BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
Department of Zoology

Lecture Outline /Summary Notes

CLASS: **M.Sc. Zoology, 2nd Semester**
PAPER CODE & NAME: **ZL-203-Parasitology -1**
Course Teacher: **Dr. Suman Mishra**

TOPIC- UNIT3: Morphology and Anatomy of Parasites-1
TREMATODA

TAXONOMIC POSITION

CLASS TREMATODA

- **Subclass Aspidobothrea**
  - **Order Aspidobothriiformes** e.g. *Aspidogaster conchicola*
  - **Order Stichocotylida** ***e.g.*** *Stichocotyle*
- **Subclass Digenea**
  - **Order Heronimiformes**
  - **Order Paramphistomiformes e.g.** *Paramphistomum*
  - **Order Echinostomatiformes e.g.** *Fasciola, Echinostoma*
  - **Order Haploporiformes**
  - **Order Transversotrematiformes**
  - **Order Hemiuriformes**
  - **Order Strigeiformes**
  - **Order Opisthorchiformes e.g.** *Clonorchis, Opisthorchis*
  - **Order Plagiorchiformes eg.** *Dicrocoelium dendriticum*
  - **Order Lepocreadiiformes**

GENERAL CHARACTERISTICS OF CLASS TREMATODA

- Body is dorso-ventrally flattened, unsegmented and leaf-like.
- Body cavity is absent and all organs lie in parenchyma .
- Suckers/hooks or clamps are present to attach to the host.
- The mouth (oral aparture) and alimentary canal is present but no anus.
- Mouth leads to muscular pharynx, oesophagus followed by two (branched or unbranched) branched caeca.
- The branched excretory system has flame cells and it discharges the waste product into excretory bladder, which usually has a posterior opening.
- All trematodes are hermaphrodites except the members of the family "Schistosmatidae", which are unisexual.
- The life cycle is usually indirect in Digenea and direct in Monogenea.
- Trematoda has following subclasses :

SUBCLASS: ASPIDOGASTREA (=ASPIDOBOTHREA= ASPIDOCOTYLEA)

- Most of them have only one host, a mollusk but few are found in turtle and fishes with molluscs and lobsters as intermediate hosts, but none are found in domestic animals.
- Adhesive organs on ventral side known as "Baer's disc" or "opisthaptor".
- There are not economically or medically important and, therefore, they have not received as much attention as other parasitic groups.
- However, they seem to represent a link between parasitic and free-living organisms which makes them of more than passing interest

BODY FORM

These worms exhibit some fascinating morphological modifications. Members of family Aspidogastridae, have a large ventral sucker, known as an **opisthaptor** , extending most of the length of the body and having muscular septa in longitudinal and transverse rows which divide the sucker into shallow **loculi** or **alveoli**. The shape, number and arrangement of these structures are taxonomically important. **Marginal bodies** which are secretory in nature are found between the marginal loculi. In the family Stichocotylidae there are individual suckers arranged in longitudinal series in place of a complex of loculi. In the family Rugogastridae, the ventral sucker is made up of transverse ridges called **rugae**. The Aspidogastrea possess a **longitudinal septum** made of layers of connective tissue and muscle arranged horizontally which divides the body into dorsal and ventral portions and may help the organism cope with the tremendous pressures exerted by contraction of the ventral sucker.

TEGUMENT

The tegument is similar to the general trematode tegument. It is syncytial with an outer layer of distal cytoplasm containing mitochondria and various types of vesicles. **Cytons** contain the nuclei internal to the superficial muscle layer and communicate with the distal cytoplasm by internuncial processes. Cytons are packed with Golgi complexes. A mucoid layer is found on the outer membrane surface which may have rib like projections to support the mucus.

DIGESTIVE SYSTEM

Digestive tract is simple with either a funnel-like mouth or a mouth surrounded by a muscular sucker or several muscular lobes ,a muscular **pharynx**, and a simple sac –like intestine (also known as the **cecum)** that reaches the posterior of the body. Intestinal mucosal surface bears lamellae apparently to increase the absorptive surface area and usually both circular and longitudinal muscles surround the intestine.

EXCRETORY/OSMOREGULATORY SYSTEM

Flame cell protonephridia are the organs for excretion and osmoregulation. The flame cells open into numerous capillaries that feed into larger excretory ducts that, in turn, feed into an **excretory bladder** at the posterior of the body. There is usually a single dorso-subterminal or terminal **excretory pore**.

The small capillaries have many **microvilli** projecting into their lumens, while the larger ducts have lamellar projections on the surface membranes, these probably have a secretory-absorptive function.

NERVOUS SYSTEM

The nervous system is unusually complex for parasitic worms and is more typical of free-living organisms. A **cerebral commissure** is located anteriorly and is made up of a complex set of nerves. The peripheral system is a modified ladder type. Many types of sensory receptors have been found among the species and are mostly around the mouth or along the margins of the ventral disk.The ventral disk and alveoli have a complex system of connecting nerves and commissures suggesting strong neuromuscular coordination. Nerve plexuses are associated with the septum, prepharynx, pharynx, cirrus pouch, uterus, and genital and excretory openings. Some cells in the system may have neurosecretory function.

REPRODUCTIVE SYSTEM

The **female reproductive system** is similar to that of Digeneans and consists of an ovary, vitelline cells, uterus, and associated ducts. The ovary is either smooth or lobed and leads into the septate and ciliated oviduct, further opening into the **ootype** surrounded by Mehlis' gland cells. The **Laurer's canal** (vestigial vagina) leads from the ootype and is a short tube that ends blindly in the parenchyma or may connect to the excretory duct. The **vitelline follicles** occur in two lateral fields, each of which has a main **vitelline duct** that fuses with the duct from the other field to form the small **vitelline reservoir**. The vitelline reservoir empties into the ootype. The **uterus** extends from the ootype to the genital atrium and usually has a posterior loop and anterior stem. The distal end of the uterus is very muscular and is called the **metraterm**. It propels the eggs out of the system.

The **male reproductive system** is similar to that of the Digeneans and comprises of a single, double, or multiple **Testes** located posterior to the ovary, a **vas deferens** which expands to form an **external seminal vesicle** that enters the **cirrus pouch** to become the **ejaculatory duct**. Some species lack the cirrus pouch. The cirrus pouch opens through the genital pore into a common genital atrium, located on the midventral surface anterior to the leading margin of the ventral disk. The axonemes of the spermatozoon filament have the typical 9 plus 1 structure of microtubules seen in other flatworms. Some aspidobothreans may self-fertilize and the cirrus can deposit sperm in the terminal end of the uterus, which serves as the vagina.

DEVELOPMENT AND LIFE CYCLE

The eggs of aspidobothreans are **ectolecithal**; most of the embryo's yolk supply is packaged within separate cells in the eggs. After fertilization, the zygotes within their eggshells pass from the parent into the environment. In some species, embryonation is complete before the eggs pass into the environment and the young hatch within a few hours. In other species, several weeks of embryonation in the environment may be required prior to hatching. The larval form is called a **cotylocidium** (**cotylocidia, pl.**) and has tufts of cilia for swimming. The larvae possess a mouth, pharynx, simple gut, and prominent posterior-ventral disk lacking alveoli. Alveoli form, tier by tier, as the worm develops. The larval tegument is similar to that of the adult and has a distal cytoplasmic, syncytial layer at the surface with internal cytons.

The life cycle is usually direct and requires no intermediate host. However, aspidobothreans that parasitize vertebrates appear to require an intermediate host. Individual worms can be removed from their hosts and survive several days in water or saline. They can even live in the intestines of fishes and turtles if they are eaten by these. Some species can mature in both clams and fish and this extreme lack of host specificity is highly unusual in parasitic species.

Representative Life Cycle: ***Aspidogaster conchicola***

This species is widespread and has been found in pericardial cavity of freshwater clams in Africa, Europe, and North America. It has also been found in other mollusk, fishes, and turtles. Adults are 2.5 to 3.0 mm long by 1.0 mm wide oval in shape with a long, mobile neck with a buccal funnel at the end. The loculi on the ventral sucker are arranged in longitudinal rows and total 64 to 66. Eggs that hatch within the mollusk can develop directly without further migration. If the egg or cotylocidium leaves the mollusk and is drawn into the incurrent siphon of the same or another mollusk, it will reach the nephridiopore and migrate through the kidney into the pericardium. The cotylocidium is 13 to 17 *u*m long at hatching, lacks external cilia, and has a simple posterior sucker lacking loculi. Growth and metamorphosis occur rapidly.

SUBCLASS DIGENEA

- Digenetic trematodes, commonly called flukes, commonly parasitize almost all classes of vertebrates. About 6000species are known.
- Nearly every organ of the vertebrate body is an infection site for one or more larval or adult digeneans.
- Adults are flat worm shaped animals, they have two suckers- the **oral sucker**, around the mouth for attachment to host tissue and to assist in feeding; and the second sucker acetabulum, found a little way further down the animals body and it serves only for attachment.
- All digenetic trematodes, except the schistosome blood flukes and certain members of the suborder Didymozoida, are monoecious.
- Sexual reproduction may be brought about by either self-fertilization or cross-fertilization between two individuals.
- Life cycles involve at least two hosts- a definitive vertebrate and a first intermediate host which is usually a mollusk or, rarely, an annelid. Second intermediate hosts are usually invertebrates and occasionally vertebrates. If there is a third intermediate host it is usually a vertebrate.
- There is an alternation of generations of the sexually reproducing adult and asexually reproducing larval forms
- Digeneans typically show a high degree of specificity towards their molluscan host and much lower specificity towards their vertebrate host or their second intermediate host, if they have one.
- The adult digeneans are of immense medical and veterinary importance because they are the causative agents of human and animal diseases.

GENERAL MORPHOLOGY

Body Form

Flukes are generally oval in shape, often leaf -like in form, dorsoventrally flattened, acoelomate, triploblastic, hermaphrodites showing a great variety in size and shape with the smallest species (*Levinsiella minuta*) only 0.16 mm in length and the largest (*Fascioloides magna*) 5.7 cm long and 2.5 cm wide. Most flukes have a powerful oral sucker around the mouth and most have a mid-ventral **acetabulum** or **ventral sucker**. A worm with only an oral sucker is called a **monostome** ,a worm with an oral sucker and the acetabulum at the posterior end of the body is called an **amphistome** and a worm with an oral sucker and the acetabulum in some other position is called a **distome**. The oral sucker shows numerous modifications viz., the oral sucker has muscular lappets in *Bunodera,* the oral sucker is modified as a holdfast organ with tentacles *in Bucephalus* , a retractable, spiny proboscis is found on either side of the oral sucker in *Rhopalius* sp. The **echinostomes** have a collar of spines around the sucker, the **Holostomes** have a forebody and hindbody and the **Schistosomes** refer to species of digeneans that usually have separate sexes whereas most digeneans are hermaphroditic. The schistosomes also lack an intermediate host and mature in the blood vessels of their definitive hosts.

Tegument

The general organization of the tegument is same as that found in the cestodes, but differs in detail and even in that in the same individual also there may be significant differences from one part of the body to the next. The adult tegument is interrupted by cytoplasmic projections of gland cells, by nerve endings, and by excretory pore openings. The adult tegument also lacks microvillus like structures, but some species have deep pits and channels that may help to increase the absorptive surface area.

The tegument is a living, complex tissue consisting of a syncytial epidermis with an outer layer of distal cytoplasm containing mitochondria and various types of Golgi-derived vesicles i.e. it is a distal anucleate layer (**distal cytoplasm**). Function of vesicles derived from golgi is not clear, however, in *Schistosoma mansoni* the vesicles help to renew the surface membrane by continuously moving outward through the distal cytoplasm. The vesicles might replace membrane damaged by host antibodies. The cell bodies containing the nuclei (**cytons**) lie beneath a superficial layer of muscle. **Cytons** contain the nuclei internal to the superficial muscle layer and communicate with the distal cytoplasm by **internuncial processes**. Various species have **spines**, **bosses** (raised, rounded areas),**papillae**, and other modifications on the tegument.

The tegument varies in the larval forms. Miracidia of some species are covered with ciliated epithelial cells interrupted by intercellular ridges. In sporocyst the ciliated epithelium is lost and the distal cytoplasm spreads over the surface of the worm. Sporocysts and rediae are covered with well-developed microvilli. The luminal surface of the tegumental cells in the redia may be thrown into a large number of flattened sheets that extend to the other cells in the body wall and to the cercarial embryos contained in the lumen. The tegument of cercaria larva changes as it develops from a primary epidermis below which a definitive epithelium forms in embryos to cercarial tegument that is similar to that of the adult. Cystogenic cells in the parenchyma begin to secrete cyst material to form an encysted

metacercarial cyst. The teguments of miracidia and cercariae may have penetrations glands that open at the anterior, and some adults have glandular organs opening to the exterior.

Muscular System

In most digeneans, superficial muscle layers can be found that consist of circular, longitudinal, and diagonal layers around the body and below the distal cytoplasm of the tegument arranged with varying degree of muscularization. Muscles may be more prominent in the anterior parts of the body, and in the lateral parts , strands connect the dorsal muscles to the ventral muscles. Muscle cells are smooth with nuclei in cytons called **myoblasts**. The suckers and pharynx often have well-developed radial muscle fibers. The intestinal ceca are often surrounded by a network of fibers that probably helps to fill and empty them.

Digestive System

The digestive tracts is well developed sac-like with a muscular pharynx and single opening to the outside that serves both as mouth and anus. In the simpler forms it is absent or unbranched, but in higher forms it branches to all parts of the body. Depending on the means of feeding, one or more components of the basic flatworm digestive tract may be missing. In general, flukes found in the lungs, intestine, urinary bladder, rectum, and bile duct of the host feed by taking in blood, mucosa, or other tissue. For example, some lung flukes will draw tissue into their oral sucker and erode the tissue with strong contractions of the pharyngeal muscles. Blood will then be consumed from the capillaries. In species that lack a pharynx, the esophageal muscles are quite strong and the esophagus serves the function of the pharynx. *S. mansoni* lacks both an esophagus and pharynx as it is bathed by the nutritive blood.

In most species, digestion of foods occurs extracellularly in the ceca. However, *Fasciola hepatica* utilizes both intracellular and extracellular processes. Various digestive enzymes are secreted by the gastrodermal cells viz., proteases, a dipeptidase, an aminopeptidase, lipases, acid and alkaline phosphatases, and esterases.

Microvilli have been found on the membranes of gastrodermal cells in all species examined. The microvilli are arranged as a brush border that increases the absorptive surface area of the cells, similar to what is found in many species of animals, including humans. Cytoplasmic processes, short and irregular to long, may project from the gastrodermal cells and extend into the lumenof intestine.

The amount of absorption through the tegument is limited although it is known that glucose and some amino acids are actively taken up. The ability to absorb other nutrients across the tegument or via the gut varies markedly among species. In species that do utilize tegument absorption, there are large numbers of tegumental mitochondria to provide energy for the active transport of the nutrients.

Excretory & Osmoregulatory System

The excretory systems of digeneans serve both excretory and osmoregulatory functions and comprises of protonephridial flame cells and ducts. Metabolic wastes are removed across the tegument and the lining of the gut by diffusion and by exocytosis of vesicles. Wastes are also removed by the excretory system.

A protonephridium is a unit of an excretory system that is closed at proximal end and open at the distal end to a collecting tubule. The flame bulb or cell is flask shaped with a tuft of fused flagella to provide the force to move the fluid within the system. Fluids and small molecules pass into the excretory system and beating of the flagella creates a gradient that draws fluid through the weir and into the collecting tubule. **Leptotriches** may extend from the internal and external surface of the weir and appear to increase filtering by keeping surrounding cells away from the weir and keeping the weir away from the tuft of flagella.

The collecting tubules of the flame bulbs join to form collecting ducts on each side of the body which lead into the **excretory bladder.** In the adult, the bladder empties out a single excretory pore usually located posteriorly. In some species, the walls of the collecting ducts are lined with microvilli suggesting that there is a transfer of substances in or out in these ducts. Freshwater trematodes have better developed protonephridial systems than do marine worms, emphasizing the osmoregulatory function of the system. The free-swimming stages of freshwater trematodes require a very efficient osmoregulatory system to remove water.

The primary nitrogenous waste product in trematodes is ammonia, but some species appear to excrete uric acid or urea.

Nervous System

The nervous system is the typical ladder type. A pair of cerebral ganglia (brain), present in the anterior end, are joined by commissures to form a nerve ring. Three main trunks: dorsal, lateral, and ventral arise from the ganglia to supply the posterior parts of the body. The ventral branch is the best developed and it is connected by commissures to the other branches. The branches provide motor and sensory endings to muscles and the tegument. Sensory endings are numerous in the anterior end especially around the oral sucker. Only one type of sensory ending (**tangoreceptor**) has been found in adults. The miracidia and cercariae larvae have numerous types of sense organs (probably chemosensory) possibly related to finding a host quickly before their stored energy supplies are exhausted. Cercaria and miracidia often have eyespots, for orientation to light. The eyespots consist of one or two cup-shaped pigment cells surrounding the parallel rhabdomeric microvilli of one or more retinular cells. Eyespots, when present, in adults are functionless.

FUNCTIONAL ANATOMY OF MALE & FEMALE REPRODUCTIVE SYSTEMS

The female Reproductive System consists of an ovary, vitelline cells, uterus, and associated ducts. The ovary is usually round or oval, but may be lobed or branched. The oviduct is short and has a proximal sphincter, called the **ovicapt**, to control passage of the ova. The female ducts, including the oviduct, are ciliated. The **seminal vesicle** is formed from an out pocketing of the oviduct. **Laurer's canal** branches from the base of Laurer's canal and ends blindly in the parenchyma or opens through the tegument. It is probably a vestigial vagina, but may store sperm in some species. The **vitelline follicles** occur in two lateral fields, each of which has a main **vitelline duct** that joins the **vitelline reservoir**. The **common vitelline duct** leads away from the vitelline reservoir and joins the oviduct. The oviduct expands to form the **ootype**, which is surrounded by numerous unicellular **Mehlis' glands**, and further expands to form the **uterus** which leads into the genital pore. The uterus may be short and straight, or long and coiled. The distal end of the uterus is very muscular and is called the **metraterm**. It propels the eggs out of the system and serves as a vagina. Both the female and male genital pores open near each other, usually in a **genital atrium**.

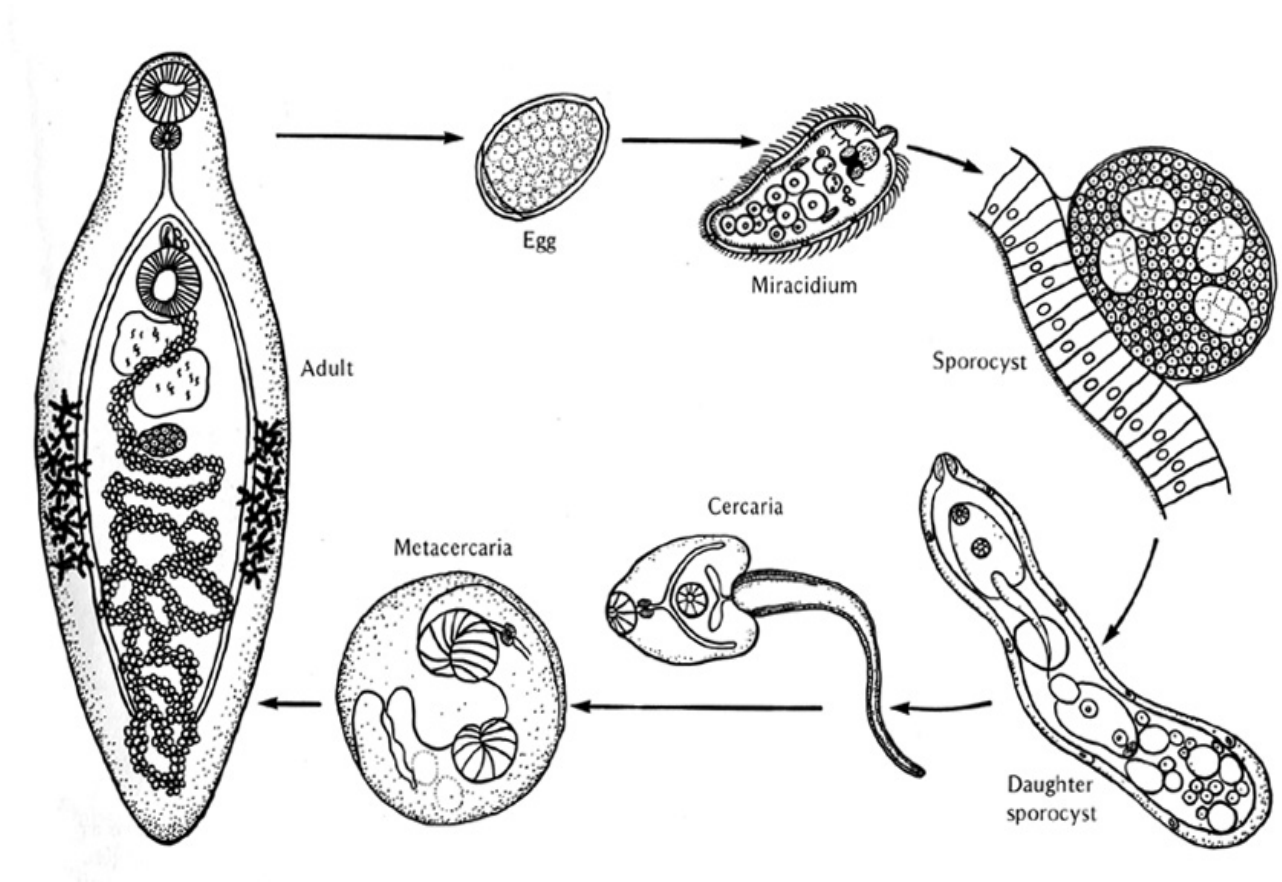
Each oocytes that leaves the ovary becomes associated with several vitelline cells and a sperm as it passes down the oviduct. Fertilization takes place in the ootype along with the secretions of the Mehlis' glands. Some species are capable of self-fertilization. Vitelline cells contribute to formation of the eggshell while the function of the Mehlis' glands' secretions are unclear. The eggshell is hardened and stabilized through the quinone-tanning.

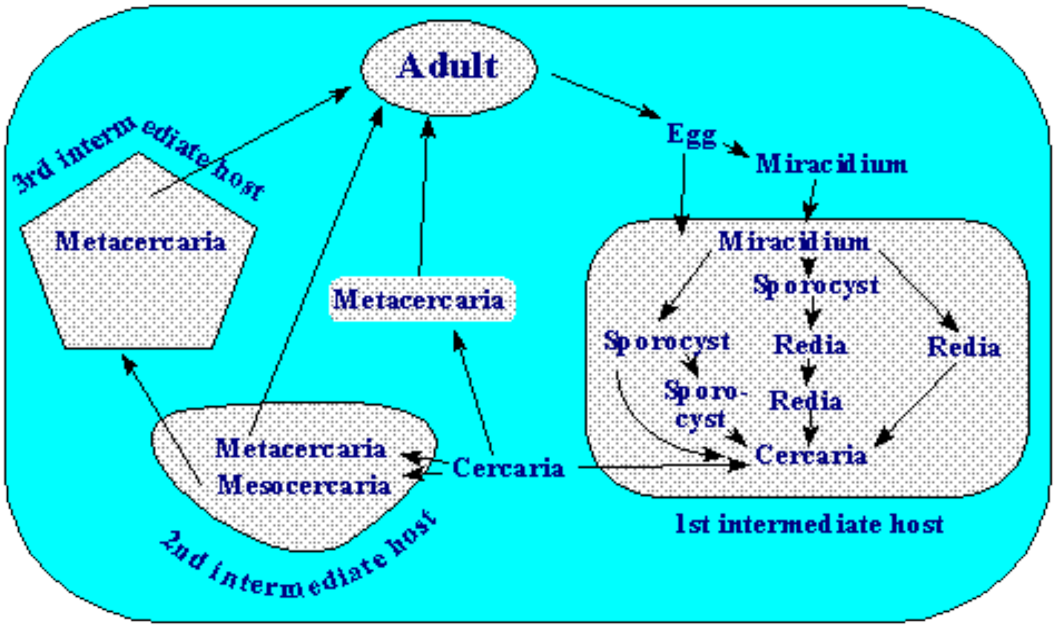
The **male reproductive system** consists of testes, that are usually double, but may single or multiple; and are located posterior to the ovary. They can be round to highly branched depending on species. Each testis has a **vas efferens** that joins with the other vas efferens to form the **vas deferens**. The vas deferens enters a muscular **cirrus pouch** and often expands into an **internal seminal vesicle** leading into a thin ejaculatory duct (**cirrus**) in the genital atrium which opens by the genital pore located midventrally anterior to the acetabulum. The cirrus can be invaginated into the cirrus pouch and evaginated for transfer of sperm to the female system. The cirrus may be covered with spines or naked. **Prostate gland cells** usually surround the ejaculatory duct and a muscular **pars prostatica** is found in some species. In some species the cirrus pouch and prostate gland are absent and the vas deferens is expanded into a muscular seminal vesicle. In other species, the vas deferens expands into an **external seminal vesicle** prior to reaching the cirrus pouch.

GENERALIZED LIFE CYCLE PATTERN

Typically, at least two hosts are required to complete the life cycle of digeneans- a vertebrate definitive host in which sexual reproduction occurs and an intermediste mollusk host that serves for one or more generations of asexual reproduction. Rarely, annelids serve as the intermediate host. The zygote, resulting from the fusion of the male and female gametes, is encased within an egg shell. Numerous eggs fill the long and often coiled uterus and are released into the lumen of host's intestine through the genital pore and later are passed to the outside in the host's feces. The eggs are deposited in water and eventually hatch, and a free-swimming miracidium emerges from each egg. The miracidium penetrates the integument of a molluscan host (the first intermediate host) and after shedding its ciliated epidermis in the snail body and develops into a sporocyst which migrates to the digestive gland. The sporocyst may also develop in other organs gonad, mantle, lymph spaces surrounding the intestine, gill chambers. The germ balls in mature sporocyst differentiates into next stage larval stage sporocyst or redia. Certain germinal cells in the brood chamber of rediae eventually give rise to a fourth larval generation –tail-bearing cercariae. Cercariae escape from their molluscan host and become free swimming. In some species, the cercariae never leave the molluscan host and enter the next host only if the infected mollusc is ingested. The free-swimming cercariae come in contact with a compatible second intermediate host—often an arthropod or some other invertebrate, or even a vertebrate and actively penetrate the host's body forming the encysted larva known as a metacercaria. When the second intermediate host is ingested by the vertebrate definitive host, the encysted metacercaria excysts in the host's intestine and gradually matures into the adult.

The alternation of sexual and asexual generations shows tremendous variability and complexity. Up to six different body forms (not counting the egg) have been recognized in digenean life cycles and within a given species, certain stages may be repeated during ontogeny, while stages found in other species may be absent. For example, some species have two generations of rediae, while in some species redia is absent. Many digenean life cycles have never been worked out till date.





Egg→miracidium →sporocyst or redia→daughter sporocysts→ cerc ariae→ metacercariae/ mesocercariae→ adults

Variation in Trematode Life Cycles

EGG FORMATION AND TYPES OF EGGS

The definitive digenean egg includes a rather complex eggshell made up of of a resistant, tanned protein overlayed by a thin lipoprotein layer**.** The release of ova from ovary is controlled by a sphincter muscle, the oocapt, situated at the ovary-oviduct junction. Ova released periodically from the ovary pass into the ootype where each ovum is surrounded by vitelline globules secreted from the vitelline gland. Some of the vitelline globules coalesce to form a semiliquid shell in the presence of Mehlis' gland secretions while the remainder become associated with the fertilized ovum and serve as the food reserve during development. The shape and size of the eggshell is, in part, determined by the shape of the uterus. Shell precursors from the vitelline glands are in the form of proteins, phenols, and phenolase. As the egg passes up the uterus, the shell becomes tanned and hardened. Lipoprotein from the Mehlis' gland cells also contribute to egg shell by providing the template for the deposition of the shell precursors and also secrete mucus which probably serves to lubricate the uterus for the passage of eggs. Thus there is a lipoprotein layer on the interior as well as the exterior of the protein shell. These lipoproteins contain 61% protein, 38% lipids, and 1% carbohydrate, including hexosamine. Most of the lipids are cholesterol and triglycérides. Only a small amount of phospholipid is present. There are exceptions such as in the human blood fluke, *Schistosorna mansoni*, the uterine wall may also produce a substance necessary for shell formation.

The Egg (Shelled Embryo)

The "egg" of a digenean contains a developing or developed embryo enclosed within its capsule or shell. Most fluke eggshells have an **operculum** at one end and the larva eventually is released through this. Blood fluke eggshells lack an operculum. There is significant variation in the size, shape, thickness, and color of digenean eggs. The egg released in water may contain an embryo that has undergone only a few cleavages when released and further embryonation occurs in response to environmental signals or they may have a fully developed miracidium that is released soon after the egg leaves the adult. Eggs that embryonate in the environment require water to prevent desiccation, Some species hatch in water, while other hatch only after being eaten by a suitable intermediate host. The hatching of some species coincides with the movements of intermediate hosts, so that the miracidia are released when the mollusk host is nearby.

Eggs of some digenetic trematodes parasitic in humans

Clonorchis	*Fasciola*	*Fasciolopsis*	*Paragonimus*	*Schistosoma hematobium*	*Schistosoma japonicum*	*Schistosoma mansoni*
25–35 µm,by 12-20 µm operculum at narrow end of egg; bile stained. A small knob at the opposite end of the operculum	130-150 µm operculated egg	130-140 µm by 80-85µm, ellipsoidal, inconspicuous operculum.	80–120 µm by 48-60 µm; operculated egg, operculum at flattened end	110–170 µm by 40-70mm; spindle shaped egg with posterior terminal spine, no operculum	70–100 µm; round to oval egg, inconspicuous lateral spine, no operculum	110–180 µm; elongate oval egg with longer lateral spine, no operculum

LARVAL FORMS

Miracidium

Miracidia are piriform and have a retractable **apical papilla at** anterior end. The papilla has five pairs of duct openings from **penetration glands** glands and two pairs of sensory nerve endings. **Apical glands** are quite noticeable just below the papilla. The apical gland is thought to secrete histolytic enzymes that help the miracidium penetrate its next host. Miracidia possess a number of sensory organs, the most important of which are the dorsally situated **eye spots**. They eventually connect to a large ganglion, the **cerebral mass**. The sensory endings The surface of the miracidium is covered with a series of ciliated plates, the number and shape of the cilia covering the miracidium are species-specific. Some species lack cilia, while others have them arranged in **ciliated bars**. Beneath the epithelium are circular and longitudinal muscles. There may be one or two pairs of protonephridia connected to excretory pores in the postero-lateral part of the miracidium. The posterior portion of the miracidium consists of large rounded germinal cells, which often are often grouped in clusters called germ balls. The free-swimming miracidia move rapidly to find an intermediate host, snail, probably attracted by the snail mucus and attach to it by the apical papilla. The miracidium sheds its ciliated epithelium and penetrates the snail by tissue tissue cytolysis, penetration is usually complete within 30 minutes. Miracidia that are eaten by their snail hosts, hatch when they have entered the snail's gut.

Sporocyst

The sporocyst is the second larval stage formed from the penetrating miracidium within the snail body by undergoing significant changes, viz., a new tegument with microvilli forms; the miracidial subtegumental muscle layer and protonephridial system are maintained, but the other miracidial structures disappear. At the conical anterior of the sporocyst body a birth pore is located, from which subsequent generations of larvae emerge. The germinal masses develop internally into either daughter sporocysts, which are essentially the same as their parent sporocysts, or into a second larval stage, the redia. A sporocyst is a nutrient absorbing sac for development of the next larval stage, the sporocyst or redia or cercariae. Nutrients are absorbed through the tegument, since there is no mouth or digestive system. Hence, miracidia, sporocysts, and rediae are sometimes referred as **germinal sacs**. Sporocysts can be found in almost any tissue, but are often near the foot, antennae, or gills. A generation of **daughter sporocysts** may form, while in other species rediae form, and in yet other species, cercariae form directly.

Redia

Rediae are elongated sac like with a blunt posterior end and have a simple digestive tract with a mouth, muscular pharynx, and short gut. They may have stumpy appendages called **procrusculi** and a birth pore. Rediae leave the sporocyst and usually migrate to the hepatopancreas or gonad of the molluscan host. They can crawl about within the host and feed on host tissues and sporocysts of their own or other species. The gut itself consists of a mouth, opening into a large muscular pharynx, which in turn opens into a simple rhabdocoel like intestine. Externally, behind the mouth many redia have a ridge-like collar, below which the birth canal opens and from which either cercariae or daughter redia emerge. The absorptive surface area of the gut is increased by lamelloid, flattened, or ribbon like processes. The gut cells appear capable of phagocytosis. The tegument also can absorb nutrients and may have microvilli or lamelloid processes. Within the rediae, daughter rediae or cercariae will develop. Redia may be absent in some groups, such as the schistosomes. Cercariae are released through a birth pore. Rediae will produce daughter rediae until the population level reaches a certain threshold at which point the rediae will start to produce cercariae.

Cercaria

The cercaria is a free-swimming, tailed (tail is reduced or absent in some species) form that will infect a vertebrate intermediate or definitive host. The typical cercaria has an anterior mouth surrounded by an oral sucker, although in some species the mouth is midventral. A prepharynx, muscular pharynx and forked intestine are also found. Many cercariae have a variety of glands near the anterior margin and it is assumed that these glands produce secretions to help penetration; hence, the name penetration glands. Schistosome cercariae have at least four types of glands. Cercariae that will encyst on vegetation or other objects, e.g. *Fasciola hepatica* have prominent **Cystogenic gland cells**. Cercariae have a well-developed excretory system and, in some species, the excretory bladder empties out of one or two pores in the tail. The number and arrangement of the protonephridia are constant in a species and have been used extensively in species identification

In almost all species of trematode it is the cercarial stage that emerges from the mollusk. Cercariae are short –lived because of limited glycogen stores, and so they must quickly find the next host. The tail-less or short-tailed cercariae crawl about or are eaten by the next host. In some cases, the cercariae do not even leave the sporocyst or redia prior to being eaten by the next host. There are many morphological forms of cercariae such as **xiphidiocercaria** (possess a stylet in the anterior margin of the oral sucker), **cercariaeum** (without a tail), **microcercous cercaria** (with a small, knoblike tail), **furcocercous cercaria** (with a forked tail), and **ophthalmocercaria** (has eyespots). If a cercaria possesses more than one of the above traits, the terms might be combined. For example, an ophthalmoxiphidiocercaria has eyespots and a stylet in the oral sucker. The cercarial features are diagnostic and help to differentiate among different species.

Mesocercaria

In the genus *Alaria*, a unique larval form, intermediate between the cercaria and metacercaria, is found. It is called a **mesocercaria**.

Metacercaria

In many species of digenean, metacercaria is a quiescent stage which is usually encysted, but in some species it is not. Blood flukes lack this stage. Most metacercaria are found on or in an intermediate host, but some encyst on vegetation, sticks, rocks, or even free in the water.The cercaria will shed its tail at the start of encystment. The process is most complex in species that encyst on inanimate objects or plants. *Fasciola hepatica* encysts on plants and has several different types of cystogenic cells producing secretions for cyst construction. Metacercariae that encyst in intermediate hosts have thinner, simpler cyst walls and the host usually contributes some components to the cyst wall.

Development of the metacercaria to the infective stage varies markedly among many species. Species that encyst on vegetation or inanimate objects are infective almost immediately to the definitive host, while some species require several days of physiological change within an intermediate host to become infective. Still other species undergo growth and metamorphosis and then enter a resting stage in which they are infective. These species can require several weeks to become infective. Some metacercaria in intermediate hosts have been found to remain viable for up to 7 years. Regardless, whether the quiescent stage is long or short, it is during this time that the parasite is infective to the definitive host.

Development in the Definitive Host

In most species, for development to occur in the definitive host, excystation take place before the worm migrates to its final site. The site may be in the intestine, lungs, liver, or circulatory system. Those in the intestine have the shortest migration. Access to the liver is usually via the bile duct. However, *F. hepatica* burrows through the gut wall into the peritoneal cavity and wanders around until it encounters the liver. Access to the lungs may be gained after migration through the gut wall into the peritoneal cavity, through the diaphragm, and finally into the lungs.

LECTURE SOURCES:

- General Parasitology By Thomas C. Cheng, Academic Press College Division, Harcourt Brace Jovanovich, Publishers. (Chapter 11)
- https://www.ncbi.nlm.nih.gov/books/NBK8037/
- http://ecoursesonline.iasri.res.in/mod/page/view.php?id=59081
- https://www.microscopemaster.com/trematodes.html
- https://www.sciencedirect.com/science/article/pii/B9780128137123000096
- Human Parasitology by Burton J.Bogitsh, Clint E.Carter, Thomas N.Oeltmann, 2019, Chapter 9 - General Characteristics of the Trematoda ,Pages 149-174. https://doi.org/10.1016/B978-0-12-813712-3.00009-6
- https://clinicalsciences.wordpress.com/article/flukes-trematodes-the-biology-xk923bc3gp4-76/
- https://nios.ac.in/media/documents/dmlt/Microbiology/Lesson-46.pdf

ADDITIONAL READING:

- https://link.springer.com/chapter/10.1007%2F978-94-017-3247-5_3
  The Main Types of Trematode Life Cycles Chapter · January 2003
  DOI: 10.1007/978-94-017-3247-5_3
- Trematode life cycles: short is sweet? By Robert Poulin & Thomas H. Cribb
  DOI:https://doi.org/10.1016/S1471-4922(02)02262-6