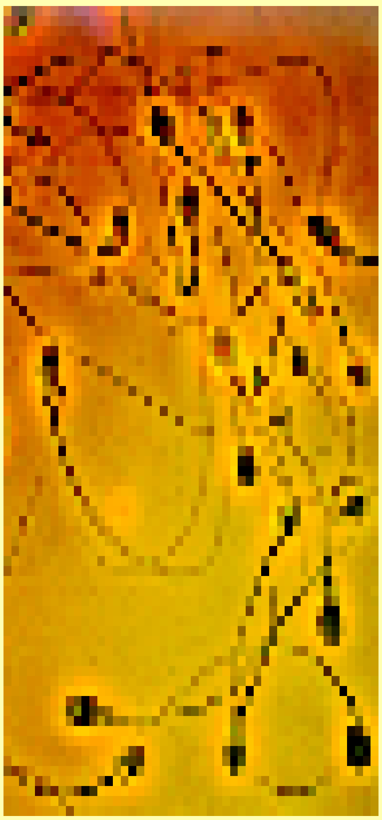
Contents

CHAPTER

20



The average healthy human male produces about 1000 new sperms every second.

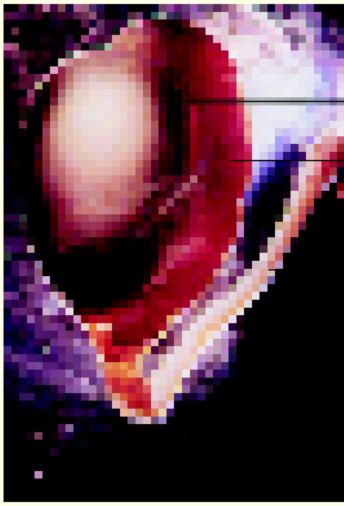
Gametogenesis

The gametogenesis (Gr.,*gamos*=marriage; *genesis*= origin) is the process of gamete formation in the sexually reproducing animals. The sexually reproducing animals contain two types of cells in their body, *e.g.*, **somatic cells** and the **germinal cells**. Both types of cells have diploid number of chromosomes but each type has its different destiny. The somatic cells form various organs of the body and provide a phase for the maturation, development and formation of the germinal cells. The somatic cells always multiply by mitotic division.

The germinal cells form the gonads (testes and ovaries) in the animal body. These cells produce the gamete cells by successive mitotic and meiotic divisions. The male gamete is known as **spermatozoon** or sperm and the female gamete is known as **ovum** or **egg**. The process of sperm production is known as the **spermatogenesis** (Gr., *sperma*= sperm or seed; *genesis*= origin) and the process of production of ovum is known as **oogenesis** (Gr., *oon*= egg; *genesis*= origin). Both the processes can be studied in detail under separate headings.

SPERMATOGENESIS

The process of spermatogenesis occurs in the male gonads or testes. The testes of the vertebrates are composed of many seminiferous tubules which are lined by the cells of germinal epithelium. The cells of the germinal epithelium



Human testis.

form sperms by the process of spermatogenesis. But in certain animals, *e.g.*, mammals and Mollusca, etc., there are somatic cells lying in between germinal cells, these somatic cells are known as **Sertoli cells.** The Sertoli cells anchor the differentiating cells and provide nourishment to the developing sperms. The insects do not possess Sertoli cells. The spermatogenesis is a continuous process and for the sake of convenience this process can be studied in two different stages.

1. Formation of spermatids; 2. Spermiogenesis.

1. Formation of Spermatids

The male germinal cells which produce the sperms are known as the **primary germinal cells** or **primordial cells**. The primordial cells pass through following three phases for the formation of spermatids :

(i) Multiplication phase. The undifferentiated germ cells or primordial cells contain large-sized and chromatin-rich nuclei. These cells multiply by repeated mitotic divisions and produce the cells which are known as the **spermatogonia** (Gr.,*sperma*=sperm or seed; *gone*=offspring). Each spermatogonium is diploid and contains 2X number of chromosomes.

(ii) The growth phase. In the growth phase, the spermatogonial cells accumulate large amount of nutrition and chromatin material. Now each spermatogonial cell is known as the **primary spermatocyte**.

(iii) The maturation phase. The primary spermatocytes are ready for first meiotic or maturation division. The homologous chromosomes start pairing (synapsis), each homologous chromosome splits longitudinally and by the chiasma formation the exchange of genetic material or crossing over takes place between the chromatids of the homologous chromosomes. The DNA amount is duplicated in the beginning of the division. By first meiotic division or homotypic division two **secondary spermatocytes** are formed. Each secondary spermatocyte is haploid and contains x number of chromosomes. Each secondary spermatocyte passes through the second maturation or second meiotic or heterotypic division and produces two **spermatids**. Thus, by a meiotic or maturation division a diploid spermatogonium produces four haploid spermatids. These spermatids cannot act directly as the gametes so they have to pass through the next phase, the **spermiogenesis**.

The microscopic structure of the testis showing section through a seminiferous tubule.

2. Spermiogenesis

The metamorphosis or differentiation of the spermatids into the sperms is known as **spermiogenesis**. Because the sperm or spermatozoon is a very active and mobile cell so to provide great amount of mobility to the sperm, the superfluous material of the developing sperms is discarded. For the reduction of the weight of the sperms following changes occur in the spermatids:

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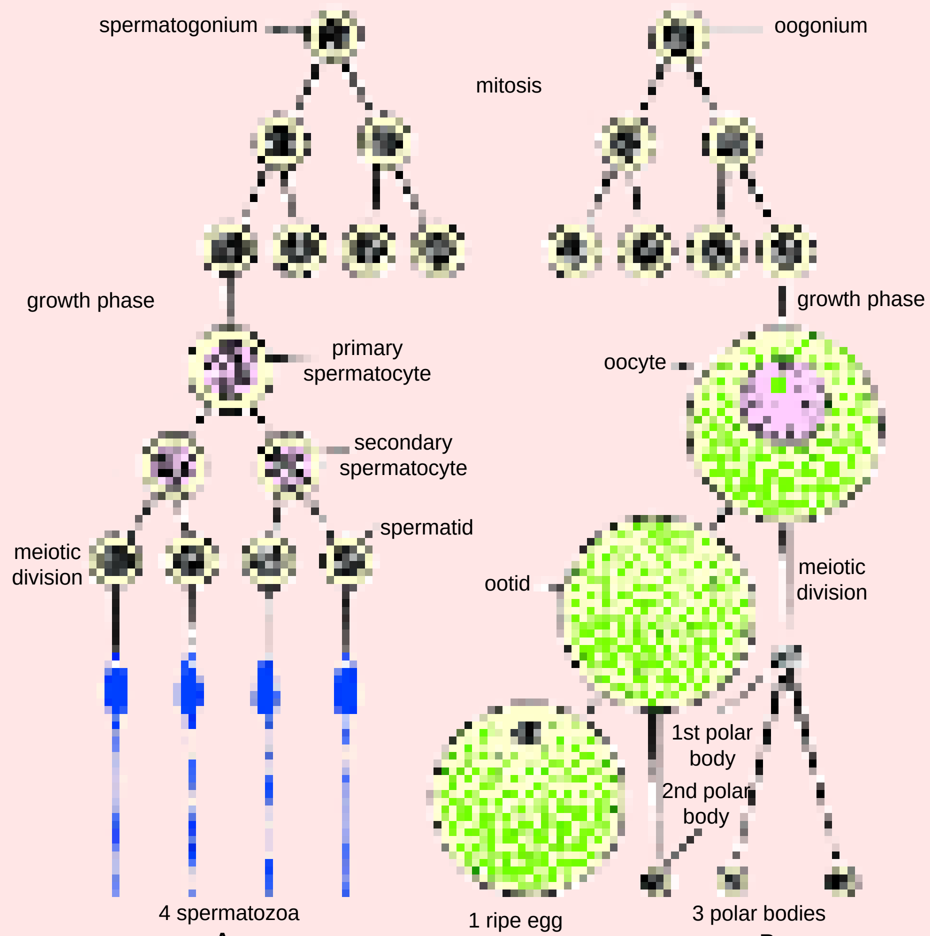
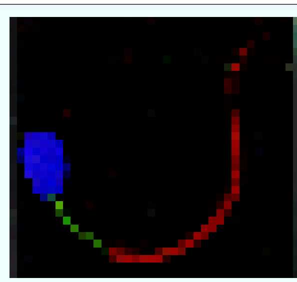
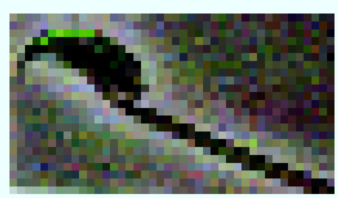


Fig. 20.1. Spermatogenesis and oogenesis. A—Spermatogenesis; B—Oogenesis.

(i) Changes in the nucleus. The nucleus loses water from the nuclear sap, shrinks and assumes different shapes in the different animals. The sperm nucleus in man and bull becomes ovoid and laterally flattened. In rodents and amphibians the sperm nucleus becomes scimitar-shaped with pointed tip. In birds and molluscs the nucleus becomes spirally twisted like a cork screw. The bivalve molluscs have the round sperm nucleus. The shape of the nucleus also determines the shape of the sperm head which becomes fully adopted for the active propulsion through the water. The RNA contents of the nucleus and the nucleolus are greatly reduced. The DNA becomes more concentrated and the



A– Mature bull sperm. The DNA is stained blue with DAPI; the mitochondria are stained green and tubulin of the flagellum is stained red.



B– Acrosome of mouse sperm, stained green by GFP.

chromatin material becomes closely packed into small volume.

(ii) Acrosome formation. The acrosome occurs at the anterior side of the sperm nucleus and contains protease enzymes which help its easy penetration inside the egg. The acrosome is formed by the Golgi apparatus. The Golgi apparatus is concentrated near the anterior end of the sperm nucleus to form the acrosome. One or two vaculoes of the apparatus become large and occupy the place between the tubules of Golgi apparatus. Soon after a dense granule known as the **proacrosomal granule** develops inside the vacuole. **Leblond** (1955) found the proacrosomal granule-rich in the mucopolysaccharides. The proacrosomal granule attaches with the anterior end of the nucleus and enlarges into the **acrosome**. The membranes of Golgi vacuoles form the double membrane (unit membrane of lipoprotein) sheath around the acrosome and forms the cap-like structure of the spermatozoa. The rest of the Golgi apparatus becomes reduced and discarded from the sperm as **Golgi rest**. In the sperms of certain animals an **acrosomal cone** or **axial body** also develops in between the acrosome and the nucleus.

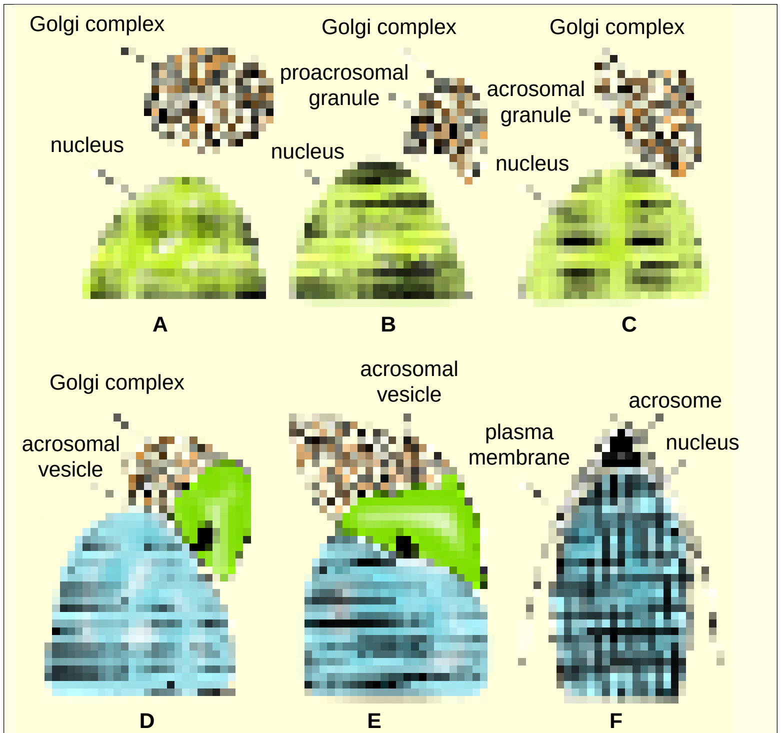
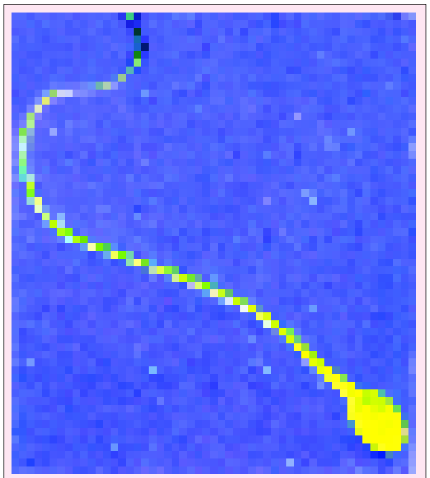


Fig. 20.2. Formation of acrosome of sperm.



A human sperm.

(iii) The centrioles. The two centrioles of the spermatids become arranged one after the other behind the nucleus. The anterior one is known as the **proximal centriole** and the posterior one is known as the **distal centriole**. The distal centriole changes into the basal bodies and gives rise to the **axial filament** of the sperm. The axial filament or the flagellum is composed of a pair of central longitudinal fibres and nine peripheral fibres. The distal centriole and the basal part of the axial filament occur in the middle piece of the spermatozoa. The mitochondria of the spermatids fuse together and twist spirally around the axial filament.

Thus, most of the cytoplasmic portion of the spermatid except the nucleus, acrosome, centriole, mitochondria and axial filament is discarded during the spermiogenesis.

OOGENESIS

The process of oogenesis occurs in the cells of the germinal epithelium of the ovary, such cells are known as **primordial germinal cells**. The oogenesis is completed in the following three successive stages : 1. Multiplication phase; 2. Growth phase; 3. Maturation phase.

1. Multiplication Phase

The primordial germinal cells divide repeatedly to form the **oogonia** (Gr., *oon*=egg). The oogonia multiply by the mitotic divisions and form the **primary oocytes** which pass through the growth phase.

2. Growth Phase

The growth phase of the oogenesis is comparatively longer than the growth phase of the spermatogenesis. In the growth phase, the size of the primary oocyte increases enormously. For instance, the primary oocyte of the frog in the beginning has the diameter about 50 mm but after the growth phase the diameter of the mature egg reaches about 1000mm to 2000mm. In the primary oocyte, large amount of fats and proteins becomes accumulated in the form of **yolk** and due to its heavy weight (or gravity) it is usually concentrated towards the lower portion of the egg forming the **vegetal pole**. The portion of the cytoplasm containing the egg pronucleus remains often separated from the yolk and occurs towards the upper side of egg forming the **animal pole**.

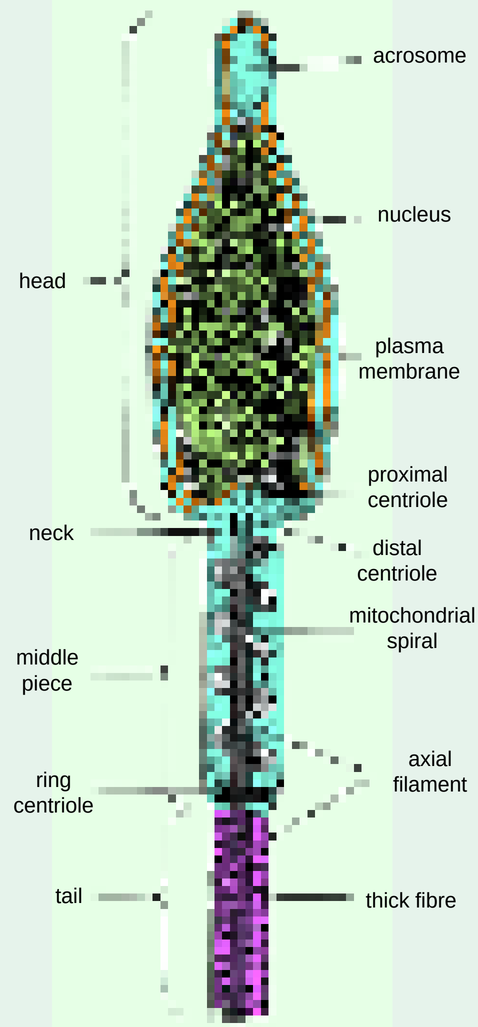
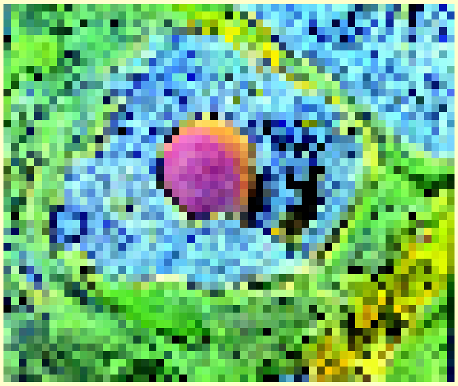


Fig. 20.3. Electron microscopic view of a flagellate spermatozoon.

The cytoplasm of the oocyte becomes rich in RNA, DNA, ATP and enzymes. Moreover, the mitochondria, Golgi apparatus, ribosomes, etc., become concentrated in the cytoplasm of the oocyte. In certain oocytes (Amphibia and birds) the mitochondria become accumulated at some place in the oocyte cytoplasm and forming the **mitochondrial clouds**.

During the growth phase, tremendous changes also occur in the nucleus of the primary oocyte. The nucleus becomes large due to the increased amount of the nucleoplasm and is called **germinal vesicle**. The nucleolus becomes large or its number is multiplied due to excessive synthesis of ribosomal RNA by rDNA of nucleolar organizer region of chromosomes. Thus, the nucleus or germinal vesicle of primary oocyte of *Triturus* has 600 nucleoli, of *Siredon* has 1000 nucleoli and *Xenopus* has 600 to 1200 nucleoli due to the synthesis of ribosomal RNA. The chromosomes change their shape and become giant **lampbrush chromosomes** which are directly related with increased transcription of mRNA molecules and active protein synthesis in the cytoplasm. When the growth of the cytoplasm and nucleus of the primary oocyte is completed it becomes ready for the maturation phase.



SEM through a primary oocyte showing an egg surrounded by follicle cell.

3. Maturation Phase

The maturation phase is accompanied by the maturation or meiotic division. The maturation division of the primary oocyte differs greatly from the maturation division of the spermatocyte. Here after the meiotic division of the nucleus, the cytoplasm of the oocyte divides unequally to form a single large-sized haploid egg and three small haploid **polar bodies** or **polocytes** at the end. This type of unequal division has the great significance for the egg. If the equal divisions of the primary oocyte might have been resulted, the stored food amount would have been distributed equally to the four daughter cells and which might prove insufficient for the developing embryo. Therefore, these unequal divisions allow one cell out of the four daughter cells to contain most of the cytoplasm and reserve food material which is sufficient for the developing embryo.

(i) First maturation division. During the first maturation division or first meiosis, the homologous chromosomes of the primary oocyte nucleus pass through the pairing or synapsis, duplication, chiasma formation and crossing over. Soon after the nuclear membrane breaks and the bivalent chromosomes move towards the opposite poles due to contraction of chromosomal fibres. A new nuclear envelope is developed around the daughter chromosomes by the endoplasmic reticulum.

After the karyokinesis the unequal cytokinesis occurs and a small haploid polar body or polocyte and a large haploid **secondary oocyte** or **ootid** are formed.

(ii) Second meiotic division. The haploid secondary oocyte and first polocyte pass through the second meiotic division. Due to the second meiotic division the secondary oocyte forms a mature egg and a second polocyte. By the second meiotic division the first polocyte also divides into two secondary polocytes : These polocytes ooze out from the egg and degenerate while the haploid egg cell becomes ready for the fertilization.

Structure of Mature Egg

The mature egg has a cell-like structure and composed of the following parts (Fig. 20.4) :

1. Plasma membrane. The mature egg is covered by a plasma membrane which is the unit membrane. It is composed of an outer and an inner layer of protein. Both the layers are 50A° in thickness. Between the proteinous layers there occurs a lipodous layer of 60A° thickness.

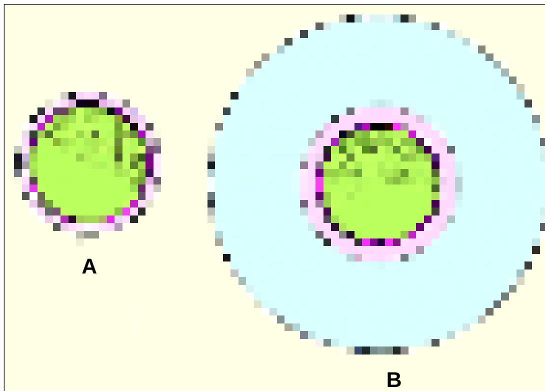


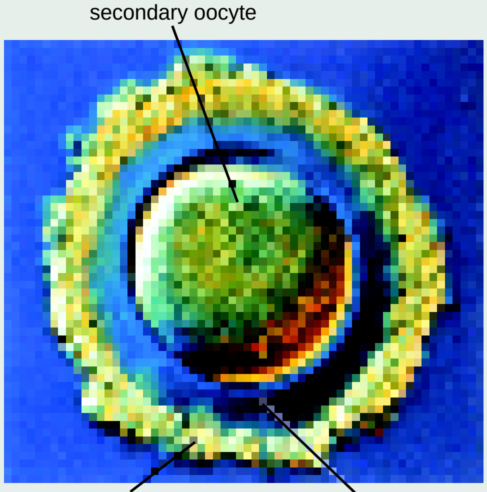
Fig. 20.4. Egg membranes of frog egg. A—Unfertilized egg as taken from oviduct; B—Fertilized egg with swollen jelly membrane (after Balinsky, 1981).

2. Primary egg membranes. In addition to the plasma membrane, the eggs of most animals except the sponges and certain coelenterates consist of certain other additional egg membranes. These membranes are known as the primary and secondary egg membranes. The primary egg membrane is secreted around the plasma membrane by the oocyte itself. In the insects, molluscs, amphibians and birds the primary egg membrane is known as the **vitelline**

membrane, while in tunicates and fishes this membrane is known as the **chorion**. The mammalian eggs contain similar membrane and in them this is known as the **zona pellucida**. The vitelline membrane is composed of mucoproteins and fibrous proteins. The vitelline membrane usually remains closely adhered to the plasma membrane but in later stages a space is developed between the plasma membrane and the vitelline membrane and this space is known as the **perivitelline space**.

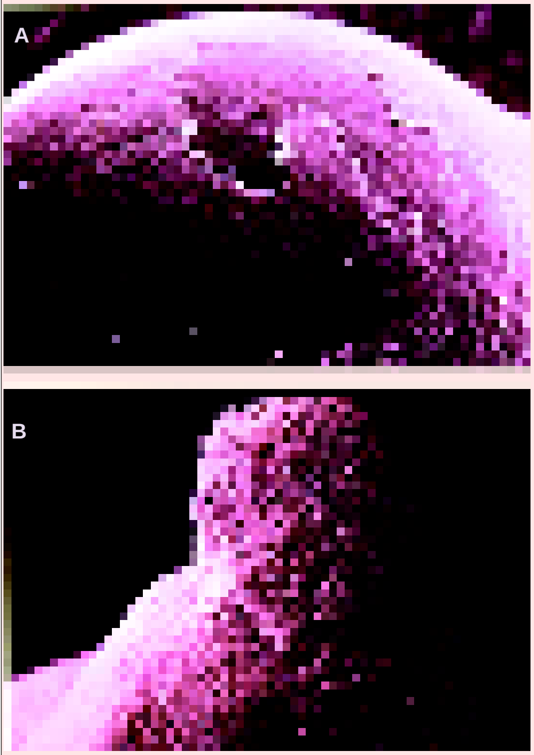
3. Secondary egg membranes. The secondary egg membranes are secreted by the ovarian tissues around the primary egg membranes. They are composed of either jelly-coats in amphibians or chitinous shells in insects, ascidians and cyclostomes.

4. Tertiary egg membranes. The tertiary egg membranes are formed by the oviduct or other accessory parts of female reproductive system. They may be composed of either jelly coats in amphibians, albumen and hard horny capsule in elasmobranch fishes, or albumen, shell membranes and calcareous shell in birds.



A human secondary oocyte shortly after ovulation.


The egg, travels down the oviduct towards the uterus. It emits chemicals that attract sperm.



The mature follicle moves to (A) the surface of the ovary and (B) literally bursts through the ovary wall like a volcano.

5. The ooplasm. The cytoplasm of the egg cell is known as the ooplasm. The ooplasm consists of large amount of reserve food material in the form of **yolk**. It is also composed of a lipoprotein, pigment granules, water, RNA, ribosomes, mitochondria and various other cellular inclusions. The peripheral layer of the ooplasm is known as the **cortex** and it contains many microvilli and cortical granules. The microvilli are formed by the outpushings of the plasma membrane and they help in the transportation of the substances from the follicle cells to the egg during the development of the egg. The cortical granules are spherical bodies of various diameters. *e.g.,* 8.0µm in the sea urchin eggs and 2.0µm in the eggs of frog. The cortical granules are surrounded by the unit membranes and are originated from the Golgi apparatus. They contain homogeneous and granular acid mucopo-

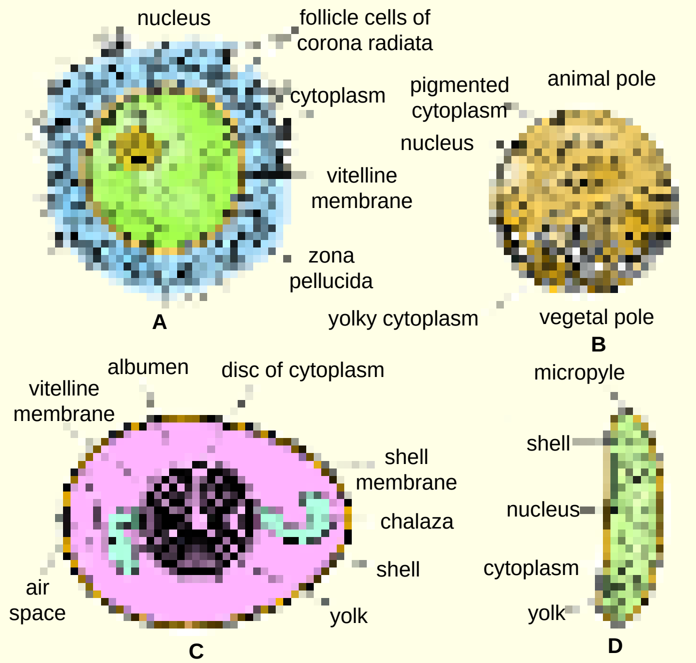


Fig. 20.5. Four main types of eggs : A—Microlecithal and isolecithal egg of man; B—Mesolecithal and moderately telolecithal egg of frog; C—Macrolecithal and highly telolecithal egg of the hen; D— Macrolecithal and centrolecithal egg of an insect, the fly.

lysaccharides and are present in the eggs of sea urchins, frogs, fishes, bivalve molluscs, some annelids and certain mammals. But they do not occur in the ova of man, rat, guinea pig, gastropod molluscs, urodele amphibians, insects and birds.

Yolk contents of the ooplasm. The amount of the yolk in the ooplasm varies from species to species. According to the amount of the yolk following types of egg cells have been recognised (Fig. 20.5).

1. Microlecithal. The eggs with very little amount of yolk are known as the microlecithal eggs, *e.g.*, *Amphioxus*, eutherian mammals.

2. Mesolecithal. The ova or eggs containing moderate amount of yolk are called mesolecithal ova or eggs, *e.g.*, *Peteromyzon*, Dipnoi and Amphibia.

3. Macrolecithal. The eggs with large amount of the yolk are known as the macrolecithal eggs, *e.g.*, *Myxine*, cartilaginous and bony fishes, reptiles, birds and Monotremata. The eggs can also be grouped into two types on the basis of the distribution of the yolk in the ooplasm.

A. Homolecithal. The eggs with evenly distributed yolk contents in the ooplasm are known as the homolecithal eggs, *e.g.*, eggs of echinoderms.

B. Heterolecithal. The eggs in which the yolk is not evenly distributed in the ooplasm are known as the heterolecithal eggs. The heterolecithal eggs may be of following types :

(i) Telolecithal. When the amount of the yolk is concentrated in the one half of the egg to form the vegetative pole of the egg, then this condition is known as the telolecithal. Telolecithal eggs may be moderately telolecithal (*e.g.*, amphibians) or highly telolecithal (*e.g.*, hen and other birds). In macrolecithal and highly telolecithal eggs the amount of the yolk is very large and it occupies the largest portion of the egg except a small disc-shaped portion of the cytoplasm. The cytoplasm contains the zygote nucleus and is known as the germinal disc, *e.g.*, eggs of fishes, reptiles and birds.

(ii) Centrolecithal. In the centrolecithal eggs the yolk accumulates in the centre of the ooplasm, *e.g.*, eggs of insects.

REVISION QUESTIONS

1. Define the term gametogenesis. Differentiate between spermatogenesis and oogenesis.
2. Describe the ultrastructure of the flagellate spermatozoon.
3. Give an illustrated account of spermatogenesis.
4. What is oogenesis ? Describe the process of oogenesis.
5. What is an egg ? Give an account of various types of eggs of animals.
6. Write short notes on the following :
   (1) Spermiogenesis; (2) Growth phase of oogenesis (3) Egg membranes.