5th Semester

Applied Zoology (ZOO516DB)

Unit-1 Host-parasite Relationship and epidemiology

1.1 Types of hosts, types of relationships (Parasitism, Symbiosis, Commensalism)

Symbiosis: Symbiotic relationships, or symbioses (plural), are close interactions between individuals of different species over an extended period of time which impact the abundance and distribution of the associating populations. Any association between two species populations that live together is symbiotic, whether the species benefit, harm, or have no effect on one another. Both positive (beneficial) and negative (unfavourable to harmful) associations are therefore included, and the members are called symbionts. Symbiosis, is any of several living arrangements between members of two different species, including mutualism, commensalism, and parasitism.

Mutualism: In past it was termed symbiosis. Mutualism, is association between organisms of two different species in which each benefits. Mutualistic arrangements are most likely to develop between organisms with widely different living requirements. In this case both of the species derive benefits and there exists a close and often permanent and obligatory relationship which is more or less essential for survival of each..

For example, termites have a mutualistic relationship with protozoa that live in the insect's gut. The termite benefits from the ability of bacterial symbionts within the protozoa to digest cellulose. The termite itself cannot do this, and without the protozoa, it would not be able to obtain energy from its food (cellulose from the wood it chews and eats). The protozoa and the bacterial symbionts benefit by having a protective environment and a constant supply of food from the wood chewing actions of the termite.

Lichens have a mutualistic relationship between fungus and photosynthetic algae or bacteria. As these symbionts grow together, the glucose produced by the algae provides nourishment for both organisms, whereas the physical structure of the lichen protects the algae from the elements and makes certain nutrients in the atmosphere more available to the algae.

Commensalism: Commensalism, in biology, is a relationship between individuals of two species in which one species obtains food or other benefits from the other without either harming or benefiting the latter. The commensal—the species that benefits from the association—may obtain nutrients, shelter, support, or locomotion from the host species, which is unaffected. The commensal relation is often between a larger host and a smaller commensal. The host organism is essentially unchanged by the interaction, whereas the commensal species may show great morphological adaptation. This relationship can be contrasted with mutualism, in which both species benefit.

One of the best-known examples of a commensal is the remora (fish) that rides attached to sharks and other fishes. Remoras have evolved on the top of their heads a flat oval sucking disk structure that adheres to the bodies of their hosts. Both remoras and pilot fishes feed on the leftovers of their hosts' meals.

Other examples of commensals include bird species, such as the great egret (*Ardea alba*), that feed on insects turned up by grazing mammals or on soil organisms stirred up by plowing. Various biting lice, fleas, and louse flies are commensals in that they feed harmlessly on the feathers of birds and on sloughed-off flakes of skin from mammals.

Parasitism:- Parasitism is a kind of relationship between species, where one organism lives on or in another organism, causing some harm to host, and the parasite is adapted structurally to this way of life. A parasite is an organism that lives in or on another living organism and derives nutrients from it. In this relationship, the parasite benefits, but the organism being fed upon, the host is harmed. The host is usually weakened by the parasite as it siphons resources the host would normally use to maintain itself. The parasite, however, is unlikely to kill the host, especially not quickly, because this would allow no time for the organism to complete its reproductive cycle by spreading to another host. Parasitism is a kind of symbiosis, a close and persistent long-term biological interaction between the parasite and its host. Unlike commensalism and mutualism, the parasitic relationship harms the host, either feeding on it or, as in the case of intestinal parasites, consuming some of its food. Within that scope are many possible ways of life. Parasites are classified in a variety of different but overlapping schemes, based on their interactions with their hosts and on their life cycles, which are sometimes very complex.

Ecto-parasite (Ectozoa): Lives outside on the surface of the body of the host. E.g ticks and mites
Endo-parasite (Entozoa): Lives inside the body of the host: in the blood, tissues, body cavities, digestive tract and other organs. E.g *Ascaris*, *Plasmodium* etc
Temporary Parasite: Visits its host for a short period. E.g mosquito
Permanent Parasite: Leads a parasitic life throughout the whole period of its life. E.g *Ascaris*
Facultative Parasite: Lives a parasitic life when opportunity arises.
Obligatory Parasite: Cannot exist without a parasitic life. E.g *Plasmodium*
Occasional or Accidental Parasite: Attacks an unusual host.
Wandering or Aberrant Parasite: Happens to reach a place where it cannot live.
Epiparasite: It is a parasite whose host, often an insect, is also a parasite and their association is called hyperparasitism

Types of Hosts

Host is the organism upon or inside which the parasite lives or the organism which lodges the parasite.

Before discussing the various types of hosts let us take an example of the malaria causing protozoan parasite *Plasmodium.* For this parasite there are two hosts, man and female *Anopheles* mosquito. In mosquito the parasite undergoes sexual reproduction to produce infective stages. When this mosquito bites the man, infective stages get transmitted to man. Here in second host the parsite undergoes asexual reproduction and produces large no of parasites. Some of the parasites get matured into gamete producing parasites. So when mosquito bites the infected man, gamete producing parasites get transmitted to mosquito where sexual reproduction takes place and the cycle continues.

The various types of hosts are as.

1. PRIMARY HOST (Definitive host): It is the host that harbours the adult stage or sexually mature stage of a parasite or the host in which the parasite undergoes sexual reproduction. e.g., Man is the primary host for *Wuchereria bancrofti* (Filarial Worm), Female *anopheles* mosquito is the primary host for malaria causing protozoan *Plasmodium vivax.*

2.**SECONDARY HOST (Intermediate host)**: Is the host that harbours the developing larval or immature or asexual stages of a parasite or the host in which the parasite undergoes asexual reproduction. e.g, Man is the secondary host for *plasmodium vivax*, Female culex mosquito is the secondary host for *Wuchereria bancrofti.*

3.Paratenic Host (A carrier or transport host): An intermediate host which is not needed for the development of the parasite, but nonetheless serves to maintain the life cycle of the parasite . It is a host, where the parasite remains viable without further development. A paratenic host is similar to an intermediate host, except that it is not needed for the parasite's development cycle to progress. Paratenic hosts serve as "dumps" for non-mature stages of a parasite in which they can accumulate in high numbers.

4. Reservoir Host: Also known as temporary host. It is the host that lodges the infective stages of a parasite in its body when the main host is not available. In the reservoir host , the parasite neither undergoes development nor causes any disease. In the absence of regular host some parasites survive in the reservoir hosts. Reservoir hosts become the source of infection for regular hosts. Reservoir hosts are not essential for the parasite to complete its life cycle. e.g, Monkey is the reservoir host for *Plasmodium*

5. Vector Host: Vector is an organism which transfers the infective stages of a parasite from one main host to another. It is host in which part of life cycle of host takes place and is instrumental in transmission of infective stages of parasite from one host to another.

Vectors are of two types , namely;

A) MECHANICAL VECTOR: It is the vector , which merely transfers the infective stages of a parasite but no part of the parasitic development takes place in it. e.g., Houseflies and Cockroaches in the case of *Entamoeba.*

B) BIOLOGICAL VECTOR: It is the vector in which the parasite undergoes a part of the development before it gets transferred to another host. e.g., Female *anopheles* mosquito in the case of *Plasmodium* and Female *culex* mosquioto in the case of *Wuchereria.*

1.2 Zoonosis Transmission, Prevention and control of diseases (Tuberculosis, typhoid)

Zoonosis: Zoonosis refers to diseases that can be passed from animals to humans. They are sometimes called zoonotic diseases. Animals can carry harmful germs, such as bacteria, fungi, parasites, and viruses. These are then shared with humans and cause illness. Zoonotic diseases range from mild to severe, and some can even be fatal.

Tuberclousis:

Tuberculosis (TB; short for tubercle bacillus) is a common, and in many cases lethal, infectious disease caused by various strains of mycobacteria, usually *Mycobacterium tuberculosis* . Tuberculosis typically attacks the lungs, but can also affect other parts of the body. It is spread through the air when people who have an active TB infection cough, sneeze, or otherwise transmit their saliva through the air. Most infections are asymptomatic and latent, but about one in 10 latent infections eventually progresses to active disease which, if left untreated, kills more than 50% of those infected. One third of the world's population is thought to have been infected with M. tuberculosis with new infections occurring at a rate of about one per second.

Zoonotic tuberculosis (TB) is a form of tuberculosis in people caused by *Mycobacterium bovis*, which belongs to the *M. tuberculosis* complex. Cattles are most important animal reservoir for *M. bovis* in relation to zoonotic exposure of humans. But the disease can affect many other species snd become established in wildlife reservoirs. It often affects sites other than the lungs (extrapulmonary), but in many cases is clinically indistinguishable from TB caused by *M. tuberculosis.*

Transmission: When people with active pulmonary TB cough, sneeze, speak, sing, or spit, they expel infectious aerosol droplets 0.5 to 5.0 µm in diameter. A single sneeze can release up to 40,000 droplets. Each one of these droplets may transmit the disease, since the infectious dose of tuberculosis is very small (the inhalation of fewer than 10 bacteria may cause an infection).

While the most common route of transmission of *M. bovis* to humans is through food (mainly untreated dairy products or, less commonly, untreated meat products), airborne transmission also poses an occupational risk to people in contact with infected animals or animal products, including farmers, veterinarians, slaughterhouse workers and butchers. Zoonotic TB can also get transmitted to humans through close contact with wild animals like elephants etc.

Prevention And control:

IMPROVE THE SCIENTIFIC EVIDENCE BASE

1. Systematically survey, collect, analyse and report better quality data on the incidence of zoonotic TB in people, and improve surveillance and reporting of bovine TB in livestock and wildlife.

2. Expand the availability of appropriate diagnostic tools and capacity for testing to identify and characterize zoonotic TB in people.

3. Identify and address research gaps in zoonotic and bovine TB, including epidemiology, diagnostic tools, vaccines, effective patient treatment regimens, health systems and interventions coordinated with veterinary services.

REDUCE TRANSMISSION AT THE ANIMAL-HUMAN INTERFACE

4. Develop strategies to improve food safety.

5. Develop capacity of the animal health sector to reduce the prevalence of TB in livestock.

6. Identify key populations and risk pathways for transmission of zoonotic TB.

STRENGTHEN INTERSECTORAL AND COLLABORATIVE APPROACHES

7. Increase awareness of zoonotic TB, engage key public and private stakeholders and establish effective intersectoral collaboration.

8. Develop and implement policies and guidelines for the prevention, surveillance, diagnosis, and treatment of zoonotic TB, in line with intergovernmental standards where relevant.

9. Identify opportunities for community-tailored interventions that jointly address human and animal health.

10. Develop an investment case to advocate for political commitment and funding to address zoonotic TB across sectors at the global, regional and national levels

ZOONOTIC TB MUST BE PRIORITIZED IN THE GLOBAL HEALTH AGENDA

The UN Sustainable Development Goals (SDGs) emphasise the importance of multidisciplinary approaches to improving health. In the context of the SDGs, WHO's End TB strategy calls for diagnosis and treatment of every TB case. This must include people affected by zoonotic TB. Zoonotic TB in people cannot be fully addressed without controlling bovine TB in animals and improving food safety. Through a One Health approach, together we can save lives and secure livehoods.

1.3 Life history and pathogenicity of *Entamoeba histolytica, Plasmodium vivax, Trypanosoma gambiense*

Entamoeba Histolytica

Entamoeba Histolytica is a parasitic protozoan and lives as an endo-parasite in the upper part of the large intestine, i.e., colon of man. It inhabits the mucous and sub-mucous layers of the large intestine. It feeds mainly on the tissues of the intestinal wall and often produces severe ulcers and abscesses. The parasite is worldwide in distribution and more common in most countries of trop-ics and subtropics rather than temperate zones. E. histolytica is scarcely pathogenic found in human beings of temperate zones.

Life Cycle of Entamoeba Histolytica:

The life cycle of E. histolytica is completed through a single host-man. Hence it is called monogenetic. Trophozoite and cyst stages of the parasite are concerned with the life cycle.

Encystment: Entamoeba histolytica multi-plies by binary fission in the trophozoite stage. They have the capacity to encyst. Unfavourable conditions in the habitat such as lack of nutrients, temperature deviations from the optimum range, decreased O2 ten-sions, lowered pH and accumulation of meta-bolic wastes may be the causes for encyst-ment.

Precystic form: Prior to encystment the trophozoite of each parasite loses its pseu-dopodium, eliminates food vacuoles and becomes spherical, called a precystic form. The diameter of this stage varies 10-20 µm and the structure of the nucleus is like the trophozoite stage of the parasite.

Mature cyst form: The precystic form secrets a thin, tough and transparent mem-brane around it, called the cyst wall. The animal having a cyst is called a cyst. The process of enclosing in a cyst is called encystment or encystation. At the early stage the cyst contains a single nucleus. The single nucleus is divided mitotically forming two nuclei. This is called binucleate cystic stage. Then the two nuclei are divided by mitosis and four nuclei occur. The nuclear divisions take place without cytoplasmic division and this tetra-nucleate cyst is called mature cyst. The whole process of encystment takes a few hours and the mature cyst lives in the lumen of the intestine of host only two days.

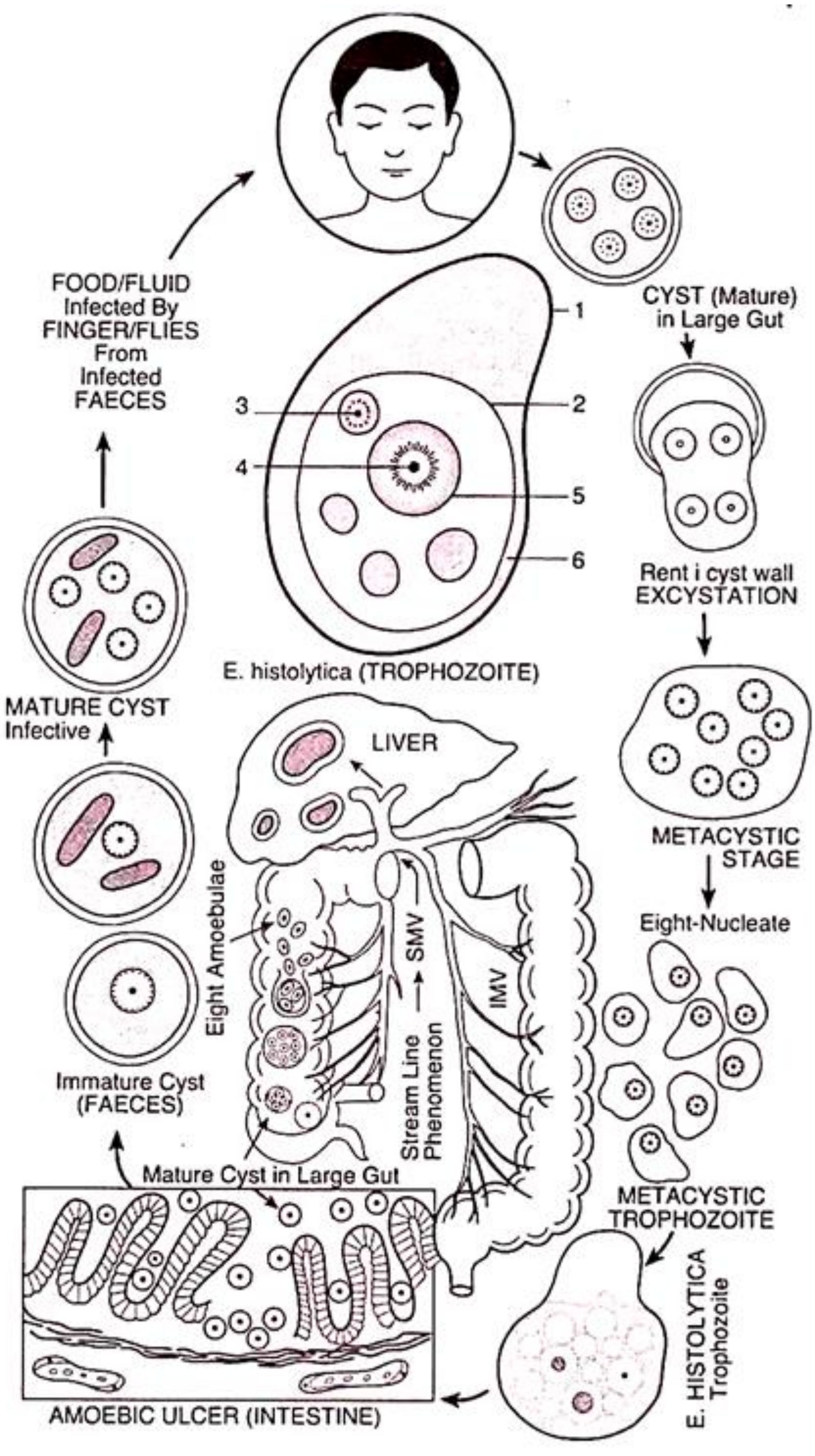
Tolerance of the cyst: The cysts of E. histolytica can survive about one month in water and about 12 days on dry land. They can tolerate the temperature up to 50° Celsius and 4 hours in formaldehyde solution.

Infection: At the tetranucleate stage the cyst is infective to a new host. The infective cysts pass out through the host's faeces and are introduced into the gut lumen of a new host through the contaminated drink, food and vegetables.

Excystment: Then the infective cysts pass into the lower portion of the small intestine (colon) of the new host. Here the process of excystment occurs. The excystment is the process by which the cysts are transformed into the trophozoites. The cyst wall in the colon becomes permeable by the action of intestinal enzymes, the trypsin of the intes-tine. The cyst wall ruptures and 4-nucleate amoeba emerges out from the cyst.

Factors for excystment: Temperature, pH, chemical composition of the medium and the flora of the bacteria may be the reasons for excystment.

Metacystic form: After the emergence of quadrinucleate amoeba, the division of cyto-plasm immediately ensues and produces four small metacystic trophozoites.



Trophozoites: Both the nucleus and cytoplasm of each metacystic trophozoite divide and as a result 8 small amoebulae are produced. These are called young uninucleate trophozoites. They are motile and penetrate the mucous membrane.

The young trophozoites feed on host tissues, blood, bacteria and yeast and gradually in-crease in size to attain maturity. Inside the tissues the trophozoites multiply and start the procystic form of the life cycle. Transformation of a quadrinucleate metacystic stage of entamoeba histolytica to eight uninucleate trophozoites

Transmission: Cysts of Entamoeba are transmitted from one individual to another in a variety of ways:

1. The cysts are generally transmitted with food or drink.

2. House flies and cockroaches may trans-mit cysts mechanically.

3. Raw vegetable is also another source of infection.

4. In many countries human faeces are used as fertilizer and thus roots and leaves of plants remain contaminated with viable cysts. Food handlers are also sometimes responsible for the spread of infection owing to imperfect personal sanitary measures.

Pathogenicity (Pathogenic Effects) of Entamoeba Histolytica:

Entamoeba histolytica causes amoebic dysentery, abscesses in liver, lungs and brain and non-dysenteric infections.

1. Amoebic Dysentery: Entamoeba histolytica secretes a tissue dissolving enzyme (probably of histolysin nature) that destroys the epithelial lining of the colon and causes its necrosis and forms the abscesses (small wounds) which later become flask- shaped bleeding ulcers. The cavity of these ulcers is generally filled with mucus, bacteria, amoeba and cell debris. The abscesses pour their contents into the lumen of the intestine. The ulcers vary greatly in number and size; in severe cases almost the entire colon is undermined. The ulceration of colon may produce severe dysentery. In amoebic dysentery, the stools are acidic and contain pure blood and mucus, in which swarms of amoeba and blood corpuscles, are usually present. The patient feels discomforted due to the rectal straining and intense gripping pains with the passage of blood and mucus stools every few minutes.

2. Abscesses in Liver, Lungs and Brain: Sometimes Entamoeba histolytica may be drawn into the portal circulation and carried to the liver. In liver the parasites settle, attack the liver tissue and form abscesses. The patient has pain in liver region, fever and high leucocyte number, a condition referred to as amoebic hepatitis. Lung abscesses are fairly frequent; these are usually caused by direct extension from a liver abscess through the diaphragm. The lung abscesses usually rupture into a bronchial tube and discharge a brown mucoid material which is coughed out with the sputum. Sometimes the parasite also forms abscesses in the brain. Abscesses elsewhere are rare.

3. Non-Dysenteric Infections: Although amoebiasis is usually thought of as the cause of dysentery with blood and mucus containing stools or of liver abscesses, these conditions are actually the exception rather than rule and some workers have reported that as many as 90% of dysentery cases in temperate climates are apparently symptomless. Even in tropics, dysentery is exceptional. Although about 10% of the general population is infected with Entamoeba histolytica, yet most of them are carriers or passers. The symptoms commonly associated with chronic amoebiasis are abdominal pain, nausea, and bowel irregularity, with headaches, fatigability and nervousness in minority of cases.

Treatment (Therapy) of Entamoeba Histolytica:

For prompt relief of acute or sub-acute dysentery the injections of Emetin are given. But certain antibiotics, such as Fumagillin, Terramycin, Erythromycin and Aureomycin are more effective and may be given orally. For eradication of intestinal infections or in chronic cases, certain arsenic compounds (Carbarsone, Thiocarbarsone and Vioform) and a number of iodine compounds (Yatren, Diodoquin and Vioform) are effective. For amoebiasis of liver or lungs, Chloroquine is quite effective. The most significant advancement in the treatment of amoebiasis is the use of Metronidazole and Tinidazole as both luminal and tissue amoebicide.

Prevention (Prophylaxis) of Infection Caused by Entamoeba Histolytica:

Following measures are essential in the prevention of the disease:

1. Sanitary disposal of faecal matter.

2. Perfect sanitation and protection of water and vegetables from pollution.

3. Washing of hands with antiseptic soap and water before touching the food.

4. Cleanliness in preparing the food.

5. Protection of foods and drinks from houseflies, cockroaches, etc.

6. Raw and improperly washed and cooked vegetables should be avoided.

Plasmodium vivax

Members of the genus Plasmodium are collec-tively known as malarial parasites because they cause a febrile disease by the bite of the malarial parasite infected female anopheles mosquitoes called malaria. Plasmodium vivax lives as an intracellular parasite in the red blood corpuscles (R.B.Cs) of man in the form of its mature adult condition, called trophozoite. The species of Plasmodium are reported from reptiles, birds and various mammals. However, Plasmodium is widely distributed in tropical and temperate countries of the world but they are no longer a problem in the colder countries of the world. Countries like India, Sri Lanka, Bangladesh, Nepal, Pakistan, etc., are worst affected. Plasmodium vivax has two hosts; man and female Anopheles mosquito. Man is considered to be the primary host and female Anopheles mosquito, the secondary or intermediate host.

Life Cycle and Plasmodium Vivax:

The life cycle of Plasmodium vivax is digenetic involving two hosts as mentioned earlier. Its life cycle is completed both by asexual and sexual phases. Asexual phase of its life cycle is completed in man by schizogony (differentiated into exoerythrocytic schizogony involving pre- and post-erythrocytic schizogonic cycles, and erythrocytic schizogony) and sexual phase of its life cycle is completed in female Anopheles mosquito by gametogony, syngamy and sporogony.

(a) Part of Life-Cycle of P. Vivax in Man (Asexual Cycle):

It is completed in the following way:

Inoculation: When an infected female Anopheles bites a man to suck his blood, then along with its saliva it injects the sporozoite stage of Plasmodium into the human blood. The parasite remains always in the body of one of the two hosts, hence, the sporozoites do not possess any protective covering. The sporozoite, infective stage, is minute measuring about 11 to 12 microns in length and 0.5 to 1 micron in width, sickle-shaped cell with an oval nucleus; mosquito inoculates sporozoites in thousands. The sporozoites are capable of slight gliding movement. In about half an hour the sporozoites disappear from the blood stream, and they enter the parenchymatous cells of the liver where they undergo at least two schizogonic cycles.

Schizogony in Liver Cells: In the liver cells, the sporozoite grows to form a large, round schizont. The schizont divides by multiple fission to form about one thousand to several thousand small spindle-shaped cells called merozoites; this multiple fission is called schizogony. The schizont ruptures and merozoites are liberated into the sinusoids or venous passages of the liver.nThis phase of asexual multiplication is pre-erythrocytic schizogony and the merozoites produced by it are also called cryptozoites or cyptomerozoites; these cryptozoites are immune to medicines and the resistance of the host.

A second phase of asexual multiplication known as an exo-erythrocytic schizogony occurs in the liver cells in which the cryptozoites enter into new liver cells and grow into schizonts, the schizont divides to form merozoites; the merozoites of the second generation are termed metacryptozoites or phanerozoites. The exo-erythrocytic schizogony may continue in more liver cells to form a reservoir of merozoites, or some merozoites after at least two cycles of schizogony may re-enter the blood stream when they invade erythrocytes. It is supposed that the merozoites of second generation, i.e., metacryptozoites are of two types; the more numerous and smaller are micro-metacryptozoites, while larger and less in number are macro-metacryptozoites. In fact, the micro-metacryptozoites invade the R.B.Cs and start erythrocytic schizogony, while the macro-metacryptozoites enter fresh liver cells to continue the exo-erythrocytic schizogony. The merozoites attack only the young and immature corpuscles, (the merozoites of P. malariae attack only old corpuscles, while those of P. falciparum attack all kinds of corpuscles indiscriminately).

Pre-patent and Incubation Periods:The pre-patent period is the duration between the initial sporozoite infection and the first appearance of parasite in the blood. In case of P. vivax, it is about 8 days on an average. The incubation period is the time taken from the infection of man by sporozoites till the appearance of first malarial symptom. In case of P. vivax, it is about 14 days on an average ranging from 10 to 17 days. Of course, during the incubation period the host shows no symptoms of malaria.

Schizogony in Erythrocytes: In the erythrocytes, a third multiplication phase of schizogony occurs which is known as erythrocytic schizogony. The micro-metacryptozoite feeds on erythrocytes, a vacuole appears in it, the nucleus is pushed to one side, and the micro-metacryptozoite is changed into what is called as the ring-shaped trophozoite, the signet ring stage, which is 1/3 to 1/2 the size of the erythrocyte. The signet ring stage is not found in P. falciparum. The trophozoite grows to become rounded and amoeboid, this is the full grown trophozoite and is known as a schizont. The large schizont makes the erythrocyte to become very large. The schizont shows yellowish-brown pigment granules of haemozoin derived from the iron of haemoglobin of erythrocyte; the enlarged erythrocyte acquires granules called Schuffner's dots. The schizont now undergoes multiple fission to form 12 to 24 oval-shaped merozoites; this phase of asexual multiplication is erythrocytic schizogony. The much weakened erythrocyte bursts and the merozoites are liberated into the plasma from where they enter new erythrocytes, then they repeat the erythrocytic schizogony once every 48 hours. However, the merozoites may again go from the blood to the liver cells and invade them to undergo another phase of asexual multiplication which is called post-erythrocytic schizogony.

Formation of Gametocytes: After many generations of schizogony in the blood, some of the merozoites slowly grow large producing much haemozoin, these are inside erythrocytes and do not change in schizonts but they grow and are transformed into two types of gametocytes called macro gametocytes and microgametocytes. The condition which brings about the formation of gametocytes is not known. Gametocytes appear in the peripheral blood at various intervals after the onset of fever, they remain inactive while in the human blood. The macro gametocytes are female, they are round with the food laden cytoplasm and a small eccentric nucleus. The microgametocytes are male, they have a clear cytoplasm and a large central nucleus. Both gametocytes contain large amounts of haemozoin; they enlarge the erythrocytes. Gametocytes remain in the human blood for several weeks, but are unable to develop any further, it is necessary for them to be taken into the body of an Anopheles', if this does not happen they degenerate and die.

(b) Part of Life-Cycle of P. Vivax in Mosquito (Sexual Cycle):

Many species of Anopheles, but not all species, act as intermediate hosts. If the gametocytes are sucked up along with human blood by a female Anopheles then they reach the stomach where corpuscles are dissolved and the gametocytes are set free.

Gametogony: The microgametocytes, after release in the stomach of mosquito, undergo the process of ex-flagellation. The cold-bloodedness of the mosquito is said to stimulate this process. However, the nucleus of microgametocytes divides into 6-8 haploid daughter nuclei. These nuclei migrate towards the periphery of microgametocyte. The cytoplasm pushes out forming long flagellum like structures having one daughter nuclei in each. Thus, 6-8 flagellum like male gametes or microgametes measuring from 20-25 microns in length are formed. Soon these gametes separate and start moving actively in the stomach of mosquito.

On the other hand, the macro gametocytes undergo maturation process, thereby two polar bodies are pushed out and a female gamete or macrogamete is formed. The female gamete is non-motile and develops a cytoplasmic or receptive cone. Stomach of an infected female anopheles with oocysts of Plasmodim

Fertilisation: If microgamete happens to reach the macrogamete, then it enters into the female gamete at the point of cytoplasmic cone and finally complete fusion of nucleus and cytoplasm of the two gametes occurs. This results in the formation of rounded zygote. Several microgametes may approach a macrogamete but only one of them enters the macrogamete and others shed off. The fusion of male and female gametes is called syngamy. Here, the gametes are dissimilar (anisogametes), hence, their fusion is called anisogamy.

Ookinete and Encystment: The zygotes, thus, formed remain rounded and motionless for 24 hours but soon they elongate to become worm-like having pointed ends and motile. The zygotes are now called ookinetes or vermicules. An ookinete measures about 15 to 22 microns in length and 3 microns in width. The ookinete moves and bores through the wall of the stomach of mosquito and comes to lie beneath the outer epithelial layer. (The ultrastructure of ookinete shows the presence of a central, irregular nucleus, dense cytoplasm, brown pigment granules, many mitochondria and ribosomes in it. It also shows the presence of contractile fibrils, the microtubules). However, here they become spherical and secrete a thin elastic membranous cyst. The cyst is also partly secreted by the surrounding tissues of the stomach. Thus, the ookinetes become encysted and in this condition it is referred to as the oocyst. The oocyst grows in size and sometimes called sporont. As many as 50 such oocysts can be seen on the stomach of the host mosquito. Howard (1906) has observed that the ookinetes which do not succeed in boring the stomach wall pass out from mosquito's body with faecal matter.

Sporogony: The nucleus of oocyst first divides by meiosis and then by mitosis several times (Bano, 1959) and its cytoplasm develops vacuoles forming faintly-outlined cells called sporoblasts. Particles of chromatin arrange themselves around the periphery of each sporoblast. Then the cytoplasm forms slender spindle-shaped haploid cells known as sporozoites. Each oocyst may have ten thousand sporozoites, and group of sporozoites gets arranged around the vacuoles. This phase of asexual multiplication in which sporozoites are formed is called sporogony which is completed in 10-20 days from the time the gametocytes are taken in by the mosquito, the time depending on the temperature. The oocyst bursts and sporozoites are liberated into the haemolymph of the mosquito, from where they reach its salivary glands and enter the duct of the hypopharynx. The sporozoites will infect a human host when the mosquito bites and the life cycle is repeated again.

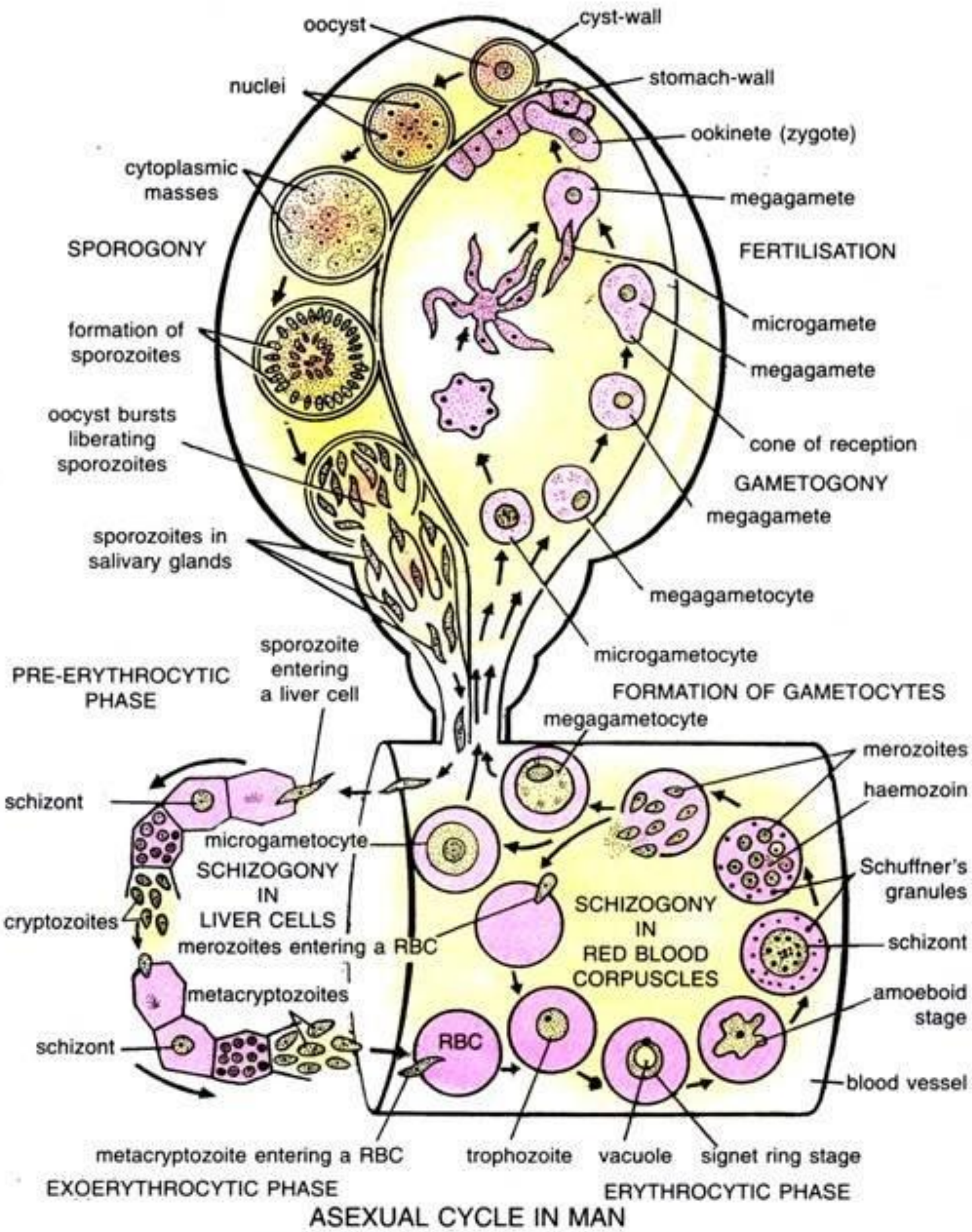


Fig. 19.3. *Plasmodum vivax.* Life cycle.

Pathogenicity:

The basic epidemiology of malaria is the feeling of feverish condition first several days after the infection of Plasmodium. The interval between the time of infection of the parasite and the appearance of symptoms of the malaria is called incubation period which varies 10-40 days and in P.

vivax it varies 13-17 days, and 9-12 in P. falciparum. The pre-patent period follows after incubation period which is the interval between the infection of the parasites and appearance of parasites in the red blood corpuscles. The symptoms of the infection at the end of the incubation period are head-aches, loss of appetite, limb pains, nausea, vomiting and sweating. Finally, the disease is characterized by paroxysm which is divisible into 3 stages, the cold stage or chill, the hot or fever stage and the sweating stage. In the hot or fever stage, the temperature rises as high as 106°F. The benign tertian malaria is caused by the infection of P. vivax and the most fatal malaria is malignant tertian malaria caused by the infection of P. falciparum.

The damage of the malignant malaria is caused by the blocking of the capillaries in the heart, intes-tine and brain, etc. by the infected red blood cells. The other names of malignant malaria are pernicious malaria, aestivo-autumnal malaria and oubtertian or tropical malaria.

The malaria fever occurs due to release of a toxic substance in the plasma of blood, the haemozoin pigments with the rupture of schizonts in the red blood cells. The haemozoin pigments induce high fever and shivering.

Prophylaxis (Prevention of infection):

The malaria can be controlled under fol-lowing categories:

1. Prophylactic use: Certain antimalarial drugs such as quinine, paludrine, daraprim and chloroquine should take small doses regularly as per doctor’s advice which may be effective as a precaution before infection for the mosquito bites.

2. Use of antimalarial drugs: The most effective drugs are Quinine, Mepacrine, Chlo-roquine, Amodiaquine, Primaquine, Pamaquine, Qaraprim, Paludrin, Resochin, Proguanil, Suphones which may be used to suppress the symptoms of various stages. For malignant malaria Pamaquine and Primaquine drugs should be taken as per doctor’s advice.

3. Protection against the bites of mos-quitoes:

i. Mosquito nets preferably insecticide treated nets should be used during sleep at night which prevent mosquito bites.

ii. Antimosquito creams such as bamber oil, odomos, mylol, dibutyl phthalate (DBP), mustard oil, is also effective which is smeared on the exposed parts of the body.

iii. Various kinds of mosquito coils con-taining cyclothrin, pyrethrum may be effective to protect the body from mosquito bites.

iv. Camphor, Oil of Citronella and Dime-thyl phthalate are used as mosquito repellents, causing insects to move away from their sources.

(i) Elimination of breeding sites of mosquitoes:

The breeding places of the mosquitoes are clean water that stagnates or flows slowly, must be eliminated in such ways:

a. Marshes, nullahs, stagnant water bod-ies, ditches must be drained off.

b. Drains and sceptic tanks must be cleared.

c. All water containing vessels and tanks must be covered with lids and clean at least once a week.

(ii) Destruction of larvae and pupae:

a. The larvae and pupae are killed by spraying kerosine oil, crude oil, petro-leum on the surface of water which forms a film on the water by which the larvae and pupae die for wanting of breathing. The use of Panama larvicide and Paris green in water is helpful to kill the larvae of mosquitoes.

b. Certain chemicals such as DDT, BHC are used as larvicides which are sprayed in the water, which kill the pupae and larvae by suffocation.

(iii) Biological control:

a. Certain fishes such as Guppy (Poecilia reticulatus), Stickle backs, Minnows, Trout, Gambusia (Gambusia affinis), Northo sp. Gold fish (Carassius auratus), Tilapia (Tilapia sp.) eat the larvae and pupae of mosquitoes (WHO Report).

b. Several types of virus, bacteria (Bacte-ria thuringiensis), Nosema (Protozoa) do harm the vectors of malarial parasites help in checking mosquito population.

(iv) Destruction of adult mosquitoes: Spraying of some of insecticides such as DDT, BHC, malathion, dieldrin, pyrethrum, etc.

Trypanosoma gambiense

It ia a protozoan flagellate parasite of human blood transmitted by Tse-tse fly. It is commonly distributed in central Africa, Egyptian countries and almost all territories which have low marshy land. *Trypanosoma gambiense* lives as a parasite in the blood, lymph, lymph nodes, spleen, or cerebrospinal fluid of man and in the intestine of blood-sucking fly *Glossina palpalis* (Tsetse fly). It causes sleeping sickness in man.

Life Cycle

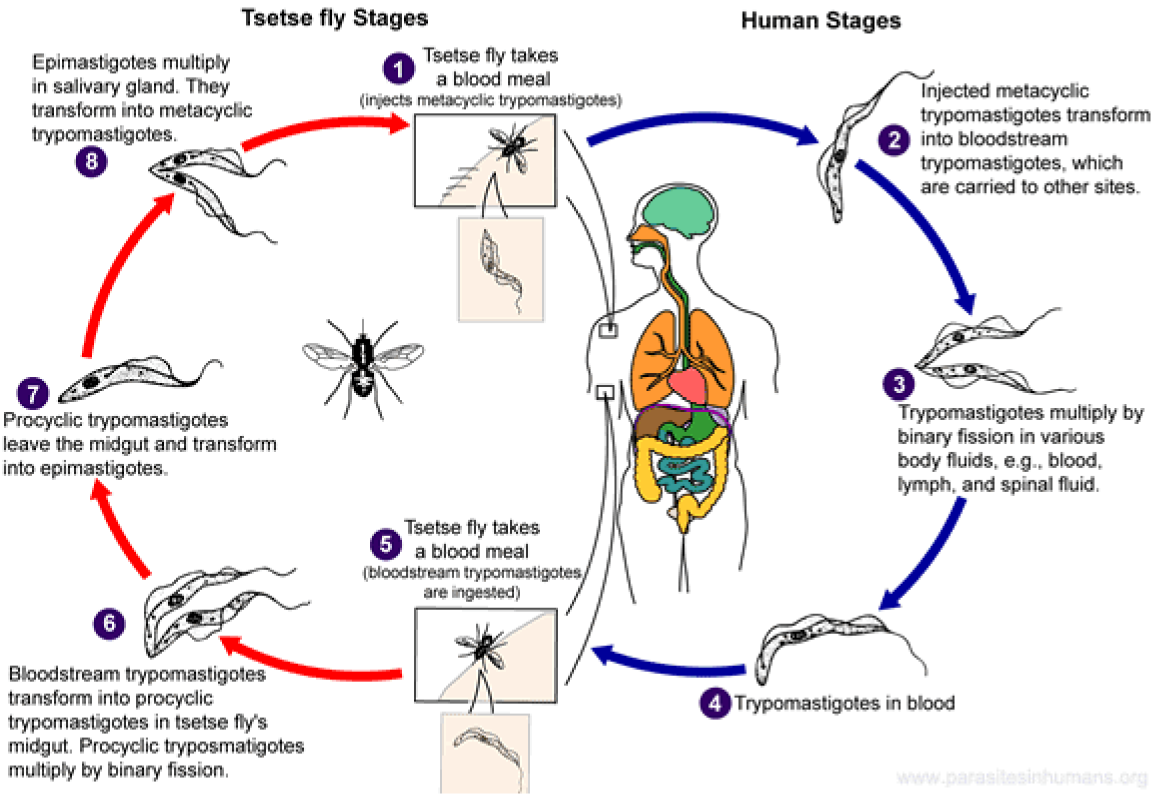
Trypanosoma gambiense is digenetic; i.e., it completes its life cycle in two hosts. The primary or definitive host is man. The mammals, like pigs, buffaloes, antelopes often act as reservoir hosts harbouring the parasite. The intermediate host is blood sucking insect called tsetse fly (Glossina palpalis).

Life cycle in man:

The metacyclic stage (infective form) of *T. gambiense* is introduced into the body of man by the bite of the tsetse fly*, Glossina palpalis*. The tsetse fly harbours the meta-cyclic form in the lumen of its salivary glands. When the vector sucks human's blood, it intro-duces the contained trypanosomes into his blood stream. During sucking through the proboscis, the fly releases metacyclic forms along with saliva. The saliva of tsetse fly contains an anticoagulant which prevents the clotting of blood.

Multiplication: All stages of Trypanosoma in man are extracellular as the parasites are found in blood plasma and not inside blood corpuscles. Within the host's blood the metacyclic forms (which are devoid of flagellum) become trans-formed into long, slender and flagellated forms. They swim within the human blood by the beating of their free flagella and the vibratile movements of the undulating membrane. The adult forms of the parasite multiply by longitudinal binary fission. The multiplication commences at the kinetoplast and is followed by the division of nucleus and cytoplasm.

Metamorphosis: When the glycolysis process is hampered and trypanosomes stop multiplying. The long slender parasites now shrink to short stumpy forms which are devoid of free flagellum. During transformation from long slender form to short stumpy form, the intermediate form along with a small free flagellum also appears. The stumpy forms do not feed and ultimately die. These stumpy forms remain latent till tsetse fly sucks them up along with the blood of the host. Unless this occurs within a reasonable time the stumpy forms degenerate and perish.



Life cycle in tsetse fly: When this insect vec-tor sucks the blood of an infected person, it also takes short stumpy forms of trypomastigote along with the sucked blood. Now these stumpy forms continue development in the midgut of insect vector.

Development in the Midgut of Insect Fly: Further change of trypomastigote occurs in the insect vector's midgut within peritrophic membrane and the short stumpy forms of the parasites trans-form into long slender forms. Now these long slender forms appear which pass to posterior end of the extra-peritrophic space (a space between the peritrophic membrane and epithelial cells), where they continue to multiply for some days. By the 15th day they escape from the peritrophic space and enter the lumen of the proventriculus (the periventricular form is the same as that of the midgut form)

Development within the Salivary Gland of Insect Fly: Later the long slender forms make their way into salivary glands through the hypo- pharynx. Here they multiply and change their morphology, first into epimastigote and then into the metacyclic stage (short stumpy forms of trypo-mastigote) which are infective to man. It has been reported that the time taken for the complete evolution of the infective forms (metacyclic stage) inside the vector insect is about 20 days. These flies remain infective for the rest of their lives, a period extending upto 185 days. When the vector fly bites a healthy person, it transfers the metacyclic forms along with saliva into his blood where they initiate another infec-tion.

Pathogenicity and Symptoms of Trypanosoma Gambiense:

The bite of an infected fly is usually followed by itching and irritation near the wound, and frequently a local dark red lesion develops. In blood, the parasite multiplies and absorbs nutrients from it. After a few days, fever and headache develop, recurring at regular intervals accompanied by increasing weakness, loss of weight and anaemia.

Usually, the parasites succeed in penetrating the lymphatic glands. Because of its infection, the lymphatic glands swell and after it the parasites enter the cerebrospinal fluid and brain causing a sleeping sickness like condition. Development of lethargic condition and recurrence of fever are the symptoms of its infection. Trypanosoma gambiense causes trypanosomiasis; most commonly referred to as sleeping sickness leading to coma stage and finally resulting into the death of the patient. In fact, two types of diseases are caused by Trypanosome which are essentially similar in symptoms. These are Gambian and Rhodesian sleeping sickness. The Gambian sleeping sickness occurs in western part of Africa and its vector is Glossina palpalis, while Rhodesian sleeping sickness occurs in rest of Africa and its vector is Glossina morsitans. The only difference between the two is that the latter is more rapid causing the death of the patient within 3-4 months of infection.

Diagnosis, Treatment and Prevention of Disease Caused by Trypanosoma Gambiense: The diagnosis is confirmed by examining fresh or stained peripheral blood or by examining the cerebrospinal fluid obtained by lumbar puncture or by examining the extract of enlarged lymphatic glands.

Treatment (Therapy): Arsenic and antimony compounds were until recently the drugs for treatment of trypanosomiasis, but now they are rarely used except for late stages when the parasites have invaded the central nervous system.

Prevention (Prophylaxis) : The following measures are suggested for preventing the infection of this parasite:

1. By eradicating the vectors. The infection of this parasite can be checked by completely eradicating the secondary host (Tsetse fly). For this, the endemic areas should be kept clean and regular spray of insecticides like DDT is suggested which help in eradicating the fly.

2. Care should be taken to keep the reservoir hosts free from its infection.

3. Preventive medicines should be taken frequently and periodically which help to a great extent from its infection

1.4 Life history and pathogenisity of Ancylostoma duodenale and Wuchereria bancrofti

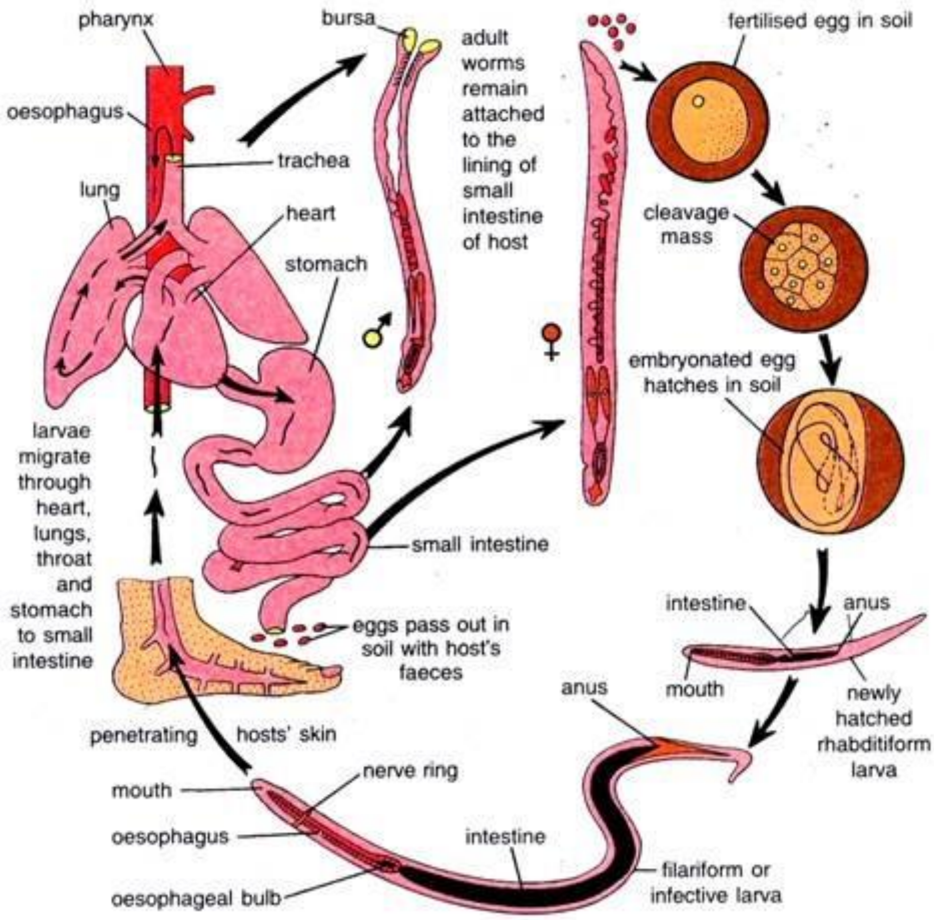
Ancylostoma duodenale

Ancylostoma duodenale is a species of the roundworm genus Ancylostoma. It is a parasitic nematode worm and commonly known as the Old World hookworm. It lives in the small intestine of hosts such as humans, cats and dogs, where it is able to mate and mature. It is also called the common hookworm.

Life History of Ancylostoma Duodenale:

The life history of Ancylostoma duodenale is monogenetic as no intermediate host is required; man is the only main host for Ancylostoma duodenale.

Copulation and Fertilization: Copulation occurs in the intestine of the host, during the process the copulatory bursa of male is applied on the vulva of female and sperms are transferred. In fact, during copulation the worms (a male and a female) assume a Y-shaped figure owing to the position of the genital openings. The sperms, thus, transferred come to lie in the seminal receptacles where fertilisation takes places. The fertilised eggs are then pushed into the uteri for laying through vagina and gonopore.



Egg Laying: The female worm lays eggs in the intestine of the host which pass out with faeces. On an average nearly 9,000 eggs are laid per day by a female. The eggs are oval or elliptical in shape measuring 65 pm in length by 40 pm in breadth, colourless and protected by a transparent hyaline shell-membrane. An egg that comes out of the host body possesses an embryo up to 4-celled or 8-celled stage. The eggs, which passed out with the faeces, are not infective to man.

Development in Soil: Under favourable conditions of environment like moisture, oxygen and temperature (about 68-85°F), the embryo develops into a rhabditiform larva or first stage juvenile; it is about 250 µm in length. This larva hatches out of the egg in the soil in about 48 hours. This larva possesses the mouth, buccal capsule, elongated pharynx, bulb-like oesophagus and intestine. It feeds on bacteria and other debris of the soil and moults twice, on the third day and the fifth day. It then develops into a filariform larva measuring about 500 to 600 pm in length. It is the infective stage of the parasite. This larva does not feed but remains infective and alive for several weeks under favourable conditions. The time taken for development from eggs to filiform larvae, is on an average 8 to 10 days.

Infection to New Host: The filiform larvae are infective to man. The larvae cast off their sheaths and penetrate the skin of a human host. The anterior end of the larva is provided with oral spears by which it penetrates the soft skin of the feet and hands, generally through hair follicles.

Migration and Later Development: On reaching the subcutaneous tissues, the larvae enter into the lymphatic's and small venules. They pass through the lymphatic-vascular system into the venous circulation and are carried through the right heart into the pulmonary capillaries, where they break through the capillary walls to enter into the alveolar spaces. They then migrate on the bronchi →

trachea → larynx, and crawl over the epiglottis to the back of the pharynx and are finally swallowed. During its migration, when it reaches to oesophagus, its third moulting occurs and a terminal buccal capsule is formed. The time taken in this migration is about 10 days. Thus, finally the growing larvae settle down in the small intestine and undergo fourth and final moult to become the adults. In about 3 to 4 weeks time they become sexually mature to repeat the life history again. The life span of the adult worm in human intestine has been estimated differently by different workers; generally it is believed to be 3 to 4 years.

Diagnosis, Disease and Pathogenicity of Ancylostoma Duodenale:

The infection of hookworm is easily diagnosed by the presence of its eggs in faecal smear from the patient. The disease caused by its infection is generally referred to as ancylostomiasis.

The hookworms are the most dangerous parasitic nematodes because they hold on to the intestinal villi and suck blood and body fluids of the host by their muscular pharynx, they also cut holes in the intestinal mucosa and leave bleeding wounds. It causes severe anaemia. In children, where incidence of infection is very great, they retard the physical and mental growth.

Some toxins secreted by the glands in the head region of worms cause stomachache, food fermentation, diarrhoea, constipation, dyspnea, palpitation of heart, eosinophilia, ill health and the patient may finally collapse.

During penetration of larvae in the skin, local irritation is caused resulting into inflammation of the surrounding tissues; these may result into tiny sores. The migratory larvae in lungs may cause haemorrhage and bronchial pneumonites.

Treatment and Prevention of Infection Caused by Ancylostoma Duodenale. Drugs like carbon tetrachloride, thymol, oil of chenopodium, hexylresorcinol, etc., are used effectively to control the infection of Ancylostoma. Some other anti-helminth drugs like tetrachloroethylene and blephenium are found to be more effective and are safe to be used.

Prevention of Infection by Ancylostoma Duodenale: The infection of Ancylostoma duodenale can be checked effectively by improving the sanitary conditions to avoid the contamination of faeces with the soil and other edibles, by protecting feet and hands from being touched with the soil. Children should be directed to keep their hands and nails clean.

Wuchereria bancrofti

Wuchereria bancrofti is a dreadful endoparasite of man; adults harbouring the lymphatic vessels and lymph nodes. Its life history is digenetic, as it involves a secondary host, the blood-sucking insects, i.e., the female mosquitoes of the genus Culex, Aedes or Anopheles; the secondary host for W. bancrofti in India and China is Culex pipiens, in Pacific Islands (except Fiji and New Caledonia) is Anopheles punctatus and in Polynesian Islands is Aedes polynesiensis. Wuchereria bancrofti is a human parasitic roundworm that is the major cause of lymphatic filariasis.

Life History of Wuchereria Bancrofti:

We know that Wucheria bancrofti is digenetic, i.e., its life history is completed in two hosts; man is the main host, while female mosquito, usually *Culex pipiens*, is the secondary host. Mature male and female worms copulate in the lymph glands of man where they usually live. Since female worm is viviparous or ovoviviparous, it delivers numerous larvae called microfilariae. The microfilariae are born in very immature stage.

However, microfilariae find their way into the blood stream where they can live for a considerable time without undergoing any developmental changes. As referred to, due to their nocturnal periodicity they are sucked up by the secondary host when it comes to take its blood-meal from the human body.

Pathogenic manifestations of heavy infection of *Wuchereria*

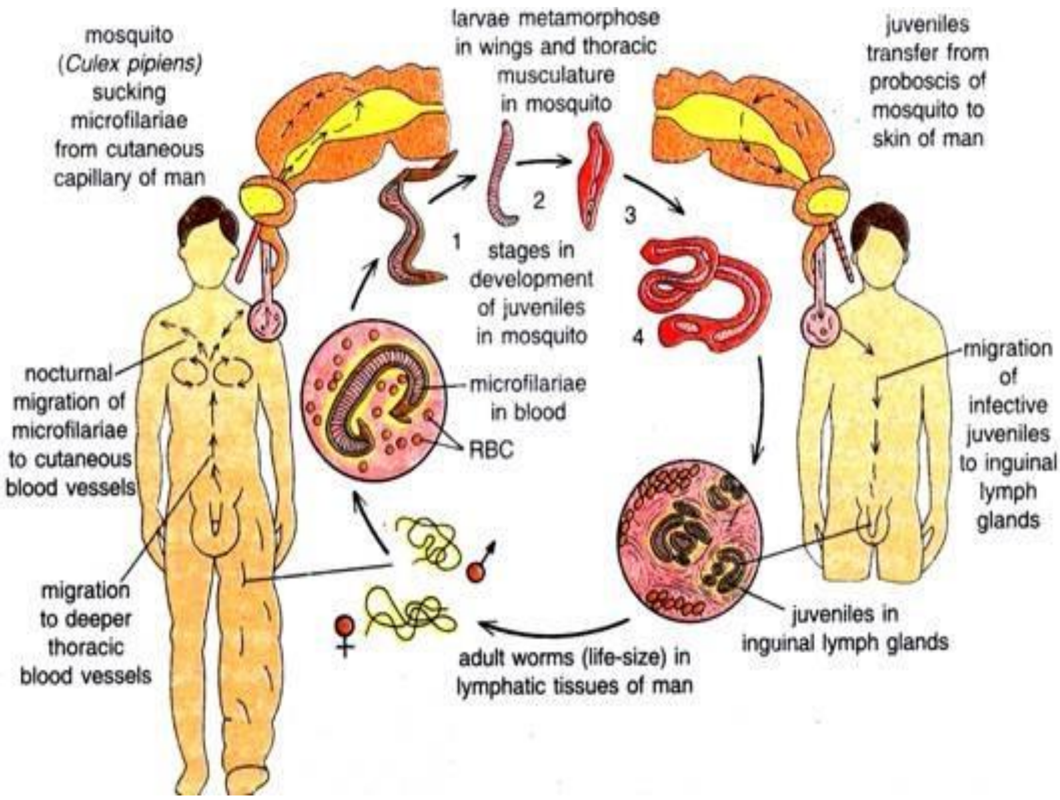
The microfilariae, after reaching in the body of the secondary host, undergo further development to become infective to man. In fact, immediately after their entry in the stomach of mosquito, the sheaths around their bodies are shed off and then they penetrate the gut wall within an hour or two and migrate to the thoracic muscles.

Here they become short and thick like sausages within 2 days having short spiky tails and measure 124 to 250 µm in length and 10 to 17 pm in diameter, they also possess rudimentary digestive tract. These are first stage larvae. Within next 3 to 7 days they grow rapidly and moult once or twice to become the second stage larvae; they measure 225 to 330 µm in length and 15 to 30 pm in diameter.

Finally, by 10th or 11th day they become fully grown and are referred to as third stage larvae; they measure about 1500 to 2000 pm in length and 18 to 23 µm in diameter. This stage is infective to man. These larvae are inactive and come to lie in the labium of the mosquito.

When the mosquito bites the warm and moist skin of man, the larvae creep out of the labium to the human skin, then they penetrate into the skin and finally come to settle down in the lymphatic's. Here, they grow and become fully adult and sexually mature within a period of 5 to 18 months.

These sexually mature worms start reproduction to repeat the life history again. The life span of adult worms is very long, probably ranging from 5 to 10 years.



Diagnosis and Disease of Wuchereria Bancrofti: The infection of Wuchereria bancrofti is diagnosed by the presence of microfilariae in stained blood smear and by the biopsy of lymph nodes. The disease caused by the infection of W. bancrofti is, in general, referred to as wuchereriasis or filariasis.

Pathogenicity of Wuchereria Bancrofti:

In fact, the pathogenic effects seen during filariasis are caused by living or dead adult worms.

A light infection does not produce serious effects; it causes filarial fever, headache and mental depression, etc. But, during heavy infection a large number of pathological effects are observed; in this condition they block the lymphatic vessels and glands causing lymphatic obstruction so that lymph cannot get back to the circulatory system.

Hence, there occurs accumulation of lymph in the affected organs due to which they swell fantastically, a condition called lymphoedema. When they infect lymph nodes then they cause lymphadenitis, in lymph vessels they cause lymphangitis and after infecting epididymis and related areas they cause hydrocele.

However, the affected organs sometimes become enormously enlarged, producing a tumour-like ugly look, this condition is called elephantiasis; the elephantiasis of feet, hands, scrotum, etc., are of common occurrence in the areas where W. bancrofti is prevalent.

Treatment and Prevention of Disease Caused by Wuchereria Bancrofti:

So far, no satisfactory treatment has been reported. However, heterazan and compounds of antimony and arsenic are used to reduce or eradicate microfilariae from the circulatory system. The only way of prevention is to protect our bodies from mosquito bite.

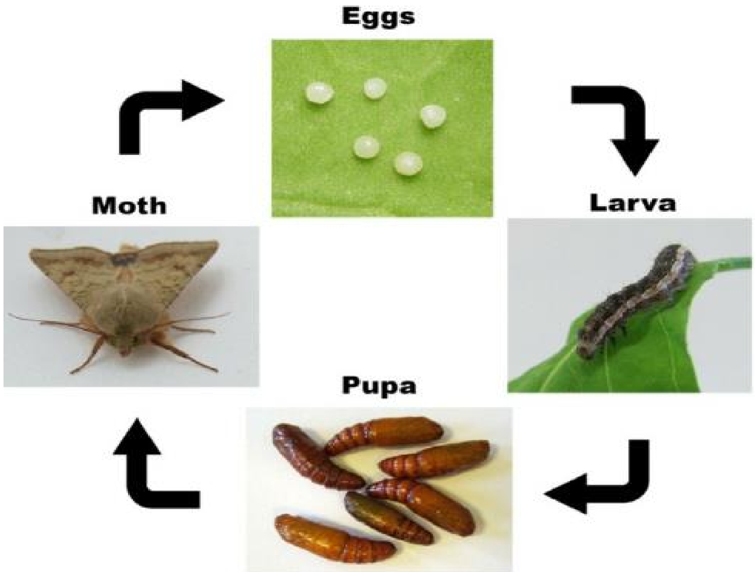
5th Semester

Applied Zoology (ZOO516DB)

Unit 2nd

2.1 Insects of Economic Importance

1. Helicoverpa armigera



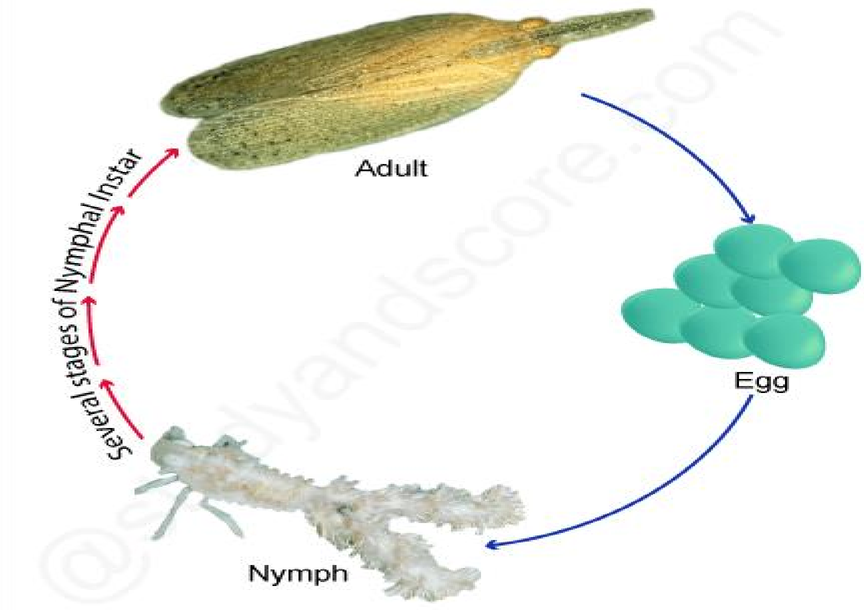
Biology: It is commonly known by the name Cotton Bollworm. The eggs are white to yellowish, brownish at hatching. Young caterpillars are pale green, but later instars are very variable in color (yellowish-green to dark brown) and markings. The adults vary greatly, too; the forewings are yellowish to orange in females and greenish-gray in males, with a slightly darker transversal band in the distal third. The kidney-shaped marking is slightly distinct and smoky.

Each female of H. armigera can lay several hundred eggs, distributed on all parts of the plants, flowers and fruit included. At optimal temperature, the larvae can hatch after less than three days. They then pass through four instars over a three to four week period.

Damage: The voracious caterpillars of H. armigera can feed on leaves and stems, but they show a strong preference for reproductive organs such as buds, inflorescences, berries, pods, capsules etc. They bore into these parts, leaving large, round holes. Older larvae often enter the plant tissue with the anterior part of their bodies only. Young instars, however, may disappear completely inside, so they are sometimes not discovered before the produce (e.g. tomatoes) is processed. Secondary infections by fungi and bacteria are very common and they lead to rotting of fruits. Injury to growing tips disturbs normal plant development; maturity may be delayed, and fruits are often dropped. So in cotton for example, attacked blooms will frequently open prematurely and stay fruitless: when the bolls are damaged, some will fall off, and those that remain either fail to produce lint entirely, or they produce lint of inferior quality.

Control: Useful non-chemical contribution to Integrated Weed Management. Careful tilling and removing harvest residues will expose the pupae to sun and predators, and can thereby significantly reduce the pest's population density.

2.Pyrilla perpusilla



Biology: This insect is a serious pest of sugarcane in northern India where it also occasionally feeds on maize, millets, rice, barley, oats, sorghum, bajra and wild grasses. Adult hoppers are straw coloured to brownish, with a pointed snout bearing piercing and sucking mouth parts. Adults are active fliers, migrating from one crop to another and breed throughout the year. Eggs are light yellowish in colour, oval, one mm long and laid on the lower surface of the leaf. Nymphs are initially greenish, later turn pale brownish, wingless.

Damage: Both adults and nymphs suck the cell sap of succulent leaves of sugarcane by their rostrum. As a result the leaves turn pale yellow. They secrete a sweet sticky transparent liquid known as honey dew which attracts the harmful fungi resulting into a good growth of black shooty mould due to which the photosynthesis is affected and hence productivity also. Because ef the attack of this pest the quality and quantity of sugar is affected.

Control: The egg masses should be collected and destroyed by burning, burying or spraying phenyl water. The pest can be controlled by spraying 0.05% of parathion, malathion, thiodon, fenitrothion or rogor. Dusting the plants with 10% Aldrin or dieldrin also helps.

3.Papilio demoleus

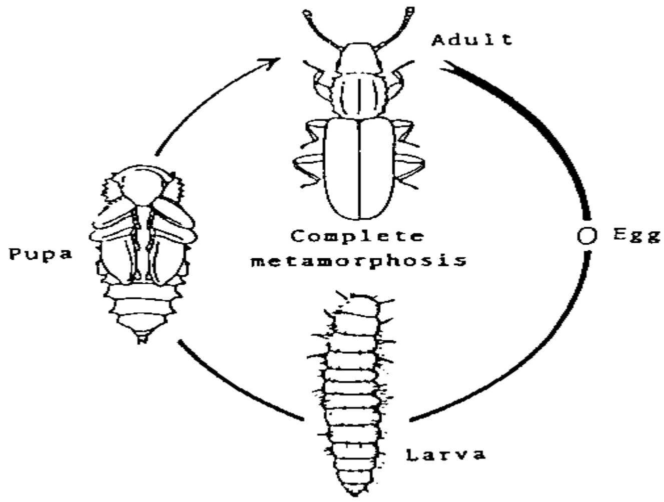
Biology: This is a common pest of all citrus plants. Adult is a large butterfly and has prominent black and yellow markings on the wings. They are active fliers and found throughout the year in plains. Eggs are small, round, smooth, yellowish and laid singly glued on to the tender leaves. They hatch in 3-6 days. First three instars of the larvae resemble bird droppings as they are brownish-black in colour, with one or two white patches. Last two instars are green in colour, sometimes with greyish markings. Pupation takes place on the plant. Pupa, which is called chrysalis, greenish to brown in colour, resembles a twisted leaf and remains attached to a branch with a fine silken thread. Pupal period is 8-15 days.

Damage: Larvae are voracious feeders of tender leaves and defoliate the trees. They eat leaves from margin inwards, leaving the larger veins intact. Younger plants cannot withstand defoliation and die.

Control: Handpicking and destruction of the larvae which are so prominent on the leaves helps to save the plants in nurseries. Dusting the trees with sodium fluosilicate or BHC 5% or spraying malathion, endosulfan, parathion, fentrothion 0.02% or lead arsenate 0.25% effectively controls the pests orchards.

Spraying spores of Bacillus thuringiensis gives high mortality of caterpillars.

4. Callosobruchus chinensis



Biology: It is commonly called pulse beetle. A pest of pulses, cowpea, soybean, gram, pigeon pea, lablab etc. Cosmopolitan in the tropics and subtropics of the world. Adult beetle is 3-4 mm long, female being larger, brownish in colour, broader at shoulders and rounded posteriorly. Adults show sexual dimorphism. Males possess deeply emarginated or indented eyes and prominently serrate antennae, while in female these characters are not distinctly marked. Fecundity is about 100 eggs per female. Eggs are whitish, elongated and stuck on the grains or on pods and sometimes on the surface of the container. Grubs are scarabeiform or eruciform, plump and with short legs and yellowish in colour. First instar larvae bear functional legs and a pair of thoracic plates to facilitate boring into the seeds. They feed on the inner contents of the grain and may damage several grains during development. Completion of life cycle takes 4-5 weeks and there may be 6-7 overlapping generations in a year.

Damage: Both larvae and adults cause damage to the grains. They bite holes in the grains to enter inside and feed on kernel, damaging several grains in the process. As the beetles can actively fly, the infestation can start in the fields, where the beetles deposit their eggs on the pods.

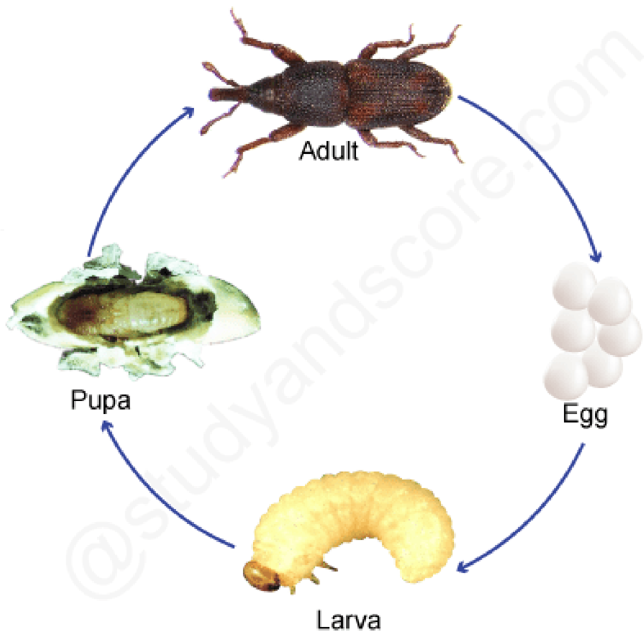
Control: Callosobruchus spp. may be controlled by fumigation treatment with phosphine

Intercropping maize with cowpeas, and not harvesting crops late significantly reduced infestation by C. maculatus

Good store hygiene plays an important role in limiting infestation by these species. The removal of infested residues from last season's harvest is essential, as is general hygiene.

Solarization (or drying and heating) can be used to control infestations of C. maculatus without affecting seed germination,

5. Sitophilus oryzae



LIFE CYCLE OF RICE WEEVIL (*Sitophilus oryzae)*

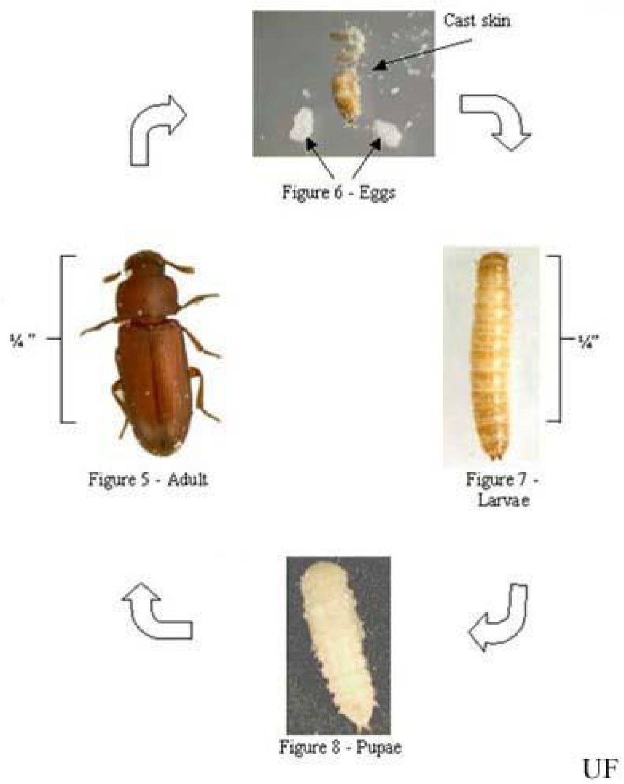
Biology: It is commonly called the rice weevil. This is primarily a pest of rice but occasionally attacks wheat, corn, jowar, flour, beans, dry fruits and biscuits. Adults are 2-3 mm long dark brown weevils, with four faint yellow spots on the elytra. Body is punctured with minute pits. Adults do not fly but try to crawl away when disturbed. Their longevity can be up to 5 months. Eggs are whitish, oval, 0.7 mm long. Females chew a small depression on the surface of rice grain, lay an egg in it and seal it with a gelatinous fluid for protection. Grubs make their way into seed to feed on kernel. They are plump,3-4 mm long, legless, dirty white in colour with a brownish head. Pupation takes place inside the grain. Pupa is light yellowish but later turns dark brown. Adult emerges by cutting a hole in the grain.

Damage: Larva as well as the adult cause damage to grains. Larvae feed inside the seed and make in hollow and exit by making a circular hole on the surface. Adults can damage several seeds by cutting an irregularly lined circular hole, through which they feed on the kernel.

Control: Good store hygiene plays an important role in limiting infestation by S. oryzae. he removal of infested residues from last season's harvest is essential.

Grain may be protected by the admixture of insecticide. Sitophilus spp. have a low susceptibility to synthetic pyrethroids but are readily killed by organophosphorous compounds such as fenitrothion and pirimiphos-methyl.

6. Tribolium castaneum



Biology: It is commonly called red flour beetle. It is a worldwide pest of stored products, particularly food grains. They are cosmopolitan in distribution. Larval and adult both the stages are found infesting and causing damage. The adults are reddish brown and are very active and survive in moderately cold winter in unheated buildings and often live for 2 years in adult stage during which period the fertilized female produces eggs. Eggs hatch into larva which are reddish yellow in colour which after 6 to 7 moultings change into pupae from which the adults arise.

Damage: These beetles cause serious damage in monsoon period. They heavily damage flour in the mills but sometimes damage the grains in store. Both the adult and larva are infective stages.

Control: Flour mills should be kept clean and dry

The infested portion of the flours should be removed

The adults or its other life stages should be removed from stores or godowns

2.2 Insects of Medical Importance

1.Pediculus humanus corporis,

Commonly known as body louse, it is the blood sucking ectoparasite of man and is cosmopolitan in distribution. It is found in the hairs of the armpits, clothes and garments. The asults are wingless, flattened, greyish white insects. It is comparatively larger then the head louse (*Pediculus humanus capitis*).

Medical Importance: They suck the blood, cause annoyance, itching and irritation and transmit certain diseases.

Epidemic typhus: This disease is caused by a PPLO, *Ricketsia prowazeki*, which multiplies in the gut of lice. Spores are released through faeces within 5 days of infection and can remain viable for 4 months in the dry conditions. They get into the human system through contact with blood, through wounds, conjunctive or by inhalation into lungs. The disease spreads in epidemic form and is capable of causing 100% fatality. Reservoir hosts are sheep and goats.

Trench fever: This is caused by *Ricketsia quintana*. The disease was common among soldiers during the world war II, when soldiers had to spend several days trapped in trenches and lice transmitted the disease in epidemic form. The mode of transmission is similar to the epidemic typhus.

Relapsing fever: This disease is transmitted by a spirochaet, *Borrelia recurrentis* which breeds in the haemolymph of the louse and escapes when the louse is crushed or dies due to the parasite. It gets into the human blood through wounds or scratches. This disease spread in great epidemic form during the World War I and II.

Local urticaria and itching: This is also called the Vagabond disease. Itching, rashes and discoloration of the skin takes place due to the allergic reaction to the bites and blood sucking by lice.

Control: Cleanliness and hygiene eradicates lice. In case of severity of infestation, clean shaving of head brings relief. Application of kerosene mixed with olive oil in equal ratio on the head kills lice. Lindane ointment, malathion (Lycil) and Mediker shampoo (also contains malathion) or any insecticide mixed with oil kills all lice on head. The application has to be repeated every week to kill nymphs emerging from eggs. Body lice can be controlled by steaming or boiling of clothes and bedding or rinsing clothes in weak insecticide solution.

2. Mosquito *(Anopheles, Aedes, Culex)*

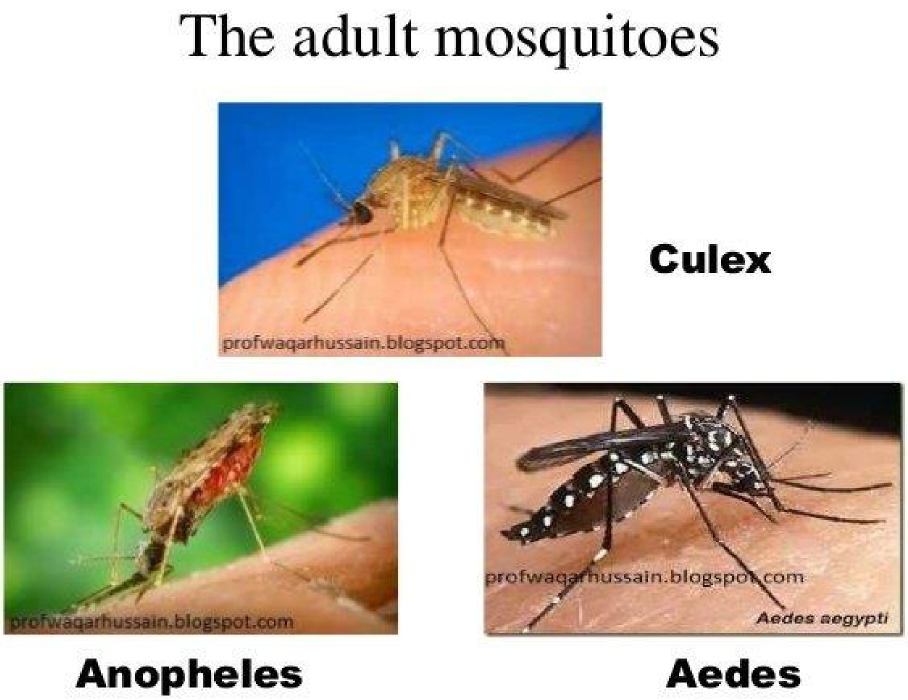
The mosquito, whose name comes from the Spanish for "small fly", is a type of insect that belongs to the family Culicidae. There are thousands of species of mosquitoes, but a distinguishing characteristic is that the female possesses a tube-like mouthpart, called a proboscis, which pierces the skin of the host to draw blood. Female mosquitoes require the nutrients (mainly vitamins) in blood to produce eggs.

Mosquitoes feed primarily on vertebrates including humans and other mammals, as well as birds, reptiles, and others. Most species have a preference for either humans or certain animals as the source of their blood meal. They are attracted by body odors, carbon dioxide, and heat emitted by person or animal. Most mosquitoes prefer biting at certain hours such as dusk or dawn. Different species also vary in their preferred places to feed or rest; some prefer natural vegetative habitats, while others favor urban environments particularly trash or receptacles in yards.

While obtaining a blood meal from a host, the female mosquito injects some of its own saliva into the skin. The saliva contains anticoagulants and anti-inflammation substances that prevent the host's blood from clotting so that the proboscis does not become trapped in the host. Upon detecting a foreign substance, the immune system of the host releases histamine and cytokines, substances that cause the itching and wheals associated with mosquito bites.

Although the itching can be very irritating, the much more serious risk from mosquitoes is their ability to serve as vectors, or carriers, for a number of diseases, including Zika virus, dengue, West Nile, yellow fever, and malaria, among many others. The disease-causing viruses and parasites are carried by specific species of mosquitoes. The most prominent mosquito-borne diseases are transmitted by three genera of mosquitoes – Aedes, Culex, and Anopheles

Males of all species have rudimentary maxillae and mandibles so that they cannot suck blood but can suck fluids and nectar from flowers. They also possess very bushy whorl plumose antennae and tip of abdomen with characteristic male genitalia. On the other hand females have short hairs on the antennae and needle-like maxillae and mandibles for piercing the skin of host for sucking blood. Other characteristics are given below according to the species.



Culex: It is dull whitish mosquito having unspotted wings and makes humming sound when flying. There are overlapping scales and six transverse whitish bands on the abdomen. Thorax has no markings on the dorsal side. While resting it sits parallel to the ground. There are about 240 species in India out of which 4-5 are vectors of diseases. It breeds in cesspools, drains, disused wells and stagnated water. Polluted water is preferred for breeding. *Culex*, a large group of mosquitoes also known as common house mosquitoes, are the principal vectors that spread the viruses that cause West Nile fever, St. Louis encephalitis, and Japanese encephalitis, as well as viral diseases of birds and horses. *Culex* mosquitoes can also transmit the parasitic disease lymphatic filariasis and the bacterial disease tularemia.

Culex mosquitoes are distributed worldwide in tropical and temperate regions, with the exception of extreme northern latitudes. They feed at night on humans and animals and are found indoors and outdoors.

Aedes: This is called zebra mosquito as it has black and white bands on the abdomen and legs. The Aedes mosquitoes are the carriers of many viral diseases including Zika, dengue, chikungunya, yellow fever, and Rift Valley disease. The Aedes mosquitoes can be identified by the distinctive black and white markings on their bodies and legs. Unlike most other mosquitoes, Aedes mosquitoes are active and bite only during the daytime, with peak activity during the early morning and in the evening before dusk. There are two specific species of Aedes that are important transmitters of viruses – *Aedes aegypti* and *Aedes albopictus. Aedes aegypti*, also known as the yellow fever mosquito, is found in urban areas, is active both indoors and outdoors, and has a preference for humans as the source of its blood meal. *Aedes albopictus*, commonly referred to as the Asian tiger mosquito, is mostly associated with areas of vegetation and is found primarily outdoors; the female will bite domestic and wild animals, as well as humans. Because the *Aedes aegypti* mosquitoes live near and prefer to feed on people, they are more likely to spread viral diseases than are the *Aedes albopictus* mosquitoes.

Although the range of the two species of mosquitoes was originally confined to localized tropical and subtropical regions - *Aedes aegypti* in Africa and *Aedes albopictus* in Southeast Asia - they are both now distributed in tropical and subtropical areas worldwide. In the United States, *Aedes aegypti* is found in the more southern states, while *Aedes albopictus* can survive colder temperatures and is found further to the north.

Anopheles. Adults are dull whitish in colour having wings with blackish spots and dark veins. They make no noise while flying. There may be scattered scales on the abdomen. Thorax without any markings on the dorsal side and scutellum not lobed and has uniformly distributed hairs on its posterior margin. Maxillary palps in both sexes are equal to proboscis but in male they are clubbed at the tip. Adult in resting position makes an angle of 45 degrees against the surface.

Anopheles mosquitoes are best known for spreading malaria, although they can transmit other diseases. They are active between sunrise and sunset, and can be found both indoors and outdoors. The females feed on both humans and animals, but some species have a preference for one over the other; species that favor humans pose the greatest risk for transmitting malaria.

Medical Importance: These groups of mosquitoes cause irritation during biting, lead to allergy and suck blood. But theie main role is in transmission of number of diseases.

Chikungunya virus causes a disease that, while rarely fatal, can cause debilitating joint pain that can last for weeks. Typical symptoms include fever and rash, as well as pain. The virus, which is classified as an alphavirus, is similar to dengue virus. The two viruses produce many of the same symptoms and both are carried by the *Aedes* mosquitoes, primarily *Aedes aegypti.*

Dengue virus causes dengue fever, a disease characterized by high fever, headache, joint pain, and rash. A more severe form, dengue hemorrhagic fever, can include bleeding and breathing difficulty and is fatal in some cases. There are four types of dengue virus, and they belong to a class of viruses known as flaviviruses – the family that also includes the West Nile, yellow fever, and Zika viruses. Dengue, transmitted predominantly by *Aedes aegypti* mosquitoes, is found in more than 100 countries.

Yellow fever virus most commonly causes fever, headache, muscle pain, and nausea in those individuals who develop symptoms (many do not); these symptoms can initially be mistaken for malaria. The virus, classified as a flavivirus, is generally transmitted by *Aedes aegypti* mosquitoes, the reason that these mosquitoes are also known as yellow fever mosquitoes.

Zika virus, the most recent of these mosquito-borne viruses to emerge, causes no symptoms or only a mild disease that may involve fever, rash, and joint pain in most people who become infected. However, the disease can cause severe neurological defects in the developing fetuses of pregnant women who are infected with Zika virus. Zika virus is classified as a Flavivirus and is transmitted principally by the *Aedes aegypti* mosquito.

West Nile virus can cause death in humans and different bird species. Most people (80%) do not develop any symptoms. Most of the remaining individuals who become infected develop West Nile fever, which is associated with fevers, aches, and nausea. A small percentage (about 1 in 150 infected persons) develops West Nile encephalitis, a more serious disease that produces high fever, neck stiffness, convulsions, muscle weakness, paralysis, and possibly death. West Nile virus belongs to the flavivirus family of viruses. It is transmitted principally by *Culex* mosquitoes. Birds are the reservoir for the virus and mosquitoes acquire the virus when they feed on infected birds.

Culex (female) is the vector of filarial worm *Wuchereria bancrofti*, which causes filariasis in humans.

Different species of anopheles mosquito transmit malaria causing protozoan called *plasmodium.*

MOSQUITO CONTROL: Mosquito control efforts have not been successful because of the ability of mosquitoes to develop resistance against insecticides very quickly and their capacity to inhabit a variety of environmental conditions. The following measures are generally adopted to reduce mosquito populations.

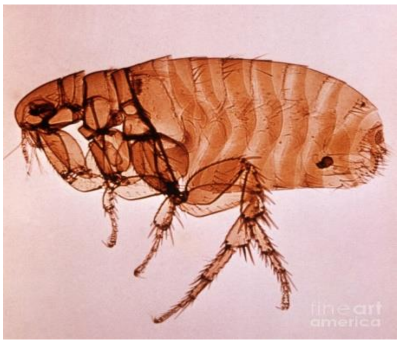
<u>Personal preventive measures:</u> Use of mosquito nets is an effective method to prevent adults from biting and transmitting malaria. Application of mosquito repellent chemicals, such as citronella oil, dimethylphthalate, odomos cream or pyrethrum cream also prevent mosquitoes from sucking blood. Mosquito repelling fumigants, e.g. tortoise mosquito coil contains pyrethrum in it and Goodknight mats or Allout liquids contain synthetic pyrethroids such as deltamethrin, decamethrin and allethrin. They effectively repel and confuse mosquitoes.

<u>Anti-larval measures:</u> Removal of breeding places effectively reduces mosquito population. Broken pots, old tyres, tins and other containers should be removed from the surroundings as they serve as breeding places for Aedes. Coolers and overhead water tanks should be periodically cleaned or treated with potassium permagnate to kill the larvae. Small water bodies, ditches and ponds that cannot be filled should be sprayed with light diesel or petroleum oil that makes a thin film on the water surface and clogs respiratory siphons of larvae. Use of Paris green (copper aceto-arsenite) also kills larval and pupal stages. Biological control of larvae and pupae in ponds has been achieved by releasing larvivorous fishes, such as the native Gambusia and Nothobranchius guntheri introduced by CIBC from Africa. These fishes actively feed on the larvae and can aestivate in mud when ponds dry up in the summer months. Naiads of dragonflies and damselflies are also effective predators of mosquito larvae and pupae.

<u>Anti-adult measures:</u>Trapping of adults by hanging black cloths to serve as hiding places during day time and then killing the adults by spraying insecticide should be done daily. UV electrocuting traps should be used to attract and kill adults. Destruction of tall grasses and bushes serve as resting places for mosquitoes in day time and hence should be removed from the surrounding areas.

Use of malathion and endosulfan aerosols in the colonies periodically has been effective in reducing their populations. Aerial sprays of pyrethrum, carbaryl, carbofuran, arprocarb mixed with mineral oil are still effective in killing adults. Synthetic pyrethroids are quite effective and new chemicals used against mosquitoes but are prohibitively expensive.

3. Xenopsylla cheopis



Fleas are small wingless insects, 2-3 mm long, with highly sclerotised, laterally compressed bodies and reddish-brown colour. Antennae short, stout, pectinate or clubbed and concealed in a groove. Mouth parts are modified for piercing and sucking. Legs adapted for clinging with curved claws. Hind leg longer, modified for jumping.

The Oriental rat flea (*Xenopsylla cheopis*), also known as the tropical rat flea, is a parasite of rodents, primarily of the genus Rattus, and is a primary vector for bubonic plague and murine typhus.

Medical importance: Fleas transmit plague that is caused by the safety pin bacillus called *Yersinia pestis or Pasturella pestis.* The disease is caused in man as well as in rats and produces three types of symptoms in man.

1. Bubonic plague. The bacillus infects lymphatic system, causing swelling and pain in the lymph glands but no fever occurs. Rats also suffer from similar symptoms.

2. Septicemic plague. Infection spreads to the blood vascular system causing fever. There is headache and pain in the back. Sudden chilliness, blood-shot eyes, rapid pulse, thick speech and high fever are other symptoms. In the case of prolonged illness spleen enlarges and becomes brick-red in colour and liver is also enlarged. Comma and death can occur due to heart failure in about a week.

3. Pneumonic plague. In this case bacillus multiplies in the lungs and pleural cavity, causing pneumonia-like symptoms. Yellowish fluid fills the lungs and pleural cavity, causing excessive coughing and heavy breathing. Infection can spread directly from man to man through droplets release during coughing. This is the most dangerous type of plague as it spreads very fast by droplet infection, particularly in high population density areas and brings about quick deaths.

Murine typhus: This is another disease transmitted by *Xenopsylla cheopis*. It is a mild typhoid fever caused by the PPLO, *Rickettsia mooseri*. The causative organism multiplies in the gut of flea and is excreted through faeces. Man gets infected either by contamination of wounds by the flea faeces or by inhalation of dust containing faeces.

Some fleas act as intermediate hosts for the tape worms like, Dipylidium caninum and Hymenolepis diminuta.

Control of fleas: Control of rats is an effective method of controlling fleas. Trapping, baiting and fumigation can eradicate rats. Cyanogas fumigation kills not only rats but also all stages of fleas in the rat burrows. Fumigation should be done every 2-3 months. Construction of rat proof godown having metalled doors and meshed windows is also an effective method to keep the rats away from human dwellings. Dusting the houses, floors, godowns and other places frequented by rats should be done frequently using residual insecticides such as BHC, endosulfan, dieldrin, aldrin etc. This will kill all stages of fleas as they breed in dust and abandoned corners.

Patients suffering from plague can be treated with streptomycin injections or oral doses of antibiotics such as tetracycline, sulphadiazene, chloramphenicol, doxycycline, azithromycin etc. given two or three times in a day.

2.2 Insect pests

Insect pests Of crops

S. No	Pest	Description
1	*Emmalocera depressella* (Sugarcane Root borer)	It is a major **sugarcane pest**, The caterpillar larva of the moth feed voraciously on the stem below the soil surface resulting into formation of dead hearts. The young sugarcanes die and the older ones dry and fall.
2	*Chilo Infuscatellus* (Sugarcane Shoot borer)	Its main host is **sugarcane**, but is also found feeding on bajra and maize. The caterpillar larva of this moth cause damage to sugarcane resulting into the formation of dead hearts
3	*Tryporyza nivella* (Sugarcane Top borer)	Its main host is **sugarcane.** The caterpillar of this moth feeds on growing buds and bores upto 4 to 5 nodes of the top shoot resulting in the drying of the leaves forming dead heart.
4	*Leptocorisa varicornis* (Rice bug or Rice Gandhi bug)	Its main host is **paddy**. It is a major pest of rice and attacks the paddy at the milky stage. Both nymphs and the adult suck the juice from th developing grains as a result of which mature grains are not formed.
5	*Hieroglyphus* (Kharif grasshopper)	It is a major pest of **paddy** crop. Both adult and nymph damage paddy crop by feeding on leaves and shoots

Insect pests of vegetables

S. No	Pest	Description
1	*Raphidopalpa foveicolis* (The red pumpkin beetle)	It feeds on **cucurbitaceous vegetables** like pumpkin, melon, cucumber etc. The adult beetles as well as grubs both are destructive stages, They feed on the leaves flower and buds of the younger plants.
2	*Pieris brassicae* (Cabbage butterfly)	They feed on **cabbage, cauliflower, turnip** etc. Caterpillar larva is the only destructive stage. They feed voraciously on plant leaves resulting into complete destruction of plant.
3	*Epilachna* (The Hada beetle)	These beetles feed on different solanaceous vegetables like **brinjal, Potato, tomato and bitterground.** The dults and grubs both feed on leaves of the plant resulting into complete defoliation.

4	*Dacus cucurbitae* (Melon fruit-fly)	It feeds on **cucurbitaceous** plants. The damage is caused due to maggots by feeding on the almost ripe fruits riddling them and polluting the pulp

Insect pests of oilseeds

S. No	Pest	Description
1	*Athelia lugens* (Mustard sawfly)	Its main host is **mustard**. The damge is caused by the caterpillar larval stage who feeds on leaves and shoots
2	*Bagrada cruciferarum* (Painted bug)	It feeds on **mustard**. Nymph and adult both are destructive stages which suck cell sap from leaves and developing pods.
3	*Acherontia styx* (Til Hawk moth)	It is a pest of **sesamum**. The larva feed voraciously on the leaves and defoliate the plant.
4	*Dichorocis punctiferalis* (Castor shoot and capsule borer)	It is a regular pest of **castor**. Caterpillar larva is the damaging stage which kills the terminal shoots.

Insect pests of tea

S.No	Pest	Description
1	*Heliopeltis theivora* (Tea mosquito bug)	Both nymphs and adults are damging stage. They suck sap from, leaves buds and tender stems
2	*Andraca bipunctata* (Bunch caterpillar)	Larva is the damaging stage. It first feeds on leaf surface by scrapping, later feeds on leaf margins and they remain clustered in bunches on branches.
3	*Biston supprersaria* (Tea semilooper)	Damaging stage is larva. It feeds on leaf surface by scrapping and later feeds on leaf margins.

Insect pests of Coffee

S. No	Pest	Description
1	*Xylosandrus compactus* (Coffee shoot hole borer)	The adult and larva both cause infestation. They form tunnel inside the branches of coffee resulting intowilting, defoliation and ultimately plant dies.
2	*Xylotrechus quadripes* (Coffee stem borer)	The larva causes infestation which bores into coffee stem forming tunnels inside the shoot. The infestation causes killing of young plantsand the older plants become unhealthy.

2.4 Insect pest management

Of all demands of man, food is of prime importance. But the fact is that one third of the food produce is lost to pest and diseases world over. Probably man's struggle against pests of crops is as old as agriculture itself. So the entomologists and farmers together must evolve methods to develop and apply the effective control measures against insect pests in order to save the crops in the field as well as under storage. Insect control programme in its broadest sense includes everything which makes the survival of insects difficult and at the same time checks their multiplication. For this purpose the insecticides has revelutionised the protection technology and with the help of insecticides most of the pest population is being managed effectively in very short period. But these insecticides have not been found much effective against fruit flies, borers and polyphagous pests. The control of pests can be broadly divided into natural and applied control. The natural control agencies do not depend upon the activities of human beings and cannot be influenced much by man. The success of applied control depends completely upon human beings for their application. If the population of insects is not being controlled by natural agencies like climatic factors, topographic factors and natural enemies, then the man made efforts are being applied to check the growth of pests. The various forms of applied control are as.

1. Mechanical Control

Destruction of the pest by mechanical means such as burning, trapping, protective screens and barriers or use of temperature and humidity is often useful.

a. **HANDPICKING**: When the infestation is low, the pest is conspicuous and labor is cheap, the pest stages can be destroyed by mechanical means. Eggs of grasshoppers can be destroyed by hand. Alfalfa aphids can be killed by using chain drags on plants less than 10 inches long. Locust nymphs which are congregating can be beaten by sticks and brooms. European corn borer in the stalk can be killed by running the corn stalks through the stalk shredder. Handpicking of sugarcane borer eggs, cabbage butterfly eggs, sawfly larvae on mustard, Papilio larvae from citrus plants and stages of Epilachna beetle is very effective, especially in small areas.
b. **BURNING**: Controlled burning is sometimes recommended to control certain pests. Weedy fallows harboring European corn borers are burnt to destroy overwintering pest stages. To eradicate the pink bollworm dried cotton stalks are piled and dried. Trash and garbage, weeds etc. are collected and burnt to destroy pest stages. Flamethrowers are used to burn locust hoppers and adults that are congregating and marching.
c. **TRAPPING**: Trapping is popular method to lure insects to bait, light etc. to kill them. Traps usually fail to give adequate crop protection but prove useful to know population build up and are convenient to collect insect samples. Many trap designs have been developed room time to time to suit different insect species. Hopper-dozers were formerly used to collect grasshoppers. In these the insects after hitting the back of the machine fall to the bottom and then through a narrow opening collect into a box.

Yellow-pan traps containing water and few drops of oil were proved useful in killing hopper adults on paddy, sugarcane and wheat crops.

Sticky traps are boards of yellow color smeared with sticky substance, which trap and kill the flying insects that are attracted to and try to rest on it.

Pitfall traps are pan-like containers bearing insecticide and embedded below the ground level. Crawling and fast-running insects often fall into them and die.

Light traps attract night-flying insects, which fall into a container having insecticide, water or oil, or hit an electric grid. Light source emitting UV light is most attractive to insects.

Pheromoe traps are particularly effective against the lepidopterous pests. Females release specific pheromone to which males are attracted from considerable distance.

d. BARRIERS: In certain instances, barriers may prevent insects from infesting the crop. Cloth screens over seedbeds protect the younger plants from insects, like flea beetles, hoppers, armyworms etc. Metal collars around young plants protect them from cutworms. Trench barriers are used to stop chinch bugs, armyworms, locusts etc. Metal or concrete barriers are used against termites. Barrier spraying of residual insecticides has become more popular against termites, locusts and several other insects. Sticky bands applied around mango tree-trunks during December-January prevent the upward movement of mango mealy bugs, which upon hatching begin to crawl up the trunk to reach the leaves.

e. TEMPERATURE CONTROL: Temperature extremes are fatal to insects. This method is used against stored grain pests. Low temperatures that are enough to dormancy can prevent damage. Low temperatures are utilized for the control of insects in flourmills and warehouses. Exposure to subzero temperature for 24 hours is lethal to most of the insects.

f. DRYING: Insects infesting stored grains require certain amount of moisture to develop. Neither the rice weevils nor the granary weevils can survive moisture contents as low as 8.0%. Drying the grains either in the sun or by heat blowers reduces infestation of majority of stored grain insects.

g. RADIATION: Gamma radiation kills all stages of the pests in storage conditions. This is a common method employed to kill insect stages during export or imports of huge quantities of grains, fruits and vegetables.

h. ULTRASONIC VIBRATIONS: Moths are often sensitive to bats' ultrasonic signals and quickly escape from the area. Imitation of the bat's echolocation system helps in scaring away the lepidopterous insect pests from the area.

2. Cultural Control

Cultural control includes such methods of planting, growing and harvesting crops, which will reduce crop damage. Slight modification in the crop rotation, weed control, disposal of crop remnants, resistant varieties, time of planting and harvesting may prove important in combating some insect pests. Control by cultural means can be achieved by the following methods:

a. **By resistant varieties**: Some varieties of plants show greater resistance to pest damage and should be planted if found desirable from other standpoints. For example, Pawnee-wheat is resistant to Hessian fly; Atlas-sorghum is resistant to chinch bug, rice varieties, namely, IR-36, Pattambi-33, IR-42 are resistant to brown planthoppers. Resistance is hereditary and can be utilized in breeding programmes. There can be several types of characters that make the variety resistant. They may be physical, like hairy leaves, which pose difficulty to potato leafhopper in feeding. Varieties of corn with long tight husk are injured less by corn-earworm. Shape of the onion leaves has an important bearing on the resistance against thrips. Certain chemicals like oxalic acid provide resistance to rice varieties against plant hoppers.

b. **By ploughing**: Timely ploughing can disturb and kill the insect pests, eradicate weeds upon which they might feed, expose them to natural enemies or to harsh weather, and bury the pest stages so deeply that few adults can emerge.Plowing effectively controls corn root-aphids because it disturbs and kills them and destroys the weeds upon which they might feed before the crop is planted. Early ploughing exposes many white root-feeding grubs, which are then destroyed by birds.

c. **By planting practices**: Some pests remain in the seed from harvest to planting time, and can start infestation. Good seed-bed preparation can not only bury many potential pests like Hessian fly but by conserving moisture gives the plant a higher chance of survival and the pests can be easily sprayed down in a smaller area. Date of planting may have an important bearing upon insect infestation. If planting coincides with the emergence or immigration of the adult pest, the crop is likely to be infested severely. Late planting of cotton is likely to be severely infested by the boll weevil because it will fruit at a time when the weevils would be most numerous. Depth of planting is important in the case of potato which if planted deeper, checks infestation of potato tuber moth, since the moth is unable to lay eggs through the cracks in soil.
d. **By harvesting practices**: Control of a number of leguminous pests is possible by timely and thorough mowing of the field. Clean cutting eliminated any leftover plants on which the insects may breed. Uniform mowing on community bases eliminated the existence of tender side-growths on which the insects can breed and live. Mowing indirectly kills the nymphs of Lygus bugs since they are exposed to high temperature, and prompt removal of the hay from the field exposes the pest on bare ground. No stubbles should be left while harvesting.
e. **By crop sanitation:** Destruction of crop residues is a good preventive measure, since it eliminates further insect breeding by cutting off their food supply. Destruction of corn, rice, sugarcane and wheat stubbles is recommended against shoot borer larvae and pupae. Harvested sugarcane crop produces secondary growth on which a sizable population of borers and hoppers can build up for the next season.

   <u>Weed control</u>: Many insects will develop on weeds very different from the crop botanically. Weed control therefore reduces infestation. Leptocorisa and Pyrilla can feed on many grasses in and around the fields. Green leafhoppers of rice can breed on barnyard grass.

   <u>Destruction of volunteer crops</u>: Volunteer crops are those which grow from self-sown or spilled seeds, or which sprout from stubbles. They should be destroyed. A summer rain may cause germination of seeds scattered during the harvesting times. Roots of harvested cotton will sprout and produce an earlier crop on which the pink bollworm can complete one generation and when the main crop emerges there is already a sizable population of the pest available.
f. **By isolation from the secondary host plants**: Insect damage can often be reduced by planting the crop as far away as possible from the other crops, which may serve as secondary hosts. Armyworms may breed on wheat and barley and later may migrate to corn and sorghum. The infestation of potato by potato-aphid, Macrosiphum solanifoli has been found to be associated with rose bushes on which this species passes the winter. Sesamia inferens can migrate from wheat to rice and sugarcane.
g. **By closed seasons:** A monophagous species can be eradicated by not growing the crop for a year or two. Closed seasons are practiced in tropical countries to decrease the damage of the pink bollworm. This is done by not growing cotton collectively by all farmers for a couple of years.
h. **By crop rotation**: Crop rotation is effective against pests that feed on relatively few plant species, and are incapable of long distance migration. Usually graminaceous and leguminous crops are grown alternatively.
i. **Pasturing:** Where enough animals are available, pasturing heavily damaged fields may utilize the remaining plants as fodder and pest stages are destroyed by feeding and trampling by the animal herds.

j. **Fertilizing:** Nitrogenous fertilizers in some soils tend to increase the susceptibility of sorghum to chinch bug. Rapidly growing cotton is more attractive to bollworms, leafworms and fleahoppers. Barley, wheats and oats can withstand greenbug infestation better when fertilized and irrigated.
k. **Flooding:** It is sometimes possible to destroy pests by flooding, as in the rice fields it destroys many migrating sugarcane pests like armyworms. Plowing followed by flooding kills pink bollworms in cotton.
l. **Trap crops:** A trap crop is a small planting of the susceptible crop made earlier than the main crop for the purpose of diverting the insects from the main crop. The plant in trap crop should be very attractive to the insect. For example broom grass is planted around wheat fields in Canada, against wheat stem sawfly, Cephus cinctus. The adult sawflies oviposit in broomgrass stem, usually in large numbers. The wheat crop when planted escapes oviposition. The emerging larvae cannibalize one another and only one larva per stem has a chance to develop, which is usually parasitized. The trap crop thus harbors parasites, which migrate to the wheat crop. Trap crops have been tried in rice against planthoppers

3. Biological Control

Regulation of pest abundance below the level of economic injury is the target of biological control, which is usually done by study, importation, augmentation and conservation of beneficial organisms for the regulation of harmful animal's population. Most of the agricultural pests are insects and these have natural enemies, which are also mostly insects. Therefore most of the examples of biological control come from insects.

Definition: Biological control is the action of natural enemies (parasites, predators and pathogens) in maintaining another organism's population density at a lower level than would occur in their absence.

The importance of biological control has lately been enhanced due to the fact that overwhelming use of insecticides has led to the resurgence of the pests and resistance to insecticides by the pests like mosquitoes, houseflies and stored grain pests. Biological control is based on the utilization of ecological principles; hence it is frequently called Applied Ecology. Maintenance of the balance of nature is an important aspect of biological control.

Natural Biological Control: includes role of natural enemies to contain pest populations in an undisturbed environment.

Applied Biological Control: includes manipulation of biotic factors (natural enemies) by man to reduce the population of a pest species.

Pests of foreign origin usually do not cause serious damage in their native country because there they are kept under check by natural enemies. But when accidentally introduced into a new country they multiply unchecked and become serious pests. Role of biological control is to find out natural enemies of such pests and introduce them in the areas of pest outbreak. Against pests of domestic origin also exotic natural enemies of species closely related to the indigenous pest are imported and released.

Examples: Control of cottony cushion scale (Icerya purchasi) by using vedalia beetle (Rodolia cardinalis) in California in 1988 is an outstanding success story. In 1887, citrus industry in California suffered massive destruction by the cottony cushion scale. Chemical control had failed. A German scholar, Albert Koebele, was assigned the job to find out natural enemies of this pest in its native home, Australia and New Zealand. In Australia, Koebele found a ladybird beetle, Rodolia cardinalis and a dipteran fly, Chryptochaetum feeding on the pest stages. He dispatched many consignments of the two species to USA for release in the orchards. Chryptochaetum failed to establish but Rodolia multiplied so fast that by July, 1889 the scale was virtually wiped out from the valley

Applied biological control is practiced in the following three ways:

a) Importation and colonization of exotic natural enemies: When the target pest is of foreign origin, it is always advantageous to search for its natural enemies in the country of its origin. It is taken as a general rule that the predominant natural enemy occurring at relatively low host densities in the native home offers greatest promise for introduction to new environment. Usually the dormant stage of the parasite (eggs or pupae), or the dormant stages of the parasitized host are shipped. Releases should be timed with the availability of the host stages to be parasitized. To evaluate the effectiveness of the natural enemy introduced, samples are collected at regular intervals and analyzed as life-table data.

b) Conservation and inundative releases of indigenous natural enemies: Conservation of natural enemies demands judicious and minimal use of insecticides on crops, so that parasites and predators are not unnecessarily killed. Selective insecticides which are not harmful to the natural enemies are used, such as organophosphates and methyl esters. Use of favorable application technique, e.g. soil application of systemic insecticides, seed treatment and use of baits, helps to conserve the natural enemies. Sometimes natural enemies are collected from the field, mass-bred in labs and then released in the field, much like biological insecticides, e.g. use of Trichogramma and Bacillus thuringiensis.

c) Manipulation of natural enemies: When a parasite or predator fails to become effective, ecological, biological and physiological studies are conducted to find out reasons for failure. There are various possible ways of enhancing the effectiveness of natural enemies as follows:

· Development of resistant strains of parasites by artificial selection under controlled conditions.

· Provision for supplementary food for adults.

· Use of behavior modifying chemicals (semiochemicals) is sometimes helpful. Extracts of tomato sprayed on corn increases parasitization of Heiothis zea. The predator Chrysopa is strongly attracted to honey dew of aphids. Synomones are chemicals produced by plants which attract natural enemies and Kairomones are chemicals released by host insects that attract natural enemies.

· Genetic improvement of natural enemies by hybridization and artificial selection of different strains, which increases vigor and effectiveness of parasites and sometimes even resistance to insecticides. Intercropping is known to augment parasitic activity.

Advantages: It is a long-time self-perpetuating control of the target pest. Unlike insecticides, there is no fear of pest developing resistance. There is no fear of environmental pollution. In this method balance of nature in the ecosystem is not disturbed. This is a long-term control method and cost of controlling the pest is economical. There is no fear of pest resurgence, as normally happens by the application of insecticides.

Disadvantages: Biological control is a long-term process and takes years before natural enemies could be established and during this period the pest can cause immense damage. Often natural enemies fail to establish, leading to failure of the entire programme. In case of pest outbreak, biocontrol fails to provide immediate relief. In some cases a natural enemy also damages some useful animals or plants. Biocontrol doesn’t provide surety. The projects usually have equal chances of failure or success.

4. Integrated Pest Management (IPM)

It is that method of pest control, which utilizes all suitable techniques of pest control to reduce pest populations and maintain them below economic injury level.

IPM is also defined as a stable system of crop protection, which based on the ecological relations within the crop and the environment, combines several methods of pest control in such a way that the pest is prevented from causing economic injury.

The idea of integrated control emerged independently in California and in Netherlands, where it was first known as harmonic control. The term pest management arose in Canada and Australia. It is also called protective management and was originally coined to define the blending of biological control agents with chemical control because these techniques used independently, either failed to produce satisfactory results or caused environmental problems. Therefore, need arose to consolidate these two methods and also other possible means into a unified programme to manage pest population so that economic injury is avoided.

Components of Integrated Pest Management

Various components and techniques that can be utilized in Integrated Pest Management programmes are as follows:

a. **Cultural control**: Use of resistant varieties of crops is a promising technique in IPM. Moderately to low level of resistance is best integrated with chemical and biocontrol agents. Crop rotation and sanitation are also used to reduce the pest population to lower levels.
b. **Mechanical control:** Use of screens or barriers or handpicking in nursery stage of the crops and use of light traps to kill egg-laying adults can bring down the population for the other methods to be effective.
c. **Biological control:** Natural enemies are commonly utilized in IPM programmes. Emphasis is given to protection and augmentation of indigenous natural enemies and recolonisation of those that have been wiped out due to indiscriminate use of insecticides.
d. **Chemical control**: Minimal use of insecticides is recommended in IPM. Rule of the thumb is not to use insecticides unless absolutely necessary. Application methods that do not bring insecticides in contact with natural enemies are favoured in IPM programmes
e. **Regulatory methods**: Plant and animal quarantines by the government and collective eradication and suppression in large areas help in providing long-lasting management. International efforts to suppress noxious pests like locusts have proved fruitful.In most of the cases, chemical, biological and varietal resistances are combined to manage the population of pest species.

Role of biological control in IPM

Being safe, permanent and economical, biocontrol should be of primary consideration in any IPM programme and should not be taken up only when other methods fail. In IPM biological control need not achieve complete success, since other methods combined also contribute in achieving the goal.

There are three major ways to integrate biological control in IPM programmes:

1. conservation and augmentation of natural enemies already available,

2. Importation and colonization of exotic natural enemies and

3. Mass culture and release of indigenous as well as exotic natural enemies.

Conservation is done by using selective insecticides to which natural enemies are resistant or use of soil application methods or habitat management like planting of nectar producing flowering plants in the vicinity of the crop. Cultural practices which maintain diversity of crops in the area are usually beneficial for the natural enemies. Intercropping of selected crops is known to augment parasitic activity. Integration of moderately resistant crop varieties with natural enemies is currently a popular component of pest management.

Role of insecticides in IPM

When pest populations reach above tolerable levels, insecticides provide immediate control. But great majority of insecticides are broadly toxic and therefore ecologically disruptive. Great need for IPM is to develop selective or even specific insecticides which will have negligible effect on non-target species. Modification of dosage, times of application, formulations and placement of material can be utilized to increase selectivity of chemicals. Successful use of pesticides of mites illustrates bright future for selectivity. Use of pheromones, hormones, repellents, antifeedants and sterilants are selelective in their action and hence must be encouraged.

An elementary integration is the application of insecticides and pheromone traps to reduce male population of the pest before undertaking control through sterile male technique, since the latter is more successful at lower pest densities. An example is the control of Mediterranean fruit fly (Ceratitis capitata) on Procida Island in Italy.

Role of varietal resistance in IPM

Use of resistant varieties is a less utilized concept. A low plant resistance is better since it does not impose too much stress on the pest species to change its behavior and develop biotypes. It also harbors natural enemies at low pest densities. A highly resistant crop, on the other hand, wipes out not only the pest species but also the specific natural enemy fauna from the area.

An interesting integration of resistance, cultural practice and chemical control is the planting of trap crop of a susceptible variety or attractive crop on the borders and main crop in the middle, and then spraying only on the susceptible variety where the pest would naturally congregate.

An integration of resistance and biocontrol was shown in California by planting moderately resistant variety of barley and sorghum which complemented the activity of the parasite Lysiphlebus testaceipes in reducing green bug (Schizaphis graminum) population. Advantages of varietal resistance in IPM programmes include: its specificity, easy compatibility with other methods, cumulative effect is carried through generations over a long period and non-disturbance of ecosystem.

Examples of Integrated Pest Management

A**. Cotton pest control in Peru**: Developed by Wille (1951) in Canete Valley which is a self-contained ecosystem surrounded by arid areas. Due to extensive use of organic insecticides and subsequent resistance developed by the cotton pests, the valley was led to the brink of disaster. The following steps were taken to save the crops:

- Prohibition of ratooning.
- Prohibition of synthetic organic insecticides and return to the old calcium and lead arsenates and nicotine sulphates.
- Repopulation of the area with; natural enemies introduced from the surrounding regions.
- Establishment of deadlines for planting, ploughing, irrigation, pruning and harvesting.
- Employment of cultural practices, which led to the establishment of healthy, uniform stands.

As a result of this IPM programme, the pest problem was solved and the whole agro-ecosystem twined into a self-balanced system.

B. **Integrated Pest Management in Paddy:** FAO developed an intercountry programme for IPM in South and Southeast Asia by integrating biological, chemical and cultural control methods.

C**. Integrated Pest Management in Sugarcane**: Chemical control is not successful in sugarcane fields because of technical and mechanical problems of insecticide applications and also insecticide contamination eventually reaching humans. Integration of biological contraol, particularly the egg parasite, Trichogramma species and modification of cultural practices has been found to keep the pest densities below economic injury levels.

D**. Integrated control of locusts**: FAO undertakes constant surveillance throughout the breeding areas and follows the following IPM programme: Eggs are destroyed by ploughing or flooding (mechanical control). Nymphs are controlled either by direct spraying by aircrafts or by barrier spraying, baiting, trenching or burning by flame-throwers. Repellents like neem-oil are sprayed on crop at the time of swarming. Swarms are either sprayed while resting on ground or by aircrafts while migrating. Some biological control is achieved by conserving predators in the breeding grounds.

5th Semester

Applied Zoology (ZOO516DB)

Unit 3rd

3.1 Varieties of cattle

Over 1000 breeds of cattle are recognized worldwide, some of which adapted to the local climate, others which were bred by humans for specialized uses.[1]

Cattle breeds fall into two main types, which are regarded as either two closely related species, or two subspecies of one species. *Bos indicus* (or *Bos taurus indicus*) cattle, commonly called zebu, are adapted to hot climates and originated in the tropical parts of the world such as sub-Saharan Africa, India, China, and Southeast Asia. *Bos taurus (or Bos taurus taurus*), typically referred to as "taurine" cattle, are generally adapted to cooler climates and include almost all cattle breeds originating from Europe, the Mediterranean region, and northern Asia. Both species were likely present since ancient times in northern Africa and the Middle East, where both natural and human-caused hybridization likely occurred. Today, Taurus/indicus hybrids are widely bred in many warmer regions, combining characteristics of both the ancestral types (such as the Sanga cattle of Africa, or Brangus [a pormoteau of Brahma and Angus] in warmer regions of the United States).

In some parts of the world further species of cattle are found (both as wild and domesticated animals), and some of these are related so closely to taurine and indicus cattle that interspecies hybrids have been bred. Examples include the Dwarf Lulu cattle of the mountains of Nepal with yak blood the Beefalo of North America with bison genes, the Selembu breed of India and Bhutan with gayal genes. The Madura breed of Indonesia may have banteng in its parentage. In addition to these fertile hybrids, there are infertile crossings such as the male Dzo of Nepal, a cattle-yak crossing which is bred for agricultural work - like the mule they have to be continually bred from the parent species.

The important cattle breeds are as.

Indigenous dairy breeds of cattle

1. **Gir:**

This breed is otherwise called as Bhadawari, Desan, Gujarati, Kathiawari, Sorthi, and Surati. Originated in Gir forests of South Kathiawar in Gujarat also found in Maharashtra and adjacent Rajasthan. Basic colours of skin are white with dark red or chocolate-brown patches or sometimes black or purely red.

Horns are peculiarly curved, giving a 'half moon' appearance. Milk yield ranges from 1200-1800 kgs per lactation. **n**This bread is known for its hardiness and disease resistance

2. Red Sindhi

This breed is otherwise called as Red Karachi and Sindhi and Mahi. Originated in Karachi and Hyderabad (Pakistan) regions of undivided India and also reared in certain organized farms in our country. Colour is red with shades varying from dark red to light, strips of white. Milk yield ranges from 1250 to 1800 kgs per lactation. Bullocks despite lethargic and slow can be used for road and field work.

3. Sahiwal

Originated in Montgomery region of undivided India. This breed otherwise known as Lola (loose skin), Lambi Bar, Montgomery, Multani, Teli. Best indigenous dairy breed. Reddish dun or pale red in colour, sometimes flashed with white patches. Heavy breed with symmetrical body having loose skin. The average milk yield of this breed is between 1400 and 2500 kgs per lactation.

Indigenous Draught breeds of cattle

4. Hallikar

Originated from the former princely state of Vijayanagarm, presently part of Karnataka. The colour is grey or dark grey. Compact, muscular and medium size animal with prominent forehead, long horns and strong legs. The breed is best known for its draught capacity and especially for its trotting ability.

5. Amritmahal

Originated in Hassan, Chikmagalur and Chitradurga district of Karnataka. Amiritmahals are grey cattle but their shade varies from almost white to near black. The muzzle, feat and tail are usually black. Horns are long and end in sharp black points

6. Khillari

Originated from Sholapur and Sitapur districts of Maharashtra. Closely resembles Hallikar breed. Grey-white in colour. Long horns turn forwards in a peculiar fashion. The horns are generally black, sometimes pinkish. Bullocks are fast and powerful.

7. Kangayam

Also known as kongu and konganad. Originated in Kangayam, Dharapuram, Perundurai, Erode, Bhavani and part of Gobichettipalayam taluk of Erode and Coimbatore district. Bulls are grey with dark colour in hump, fore and hind quarters. The horns are spread apart, nearly straight with a slight curve backwards. Cows are grey or white. The eyes are dark and prominent with black rings around them. Moderate size with compact bodies.

8. Bargur

Found around Bargur hills in Bhavani taluk of Erode district in Tamilnadu. Developed for work in uneven hilly terrains. Generally brown colour with white markings. Animals are well built, compact and medium in size. Known for their speed and endurance in trotting. Cautious in behaviour and tends to remain away from strangers.

9. Umblachery

It is otherwise called as Jathi madu, Mottai madu, Molai madu, Therkathi madu. Originated inThanjavur, Thiruvarur and Nagappattinam districts of Tamil Nadu. Suitable for wet ploughing and known for their strength and sturdiness. Umblachery calves are generally red or brown at birth with all the characteristic white marking on the face, on limbs and tail. The legs have white markings below the hocks like socks. The practice of dehorning of bullocks is peculiar in Umblachery cattle.

10.Pulikulam

This breed is commonly seen in cumbum valley of Madurai district in Tamil Nadu. Also known as Jallikattu madu, kidai madu, sentharai. Small in size, usually grey or dark grey in colour. Well-developed hump. Mainly used for penning in the field. Useful for ploughing. Presence of reddish or brownish spots in muzzle, eyes, switch and back is the characteristic feature of this breed. Typical backward curving horns of like Mysore type cattle. Breeds are active, useful draught animals but not fast trotter

11.Alambadi

Originated from Alambadi of Dharmapuri district in Tamilnadu. Grey or dark grey in colour. White markings will be seen in forehead, limb and tail. Horns are backward curving like Mysore cattle. Resembles Hallikar and also known as Betas. It is useful in ploughing.

<u>Indigenous Dual purpose breeds of Cattle</u>

12.Tharparkar

Originated in Tharparkar district (Pakistan) of undivided India and also found in Rajasthan. Otherwise known as White Sindhi, Gray Sindhi and Thari. They are medium sized, compact and have lyre-shaped horn. Body colour is white or light grey. The bullocks are quite suitable for ploughing and casting and the cows yield 1800 to 2600 kgs of milk per lactation.

13.Hariana

It was originated from Rohtak, Hisar, Jind and Gurgaon districts of Haryana and also popular in Punjab, UP and parts of MP. Horns are small. The bullocks are powerful work animals. Hariana cows are fair milkers yielding 600 to 800 kg of milk per lactation.

14.Kankrej

It is otherwise called as Wadad or Waged, Wadhiar. Originated from Southeast Rann of Kutch of Gujarat and adjoining Rajasthan (Barmer and Jodhpur district). The horns are lyre-shaped. Colour of the animal varies from silver-grey to iron-grey or steel black. The gait of Kankrej is peculiar called as 1 ¼ paces (sawai chal). Kankrej is valued for fast, powerful, draught cattle. Useful in ploughing and carting. The cows are good milkers, yielding about 1400 kgs per lactation.

15. Ongole

Otherwise known as Nellore. Home tract is Ongole taluk in Guntur district of Andhra Pradesh. Large muscular breed with a well developed hump. Suitable for heavy draught work. White or light grey in colour. Average milk yield is 1000 kgs per lactation.

16.Krishna Valley

Originated from black cotton soil of the water shed of the river Krishna in Karnataka and also found in border districts of Maharastra. Animals are large, having a massive frame with deep, loosely built short body. Tail almost reaches the ground. Generally grey white in colour with a darker shade on fore quarters and hind quarters in male. Adults females are more whitish in appearance. The bullocks are powerful animals useful for slow ploughing, and valued for their good working qualities. The average yield is about 900 kgs per lactation.

Exotic dairy breeds of cattle

17.Jersey

Originated from Jersey Island, U.K. Smallest of the dairy types of cattle. In India this breed has accliamatized well and is widely used in cross breeding with indigenous cows. The typical colour of Jersey cattle is reddish fawn. Dished forehead; compact and angular body. Economical producers of milk with 4.5% fat. Average milk yield is 4500 kgs per lactation.

18.Holstein Friesian

originated from the northern parts of Netherlands, especially in the province of Friesland. Largest dairy breed and ruggedly built is shape and possess large udder. Breeds have typical marking of black and white that make them easily distinguishable. The average milk production of cow is 6000 to 7000 kgs per lactation.

19. Brown Swiss

The mountainous region of Switzerland is the place of origin of Brown Swiss breed. Breeds are rugged in nature and good milk production. Average milk yield is 5000 kgs per lactation. The Karan Swiss is the excellent crossbred cattle obtained by crossing this breed with Sahiwal cattle at NDRI, Karnal.

20.Red Dane

Orginated in Denmark. Body colour of this Danish breed is red, reddish brown or even dark brown. It is also a heavy breed; The lactation yield of Red Dane cattle varies from 3000 to 4000 kgs.

21. Ayrshire

Origin is Ayrshire in Scotland and considered as most beautiful dairy breed. These are very active animals but hard to manage. They do not produce as much milk or butter fat (only 4%) as some of the other dairy breeds. The breed was also known as Dunlop cattle or Cunningham cattle

<u>Cross bred - Dairy Cat</u>

22.Jersey cross

Jersey crosses are produced by upgrading/ cross breeding the non descript / Indigenous breeds of cows with Jersey breed semen. Jersey crosses are suitable dairy animals for tropical plains of our country. They are medium sized, have better heat tolerance than other exotic crosses and well adapted to our climate. Depending on the milk production potential of our indigenous cows, the Jersey crosses may show 2 to 3 fold increase in milk yield in the first generation.

3.2 Principles and management of poultry breeding

Poultry farming is the process of raising domesticated birds such as chickens, ducks, turkeys and geese for the purpose of farming meat or eggs for food. Poultry - mostly chickens - are farmed in great numbers. The poultry industry breeds chickens destined for both commercial egg and meat production. Geneticists design special breeding programs to select birds with the best characteristics for egg or meat production. This selection process (called genetic selection or genetics) allows the industry to select strains of birds which are produced very efficiently in intensive housing systems. There are two main types of commercial chicken breeds: layers and meat (broiler) chickens.

The principles of poultry husbandry

There are a number of requirements by which animals should be managed so that the best performance is achieved in a way acceptable to those responsible for the care of the animals and to the community generally. These requirements are the keys to good management and may be used to test the management of a poultry enterprise in relation to the standard of its management. These requirements are also called Principles.

The importance of each Principle changes with the situation and thus the emphasis placed on each may alter from place to place and from time to time. This means that, while the Principles do not change, the degree of emphasis and method of application may change. Every facet of the poultry operation should be tested against the relevant principle(s). The **Principles of Poultry Husbandry** are:

The quality and class of stock

If the enterprise is to be successful it is necessary to use stock known to be of good quality and of the appropriate genotype for the commodity to be produced in the management situation to be used. The obvious first decision is to choose meat type for meat production and an egg type for egg production. However, having made that decision, it is then necessary to analyse the management situation and market to select a genotype that suits the management situation and/or produces a commodity suitable for that market. A good example is that of brown eggshells. If the market requires eggs to have brown shells, the genotype selected must be a brown shell layer. Another example would be to choose a genotype best suited for use in a tropical environment. The manager must know in detail the requirements of the situation and then select a genotype best suited to that situation.

Good husbandry

The following are of major importance when considering the health, welfare and husbandry requirements for a flock:

Confine the birds

Confining the birds provides a number of advantages:

- Provides a degree of protection from predators
- Reduces the labour costs in the management of the birds

- Increases the number of birds that can be maintained by the same labour force
- Reduces the costs of production
- Better organisation of the stocking program
- Better organisation management to suit the type and age of the birds housed

Importantly, the confinement of the birds at higher stocking densities has a number of disadvantages also including:

1. Increases the risk of infectious disease passing from one bird to another
2. Increases the probability that undesirable behavioural changes may occur
3. Increases the probability of a significant drop in performance
4. Birds housed at very high densities can often attract adverse comments

Protection from a harsh environment

A harsh environment is defined as the one that is outside of the comfort range of the birds. In this context high and low temperature, high humidity in some circumstances, excessively strong wind, inadequate ventilation and/or air movement and high levels of harmful air pollutants such as ammonia are examples of a harsh environment. Much effort is made in designing and building poultry houses that will permit the regulation of the environment to a significant degree.

It is the responsibility of those in charge, and responsible for, the day-to-day management of the birds that the environment control systems are operated as efficiently as possible. To this end, those responsible require a good knowledge of the different factors that constitute the environment and how they interact with each other to produce the actual conditions in the house and, more importantly, what can be done to improve the house environment.

Welfare needs

A successful poultry house has to satisfy the welfare needs of the birds which vary with the class, age and housing system. Failure to satisfy these needs will, in many cases, result in lower performance from the birds. These needs include:

- The provision of adequate floor space with enough headroom
- The provision of good quality food with adequate feeding space
- The provision of good quality water with adequate drinking space
- The opportunity to associate with flock mates
- The elimination of anything that may cause injury
- The elimination of all sources of unnecessary harassment

<u>The maintenance of good health</u>

The presence of disease in the poultry flock is reflected by inferior performance. It is essential that the flock is in good health to achieve their performance potential. There are three elements of good health management of a poultry flock. These are:

1. The prevention of disease

2. The early recognition of disease
3. The early treatment of disease

Prevention of disease

Preventing the birds from disease is a much more economical way of health management than waiting for the flock to become diseased before taking appropriate action. There are a number of factors that are significant in disease prevention. These are:

1. Application of a stringent farm quarantine program:

- The isolation of the farm/sheds from all other poultry.
- The control of vehicles and visitors.
- The introduction of day-old chicks only onto the farm.
- The prevention of access to the sheds by all wild birds and all other animals including vermin.
- The provision of shower facilities and clean clothing for staff and visitors.
- The control of the movement of staff and equipment around the farm.

2. The use of good hygiene practices:

- The provision of wash facilities for staff, essential visitors and vehicles prior to entry.
- The use of disinfectant foot baths at the entry to each shed.
- The thorough cleaning and disinfection of all sheds between flocks.
- Maintaining the flock in a good state of well being by good stockmanship, nutrition and housing.
- The use of a suitable vaccination program.
- The use of a preventive medication program.
- The use of monitoring procedures to keep a check on the disease organism status of the farm, to check on the effectiveness of cleaning and sanitation procedures and to test the immunity levels to certain diseases in the stock to check the effectiveness of the vaccination program.

The early recognition of disease

Early recognition of disease is one of the first skills that should be learned by the poultry flock manager. Frequent inspection of the flock to monitor for signs of sickness are required. It is expected that inspection of all the birds is the first task performed each day, to monitor for signs of ill health, injury and harassment. At the same time feeders, drinkers and other equipment can be checked for serviceability. If a problem has developed since the last inspection, appropriate action can be taken in a timely manner.

The early treatment of disease

If a disease should infect a flock, early treatment may mean the difference between a mild outbreak and a more serious one. It is important that the correct treatment be used as soon as possible. This can only be achieved when the correct diagnosis has been made at an early stage. While there are times when appropriate treatment can be recommended as a result of a field diagnosis i.e. a farm autopsy, it is best if all such diagnoses be supported by a laboratory examination to confirm the field diagnosis as well as to ensure that other conditions are not also involved. When treating stock, it is important that the treatment be administered correctly and at the recommended concentration or dose rate. Always read the instructions carefully and follow them. Most treatments should be administered under the guidance of the regular flock veterinarian.

Nutrition for economic performance

Diets may be formulated for each class of stock under various conditions of management, environment and production level. The diet specification to be used to obtain economic performance in any given situation will depend on the factors such as:

1. The cost of the mixed diet
2. The commodity prices i.e. the income
3. The availability, price and quality of the different ingredients

Maximising production is not necessarily the most profitable strategy to use as the additional cost required to provide the diet that will give maximum production may be greater than the value of the increase in production gained. A lower quality diet, while resulting in lower production may bring in greatest profit in the long term because of the significantly lower feed costs. Also the food given to a flock must be appropriate for that class of stock – good quality feed for one class of bird will quite likely be unsuitable for another.

The following are key aspects in relation to the provision of a quality diet:

- The ingredients from which the diet is made must be of good quality.
- The weighing or measuring of all the ingredients must be accurate.
- All of the specified ingredients must be included. If one e.g. a grain is unavailable, the diet should be re-formulated. One ingredient is not usually a substitute for another without re-formulation.
- The micro-ingredients such as the amino acids, vitamins, minerals and other similar materials should not be too old and should be stored in cool storage – many such ingredients lose their potency over time, and particularly so at high temperatures.
- Do not use mouldy ingredients – these should be discarded. Mould in poultry food may contain toxins that may affect the birds.
- Do not use feed that is too old or has become mouldy. Storage facilities such as silos should be cleaned frequently to prevent the accumulation of mouldy material.

The practice of good stockpersonship

The term “stockpersonship” is difficult to define because it often means different things to different people. However, “stockpersonship” may be defined as ‘the harmonious interaction between the stock and the person responsible for their daily care’. There is no doubt that some stock people are able to obtain much better performance than others, under identical conditions. The basis of good stockpersonship is having a positive attitude and knowledge of the needs and behaviour of the stock under different circumstances, of management techniques and a willingness to spend time with the stock to be able to react to any adverse situations as they develop to keep stress to a minimum. Having the right attitude is also a very important element. The stockperson who spends as much time as possible with the stock from day old onward by moving among them, handling them and talking to them, will grow a much quieter bird that reacts less to harassment, is more resistant to disease and performs better.

The maximum use of management techniques

There are a number of different management techniques available for use by stockpersons that, while not essential for the welfare of the stock, do result in better performance. Examples of these are the regulation of day length, the management of live weight for age and of flock uniformity. The good manager will utilise these techniques whenever possible to maximise production efficiency and hence profitability of the flock.

A carefully controlled environment that avoids crowding, chilling, overheating, or frightening is almost universal in poultry farming. Cannibalism, which expresses itself as toe picking, feather picking, and tail picking, is controlled by debeaking at one day of age and by other management practices. The feeding, watering, egg gathering, and cleaning operations are highly mechanized. Birds are usually housed in wire cages with two or three animals per cage, depending on the species and breed, and three or four tiers of cages superposed to save space. Cages for egg-laying birds have been found to increase production, lower mortality, reduce cannibalism, lower feeding requirements, reduce diseases and parasites, improve culling, and reduce both space and labour requirements.

Poultry breeding is an outstanding example of the application of basic genetic principles of inbreeding and crossbreeding as well as of intensive mass selection to effect faster and cheaper gains in meat and maximum egg production for the egg-laying strains. Maximum use of heterosis, or hybrid vigour, through incrosses and crossbreeding has been made. Rapid and efficient weight gains and high-quality, plump, meaty carcasses have been achieved thereby.

The use of records

There are two types of records that need be kept on a poultry enterprise:

1. Those required for financial management – for business and taxation reasons
2. Those required for the efficient physical management of the enterprise

For records to be of use in the management of the enterprise, they must be complete, current and accurate, be analysed and then used in the decision making process. Failure to use them means that all of the effort to gather the information will have been wasted and performance not monitored. As a result, many problems that could have been fixed before they cause irreparable harm may not be identified until too late.

Marketing

There are three important elements to good marketing practice:

1. Produce the commodity required by the consumer – this usually means continuous market research must be carried out to relate production to demand.
2. Be competitive – higher price is usually associated with good quality and/or specialised product. Therefore, it is necessary to relate price to quality and market demand and to operate in a competitive manner with the opposition.
3. Reliability – produce a commodity for the market and ensure that supply, price and quality are reliable.

3.3 Processing and preservation of eggs

The production of clean and wholesome eggs has received considerable attention in the developing and the developed countries in the world. Eggs are used for household purposes, for confectionery and for other industrial purposes. About 95% of the eggs are used for table and cooking purpose and the remaining 5% are used in confectionery. However the quality of eggs gets deteriorated due to various factors like hot weather conditions, storage in warm dry places, dirty eggs, fertile eggs, ungraded eggs and defective packing and handling. It is recorded that 5% of entire spoilage of egg is due to bacterial contamination. The uncared eggs deteriorate quickly. So eggs should be collected within a few hours after being laid. The preservation of the quality of egg is of great importance in marketing. The problem is however beset with great practical difficulties. For the proper care freshly laid eggs are taken to the egg room, maintained at 16°C and cooled as soon as possible. The following methods are found useful in preserving of eggs.

1. **Production of infertile eggs.**

The fertile eggs deteriorate quickly than the infertile eggs at suitable higher ranges of temperature, so the production of infertile eggs helps in preserving egg quality considerably. Infertile eggs can be obtained by separating the cocks from the hens except during breeding seasons. It is common impression that the presence of a male bird is necessary for the hens to lay eggs. Hens are capable of laying eggs without the presence of cock bird and the eggs thus obtained are infertile ones. But this however is not always possible under the existing conditions of poultry rearing in rural areas, therefore defertilization of eggs has to be recommended.

2. **Defertilization.**

For the defertilization eggs are kept in hot water maintained at a temperature range of 135°F to 145°F for about 15 minutes to destroy the germ. The defertilized egg is as good as infertile egg and can be kept without deterioration for longer period. Eggs to be defertilized are put in an open basket of wire and dipped into the hot water for about 15 minutes after which they are removed and kept in some cool places. In well organised poultry centres, somewhat more elaborated defertilization plants are installed, which consist of water tanks with mechanical stirrers, electrical heating arrangements, some wire baskets and egg cooler.

3. **Egg cooling.**

It is well known that the temperature above 68°F is favourable for the development of embryo and consequently makes for rapid deterioration of egg quality. A temperature below 68°F is suitable for maintaining the quality and freshness of the egg. In winter season cooling device is not needed as temperature is normally low. The ideal thing is the refrigerated coolers. Some of the cooling systems which can be adopted by poultry farmers are as:

a. **Cool room:** Egg room can be cooled by keeping outlets open and sprinkling water on floor to keep room constantly moist. A ceiling fan in addition will very much be helpful.
b. **Underground cellar:** If a cool room is not possible an underground pit should be made which can provide desirable low temperatures for the proper cooling of eggs.
c. **Earthen pot:** A large earthen pot can be maintained at low ranges of temperature by keeping it partially buried in sand heap on which water is sprinkled frequently. In the bottom of the pot a layer of dry straw or hay should be kept to avoid the percolating dampness. The pot should be kept in well ventilated place and the mouth of the pot should be covered with thin muslin so that air and moisture can freely pass inside the pot.

d. **Cold storage:** The egg quality is fairly well maintained for about 9 months in cold storage at 0°C and 85% relative humidity. In india the cold storage of egg is now under practice in well organised poultry farms.

4. **Freezing eggs.**

It is one of the best means of conserving the quality of eggs. In this method deterioration is arrested, and the frozen eggs can be held in cold storage for an extended period until needed. In this method shell eggs are placed in cold storage to preserve the quality. After thorough chilling eggs are taken to the candling room. After the eggs are candled they are transferred to the breaking tables, where the shell is broken against the blunt knife located above a small tray which is supplied with cups to hold the contents of the egg. Separated yolk and white or mixed yolk with whitecan be preserved through freezing, which checks the growth of bacteria. Frozen whole eggs are used for preparing cakes, pasteries, ice cream etc.

5. **Drying eggs.**

The drying of eggs is more convenient way of preserving the eggs than even freezing. The drying of eggs reduces them to one fourth of their original weight, so that about 70 normal sized eggs make 1 kg of dried egg. In this method egg pulp is forced under pressure into a drying chamber and sprayed through a nozzle. The incoming air is held at higher ranges of temperature while the exhaust air has atemperature of lower ranges. The spray dried product is usually a fine powder, while the pan dried product is made up of flakes or scales which can be grinded into powder.

6. **Lime sealing of egg**

The lime sealing of the egg prevent the moisture from evaporating and escape of carbon dioxide through the pores of shell. For lime sealing shell eggs are dipped for about 18 hours in lime water, containing powdered salt.

7. **Oil coating of egg.**

The oil coating of egg shell for conserving the quality of egg is an economical and convenient method for common poultry farmers. The oil used for this purpose is carnation oil, a white mineral oil refined from paraffin and coconut oil. The eggs kept in wire basket are dipped for 5 to 10 seconds in a vessel containing the coating oil. Further, baskets having eggs are taken out from the vessel and are hung on a hanger for about one hour. During this period fan can be used for proper drying of oil coated eggs. The dried eggs are ready for storage. The oil coated eggs can be kept for about 30 days at room temperature and for about 80 days at a temperature lower than room temperature. Oil coating should be done as soon as eggs are laid.

8. **Water glass method.**

It is a good method for preserving the quality of eggs. For this purpose commercial water glass (Sodium silicate) is mixed with cooled boiled water ina definite ratio and is kept in an earthen pot and both are mixed thoroughly with a wooden piece. Eggs are dipped in this solution and are kept in a cool place.

Processing of egg products

A number of useful products like albumen flakes,, egg yolk and egg powder are formed by egg processing.

1. **Albumen flakes**

For the preparation of albumen flakes, the thick albumen of egg is broken by microbial fermentation and glucose is removed. Now the content is acidified and dried in the form of albumen flakes. The albumen flakes are used for the preparation of sensitive mixtures for coating zinc or aluminium files for offset printing. The flakes are also used for the tanning of costly leather.

2.**Frozen yolk**

The yolk obtained as by product during the processing for albumen flakes can be frozen for uses in various purposes. The major products of frozen yolk are, plain yolk, sugared yolk, salted yolk and yolk emulsions. Sugared yolk and salted yolk is mixed with10% sugar and salt respectively which acts as anticoagulant and minimises the chemical changes in yolk during freezing. Another method for the preservation of frozen yolk is by the addition of 6% sodium chloride and 1% of sodium benzoate to it. The frozen yolk after treatment with 0.04% pepsin can be kept undamaged for months.

2. **Egg powder**

For the preparation of egg powder eggs are cleaned in running water, dipped into 2% solution of bleaching powder. The cleaned eggs are broken and liquid thud obtained is churned and filtered to separate pieces of shell and chalazae. For the removal of sugar 0.5% yeast is added and kept at 36°C for 1.5 hours. Now fermented liquid is pasteurized at 60°C for about 30 minutes, cooled and 1N HCL is added to bring the pH to 5.5. This solution is spray dried at an inlet temperature of 160°C and an outlet temperature of 60°C keeping the automizer at 20000 rpm. Thus egg powder is ibtained which is further kept in vaccum self drier at 60°C for about 3 hours. In this powder 1.2% sodium carbonate is added and is canned in sealed containers. The dried egg powder can be kept for long period even at higher ranges of temperature.

3.4 Diseases of poultry

Avian encephalomyelitis

Avian encephalomyelitis (AE) is a viral infection of the central nervous system of poultry, primarily chickens, turkeys, Japanese (coturnix) quail, and pheasants. It is found worldwide and is characterised by ataxia (loss of muscle coordination) and tremors, especially of the head and neck, and a drop in egg production and hatchability in hens. The disease is most common in chickens 1-6 weeks of age.

AE is caused by a picornavirus. Vertical transmission is the most common way the disease is spread but it is also spread by direct contact between susceptible hatchlings and infected birds. There is no treatment for AE. Control of the disease is through prevention.

Avian influenza (bird flu)

Avian influenza—known informally as avian flu or bird flu is a variety of influenza caused by viruses adapted to birds. The type with the greatest risk is highly pathogenic avian influenza (HPAI). Bird flu is similar to swine flu, dog flu, horse flu and human flu as an illness caused by strains of influenza viruses that have adapted to a specific host. Out of the three types of influenza viruses (A, B, and C), influenza A virus is a zoonotic infection with a natural reservoir almost entirely in birds.Avian influenza, for most purposes, refers to the influenza A virus. It is a highly contagious viral infection which may cause up to 100% mortality in domestic chickens or turkeys. Avian influenza is most often spread by contact between infected and healthy birds, though can also be spread indirectly through contaminated equipment.[20] The virus is found in secretions from the nostrils, mouth, and eyes of infected birds as well as their droppings. The highly pathogenic influenza A virus subtype H5N1 is an emerging avian influenza virus that is causing global concern as a potential pandemic threat. It is often referred to simply as "bird flu" or "avian influenza", even though it is only one of many subtypes. People who do not regularly come into contact with birds are not at high risk for contracting avian influenza. Those at high risk include poultry farm workers, animal control workers, wildlife biologists, and ornithologists who handle live birds.[18] Organizations with high-risk workers should have an avian influenza response plan in place before any cases have been discovered. Biosecurity of poultry flocks is also important for prevention. Flocks should be isolated from outside birds, especially wild birds, and their waste; vehicles used around the flock should be regularly disinfected and not shared between farms; and birds from slaughter channels should not be returned to the farm.

Avian Intestinal Spirochaetosis

(AIS) is a disease that affects commercial laying and meat breeding hens and results from the colonisation of the caeca and rectum by one or more species of anaerobic spirochaetal bacteria. AIS is characterised by chronic diarrhoea in diseased birds, and subsequently results in faecal staining of eggs and wet litter. The resultant wet litter is an industrial problem and necessitates the mechanical cleaning of cages. A delay and (or) reduction of egg laying capacity is also observed, and hatched broiler chicks from eggs of infected parents show reduced performance compared to those of healthy parents.

Avian tuberculosis

It is chronic bacterial infection that spreads slowly through a flock. All bird species appear to be susceptible, however pheasants seem highly susceptible whereas turkeys rarely succumb to the disease. The disease is more common in captive than wild birds, however it is uncommon in poultry flocks due to the poultry husbandry practices and their short life span. ymptoms do not usually develop until late in the infection and affected hens are usually more than one year old. The disease in birds is characterised by gradual weight loss, sluggishness and sometimes lameness. Combs and wattles shrink and become pale. Avian tuberculosis is caused by the bacterium Mycobacterium avium. This bacterium is closely related to the human and bovine TB bacteria. There is not treatment for avian tuberculosis. Control is achieved through depopulation and good biosecurity practices including rodent control, screening against wild birds, isolation from other birds and animals and good sanitation.

Chicken anaemia virus infection

(known generally in the industry as CAV) is an acute viral infection of chickens that is found worldwide. CAV can infect chickens of all ages but disease is only seen in young chickens and is characterised by depression, anaemia, inappetence, haemorrhage and a sudden rise in mortality. CAV is a small DNA virus. The virus can be spread both vertically (from parents to offspring) and horizontally (between birds within a flock), via the faecal-oral route. There is no specific treatment. Secondary bacterial infections may be treated with antibiotics and minimised through good biosecurity practices, including hygiene and management.

Coccidiosis

It is one of the most common and economically important diseases of chickens worldwide. It is caused by a parasitic organism that damages the host’s intestinal system, causing loss of production, morbidity and death. This disease has a major economic impact on the global poultry industry. Coccidial parasites are protozoa belonging to the phylum Apicomplexa. Chicken coccidiosis is caused by seven species, all from the genus Eimeria: E. acervulina, E. brunetti, E, maxima, E. mitis, E. necatrix, E. praecox and/or E. tenella. The life-cycles of these species are direct. Chickens ingest sporulated oocysts (the parasite ‘egg’) from contaminated litter, and these pass into the intestinal tract, where the parasites invade the cells of the intestinal wall. Several cycles of replication occur which lead to the formation of new oocysts which are shed in the faeces. Depending on environmental conditions (including temperature and humidity), the oocysts sporulate and become infective. The entire cycle takes 4 to 6 days. It is the replicative phases of the parasite which lead to damage in the intestinal tissues. Individual birds may show no clinical signs, or may suffer a mild loss of appetite, weight loss or decreased weight gain, diarrhoea (which can be bloody), dehydration and death. Chemotherapy has been the main approach for controlling coccidiosis in chickens. Anti-coccidial drugs are usually used preventatively and if a farmer were to wait for overt signs of disease before treating the flock, morbidity and mortality would be high and the economic damage already done.

Egg drop syndrome

(EDS) is caused by a viral infection in laying hens. It is characterised by production of soft-shelled and shell-less eggs in apparently healthy birds, and leads to a sudden drop (10-40%) in recorded egg production or a failure to achieve a normal peak in production. It can be difficult to identify the early stages of the disease as hens will eat the shell-less eggs, and the only evidence that may remain is the membranes, which is a sign that is easy to miss. In flocks where some birds have acquired immunity due to the spread of the virus, a failure to reach expected production targets is observed. Clinical signs include diarrhoea and brief loss of shell colour and egg yolk pigment prior to the production of soft-shelled eggs and mortality is usually negligible. Ducks and geese are the natural hosts for the EDS virus and are asymptomatic carriers. EDS is caused by infection with the EDS virus which is an adenovirus. The incubation period is three to five days and the course of the disease is four to 10 weeks. The virus is transmitted through any of the conventional means of viral disease spread and is also transmitted on and in the egg (horizontal and vertical transmission).

Fatty liver syndrome

It is a condition that affects only hens, primarily caged layers. It is a metabolic or nutritional disease and is characterised by general obesity with an enlarged, fatty liver that becomes soft and easily damaged. Mortality rates vary and death is often caused by internal haemorrhage due to rupture of the liver. The principal cause is thought to be excessive calorie intake, but it may also be related to exposure to the mycotoxin aflatoxin, calcium deficiency and/or stress. The principal causes of fatty liver syndrome are related to feed ingredient quality or inappropriate feed formulation. Unless caused by aflatoxin or calcium deficiency, the main treatment for this condition is to reduce the amount of dietary energy consumed. If aflatoxin is involved, the contaminated feed must be replaced. If a calcium deficiency is suspected, adding large particle calcium to the diet is recommended.

Fowl cholera (Pasteurelossis)

It is a contagious bacterial infection. The disease can range from acute septicaemia (blood poisoning) to chronic and localised infections. Domestic fowl, game birds and small feral birds are susceptible. Clinical findings vary greatly depending on the course of the disease. In acute cases, increased mortality is usually the first indication. Affected birds have swelling of the face or wattles, discharge from the nostrils, mouth and eyes which may become "cheesy", laboured breathing and, in some cases, lack of coordination. The face, combs and wattles may become cyanotic (turn a bluish colour). Other symptoms include depression, loss of appetite, lameness, diarrhoea and ruffled feathers. Fowl cholera is caused by the bacterium *Pasteurella multocida*. Fowl cholera can be treated with sulfonamides and antibiotics

Fowl pox

It is a relatively slow-spreading viral infection that affects most bird species, including all commercial forms of poultry. It occurs in both a wet and dry form. The wet form is characterised by plaques in the mouth and upper respiratory tract. The dry form is characterised by wart-like skin lesions that progress to thick scabs. The disease may occur in any age of bird, at any time. Mortality is usually not significant unless the respiratory involvement is severe. Fowl pox can cause depression, reduced appetite and poor growth or egg production. The course of the disease in the individual bird takes three to five weeks. Fowl pox is caused by an avian DNA pox virus. There are five or six closely related viruses that primarily affect different species of birds but there is some cross-infection. Infection occurs through skin abrasions or bites, through the respiratory route and possibly through ingestion of infective scabs. It can be transmitted by birds, mosquitoes or fomites (inanimate objects such as equipment). There is no treatment for fowl pox and prevention is through vaccination of replacement birds.

Histomoniasis

It is a parasitic protozoan infection of turkeys, chickens, peafowl and several game bird species. Most infections are fatal in turkeys, but mortality is less common in other birds. Although chickens are relatively resistant to the condition, significant disease has been observed in breeding chickens and free-range layers. Clinical signs include depression, inappetence, poor growth, increased thirst, mustard-yellow diarrhoea, listlessness and dry, ruffled feathers. The common name for this disease is 'blackhead', which stems from the clinical sign where the bird's head may become cyanotic (blue-black in colour). Histomoniasis is caused by the protozoan Histomonas meleagridis which acts with existing intestinal bacteria, such as Escherichia coli, to cause the condition. After the protozoan is ingested it first infects the caeca then migrates through the blood stream to the liver. It is then passed out in the droppings and also within the eggs of the caecal worm Heterakis gallinae, if that is also present in the bird. Most infections are caused by birds ingesting infected caecal worm eggs and sometimes directly by contact with infected birds. Outbreaks spread quickly through flocks by direct contact.

Infectious bronchitis

It is a highly contagious viral respiratory infection of chickens, however the virus will also infect the urogenital and gastrointestinal tracts. The clinical signs of infectious bronchitis are non-specific and so laboratory tests are required to confirm diagnosis. Clinical signs are strongly dependent on the tropism (preferred tissue to infect) of the strain, but commonly include include coughing, sneezing and gasping in young birds, loss of appetite and wet litter. Feed intake decreases sharply and growth is retarded. Mortality in young birds can be high (up to 30%), however minimal mortality is experienced in older birds (> 5 weeks old). Less common strains can cause a sharp drop in egg production in layers, and production usually drops to near zero within a few days. Recovery occurs within 3 – 4 weeks, however some flocks never regain an economical rate of lay. During an outbreak, small, soft-shelled, irregular-shaped eggs are produced. Infectious bronchitis is caused by a coronavirus. The virus is highly variable and new serotypes and genotypes continue to appear. The virus dies quickly outside of the host but can spread through the air and can travel considerable distances during an active outbreak. The highly contagious nature of this disease generally results in all susceptible birds on the premises becoming infected, often in spite of biosecurity measures such as sanitary or quarantine precautions, which should always be maintained. There is no treatment for this disease. Secondary infections with bacterial diseases are common and antibiotics may reduce losses from these infections. The virus is easily destroyed by heat and ordinary disinfectants. In young chickens it is helpful to increase the brooder temperature and to optimise environmental conditions.

Infectious coryza

It is a contagious bacterial respiratory infection of chickens. While there are reports of a similar disease in other birds such as pheasants and guinea fowl, there is considerable doubt if these non-chicken cases are associated with the same aetiological agent. The disease occurs most often in adult birds. Infection can spread slowly, with chronic disease affecting only a small number of birds, or rapidly, with a higher percentage of birds being affected. Clinical signs include swelling around the face and wattles, watery or pus-like discharge from the eyes and nostrils, difficulty breathing, sneezing, loss of appetite, weight loss and a drop in egg production. Infectious coryza is caused by the bacterium *Avibacterium paragallinarum*. Earlier names for this organism, including *Haemophilus paragallinarum* and *Haemophilus gallinarum* should no longer be used. The bacterium is spread through contact with infected birds or exudates. Recovered birds remain carriers of the bacteria for long periods and as such, once a flock is infected all birds must be considered as carriers. Birds can be more susceptible if already infected with other respiratory viral or bacterial infections. Infectious coryza can be treated with a number of antibiotics and vaccines are used to prevent infection in high incidence areas. However, control of the disease requires good husbandry practices. Prevention is best achieved using biosecurity principles based on an all-in/all-out replacement policy and ensuring replacement birds are not infected.

Lymphoid Leukosis

It is a neoplastic (tumour causing) viral infection of chickens that is found in flocks worldwide. The virus has been eradicated from some SPF (specific pathogen free) flocks. Globally, the frequency of infection has been reduced substantially in the primary breeding stocks of several commercial poultry breeding companies. This control program has led to infection becoming infrequent or absent in commercial flocks. The frequency of avian Leukosis tumours, even in heavily infected flocks, is typically low (<4%), and disease is not often apparent in infected flocks. However, mortality up to 1.5% excess mortality per week has been reported in commercial broiler-breeder flocks naturally infected with an avian Leukosis virus.

Affected birds show non-specific clinical signs including reduced feed intake, weakness, diarrhoea, dehydration, weight loss, depression and reduced egg production. Palpation often reveals an enlarged bursa of Fabricius and sometimes an enlarged liver. The disease can be immunosuppressant which increases susceptibility to other diseases. Lymphoid Leukosis is caused by certain members of the Leukosis/sarcoma group of avian retroviruses. These viruses are commonly called avian Leukosis viruses and belong to subgroups A, B, C, D, E, and J. Subgroups A and B have been most prevalent in western countries, until the emergence of subgroup J. There is no treatment for Lymphoid Leukosis. Lymphoid Leukosis appears to be controlled best by reduction and eventual eradication of the causative virus, which are rapidly inactivated at ambient temperature and on exposure to most disinfectants. Prevention is also helped by obtaining chicks from breeder flocks that are free of the virus and rearing birds in isolation with adequate ventilation.

Marek's Disease Virus

(MDV) is a highly contagious viral infection that predominantly affects chickens but can also affect pheasants, quail, gamefowl and turkeys. It is one of the most common diseases that affects poultry flocks worldwide. Clinical disease is not always apparent in infected flocks, however subclinical disease is often more economically important as it reduces weight gain and egg production. Mortality rates can be very high in susceptible birds. Marek's Disease (MD) results in enlarged nerves and in tumour formation in nerve, organ, muscle and epithelial (cells that line the internal and external surfaces of the body) tissue. Clinical signs include paralysis of the legs, wings and neck, weight loss, grey iris or irregular pupil, vision impairment and the skin around feather follicles can be raised and roughened. Affected birds are immunosuppressed and as a consequence are more susceptible to other infectious diseases. MD is caused by a highly cell-associated (virus particles that remain attached to or within the host cell after replication) but readily transmitted herpesvirus. The route of infection is usually respiratory. The serotypes that exist are 'virulent' (disease causing) chicken isolates (serotype 1) and 'avirulent' (non-disease causing) chicken isolates (serotype 2). The avirulent virus that is commonly found in turkeys is designated serotype 3. here is no treatment for MD. Vaccination is the central strategy for the prevention and control of MD. While vaccination will prevent clinical disease and reduce shedding of infective virus it will not prevent infection. Cell-associated vaccines are generally more effective than cell-free vaccines because they are neutralised less by maternal antibodies.

Mycoplasmosis

It is a collective term for infectious diseases caused by the micro-organisms called mycoplasmas. There are a number of mycoplasmas that can infect poultry, with Mycoplasma gallisepticum (MG) (which affects a number of bird species including chickens, turkeys, gamebirds and pigeons), M. synoviae (MS) (which affects chickens and turkeys), and M. meleagridis (MM) (which only affects turkeys) being the main species.

MG can cause chronic respiratory disease and decreased growth or egg production and affected carcasses sent to slaughter may be downgraded. Some chickens may not show symptoms. Observable clinical signs may include rales, coughing, sneezing, nasal discharge, frothiness and swelling around the eyes or difficulty breathing. Signs are often more severe in turkeys. MS can cause respiratory disease similar to MG but if it becomes systemic it can cause lameness, swollen joints, loss of weight and breast blisters. Greenish diarrhoea can also be present in dying birds. MM is a venereal disease that can result in high mortality of young poults through starvation. Signs in young poults include unthriftiness, difficulty breathing, poor growth and neck and leg deformations. Breeder flocks may experience a drop in egg production and hatchability. All of these mycoplasmas can be transmitted vertically and so can be introduced into the flock through infected eggs, including venereal transmission by males for MM. Vertical transmission has been greatly reduced through the establishment and maintenance of MG, MS and MM-free breeder flocks. They can spread through bird-to-bird contact and contact with exhaled respiratory droplets either as aerosols or on equipment, people and surroundings. Birds recovered from MG and MM remain carriers of the organisms and continue shedding for life. All of these mycoplasmas are sensitive to several antibiotics, however vaccines for some mycoplasmas are also available. Good biosecurity procedures are critical for prevention. Mycoplasmas are destroyed by disinfectants and sunlight.

Newcastle Disease (ranikhet disease)

It is a highly contagious viral infection that affects many species of domestic and wild birds to varying degrees. Domestic fowl, turkeys, pigeons and parrots are most susceptible while a mild form of the disease affects ducks, geese, pheasants, quail and guinea fowl. The disease can result in digestive, respiratory and/or nervous clinical signs, which range from a mild, almost inapparent respiratory disease to very severe depression, drop in egg production, increased respiration, profuse diarrhoea followed by collapse, or long-term nervous signs (such as twisted necks), if the birds survive. Severe forms of the disease are highly fatal. Newcastle Disease is caused by a paramyxovirus that can vary in pathogenicity from mild to highly pathogenic. Spread is usually by direct physical contact with infected or diseased birds. The virus is present in manure and is breathed out into the air. Other sources of infection are contaminated equipment, carcasses, water, food and clothing. People can easily carry the virus from one shed or farm to another. Newcastle Disease virus does not affect humans in the same way that it does birds but it can cause conjunctivitis in humans.

Toxoplasmosis

It is a zoonotic (can be transmitted from animals to humans) parasitic protozoan disease and is rare in poultry. It is more common in aviaries and backyard poultry than commercial producers. It is characterised by disorders of the central nervous system but can also affect reproductive, musculoskeletal (muscles and bones) and visceral organs (internal organs of the chest and abdomen). Clinical signs in poultry include weight loss, inappetence, shrunken comb, drop in egg production, whitish diarrhoea, incoordination, trembling, opisthotonos (severe spasm in which the back arches), torticollis (twisting of the neck) and blindness. All chickens infected before eight weeks of age develop clinical signs. In older birds, infection can be asymptomatic (infected hosts show no symptoms) or latent (symptoms only develop under certain conditions).

Toxoplasmosis is caused by the parasitic protozoa Toxoplasma gondii. Cats are the only definitive hosts (a host in which the parasite can sexually reproduce) and so both wild and domestic cats serve as the main reservoir of infection. There are three infectious stages in the lifecycle of this protozoa. Stage one is within the tissue of the host, stage two is when the protozoan is excreted by the host in the faeces and stage three is when the protozoan transferred across the placenta in mammals to their offspring. Transmission can therefore occur by eating infected tissue, contact with infective faeces or transfer from an infected mother to a developing foetus (in mammals only). Drugs are available that suppress multiplication of the parasite within the host but they will not usually eradicate the infection. Good biosecurity and management procedures are the principle forms of control in commercial poultry flocks. Pet animals should be kept away from poultry and poultry feed. Establish good rodent control and use separate staff for infected and uninfected flocks.

Trichomoniasis

It is a parasitic protozoan disease that affects domestic fowl, pigeons, doves, and hawks. It occurs in the digestive as either the 'lower' form, which is characterised by depression, weight loss and watery yellow diarrhoea or the 'upper' form, which is characterised by depression, drooling and repeated swallowing movements, sunken and empty crop, open-mouth breathing and bad odour. The upper form is rare in turkeys and chickens. Most caged, domestic and game birds (except waterfowl) are susceptible but the disease is more serious in young birds. Recovered birds remain carriers for life. Trichomoniasis is caused by infection with the parasitic protozoa *Trichomonas gallinae*. This protozoa has variable pathogenicity (ability to cause disease). Transmission of the protozoa is by bird to bird contact or by contact with infected litter, feed or water. The protozoa is shed in the faeces of infected birds and can be regurgitated in crop milk. Treatments are available that will control the disease but there may be restrictions on their use in commercial flocks. Prevention requires good biosecurity and management practices to eliminate the sources of infection. Drain water pools on ranges, screen out wild birds, separate young birds from adults as well as susceptible birds from recovered (carrier) birds.

5th Semester

Applied Zoology (ZOO516DB)

Unit 4th

4.1 Genetic improvements in aquaculture industry, Induced breeding

INTRODUCTION

The wild harvest of fish, invertebrates (mainly molluscs and crustaceans), and aquatic plants (mainly seaweeds), has provided human populations across the globe with important sources of nutrition from ancient times. Today aquaculture and capture fisheries directly employ over 180 million people, supporting the livelihood of 8 percent of the world's population, and each sector provides about 50 percent of the world's aquatic food supply.1 There are more than 31 000 species of finfish, 85 000 species of mollusk, 47 000 species of crustacean and 13 000 species of seaweed, with more than 5000 species accessed in wild fisheries and about 400 species used in aquaculture. Aquatic genetic resources underpin the productivity and sustainability of world aquaculture and capture fisheries, and the essential services provided by aquatic ecosystems in marine, brackish and freshwaters.

The application of genetic principles to aquatic species used in aquaculture is a relatively recent phenomenon and the sector has not yet made full use of available technologies to increase production as other food producing sectors have done. Indeed it is only over the past two decades that there has been widespread acceptance that genetic improvement and the application of biotechnologies has an important role to play in aquaculture development and that very significant genetic gains can be achieved through the appropriate application of well planned genetic breeding programmes for aquatic species.

This document accompanies working document COFI:AQ/VI/2012/9 – Genetic resources and technologies in aquaculture development: opportunities and challenges and summarizes current and future applications of long-term and short-term genetic technologies in aquaculture production, and briefly touches upon other applications for the characterization and management of aquatic genetic resources and their increasing importance for traceability of fish and fish products.

APPLICATION OF GENETIC TECHNOLOGIES IN AQUACULTURE PRODUCTION

Genetic technologies can be utilized in aquaculture for a variety of reasons, although the main use is to improve production. Improvements in marketability, disease resistance, body shape, color, culturability, and the conservation of natural resources can be facilitated by the appropriate genetic technology. Genetic improvement programmes can be used to provide short-term or long-term gains. The short term gains are usually immediate, within two generations, and generally not cumulative (unless combined with other long-term programmes), whereas the long term programmes such as selective breeding produce gains that accumulate each generation.

Long-term genetic improvement strategies

Domestication and the full potential for the utilization of aquatic genetic resources will only be realized through long-term breeding programmes. The aquaculture sector lags far behind the crop and livestock sectors with regard to the development of domesticated and genetically improved strains.

Selective breeding

Growth rate is the characteristic most often improved in selective breeding programmes and increases of up to 20% per generation have been reported. Other traits have been shown to have additive genetic variance and therefore, amenable to improvement. Traits such as disease and stress resistance, timing of maturity and flesh quality are now being increasingly included in selective breeding programmes. Breeding programmes have been expanded and their design optimized, and new ones initiated. Examples of species used in recent breeding programmes include Atlantic cod, Atlantic salmon, common carp, gilthead seabream, hybrid striped bass, Lake Malawi tilapia, Mediterranean sea bass, Nile tilapia, red sea bream and rohu carp.

On disease resistance, the adoption of domesticated and genetically improved whiteleg shrimp Penaeus vannamei resulted in a drastic increase in shrimp aquaculture output but also posed serious risks of persistent infections, e.g. with viral pathogens that can be passed from broodstock to postlarvae. The use of specific pathogen free (SPF) domesticated shrimp should be supported by robust biosecurity as a prime consideration

Another potential application of genetic selection techniques is in the area of enhancing feed utilization, i.e. to determine whether carnivorous fish with natural capacity for protein utilization asmain energy source can be genetically selected. Classic selective breeding programmes will continue to be the main engine driving the global finfish aquaculture industry forward.

Genetic engineering

Genetic engineering technology is now beginning to find application in the production of aquaculture feed to assist in reducing the dependency on fishmeal and fish oil and to improve the terrestrial animal- and plant-based feed ingredients. Examples include: genetically engineered yeast for production of important feed ingredients such as fish growth hormone and carotenoid pigments; pre-processing techniques of plant material to reduce the effects of antinutritional factors, breeding of plants with a better amino acid profile and less antinutritional factors, and converting low grade land animal by-products into high-value protein.

Transgenic fish has been produced since the mid 1980s with most research focused on the transfer of growth hormone genes8 . In several cases, significant increases in growth have been reported. Currently, no transgenic fish have been approved for commercial release as food for humans.

Short term genetic improvement strategies

Short-term genetic improvement techniques may not require the same level of record keeping nor management as long-term projects and can impart significant gains with simple technologies in a short period of time.

Hybridization and crossbreeding

Crossbreeding and hybridization can be utilized to combine favourable qualities from two genetically different groups and to take advantage of hybrid vigour (heterosis). Interspecific hybridization has resulted in fish with improved growth rates, manipulated sex ratios, sterile animals, improved flesh quality, increased disease resistance, improved tolerance to environmental extremes and other altered traits

Chromosome set manipulation

Manipulation of chromosome-sets (polyploidization) has been accomplished for many aquatic species through thermal and chemical shocks to developing embryos. Triploid organisms are useful because they are sterile and therefore able to put more energy into the growth process rather than into maturation and reproduction. Whilst chromosome-set manipulations have not resulted in many commercial applications for finfish, the use of triploids has become an important part of the oyster farming industry and may have similar potential in other shellfish. For example, triploid Pacific oysters have shown 14 - 159% growth improvement over diploid controls. At the same time, sterility reduces the risk of breeding with native species which may be of importance in stocking programmes such as the use of grass carp for vegetation control or to address environmental impacts of fish escaping from farms.

Sex manipulation

Manipulation of sex can be of advantage in species with sexual dimorphism in important traits or when reduced chance of reproduction is desired. Monosex male stocks have considerable commercial benefit in a number of species, most notably in tilapia due to problems of both precocious maturation and unwanted reproduction within the production system exhibited by this species. Also, female trout and salmon grow better and female sturgeon produce caviar. The sex of fish can be easily manipulated using hormonal treatments, but there has been concern about the use of hormones in animal production resulting in an increased use of other biotechnologies in those developing countries whose production goes to export markets.

Emerging technologies

A number of new genetic technologies are now beginning to be applied in cultured aquatic species. Genome technologies include DNA marker, novel sequencing, gene discovery, genome mapping (showing the relative positions of genes along a chromosome) and genome expression technologies that examine how genes actually function in the organisms. These technologies will be useful to find important genes affecting traits such as disease resistance, growth rate and sex determination, allowing more precisely targeted selection to improve aquaculture performance.

Other applications

The application of genetic technologies for the characterization of genetic resources has different applications in aquaculture ranging from identification of valuable genetic resources for genetic improvement programmes, management of farmed broodstocks, and discrimination between wild and cultured specimens, to monitoring of genetic effects of aquaculture escapees on wild populations

The broad spectrum of applicability and high resolution of genetic markers can help to increase value in post-harvest and trade applications for fish and fish products. Traceability is a key aspect of aquaculture certification schemes12. Genetic markers provide an extremely sensitive means to identify samples of fish which could not be identified by other means, including frozen material, fillets, and early life history stages, e.g. eggs and larvae. Molecular genetic diagnoses of fish and fish products have already identified cases of mislabelling, consumer fraud and have helped convict offending parties13.

Immunodiagnostic and molecular technologies are widely applied in pathogen screening and detection, elucidation of pathogenicity and disease diagnosis and have played an important role in health management due their high sensitivity, specificity, and ability for rapid diagnosis

Linking the use of genetic technologies in fishing and aquaculture will increase efficiency and efficacy of the technologies. However, it should be noted that many of these technologies require specialized equipment and highly skilled staff.

Induced breeding

Inducedfish farming has allowed farmers to breed and raise species that do not naturally reproduce in captivity, to manipulate the timing of reproduction to suit production cycles, getting fish to spawn on a predetermined date and fertilise and incubate eggs under hatchery conditions. There are two main strategies used to induce reproduction. The first is to provide an environment similar to that in which spawning occurs in nature. Catfish, for example, likes to spawn in enclosed spaces and goldfish in vegetation and at high temperatures.

The artificial process by means of which the extract of the pituitary is introduced inside the body of both the matured male and female fishes, then the carps after being excited lay eggs in the pond water and subsequently fertilization takes place and the process is called induced breeding of fishes. This process of breeding is also known as hypophysation.

The second strategy is to inject the fish with one or more naturally occurring reproductive hormones or their synthetic analogs to manipulate maturation of gonads and ovulation. The hormones injected include, **Gonadotropin Releasing Hormone(GnRH)**analogs, dopamine antagonists and gonadotropins.**Leutinizing Hormone Releasing Hormone (LHRH)** is a mammalian hormone that has been employed successfully to induce reproduction in fishes. **Dopamine** inhibits the action of LHRH and hence a dopamine antagonists are given for induced breeding.

Two types of **gonadotropin** extracts have been used to induce ovulation in fishes, namely, **Human Chorionic Gonadotropin (HCG)** and **fish pituitary extract**. Pituitary extracts are made by removing the pituitary from a fish and extracting the hormones, which may then be injected into another fish. HCG offers three major advantages over the pituitary extract, namely,**1)** it is much less expensive, **2)** it is more stable and **3)** it comes in a purified form. An intraperitonial injection is given through the ventral part of the fish behind the pelvic or pectoral fin. Intramuscular injections are commonly given on the dorsal part of the fish above the lateral line and below the dorsal fin.Two doses with a time gap of 12 to 24 hours are given.

Collection of Pituitary extract:

From the matured fishes of both sexes either belonging the same species as the recipient or a closely related the pituitary glands are collected. It is preferred to collect the pituitary gland from freshly killed fishes. But it has been observed that the pituitary glands taken from five to eight days old ice-preserved fishes have also given successful results. In the fish markets, where the head of the cut fishes are available the pituitary glands can be taken out from the posterior end of the cranium through the foramen magnum after cleaning the brain tissue.

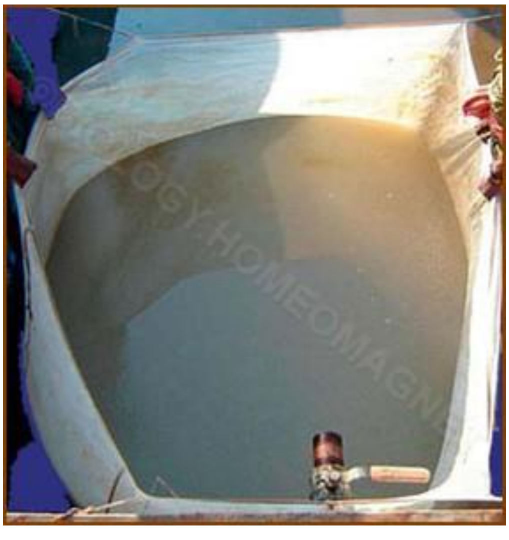
Preparation of Pituitary extract:

Injection of Pituitary Extract

For the **induced breeding** of fishes the preparation of pituitary extract is very important. But it is very easy to prepare. Immediate after the collection of the pituitary glands are kept in absolute alcohol for dehydration. After 24 hours, the alcohol is changed for further dehydration and defattening. The glands are then weighed and preserve in fresh alcohol in dark colored phials. It may be stored at room temperature or in a refrigerator. The weight of each pituitary gland varies from 7 to 19 mg in Rohu weighing 1kg to 3.8 kg and 3 to 23 mg in Mrigal weighing 0.3 to 3.6 kg. At the time of injection to carps for the induced breeding, the required quantity of pituitary glands are taken out of the phials and the alcohol is allowed to evaporate. The glands are then macerated with a tissue homogenizer either in distilled water or 0.3 percent of saline water. The gland suspension is then centrifuged and the supernatant fluid is drawn into a hypodermic syringe for the injection.

Method of injection and Spawning:

During the rainy season, the extract of the pituitary gland of the same species which is prepared on the above said scientific process is injected in the muscle of the matured carps, 1.5 kg the 5.5 kg weight in general. Just before evening, per one female with two males of the approximate same body weight are to be injected the pituitary extract by hypodermic syringe. Injection of the carps is to be done outside of the water lying on a piece of sponge which is used only to avoid the injury of the carps. In case of male carps the pituitary extracts are introduced once and in case of female carps it is introduced twice.



A Spawning Hapa

At first, at the rate of 2 to 3 mg of pituitary extract per kg of body weight is introduced in the muscle of the caudal peduncle or near the dorsal fin of the female carp. But in should be kept in mind that the injection should not be done on the lateral line sense organ of the carp. The needle of the syringe is to be introduced between the scales but with an angle of 45° with the body. After six hours of first injection, the second injection is given to the same female at the rate of 5 to 8 mg of pituitary extract per kg of body weight.

Then the carps, i.e., one female and two male are placed in a breeding hapa for spawning. Inside of the breeding hapa both the female and male carps are exited. After the excitation the female carps lays eggs. The eggs are externally fertilized by the spermatozoa that are discharged by the males. After that all the fishes are removed from the breeding hapa and then the eggs are collected by a net and are transferred to the inner part of the hatching hapa. After 14 to 18 hours, the spawns enter into the outer hapa and the induced breeding process completed. Then the spawns are collected from the outer hapa and transferred to the pond for nursery.

What are the advantages of induced breeding?

i) Eggs and spawns of carps at the collected from the river bed, there are every possibility of mixture of other fishes of eggs and spawns. Whereas, in the induced breeding there is no possibility of mixture and as a result the pure form of fish seeds are obtained. ii) Desired species of carps can be cultured through the induced breeding. iii) Large numbers of eggs are available from a fish through induced breeding. iv) In the same season, a carp can be induced to breed more than once. v) Transportation cost becomes very low as the carps can be breed in any desired pond. vi) Between the different species of fishes hybridization can be done and it is possible to get hybrid variety of fishes.

4.2 Prawn fisheries-culture

The prawn production in India accounts for about 15% of the total world production of prawn and shrimps. For marine prawns, the percentage of Indian production to the world production is about 20%. The major commercial prawn species reared in India are *Macrobrachium. rosenbergii* and *M. malcolmsonii.*

BIOLOGY

Macrobrachiumrosenbergii, also known as the giant river prawn or the **giantfreshwater prawn,** is native to the Indo-Pacific and northern Australian Regions. The adult is found in freshwater, while its larval stages live in brackish water after the juvenile stage. During mating, the male attaches its spermatophore on the ventral side of the abdomen of female's body and the eggs coming out of female genital opening are fertilised by the sperms derived from spermatophores.

The fertilised eggs are held in the brood chamber or egg basket, which is made by the interlocking ***appendixinterna*** of the pleopods and are aerated by vigorous movements of the swimmerets for 2-3 weeks. This is in contrast to shrimps, whose fertilized eggs are released into the sea. Females can lay 80,000-100,000 eggs during one spawning and eggs take an average of 20 days at 28°C to hatch into larvae.

After hatching, larvae are dispersed by the rapid movements of the abdominal appendages of the female. Larvae are planktonic and swim upside down actively with tail first posture and feed on small planktons. Larvae complete development in 15-20 days and metamorphose into post larvae, which resemble miniature adults and generally feed near bottom and then begin to migrate upstream into freshwater rivers within one or two weeks after metamorphosis and are soon able to swim against the rapidly flowing currents (contranatant behaviour) and can also crawl over the stones in shallow waters.

HATCHERIES AND NURSERIES

Freshwater prawn hatcheries need supplies for both freshwater and sea water; the latter can be drawn from areas where the salinity is 30 to 35 ppt. The brackish water derived from the mixture of seawater, brine or artificial sea salts mixed with freshwater should have salinity of 12-16 ppt, pH of 7.0 to 8.5 and dissolved oxygen level of 5 ppm.

The prawn farm site should also have the following facilities:

- A secure power supply to ensure that the components of hatchery, e.g. aeration, water flow etc. can continue to function uninterrupted.
- An uninterrupted access for incoming and outgoing materials by road.
- Access to the uninterrupted seawater and freshwater supplies.
- Farm should not be close to cities, mines and industrial centres or to other activities that may pollute the water supply.
- Farm should be situated in a climate where the temperature range of 28-31°C can be easily maintained.
- Food supplies for larvae should be easily procured when required.
- Should have access to biological and veterinary assistance whenever required.
- Should be close to other nursery facilities feed sites.
- Should be close to the market for quick selling after harvesting.

OBTAINING BERRIED FEMALE PRAWNS

Berried females are those that carry fertilised eggs in their egg basket. They can be obtained from rivers, canals, lakes and estuaries, where they are most abundant in the beginning of rainy season. In the tropics, berried females can be obtained all the year round from farm ponds containing adult animals. Selecting fast-growing, berried females from ponds has a positive effect on the weight of prawns at harvest.

In the tropics, where berried females are readily available, special brood holding facilities are not required but in temperate areas, indoor brood stocking facilities are essential. Brood stock is disinfected by placing into freshwater containing 0.2-0.5 ppm of copper sulphate or 15-20 ppm of formalin for about 30 minutes. Prawns should be fed daily at the rate of 1-3% of total biomass.

Berried females can be collected from the holding system and placed in tanks where the eggs will hatch into first instar larvae, which are collected by netting. The hatching tanks should be covered to prevent bright sunlight to reach larvae for which the inner side of the tanks should also be painted with black epoxy-resin paint.

LARVAL REARING TANKS

Different designs of containers can be used to grow freshwater prawn larvae, which may be circular flat-bottom tanks, circular conical-bottomed plastic tanks, plastic-lined wooden tanks, rectangular concrete tanks, concrete-faced brick tanks and earthen water jars. Good drainage system is essential as water has to be removed from tanks at harvesting time. Mixing tanks are also required for preparing the brackish water to be used in the hatchery as well as storage tanks. Aeration of water is also essential which can be done through PVC pipes, with holes cut at one foot intervals.

Larvae should not be exposed to direct sunlight, for which 90% of the tan area should be covered and shady. Some natural light is essential for good larval survival, which can be provided through transparent roofs over the hatcheries. Physical filters that include sand filters, drum screen filters, and medium filters should be easy to clean and designed to minimize water loss.

Water needs to be chemically treated before it can be used in rearing tanks and also should be physically filtered by passing through the sand bed before transferring it to another tank for treatment. Mix the seawater or brine with freshwater to form 12 ppt of brackish water. The optimum temperature range for *M. rosenbergii* is 28-31°C. Below 24-26°C the larvae will not grow well and the time taken for them to reach metamorphosis will be longer.

LARVAL FEEDING

A wide range of feeding material is used by different hatcheries, which includes nauplius larvae of shrimps, freshwater cladocerans, fish eggs, squid flesh, frozen adult *Artemia*, rotifers, fish flesh, egg custard, worms and commercial feeds available in the market. The quantity of food to be given depends on the utilization of feed by larvae that vary from place to place. The quantity of feed consumed will increase as the larvae grow.

HARVESTING POST LARVAE

When post larvae are about 7-8 mm long, they can withstand transfer from 12 ppt water into freshwater. However, they should not be harvested from the larval tanks and transferred directly into holding tanks containing freshwater but should be acclimatized to fresh water in the larval tanks itself. When majority of larvae have metamorphosed, water level in tanks should be reduced to about 35 cm. Then gradually the tank should be flushed with freshwater over a period of 12 hours. The post larvae can then be collected and transferred or the larval tanks can be refilled to 70 cm with fresh water and the animals temporarily held in them. The best way to harvest post larvae from the larval tanks is to reduce the water level and then remove them by nets.

HOLDING POST LARVAE BEFORE SALE

Post larvae cannot be held in holding tanks for more than a week or two prior to stocking in nurseries. When the post larvae are in the holding tanks, the rearing water should be changed every 2-3 days) to provide aeration. Post larvae can be stocked at densities of about 5,000/m2 for one week, although survival increases by reducing the density.

REARING PONDS

Pond size should be such that can be managed easily. Generally most farms have ponds of around 0.2-0.6 ha size. Large ponds are normally wider than 30 m and often drained for harvesting. The average depth of water in freshwater prawn ponds in tropical areas should be about one meter; with a minimum of 0.75 m and a maximum of 1.2 m. Deeper ponds are used in colder areas to maintain more stable water temperatures. The banks of the ponds or embankments or bunds must be high enough for the highest water level expected in the pond, which generally should be 1-2 feet higher than water level. The flow of water into each pond must be controlled by valves, stop-logs or plugs. Paddle wheels are the most efficient method of increasing dissolved oxygen levels in the pond water.

STOCKING

Stocking the ponds quickly reduces competitors and predators, which have less time to become established. Often post larvae that are a week or two old after metamorphosis are used to stock ponds, where they remain until harvesting. A stocking density of about 40,000/ha is recommended for the monoculture of *Macrobrachiumrosenbergii*. Using larger juveniles for stocking increases the survival rate as well as the average weight of the animals by as much as about 30%.

FEED TYPE

Natural productivity of the ponds generally gives small production from the ponds. Therefore, intensive farming must involve supplementary feeding to increase productivity. Some farms claim to rely on fertilizers, rather than feeding at the beginning of the rearing period, which stimulates algal bloom and lot of micro flora and fauna in the ponds. Others find that providing feed from the beginning of the rearing period improves performance and is cost-effective. Commercial feeds are the most productive and reliable to use but they are expensive and unaffordable to small farmers.

HARVESTING MARKETABLE PRAWNS

Basically there are two methods of harvesting: **culling** and **draining**. The time of harvesting depends partly on the growth rate and partly on the size of animals for market requirements. Culling is used to harvest market-sized animals from the ponds to remove faster growing prawns which increase density quickly. In tropics culling usually starts 5-7 months after post larvae have been stocked to take out the market-sized animals for selling and keeping the smaller ones and soft-shelled animals in the pond for further growth. After about 8-11 months ponds are drained and all animals are sold. In cull harvesting, a seine net is pulled through the pond to remove market-sized animals, while in drain harvesting, a harvesting sump is installed in front of the gate or outside the pond, in which prawns will accumulate while water is being drained.

DISEASE CONTROL

Several diseases affect freshwater prawn larvae as well as adults. Some hatcheries use formalin at the rate of 200 ppm daily as an effective remedy for protozoan and hydrozoan parasites and fungal diseases. Formalin can also be used at a lower level of about 30 ppm for longer periods, followed by water change after 24 hours. Larvae can also be transferred to disinfecting tanks every 5-10 days to get rid of diseases and parasites. Daily dip of larvae in Malachite green (0.2 ppm) for 30 min has also been used for treatment. Also, dipping in copper sulphate 0.4 ppm solution for 6 hours is recommended. Antibiotics and sulfa drugs are sometimes used to control filamentous bacteria and some hatcheries use lime (CaO) as a prophylactic measure

4.3 Freshwater fish culture

Fish farming or pisciculture involves raising fish commercially in tanks or enclosures such as fish ponds, usually for food. It is the principal form of aquaculture, while other methods may fall under mariculture. A facility that releases juvenile fish into the wild for recreational fishing or to supplement a species' natural numbers is generally referred to as a fish hatchery. Worldwide, the most important fish species produced in fish farming are carp, tilapia, salmon, and catfish.

Indian aquaculture has been growing at a fast pace over the last two decades, with freshwater aquaculture contributing over 95% of the production. The three Indian major carps, namely catla *(Catla catla),* rohu *(Labeo rohita)* and mrigal *(Cirrhinusmrigala)* contribute to the bulk of production amounting to about two million tonnes annually (FAO, 2003). Silver carp, grass carp and common carp formthe second important group for fish production. Average national production from pondfisheries has increased from 0.6 tonnes/ha/year in 1974 to 2.2 tonnes/ha/year in 2002 (Tripathi, 2003).

COMPOSITE FISH CULTURE

The three major carps cultured in India, namely, **catla***(Catla catla),***rohu***(Labeo rohita*) and **mrigal***(Cirrhinus mrigala),* contribute as much as 87 percent of the total Indian aquaculture production. Three exotic carps were also introduced, namely, silver carp *(Hypophthalmichthys molitrix);* grass carp *(Ctenopharyngodon idellus*) and common carp *(Cyprinus carpio)*. There are also several other medium and minor carp species, namely,*Labeo calbasu, L. fimbriatus, L. gonius, L. bata, L. ariza,Cirrhinus mrigala, Puntius sarana, Hypselobarbus pulchellus, H. kolus* and *Amblypharyngodon mola*, which are important in aquaculture. Among catfishes, magur*(Clariasbatrachus)* is the only species that is widely cultured, while the catfish, 'Singhi' *(Heteropneustes fossilis)* is cultured to some extent in the eastern states.

Attempts have also been made to culture the other catfishes like *Pangasius pangasius, Wallago attu, Sperata seenghala, S. aor* and *Ompokpabda*. The finfish species of importance include climbing perch *(Anabastestudineus),* murrels *(Channa striata* and *C. marulius)* and tilapia *(Oreochromismossambicus* and*Oreochromis niloticus).*

PREPARATION OF PONDS

Pond preparation involves making the ponds weed and predator-free and generating adequate natural food for the survival and growth of fishes. Control of aquatic weeds, removal of undesirable flora and fauna and improvement of soil and water quality are important aspects of fish management.Weeds have to be removed from the ponds first, after which the tank is fertilized with both organic and inorganic fertilizers, such as Oil Cake and raw Cow Dung @ 5,000 kg/acre.

The PH of pond water should be 7.5 – 8.00, for which lime is added in the tanks @ 200 kg/acre per annum. The lime increases pH and also helps in eradicating fish parasites.The organic fertilizer in the form of raw cow dung is added in the tank @ 500 kg/acre per annum. This is followed by the application of inorganic fertilizers like Super Phosphate @ 120 kg/acre and Ammonium Sulphate @ 200 kg/acre, in spaced intervals.

SPAWNING

Because of constant temperature and favourable weather conditions, carps spawn all the year round in India. Spawning takes place early in the morning when the water surface cools down to about18 degrees. The female carp swims near the water surface followed by the male carp in nuptial swimming and rubbing each other's bodies. Female lays egg and male releases its milt and eggs are fertilised.

Three days after fertilization, the eggs begin to hatch. The newly hatched larva is about 5.5 mm long, delicate and transparent, with a yolk sac attached to the belly. It rarely swims but settles on the bottom or on some floating object. On the second day, the larva starts swimming and on the third day swims actively from surface to bottom. During these stages, the larva or fry gets its nourishment from the yolk sac, which disappears on the third day and the fry now must search for food and eat.

Supplementary fry-feed in the form of hard-boiled egg yolk or powdered milk can be applied on the water surface at this time.

Carpscan feed on almost anything like insects, shells and worms and can also eat aquatic plants, bread crumbs, rice bran and fish meal made from corn, copra and soybean.

CHOOSING BROODERS

Both female and male brood fish should be carefully tended for 2-3 months before induced spawning operations are carried out and males and females should be segregated and kept in separate ponds.

To be good brooders the fish must be more than one year old and 150 gm in weight. Sex can be determined by the shape of the genital papilla which is pointed in male and oval in female. When the female is ready for induced spawning operations, It should have a bulging abdomen that is soft to touch. The cloaca is reddish and prominent, and the contour of the enlarged ovaries can be seen on both sides of the abdomen. The head should be small and the snout pointed.

Nursery ponds are constructed to rear carp fry or larvae. A normal sized nursery pond measures 5 x 10 m, with a depth of 0.5 m. Before filling up water the pond should be cleaned thoroughly to get rid of predators and parasites that may be destructive the larvae.About 1,500 to 3,000 fries can be stocked in the nursery pond andfed with milk, wheat flour or boiled egg yolk by spreading it on the water surface. This feed can be supplemented with rice bran, bread crumbs or fish meal, which can be given twice a day, in the morning and in the afternoon.

Rearing ponds, where adult carpsare cultured until they reach marketable size, are needed, which have dimensions of 15 x 50 m and depth of 1.5 to 2 m. Rearing ponds should also be thoroughly cleaned before filling them with water. This is done by exposing the bottom and letting it dry thoroughly.Next step involves application of fertilizers, which encourages growth of aquatic plants, moss and algae, which are important natural food and also lead to growth of micro fauna. Manure in the form of chicken dropping is the most commonly used being cheaper and more readily available in large quantities. When carp fry reaches the length of about 5 to 7 cm, they are transferred from the nursery pond to the rearing pond and allowed to grow to adult stage.

STOCKING OF PONDS

Ponds are stocked with fish fries of appropriate size. Fingerlings of over 10 cm in size are recommended for stocking in culture ponds. Stocking of smaller fishes may result in higher mortalities and slow growth during the initial months. In fish polyculture a fingerling size of 50-100 g is preferred for stocking to ensure higher survival and better growth. Generally, a density of 5,000 fingerlings is kept as a standard stocking rate per ha for carp polyculture, which will give a yield of 3-5 ton/ha/yr.

Prior to stocking, the fish fries should be dippedin 3-5% potassium permanganate solution for 15 seconds to kill parasites. In composite fish farming, a combination of six species are cultured, namely, Catla, Rohu, Mrigal and exotic Carps like Silver Carps, bass and common Carp.Supplementary feeds like Groundnut Oil cake and Rice Bran are fed to fishes during culture. At the end of the culture period of say 12 months, the fish will reach marketable size and fetch attractive prices.

POST-STOCKING POND MANAGEMENT

While fertilizing the carp ponds, 20-25% of the total amount of organic manures is applied a fortnight before stocking and the remaining amount is applied in equal instalments on a bimonthly basis. Other commonly used organic manures include poultry manure, pig dung, duck droppings, cow dung, domestic sewage, etc. *Azolla*, a nitrogen-fixing fern is used as a bio-fertilizer for aquaculture at the rate of 40 tonnes/ha/yr, which supplements nutrients required for intensive carp culture. The bio-processed organic manure, biogas slurry has also been used as manure in carp culture.

The supplementary feed in carp polyculture is usually restricted to a mixture of groundnut/mustard oil-cake and rice bran. Grass carps are fed with aquatic vegetation such as*Hydrilla, Najas, Ceratophylum,* duck weeds, etc. which can be kept in special enclosures in corners of the pond. Feeding preferably twice-a-day is advocated @ 5% of the initial biomass of stocking material for first month and then gradually reducing it

Aeration may be done mechanically to increase the concentration of dissolved oxygen in ponds, by paddle wheel aerators, aspirator aerators and submersible pond aerators. It is also necessary to replace certain amount of water at regular intervals.

HARVESTING

Harvesting of fishes is usually done after a culture period of 10 months to one year. However, fishes attaining the marketable size can be harvested periodically depending on several factors, which also reduces the pressure of density in the ponds and thereby providing sufficient space for the growth of fishes

4.4 Pearl and Lac culture

Pearl culture

Pearl is a spherical or irregular mass formed by the calcareous secretion of the nacre (mother of pearl) found in the glandular mantle of pearl oysters, deposited in concentric layers around a nucleus which is composed of foreign object causing irritation. The shape, size and colour of the pearls are variable in different kinds of pearls. In most cases, the pearls are irregular in shape, and perfect round-shaped pearls are rare. Pearl is secreted by the mantle as a pro-tection against foreign objects, usually the parasites or coarse sand grains. The parasites are recorded to be the larval forms of trematodes (in most cases). Sometimes a course sand grain may act as a stimulant for the production of a pearl. The parasite gets an accidental entry into a pearl oyster body and occupies a position between the mantle and the shell.

As a response to the irritation caused by the foreign object, the nacre glands in the mantle (Fig. 16.76) begin to secrete calcareous substances which are deposited around the foreign body in thin concentric layers.

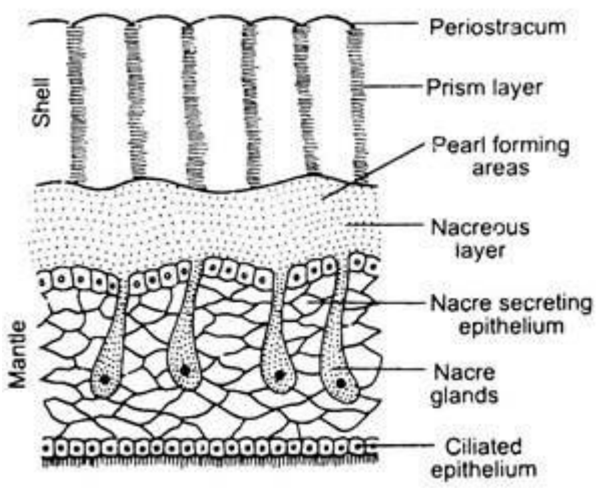


Fig. 16.76: Nacreous layer and nacre glands of pearl oyster.

As a result a pearl is produced (Fig. 16.77). The iridescence of the pearls is produced by the refraction of the light rays from various nacre layers of the pearl. Duration of the pearl growth may vary according to species and usually takes a couple of years. The giant Tridacna clam which can produce a pearl of the size of a golf-ball, may take as long as 10 years.

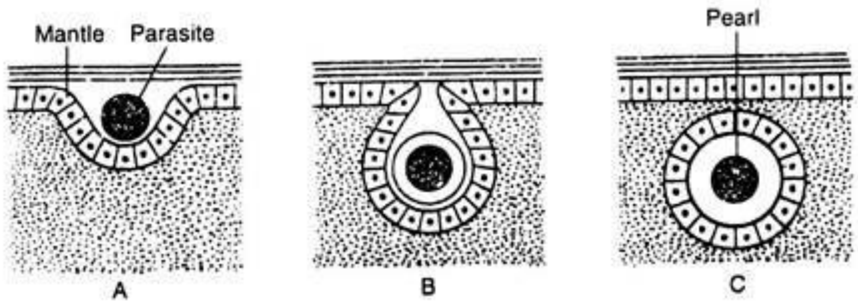


Fig. 16.77: Stages (A–C) of pearl formation.

The pink conch Slrombus gigas can produce a pink pearl, and Pinna and Atrina vexillum of Indo-Pacific can produce occasionally black pearl.

Any mollusc, which has the mother-of-pearl layer on the inner surface of its shell, is generally capable of producing a pearl. However, pearl as a jewel is only produced by a few species, which are listed below. Selection of the right species (oysters) is the primary step of the pearl culture. The production of good quality pearls is considered to a limited number of species. Some of the commonly used marine species are Pinctada martensis (Japanese pearl oyster), Pinctada maxima (silver lipped pearl oyster), Pinctada margaritifera (Black lipped pearl oyster), and Pteria penguin (Black winged pearl oyster). Several species of pearl oysters, viz., Pinctada vulgaris (= Pinctada fucata), Pinctada margaritifera, Pinctada anomioides, Pinctada atropurpurea, Pinctada chemmitzi and Pinctada sugillata are found in Indian waters. Of these species, P. vulgaris (= P. fucata) (Fig. 16.78) is the commonest and widely distributed in the Gulf of Mannar, the Palk Bay, and the Gulf of Kachchh.

There are evidences that the Chinese first developed the techniques of production of artificial pearls. Ye-Jin-Yang, a Buddhist priest who lived between 1200 and 1300, practised the method to obtain the artificial pearls. He inserted the tiny pellets of hardened clay or Buddha miniature made of tin within freshwater mussels and placed it between the inner shell and the mantle.

These live mussels keeping in a bamboo cage were left dangling in pools or canals, and after one year pearls were collected by opening the shell. But the scientific method of the artificial pearl culture who mastered the technology was Japanese scientists.

First two scientists Kokichi Mikimoto (1858-1954) and Tatsuhi Mise (1880-1924) put the industry on a business-like basis and pushed Japan into a forefront as a leadership of pearl production. The modern scientific techniques practised in Japan and other countries including India, were introduced by Tokichi Nishikawa (1939), a scientist of Tokyo University.

In 1893, Mikimoto first produced hemispherical cultured pearls and took the patent for his technique in 1896, and Tatsuhi Mise produced fully spherical cultured pearls and obtained the patent in 1907.

TECHNICAL REQUIREMENTS FOR PEARL CULTURE

The technical requirements for establishment of Pearl farm and its successful operation are briefly described below:

PROCESS OF PEARL CULTURE

The process of pearl culture includes the follwing steps which are very crucial for obtaining high grade of pearls with good commercial value.

Step 1: Construction of pearl farm

Construction of a pearl farm includes three steps. They are,

- Selection of farm site
- Construction of farm
- Well-planned work schedule

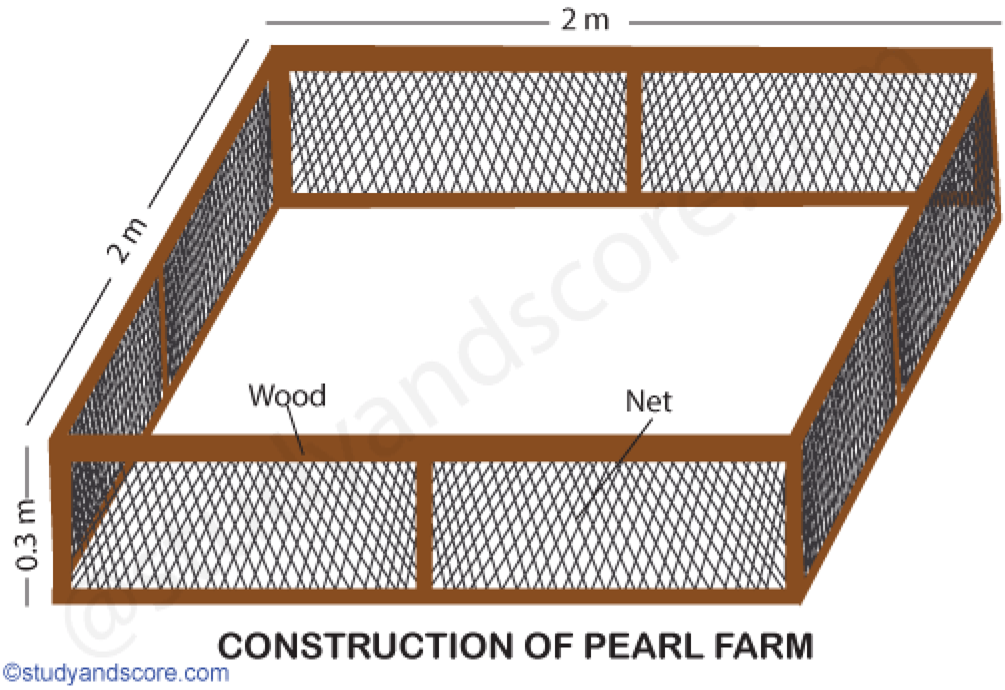
Selection of farm site: This step determines the type of pearls produced, and the oyster survival rate. Some of the points to be noted while selecting the site are:

***** Natural features like mountains and reefs are needed to protect the farm from winds, currents, storms, etc.

***** Constant regularity of temperature

***** Type of sea bed, such as rocky or sandy.

***** Gentle currents are essential for the survival of the oysters as they bring food and oxygen.



Construction of pearl farm: The whole pearl farm system is based on series of floating wooden rafts. Ten units of wooden rafts are used. Each raft consists of two to five pieces of wood making the total length to 20 ft. The raft is covered with wire mesh baskets, each of which house 10 oysters.

Well-planned work schedule: A typical work schedule plays a very critical role in pearl culture. The timing for collecting and seeding the oysters must be scheduled and followed strictly.

Step 2: Collecting oysters

After the construction of pearl farm, the divers set out to the bottom of the sea, to collect the oysters. Divers are pulled by large lugger boats in the direction of the tidal flow. Oysters are generally located on a flat rock bottom and are usually covered with marine animals and a thin layer of silt. Therefore, it is often very difficult for divers to recognise them. The shells collected, are cleaned, sized, and placed into baskets for storage until they are transferred to the pearl farm.

Step 3: Seeding

Two-three year old healthy oysters are considered for surgical implantation known as seeding. This is a very delicate operation and involves three stages:

Preparation of the graft: A donor oyster is sacrificed to obtain mantle. Mantle is needed by the host oyster to accept the nucleus. The mantle is located on the outer section of the oyster and Mantle produces the nacre which forms pearl. Before a graft is taken from the mantle, the oysters are starved for several days to slow down the metabolism of the oyster. This helps to decrease the risk of core rejection and open the oyster easily.

Attaching the graft: The oyster is opened with special wedges and pliers, then a scalpel slit is made in the soft tissue near the reproductive organ and a graft of living mantle is inserted into the slit.

Inserting the core: A nucleus is placed in the scalpel slit and the oyster is then returned back to the water. The inserted core irritates the oyster, provoking it to gradually coat the core with thin layers of mother of pearl nacre. After some time, the oysters are collected, and x-rayed to see whether the implants have been accepted. Oysters which have rejected the implant are returned to the water and are once again operated. The oysters which have accepted the implant are transferred to the pearl farm.

The person who is seeding must be extremely careful not to harm the tiny pea-crab which lives unharmed within every healthy oyster. It is presumed that the crab assists the oyster by keeping it clean and by sharing the debris which the oyster sucks in.

Step 4: Caring the oyster

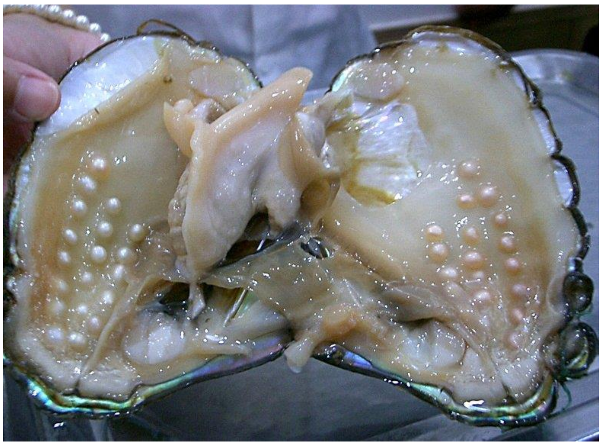
The shells which have been collected and transferred to the pearl farm are placed in baskets or panels which are attached to long lines connected to the floating rafts. The rafts are dropped down into the ocean with the oyster securely inside the basket, where they remain until they become operated on for further seeding.

The oyster can produce more than one pearl in its lifetime. Regular cleaning of the shells to remove seaweed results in better pearls plus makes them easier to handle. The cleaning is done by a machine which uses water jets and brushes to clean off any seaweed. The oysters need very tender loving care so as to be productive when harvested.

METHODS IN PEARL CULTURE

Harvesting

After 2-3 years, the oysters are harvested. It is necessary to make a trial harvest to determine whether the pearls have a sufficient coating. If it is not sufficient then an additional six months to a year of culturing is necessary. The oysters are split open and pearl bags are cut by the scalpel to remove the pearls. Collected pearls should be thoroughly dried after the harvest to prevent loss of luster.



Sorting pearls

There are many different steps involved with the sorting of pearls. Firstly, the pearls are sorted according to whether they can be used for the cultured pearl industry or not.

These are categorised into three sections:

- Unmarked pearls
- Pearls with one major blemish
- Pearls with more than one major blemish

Uses of Pearl:

(1) Used as an ornament and a symbol of grandeur.

(2) Used in ornamental handicraft.

(3) It is a very precious medicine for surgery, pediatrics, ENT, etc. as used by the Chinese.

By-Products of Pearl:

The by-products of pearl culture is referred to the total mass of the oysters after extraction of the cultured pearl. The by-products of pearl culture are, thus, the seed pearls, shell and the flesh.

(1) The tiny seed pearls (which are unsuitable as a gem) are used in the preparation of medicine.

In India pearl powder and pearl liquid are important ingredients as follows:

(1) Pearl powder is a highly stimulant tonic and aphrodisiac. Its other medicinal values are — laxative, sedative, emetic and nutritive.

(ii) Pearl powders act as an antacid. It is also used in heart burn and bilious affections.

(2) In case of class 'C' category of pearls (not used in jewellery), the nacreous layer is removed from the nuclei and ground into a powder. It is then dissolved in phosphoric acid. The final product (pearl calcium tablet) is formed by additional chemical processes. The pearl calcium tablet, thus formed, is marketed in Japan for pregnancies, weak bodies, tooth cavities, stomach acids and allergies.

(3) Large oyster shells, for their mother-of-pearl layer, are used in shell craft.

(4) Small and broken shells are ground and used as ingredients in poultry-feed.

(5) The adductor muscle portion of the flesh of oyster is used for human consumption.

(6) After removal of the pearl, the entrails of the oyster are used for feeding fishes.

Lac culture

History:

Lac has been used in India from time immemorial for several purposes, from the epic of Mahabharat it has been recorded that Kauravas built a palace of lac for the destruction of Pandavas. We come across references of lac in the Atharvaveda and Mahabharata, so it can be presumed that ancient Hindus were quite familiar with lac and its uses.

Scientific study of lac started much later. In 1709 Father Tachard discovered the insect that produced lac. First of all Kerr (1782) gave the name Coccus lacca which was also agreed by Ratzeburi (1833) and Carter (1861). Later Green (1922) and Chatterjee (1915) called the ac- insect as Tachardia lacca (kerr). Finally, the name was given as Laccifer lacca.

A number of species of lac insects are known, of this Laccifer lacca is by far the most important and produces the bulk of the lac for commerce. The insects live as a parasite, feeding on the sap of certain trees and shrubs. The important trees on which the lac insects breed and thrive well are –

Kusum (Schleichera trijuga)

Palas (Butea frondosa)

Ber (Zizyphus jujuba)

Babul (Acacia arabica)

Khair (Acacia catcchu)

Arhar (Ca]anus indicus)

Before coming to the actual mechanism of lac secretion and its processing, it is advisable for a lac-culturist to have detailed knowledge of lac insect and its life cycle. The adult lac insect

Shows a marked phenomenon of sexual dimorphism. The male and female insect varies in shape, size and also in presence or absence of certain body parts

Life Cycle:

The females after fertilization are capable of producing eggs. But it has been noticed in case of lac insects that the post fertilization developments start when the eggs are still inside the ovary. These developing eggs are oviposited into the incubating chambers (formed inside the female cell by the body contraction of females). A female is capable of producing about one thousand eggs (average 200-500). Inside incubating chamber, the eggs hatch into larvae.

The larvae are minute, boat shaped, red coloured and measure little over half millimeter in length. Larva consists of head, thorax and abdomen. Head bears a pair of antennae, a pair of simple eyes and a single proboscis. All three thoracic segments are provided with a pair of walking legs. Thorax also bears two pairs of spiracles for respiration. Abdomen is provided with a pair of caudal setae.

These larvae begin to wander in search of suitable centre to fix them. This mass movement of larvae from female cell to the new off-shoots of host plant, is termed as “swarming”.

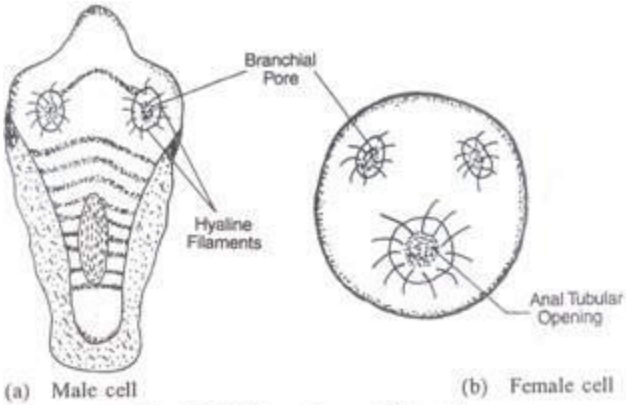


Fig. 35. Different forms of lac cell.

The emergence of larvae from female cell occurs through anal tubular opening of the cell and this emergence may continue for three weeks. The larvae of lac are very sluggish and feed continuously when once they get fixed with the twig. In the meantime the larvae start secreting resinous substance around their body through certain glands present in the body. After some-time the larvae gets fully covered by the lac encasement, also known as lac cell. Once they are fully covered, they moult and begin to feed actively.

The cell produced by male and female differ in shape, and can be easily distinguished sometimes later. Male cells are elongated and cigar shaped. There is a pair of branchial pores in the anterior side and a single large circular opening covered by the flap in the posterior side. (fig. 26, a). It is through the posterior circular opening that the matured male lac insect emerges out of its cell.

Female cell is oval, having a pair of small branchial pores in anterior side and a single round anal tubular opening in posterior side. Through the anal tubular opening are protruding waxy white filaments, secreted by the glands in the insects body, which is an indication that the insect inside the cell is alive and is in healthy condition. These filaments also prevent the blocking of the pore during excess secretion of lac.

Larvae moult in their respective cells. It is the second stage larva which undergoes pseudopupation for a brief time, whereby it changes into adult stage. Now the male emerges out from its cell, moves on lac incrustation and enters the female cell for fertilization. In this way the life cycle is completed.

Lac Secretion:

Lac is a resinous substance secreted by certain glands present in the abdomen of the lac insects. The secretion of lac begins immediately after the larval settlement on the new and tender shoots. This secretion appears first as a shining layer which soon gets hardened after coming in contact with air.

This makes a coating around the insect and the twig on which it is residing. As the secretion continues the coating around one insect meet and fuses completely with the coating of another insect. In this way a continuous or semi-contmuous incrustation of lac is formed on the tender shoots.

Fig. 36. Lac incrustation.

Cultivation of Lac:

Cultivation of lac involves proper care of host plants, regular pruning of host plant, infection or inoculation, crop-reaping, control of insect pests, and forecast of swarming, collection and processing of lac.

The first and perhaps the most important prerequisite for cultivation of lac is the proper care of the host plant. It is the host plants on which lac insects depend for their food, shelter and for completion of their life cycle. There are two ways for the cultivation of host plants. One is that plants should be allowed to grow in their natural way and the function of lac-culturist is only to protect and care for the proper growth of plants.

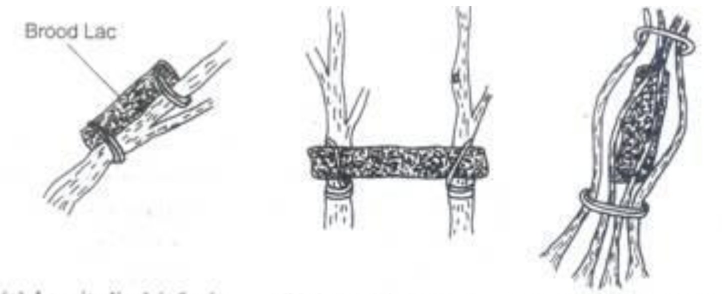
Another way is that a particular piece of land is taken for the purpose and systematic plantation of host plant is made there. Regular watch is necessary in this case by providing artificial manures, irrigation facilities, ploughing and protecting the plants from cattle and human beings for which the land should be fenced. The larvae of lac insects are inoculated on host plants only after the host plants have reached a proper height.

The lac larvae feed on the cell sap by inserting their proboscis in the tender twigs. The proboscis can only be inserted in the tender young off-shoots. For this before inoculation, prunning of lac host plants is necessary. The branches less than an inch in diametre are selected for pruning. Branches half inch of less in diametre should be cut from the very base of their origin. But the branches more than half inch diametre should be cut at a distance of 1 ½ inch from the base.

Inoculation:

The method by which the lac insects are introduced to the new lac host plant is known as inoculation. This may be of two types, namely "Natural infection" and "Artificial infection". When infection from one plant to other occurs by natural movements of insect, it is called natural infection. This may be due to overcrowding of insect population and nonavailability of tender shoots on a particular tree.

Artificial infection takes places through the agencies other than those of nature. Prior to about two weeks of hatching, lac bearing sticks are cut to the size of six inches. They are called"Brood lac". Brood lacs are then kept for about two weeks in some cool place.



(a) Longitudinal infection (b) Lateral infection (c) Interlaced infection

Fig. 37. Three different ways of artificial inoculation of lac.

When the larvae start emerging from this brood lac, they are supposed to be ready for inoculation. Strings co be used for tieding the brood lac with the host plant may be of different types in longitud infection the brood lac is tied in close contact with host branches. In lateral infection the brood lac is tied across the gaps between two branches. In interlaced method, brood lac is tied among the branches of several new shoots.

Lac Crop:

The lac insects repeat its life cycle twice in a year. There are actually four lac crops since the lac insects behave in two ways either they develop on Kusum plants or devlop on plants other than Kusum. The lac which grows on Non-Kusum plants is called as “Ranjeem lac,” and which grows on Kusum plant is called as “Kusumi lac. Four lac crops have been named after four Hindi months in which they are cut from the tree. They are as follows:

Ranjeeni Crop:

(i) Katki:

Lac larvae are inoculated in June-July. Male insect emerges m August-September. Female give rise to swarming larvae in October-November and the crop is reaped in Kartik (October and November).

(ii) Baisakhi:

Larvae produced by Katki crop are inoculated in October-November, male insects emerges in February-March, females give rise to swarming larvae m June-July, the crop is reaped in Baisakh (April-May).

Kusumi Crop:

(i) Aghani:

Lac larvae are inoculated in June-July, male insect emerges m September, female give rise to swarming larvae in January-February and crop is reaped in Aghan (December-January).

(ii) Jethoi:

The larvae produced by Aghani crop is inoculated in the month of January- February, male emerges in March-April, female give rise to swarming larvae in June- July and the crop is reaped in the month of Jeath (June-July).

The time of infection with swarming larvae, the time of emergence of male insects, the time of reaping the crop, and the time of producing swarming larvae by female etc., are shown m tabular form below

Scraping and Processing of lac:

Lac cut from the host plant is called as “stick lac”. Lac can be scraped from the twigs before or after the emergence of larvae. If it is used for manufacturing before the emergence of larvae, the type of lac produced is called as “Ari lac” and if it is used for manufacturing purpose after swarming of larvae has occurred, the lac is said to be Phunki lac”.

The scraping of lac from twig is done by knife, after which they should not be exposed to sun. The scraped lac is grinded in hard stone mills. The unnecessary materials are sorted out In order to remove the finer particles of dirt and colour, this lac is washed repeatedly with cold water.

Now at this stage it is called as “Seed lac” and is exposed to sun for drying. Seed lac is now subjected to the melting process. The melted lac is sieved through cloth and is given the final shape by molding. The final form of lac is called “Shellac”. Colour or different chemicals may be mixed during melting process for particular need.

Composition of Lac:

Lac is a mixture of several substances, of which resin is the main constituent. The approximate percentage of different constituents of lac is given below:

Resin – 68 to 90%

Dye – 2 to 10%

Wax – 5 to 6%

Mineral matter – 3 to 7%

Albuminous matter – 5 to 10%

Water – 2 to 3%

USES OF LAC

The various applications of lac can be summarized as follows:

Lac resin is used in food processing industry; cosmetics and toiletries industry; varnish and printing industry; coating of fruits and vegetables; electrical industry; leather industry; adhesive industry; pharmaceutical industry; perfumery industry; miscellaneous applications.

Lac dye (erythrolaccin) has been used in India as a skin cosmetic and dye for wool and silk. In China it is a traditional dye for leather goods. The use of lac for dye has been supplanted by synthetic dyes. It is used in medicine to protect liver and to fight obesity.

Lac is used in food, confectionery and beverages industry and textile industry.

Lac wax is used in polishes for shoe, floor, car polishes etc. It is used in electric insulations, lamination of papers, hat proofing and coating of pictures and fossils.

Lac is used for manufacture of tailors chalks, crayons, bottle sealers, lipsticks, enamels, printing inks, gramophone records and in fireworks.

NATURAL ENEMIES OF LAC

Predators:

Two moth predators cause a lot of damage to lac.

1. ***Eublemma amabilis.*** The larva is dirty white in colour and tunnels through the lac encrustation and feeds on larvae and adults. It pupates within the tunnel and adults after emerging lay their eggs near the lac encrustation.
2. ***Holcocera pulverea.*** The damage by the brownish larva is similar to the above species. Pupa is slightly bigger and yellowish-brown.

Parasites:

The following insects are parasitic on lac insect.

Paraecthrodryinus clavicornis; Erencyrtus dewitzi; Tachardiaephagus tachardiae; Eupelmus tachardiae; Tetrasticus purpurens.

The above natural enemies can be controlled by maintaining healthy cultures and by enclosing the brood lac sticks in wire mesh before inoculation so that natural enemies are not able to emerge and cause re-infestation