REPRODUCTION IN FISH

As a rule fishes are bisexual animals which means ovary and testis are found in two different individuals. This difference in sex persists throughout life, yet there are over 100 species of fishes throughout the world which are hermaphrodites. There are even some cases where the individual specimen changes sex after spawning (sex reversa1). For instance, *Lates calcarifer* are protandrous hermaphrodites, males often change their sex after spawning, though not all females are originally males (Moore, 1979; Davis, 1982). Hermaphroditism probably evolve under conditions where it is hard to find a mate, or where there is a differential size between the two sex (Lowe-Mcconnell, 1987). It is interesting to note that sexes become exceedingly variable in many tropical fishes. Sometimes in the mature (gravid) population all the individuals are males (Jenynsia) at other times almost entirely females (Molliensia). If male is smaller than its female partner, larger proportion of male offspring may be expected, conversely if the female partner is equal to or smaller than the male, the offspring will be mostly females (Thumm, 1908). Hermaphroditism generally occurs in the species belonging to **Serranidae, Labridae, Scaridae and Sparidae**. Individuals belonging to these families are mostly protogynous i.e. Females change to males as they grow under induced circumstances (Robertson, 1973). The reverse change, protandry, from male to female is also known to occur as in polynemids (Reinboth, 1975; Warner, 1978). It has also been suggested that sex change can be triggered by sex-ratio threshold (i.e. If there is a great disproportion in the number of males and females). However, the physiological changes underlying sex reversal may be different in different groups of fishes (Shapiro, 1981). The including factors may be either social' or "environmental in the sex reversing fishes. In true hermamaphrodite fishes eggs and sperms develop in the same gonad and self fertilisation takes place in those fishes Usually testes ripen first and the ovaries later. However, in some cases the gonads ripen in reverse order.

STRUCTURE OF THE GONADS

Testes are paired, lobulaled structures and remain separated in most fishes. They lie close to the kidneys and remain attached to the dorsal body wall by a band of tissue called mesorchium. In elasmobranchs, the testes extend from the base of the liver to the rectal glands near the cloaca. The proximal part of the testis is attached with the rectal gland of each side through a 'band of non- glandular tissue. Teleosts do not have rectal gland and testis are generally separated. The size and colour of the testis varies even in the same individual at different maturity stages. Nor mally in mature individuals testes are flat, white in colour and their ventral edge frequently have wave like outline (Fig. 8.1) while in immature males, it is generally whitish or greyish in colour. Histologically, the testes contain a large number of closely compact and highly convoluted tubules called seminiferous tubules. The tubules are of various sizes and they are generally bound together by a thin layer of connective tissue. Besides connective tissue, the spaces between the lobules are also filled with blood capillaries and interstitial cells (Leydig cells), The Leydig cells are said to be the source of male hormones. In teleosts, the seminiferous tubules open directly in to a spermatic duct which is usually lined by a secretory epithelium. In elasmobranchs, usually spermatozoa from the seminiferous tubules are carried by a large number of fine tubules called vasa efferentia. The vasa efferentia are in turn open to a longitudinal duct called vas deferens (Wolffian duct) and the two Wolffian ducts from two sides ultimately terminate into the cloacal chamber. During spermiogenesis, the spherical and nucleated sperm mother cells undergo cell division and give rise to primary spermatocytes. From primary spermatocytes smaller secondary spermatocytes arise through mitotic divisions. The latter divides to produce spermatids which are further reduced in size and contains an elliptical nucleus in its substance. The spermatids again undergo cell division and give rise to tiny sperms. It is interesting to note that the entire testis may be functional in all fishes. In certain species (eg. *Tor tor*) only the anterior portion contains germ cells and the posterior sterile probably serves for the storage of sperms during the spawning season. The ovary is also a paired, elongated sac like structure lying in the abdominal cavity. The two ovaries are suspended from the body wall by a pair of mesenteries called mesovarium. There is a great variation in ovarian size even in the same individual. In a fully mature (gravid) female, the ovary occupies almost the entire abdominal cavity. The two ovaries are free at anterior but may be fused posteriorly (Fig. 8.2). From the posterior part of each ovary gives rise a short oviduct which unites with its fellow of the opposite side and open to exterior either by a separate genital aperture or by a common urinogenital opening. The eggs are set free and pass into the oviduct through the ovarian funnel. In some forms (eg. Eel), however oviducts are absent. The ova are discharged by genital pores which may be regarded as degenerate oviducts (Parker and Haswel1,1967). The colour of the immature ovary is pinkish or reddish while it is usually yellowish and granular in mature specimens. In viviparous fishes, the two oviducts have no connection with the ovaries. The oviducts in such forms are funnel shaped at the anterior most ends and posteriorly the two oviducts enlarge to form uteri where embryos develop. Histologically, the ovarian wall consists of three layers-the outer most germinal epithelium, the middle tunica albuginea made up of connective tissue and the innermost germinal epithelium. The germinal epithelium projects inwardly and gives rise to ovigerous lamellae which are the seat for the development of oocytes. The ovigerous lamellae contain large number of oogonia. Each oogonium passes a number of maturation stages and eventually develops into definite ova. This process of development is called oogonesis.

HISTOLOGY OF THE TESTIS:

The structure of the testis is variable in teleosts, and two types have been recognised: (i). Lobular type and (ii). Tubular type. Most teleosts have typical lobular type of testis consisting of a large number of seminiferous lobules which are closely bound together by a thin layer of connective tissue. The lobules are of various sizes and are highly convoluted structures, separated from each other by a thin connective tissue stroma. The walls of the lobules are not lined by a permanent germinal epithelium. The lobules open into a spermatic duct which is generally lined by a secretory epithelium. In some species as Glyptothorax, *Rita rita*, the lobules, project out individuallv from the sperm duct and are not bound together into a compact mass, as found in most teleosts: The lobules of the testis may be surrounded by lobule boundary cells which resemble connective tissue cells. The spaces between the lobules are filled with connective tissue, blood capillaries and interstitial cells. Within the lobules, the primary spermatogonia undergo mitotic divisions to produce cysts containing spermatogonial cells. As maturation proceeds, cysts enlarge and finally rupture to liberate sperm into lumen of the lobule which continues into the sperm duct. The second tubular type of testis is found only in Atheriniformes (e.g., *Poecilia reticulata)*. In this type the tubules are arranged regularity between the external tunica propria and the central cavity. There is no structure comparable to lobular lumen in this type. The spermatogonia are restricted to the distal end of the tubule, immediately below the tunica albuginea. During the growth-period, the resting germ cells become active and divide and are transformed into sperm mother cells or nests of spermatogonia. The spermatogonia are large, spherical cells containing a large round, centrally placed nucleus, having a distinct nucleolus. The cytoplasm of these cells does not take much stain. These cells multiply and give rise to primary spermatocytes which are small in size than the spermatogonia and possess dark stained nucleus. These undergo various stages of division during which the chromatin matter is visible as a fine reticulum and is later thickened on one side of the nucleus. The secondary spermatocytes arc smaller in size and their chromatin material is seen in the form of a thick clump. They last for a short period and divide to give rise to spermatids which are still smaller in size and possess that an elliptical nucleus that is deeply stained with hematoxylin. The spermatids give rise to sperms which are further reduced in size. The process of metamorphosis of spermatids into sperms is called 'spermiogenesis'. At the end of spermiogenesis, the seminiferous tubules are packed with sperm masses.

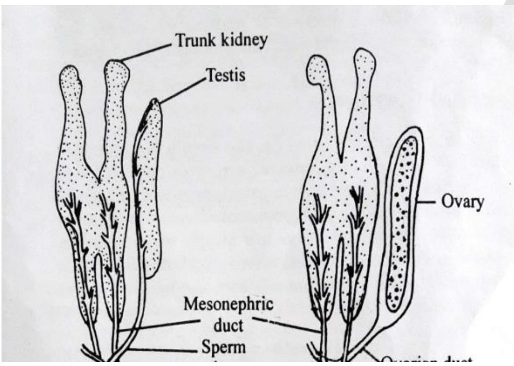
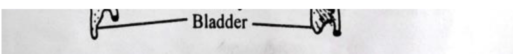
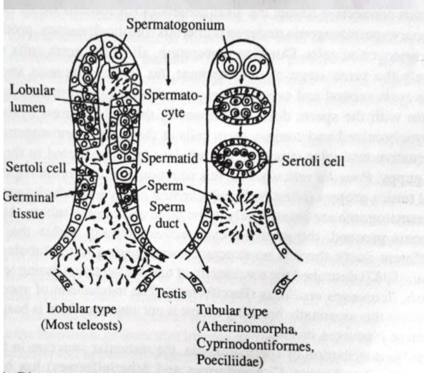


Figure 1 Testis and ovary of Teleost





Diagrammatic representation of testis structure in teleosts: Lobular type; tubular type.
Source: **Nagahama (1983, 1986)**

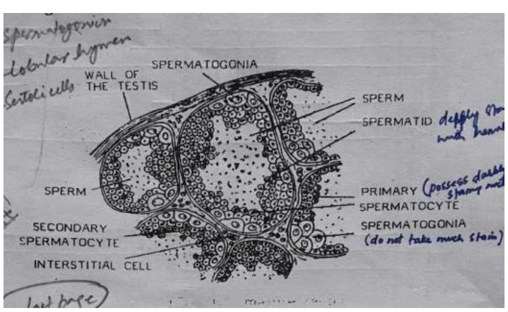


Fig. T.S. mature Testis

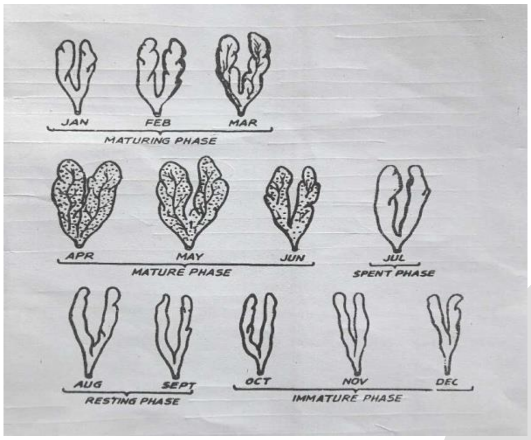


Fig. Seasonal changes in testes

FEMALE REPRODUCTIVE ORGANS: The ovaries are paired elongated sac-like structures lying in the abdominal cavity, ventral to the kidneys. They are attached to the body wall by means of the mesovarium. The anterior ends of the two ovaries are free but their caudal ends may become united into one. The hinder end of each ovary is continued posteriorly into a short oviduct. The two oviducts fuse and open to the exterior by a separate genital aperture or by common urinogenital opening. Generally both the ovaries are equal in size. But occasionally they are unequal also. They are thin, flaccid and trasluscent when immature, but on maturity they become enlarged and lobulated while the ripe ova are seen bulging out. The wall of the ovary is fairly thick during the non-breeding season but becomes thin and highly vascular during the spawning period. It consists of three layers (i) an outer-most thin periritoneum, (ii). a thicker tunica albugines made up of connective tissue, muscle fibres and blood capillaries, (iii) the innermost layer is the germinal epitheliumwhich projects into the ovocoel in the form of lamellae. · These ovigerous lamellae are the seat for the development of oocytes which are visible in various stages of development. The germ cells or oogonia are found in clusters in the lamellae and probably originate from the germinal epithelium. An oggonium has a large nucleus and a thin layer of ooplasm which is chromophobic. Each oogonium passes through a number of maturation stages to become a ripe ovum. Several stages can be present at a time in ovary. As oogonium increases in size there is increase in the quantity of ooplasm which is stained with basic dyes. The developing egg is called as oocyte.

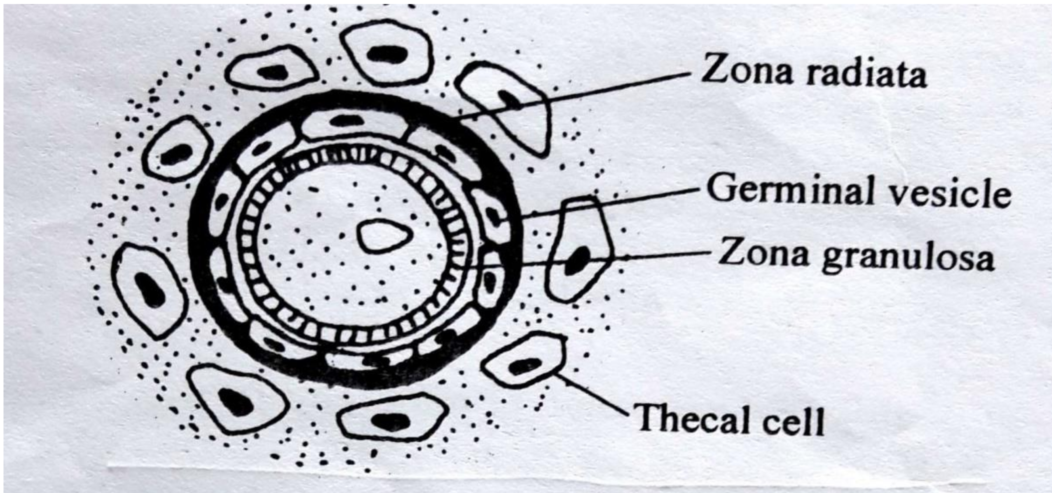


Fig. General structure of mature egg.

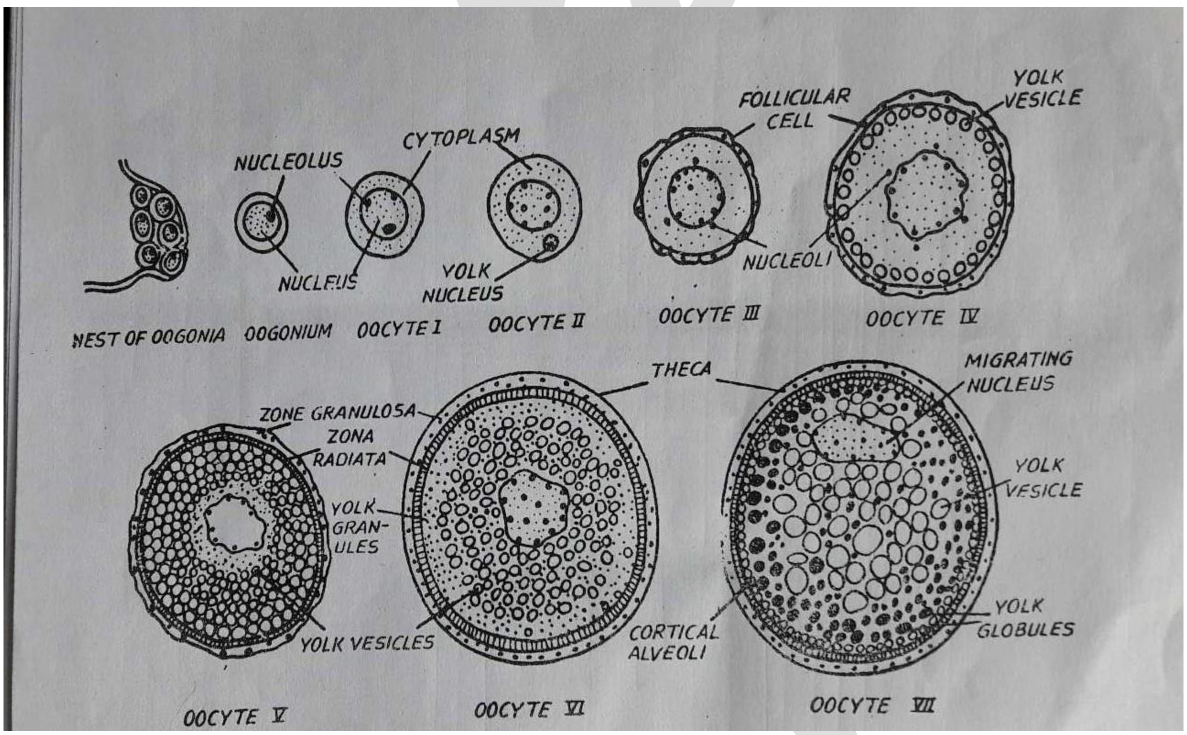


Fig. Stages of Egg Maturation

TY ES OF SPAWNING

By and large fishes are oviparous which means the female lay eggs that hatch externally. All the fishes, however, are not oviparous. There are certain species which are ovoviviparous (non-placental) where eggs hatch internally, but the young does not receive nourishment from the mother. Skates and rays are mostly ovoviviparous. Besides, there are viviparous fishes where eggs hatch internally and the young receives nourishment from the mother before extrusion (e.g. Scoliodon). Oviparous fishes may be further grouped into following categories on the manner of laying their eggs-

(a) Phytophils: Fishes which lay eggs among aquatic plants (e. g. *Cyprinus carpio*).

(b) Pelagophils: Fishes which lay their eggs directly on surface water i.e. Egg floating type. (e.g. *Sprattus sprattus*).

(c) Lithophils: Fishes which spawn on rocky bottom. The eggs are generally larger in size owing to a relatively high amount of yolk (e.g. Notopterus).

(d) Psammophils: Fishes which breed in sandy surface (e.g. loach).

(e) Ostracophils: Fishes which lay their egg inside the molluscan shell or crabs. For example, snail fishes of the Antarctic region lay their eggs in the gill cavities of crabs and other crustaceans.

Both monogamy and polygamy occur among fishes. The duration of spawning period varies from species to species. Some complete their egg laying activities within an hour while some lay eggs in batches which may take several months. Three types of spawning are generally encountered in Indian freshwater fishes.

In the first category are included all those species which have restricted breeding season. Indian major carps belong to this category which breeds during monsoon (June-July).

In the second category includes fishes which have prolonged breeding season. Murrels belongs to this category.

In the third category are included fishes which spawn throughout the year e.g. *Tilapia*

SPAWNING CYCLE AND PERIODICITY

Fishes exhibit a marked seasonal cycle in eggs or sperm production. That the maturity stages of an individual fish undergo cyclical changes can be revealed from the morphological and histological examinations of gonads. The term maturity stages mean the degree of ripeness of the gonad of a fish. Most Indian carps have a yearly cycle of reproduction and once they have begun it, they follow it until they die. On the other hand minnows breed several times in a year. Tilapia, after attainment of maturity breeds 6 to 11 times a year. There are also instances that fishes spawning once in about 5 years (*Oncorhynchus*). Again, some fishes especially certain migratory species like *Anguilla* breeds once in a life time. Seasonal morpho-histological changes are noticed in the gonads of teleosts and the cycle can be divided into a number of phases as described below

1. **Immature or juvenile phase**: Gonads small, inconspicuous, transparent and pale in colour. Sexes indistinguishable. Testes ribbon or thread like. Seminiferous tubules are small in size. Ovaries also thin and ovigerous lamellae are visible. They should be distinctly recognised as possessing a nucleus and a protoplasmic layer.
2. **Inactive or Resting phase**: Immature but sex can be distinguishable with or without aid. Sperm present as traces, and eggs just visible to naked eye.
3. **Maturing or ripening phase:** Gonads increasing in size, occupying about 2/3rds length of the abdominal cavity. Testis becoming creamy white, translucent and firm. Numerous primary and secondary spermatocytes are visible. Ovary swollen and containing conspicuous opaque eggs. A large number of yolk-vesicles appear in the periphery of the ooplasm. However, ova are not fully yolked.
4. **Mature or Gravid phase**: Gonads are highly vascularised and occupying almost entire length of the body cavity i.e., the gonad has achieved its maximum size and weight. Testes are full of sperm, some extruded with pressure. Seminiferous tubules are larger in size and full of sperm. Ovary fully developed, yellowish in colour with conspicuous superficial blood vessels. Eggs full of yolk and with distinct yolk spherules, but still contained within ovarian follicle. This stage culminates in running ripe fish when milt or oocytes may be readily extruded if light pressure is applied on the abdominal region.
5. **Spent phase:** Gonads thin and flaccid. Testes greyish with patches of whit unshed milt. Empty and collapsing seminiferous tubules are seen Ovaries reddish, sac like with some large, unshed or resorbing ova. Ovaries collapsed with no eggs seen by naked eye. In some cases a few residual eggs present. Testes and ovaries revert to stage II.

However, the foregoing description is a general account (the maturity stages of fishes. There are variations in the state of gonads in different groups of fishes. Nevertheless, the basic pattern of maturity cycle of all teleostean fishes is more or less similar.

TYPES OF FISH EGG AND FECUNDITY

According to the nature of buoyancy the egg of fish are of three types-

(a) Pelagic: These eggs are also known as planktonic or floating type as they float on the surface water individually or in a string or mass covered with mucus. The specific gravity of pelagic eggs is almost equal to that of water. They are small and usually provided with a non-adhesive membrane (e.g. Eggs of mullet).

(b) Demersa1: Owing to their heaviness, demersal eggs sink to the bottom. They contain relatively larger amount of yolk in them. Further, they are sticky, adhesive and usually attached to the debris of the bottom (e.g. eggs of *Lates cal*carifer).

(C) Semibuoyant: These types of eggs neither float nor sink. They are found suspended in the water column (e.g. Eggs of *Gudusia chapra*). The size of the egg also varies considerably., Generally highly fecund fishes have smaller eggs. Again, demersal eggs are larger than the pelagic eggs. The size of the egg is mostly dependent on th yolk reserve the size of the egg also increases considerably after fertilization. In certain carps, the fertilised egg swell up several times than their original size. Fecundity has been considered as the number of ripening eggs in the female prior to spawning (Bagenal and Braum, 1968). Fecundity varies from species to species and even among the individuals belonging to the same species, depending on their age, length, weight, environmental condition etc. According to Woodhead (1978), fecundity may act as a regulatory mechanism by means of which the numerical strength of a population is brought into the line with the food availability of the water body. Generally, an improvement in feeding condition, either by an increase in food supply, a reduction of the population by fishing, or transfer to another water body, result in a greater number of eggs laid during the spawning season. When living conditions deteriorate and the growth rate of the fish is reduced, the age at first maturity increases and these results a fall in the fecundity rate. On the whole, the fecundity of fishes is much higher than that of terrestrial vertebrates. The most fecund fishes are those which have floating pelagic eggs; in second order are those which have adhesive eggs to some submerged substratum, Fishes which protect or hide their eggs usually have a lower fecundity rate (Kryzhanovisky, 1949 and Nikolsky, 1963). Differences occur in fecundity of fishes of the same length in different populations (Baxter, 1963). Thus, Mulder (1973) found the fecundity of *Labeo cap*ensis at 35 cm length was only 67,000 from Vaal river while Baird (1976) observed that fecundity of the same species at the same length was 1,06,000 from

Caledon river. Several authors emphasized both genetic and environmental factors to explain variations in feeundity within and between populations (Hempel, 1965, Parrish and Seville, 1965; Bagenal, 1966 and Nikolsky, 1969). Among environmental factors, food supply and temperature were often mentioned (Leggett and Power, 1969, Hodder 1972 and Messeih, 1976). Bagenal (1967) viewed that while temperature and feeding conditions during the maturation may play a role in determining fecundity, the main factor will however, be selection. According to Nikolsky (1963) the fecundity of fishes, as that of other animals, is an adaptation which ensures the survival of the species under the conditions in which it originated and exists. According to him fecundity of fish increases where there is a high mortality of fry and fingerlings due to predation or other environmental factors. He also viewed that changes in individual fecundity are regulated by changes in the food supply and also faster growing individuals usually have a higher fecundity than slower growing ones of the same size. The species responds to changes in the environment by changes in its fecundity. The relative fecundity is a term used to denote the number of eggs per unit weight or length of the fish (Toots, 1951; Anokhina, 1963 and Hardisty, 1964). However, the fecundity (absolute fecundity) and relative fecundity vary even in the same species under different ecological conditions (Biswas, 1982).

FERTILIZATION:

Fertilization usually means union of male and female gametes. In a sense, fertilized egg is the seat for the creation of a new individual. As a rule fertilization in fishes is externa1 (i.e., eggs are fertilized outside the body of the female). Thus, fishes by and large are oviparous. However, there are many viviparous species found both among cartilaginous and bony fishes. Generally, males of these viviparous species have a copulatory organ. Of course, there are instances that internal feriilization occurs in both egg- laying and viviparous fishes. There is another group of fishes which is termed as ovoviviparous. Here, the eggs develop inside the body of the mother but unlike the viviparous type the developing eggs do not get nourishment from the mother's body. Tilapia is an excellent example of ovoviparity. While large scale mortality is common in oviparous fishes, both ovoviviparity and viviparity ensure greater survival rate of the spawns. The ovum of fishes or any other animal, through single celled but in reality it is a composite structure. The essential components of a fish ovum are like those of an vertebrate egg. The outer membrane of the ovum is called vitelline membrane which surrounds the cytoplasm.

Embedded in the cytoplasm is a dense nucleus. The nuclear membrane separates nucleus from the cytoplasm. Within the cytoplasm, besides the presence of cell inclusions, is found a nutritive material termed as yolk or deutoplasm (Fig-8.3). Depending on the amount of yolk in the egg, it is termed polylecithal as it possesses relatively high amount of yolk. The size of the fish egg varies from species to species. Initially the egg (oocyte) is very small. During the course of maturation and development the egg gradually enlarges. At ovulation the follicle (ovarian follicle) ruptures and the eggs are released. At this time the egg is enclosed in a vitelline membrane. The male gamete or sperm is usually discharged as a mass of whitish fluid called milt. The oozing milt contains millions of sperms. In size, the sperm is smaller than the ovum and it has a head, a middle piece, and a tail. The nucleus almost fills the head region. The terminal pointed end of the head is termed as acrosome. The middle portion bears mitochondria while the tail contains an axial filament, controlling undulations of the sperm. Usually fertilization in fishes is accomplished by the nearly simultaneous release of sperm and ova close together. During fertilization, the head of the sperm enters into the egg through micropyle (a small aperture found in the outer membrane). An ovum is fertilized by a single sperm. Once a sperm has penetrated through the egg membrane, a sort of barrier is formed beneath the membrane which prevents further penetration of sperm Kryzhanovksy, 1953). The chance of fertilization of the egg of a fish depends on many factors. The important factors are motility of sperms physico-chemical factors of the surrounding environment, water current etc. Generally the motility of fish sperm is only for about 10 secs. Thus, the chance of fertilization of the egg in a hill stream is far less than that of a stagnant pool. Among the physico-chemical factors, temperature, dissolved oxygen and pH of water play very important roles during fertilization and initial development stages of fishes.

DEVELOPMENT;

In broad sense, development is a process by which an organism reaches its adulthood. However, unlike other vertebrates the development in fishes is continuous. Development starts right from the moment the egg is fertilized. After several stages of development the tiny organism reaches maturity (adulthood). At that time the adult organism is capable of producing new life of its own kind. And after reaching the adulthood also the growth process do not ceases. The eggs and larvae start life that is completely different from the life of the adults. The moment of hatching is in fact the beginning of a hazardous Period in the life of all aquatic animals including fishes. It then faces the twin problems of adjusting itself with the physico-chemical factors of the surrounding medium in one hand and to the predators on the other. For convenience, the development of the fish is being discussed here in two heads viz. (I) embryonic development and (ii) larval development.

Embryonic development

In a ful1y ripe egg, a small opening known as micropyle appears in the shell. Through this micropyle, polar bodies escape and waters from outside enters into it. This causes swelling of the egg. The swelling may be as much as four times of the original size. Now, a gap called perivitelline space (Fig. 8.3.2) is found in which the embryo is bathed during its development. Usually, the water mixes with the yolk and makes the egg to become transparent. May be mentioned here that the fertilized egg is transparent whereas unfertilized one is opaque. After fertilization' the micropyle is closed and no more spermatozoa and even water can pass through. Gaseous exchanges, however, can take place through the vitelline membrane. The environmental conditions particularly the temperature and pH of water have great influence on the developing embryo.

Embryonic development begins the moment the egg is penetrated by a sperm i.e. Just after fertilization. Fertilization ends in the fusion of male and female gametes which also make the way of exerting their influence of parental genes. The embryonic development in fishes is basically the same as in other chordates. The fertilized egg first undergoes segmentation and thus it passes from the one-celled to many celled stage (Fig. 8.4). This segmentation is known as cleavage. It is the process by which the fertilized egg is divided into successively smaller cells called blastomeres. In both cartilaginous and bony fishes, the cleavage is incomplete and is confined to the superficial cytoplasmic layer. The deeper yolky portion remains unchanged (unsegmented). This type of cleavage where only a small disc like part (germinal disc) of the egg divides is known as meroblastic and the disc of cells thus formed on the upper or animal pole is known as the blastoderm (Fig. 8.4). C1eavage ultimately result in the formation of blastula stage which is characterized by the single layered cells (blastomeres) and having segmentation cavity (called blastocoel) formed under the blastoderm. A large number of free blastomeres form a layer of cells called the periblast and lie just above the yolk. Actually the space between the blastoderm and periblast is the blastocoel. The blastoderm ultimately gives rise to future embryo. In most bony fishes, gastrulation starts with the presumptive endodermal and mesodermal cells as the posterior end migrate forwards under the blastoderm, thus forming the hypoblast. The cell of the blastoderm has continued to grow over the yolk. This process is known as epiboly. The presumptive ectoderm cells grow over and cover the yolk mass from outside, forming a layer of cells called epiblast. Simultaneously periblast also grows and forms an inner covering of the yolk. The periblast and epiblast enclose the yolk in a yolk sac, Formation of yolk sac signifies the termination of gastrulation. The embryo proper is now distinctly separated from the yolk sac which can be seen from outside. The embryo is connected wit, h yolk sac by a yolk stalk (Fig. 8.4). Blood vessels develop in the wall of the yolk sac and as the embryo grows the yolk sac is gradually reduced in size. This indicates that the yolk sac provides nourishment to the developing embryo. The characteristic feature of gastrulation in fishes is that formation of primary rudimentary organs starts in the anterior part of the embryo. Various organs of the body are formed from the ectoderm, mesoderm and endoderm. The ectoderm gives rise to the epidermis and its derivatives like brain and spinal cord, the lens of the eye and internal ear. Similarly, muscles, appendages, axial skeleton, skin, scales ete. Develop from mesoderm cells. Endoderm cells make up the inner lining of the digestive tract and sex cells. Certain endocrine glands such as thyroid and ultimobranchial glands are also derived from endoderm cells. The embryonic phase is therefore, the interval in which the major organ systems begin to appear. It ends in hatching. However, the exact state of development an embryo at the time of hatching not only varies among species but may vary within a species, depending on environmental conditions. Following is the summary of the embryonic development in *Clarias batrachus* as observed on one typical case (Thakur 1978):-

Stage 1. Fertilized egg.

Stage 2. Two-celled stage (45 min. After fertilization)

Stage 3. Four-celled stage(1 hour)

Stage 4. Eight-celled stage(1 hr 20 min.)

Stage 5. Multi-celled stage(2 hrs 30 min.)

Stage 6. Morula stage((3 hrs. 30 min.)

Stage 7. Formation of germinal ring(5 hours)

Stage 8. Embryo formation (7 hrs 30 min.)

Stage 9. Differentiation of head and tail ends of embryo (10hours)

Stage 10. Somite differentiate (12 hours)Stage 11. Formation of optic cups, eight somite stage (14hrs 30 min.)

Stage 12.12 somite stage (16 hours)

Stage 13. Kupfer's vesicle appears (18 hours)Stage 14. 25 somite stage(19 hours)

Stage 15. Optic Cups are visible; Kupfer's vesicle disappears (20 hours) 25 somite stage (19 hours)

Stage 16. Twitching movements starts (20 hrs 30 min.)Stage 17. Twitching movements more frequent; tail end gets freed (21 hours)

Stage 18. Over 40 somite stage (21 hrs. 30 min.)

Stage 19. Twitching movements more vigorous, egg capsule weakens (21 hrs. 45 min.)

Stage 20. Egg-capsule ruptures (21 hrs. 50 min.).

Stage 21. Larva hatches out (21 hrs. 55 min.)

LARVAL DEVELOPMENT.

The larval phase begins once the embryo is free of the egg membrane. The embryo now ceases to be curled up, becomes increasingly fish like, continues to rely on its yolk or mother for nutrition (Moyle and Cech, 1988). The duration of this phase, however, varies widely among species. As soon as the yolk content is absorbed (generally yolk sac is absorbed on the third day in case of Indian major carps) the larva should develop the ability to capture food organisms. The larva is now carnivorous taking mainly zooplankton regardless the species is herbivorous or carnivorous in late r(adult) stage. A larval fish, while still using its stored yolk, is called either a pre-larva or a sac fry. After absorption of the yolk, it is called postlarva (advanced fry).

Larval development continues until the fry reaches the fingerling stage, when it more or less resembles the adult. Usually the period terminates when the axial skeleton is formed and the embryonic median fin fold is gone. Mention may be made that the development in fish larvae does not occur at the same rate among all the individuals in a population. Biswas and Phukon (1989, 1990, 1991) in a series of experiment observed that hatchlings emerging from the eggs of same brooder and same time are not equal in size. This variation in size becomes more conspicuous when the hatchlings are about two weeks old. It is probable that the sudden increment of growth in a section of fish spawn is related to genetical factors (Biswas and Phukon, 1992).

SEXUAL DIMORPHISM

In a majority of fish species identification of sex by external examination is rather difficult, because there is hardly any difference in the external characters between the two sexes. However, there is also a number of species where sexual difference or sexual dimorphism is not uncommon. Sexual dimorphism is generally of two types-primary and secondary. Primary sexual characters i.e. ovary and testis and other associated structures are internal and cannot be ascertained from outside. Thus, secondary sexual characters are very important as far as sex determination in fishes is concerned. Most of the secondary sexual characters are, however, in no way related to spawning and they usually meant for attracting the opposite sex. Sexual dimorphism in Indian major carps (catla, rohu and mrigal) is prominent during the breeding season. The male is generally having rough pectoral fins and comparatively slender body while the females are easily recognizable by their bulging abdomen and protruding vent. In fact, most of the carps exhibit similar features during spawning season. Size differences between the two sexes are common in most of the fish species. Generally females are larger than the males which may be due to the fact that the latter attain maturity earlier and they also have shorter life span. In a few instances however, males are found to be larger than their female partner (e.g. Tilapia). The larger size is said to be a protective adaptation (Nikolsky, 1963) and usually the larger parent protects the offspring (Lowe-Mcconnell, 1987).

Further, certain changes coinciding with the breeding season (termed as "nuptial dress")have been observed in several groups of fishes. The nuptial dress may be of several kinds-most common being colouration. Colouration of fishes is termed as dichtromation and usually it serves as attraction and recognition of males. Males of several tropical freshwater' species are brightly coloured with red and black dominating (as in *Colisa fasciata*) obviously to attract the females. Colouration is not distinctive of the sex in cartilaginous fishes, but usually the basal part of the ventral or pelvic fins in the male is used as a clasper to keep hold of the female during pairing. This type of intromittent copulatory organs are found in a few bony fishes also. As for example, in larvicidal fish *Gambusia affinis*, the anal fin of the male is enlarged to from the copulatory organ (gonopodium). Presence of conical genital papilla helps to distinguish sexes in the catfish, *Mystus seenghala*. Length and structure of the fins vary significantly between males and females in many species. Thus, in *Labeo dero*, dorsal fin in the mature male is highly elongated (Hora, 1936; Biswas,1982). In some other forms, the tips ofthe dorsal spine of males become club shaped whereas females possess normal dorsal spine. Bright, horny tubercles (e.g. *Labeo pangusia*), hooked shaped jaws (humped back salmon) are, some of the features by which males can be distinguished from the female specimens. Furthermore, certain other special features such as shape of the snout, mouth, lips or development of bristles on the head of the male have also encountered in several species. Thus, it can be seen that practically every external part of the male is affected, naturally different parts in different groups of fishes. Morphological differences between the sexes may be attributed to over activity of male hormone. Another feature is that males are generally more active than their female counterparts in most of the species.

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