

Developmental Biology

Introduction

All the events which change a blastos or a zygote into a fully formed animal and therefore, contribute to its growth to adulthood and finally to old age and death are referred to as development. Embryology is the study of development of an organism. Entire process of development is called embryogenesis or ontogenesis. Father of Modern embryology – Karl Ernst Von Baer (1792-1876). Development of new individual from an asexual reproductive body is called blastogenesis. Development of a new individual from the zygote is called embryogenesis.

12.1 Types of animals

(i) **Oviparous** : Egg laying animals *e.g.* Insects, fishes, amphibians, reptiles, birds, prototherian mammals.

(ii) **Ovo-viviparous** : Animals in which egg develops but without getting maternal nourishment. *e.g.* some snakes.

(iii) **Viviparous** : Animals give child birth. *e.g.* Eutherian mammals.

12.2 Classification of eggs

(i) On the basis of amount of yolk

(a) **Microlecithal or Alecithal** : Little amount of yolk or without any yolk *e.g.* Starfish, Amphioxus, Eutherian mammals.

(b) **Mesolecithal** : Containing moderate amount of yolk. *e.g.* Amphibians (frog)

(c) **Macrolecithal or Megalecithal** : Containing large amount of yolk *e.g.* Arthropods, Fishes, Reptiles, Birds and Monotremata.

(ii) On the basis of distribution of yolk

(a) **Isolecithal** : Yolk uniformly distributed. *e.g.* Microlecithal eggs.

(b) **Telolecithal** : Yolk is concentrated towards vegetal pole. *e.g.* Mesolecithal and Macrolecithal eggs

(c) **Centrolecithal** : Yolk is concentrated in the centre. *e.g.* Insects.

(iii) On the basis of shell

(a) **Cleidoic eggs** : Eggs surrounded by porous calcareous shell. Shell of hen's egg is secreted by uterus (shell gland) *e.g.* Reptile, Birds.

(b) **Non-cleidoic eggs** : Without calcareous shell *e.g.* Fishes, Amphibians.

12.3 Fertilization

A physiochemical process involving fusion of male gamete (spermatozoa) and female gamete (ovum)

- (1) External fertilization occurs in aquatic animals outside body *e.g.* Frog.
- (2) Internal fertilization occurs in terrestrial animals inside body *e.g.* Echidna, Rabbit and Man.
- (3) Fertilizins are the substance emitted from mature eggs present on the surfaces.
- (4) Antifertilizin is present on the surface layer of the cytoplasm of spermatozoa.
- (5) Acrosome of sperm releases sperm lysin, hyaluronidase for penetration into egg.
- (6) In man whole of sperm enters into egg while in others only head enters.
- (7) Fusion of male and female pronuclei is called Amphimixis.
- (8) Immediately after penetration a new membrane namely **fertilization membrane** develops in the place of vitelline membrane which block entry of late arriving sperms.
- (9) Fertilization in birds generally takes place when the egg is in the oviduct (Mullerian duct).
- (10) In mammals (Rabbit & Human beings) fertilization of the ovum occurs in fallopian tube.
- (11) Capacitation of sperms is represents a change in sperm to make them capable of fertilizing the ovum.

12.4 Abnormal fertilization

- (i) **Polyspermy** : Penetration of many sperms into an ovum simultaneously. Only one of the spermatozoa will be successful in uniting with female pronuclei
- (ii) **Polygyny** : When two female pronuclei unite with a male pronucleus.
- (iii) **Polyandry** : Conjugation of two or more male pronuclei with a female pronucleus.
- (iv) **Gynogenesis** : Activation of egg by sperm but there is no fusion of its pronucleus.
- (v) **Androgenesis** : Non-participation of female pronucleus in fertilization.
- (vi) **Somatic fertilization** : Common in angiosperms, characterized by involvement of two pronuclei of male, one of which fuses with the egg nucleus and the other with two polar nuclei. The second forms the triploid endosperm nucleus.

12.5 Cleavage

In all animals fertilized ovum develops in the sequence– zygote, cleavage, morula, blastula, gastrula and neurula. Cleavage is successive mitotic cell division of the egg to form a multicellular morula. Swammerdam (1738) observed the first cleavage of frog.

- (i) **Planes of cleavage**
 - (a) **Meridional** : Cleavage furrows passes through the entire centre of animal vegetal axis
 - (b) **Vertical plane** : Cleavage furrow pass in a direction from the animal pole towards vegetal pole but not through the median axis.
 - (c) **Equatorial plane** : The cleavage bisects the egg at right angles to the main axis and half way between the animal and vegetal poles.
 - (d) **Latitudinal plane** : It is similar to equatorial, but it course through the cytoplasm on either side of equatorial plane.
- (ii) **Patterns of cleavage**

(a) **Radial** : All blastomeres are placed in a radially symmetrical manner around the animal vegetal axis e.g. Sponges, Coelenterates and Echinoderms.

(b) **Spiral** : Blastomeres are arranged in a spiral manner e.g. Platyhelminthes, Annelida and Molluscs.

(c) **Bilateral** : Blastomeres are arranged so that right and left sides become apparent e.g. Amphibia and Higher mammals.

(iii) **Concept of potency**

(a) **Determinate cleavage** : All the blastomeres remain together and each blastomere has its characteristic position and form a specific part of the embryo e.g. Nematoda, Mollusca (Dentalium)

(b) **Indeterminate cleavage** : The plane of cleavage is not rigid. Blastomeres have no characteristic position and alterable fate. e.g. Sea urchin, Chordates (frog, rabbit, man)

(iv) **Types of cleavage**

(a) **Holoblastic**– Cleavage furrow bisects entire egg.

(1) **Total equal or Holoblastic cleavage** : Produces blastomeres of equal or approximately equal size in microlecithal eggs e.g. Starfish, Amphioxus, Marsupials and placental mammals like rabbit & man.

(2) **Unequal holoblastic cleavage** : Produces unequal size blastomeres as in mesolecithal & telolecithal eggs. e.g. Amphibians (frog)

(b) **Meroblastic cleavage** : Partial or incomplete.

(1) **Discoidal** : Cleavage remain restricted to the disc-shaped active cytoplasm of animal pole eg Macrolecithal & Telolecithal eggs of reptiles, birds & monotreme mammals.

(2) **Superficial cleavage** : Firstly nucleus divide, migrate to periphery and then divides into many cells e.g. Insects.

12.6 Phases of embryonic development

(i) **Morula** : A solid ball of cells formed by the cleavage of zygote (having no cavity).

(ii) **Blastula** : A blastula is made up of blastomeres.

(a) **Stereoblastula** : Composed of densely packed large sized cells eg Cnidaria, Annelida (Neries) and Some mollusca.

(b) **Coeloblastula** : With a central cavity, blastocoel eg Amphioxus and Frog.

(c) **Discoblastula** : Disc-shaped blastula is formed by meroblastic cleavage e.g. Fishes, Reptiles, Birds and Monotremes.

(d) **Superficial blastula** : Formed by meroblastic superficial cleavage e.g. Insects.

(iii) **Gastrula** : Formed by a process of gastrulation. Gastrulation is derivation of three germinal layers i.e ectoderm, mesoderm & endoderm. Termination of gastrulation is indicated by obliteration of blastocoel.

12.7 Development of frogs

(1) Sexual embrace of the male and female frog, is called *Amplexus*.

(2) Spawning is the act of laying of eggs.

(3) Frog's egg is mesolecithal and telolecithal

(4) Cleavage is holoblastic, unequal & indeterminate.

(5) Coeloblastula develops in frog.

(6) Gastrulation includes three kinds of morphogenetic movement of cells namely epiboly of ectoderm, emboly or invagination and involution of choardamesoderm.

(7) Blastopore will give rise to future anus of frog (Dueterostome).

(8) Archenteron represent the lumen of future gut.

(9) Formation of notochord is known as Notogenesis.

(10) The hatched young frog is called tadpole.

(11) Tadpole of frog is herbivorous, ammonotelic with pronephric kidney.

(12) During metamorphosis nervous system shows least changes and respiratory system maximum changes.

(13) During metamorphosis adequate amount of thyroxine is secreted by thyroid of tadpole.

(14) Metamorphosis is affected by iodine in pond water.

12.8 Embryonic development in mammals

(1) Insemination occurs during sexual intercourse.

(2) 300 million sperms are deposited in the vagina during an ejaculation.

(3) The area of ovum which extrudes the polar bodies and receive sperm is called Animal pole.

(4) Fertilization occurs in fallopian tube in female.

(5) Cleavage is simple holoblastic.

(6) Cleavage in mammalian ovum takes place during its passage through the fallopian tube to the uterus.

(7) The several cleavages forms compact ball of cells called morula.

(8) Zona pellucida remains upto onset of cleavage

(9) Due to rearrangement of blastomeres and formation of a central cavity Blastodermic vesicle or Blastocyst (Blastula) is formed.

(10) Outer layer is trophoblast draws nutrition from mother's uterine circulation.

(11) Chorion and Amnion are produced from Trophoblast.

(12) Body of embryo proper is formed from inner cell mass.

(13) During gastrulation endoderm is formed by delamination of cells from the inner cell mass.

(14) Mesoderm is formed from caudal region of embryonic disc after the formation of endoderm.

(15) Outer layer of trophoblast form ectoderm.

(16) A human embryo is umplanted when it is a blastula (6-7 days old)

(17) The first two months of development is considered the embryonic development.

(18) After the second month it will be called as foetus.

(19) Parturition is the process of child birth controlled by hormones oxytocin and relaxin.

12.9 Extra-embryonic membranes

Extra-embryonic membranes (Foetal membranes) are the membranes formed of embryonic tissue that lie outside the embryo. It is found in amniotes (Reptiles, birds and mammals). The four extraembryonic membranes are Amnion, Chorion, Yolk sac and Allantois.

(i) Amnion (Ectoderm + Somatic mesoderm = Somatopleure). Surround embryo.

(ii) Chorion (Ectoderm + Somatic mesoderm = Somatopleure). Outermost.

(iii) Yolk sac (Endoderm + Splanchnic mesoderm = Splechnopleur). Contains yolk in reptile and birds but without yolk in mammals.

(iv) Allantois (Endoderm + Splanchnic mesoderm = Splechnopleur). Functions as an embryonic urinary bladder. Main function of allantois of mammalian embryo is nutrition.

Chart showing fate of germ layers in vertebrates

Layer	Embryo	Adult
Ectoderm	Somatic ectoderm	→ Epidermis, skin derivatives, olfactory organ, lense of eye, inner ear, anterior pituitary, mouth
	Neural crest	→ Branchial skeleton, ganglia, sensory nerves, adrenal medulla
	Neural tube	→ Brain, spinal cord, motor nerves, retina, optic nerve, posterior pituitary
Endoderm	Archenteron (Primitive gunt)	→ Digestive tract lining, liver, pancreas, respiratory system bladder, thyroid, parathyroid, thymus
Mesoderm	Notochord	→ Reduced or obliterated
	Epimere	→ Dermatome
		→ Sclerotome
		→ Myotome
	Mesomere	→ Excretory system, gonoducts
	Hypomere	→ Somatic layer
		→ Splanchnic layer
Coelom	→ Parietal peritoneum → Visceral peritoneum, mesenterics, circulatory system, gonads, visceral muscles → Body cavities	

12.10 Placenta

Placenta is universally present in eutherian mammals for exchange of materials between foetal and maternal circulation. Placenta helps in nutrition, respiration, excretion. Placenta secrete hormones like relaxin and human chorionic gonadotrophin (HCG). HCG exert a protective influence on the unborn child, it influence on the production of progesteron from the corpus luteum while relaxin causes relaxation of pelvic ligaments and pubic symphysis to facilitate birth of the young.

(i) Types of placenta on the basis of foetal membranes involved in the formation of placenta

(a) **Yolk sac placenta** : Formed of yolk sac and chorion *e.g.* Marsupials like kangaroo and opossum.

(b) **Allantoic placenta** : Formed of allantois and chorion *e.g* most of eutherians.

(c) **Chorionic placenta** : Formed of only chorion *e.g.* primates.

(ii) Types of placenta on the basis of intimacy between foetal and maternal blood.

(a) **Epitheliochorial** (6 layers) : *e.g.* Odd hoofed mammals(horse, lemurs and pigs)

(b) **Syndesmochorial** (5 layers) : *e.g* Even hoofed mammals (cow,sheep,goat, camel etc.)

- (c) **Endotheliochorial** (4 layers) : *e.g.* Carnivores (dog, cat, lion, tiger, etc.)
 - (d) **Haemochorial** (3 foetal layers) : *e.g.* Primates (monkeys, apes human female)
 - (e) **Haemoendothelial** : Only foetal blood capillary *e.g.* rodents and lagomorphs (rabbit).
- (iii) Types of placenta on the basis of fate of uterine wall at the time of birth
- (a) Deciduate placenta *e.g.*, human, pig, whale, lemur.
 - (b) Non-deciduate placenta *e.g.*, horse, ass, zebra.
 - (c) Contra-deciduate placenta *e.g.*, mole.
- (iv) Types of placenta on the basis of distribution of villi
- (a) **Diffused** : *e.g.* horse, pig, whale.
 - (b) **Cotyledonary** : *e.g.* cow, sheep, goat.
 - (c) **Intermediate** : *e.g.* camel, giraffe.
 - (d) **Zonary** : *e.g.* elephants, dog, cat.
 - (e) **Discoidal** : *e.g.* rabbit, bats, rodents.
 - (f) **Meta discoidal** : *e.g.* primates.