

B.Sc. (Hon's) (Fifth Semester) Examination, 2014
Zoology
Paper: LZC-503
(Reproductive and Development Biology)
Model answer

Section A

1.

- | | |
|--------|-----|
| (i) | (c) |
| (ii) | (b) |
| (iii) | (b) |
| (iv) | (c) |
| (v) | (b) |
| (vi) | (b) |
| (vii) | (d) |
| (viii) | (c) |
| (ix) | (c) |
| (x) | (a) |

Section B

Answer No. 2.

Fertilization is the phenomenon of fusion of gametes to initiate the development of a new individual organism. In animals, the process involves the fusion of an ovum with a sperm, which eventually leads to the development of an embryo.

In sea urchin, fertilization is external. Generally the events which occur during or after the fertilization phenomenon comes under the post fertilization events. In sea urchin it mainly includes:

1. Block to polyspermy
2. Egg activation
3. Initiation of cleavage

1. Block to polyspermy

Although many sperm attach to the coats surrounding the egg, it is important that only one sperm fuses with the egg plasma membrane and delivers its nucleus into the egg. Two mechanisms are used by animals to ensure that only one sperm fertilizes a given egg: the fast block to polyspermy and the slow block to polyspermy.

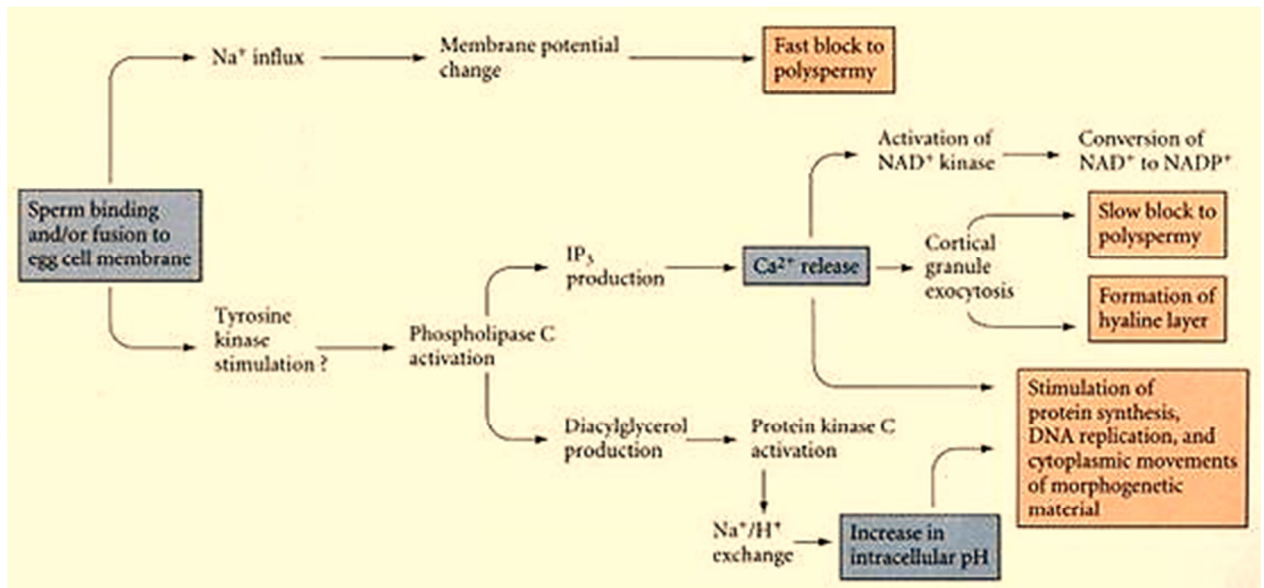


Figure showing the different types of block to polyspermy

a. Fast block to polyspermy:

In sea urchin, a fast block to polyspermy occurs within a tenth of a second of fusion. The fast block to polyspermy involves the opening of Na⁺ channels in the egg plasma membrane. Na⁺ flows into the egg cell, depolarizing the membrane. This depolarization prevents additional sperm from fusing to the egg plasma membrane. The egg plasma membrane is restored to its normal -70mV potential within minutes of fusion as the Na⁺ channels close, other + ions flow out of the cell, and Na⁺ is pumped out.

b. Slow block to polyspermy:

The slow block to polyspermy begins within 10 seconds of fusion of the sperm and egg plasma membranes. A compound called inositol triphosphate (IP₃) causes the release of Ca⁺⁺ from intracellular stores in the egg endoplasmic reticulum. Ca⁺⁺ is first released at the site of sperm entry, and during the next minute, a wave of free Ca⁺⁺ passes through the egg. This Ca⁺⁺ results in the fusion of cortical vesicles with the egg plasma membrane, releasing their contents into the space surrounding the egg, called the perivitelline space. This raises the vitelline membrane, and inactivates bindin receptors on the vitelline membrane. Thus, any additional sperm are released from the vitelline membrane and no more bind.

2. Egg Activation:

Ca⁺⁺ release at fertilization results in an increase in metabolic activity within the egg, apparently due to an increase in the intracellular pH of the egg. Diacyl glycerol (DAG) causes protein phosphorylation cascades to be initiated, with one result being the

phosphorylation and activation of a plasma membrane $\text{Na}^+:\text{H}^+$ ion exchanger. Na^+ is pumped into the cell, H^+ is pumped out of the cell, and the pH inside the cell increases.

3. Initiation of cleavage:

After fertilization, the zygote begins cleavage. In typical sea urchins, cleavage occurs in a stereotyped way, producing progressively smaller cells (blastomeres). In the early cleavages, the orientation of the mitotic spindle changes in a specific manner, resulting in divisions that are either vertical or horizontal. Sea urchins undergo radial cleavage, as do "typical" deuterostomes, such as chordates, ascidians, and other echinoderms. Like embryonic cleavages in other organisms, sea urchin cleavages result in more cells, but without an increase in the total cellular volume of the embryo.

Answer No. 3.

Cleavage is the division of cells in the early embryo. The zygotes of many species undergo rapid cell cycles with no significant growth, producing a cluster of cells the same size as the original zygote. The different cells derived from cleavage are called blastomeres and form a compact mass called the morula. Cleavage ends with the formation of the blastula.

Characterstics of cleavage and mitosis

Cleavage	Mitosis
Cleavage refers to the process of division of cytoplasm (Cytokinesis) in the animal cells. Cleavage in the animal cells takes place after the telophase of mitosis.	Mitosis is a type of cell division in which a cell nucleus divides into two identical nuclei.
Depends on a transient structure based on actin and myosin filaments, the contractile ring	Depends on a transient microtubule-based structure, the mitotic spindle
In embryology, it also refers to the first process of development that follows fertilization. In this process, a large single cell zygote is divided into smaller cells known as blastomeres.	In embryology, mitosis is the process by which cells divide. The dividing cell is what causes an embryo to become a fetus.

Mitosis consists of DNA replication, cytokinesis, and cell growth, resulting in two cells of the same size as the parent cell. Cleavage, is similar to mitosis, but lacks the growth phase. The fertilized egg splits into 2, 4, 8, then 16 cells in very rapid succession. As a result, the

fertilized egg (quite large compared to most cells) splits into 16 cells of a much smaller size (with a combined size equal to the parent cell).

Types of cleavage

There are two main types of cleavage

I. Holoblastic (complete) cleavage

Cleavage found in eggs that contain no (mammals) or only moderate amounts (frog) of yolk, cytokinesis divides the cells completely.

It may be equal or unequal type.

II. Meroblastic (incomplete) cleavage

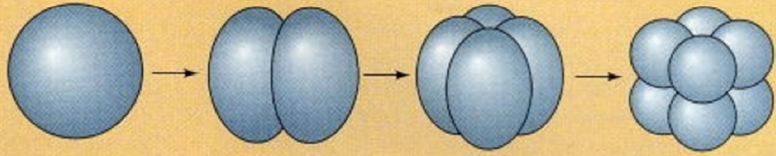
Cleavage found in eggs that contain a large amount of yolk, cytokinesis does not divide the egg completely.

I. Holoblastic (complete) cleavage	II. Meroblastic (incomplete) cleavage
<p>A. Isolecithal (sparse, evenly distributed yolk)</p> <ul style="list-style-type: none"> • 1. Radial cleavage (echinoderms, hemichordates, amphioxus) • 2. Spiral cleavage (annelids, most mollusks, flatworms) • 3. Bilateral cleavage (tunicates) • 4. Rotational cleavage (placental mammals, nematodes, marsupials) <p>B. Mesolecithal (moderate vegetal yolk disposition)</p> <ul style="list-style-type: none"> • Displaced radial cleavage (amphibians, some fish [the lampreys, gars and bowfins]) 	<p>A. Telolecithal (dense yolk throughout most of cell)</p> <ul style="list-style-type: none"> • 1. Bilateral cleavage (cephalopod molluscs) • 2. Discoidal cleavage (some fish [the hagfishes, chondrichthyans and most teleosts], sauropsids [reptiles and birds], monotremes) <p>B. Centrolecithal (yolk in center of egg)</p> <ul style="list-style-type: none"> • Superficial cleavage (most insects)

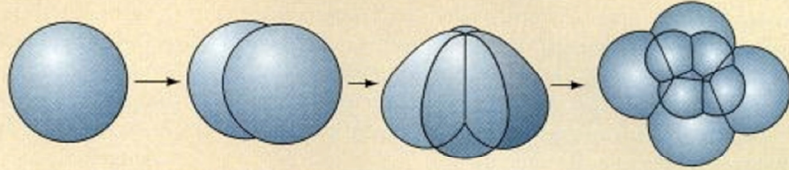
I. HOLOBLASTIC (COMPLETE CLEAVAGE)

A. Isolecithal
(Sparse, evenly distributed yolk)

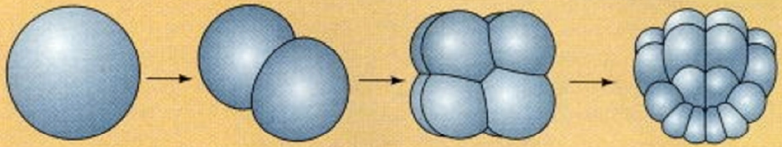
1. Radial
Echinoderms, amphioxus



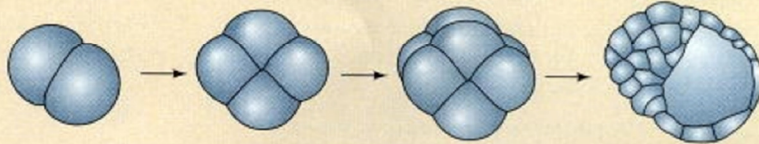
2. Spiral
Annelids, molluscs,
flatworms



3. Bilateral
Tunicates

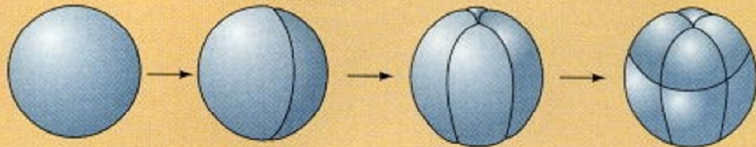


4. Rotational
Mammals, nematodes



B. Mesolecithal
(Moderate vegetal yolk disposition)

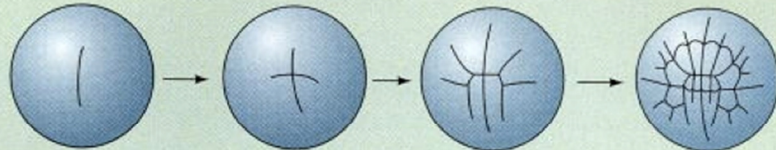
Radial
Amphibians



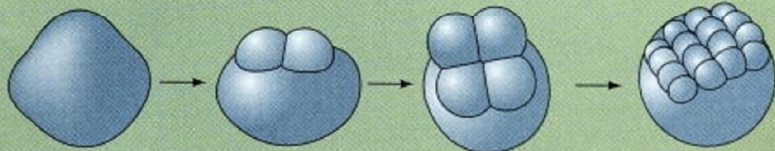
II. MEROBLASTIC (INCOMPLETE CLEAVAGE)

A. Telolecithal
(Dense yolk throughout most of cell)

1. Bilateral
Cephalopod molluscs

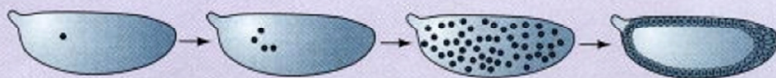


2. Discoidal
Fish, reptiles, birds



B. Centrolecithal
(Yolk in center of egg)

Superficial
Most insects



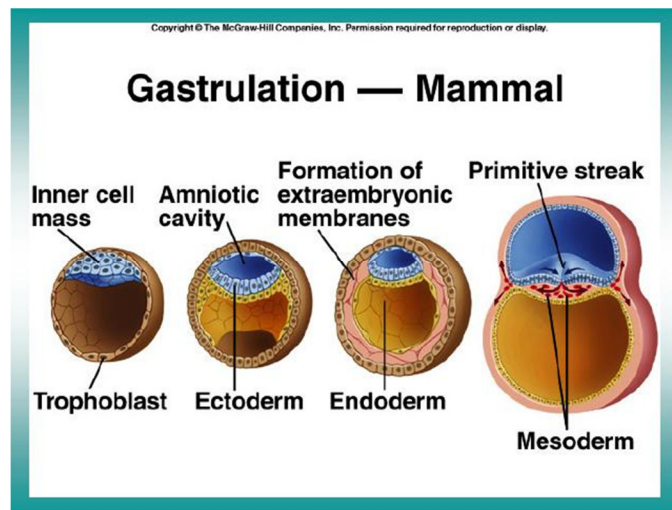
Answer No. 4.

Gastrulation is a phase early in the embryonic development of most animals, during which the single-layered blastula is reorganized into a trilaminar ("three-layered") structure known as the gastrula. These three germ layers are known as the ectoderm, mesoderm, and endoderm.

Gastrulation is characterized by cell movement and reorganization within the embryo (**morphogenetic movements**) to the interior of the embryo, forming three primary germ layers: ectoderm, mesoderm, and endoderm.

Mammalian gastrulation:

In mammals gastrulation takes place after the formation of the blastula. Gastrulation is followed by organogenesis, when individual organs develop within the newly formed germ layers. Each layer gives rise to specific tissues and organs in the developing embryo. The ectoderm gives rise to epidermis, and to the neural crest and other tissues that will later form the nervous system. The mesoderm is found between the ectoderm and the endoderm and gives rise to somites, which form muscle; the cartilage of the ribs and vertebrae; the dermis, the notochord, blood and blood vessels, bone, and connective tissue. The endoderm gives rise to the epithelium of the digestive system and respiratory system, and organs associated with the digestive system, such as the liver and pancreas.



Major events occur during mammalian gastrulation are:

1. Formation of primitive streak
2. Formation of organizer
3. Occurrence of morphogenetic movements
4. Initiation of neurulation
5. Development of extra embryonic membranes
6. Formation of ecto, endo and mesoderm.

7. Decision of fate map

Mammalian gastrulation begins with formation of a primitive streak in the epiblast and continues much like birds. Mammalian eggs have little or no yolk, but mammalian gastrulation is nonetheless similar to bird gastrulation due to evolutionary remnants from ancestral reptiles that laid very yolky eggs. In humans, gastrulation occurs after implantation, around days 14-16 after fertilization in human embryogenesis.

Answer No. 5.

Metamorphosis

Metamorphosis is the process in which an animal undergoes noticeable changes in its physical appearance as it moves from one stage of its life to another. Metamorphosis is a biological process by which an animal physically develops after birth or hatching, involving a conspicuous and relatively abrupt change in the animal's body structure through cell growth and differentiation.

Animals that commonly undergo metamorphosis include insects, amphibians and some fishes.

Metamorphosis is associated with adaptive changes in the way an organism interacts with its environment. For example, adult amphibians often eat very different foods than their larvae. Thus, adults and larvae do not compete for food. A second example of the adaptive significance of metamorphosis is in barnacles in which adults are sessile but the larvae are free-swimming. Thus, the dispersal of larvae gives adults the opportunity to colonize new habitats where the local environment might be more favorable.

Types of metamorphosis

1. Progressive metamorphosis

Metamorphoses in which larvae possess primitive characters and as they attain adulthood they develop advanced characters.

Example: In amphibians and majority of insects.

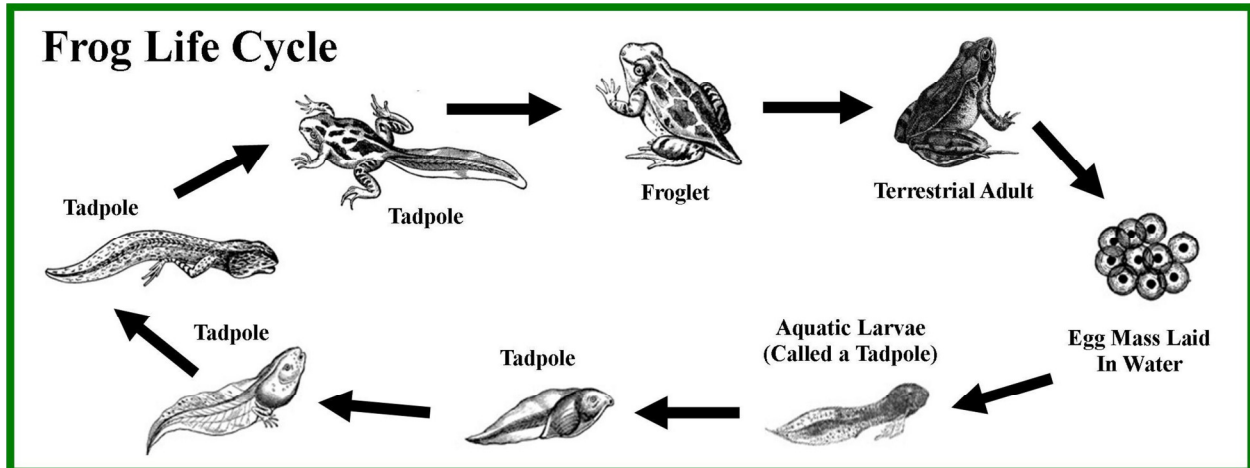
2. Retrogressive metamorphosis

Metamorphoses in which larvae possess advanced characters such as locomotory organs and sense organs but as they metamorphose into adult, these advanced features degenerate and adult develops primitive features. This type of metamorphosis is called retrogressive

Example: *Herdmania*

Metamorphosis in frog:

Amphibians are vertebrates that include frogs, toads, newts and salamanders. This means that amphibian larvae (eggs and tadpoles) live in water, but gradually change to become better suited to live on land. The female amphibian can lay as many as 4,000 eggs. When the eggs hatch, the tadpoles consume the soft egg jelly, called the egg sac.



Metamorphosis in frog:

Morphological changes associated with metamorphosis

In amphibians, metamorphosis is generally associated with the changes that prepare an aquatic organism for a primarily terrestrial existence. In anurans (frogs and toads), the metamorphic changes are more dramatic, and almost every organ is subject to modification. Regressive changes include the loss of the tadpole's horny teeth and internal gills, as well as the destruction of the tail. At the same time, constructive processes such as limb development and dermoid gland morphogenesis are also evident. The means of locomotion changes as the paddle tail recedes while the hindlimbs and forelimbs develop. The tadpole's cartilaginous skull is replaced by the predominantly bony skull of the frog. The horny teeth used for tearing pond plants disappear as the mouth and jaw take a new shape, and the tongue muscle develops. Meanwhile, the large intestine characteristic of herbivores shortens to suit the more carnivorous diet of the adult frog. The gills regress, and the gill arches degenerate. The lungs enlarge, and muscles and cartilage develop for pumping air in and out of the lungs. The sensory apparatus changes, too, as the lateral line system of the tadpole degenerates, and the eye and ear undergo further differentiation. The middle ear develops, as does the tympanic membrane characteristic of frog and toad outer ears. In the eye, both nictitating membranes and eyelids emerge.

Biochemical changes associated with metamorphosis

In addition to the obvious morphological changes, important biochemical transformations occur during metamorphosis. In tadpoles, the major retinal photopigment is porphyropsin. During

metamorphosis, the pigment changes to rhodopsin, the characteristic photopigment of terrestrial and marine vertebrates. Tadpole hemoglobin is changed into an adult hemoglobin that binds oxygen more slowly and releases it more rapidly than does tadpole hemoglobin. The liver enzymes change also, reflecting the change in habitat. Tadpoles, like most freshwater fishes, are ammonotelic; that is, they excrete ammonia. Adult frogs are ureotelic, excreting urea, like most terrestrial vertebrates, which requires less water than excreting ammonia. During metamorphosis, the liver begins to synthesize the urea cycle enzymes necessary to create urea from carbon dioxide and ammonia.

System	Larva	Adult
Locomotory	Aquatic; tail fins	Terrestrial; tailless tetrapod
Respiratory	Gills, skin, lungs; larval hemoglobins	Skin, lungs; adult hemoglobins
Circulatory	Aortic arches; aorta; anterior, posterior, and common jugular veins	Carotid arch; systemic arch; cardinal veins
Nutritional	Herbivorous: long spiral gut; intestinal symbionts; small mouth, horny jaws, labial teeth	Carnivorous: Short gut; proteases; large mouth with long tongue
Nervous	Lack of nictitating membrane; porphyropsin, lateral line system, Mauthner's neurons	Development of ocular muscles, nictitating membrane, rhodopsin; loss of lateral line system, degeneration of Mauthner's neurons; tympanic membrane
Excretory	Largely ammonia, some urea (ammonotelic)	Largely urea; high activity of enzymes of ornithine-urea cycle (ureotelic)
Integumental	Thin, bilayered epidermis with thin dermis; no mucous glands or granular glands	Stratified squamous epidermis with adult keratins; well-developed dermis contains mucous glands and granular glands secreting antimicrobial peptides

Hormonal control of amphibian metamorphosis

The control of metamorphosis by thyroid hormones was demonstrated by Guder-natsch (1912), who discovered that tadpoles metamorphosed prematurely when fed powdered sheep thyroid gland. In a complementary study, Allen (1916) found that when he removed or destroyed the thyroid rudiment from early tadpoles (thus performing a thyroidectomy), the larvae never metamorphosed, instead becoming giant tadpoles.

The metamorphic changes of frog development are all brought about by the secretion of the hormones thyroxine (T4) and triiodothyronine (T3) from the thyroid during metamorphosis. It is thought that T3 is the more important hormone, as it will cause metamorphic changes in thyroidectomized tadpoles in much lower concentrations than will T4.

Answer No.6.

Sexual reproduction in most species is regulated by regular endocrine changes, or cycles, in the female. These cycles begin postnatally, function for variable times and can then decrease or cease entirely. There are a number of different species-specific female hormonal cycles which can regulate reproduction.

In mammals mainly two reproductive cycles are found

- a. Estrous cycle
- b. Menstrual cycle

A. Estrous cycle

The estrous cycle (oestrous cycle) comprises the recurring physiologic changes that are induced by reproductive hormones in most mammalian therian females. Estrous cycles start after sexual maturity in females and are interrupted by anestrous phases or pregnancies. Typically, estrous cycles continue until death.

It comprises of 4 stages:

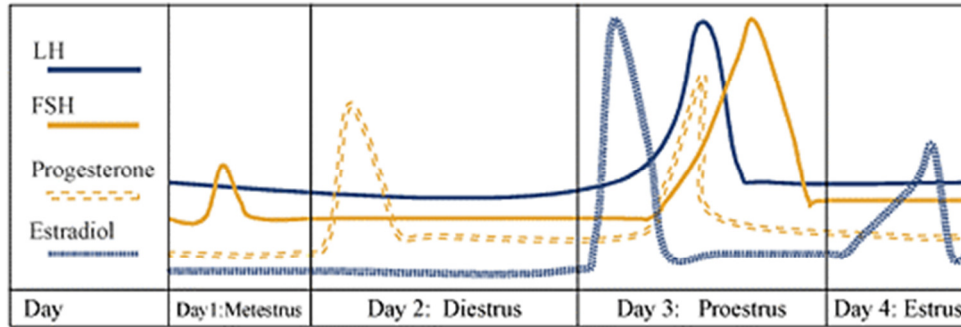


Figure showing different hormonal level during different estrous cycle stages

a. Proestrus

The first stage in the estrous cycle immediately before estrus characterized by development of both the endometrium and ovarian follicles.

b. Estrus

The second stage in the estrous cycle immediately before metestrus, it refers to the phase when the female is sexually receptive ("in heat"). Under regulation by gonadotropic hormones, ovarian follicles mature and estrogen secretions exert their biggest influence.

c. Metestrus

The third stage in the estrous cycle immediately before diestrus characterized by sexual inactivity and the formation of the corpus luteum.

d. Diestrus

The last stage in the estrous cycle immediately before the next cycle proestrus characterized by a functional corpus luteum and an increase in the blood concentration of progesterone

B. Menstrual cycle

The menstrual cycle is the cycle of natural changes that occurs (in the human fertile females and other female primates) in the uterus and ovary. The menstrual cycle is essential for the production of eggs, and for the preparation of the uterus for pregnancy. The cycle occurs only. In human females, the menstrual cycle occurs repeatedly between the age of menarche, when cycling begins, until menopause, when it ends.

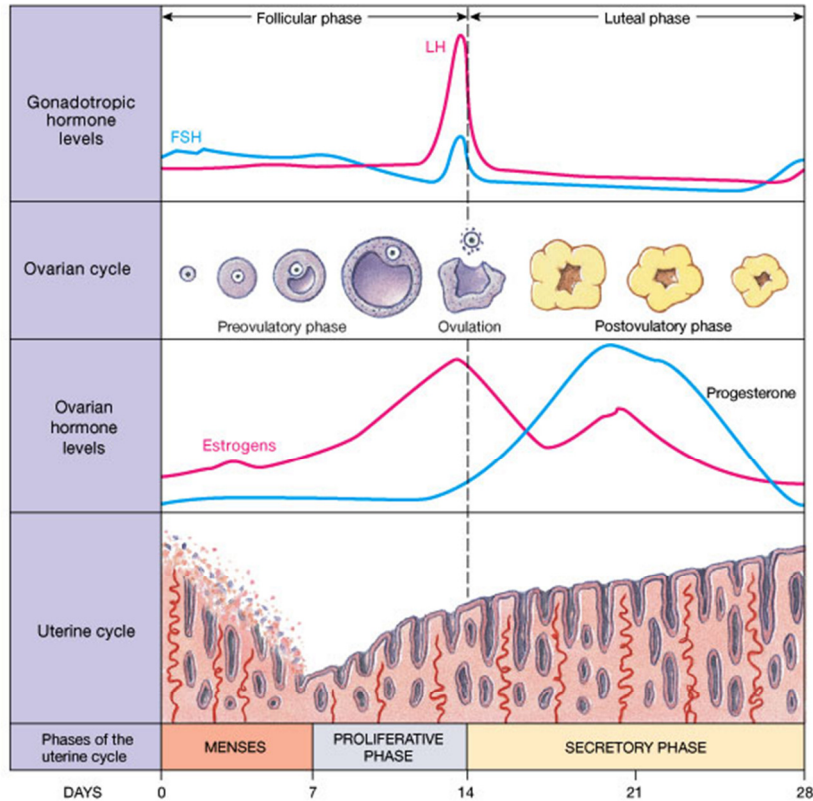


Figure showing different hormonal level during different menstrual cycle stages

It comprises of three ovarian and three uterine cycle phases:

Ovarian cycle phases:

1. Follicular phase

The follicular phase is the first part of the ovarian cycle. During this phase, the ovarian follicles mature and get ready to release an egg. Through the influence of a rise in follicle stimulating hormone (FSH) during the first days of the cycle, a few ovarian follicles are stimulated.

2. Ovulatory phase

Ovulation is the second phase of the ovarian cycle in which a mature egg is released from the ovarian follicles into the oviduct. During the follicular phase, estradiol suppresses production of luteinizing hormone (LH) from the anterior pituitary gland.

3. Luteal phase

The luteal phase is the final phase of the ovarian cycle and it corresponds to the secretory phase of the uterine cycle. During the luteal phase, the pituitary hormones FSH and LH cause the remaining parts of the dominant follicle to transform into the corpus luteum, which produces progesterone.

Uterine cycle phase:

1. Menstruation phase

Menstruation is the first phase of the uterine cycle.

2. Proliferative phase

The proliferative phase is the second phase of the uterine cycle when estrogen causes the lining of the uterus to grow, or proliferate, during this time. As they mature, the ovarian follicles secrete increasing amounts of estrogen.

3. Secretory phase

The secretory phase is the final phase of the uterine cycle and it corresponds to the luteal phase of the ovarian cycle. During the secretory phase, the corpus luteum produces progesterone, which plays a vital role in making the endometrium receptive to implantation.

Answer No.7.

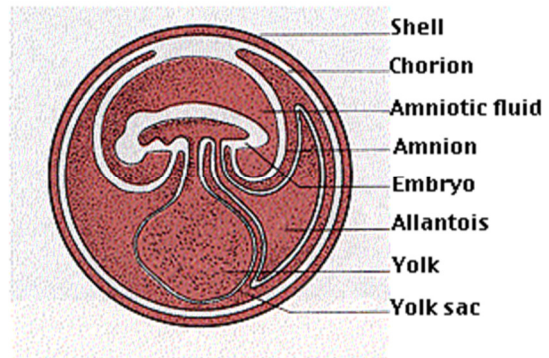
Extraembryonic membranes are membranous structures that appear in parallel with the embryo and play important roles in the embryonic development. They form from the embryo but do not become part of the individual organism after its birth.

The presence of each extraembryonic membrane varies according to the vertebrate class.

In fishes and amphibians only the yolk sac is present. In reptiles, birds and mammals besides the yolk sac there are also the amnion, the chorion and the allantois.

The embryos of reptiles, birds, and mammals produce 4 extraembryonic membranes, the

- amnion
- yolk sac
- chorion
- allantois



In birds and most reptiles, the embryo with its extraembryonic membranes develops within a shelled egg.

- The **amnion** protects the embryo in a sac filled with **amniotic fluid**.
- The **yolk sac** contains yolk — the sole source of food until hatching. Yolk is a mixture of proteins and [lipoproteins](#).
- The **chorion** lines the inner surface of the shell (which is permeable to gases) and participates in the exchange of O₂ and CO₂ between the embryo and the outside air.
- The **allantois** stores metabolic wastes (chiefly [uric acid](#)) of the embryo and, as it grows larger, also participates in gas exchange.

Amnion

- Surrounds the embryo in fluid-filled sac (Amniotic fluid)
- Innermost membrane

- Protects embryo (Shock absorption, Temperature fluctuations, Prevents desiccation)

Yolk sac

- Surrounds the yolk
- Uptake and modification of yolk lipids to lipoproteins
- Provides the nourishment required for embryonic growth

Chorion

- Surrounds the embryo
- Outermost membrane
- Chorion + Allantois = “exchange organ”
Oviparous -Gas exchange
Viviparous -Gas and nutrient exchange

Allantois

- Outpocketing of hindgut
- Waste removal
Removes metabolic wastes produced by the embryo “primitive bladder

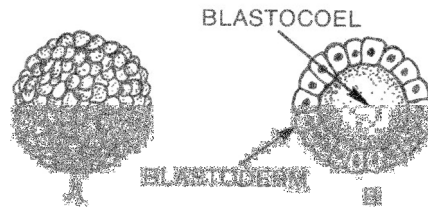
With these four membranes, the developing embryo is able to carry on essential metabolism while sealed within the egg. Surrounded by amniotic fluid, the embryo is kept as moist as a fish embryo in a pond.

Although (most) mammals do not make a shelled egg, they do also enclose their embryo in an amnion. For this reason, the reptiles, birds, and mammals are collectively referred to as the amniota.

Answer No. 8.

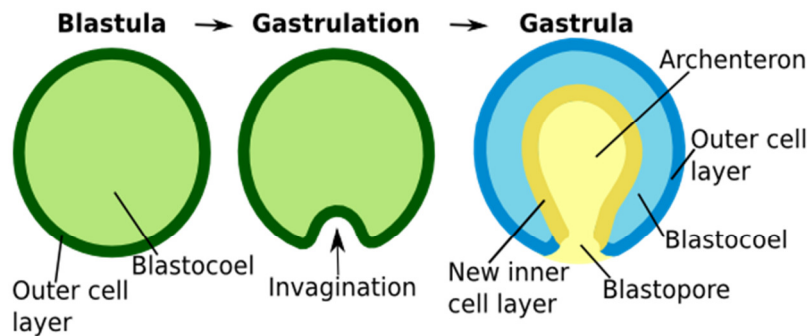
In all sexually reproducing coelomates, there are four main stages of embryogenesis, namely; fertilization, cleavage, gastrulation, and organogenesis. Fertilization is the fusion of haploid male and female gametes to form a diploid zygote. Zygote is the new cell, which is also known as fertilized ovum. In the process of cleavage, the zygote rapidly divides into many cells, without increasing the overall size of it and ends up with a structure called blastula.

Blastula



Blastula represents the first important stage after the fertilization and plays an important role in the development of organisms. It is a hollow, spherical, one celled thick structure formed by the process called blastulation. Both holoblastic and meroblastic cleavages give rise to blastula. The cavity inside the blastula is called blastocoel, and its outer single cell layer is called blastoderm.

Gastrula



The continuous development of blastula finally results the gastrula. The conversion process of the blastula into gastrula is called 'gastrulation'. Gastrulation is followed by the organogenesis. Gastrula is composed of three primary germ layers, which eventually give rise to organs in the late embryo. The primary germ layers are ectoderm, mesoderm, and endoderm. Ectoderm is the outermost layer of gastrula, which differentiates into skin, brain, spinal cord, and nerves of embryo. Mesoderm is the middle layer, which forms muscles, connective tissues, reproductive organs, cartilage, bones, and dermis of skin and dentine of teeth. Endoderm is the innermost layer of the embryo and basically differentiates into primitive gut.

Difference between Blastula and Gastrula

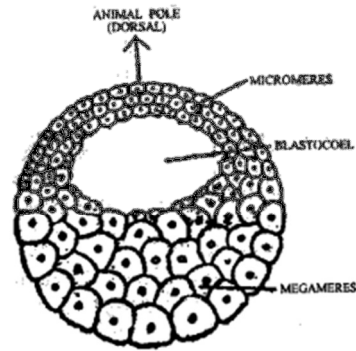
- (i) During the embryogenesis process, formation of blastula is followed by gastrula.
- (ii) Formation of blastula is called blastulation, whereas the formation of gastrula is called gastrulation.
- (iii) Rapid mitotic divisions of zygote results blastula while slow mitotic divisions of blastula results gastrula.
- (iv) During the formation of blastula, cells do not move, but during the formation of gastrula, cell masses move by morphogenetic movements.
- (v) Three primary germ layers are present in gastrula unlike in the blastula.

- (vi) Blastula is often called a pre-embryo, whereas gastrula is referred to as a mature embryo.
- (vii) Gastrula has more cells than blastula.
- (viii) Gastrula has differentiated cells, while blastula has undifferentiated cells.

Types of Blastula:

In chordate the blastula are of following type –

a. Coeloblastula

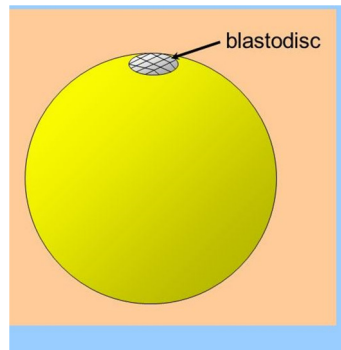


(Blastula of Telolecithal frog Eggs)

A blastula having cavity inside is called coeloblastula. It is formed through complete holoblastic cleavage. The blastoderm is formed of a single layer of cells. Its blastocoel is filled with mucopolysaccharide.

e.g. Echinoderms and Amphibians

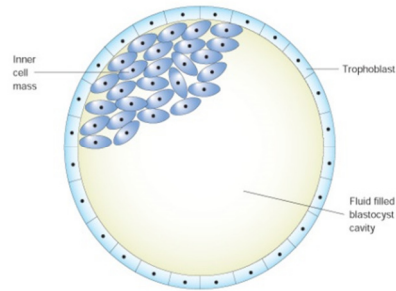
b. Discoblastula



It is formed as a result of discoidal cleavage. The blastocoel is small & it is called as subgerminal space. It is situated below the blastoderm.

eg. Bony fishes, reptile, birds & prototherian mammals.

c. **Blastocyst**



It is formed in mammals as a result of holoblastic cleavage.

Outer cells are called as trophoblasts or cells of Rauber. They form a trophoderm. This layer get attached to the uterine wall. Inner cells form the embryo are called as inner cell mass.

eg. Mammals (Human)