It provides a landing board for the bees. It has two gates in front position—one for entry and the other for exit of bees.

Brood chamber (Brood box or deep super or hive body): It is the main part of hive. It is the most bottom box of the hive and is where the queen bee lays her eggs. It is a large wooden box, called a super that holds about 10 frames of comb. The inner space, called the brood nest, is reserved for the bees to rear brood and store



Sericulture

Silk Moth
(*Courtesy:* Dr. Andrew N. Herd;
A Fly Fishing History.)

Sericulture refers to the rearing of silkworms under controlled conditions for large scale production of silk. Silk has a long history of its use. It is such a fine and beautiful natural fibre that it is often referred to as the queen of fibres. Silk clothes are of great value and usefulness and give the feelings of good luck and affluence. This is the reason why there have been repeated attempts in many parts of the world for the large scale production of silk. Two different views have been mentioned in ancient literatures regarding the origin and use of silk. One view says that silk industry originated for the first time in the Himalayan region around 2000 B.C. and from there it was introduced to other parts of the world. The other view holds that it originated in China around 3000 B.C.

12.1 TYPES OF SILKWORM

Silkworms are insects which produce silk from their cocoons. Silkworms are in fact the larval stages called caterpillars of the insect silk-moth belonging to the superfamily Bombycoidea, order Lepidoptera and class Insecta. The moths belonging to families Bombycidae and Saturniidae yield silk of commerce. The following are a number of species of silk-moths which are capable of producing silk:

(1) The Mulberry Silkworm *Bombyx mori* (family–Bombycidae distribution many countries including India; name of silk–Mulberry silk).

(2) The Tasar Silkworm *Antheraea mylitta, A. paphia* (family–Saturniidae distribution–India, China and Sri Lanka; name of silk–Tasar silk).

(3) The Eri Silkworm *Attacus ricini, Samia cynthia ricini, Philosamia ricini* (family–Saturniidae; distribution–India; name of silk–Eri Silk or Arandi Silk).

(4) The Munga Silkworm *Antheraea assama* (family Saturniidae; distribution–India; name of silk–Munga Silk).

(5) The Oak Silkworm *Antheraea pernyi* (family Saturniidae; distribution–China; name of silk–Shantung Silk).

(6) The Japanese Oak Silkworm *Antheraea yamamai* (family Saturniidae; distribution–Japan; name of silk–Japanese Silk).

(7) The Wild Silkworm *Philosamia cynthia* (family Saturniidae; distribution–India; name of silk–Wild Indian Silk).

(8) The Himalayan Silkworm *Antheraea roylli* (family Saturniidae; distribution–India; name of silk–Himalayan Silk).

(9) The Giant Silkworm *Attacus altas* (family Saturniidae; distribution–India, Malaysia; name of silk–Giant Silk).

Out of a number of species of silkworm only four, viz., Mulberry, Tasar, Eri and Munga Silkworms are commercially exploited now-a-days.

12.1.1 The Mulberry Silkworm [*Bombyx mori* (Family–Bombycidae)]

It is a well known silkworm of commerce. The insect has been introduced from China into many parts of the world and is now widely domesticated. It is reared on mulberry plant for its silk which may be white or yellow in colour. The *silkworm gut* is the dried silk extracted by desiccation from the silk glands of larvae.

12.1.2 The Tasar Silkworm [*Antheraea paphia, A. mylitta* (Family–Saturniidae)]

This silkworm is commonly found in India, China and Sri Lanka. They do not mate in captivity and so they cannot be domesticated. Therefore, the cocoons have to be collected from the host trees in the forest. The silk is reelable and hence the pupae have to be killed before emergence of the adult to prevent cutting of the silk thread into pieces. It is a wild variety and hence M.P., Orissa, Andhra Pradesh, Maharashtra, Bihar, Karnataka and West Bengal containing large forest area are the suitable states for cultivation of tasar silkworm. In forest area, it feeds well on asan, arjun, sal, ber, jamun, fig, oak, sidha, etc. The female silkworm oviposits about 200 eggs on the young leaves of the host trees. After about a week, eggs hatch into green caterpillars. The caterpillar larvae feed for about 45 days. The last instar larvae undergo pupation and spin cocoons which hang from terminal branches. The pupation period is about 30 days. It is uni- or bi-voltine.

12.1.3 The Munga Silkworm [*Antheraea assama* (Family–Saturniidae)]

It is semi-domesticated multivoltine species. It is extensively cultivated in Assam and is a potential source of cottage industry. The caterpillars feed on the leaves of som (*Machilus bombycina*) and soalu (*Litsaea polyantha*) plants.

12.1.4 The Eri Silkworm [*Samia cynthia ricini, Attacus ricini* or *Philosamia ricini* (Family–Saturniidae)]

It is a multivoltine species producing 4–6 crops per year. It is commonly reared in Assam, Bengal, and Kerala in India and in East Asia. It is reared on castor (*Ricinus communis*). The caterpillars consume castor leaves. The caterpillars are green in colour. Before pupation it constructs a loosely spun cocoon. The silk which is locally called arandi silk is white or brick-red in colour, durable but not glossy. As there are more than one strands of silk, they are not reelable and have to be spun like cotton. The fertilized moth lays about 120–200 eggs in clusters. Eggs hatch after 7–10 days. The larval period ranges between 16–25 days. Thereafter, it makes cocoon and pupates anywhere on the host plant. After emergence of the adult moth, the cocoons are soaked in cold water for 18 hours and in the warm water for 45 minutes, washed in washing soda solution, dried and spun into silk. It has been observed that 7g of eggs produced 400 larvae that yield about 1 kg. of silk after consuming leaves from about 1250 m^2 of castor crop.

12.2 LIFE HISTORY OF *BOMBYX MORI*

Bombyx mori is cultivated widely in many parts of the world. In India it is mainly cultivated into Kashmir, Karnataka, Tamil Nadu, West Bengal and Punjab. Depending upon the climatic conditions, the mulberry silkworms are classified into univoltine (one generation of crop per year), bivoltine (two generations of crop per year) and multivoltine (more than two generations of crop per year). Univoltine race produces good quality of silk and is cultivated in Jammu and Kashmir and Punjab in India and Europe. Bivoltine and Multivoltine races, on the other hand, produce inferior quality of silk and are found in West Bengal, Assam and South India.

The unisexual adult moth which has just come out of cocoon is about 2.5 cm in length. The female is slightly larger and heavier than male and hence, cannot fly. Their body colour is creamy. Head, thorax and abdomen make the body. Head bears paired compound eyes, paired branched antennae and siphoning type of reduced mouthparts. Hence, they are unable to feed during the very short life span of 2–3 days. Thorax has three pairs of small legs and paired fore-wings and hind-wings. The wings are weak and membranous. Abdomen is very much swollen due to the presence of large number of eggs. Mating occurs soon after emergence and it continues for 2–3 hours. It is followed by fertilization which is internal. The mated and fertilized female lays about 300–500 eggs

within 24 hours of mating. The eggs are laid in clusters on the surface of mulberry leaves and are covered with gelatinous secretion by which they are also attached with the leaves. The eggs are small about 1.0–1.5 mm in length, dull white in colour and are referred to as seeds. The number of eggs laid is directly proportional to the quality of nutrition, i.e., the quality of leaf of mulberry taken by the caterpillars during feeding.

Depending upon the climate, the eggs are of two types. The diapause type of eggs is laid by the silkworm living in temperate (cold) regions. As these silkworms are under diapause during most of the year and their development takes place during spring, so only one generation is produced in a year. During diapause all the vital activities of the eggs are suspended. The non-diapause eggs are laid by the silk worms living in tropical and sub-tropical (hot) regions like India. As these eggs grow and develop after laying, so more than one generations are produced in a year.

Hatching occurs at the end of incubation period of 8–12 hours. The eggs hatch into caterpillar larvae. The young caterpillar larvae are about 3 mm long and feed greedily on young leaves of mulberry. The full grown caterpillar attains a size of about 75 mm, which is 25 times of the original size. During this period of about 25 days, it moults four times. The full grown caterpillar is a long, roller-shaped, dull white in colour with a small anal horn. The full grown caterpillar develops salivary glands, suspends feeding and undergoes pupation. Pupation occurs inside the pupal case known as cocoon. The salivary glands, also called silk glands, secrete silk protein fluid through spinneret, a narrow pore situated on the hypopharynx. The caterpillar spins its silk cocoon with the help of its secretion. The two silk glands release a continuous stream of silk material mixed with a resinous substance called sericin, secreted by glands of filippi. The sericin helps sticking of the silk threads coming from the two silk glands. The silk strand coiled around the cocoon in concentric manner which is accomplished by the constant movement of the head of the full grown larva from one side to the other at the rate of about 55–65 turns per minute. Spinning of cocoon takes about 3–4 days. The cocoon which is white in colour, is made from a continuous strand of about 1000–1200 m in length secreted by the silk glands of caterpillar larva. Pupation occurs insido the cocoon. Pupae of silk worms are called chrysalis. After 12–14 days the pupae are metamorphosed into the baby insect called imago. As soon as this imago develops into the adult, it secretes an alkaline secretion containing a protein digesting enzyme *cocoonase* which dissolves the silk protein of cocoon at one end. Now the adult silk worm pushes its head through this end and comes out from the cocoon (Figure 12.1 Life cycle).

12.3 SERICULTURE—THE COMMERCIAL SILKWORM KEEPING

Sericulture is the practice of rearing of silk worms for procuring silk on commercial scale. The whole practice is completed under the following steps.

12.3.1 Growing of Food Plants

Bombyx mori feeds on the leaves of mulberry. Mulberry is a deciduous medium sized tree (Figure 12.2). It belongs to family Moraceae. Different varieties are available and the quality of silk depends on the type of variety. The plants can be grown in every soil and in every climate. It is multiplied by cuttings and seeds. The two species of mulberry are *Morus alba* (toot) *and Morus indica* (shah toot).

12.3.2 Selection of Silkworm

Suitable strain of silkworm is selected according to the climatic conditions of the place of rearing of silkworm.

12.3.3 Tools and Materials

Different types of tools and materials are required for sericulture.

Machana

The suitable place for silkworm rearing is called machana.

Chopping knife

It is needed to make small pieces of mulberry leaves.

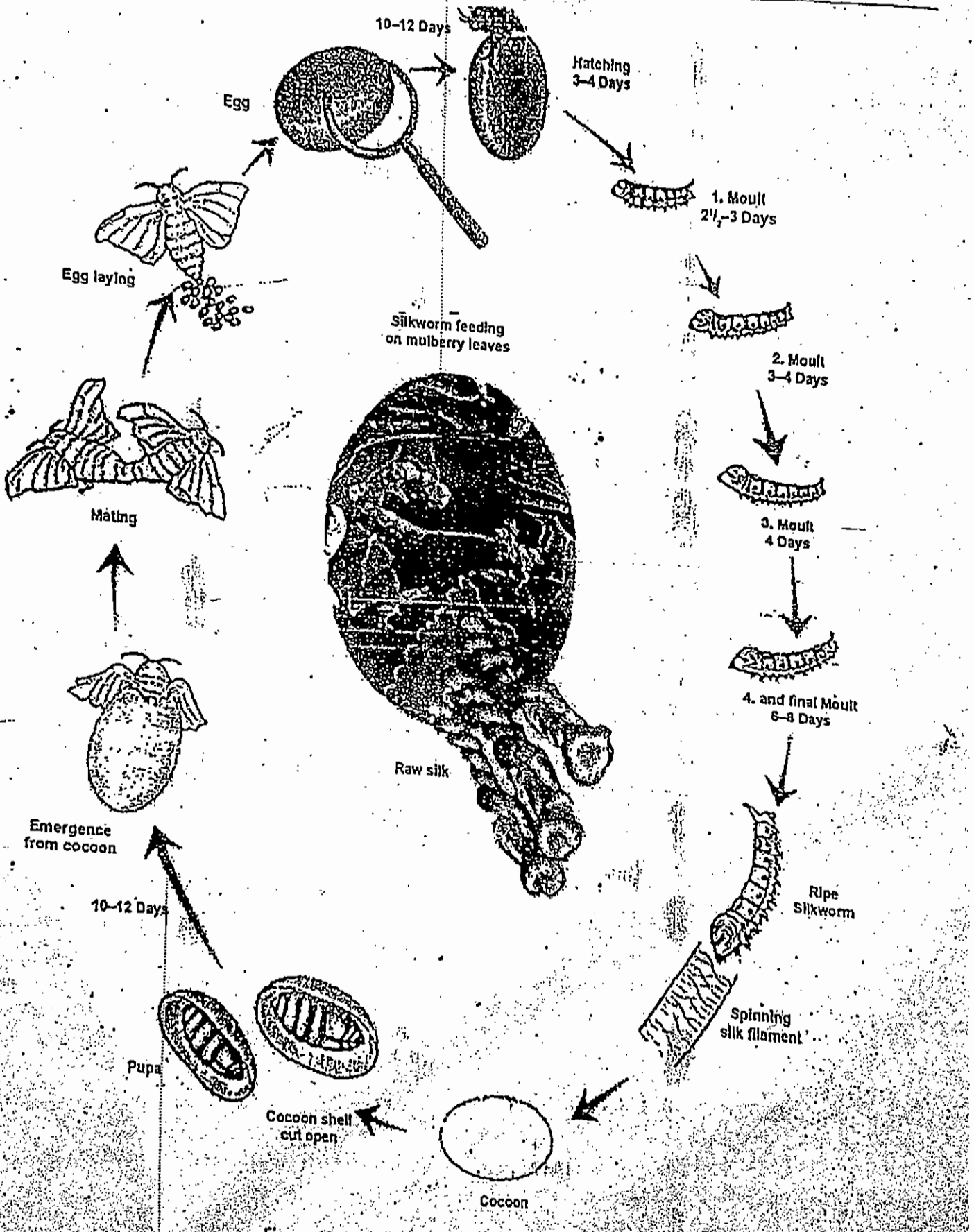
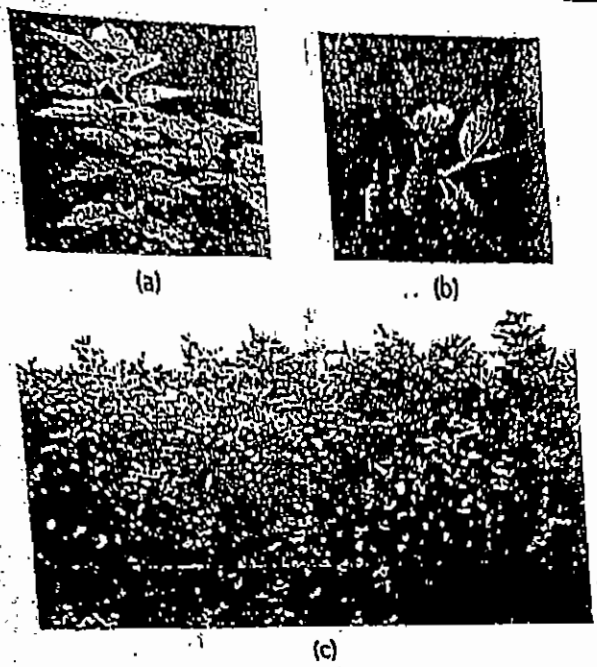


Figure 12.1 Life cycle of Silkmoth (*Bombyx mori*).



(a) (b) (c)

Figure 12.2 (a and b) Mulberry leaves and fruits. (c) Mulberry cultivation. (Courtesy: Department of Sericulture, Tamil Nadu Agricultural University, and Coimbatore.)

Basket

These are bamboo baskets required to collect mulberry leaves.

Rearing trays

These are trays made of split bamboo to keep the laid eggs with fine cut mulberry leaves.

Rack

These racks are made of bamboo to keep the rearing trays containing various stages of the caterpillar. Ant-pans are kept at the base of the legs of the rack to make it ant proof.

Spinning tray or Chandraki tray

The tray is a circular basket with spiral wall for keeping the full grown caterpillars for pupation. The tray helps the worms to attach their cocoons to the wall of the tray.

Refrigerator

The refrigerator is needed for storing the eggs or seeds for next generation.

Oven

The oven is required to control the growth of different stages of life cycle at different temperatures.

Thermometer

A thermometer is needed for reading the temperature of the room.

Hygrometer

A hygrometer is required to find out per cent humidity in the atmosphere.

12.3.4 Grainage Management

Grainage is the place for commercial production of seeds (eggs) of silkworm. Grainage management is done to ensure good quality of seeds to sericulturists. Grainage management is done in the following ways.

Selection of cocoon

Large and healthy cocoons are selected during harvesting season for the next crop. These cocoons are kept in well ventilated room at a constant temperature of 25 °C and at 75 per cent humidity. They are spread as a single layer in the trays arranged in racks.

Segregation of sex

After selection, cocoons are segregated on the basis of sex by cutting one end of the cocoon either manually or by machine. This is done prior to moth emergence at pupal stage to avoid self breeding.

Mating

The adult male and female moths emerge after fifteen days of cocoon formation. In order to avoid self breeding, healthy adult moths of different races are allowed to mate. Mating is completed in about 6 hours. The males are now separated. The separation is done by holding the female and twisting the male softly so that the external genitalia of the female is not injured. The males can be provided rest and employed for second mating. After first mating, the male moths can also be stored at low temperature of 7–10 °C (Figure 12.3).

Egg production

Eggs (seeds) are produced by cellular bag method, cellular card method, flat card method and loose eggs method. Ripe healthy cocoons are selected for mating and production of eggs. Many long strings of cocoon masses can be observed suspended on strings in the seed station. Within the prescribed

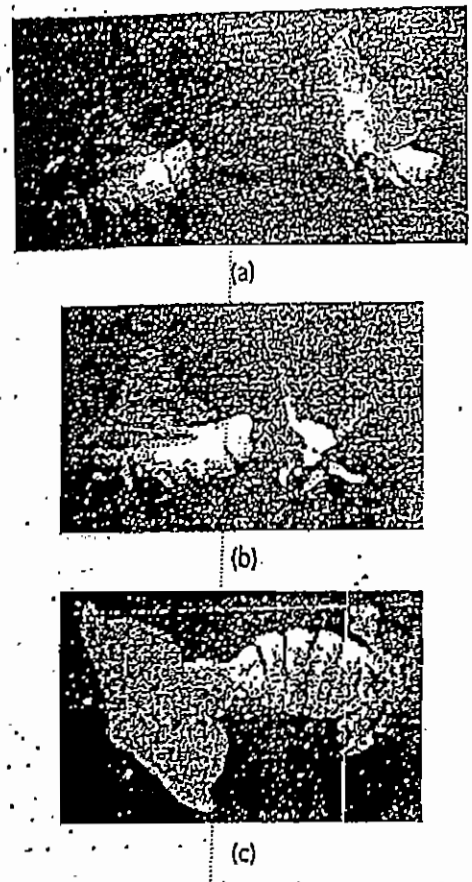


Figure 12.3 (a–c) Pheromone plays its role in mating. (Department of Entomology, University of California, Davis.)

period of time the moths emerge and are segregated into males and females. For the purpose of mating females of one strain are kept with the males of another strain. Usually the mated female moths are kept in sterilized linen bags with their mouth tied. These bags are hung from the ceiling. Within a very short period of time the mated females lay eggs inside the bags and die. The eggs are collected and washed several times and examined for infections. The good quality eggs are kept for incubation. These quality eggs are also supplied to farmers as seeds for the rearing of silkworm (Figure 12.4).

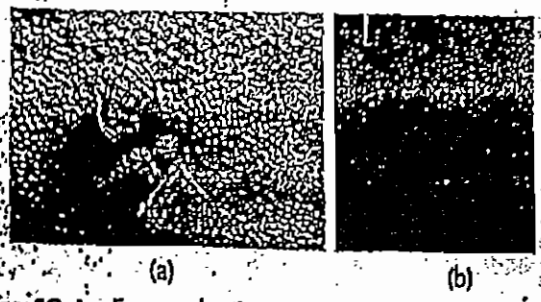


Figure 12.4 Egg production: (a) A female silk moth laying eggs. (b) Eggs of silk moth enlarged. (*Courtesy:* Dr. Kevin Wanner, Department of Entomology, University of Illinois, Urbana.)

Incubation and hatching of eggs

The incubation period is 8–12 days depending on the prevailing temperature. For incubation eggs are spread evenly in sterilized trays and put in incubators at 4 °C. The eggs are moved at regular intervals by a feather for 100 per cent uniform hatching. For good hatching of eggs (seeds) more efficient methods have been developed in which eggs are collected and kept with mulberry leaves, working as stimulant, for hatching in shady places on white sheet of paper in insect proof trays on a stool. The legs of the stool must be kept in water to avoid reach of insects.

The incubation is planned after assuring the availability of mulberry leaves, normally when the mulberry buds break into leaf. When the leaves are not available, the eggs are kept in diapause conditions. These eggs are supplied to the farmers. Farmers are also supplied with second instar larvae for rearing. Supply of eggs and second instar larvae depends on the experience of rearers.

Rearing of larvae

After hatching, the caterpillars are 5–7 mm in length with rough wrinkled and greyish coloured body. The body consists of 12 segments divided into head, thorax and abdomen. The head is provided with mandibulate mouth-parts for feeding. The thorax has three segments each with a pair of true jointed legs. The abdomen is 10 segmented. The third, fourth, fifth, sixth and tenth segments are provided with pairs of unjointed pseudolegs. The eighth segment has a short dorsal anal horn. There are series of spiracles on lateral sides of abdomen.

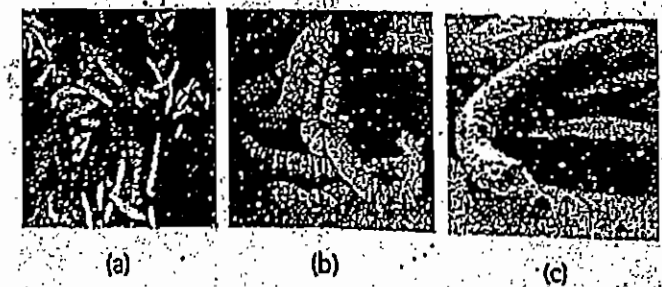


Figure 12.5 (a–c) Silkworms feasting on mulberry leaves. (*Courtesy:* Fastily at Wikipedia commons, 2008; Lesley, ozwildlifestudio.)

The caterpillars are placed in rearing trays/ feeding trays containing a layer of uniformly distributed finely chopped tender mulberry leaves. Rearing trays containing just hatched larvae are

covered with perforated paper. The tender and finally cut mulberry leaves are placed over the paper. The young larvae emerge out through the pore on the paper and feed. Rearing is done in special room or cabin with a temperature of 27°F and moisture 60–70 per cent. The caterpillars move on the leaves in a peculiar looping pattern. They feed voraciously upon the mulberry leaves and grow fast. For the first 2–3 days, rearing trays are cleaned and the leaves are replaced every 2–3 hours. From the fourth day the caterpillars are fed washed full leaves. The larvae undergo four moultings and before each moulting the larvae stop feeding. The maturity is reached in about 45 days after hatching. The mature catorpillar measures about 7–10 cms in length. The mature larvae develop a pair of salivary glands (silk glands) (Figures 12.5 and 12.6).

Figure 12.6 Feeding trays containing silkworms. (*Courtesy*: The Forgotten Village.)

Cocoons of silkworm

Pupae Male silkmoth Female silkmoth

Figure 12.7 Cocoons, pupae and adults. (*Courtesy*: Department of Entomology, University of Illinois, Urbana.)

Production of cocoon

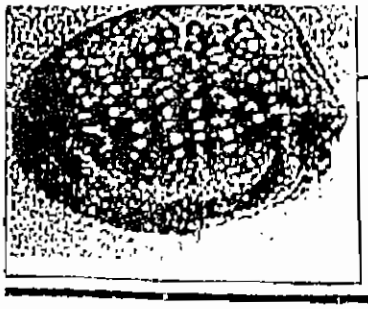
When the mature caterpillar larvae stop feeding on the mulberry leaves and exhibit lifting and moving its front part of the body in a circular fashion they are transferred to spinning trays containing dry leaves, twigs and straws for further development (pupation). The caterpillars occupy corners in the trays and start releasing the sticky secretions from the silk-glands through a very narrow pore spinneret situated on the hypopharynx. The secretion is continuous and continues for 3–4 days. After coming in contact with air the sticky secretion hardens and gets converted into a fine long and solid thread of silk. Due to the movement of larval body the thread becomes wrapped around the body of larva forming a pupal case or cocoon. By the time the secretion process is over the caterpillar larva is enclosed within an oval shaped whitish or yellowish cocoon which is hard and thick. Within 15 days the process of pupation is over and the caterpillar is changed into a brownish pupa or chrysalis. During pupation metamorphic changes occur in which abdominal prolegs are lost and two pairs of wings appear on the thorax. The cocoons are collected and preserved as soon as they are formed to get the silk of commerce. If the next crop of insects are desired the healthy cocoons are selected just after their formation and kept in cages for further development. The pupa is changed to young adult moth (imago) in about 15 days. This imago releases an alkaline fluid to soften one end of the cocoon and then escapes with force. As soon as the silk moths escape, they mate, lay eggs and die (Figures 12.7 and 12.11).

Stifling

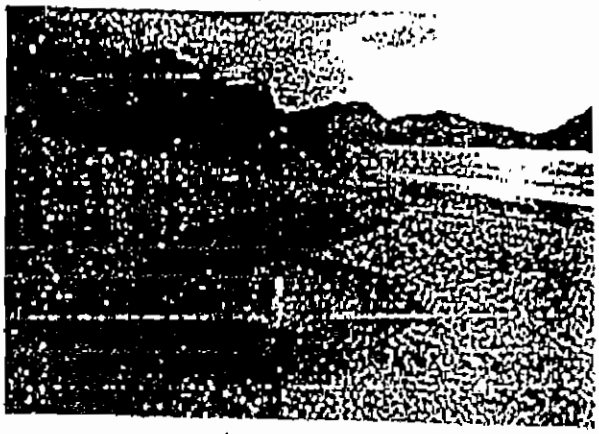
This is the process of killing the pupa present inside the cocoon. This is done to avoid cutting of silk thread into pieces by the emerging imago. The cocoons are kept over porous trays placed over a cauldron containing boiling water. The steam percolates through the pores and kills the pupa inside the cocoon. The steam also loosens the silk threads which hastens the process of removal of threads in commercial sericulture. Now, the steam treated cocoons are kept in dry places for weeks during which the killed pupa dries up.

Reeling

The process of removing silk thread from th killed cocoon is called reeling. Preserved cocoo are dipped in water in metallic vessel for abo 15 minutes and are continuously stirred with rod. This makes the unwinding process easi The boiled cocoons are now put in water. N



Pearl Aquaculture



(*Courtesy:* Hothai/cannangdongvat.)

17.1 INTRODUCTION

The credit of having earliest knowledge about pearls goes to Chinese about 4500 years back. Pearl is a small, calcareous object produced by pearl oyster. It is shining, white, and yellowish, bluish or pinkish coloured, globular in shape and about 10 mm in diameter. It is delicate in nature. Pearl is costly and has great ornamental value. Pearl can be captured from nature as well as cultured by man. The science of procurement of pearls by capturing or by culturing is referred to as Pearl Culture or Pearl Fisheries.

17.2 PEARL CAPTURE (PEARLS FROM NATURE)

17.2.1 Pearl Oysters

Pearl has animal origin and is found within the shell of an oyster called pearl oyster. Under scientific classification, the pearl oyster is known by the genus name *Pinctada*, which belongs to family pteriidae, class bivalvia and phylum mollusca. It is a small bivalve mollusc living in sea water. They occur away from the coasts, especially in undisturbed areas of the sea at a depth of 10–15 fathoms. Although a number of bivalve molluscs are capable of producing pearl under suitable climatic conditions but the good quality pearl is produced by marine forms of the genus *Pinctada*. The important marine species in this respect are *Pinctada vulgaris*, *Pinctada chemnitzi*, *Pinctada margaritifera*, *Pinctada anomioides*, and *Pinctada atropurpurea*. All these forms are available in the sea water of the country. Beisdes this, marine bivalve molluscs like *Haliotis* (Ear-shell), *Mytilus* (sea muscle), and *Placuna* spp. (windowpane oyster) also produce pearls but of inferior quality and hence, of no economic value. In addition to this, some freshwater bivalve molluscs like *Unio* and *Anodonta* also produce pearls but of inferior quality.

17.2.2 Pearl Formation

Pearl formation takes place in the warmer parts of the world and hence, pearls are recovered from warm water oceans. Pearls are commonly found in the sea water of India, Pakistan, Bangladesh, Sri Lanka, Japan, Australia, Central America (including South Pacific islands) and other coastal countries. The main natural sites of production of pearls include the coasts of Japan; Persian Gulf, the Gulf of Mannar (Ceylon), Sulusea (near Philippines), coasts of Australia, shores of Central America—Panama bay, Gulf of California, islands of South Pacific. In India the pearl oyster beds

and several other industrialists who joined the bandwagon.

After World War II, pearl culture industry was established in Australia, Philippines, Burma, Thailand, Malaysia and Indonesia, all with Japanese collaboration. In India, since late James Hornell sowed the idea of pearl culture in 1916, there has been interest and some experimental work done in Tamil Nadu since 1938 and in Gujarat, since 1958. However, success in developing the technology was achieved only in 1973 when the first batch of free, spherical cultured pearls was produced at the Central Marine Fisheries Research Institute. While research on pearl culture continued since then, it took a decade for the establishment of an industry for the production of cultured pearls in 1983.

17.6.2 Resource of Pearl Oysters

The pearl fisheries of India in the Gulf of Mannar and Gulf of Kutch have been well known for the production of the finest of natural pearls. Both are based on the species *Pinctada fucata*. The major problem with these resources has been that production in natural beds has fluctuated very wildly. Resource of such character cannot be depended upon in pearl culture for which the supply of oysters has to be on time and in required numbers. A second species of pearl oyster *P. margaritifera* has recently been suggested as a potential candidate species for pearl culture in India based on the indicative survey on mariculture potential of Andaman and Nicobar Islands carried out by the CMFRI. The species does not occur along the mainland coast in any appreciable numbers. A species which is believed to occur in the Andaman and Nicobars is *P. maxima*. Several other species such as *P. sugillata* and *P. anomioides* occur in the Indian waters but these have not been found useful in production of cultured pearls. It is obvious that *P. fucata* will form the mainstay in any pearl culture effort in India with *P. margaritifera* as supporting species when technology is worked out.

The problem has been in the area of assured steady supplies of pearl oysters. The efforts on enhancing the resource through spat collection have not been very successful. Spat collection on the natural beds of Gulf of Mannar is logistically difficult in terms of distance, depth, accessibility and security and no meaningful effort could be made so far. Spat settlement in inshore areas has been moderate but it is composed of multispecies *Pinctada* populations with a progressively declining *fucata* component as seen at Vizhinjam and at Tuticorin. The general conclusion that arises from the experimental work conducted so far is that inshore spat collection would not be of much use in pearl culture.

17.6.3 Pearl Culture

In such a situation of despair, the silver lining was the development of hatchery technology for production of pearl oyster at the CMFRI. It has been shown that over a million spat of *P. fucata* can be produced in one larval rearing in the hatchery. The technology is adoptable for any species of marine bivalve. Experimental success has been obtained with *P. margaritifera*. It is a question of rearing the spat up to the stage they can be used in pearl production programme which is one of farm management problems. Maintaining a breeding reserve of pearl oysters in the Gulf of Mannar and Sea-ranching of pearl oyster from hatchery to the natural beds to see the possibility of reviving the pearl oyster population are some other options, which are being tried to overcome the limitations.

17.6.4 Technology of Pearl Culture

For over half a century the technology of pearl culture has not undergone much change from the basics of cultured pearl production. Till late 1960s when the pearl crash occurred after 1966, even the need for change was not recognised at the farmer's level. Subsequently there has been overwhelming interest in experimental work in two directions, namely genetic improvement of stocks and tissue culture of mantle. The application of mantle tissue culture in production of cultured pearl has already commenced.

The techniques of farming and pearl production developed in 1973 continue to remain the basis of pearl culture. There is need for change and improvement in technology along modern lines if pearl culture in India is to be competitive.

17.6.5 Infrastructure and Manpower

Pearl oyster farming is the major component of the activities of pearl culture. This is a continuous operation with rafts, longlines or bottom platforms

17.6 INDIAN PEARL INDUSTRY-PROBLEMS AND PROSPECTS

17.6.1 Introduction

When Kokichi Mikimoto took the small step forward, in 1893, by producing a few blister pearls in the Japanese pearl oyster *Pinctada martensii* (= *P. fucata*) at the coastal village of Jinmiyonmura on Ago Bay, a new industry of pearl culture was born. As he was building up a small-scale industry, a few marine scientists and technicians got themselves interested in it and, in 1907, Tokichi Nishikawa produced the first spherical cultured pearl in the oyster. Subsequently, the credibility of cultured pearl as jewel was established in the 1920s and was followed by a boom of pearl culture industry with a master touch of Mikimoto

[illegible] on both eastern and western coasts at depth of about 20 m and at a distance of [illegible] km from the shore. But the east coast is more extensive and productive than the west coast. The best quality of pearl called Lingha Pearl is obtained from these pearl banks. The pearl oysters inhabit the coral reefs and the ridges of rocks. In India the major sites of pearl fisheries include Gulf of Kutch, Gulf of Mannar, Kanyakumari, Rameshwaram, Bay of Bengal, Pak Bay, Barodu, Tuticorin, etc. Tuticorin, the most productive region on the east coast lies in the Gulf of Mannar/Palk strait.

According to the widely accepted view pearls are the result of stimulation caused to the mantle by the entry of foreign objects. Pearl formation in nature takes place when a minute foreign object such as sand particle, insect, larva or any other similar object reaches in between the shell and the mantle. Subsequently, the foreign body gets enclosed in a sac of mantle epithelium. The foreign body stimulates the mantle epithelium to secrete nacre around it. The nacre is deposited in concentric layers around the foreign particle. As soon as these layers of nacre dry and harden the pearl is formed. The pearl size is dependent upon the degree of stimulation caused by the foreign particle and the time taken for the formation of a pearl of average size is 3–5 years (Figure 17.1).

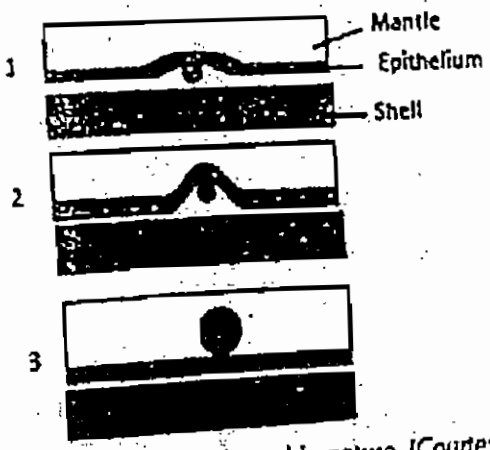


Figure 17.1 Formation of pearl in nature. (Courtesy: gemologyproject.)

17.2.3 Fishing of Pearl Oysters and Procurement of Pearls

The fresh-water molluscs are also known to produce pearls but they are of poor quality. Therefore, marine pearl oysters make the chief source of pearls. Marine pearl oyster are found attached to the rocks or dead coral reefs at a depth of about 18–25 m and at a distance of 15–20 km from the shore. When the pearl oysters are present in large number, such spots are referred to as pearl-beds or pearl banks. Summer is the best season for pearl fishing and the best time of collection is morning to mid-day. Divers collect the pearl oysters by going deep into water with the help of sinking stones. They collect the pearl oysters in small bags tied around their waist. The collected oysters are left at the beach for about 3–4 days to allow them for partial decomposition. As a result, shells of oysters can easily be removed by hands. The shell-less and partially decomposed oysters are rinsed more than once. As a result, the debris containing pearl sinks to the bottom of the container. This pearl bearing debris is now washed many times to release the pearl from the debris. Eventually the pearls are collected.

17.3 PEARL CULTURE (PEARL BY MAN)

Pearl culture refers to the practice of rearing pearl oysters to obtain pearl from them by artificial means. Pearl culture was first started in Japan. Kokichi Mikimoto (1858–1954) has the honour of being the father of pearl industry in Japan. In 1894, he produced the first pearl by using artificial techniques. At present the pearl industry is an established industry in Japan. Some other countries are also engaged in pearl culture at large scale.

Pearl culture is done in natural climatic conditions in sea water under suitable depth and temperature. The fundamental concept of pearl culture is to put some foreign particle between the shell and the mantle of the pearl oyster and allow the oyster to irritate and secrete nacreous layers around the particle to get it transformed into pearl. Two methods are adopted in the surgical impregnation of the foreign particles in the oyster. In the old method, the foreign material is inserted between mantle and shell into a pocket of mantle referred to as pearl pocket. Hence, a hole is made in the shell and the foreign material is introduced. As the result of this technique is not satisfactory, hence, it is not preferred. The new method is good and is referred to as the grafting method or nuclear insertion method. In this method, a calcareous substance designated as nucleus is

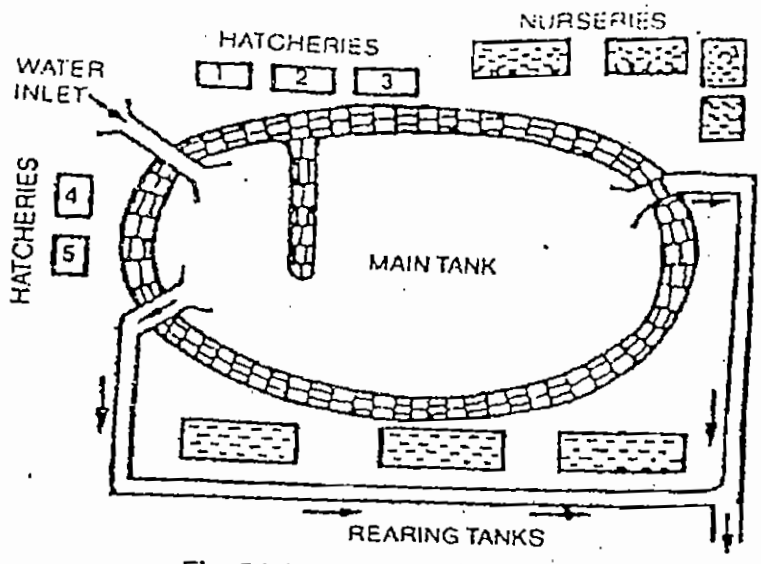


Fig. 34.1. Plan of a Fish Farm

(i) Hatching pits –

It is also called as spawning pond. These are small tanks, usually of 2.5 X 1.25 X 0.75m are used for hatching fertilized eggs, and are located near the riverine collection grounds. Continuous but slow flowing water is desirable for aerating the eggs. The tanks are fixed up with *happa* of size 2 X 1 X 0.5m made of cheap coarse cloth and mosquito curtain cloth is fixed up. The spawn is collected in the *happa* where the hatching takes places. Maximum numbers of hatching pits are upto 6.

(ii) Nursery ponds –

These ponds are 15 X 15 X 1.5m in size and may be seasonal, so that they dry up during summer. Young fry about 3-5 days old are transferred from spawning ponds to nurseries, where they remain for about 30 days. This helps in eradication of fish enemies and in increasing productivity. In this pond the fry develops into fingerling size. The main objective of constructing nurseries is to create suitable conditions of food availability. The nursery pond fills with water in 10 days, and there should be a change of water in not more than 5-10 days. A constant flow of water is desirable.

(iii) Rearing ponds – 0.2 ha. small body preferred.

These ponds may be seasonal or perennial and are used for rearing advanced fry for 2-3 months. Theses ponds are made long and narrow, gently sloping to facilitate netting operations and the size of 90 X 30 X 4m. The rearing ponds form second phase of carp culture and are used for growing spawn, fry and fingerlings by providing more space and food so that reach the latter size as early as possible. The rearing period may be varying from 2-3 months. Their number may be upto 12.

(iv) Stocking ponds – is rearing of adult.

These ponds are fairly large perennial ponds more than, about 6 feet deep. Their size may be 300 X 88 X 6 feet deep. These ponds are long in size due to that netting is easily possible. A fish form may also have quarantine ponds (for the treatment of fishes), marketing ponds.

2. Fish farm management

The productivity of the pond depends upon its soil base, and can be greatly enhanced by

(1) Controlling the vegetation

All undesirable plants and weeds must be removed regularly by using various methods of weed control. The vegetation may causes problems of predatory animals, and minerals from the water. Vegetation also causes silting of the pond and mud accumulation.

(2) Cleaning the pond bottom

Pond should be emptied, dried and cleaned to maintain its usefulness. Cleaning and dried process of pond play an important role in removing the unwanted parasitic animals and their larvae's from the pond bottom.

(3) Liming

The first step in fertilization of a pond is the application of lime. Quick lime is generally used. It raises the pH of the water and acts as antiparasitic substance. Liming should be done when the pH is too low (acidic), soil is too muddy, organic matter too high. A dose of 100-200 kg/ha is sufficient. Generally, lime spread on the pond bottom, 10-15 days before stocking the pond with fish. Liming improves the pH of pond's soil and is restored to almost normal i.e. between 7.0 to 9.0.

(4) Fertilization

The natural productivity of a pond can be increased by using fertilizers which provides the nutrients, vitamins and minerals. Fertilizers may be organic or inorganic. The process of fertilization increases the productivity by increasing natural food. Superphosphates are used in many countries to raise the production of fish. Inorganic nitrogenous fertilizers used in a fish pond are sodium nitrate, ammonium sulphate, ammonium nitrate, ammonium carbonate, urea etc.

Inorganic fertilizers cause phytoplankton blooms, and heavy growth of zooplankton. Inorganic fertilizers like phosphorus and nitrogenous fertilizers is effective in producing algal blooms. Organic fertilizers are mainly excrements from farm animals such as cattle, pig, goat, sheep, horse and poultry fertilizers carry almost all the nutrients required by the fish and stimulate the growth of zooplanktons and phyto-planktons. The advantage of applying organic manure is to improve the soil structure, water holding capacity, drainage, and Base Exchange capacity and also to check soil erosion.

(5) Cleaning the pond bottom

Pond should be emptied, dried and cleaned to maintain its usefulness. Cleaning and dried process of pond play an important role in removing the unwanted parasitic animals and their larvae's from the pond bottom.

(6) Eradication of Predatory and Weed Fishes

A large number of species are predatory and eat away the fry of fishes. Predatory and weed fishes can be removed from all ponds by the using different method --

(a) Repeated drag netting (b) Fishing out with hooks and line (c) Draining out and drying the pond (d) By poisoning the water

(7) Control of Physico-chemical factors

All the physico-chemical parameters of the water should be thoroughly checked and corrected during total period of cultivation. This is necessary because their concentrations may alter depending upon the environmental conditions. The pH of the pond water may change according to the environmental/seasonal conditions which affects the oxygen level of the pond water.

(8) Control on fish diseases

Fishes are more susceptible and prone to diseases, because the favorable conditions for introduction and spread of diseases. Pond water gets easily polluted from unused food, and decomposing organic matters, leading to rapid unhygienic conditions. Abrupt fluctuation in temperature, pH etc., all these conditions favorable to quick spread of diseases in fishes. Diseases of fishes may be grouped into three types:

1) Nutritional diseases

2) Diseases due to intrinsic causes

3) Diseases caused by parasites and pathogens

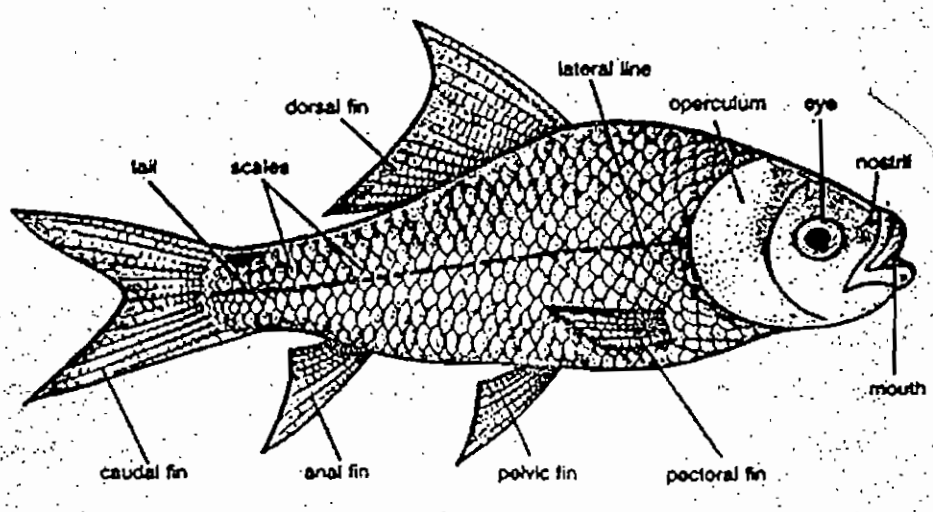
These all diseases are controlled by giving different types of treatment of the pond water and fishes.

13) *Catla*:

Phylum	**Chordata**
Superclass	**Pisces**
Class	**Osteichthyes**
Order	**Cypriniformes**
Genus	*Catla*

Distinguishing characters:

1) It is commonly known as **Katla** in Hindi. It is a largest Indian Carp, commonly found in freshwater. 2) Body is deep, stout with broad snout. Mouth is large, provided with prominent lower lip and large gill apparatus. 3) The colour is grayish on the dorsal side while silver on the ventral side. 4) Dorsal profile is more in convex in comparison to the ventral one. 5) Dorsal fin is quite large and caudal fin is bilobed. 6) Scales are pink in the center of dorsal side and whitish below. 7) Eyes are large situated in the anterior half of the head. 8) Dorsal fin is quite large. Caudal fin is bilobed. 9) Air bladder is large consists of two parts- anterior and posterior. 10) It is commercially important food fish and can be grown in polyculture system.



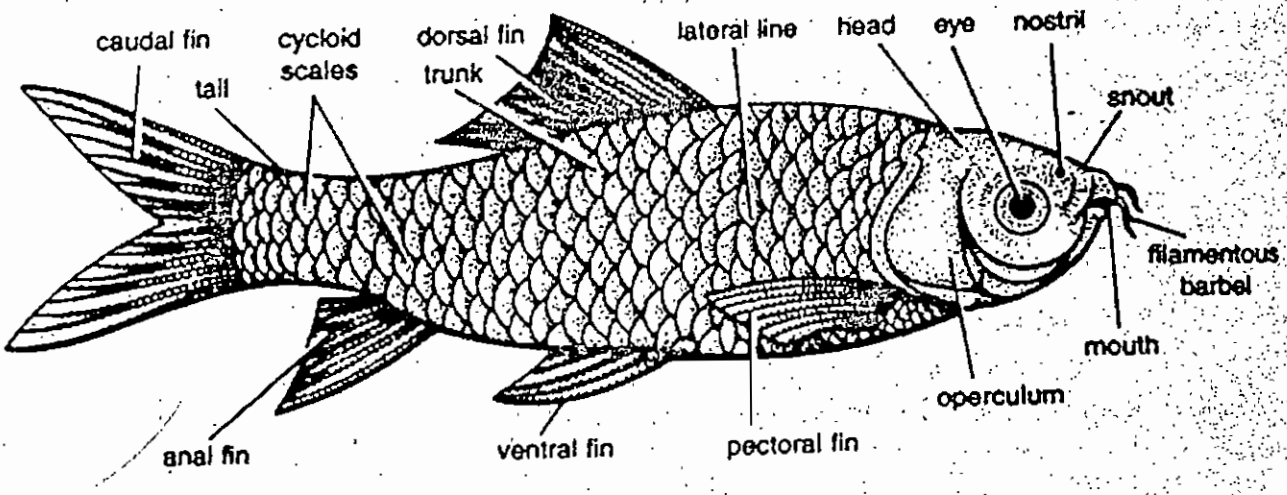
Catla

14) *Rohu*:

Phylum	**Chordata**
Superclass	**Pisces**
Class	**Osteichthyes**
Order	**Cypriniformes**
Genus	*Labeo*
Species	*rohita*

Distinguishing characters:

1) *Labeo rohita* is commonly known as **Rohu** in Hindi. 2) Body is elongated, spindle shaped, with grey colour on back and silvery white on the two sides of the body. 3) Fully grown adult measures about 1 meter in length and about 4 k. g. in weight. 4) Scales are large, orange to reddish in colour in the center and are cycloid type. 5) Head is prominent with blunt snout. 6) Mouth is large transverse aperture bounded by thick and fleshy lobes. 7) Trunk is thick. Lateral line is present on either side of trunk and tail. 8) Trunk bears single dorsal fin, one pair of pectoral fins and pelvic fins. 9) Tail is laterally compressed and has homocercal caudal fin. 10) Air bladder is large consists of two parts- anterior and posterior. 11) Very popular fish for its excellent taste and flavor and can be grown in polyculture system.



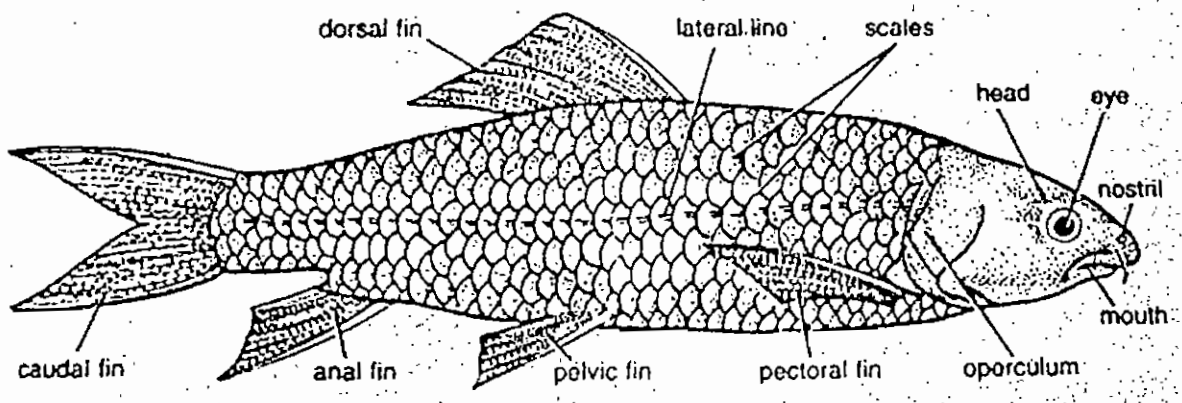
Rohu

15) *Mrigal*:

Phylum	**Chordata**
Superclass	**Pisces**
Class	**Osteichthyes**
Order	**Cypriniformes**
Genus	*Cirrhina*
Species	*mrigala*

Distinguishing characeters:

1) It is commonly called **mrigal** and is freshwater carp of India. 2) The body is elongated and compressed and measure about 66 to 68 cm with 1.4 to 2.8 k.g. in weight. 3) The body is silvery but dark gray along back. The body is covered by large cycloid scales but absent on heads. 4) The mouth is wide and lips are thin. 5) Snout is rounded. 2 to 4 small barbles situated inside the fold of lips. 6) Pectoral, pelvic and anal fins are orange with black tips. 7) Caudal fin is strongly forked. 8) Lateral line is clear. 9) Upper margin of the body is concave particularly in the posterior side. 10) Economically very important as a tasty and delicious fish and can be grown in polyculture system.



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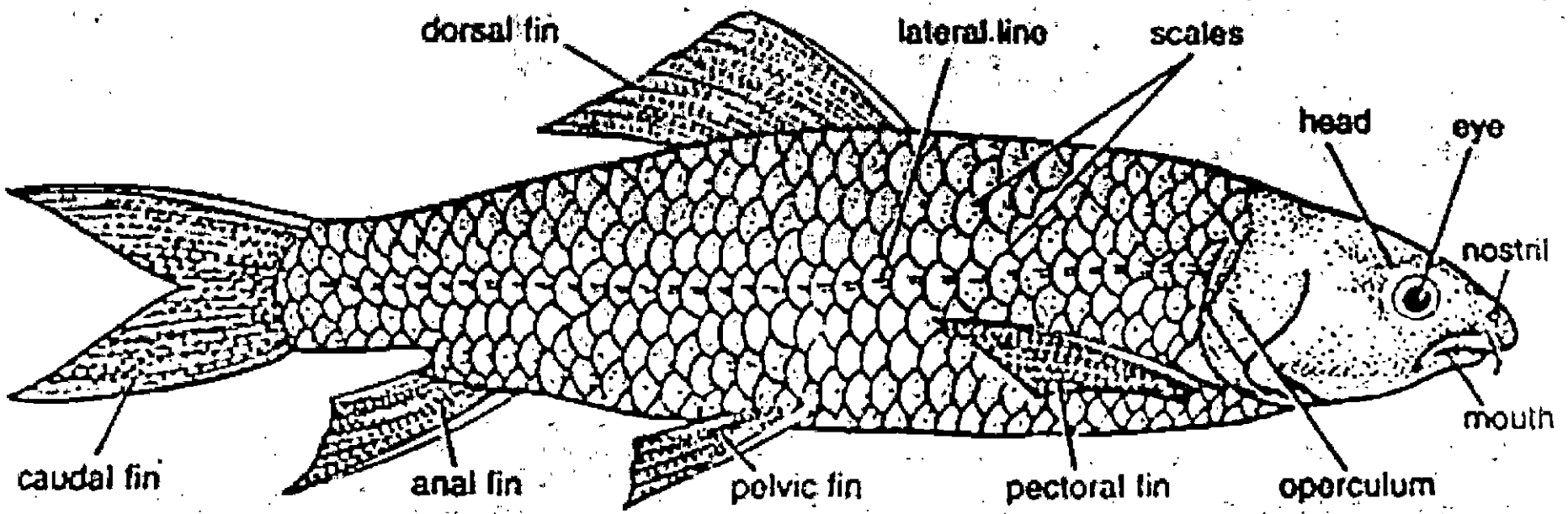
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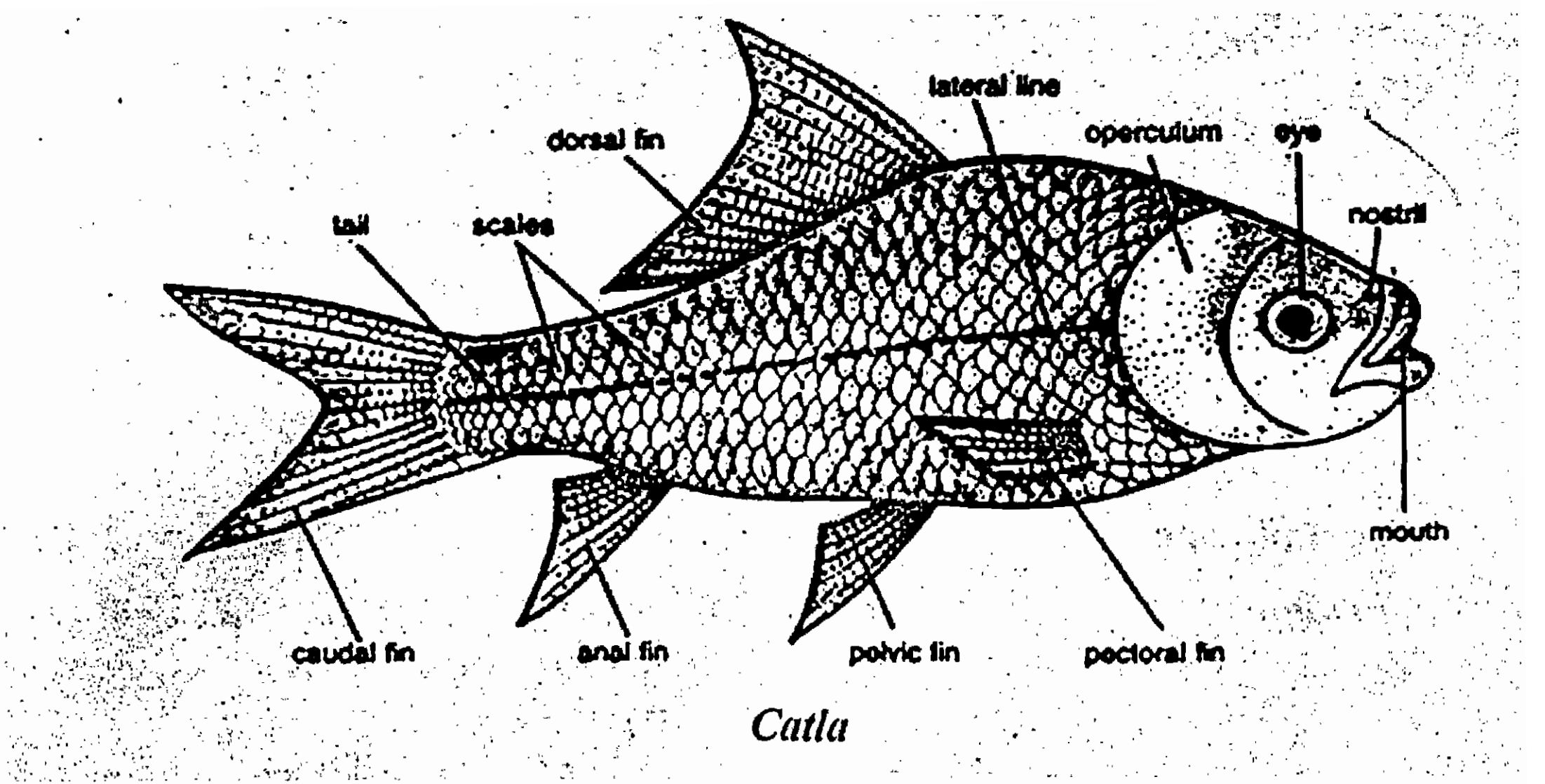
pelvic fin
pectoral fin
operculum

Mrigal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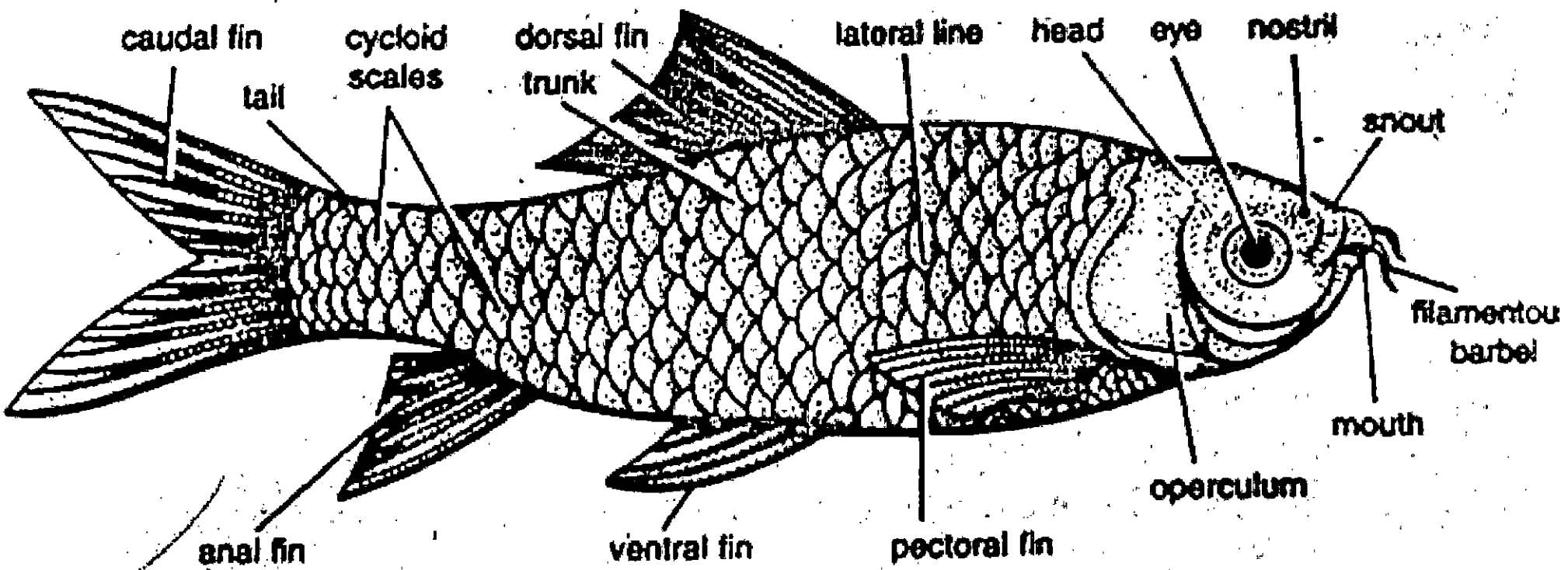
Catla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ventral fin
anal fin

Rohu

4.4 Vermiculture and Its importance

Introduction:

Vermiculture is scientific culturing or **rearing of earthworms.** Rearing of earthworm is done to obtain good quality of bio-fertilizer or compost called **vermicompost.** Apart from this they are also used for recycling of organic industrial wastes and as a protein food for poultry and fishery industry. Earthworm belongs to **phylum-Annelida, class-Oligochaeta** and **order-Neooligochaeta.**

Habit and Habitat of Earthworm:

It lives in soil of forest, grassland, gardens, plant-nursery, crop farms etc. Ecological factors like pH, moisture content, salinity and temperature play important role in the habitat of earthworm. It is active day and night silently and feeds on organic material present in soil. Worms tunnel (burrows) deeply in the soil ad brings the subsoil on the top. By doing this it mixes different soil components and atmospheric oxygen making soil fertile. Earthworm consumes the soil organic

material and converts it into rich humus. Earthworm secretes sticky substance called slime to keep its skin moist. Slime contains nitrogen, making soil rich in nitrogen which is important for plants.

General information about Earthworm:

Earthworms are terrestrial annelids, with external and internal metameric segmentation. It has a long and cylindrical body. They lack any appendages and suckers. They have a few hook-like setae on all segments except the first and the last one. Setae are useful for holding the object and locomotion. Earthworms are hermaphrodite. They are coldblooded animals. They produce cocoons in which fertilisation and development of embryo takes place. Earthworms mainly feed on dead organic matter which generally does not occur abundantly in soil. As a result, they tend to swallow large quantities of soil for extracting sufficient nourishment from it. Ii is estimated that in one acre of land, there can be more than one million earthworms.

Useful species of Earthworms:

There are around 1800 species of earthworms but only few species are used in vermiculture. Few factors such as conversion ratio i.e. rate of converting organic material into vermicompost, annual cocoon production, high tolerance for varying temperatures, soil pH and moisture content are taken into consideration before selecting species for vermiculture.

Following are the most commonly used species of earthworms for vermiculture purpose:

a)*Eudrillus eugeniae*:

It is one of the widely used species for vermiculture. It is cosmopolitan but originally belongs to Africa and popularly called as "African night crawler." This species has been found to be best for vermicomposting and the production of protein meal. It has excellent growth and high conversion ratio. In culture methods, optimum temperature is 20 to 28°C of temperature. It is found in soil depth up to 15 to 22 cms with variable moisture content.

b) *Eisenia foetida*:

It is a fast growing earthworm. Their annual cocoon production is almost 35 times as compared to *E. eugeniae*. They have high conversion ratio making them suitable for vermiculture. Other factors are more or less similar to *E. eugeniae*.

c) ***Perionyx sansibaricus*** and ***Perionyx excavates***:

It is one of the best Indian species for vermicomposting. It lives in a soil up to 3 to 8 cms. Temperature range is 20 to 28 °C with varied pH. Moisture content is ranging from 20-40%. Other species *Perionyx excavates* resembles with *P. sansibaricus*. Both species are good converters of organic matter and found suitable for southern part of India. They are purely used for the purpose of vermicomposting.

d) ***Pheretima elongata*** e) ***Lumbricus rubellus*** f) ***Pontoscolex corethrurus***

Methods of Vermiculture

Two methods are followed for vermiculture:

a) Bin (container) Method. b) Windrow Method.

a) Bin Method:

1) Rearing earthworms in a container, box or waste bin is called bin method.
2) For this method light weight material such as plastic, wood, tin etc. should be used.
3) Such containers are easy to carry from one place to other.
4) The size of container should vary according to the need.
5) The ideal size is 50 cm in length, 35 cm in width and 15-20 cm in depth. 6) The bottom of box is provided with a few holes. 7) Plastic screen or net is placed on the inside bottom. This prevents the escape of worms from bottom holes but it allows excess of water to drain. 8) The container is half filled with bedding material. 9) The bedding material includes mixture of 1/3 part of soil and 2/3 part of organic materials. 10) Sources of organic materials are decayed leaves, hay, straw, rice or wheat bran, vegetable wastes, kitchen garbage, cow dung, poultry droppings, biogas sludge etc. 11) Water is added to the culture medium so as to hold 70% of moisture. 12) Bed should be loosely arranged which create good ventilation, minimizes the foul odour and give free movements to the worms. 13) The worms are placed gently on the top of the bedding and spread them evenly. 14) Worms prefer darkness hence uncovered the container for few minutes so that they move down into bed to avoid light. 15) Then bin should be covered with news paper or jute cloth or coconut leaves to conserve moisture, to provide darkness and to keep earthworms safe from enemies. 16) They should be fed regularly with fruit and vegetable wastes, kitchen wastes, cow dung etc. 17) Rock dust or black sand should sprinkle regularly along with food. 18) Bad smell indicates overloading of food. Insect flies indicate acidity. Hence allow bed to be airy. 19) If bed is proper then it will not smell. 20) Worm number will increase according to the amount of food they are fed. After reaching at particular point their number will stabilize. 21) Stir the top occasionally. The entire contents can be used as manure (vermicompost) within 3 months of treatment. 22) Set up a second vermiculture bed using a small portion of the above manure as vermiculture.

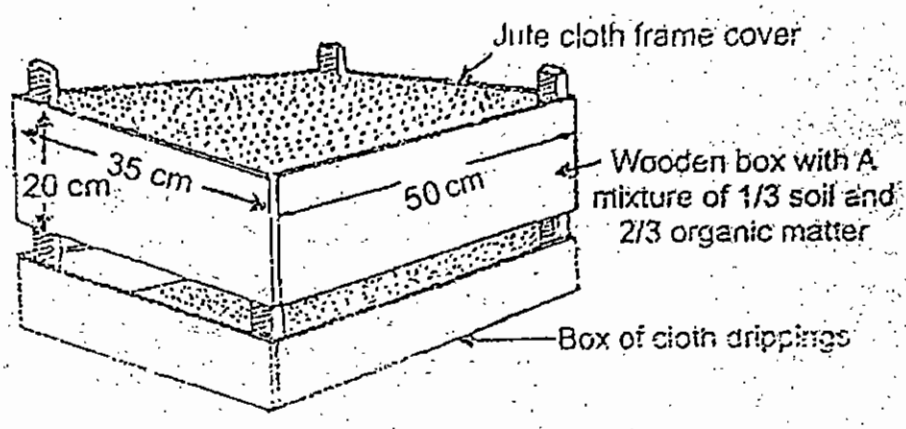

Fig. 4.13: A design of Vermiculture Wooden Box.

b) Windrow Method:

1) Rearing worms in a bed prepared on the open ground is called windrow method. 2) The beds are prepared in rows exposing to wind hence the name windrow. 3) A bedding of 5 inches height is prepared on the ground. 4) The bed is made of a mixture of domestic wastes and composted manure. 5) The bed is sprinkled with a water so as to maintain 70% of moisture. 6) The worms are gently placed on the top of the bedding and should be evenly spread. 7) About 1-2 inches of manure is fed on the top. 8) Feeding should be done at regular intervals. 9) When windrow reaches about 3 feet height, split the row along with its length into two parts. 10) A fresh bedding is added to the 1st half and a new windrow is made with the other half. 11) Windrow is fed up with wet feed materials. 12) The bedding is moisture when the top is dried out.

Harvesting (common for both bin and windrow methods)

1) After a period of three to six months the wastes are completely transformed into castings of Earthworm. 2) The casting of earthworm is nothing but its excreta. 3) These castings or excreta are extremely nutrient rich now called as vermicompost. 4) The harvesting is done as follows:

i) Stop feeding the worms 10 days before harvesting and left them starve.

ii) A laundry bag with holes is taken and is filled with food such as sweet fruits.

5) The bag with food inserted into a corner of a bin or bed. 6) After couple of days worms will move into the bag. 7) The bag is removed and the compost is harvested from the bin. 8) The harvested compost is nutrient rich bio-fertilizer. 9) Application of this vermicompost to garden plants or farm crop will give excellent results. 10) The separated earthworms are reused to prepare another bed.

Importance of Vermiculture:

1) Earthworms make soil loose and airy which is necessary for growing crops.
2) While feeding earthworm brings sub-soil on the top, it helps in mixing the soil.
3) Earthworms also provide the nutrient rich humus from soil surface to plant-roots.
4) It maintains the pH of soil. 5) Earthworms also adds its castings (excreta) to the soil which is rich in nitrogenous material, phosphorous, potassium etc making soil highly fertile and promotes plant growth thereby increasing crop production. 6) Earthworm contains 50-70% of proteins making it excellent food for poultry animals and aquaculture. 7) Earthworms are also used as a food by Maori people in New Zealand and natives of New Guineas. 8) In Indian Unani system of Medicine preparation made from dried earthworms is used to treat wounds, piles, boils, sore throat, respiratory infections, jaundice, rheumatic pains, bladder stones etc. 9) Earthworms play key-role in converting city organic wastes and sewage into vermicompost which is act as a good bio-fertilizer for plants. 10) Earthworms are used as bait for fishing. 11) Earthworm is excellent material for dissection to learn about the Annelid animals.

10) Vermicompost has following significance

i) It makes soil more fertile.

ii) It provides vitamins, inorganic salts to plants for proper growth.

iii) It increases the microbial wealth in the soil.

iv) It is used to enrich minerals in fish culture ponds

v) It is used for mushroom culture.

vi) It eliminates foul odour from the organic wastes.

vii) Vermicultre technology promises for waste disposal and manure generation.

viii) Spreading of vermiculture technology will generate employment opportunity.

ix) As vermicompost does not contain any artificial chemicals it does not cause soil, water or air pollution.

SCOPE OF ETHOLOGY

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Dept Of Zoology
Maharaja college
(B.Sc Part I Zoology Hons Paper I)

Ethology is the study of animal behaviour to find out natural responses of animals to various environmental stimuli. Ethology involves laboratory as well as field studies and has strong relationship with other sciences such as ecology, environmental science, neurology, physiology, psychology and evolution.

The beginning of modern ethology commenced with the experimental as well as field studies done by the Dutch biologist Nikolas Tinbergen, Austrian biologists Konrad Lorenz and the German Karl von Frisch, who were jointly awarded Nobel Prize in 1973 for their contribution to this new science.

The study of the behavior of animals is wish to learn more about its scientific approaches intrigued by their own observations. The main challenge is to understand the fundamental nature of the scientific approach that must be used to study behavior more formally. Only a rigorous experimental characterization of behavioral phenomena will yield common generalities on how and why animals do what they do - rather than providing a simple catalog of anecdotes. The study of behavior thus critically depends on our ability to phrase our general inquiry as a series of questions that can be answered with standard scientific approaches, that are amenable to experimental probes, and which lead to an explicit and unambiguous interpretation of its results.

Proximate Explanations Neural, Endocrine, and Genetic Mechanisms

It explains how a behavior is elicited and coordinated. It includes a search for the impact of genetic components, physiological mechanisms, environmental conditions needed, and hormones on behavior.

Ontogeny Development

The behavior is present because the individual developed an ability to do it this way.

Survival Value

Explanations are phrased as ultimate causes that explain why a behavior has evolved. Selection ought to favor individuals with behaviors that help it increase its reproductive success. The behavior is present because the individual inherited them from parents who were historically successful with this behavior.. This includes a search for functional significance or adaptiveness of behavior.

LABORATORY STUDIES

Neuroanatomical techniques

Different types of behaviour are controlled by specific regions of the brain. If a particular part of the brain is damaged, the behaviour of the animal is altered. Broca (1861) identified speech area on the cerebral cortex by the slurring of speech of a patient as a result of injury to the brain. Brain parts can be damaged by making cuts with a knife or by the neurotoxic kainic acid and behaviour is observed.

Stereotaxic equipment can be used to place small and precise injuries in brain. Micropipettes can be used to inject minute quantities of chemicals in precise locations of brain, such as limbic system, and behaviour can be recorded.

Neurophysiological techniques

Physiological studies can be done by recording electrical activity of brain by EEG or by stimulating different areas of brain by planting electrodes. Alpha, Beta, Theta and Delta waves are recorded by EEG. Alpha waves that are believed to emanate from the parietal and occipital lobes of brain reveal resting and peaceful relaxed state of brain that is otherwise alert. Beta waves are produced in frontal lobes and indicate the daily mental activity, concentration and thought. Theta waves denote emotional stress and sometimes hallucination. Delta waves are generated in deep sleep.

Neurochemical techniques

These techniques involve stimulation of parts of brain by drugs such as alcohol, opium, hashish, bhang etc. which alter the behaviour of the animal. Tranquilizers, barbiturates and drugs like calmpose, larpose etc. are phychoactive drugs which affect the brain and change the behaviour of animals.

Hormones such as estrogen and testosterone can be introduced into hypothalamus through canulation and the behaviour changes can be recorded. Adrenalin, histamine, testosterone and dopamine stimulate different parts of the limbic system. The modern techniques, e.g. PET scanning, CT scans, MRI etc. detect glucose utilization in different parts of brain, which is an indication of activity of that part.

FIELD STUDIES

BEHAVIORAL SAMPLING METHODS

Focal Animal Sampling

In this sampling method an individual from a group of animals is selected and all behaviours are recorded for a specified time period. During the specific period, all activities that the animal performs are recorded, while the activities of the other animals of the group are not recorded.

After the time period is over, the observer moves to another individual of the group to record its activities. This continues until all animals of the group have been observed for the specified time period. Individuals are identified by marks and named. Jane Goodall conducted such studies on chimpanzees. This method provides unbiased data on a wide variety of questions about the animals and is generally considered most satisfactory approach to studying animal behaviour.

Libitum sampling

A group of animals is selected and the observer remains with this group for a considerable period of time to observe all activities of the group. No constraints are placed as to what should be recorded and when.

All behaviours including interactions among the individuals are recorded in field notes. For instance Diana Fossy observed gorillas by living with the group whole day and observing all kinds of behaviour. Because the observer can never keep track of every minute activity of animals, the results of these observations can be biased depending on the situations that attract the observer's attention.

Instantaneous Sampling

In this method the observer records the behaviour of an individual in a group at predetermined time intervals, e.g. hourly or half hourly or per minute. The observer records the state of the animal rather than events. The sample interval should be as short as possible and behaviours should be easily identifiable.

Continuous Sampling

In this method, the observer simply records all the activities of the animals while they are being watched. This sampling method is very helpful in recording the sequence of activities that make the behaviour, such as courtship display in birds or fighting sequences in deer or moose.

Scan Sampling

In scan sampling the behaviour of all individuals of a group of animals are recorded at fixed time intervals. This involves rapid scanning of the whole group of subjects at regular interval and behaviour of each individual is recorded. Usually the observer restricts himself to recording of few categories of behaviour. An example of scan sampling would be to observe a group of animals and record the behaviour of each animal per unit of time. This provides data on the distribution of behaviour states in group for a long time period.

All Occurrence sampling

Sometimes certain behaviours are performed by several animals at the same time. For example, one animal starts the alarm call and other animals follow. In such cases the behaviour can be recorded as one event. One can record the number of alarm calls per unit of time, which will provide rate of occurrence of the behaviour in a fixed period of time.

Sequence Sampling

In this method, focus is on an interaction instead of on the individuals. The whole sequence is recorded from beginning to end. For example, the aggressive and submissive behaviours can be recorded in social primates. Various types of interactions in social insects such as ants, termites and honey bees can be recorded by sequence sampling.

One-zero sampling

Recording of the occurrence is done in "Yes" or "No", depending on the activity performed or not. The results can be presented in frequencies. For example attack behaviour in territorial animals or infant-killing in monkeys.

Tracking Animals

In order to study the behaviour of animals in their natural environment it is important that the animals are spotted in the wild, identified and studied without disturbing them. Animals can be identified by natural marks such as broken horn or tail, body scars or ear notches. Size and shape of the horns and tusks, facial features or pattern of stripes and spots can also be of help in identification. Photographs can be taken or drawings are made to record the identifications.

Behaviour - Watch animal activites. or force of action

- systamatic study of animal Behaviour - Ethology.

INTRODUCTION TO ANIMAL BEHAVIOR

The word **'ethology'** is derived from two Greek word **'ethos'** meaning **culture** and **'logos'**, meaning **study**. Behavior can be defined as observable activities an animal performs in response to the various stimuli in order to survive and reproduce.

A behavioral act is a **response to a stimulus** which is the basic and universal concept of behavior. A stimulus is always a change in the **internal or external** environment of organisms. A stimulus may be in the form of **signs/symbols** or releases. Signs can be **visual, auditory, chemical** or other types of **sensory models**.

A releaser stimulus releases certain **programmed stereotyped activities or fixed action pattern** (FAP) of behavior. A stimulus always elicits a response which is an attempt to adapt to the change. Thus behavior is generally stimulus- response oriented. The behavior of an organism is essentially an expression of the capabilities of its nervous system. While the environment determines the nature of the stimulus, the response involves the body, especially the nervous system of the organism which is genetically determined.

AIMS AND OBJECTIVES OF ETHOLOGY

1. To understand why animals behave the way they do.
2. Understand the cause f behavior
3. The physiological mechanism that generates the action
4. To understand how behavior develops
5. To study the evolutionary history of behavior
6. To analyze the potentials of the nervous system
7. To study the range of behavior prevalent in the animal kingdom starting from innate to learned behavior, from fighting to cooperating etc
8. For effective management of game animals
9. The farmer must be aware of habits of his animals to get maximum benefit
10. The cattle breeding, poultry, piggery, fishery, sericulture etc have been developed as industries for the benefit of mankind, only after understanding the behavior of the respective animals

11. Knowledge of behavior of animals like rodents, insects etc that damage the crop has helped in effective pest control
12. Man may want to keep pets for recreation. For healthy pet management it is essential to understand the behavior
13. The information and the insight gathered in animal behavior can be used to understand human behavior.
14. Behavioral studies can help in animal conservation. By understanding the nesting and territorial habits of the birds can help to create or preserve the habitats required by them. It can also help to increase the number of endangered and threatened animals

HISTORICAL PERCEPTION OF ANIMAL BEHAVIOUR

The history of ethology is as old as mankind because human beings were hunter gathers. It was thus mandate for them to be careful students of animal behavior and in fact revealed in the paintings on the walls of excavated caves of pre-historic times.

The great Greek philosopher, Aristotle (372BC) who for the first time wrote excellent description of animal behavior in his book "Historia Animalium" meaning the History of Animals. He keenly recorded the various behaviours of animals; however the conclusions he drew from his observations were incorrect. He stated that Redstart changed into robins in winter because of the close similarities between the two species. In fact Redstart birds migrated during winter.

Another keen observer of animal behaviour was William Harvey, a 17 th centuary scientist who studied the breeding, nesting and incubation behavior of many birds.

Gilbert White (1720-1793), a vicar in England made meticulous observations of behavioural aspects of man and animals especially the swallows. Like Aristotle, he was unable to interpret his finding by using a scientific approach. He believed that swallows buried themselves in the muddy bottom during winter. He arrived at this conclusion as the swallows aggregates in the reef beds before they migrate during the night.

It was Charles Darwin (1809-1889) who is regarded as the first one to make scientific study of animal behavior in his book, 'The expression of emotions in man and animals'. This book gave

details of animal behavior and it is till date considered as a classic book. He stated that the phylogenies of behavioural development were subjected to the same laws of natural selection which governs the morphological developments of organisms.

After Darwin's theory of Natural selection was stated, it gave a new impetus and a new direction to the study of an animal behaviour .The application of laws of natural selection to ethology gave a new perspective to the better understanding of animal behavior.

After Darwin's death, his student, John Romanes wrote an excellent book on "Animl intelligence". Early work on Ethology was based on the observations of pets, domestic and farm animals. Fundamental change in the approach of studying behavior in the wild came with works of a German Zoologists, Oskar Heinroth (1871-1945) who devoted his life studying water fowls. He enumerated his observations in the book, "Ethology of Anatidae".

Ethology reached its peak of popularity in the works of three great ethologists, Karl Von Frisch from Germany, Konrad Lorenz, an animal Psychologist in Vienna, Austria and Niko Tinbergen, a Zoologist in Holland. These three shared a Nobel prize in 1972-73 for their remarkable contributions in the field of animal behaviour. They are also credited for introducing an absolutely new branch of science to Zoology and making it popular among common people. Prior to Fischer, Konrad and Tinbergen, I P Pavlov (1849-1936) a Russian physiologist received worldwide acclamation for his work on condition reflex observations in psychological studies on learning.

Karl Von Frisch (1886-1982), a German scientist disclosed his famous studies on communication in honeybees. He described the bee dance used by foraging bees to communicate the distance, location and nature of food resources.

Konrad Z Lorenz (1903-), founding father of ethology developed a theory on animal behavior which stressed its inherited aspects and relative fixity. He formulated imprinting behavior in goselings. His books, 'King Solomon's ring' and 'Man meets dog' demonstrates his deep understanding on animal behavior.

Niko Tinbergen (1904-), a Dutch ethologist, a co founder of modern ethology along with Lorenz is famous for his work on instinctive behavior. He worked on the courtship behavior in stickle back fish, food begging in chicks of sea gulls, nesting behavior of digger wasps.

B. F. Skinner (1904-), an American psychologist did extensive work on learning by reward or reinforced learning in caged rats. This led to formation of Skinnerian Psychology.

Today we have dedicated men and women like Jane Goodall, Joy Adamson etc , who have studied the behavior of apes in the African jungles and the behavior of lion

TYPES OF ANIMAL BEHAVIOUR

Behaviour can be categorized into two main types,

1. Innate or inherent behaviour or
2. Learned or acquired behaviour

Innate or inherent behaviour or stereotyped behaviour is inborn or inherent behaviour sequence of activities which is predictable, species specific, genetically controlled and independent of past experience. Since this is type of behaviour follows a fixed patern (FAP) which is predictable and found in all members of a species it also called stereotyped behaviour

Characteristics of innate or stereotyped behaviour

1. Pattern of behaviour is inherited. It is passed on from parents to offsprings,
2. It is unlearned behaviour
3. It occurs in all the members of a species hence it is species specific and predictable.
4. It is not dependent on past experience as it is an inborn response to a stimulus
5. It takes place in individuals even when kept in isolation away from their fellow members
6. Innate behaviour has high adaptability and survival value.

Types of innate behaviour

There are different types of innate or stereotyped behaviour

1. **Taxis**
2. **Kinesis**

3. **Reflexes**
4. **Instincts**

1. Taxis

Taxisis the simplest type of innate or stereotyped behaviour. It is an orientation of an animal (directed either towards or away) in response to the source of stimulus. If the orientation is towards the stimulus it is called as **positive taxis** and if it is away from the stimulus it is known as **negative taxis**

Taxes are usually named after the stimuli. Hence there are **phototaxis, chemotaxis, thermotaxis, geotaxix** etc. A plant or animal that move towards light shows positive phototaxis. Certain burrowing animals like rodents or planaria that more away from the source of light exhibits negative phototaxis.

Example for positive phototaxis

The protozoan, Euglena response to a variety of stimuli and is very sensitive to light. It swims towards light, hence it shows positive phototaxis. This behaviour is of distinct advantage to the animal because light is necessary for assimilation of CO_2 by the chlorophyll. If a dish a containing Euglena is covered on one half and the other half is exposed to light it is seen that euglena will avoid the dark region and will aggregate in the bright region of the dish.

It is seen that euglena will orient itself parallel to the source of light. It is able to respond positively to the source of light stimulus due to the presence of the paraflegellar body, a photoreceptor located infront of the eyespot or stigma. When the shadow of the eye spot falls on the paraflagellar body it will turn its head till the photoreceptor organ is directed towards the source of light and the animal will move towards the light source. If the position of the source of light is changed, once again the euglena will turn its head so that light falls on the paraflagellar body and the animal orients itself towards the source of light.

Example for negative phototaxis

Maggots that are about to pupate moves away from light source towards a dark location hence they show negative phototaxis. When maggots are kept on a surface illuminated by a beam of light, it will move away from the source of light more or less in a straight line. However it will

often move its head from side to side measure the intensity of light with its single light receptor located on the head. If the intensities on both the sides are equal, then the animal's body is oriented along the beam of light. By comparing successive light intensities the maggots are able to orient itself so as to crawl away from the light source. The periodic lateral movement of the head ensures the animal that it is on the right track , that is away from the light source.

2. Kinesis

Kinesis is a type of locomotory behaviour in relation to the source of stimulus. The animal responds to the variation in the intensity of the stimulus and not the source of direction of the stimulus. To respond to such stimulus the animal only requires sense organs sensitive to variation in stimulus intensity.

There are two types of kinesis

a. Orthokinesis

b. Klinokinesis

Ortho kinesis is a response that involves changes in the speed of movement of the whole body in response to stimuli like humidity, preserve and diffused light.

Eg:Wood louse, *Porcellerio scaber*, a small crustacean that live in damp areas, and they tend to lose water from their body fairly rapidly when exposed to low humidity. When wood lice are kept at the junction in a choice chamber where one side has high humidity and the other half has low humidity. It is noticed that after a short while the wood lice begin to move and the speed of movement and the rate of turning is greatest in the driest part of the chamber and least in the humid part. This increased and apparently random movement is an attempt by the animal to remain in the most favorable environment.

Klinokinesis: In Klinokinesis the speed of locomotion remains constant but the rate at which the animal changes direction depends on the intensity of the stimulus.

Eg: A planaria changes its direction ever so often as it crawls. If the light intensity above the animal is increased it changes direction more frequently but moves at the same speed . The

increase in rate of turning falls after sometime but increases again with a further increase in the intensity of light.

3. Reflexes

A simple movement of a part of the animal in response to a stimulus is called reflex. It is a quick, innate and immediate response of a part of the body to an external or internal stimulus, which has great adaptive and survival value to the organism. Reflexes are inherited and unlearned behaviour found in all members of the species. The knee-jerk, constrict of pupil of eye in the bright light, blinking of eye, peristalsis, coughing etc. in man, flight in birds, web spinning in spiders are all examples of reflexes. A reflex action requires a reflex arc which consists of a sensory organ (**receptor**), a sensory nerve (**afferent nerve**), the spinal cord or brain, an intermediate motor or **efferent nerve** and a motor organ or effector.

A reflex action thus involves the sense organs and nervous system. The stimulus is received by the receptor or sense organ which sets up a sensory impulse. This impulse is transmitted to the central nervous system (brain and spinal cord) through the intermediate nerve. This motor impulse is transmitted to the effector or motor organ, muscles and glands which either contract or secrete in response to the stimulus. Many pattern of animal behaviour are complex combinations of simple reflex.

Advantages of reflex

1. Enables the animal to respond immediately to harmful stimuli hence it has great adaptive and survival value
2. Since many of the reflex actions are controlled by the spinal cord, it relieves the brain from too much work.

4. Instinct

Instinct is the most complex type of stereotyped behviour which is unlearned, predictable, genetically controlled and species specific and it is in response of a sign or releaser stimuli. Of all the stereotyped behaviour instincts are the most fascinating to study.

Eg: Building of nest by birds, singing to attract males, territoriality, migration, parental care etc.

Characteristics of instinctive behaviour

I. Instinctive behaviour is in response of a sign or releaser stimulus. Sign stimulus is one which triggers an instructive response which could be a part of the whole stimulus. A releaser stimulus is one which triggers a series of stereotyped behaviour.
2. It is the result of both external stimuli and inner environmental conditions. External stimuli represent environmental factors like temperature, photoperiods, suitable nesting material, food sources. The internal conditions refer to the level of hormones in the blood.
3. Though it is categorized as unlearned and stereotyped behaviour, it can be modified by exposure, learning and experience. Eg: A male bird will sing a simple song when kept in isolation. Birds need to hear the songs of adults to be able to sing the complete song,
4. External stimuli are able to trigger a series of instinctive behaviour provided the internal conditions are conductive. If there is sufficient concentration of hormones in the bird and minimum external stimulus is sufficient to trigger the entire series of behaviour.

Examples of instinctive behaviour

1. **The reproductive behaviour in three spined stickleback fish**
   a. A sexually mature stickleback fish male will have a red coloured belly to attract the female. A mature stickleback fish migrates to warm shallow waters. Migration is an instinctive behaviour triggered by the increase in gonadotropic hormones which is inturn controlled by environmental factors like temperature and photoperiod.
   b. On reaching shallow waters the fish builds a nest which is open at both ends with the help of plants and weeds. The nest building behaviour is triggered by the presence of green vegetation in the water. Thus he acquires a small territory.
   c. He exhibits territoriality or defends the area around the nest from other male fishes that are also in search of suitable nesting grounds.
   d. The fish becomes aggressive and exhibits threat posture by facing downwards. The sign stimulus for territorial and aggressive behaviour is the red belly of other male fish.
   e. The presence of a female triggers the courtship behaviour in the male because of its swollen belly that is full of eggs. The male performs a ziz-zag dance which

attracts the female. During his dance the male always exposes his red belly to the female.

f. The male leads the female into the nest to releases its ova that are immediately fertilized by the male. After this the female is driven out and the male may lure other females to its nest.

g. The presence of eggs in the nest triggers parental care in the male fishes and begins to fan the eggs with its fins and young once are taken care by the males.

Hence various stereotyped instinctive behaviour in stickle back fishes are migration, nest building, territoriality, aggression, courtship and parental care. **Tinbergen** conducted simple experiments to demonstrate the instinctive behaviour pattern in Stickle back fish.

- Males presented with models of stuffed female or even a bloated male elicited the courtship dancing behaviour.
- When a female is presented with a red belly model of the male fish it faithfully followed it, suggesting the visual sign triggered these behaviours.

2 Food begging behaviour in herring gull

Food begging is common instinctive behaviour of hunger birds. Young birds beg for food from their parents by opening their mouth wide and making chirping sound to attract the parent's attention. This seems to elicit the instinctive parental behaviour in the parents and they will feed the hungry mouths of their offsprings. The food begging behaviour in herring gull chicks has been extensively studied by Tinbergen and his associates.

a. Young chicks beg for food by pecking at the bill of parent, because of which the parent regurgitates the food and feed the young one.

b. Tinbergen has shown that the pecking behaviour in the chick was stimulated by a red spot present at the tip of the parent's beak. The adult herring gull has a yellow beak with a red spot at its tip. It has been proved that it is the red spot that elicits the food begging behaviour in birds by Tinbergen. They conducted certain simple experiments which established their observations.

c. The same begging response could be generated in the young gulls when they were presented with different colored spots on the beak. It was observed by repeated trials that the

maximum response was elicited by a red spot on the beak of the dummy followed by black, blue and white spots. The beak with no spot elicited the least response.

Escape reactions of ducklings and goslings

Unlike the above examples where a red belly or just a spot could generate an instinctive behaviour in this case, the whole or entire shape of the model was responsible for the reaction.

a. The ducklings and goslings in the farmyard show two different responses to the same model when it is sailed above them. If the model is sailed to the left the young birds do not show any signs of running away. However when the model was sailed to the right they responded by running away
b. This escape response exhibited by the ducklings and goslings was due to fact that the models appeared differently when sailed in the opposite direction.
c. When the model moved to left the model appeared like a duck or goose, however when it moved to the right it appeared as a predatory bird like hawk or eagle which elicited the fear response which generates the escape reaction in the young ones.

Learned behaviour/ acquired behaviour

Thorpe defined learning as a long lasting adaptive change in behaviour resulting from past experience; hence it is acquired during the life time of an individual.

Characteristics of learned behaviour

1. It is acquired during the life of an organism due to constant experience
2. It is experience dependant and can be modified through experience
3. Learning is flexible
4. Learning behaviour differs from individual to individual to individual among the same species hence not species specific
5. Learned behaviour is certainly not inherited though the ability to learn is almost certainly inherited as it is dependent on the development of the nervous system of the organism which is inherited
6. All organisms from protozoa to humans have the ability to learn atleast to some extend

7. However learning in humans surpasses all other animals .Almost everything we do has been learned .No other species surpasses the humans in their amount and range of information that is acquired through learning.

   Thorpe identified the following types of learning

   1. Habituation
   2. Imprinting
   3. Trial and error
   4. Conditioned reflex/ Classical conditioning
   5. Insight learning

Habituation

Habituation is the **simplest** and most common type of learning seen in all organisms as simple as protozoan to as complex as man.

It can be defined as the gradual decrease in response to repeated exposure to the same stimulus if found to be harmless. Hence it is a king of negative learning wherein the animal learns to ignore a harmless stimulus and fails to respond. Thus habituation is the ability to **ignore a prolonged stimulus**. It is the gradual learning by an organism not to respond to stimuli which are repeatedly found to be of not adaptive value to it.

Crows present in corn field | Introduction of scarecrow | Prolonged exposure to scarecrow

Advantages

1. It **saves energy by avoiding unnecessary response**: It is a vital process because without it, the animals bombarded by the numerous visual auditory, olfactory gustatory and tactile stimuli from their environment would be in a constant and needless state of alarm or expectation.

2. Habituation behaviour **filters out the multitude of back ground stimuli** that have no important consequences thus leaves the animals attention **free to concentrate on the stimuli which are essential for its survival** and which may be potentially harmful.

Examples

a. Lack of continued response to strong odour is a common example of **sensory habitation.** Sensory system may stop after sending signals to the brain in response to a continuous repeated stimulus.

b. If the web of a **spider** is disturbed at one end, but finding nothing it returns. If this stimulus is repeated severe; times it will gradually stop responding as the stimulus was of no important consequence to the spider and hence it will ignore the stimulus. However the spider will respond if some other end of the web is disturbed.

c. **Prairie dogs** give alarm calls when mammals, large birds or snakes approach which warns others of the presence of these predators. These alarm calls facilitate escape into their burrows. However, when their burrows are located near trials used by humans gives alarm calls every time a person walks by would be a wasted effort. Thus habituation to humans is an important adaptation to these animals.

IMPRINTING

Imprinting is a **relatively simple** but specialized type of learning that takes place during **critical period** or sensitive period early in the life of an organism. It is especially **rapid and relatively irreversible learning** process that occurs **early in life.** The central concept of imprinting is the innate release mechanism whereby organisms genetically predisposed to be especially response to certain stimuli during the critical period.

It was first described by **O. Heenroth** and later demonstrated by **Konard Z Lorenz** on Goslings and Ducklings which is also called **following behaviour.**

Lorenz investigated the phenomenon of imprinting

- Newly hatched bird imprints on the first moving object it sees (imprinting stimulus) and then will direct their social behavior toward that object
- Lorenz split a clutch of graylag goose eggs; left half with mother to incubate and raise; they showed normal behavior, followed her, grew up to interact and mate with conspecifics
- Half the clutch placed incubator, offered himself as a model for imprinting; goslings followed him as if he were their parent; failed to recognize mother or other conspecifics; as adults, tended to develop social relationships with humans, not geese; some initiated courtship with humans .

Characteristics of imprinting

1. Imprinting will occur only during the **critical period** of an animal's life. The time of the critical period varies in ducks it takes place from 13-16 hours of hatching and no imprinting occurs after 36 hours. In checks the critical period is between 5-25 hours after which no imprinting is possible. Human babies have a sensitive period that occurs between 18 months to 3 years. During this critical period the absence of the mother or a foster care taker results in behavioral abnormalities later in life, they are unable to show normal bonding.
2. Imprinting is a form of learning behaviour where the young ones learn to recognize an object or person considering it to be their parent hence develop an almost irreversible attachment to it. Thus imprinting is an innate behaviour but the recognition of the object is learned. It is innate as it cannot occur anytime during the life of an animal but it is seen only during a particular period called critical or sensitive period.
3. Imprinting occurs towards any moving object or person first seen by the animal. If was first seen in birds but later also observed in fishes and mammals
4. Imprinting is **relatively permanent**

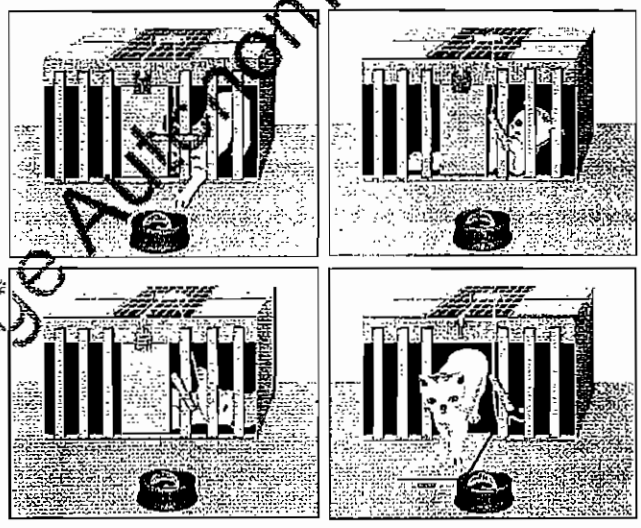
Advantages of Imprinting

1. Though imprinting is seen for a short period in the years there is a long lasting effect.
2. Imprinting influences social behaviour and mate selection
3. It allows the young ones to recognize their own kind and especially theiur parents which is necessary for their survival

TRIAL AND ERROR LEARNING/ INSTRUMENTAL CONDITIONING / OPERANT CONDITIONING

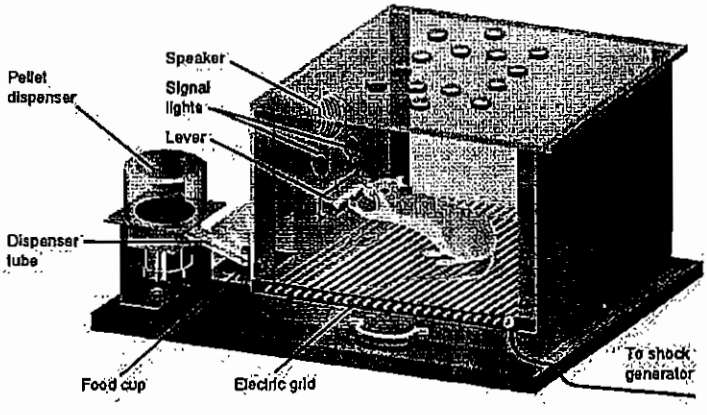
Trial and error learning or operant learning is a type of **associative learning** where particular actions can be reinforced **by providing a reward after successfully completing the task**. The pioneers in this type of instrumental learning in the laboratories are E. L. Thorndike and B. K .Skinner.

Edward Lee Thondike was one of the most famous and popular behaviorists of the 20th century who investigated this type of learning in cats using a series of **puzzle boxes or problem boxes.** The doors of these puzzle boxes could be open by pushing a lever or button pulling a string. The cat confined in such a puzzle box tries to escape by moving about randomly or restlessly inside the cage and in this process accidently it pushed the lever or pulled the string and the door opened which resulted in obtaining its food. This process was repeated for the next few times till the cat learned to associate the pushing of the lever or pulling of the string resulted in obtaining the reward ie, food



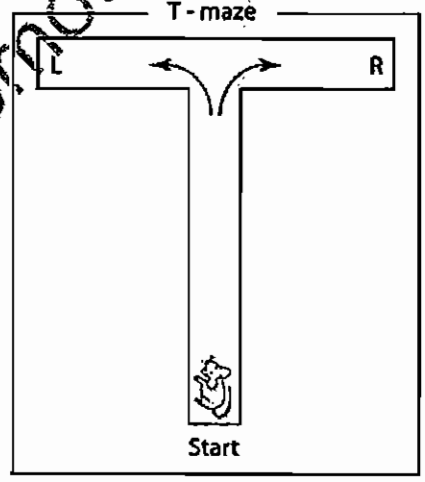
Gradually after several attempts or trail and errors the cat learned to eliminate all activities that did not get any reward and at the same time it reinforced or repeated the activities that were rewarding. Finally the cat learned to push the lever or button or pull the string to open the door as soon as it was confined in the box without making any errors.

B. F. Skinner, another famous American behaviorist performed a number of operant or trial and error learning experiments in his famous Skinner box by using model animals like rats and pigeons. The **skinner box** experiments



were slightly more complex as it had more variables introduced in the experiment.

The skinner box had a **red light, green light, loud speaker, a lever, a food dispenser** and the floor had an **electric grid.** The rat in the box learned through trial and error that it could obtain the reward ie, food when it pressed the lever only when the green light was switched on, while pressing the lever when the red light was switched on, did not fetch any reward and pressing the lever when loud speaker was on resulted in an electric shock. The rat gradually learned to press the lever to obtain the reward or food when the green light was on. It gradually avoided the activity of pressing the lever when red light was on as it did not get any reward. The number of trials and errors made to associate loud sound with the electric shock or the punishment were much fewer when compared to the number of trail and errors made to learn to associate red light with no reward. **This type of learning where the animals learn to repeat or reinforce activities that are pleasurable or fetch a reward and avoid activities that are painful or associated with punishment is called trial and error learning or instrumental or operant conditioning.**



Another simple experiment conducted by skinner to demonstrate trial and error learning was a **'T' shaped maze** where the animal must turn to the right or left. On one turn the animal may find its reward ie, food or escape, while on the other turn it receives a punishment ie, an electric shock. By series of trials some successful and others unsuccessful the animals learn to take the favorable route which is rewarding and avoid the unfavorable route and its performance improved with time. Ultimately the animal learns to make the correct choice almost all the time. Learning through random and often erratic activity is called trial and error learning. The animal's capacity to learn is indicated by the number of trials required before the animal makes the right choice.

Thus in trial and error learning an animal faced with several alternatives is rewarded (Positively reinforced) for making the proper choice and learns to make this response without hesitation. This type of learning is employed by animal trainers to make animals learn all types of tricks by using positive reinforcement. Skinner believed that human too are controlled primarily by positive reinforcement, although many disagree this idea.

COMMUNICATION IN ANIMALS (ZOOSEMIOTICS)

Communication is the transfer of information or message or exchange of signals between members of which is essential for their survival. Every organism interact to some degree with other organisms which can be either intra-specific i.e, communicating between members of the same species or inter-specific i.e, transfer of messages between members of the different species, which occurs occasionally. Essential informations need to be conveyed are presence of food source, readiness for mating and danger of predators. The information is send by the sender and received by the receiver which is accompanied by a change in behaviour.

Methods of communication

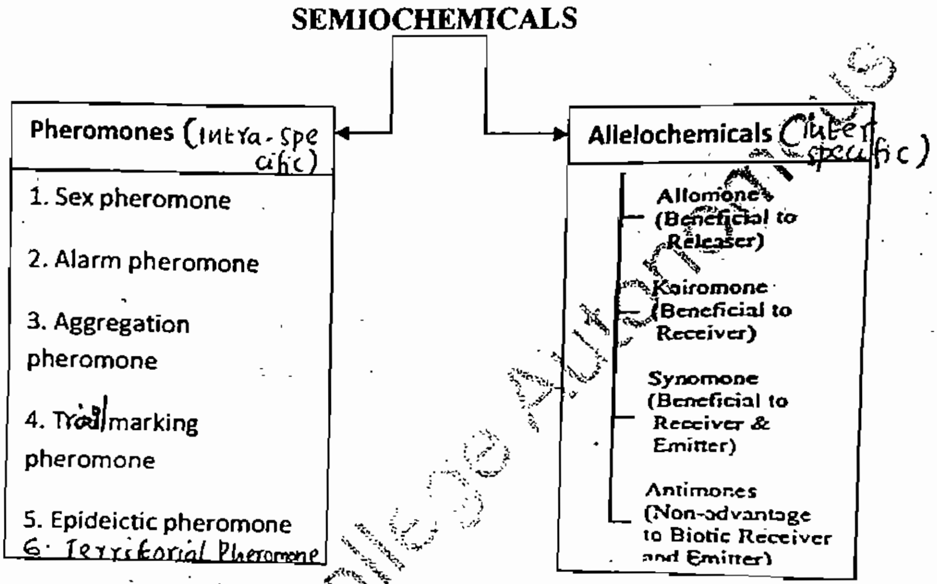
Many animals effectively use or empty signals and signs to transfer information. Most animals have the ability to send receive and interpret meaningful signals. A signal may be in the form of gestures, movements, sound, colour patterns, hence they may be chemical, tactile, visual or auditory. Each of these signals have their advantages and disadvantages making one suitable for one away of life and another adapted to some other habitat. The complexity of communication is dependent on the complexity of the nervous system.

1. **ODOUR, CHEMICAL OR OLFACTORY COMMUNICATION**
2. **VISUAL OR LIGHT SIGNALS**
3. **SOUND/ACOUSTIC/AUDITORY COMMUNICATION**

1. ODOUR, CHEMICAL OR OLFACTORY COMMUNICATION

- Chemicals involved in communication are called as **Semio-chemcials**. They are of two types - **Pheromones** (intra specific) and **allelochemicals** (inter specific)
- Most animals excrete certain chemicals substances into the environment by which they can be identified by other members of the group. These chemical messengers are known as **scents or pheromones** which are produced by special **scent glands** and perceived by olfactory organs or other **sense organs**.
- Pheromones or scents are defined as **volatile chemicals** secreted by animals that influences the behaviour of their animals of the **same species.** Pheromones are chemicals signals used to communicate between members of the same species.

- Exchange of information through **chemicals is a primitive** form of communication However animals can sill communicate **complicated** and **unambiguous messages** using chemicals. .
- **Allelochemicals** are used for inter-specific communication especially as repellents to ward of intruders.



- Chemicals involved in communication are termed as semiochemicals
- Semiochemicals are divided into intraspecific and interspecific communication chemicals.

Pheromone:

- In 1959, Karlson and Luscher proposed the term pheromone to represent chemicals used for intraspecific communication.

Pheromone: A substance that is secreted by an organism to the outside environment and causes a specific reaction in a receiving organism of the same species.

Some examples of sex phermones :

- Grandlure of Cotton boll weevil, *Anthonomus grandis*
- Gossyplure of Pink bollworm is a natural sex pheromone whereas Hexalure is parapheromone
- Helilure of *Helicoverpa armigera*

2. **Alarm pheromones :**

A substance produced by an insect to repel and disperse other insects in the area. These pheromones are reported in Homoptera, Isoptera and Hymenoptera and are released by organs such as mandibular, anal, Dufour's and poison glands in ants, cephalic glands in termites, sting apparatus and mandibular glands of worker bees and cornicles or siphunculi in aphids. They produce effects like dispersion, attraction or aggression. An individual also releases them when an enemy (predator) attacks.

3. **Aggregation pheromones :**

A substance produced by one or both sexes that brings both sexes together for feeding and reproduction. These are the chemicals that allow insects to congregate for feeding and other activities. These are released by members of one sex only but elicit responses in members of both sexes of a species e.g. bark and ambrosia beetles of the family Scolytidae etc.

4. **Trail marking pheromones :**

Trail marking pheromones are substances of low persistence that are released and perceived by individuals in a trail. These pheromones are specially found in social insects like hymenopterans and termites. The ants, formica rufa uses formic acid as a trail marker. They facilitate migration of a colony to new site in search of food.

5. **Epidiectic pheromones :**

These compounds function in the regulation of population density by controlling the dispersion of individuals.

6. **Territorial pheromones :**

Secreted by males of some species and attract both males and females for e.g. males of bumblebees and carpenter bees demarcate the territory for foraging activity. Sex pheromones are useful in integrated pest management in three distinct ways viz., monitoring of insect populations, mass trapping and mating disruption.

Examples among invertebrates

Insects have been most extensively studied for their pheromones and structures related to their production and reception. Sex pheromones are often used by female insects as sex attractants to attract the males belonging to the same species.

For example:

1. The **female gypsy moth** produces a chemical called **'gyplure'** which is transported by the wind to several kilometers. Male moth perceives the odour by means of special receptors located on their **feathery antenna**. They follow this odour to reach the females which are flightless. scientists have produced commercial chemical called **"disparlure"** which mimics the natural chemical sex attractants of female moths. With a higher amount of pheromones in the air it confuses the male and they are unable to find the females. These pheromones can also be used to lure males into traps thus preventing the mating of the moths hence controlling their population.
2. Ants are famous for chemical or odour communication. Pheromones in ants are used for **trailing** and recruiting nest mates to the resources of food. A scout ant leaves the nest in search of food moves about randomly until food is located. On the return trip it takes the shortest route home and on the way back she lays down an odour trail. Back in the nest it alerts the next mates of the food resource and the recruit ants will follow the trial directly to the food and back thus helping in orientation. The pheromones are also used as **sex attractants** to attract the opposite sex for reproductive purposes. Other times a signal may have a negative effect ie, they may act as **repellents**. This can be exploited by man to produce chemical repellants to keep away ants. When disturbed ants liberate **alarm substances** which disperse in air thus warning other ants of impending danger. These are released from their **mandibular or anal glands** which attracts other members of the colony which quickly reach for the rescue of their nest mate or conspecific

3. The queen bee attracts the drones by pheromone produced by the mandibulate gland. By producing varied concentrations she determines the number in a caste prevents further construction of queen chamber and orders all her workers to perform their tasks tirelessly. Thus the pheromone of the queen helps to **maintain the integrity and stability of the colony**.

Examples among vertebrates

Many vertebrates produce odours to carry many information to conspecifics and to members of other species.

1. Animals like house shrews, striped hyena, some fishes etc produces **alarm or distress** chemicals when under stress or injured
2. Carnivores like dogs, cats, tigers, foxes use urine to mark their territories. **Tigeramine** is a thick milky fluid with a strong odour produced by tigers
3. Other animals like rhinoceros and hippopotamus mark their territories with faecal matter and urine. Rhinoceros mark their territory with piles of faeces, left around the edges where other individuals may encroach.
4. Male elephant have temporal glands which produces scent to indicate their readiness for mating.
5. Male musk deers have musk glands located at the end of penis; liberate the pheromone called **muskone** that is used to mark territory and also to attract females.
6. In primates, pheromones help to identify hierarchy and to establish mother-child bonding.

Advantages of chemical communication

1. Acts as a sex attractant and helps in trailing to find food source by foraging workers
2. Acts as a repellent to keep away other species
3. Helps in recognition and identification of members of the same species and conspecifics
4. Pheromones acts as alarm or distress chemicals thus warning other members about danger
5. Helps in marking territory through faecal matter, urine, saliva and secretions from special glands
6. Pheromones helps to establish hierarchy, dominance, grooming and bonding between mother and child
7. It is effective over distance and around corners
8. Chemical signals also convey the level of aggression or submissiveness in members of a society, thus they act as warning signals. This reduces excessive aggression, blood-shed and loss of life and thus maintains the integrity of the society

Disadvantages

1. Chemical or pheromone production requires the expenditure of energy

2. Since these pheromones are highly volatile in nature they have to be constantly replaced
3. Pheromones are carried by air, thus it is dependent on the air current or wind direction. Thus they are carried only upwind.
4. The odour may not only attract their mates but also predators

2. VISUAL OR LIGHT SIGNALS:

The bright colors of some insects, fish and birds suggest that they are important to the survival of these animals. Visual signals travel with the speed of light and hence it is the fastest mode of communication. However the animals that depend on light signals must have good vision, must be relatively large, as they cannot be seen far away, nor travel around obstacles. Hence visual signals are excellent for communicating over short distances, since they produce simple and unambiguous messages by their gestures, postures and color patterns.

1. Facial expression, gestures and body postures can communicate aggression, submissiveness, fear, anger, playfulness, joy and threat.

   Examples:

   a. **A cat** with its back arched, teeth exposed and hair standing on edge suggests that it is extremely aggressive.

   b. **A dominant monkey** in a troop will walk around with its tail up and head held high majestically, while a submissive male monkey will have a crouched or subdued position. During the mating season the females expose their swollen and brightly coloured rear end.

2. Moving group of animals have small visual signals

   Example: A black patch on the back of a **lion's** ear or the wingbars on the snipe birds help to maintain contact between members of a group.

3. Some animals employ **distraction display** to escape from their enemies. For example the **hawk moth** will suddenly spread its forewings to display the eye spots on their hind wing which confuses and distracts their predators.

4. Colour display is an important means of visual communication. The bright Plumage of many male birds advertise its species, sex and its readiness for mating. Hence visual

signals are ideal for courtship behavior to attract the opposite sex. Some animals even change colour

For example:

a. The male bird become more brightly coloured and patterened during breeding season, even moulting their feathers to achieve this.
b. The most striking are the fishes. The male stickle back fish turns bright red on its belly with brilliantly iridescent blue eyes.
c. The chamaeleons change colour (camouflage) according to their environment, thus escaping from its predators.
d. Some animals mimic or appear like poisonous forms which help them to escape from their predators.

5. Fireflies use a brilliant display of light signals to effectively communicate with other members of the species in the dark. They are bioluminescent ie, species in the dark. They help in the species recognition, sex attractant and also to obtain food. The males fly around producing a pattern by which they reply.

Advantages of visual communication

a) It is the fastest mode of communication ie, the speed of light
b) It is most effective in short distance communication to send precise and unambiguous message.
c) It is effective in all direction and independent of wind
d) It is used to advertise their sex, aggressive state, state of readiness for mating and territoriality
e) Mimicry and camouflage helps to escape from predators.

Disadvantages of visual communication

a. For visual communication to occur it requires a clear line of vision
b. It is most effective over short distances
c. Visual signals may be intercepted by predators
d. It cannot cross carriers and corners
e. Colour patterns are effective only during the days while light signals are effective only in the night

3. SOUND/ACOUSTIC/AUDITORY COMMUNICATION

Sound/Acoustic/Auditory signals are familiar means of communication among insects, birds and vertebrates. Sound signal have certain characteristics like frequency, amplitude, duration and rhythm which can be used by animals to communicate a wide variety of complex information. Sound waves can radiate out in all directions and more so in water and are not affected by barriers and can be effectively used in the day and night times. These properties make sound signals ideal as advertising signals used in the mate attraction, aggression, warning and alarm communication.

Sound is produced vocally by birds, amphibians and mammals with the help of syrinx, vocal sacs and larynx. These are various ways by which sound signals are produced.

1. Insect vibrates various parts of their body to produce sounds. For example, **crickets** produce loud sound by rubbing the hind legs with their wings. This is called **stridulation**. The **Madagascar cockroaches** produce hissing sound by expelling air through the **spiracle**.
2. **Some birds** like the wood pecker produce loud drumming sound by tapping a hollow object. Snipes produce sound by rapidly passing air through their tail feathers.
3. **Bats** and whales produce **ultrasonic sounds** to communicate.
4. **Elephants** can also communicate by producing **infrasonic sounds**.

Examples:

a) The songs of birds are the most familiar and well studied example of acoustic signals. The song of the male birds during the breeding season provides information to other birds as to his species, sex, breeding condition, aggression and territorial behavior. Bird songs serve two main functions ie, to attract the mate and act the same time it repulses other male rivals. Hence singing ensures successful mating and reducing unnecessary conflicts.

b) Animals that live in societies or colonies among the vertebrates communicate various information to other members like source of food and presence of predators by alarm or warning calls, mating calls to attract the opposite sex.

Advantages Of Auditory Communication

(1) more than one receiver so that you don't have to send message individually

(2) to alert others in the group of oncoming predators

(3) travel fast in all directions

(4) clear beginning and end

(5) can change message quickly

Disadvantage of auditory communication

(1) message received by other animals/predators

(2) omnidirectional

(3) discreteness can be disadvantageous because you need to keep generating it if you need a continuous signal

(4) expensive in terms of cost of energy

(5) over distance message can get distorted

SOCIAL ORGANIZATION

A society is a group of individuals belonging to the same species and organized in a cooperative manner. The members of a social organization are interdependent and variously specialized in function and their survival depends on co operation in the group. A social organization is a large group of members who intercommunicate extensively, exhibit division of labour and bear some relatively permanent social relationship to one another. Such organization exists in both invertebrates and vertebrates. Among vertebrates, arthropods viz, ants, bees and termites have well organized colonies. A well established social organization is seen in primates such as monkeys, baboons, langurs etc.

Benefits of a Social Organization

There are many benefits of living in a social organization. They are.

a. **Better protection** against predators.
b. There is **improved protection of limited resources** against other groups of the same species and related species. (Members of a social organization together help in protecting their territory, food material and mates against other groups).
c. There is **enhanced or increased chances of foraging success** or in plain words many individuals are better than one in searching for food.
d. There is **reduction in predator pressure** by improved detection and repulsion of enemies. (Individuals in a group are more alert to dangers and are also able to chase away the predators when they are together).
e. There is an **improved care of offspring** through communal feeding and protection. (The young ones will be taken care of not just by the parents but also by others in a society).

Disadvantages of Social Organisation

a. There is increased competition within the group for food, mates, nest sites, nest materials and other limited resources.
b. Increased risk of infection due to outbreak of diseases or epidemics.
c. Increased risk of exploitation of parents.
d. Increased inbreeding will weaken the progeny.

ORIGIN AND EVOLUTION OF A SOCIAL ORGANIZATION

A social organization could have originated due to the following reasons.

a. The offspring chose to stay with their parents

The children or offspring would have been **helpless after birth** and not precocial like the calves. The helpless offspring depend on the mother for **milk**. They need to be **kept warm** by clinging on to the mother. They need **protection** and have to **learn a number of survival tactics** before they can venture out on their own. The period of infancy could be **extended** ie they take a long time to grow up. During this period they need to learn from the parents **how to obtain food**, who their **enemies** are and how to escape from them. Staying together makes them aware of their **social responsibilities** and they learn to **care for one another**. They are able to understand the **bonding** between various members and how to move up in the rank order. They learn the **benefits of becoming the alpha male** or the most dominant one. They learn to **take up responsibilities** crucial for the survival of the organization. They **learn to communicate** and become **receptive** to other members.

b. When two adults chose to stay together

Just like the above case where children chose to live with parents for the benefits they can obtain. Two individuals could chose to stay together. The adults would have realized that **'two is better than one.'** The adults staying together obtain a lot of benefits. There is **sharing of work**, sharing **of responsibilities**, there is **social contact for healthy growth**, there is **security and protection against predators** as they could alert each other of dangers. They **learn the benefits of cooperation** and **division of labour**. The **need for another person to be around**, to communicate and be receptive is an intergral part of a social organization.

After a social organizaton originated because of many benefits that a species can derive form it the organization has survived over centuries. The organization could have **evolved** from a small group to larger ones. Ultimately the main aim is of **survival of the species not just of an individual**. As every species has the instinct to survive and to propagate its own kind, a social organization has become more and more evolved. **Social behaviour** has become more evolved from just mutual cooperation and division of labour to group dyanmics where more sophisticated behaviour such as **altruism** and **kin selection** is seen.

A PRIMATE SOCIETY

There exists a variety of social organization in primates. The group could comprise of just one male with a group of females called a harem, a multi male group or a large troupe.

a. The **solitary ones** are the lemurs, loris and tarsiers. They are arboreal, nocturnal and feed on insects. They make contacts only during the breeding season.
b. **White handed gibbons** (*Hylobates lar*) are monogamous species. A pair lives with their offspring. The offspring move away after they become sexually mature. They are territorial.
c. The **gelada baboons** show variation in social organization depending on the availability of food. There are single male herds. There are herds with a 'single' male and a harem of females.
d. The **mountain gorilla** lives in small groups, headed by a single male and includes other males as well. They are not territorial.

Some of the smallest primate societies are seen in the gibbon and orangutan. Orangutan is an exceptionally solitary animal while the gibbons live as small family units, the father mother and their offsprings. Some of the largest groups are to be found in the terrestrial primates-baboon troops range up to 90.

A high level of intercommunication is seen between the members of a primate group. Each individual is constantly responsive to the movement, gestures and calls of others. Primate societies are as much characterized by positive interactions as negative ones mutual grooming is very important as a placatory gesture in primates. Often a dominant will allow itself to be groomed by a subordinate following a brief threat to subordinate. Sexual presentation is a common appeasement gesture in baboon, chimpanzees and is made by males or females towards a dominant animal.

The pattern of grooming relationships in a group is often a good measure of its detailed structure. In shrews and macaque a good proportion of the grooming into their mother or siblings and this serves to establish a social unit (genealogical unit). Primates vary greatly in the degree of fighting. Even within a single species, there may be considerable variations in langur populations of Northern India are as more peaceful than those in the south .This is probably due to the fact that population densities are much greater in the south where the aggressive group live.

Since primate groups are never very large and to avoid inbreeding problems transfer to another group. There is a good deal of disputing as young males become sexually mature and

this is the commonest time for them to leave. The commonest type of primate group in which there are usually several adult males. Some primate societies such as that of the Hamadyas baboons (*Papiohamadys),* the Langur *(Presbytis extellus)* population of south india is based on one male group.

FEATURES OF SOCIAL ORGANIZATION IN MONKEYS

Social organization in monkeys can be broadly studied under the following categories.

a. Size and composition of a social organization
b. Territoriality and aggression
c. Feeding behaviour
d. Dominance hierarchy
e. Communication
f. Grooming
g. Sexual behaviour
h. Parental care
i. Altruism

a. **Size and composition of a social organization**

Monkeys are the most common and successful primates. They are mostly arboreal or rarely may be terrestrial. They are diurnal, prefer to live in groups. The Bonnet monkey, *Macaqua radiate* is the most common macaque of south India. It can be easily recognized by a cap of brown hair that appears like a baby's bonnet (cap).There is sexual dimorphism and males are larger than female with distinct canines. They live in groups called troops and live in forests, villages and also in cities A troop consist of 30 individuals with both males and females of different age groups

a. **Infants:** They have chocolate colour hair
b. **Juveniles**: between 1-2 years with brown hair
c. **Seniors**: : between 2-3 years with brown hair
d. **Sub adults**: 3-5 years old males and 2-3 years old females
e. **Adults**. 4 years old males and 3 years old females. Have brown hair on the back and white hair on belly. The older individuals have yellowish grey hair.

b. Territoriality and aggression

Macaques are seen around large banyan trees and tamarind trees.They are also spotted near peanuts and horsegram fields.They are also spotted near temples and gardens.They are a menance to sericulturista as they feed on silkmoth larvae. Bonnet monkeys are ground dwellers.

Their home range could be 1-3 km, which can be changed based on season, availability of food and encroachment by man

There is no much aggression. At times when a male of one troop encroach into others core areas they will be chased away and threatened. Aggression is seen within the troop in a feeding area, if there is a scarcity of food. There is no aggression resting area.

Certain amount of aggression does occur within the troop this is to maintain the stability. Aggression is linked to **dominance hierarchy.**

The **movement of the troops out of their home ranges does occur.** The movement of the troops are influenced by rainfall, scarcity of food and human encroachment. During rainy days their movements will be restricted, but sometimes they may be forced to move into newer areas looking for food. During harvest time the food is guarded and thus they are chased away from their territories.

When they move or migrate the **dominant male leads the troop** followed by the adult male and females followed by females with babies and juveniles. The remaining males are seen in the rear of the troop. The **sub adults and juveniles** move on land following the adults, they also climbe on to the branches of the trees and leap around as they are hyper active. Some of them lag behind looking for food or falling off the branches. However they ultimately join the troop. The dominant male calls out to them to make sure the members are together.

c. Feeding Behaviour

The bonnet monkeys feed **during the morning and evenings** resting in between and normally avoid feeding at night. They are seen feeding throughout the day if food is available. The monkeys are **omnivorous** and feed on a variety of food like, crops ie paddy, grams, peanuts, wild fruits gum juice, insects, larval forms, arachnids, cultivated crops such as coffee fruits, citrus fruits and cardamom. They eat the leaves, fruits, stem, bark, stilt roots etc. They also eat birds' eggs and fungi. Strange things such as its own faecal matter and copulatory semen are eaten by one or both partners.

They feed in a hurried manner and store food in cheek pouches. The food is later taken out by using their hands or movements of the tongue and chewed slowly.

d. Dominance Hierarchy

The troop always has a dominant male (alpha male)The crowning of alpha male occurs with threats and attack. The threat posture is seen in a typical male is an open mouth with teeth exposed, ears are held against head. The head and body is held stiff. The attack includes biting and manual biting. There will not be much injury caused to other. Staring is also a part of competition. The male stares at another male with head held forward and brow protruded.The loser walks away.The dominant male moves around majestically with its tail raised in the form of S letter. The subordinate male assumes a crouching or subdued position

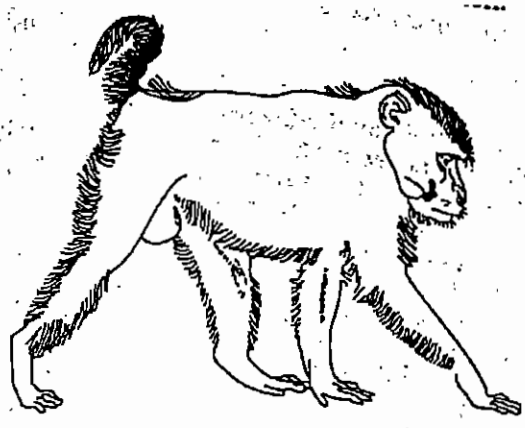


Figure 2.28 Dominant male

Figure 2.29 Subordinate male

e. Communication

Communication is an essential part of a social orgnaization. Communication is of various types, using signs and signals, sounds and odours .

The **body language of the individuals** in the troop depends on their social ranking. The dominant male has a majestic gait while the subordinates have a subdued posture. The females that are in heat or estrous females invite the male to mate during the breeding season. The facial expressions are used to convey their feelings. The **threating expression**, the **brow** movement, the **jaw thrust** and **rocking of the head** occurs to summon the partner or others.

The monkeys are able to make **different sounds** that convey different feelings and intentions. The **growl** to threaten others, they **give out a loud whooping cry** to warn the others of a danger. They make **soft sound** to invite others to groom them. They can also **cry loudly** in distress in an event of injury.

Odours are **pheromones** that are sexual attractants. Pheromones produced by females are used to attract the males. The males recognize a female in heat and inspect her before copulation.

f. Grooming

Grooming is the cleaning of the body surface either by themselves or by others. The cleaning process involves, **licking, picking nits from the hair and nibbling** or **even scratching**. If the monkeys groom themselves it is **autogrooming** and if they are groomed by others it is **allogrooming**. **Mutual grooming** occurs between two consenting individuals. There can also be **group grooming** where more than two or three adults sit together and groom each other.

i. Grooming is an activity that brings **about social contact**, encourages the **mingling** among different individuals of various ranks. There is a bonding between the individuals.
ii. It **reduces aggression** among the individuals.
iii. It helps keep the members of the troop **clean and devoid of ectoparasites**.
iv. It is a **relaxing activity** and they spend a lot of time grooming while they are not feeding or moving around.
v. Grooming allows the **subordinate male to get closer** to the dominant male which is otherwise not possible.

g. Sexual Behaviour

The bonnet monkeys have a breeding season that lasts from August to November. There is an increase in the population during February and March. Mating is influenced by increase in humidity, more rainfall and low temperature. In some troops there has been incidence of mating even in other months.

The males approach females for copulation. The dominant males have the first choice and females also oblige them. The females assume a presentation display when the dominant males are around. The female **turns its back to the male and lifts her tail**. This is an **invitation** for the males to mate. This posture conveys that she is willing to mate. During the breeding season some female monkeys have a **swollen and brightly coloured rear end**.

However the females are **not averse to mating with the subordinates** too. The males do not disturb the mating couple even if the females are with lower ranking males.

The males are attracted to estrus females due to pheromones and there is **genital testing** of the females by the males or **anogenital exploration.** The males **check out** if the females are in a receptive condition and only then mate with her.

They are normally polygamous. There have been very **few incidences** of a male and a female forming permanent pair or consort relationships.

h. Parental Care

The **period of gestation is about 150 days.** Normally only one individual is born but there may be rare incidences of twins. The infants are helpless and bonnet monkeys have a longer dependency period on the mother. The first **4 to 6 weeks** of the infants life is spent clinging to the ventral side of the mother and feeding on milk. The infant- mother relationship is very close and the bonding last for almost a year or more or till another infant is born.

The baby leaves the mother after it is about **three months** and moves about but stays close to her. The mother keeps a watch on him. The baby is able to eat and chooses softer food, which it can chew and store in its cheek pouches. It is easily weaned off by the end of the 11th month or after a year.

The babies **are well cared by the mother and also by other members later.** The mother suckles the infants, grooms him and plays with him. An infant is a powerful focus of attention and all members of the troop come to look at him, approach him when he is three months old to play with him or just to hold him. The mother **allows the baby** to be taken away for brief periods so that she could rest or feed. The **other females become baby sitters** and the **males play with him by making him ride on their backs.** The **younger males also have the habit of taking the baby** and presenting him to the dominant male to show off. This behaviour is an excuse to gain proximity to the dominant male that is not otherwise possible.

learning experience. The baby learns to

i. Altruism

Group selection or kin selection is seen in **animals that live in a social organization.** In a social organization, there is a close bonding between members of the colony. Both invertebrate and vertebrate colonies exhibit kin selection. Group selection aims at **saving the fit ones or selected ones or the younger generation** so that they live to reproduce and continue the species. This requires **'altruistic behaviour'** from the other individuals. Thus **altruism** is considered a key factor in kin selection.

In the **larger vertebrates in a troop of primates** the older members of the colony take up responsibility to protect the young or juvenile as they are the ones that carry their genes to the next generation. The older members do not mind sacrificing their lives to save the younger and fit individuals. The **hierarchical system** is important in a social organization. The dominant male or the female makes sure the organization runs smoothly. The distribution of food is also an important event. The food is made available to the young and juveniles as they are not capable of fending for themselves.

Many altruistic behaviours are seen in a primate colony. The monkeys look after the young ones not necessarily their own. Obtaining food and sharing of food, co-operative group defense against intruders is common troop behaviour.

Mutual altruistic behaviour is also seen. If a male A stays close to a female during estrus and a male B want to mate with her another individual C may risk his life and help B. Later in life B may help C if C approaches him. This kind of behaviour is reciprocal altruism. Where the policy of 'you scratch my back and I'll scratch yours' works well.

In conclusion we can state that the social organization of a primate colony is a well-organized one and is a successful one as it has withstood the pressures of time and evolution. This is due to the fact that the benefits of being in a colony outweighs its disadvantages.

QUESTIONS

1. Give an account of the social organization in primates.
2. Explain the origin and evolution of a social organization and explain the salient features of a primate colony.
3. Write short notes on,
   a. Origin of a social organization.
   b. Parental care in primate society.
   c. Dominance hierarchy in primate society.
   d. Communication and sexual behaviour in a primate society.
   e. Size and composition of a primate society.
   f. Territorial and aggression in a primate colony.
   g. Altruistic behaviour.