REPRODUCTION IN VERTEBRATES

Terms used in reproduction

1) **Oviparity:** animals deposit fertilized eggs in the external environment for development e.g. in all birds some reptiles and some fish.
2) **Ovoviviparity:** animals retain eggs in the mother's body to complete development, but embryos still obtain all of their nourishment from the egg yolk. The young are hatched from the mother's body when fully developed. E.g. in many reptiles and some fish
3) **Viviparity:** eggs develop to advanced stage in the mother's body and the embryo obtains nourishment directly from the mother's blood, rather than just from the egg yolk. E.g. in mammals
4) **Internal fertilization:** is where fusion of male and female gametes occurs inside the body of the female animal.
5) **External fertilization:** is where fusion of male and female gametes occurs outside the body of the female animal.
6) **Isolecithal eggs (Gr. *Isos*, equal, + *lekithos*, yolk):** eggs with very little yolk that is evenly distributed in the egg e.g. human eggs.
7) **Mesolecithal eggs (Gr. *mesos*, middle, + *lekithos*, yolk):** eggs with moderate amount of yolk concentrated in the vegetal pole e.g. in amphibians.
8) **Telolecithal eggs (Gr. *telos*, end, + *lekithos*, yolk):** eggs contain an abundance of yolk that is densely concentrated at the vegetal pole of the egg. E.g. in birds, reptiles, most fishes.
9) **Cleidoic eggs:** shelled eggs e.g. eggs of birds, reptiles
10) **Gametogenesis:** the series of transformations that result into the formation of mature gametes.
11) **Spermatogenesis:** the series of transformations that result into the formation of male gametes.
12) **Oogenesis:** the series of transformations that result into the formation of female gametes.
13) **Menopause:** a period when ovulation and menstruation cease in human females.

SEXUAL REPRODUCTION IN HUMANS

Mechanisms leading to fertilization and subsequent development in mammals are of evolutionary advantage to their success. Describe some of the mechanisms you consider are of evolutionary advantage.

- Fertilisation and development are internal to limit wastage of gametes and provide protection to the young respectively.
- The breeding seasons coincide with the breeding cycle so that birth occurs at a time when environmental conditions are most favourable for growth of young.
- Feeding young ones on nutritious milk enables them to prepare for adult food as the digestive system develops.
- Secondary sexual characteristics enable easy identification of mating partners
- Parental care provides protection from predation and harsh environmental conditions to the young.
- Development of placenta enables gaseous exchange and the young to excrete wastes.
- Females are often more receptive to males during ovulation or the act of copulation stimulating ovulation.

Main features of sexual reproduction in mammals

- Fertilisation is internal
- Females go through a sexual cycle known as menstrual cycle
- Sexual cycle is restricted to the breeding season, except in humans and other primates, which are sexually receptive throughout the year
- Young ones are born at an advanced stage.
- There is display of courtship behaviour that leads to mating.
- Development of embryo is internal and completely dependent on the mother for food and protection.
- The young are fed on milk
- Parental care to the young is prolonged

PRIMARY AND SECONDARY SEX ORGANS

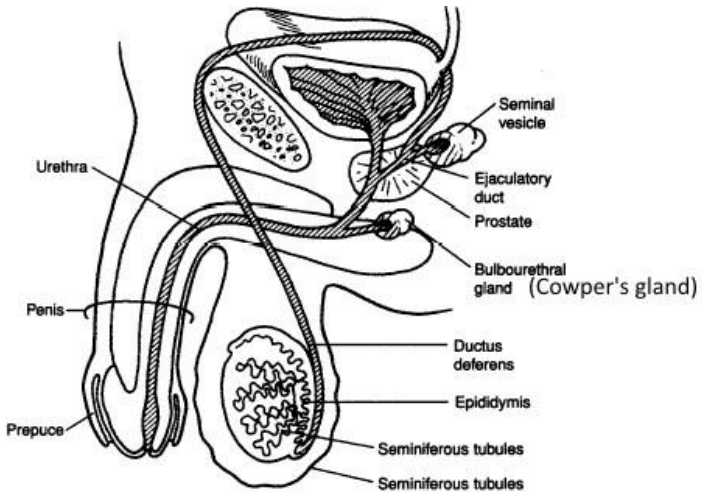
Primary sex organs: organs, which produce gametes and secrete sex hormones i.e. the gonads (testes in males and ovaries in females)

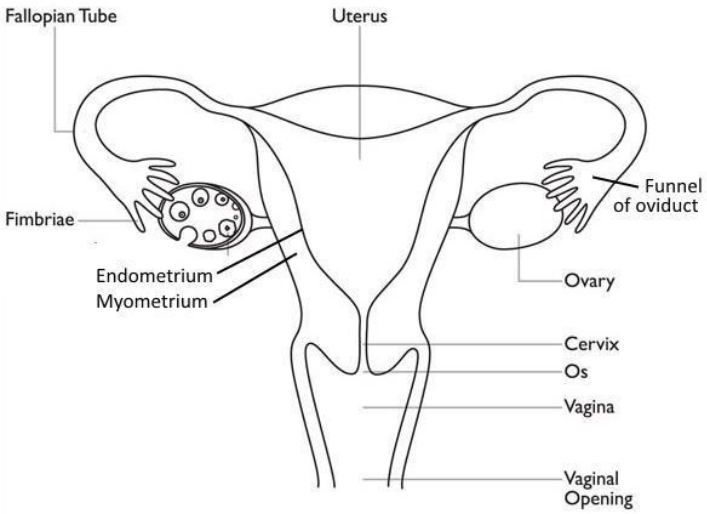
Secondary sex organs (accessory organs): organs associated with testes or ovaries which play some roles in reproduction but other than gamete production and hormone secretion. E.g. penis, prostate, seminal vesicles, sperm duct in males, and fallopian tubes, uterus, vagina, mammary glands in females.

Primary sex organs	Secondary sex organs
-Produce gametes -Secrete sex hormones -Development is under the control of FSH and LH	-Do not produce gametes - Do not secrete sex hormones -Development is under the control of Oestrogen and progesterone in females and testosterone in males

Accessory or external sex characters: are external characters, which do not play any direct role in reproduction but are distinct and enable sexes to be distinguished as male and female. E.g. low pitch voice and facial hair (males) and high pitch voice (females)

Structure of the human reproductive systems.

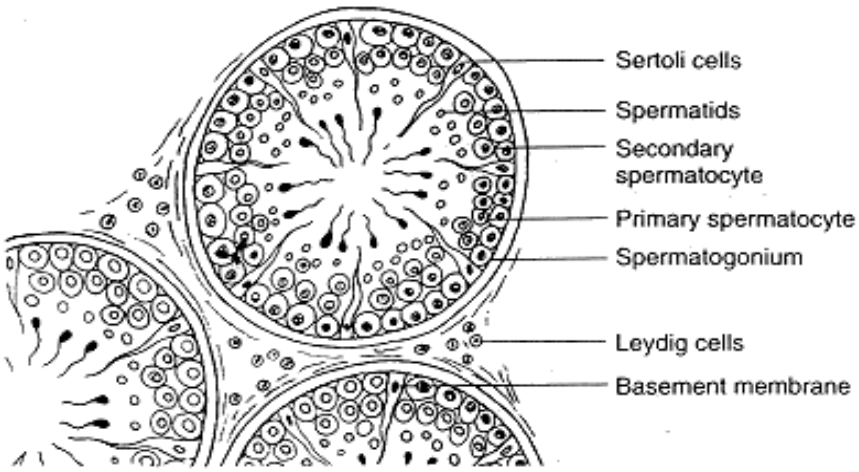


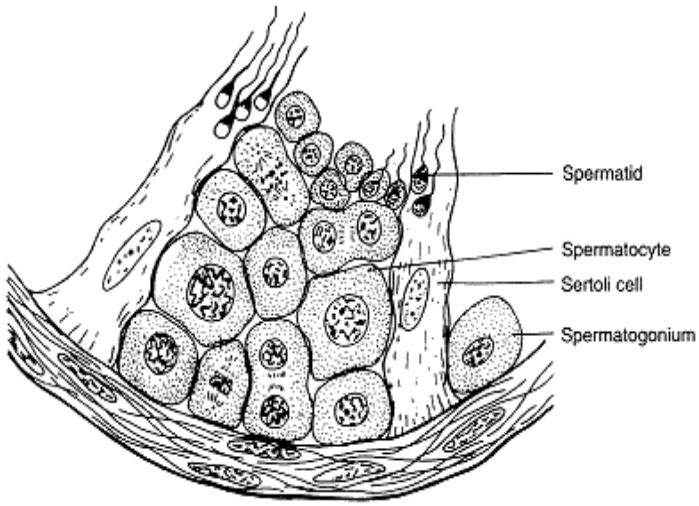


Functions of parts of the human reproductive systems

Male	***reproductive system***	***Female reproductive system***	
Part	**Function**	**Part**	**Function**
Penis	-Delivers sperm to the neck of the cervix, as close to the site of ovulation as possible.	**Ovaries**	-Are sites for egg production -Secrete the hormones oestrogen and progesterone.
Scrotum	-Regulates teste's temperature at 3^0C lower than body temperature for proper sperm formation. When cold, the cremaster muscle elevates the testes to absorb heat from the body, this's reversed at high temperature.	**Funnel of oviduct**	-The finger-like projections sweep the egg into oviduct.
Testes	-Contain seminiferous tubules that produce sperm. -Produce the male sex hormone testosterone.	**Oviducts (Fallopian tubes)**	-Walls are muscular and lined with ciliated epithelium for moving egg from ovary towards uterus.
		Uterus	-Site of implantation of fertilized egg, development of foetus during pregnancy and origin of muscular contractions that precede parturition.

Prostate gland	-Secretes an alkaline fluid that neutralizes the acidic vaginal secretions to avoid reduction in sperm motility at low PH.	**Vagina**	-Passage for menstrual flow, receptacle for penis during coitus and lower part of birth canal.
Seminal vesicles	-Secrete an alkaline mucous fluid rich in fructose-the respiratory substrate for sperm motility.	**Clitoris**	-Tactile stimulation excites the female sexually during intercourse.
Cowper's (bulbourethral) gland	-Produces a mucous secretion for lubricating the penis during intercourse and neutralizing the acidity of any remaining urine.	***Labia minora* and *Labia majora***	-Produce a lubricant mucus secretion during intercourse and protect the clitoris from abrasion.
Epididymis	-Sperm maturation site (1-10 days). -Stores spermatozoa (up to 4wks)		
Vas deferens	-Stores sperm (up to many months) before ejaculation.		





Main events during Spermatogenesis

Spermatogenesis is the process by which spermatogonia in seminiferous tubules of testes develop into sperm that can leave the male's body.

Phases	Processes
Multiplication phase	At puberty, diploid germinal epithelial cells (primordial germ cells) of seminiferous tubules undergo repeated mitotic divisions to form a number of diploid **spermatogonia**.
Growth phase	Each **spermatogonium** increases in size and becomes a **primary spermatocyte**.
Maturation phase	Each primary spermatocyte undergoes the **first meiotic division** to form two **haploid secondary spermatocytes**, which undergo **second meiotic division** to form four **haploid spermatids**, connected to each other by cytoplasm. The spermatids get embedded into **sertoli cells** (loosely called "**nurse cells**") to be transformed into sperm by: i) Losing part of cytoplasm ii) Condensation of nucleus into head. iii) Formation of flagellated tail. The mature spermatozoa (sperms) finally detach from sertoli cells and are released into the lumen of seminiferous tubules.

Functions of sertoli (sustentacular) cells:

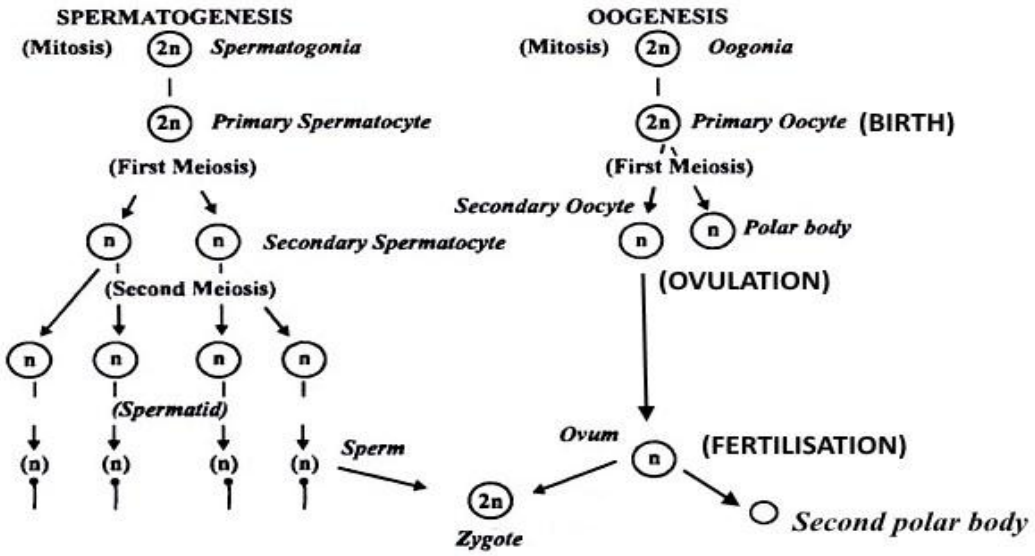
i) Provide nourishment to developing spermatids.
ii) Phagocytise (eat off) the cytoplasm of spermatids.
iii) Secrete a fluid that carries spermatids through the tubules.
iv) Phagocytise foreign particles that invade the tubules

Development of ova in humans

Oogenesis is the production of eggs in the ovary of females

Phases	Processes
Multiplication phase	During embryonic development, diploid oogonia (germinal epithelial cells of ovary) undergo repeated mitotic divisions to increase in number
Growth phase	Some oogonia undergo mitosis to form **primary oocytes**, which remain at prophase I of meiosis, while the rest (now called **follicle cells/granulosa cells**) enclose the primary oocytes.
Maturation phase	At puberty, granulosa cells multiply to form **primary follicle** & other cell layers around the primary oocyte. -The primary oocyte undergoes meiosis up to metaphase II only to form a **secondary oocyte** and 1st **polar body** The primary follicle develops to form fluid filled **secondary follicle** and later **Graafian follicle,** which enclose **secondary oocyte** & **1st polar body.** -At fertilization, the secondary oocyte completes meiosis II to form a large **ootid (ovum)** and **second polar body.** -The first polar body also undergoes meiosis at the same time to form two small polar bodies. -All the three polar bodies degenerate and only one functional egg remains

Note: The egg released from the Graafian follicle during ovulation is a secondary oocyte, which has undergone meiosis up to metaphase II only. Meiosis II is completed at the time of fertilization and turns the secondary oocyte into an egg



Significance of formation polar bodies during oogenesis.

- Polar bodies take the extra chromosomes resulting from meiosis in order for the ovum to carry haploid number of chromosomes.
- The unequal cytoplasmic division results into the formation of a large egg with the cytoplasm containing sufficient yolk for the development of the embryo.

Comparison of spermatogenesis and oogenesis in humans

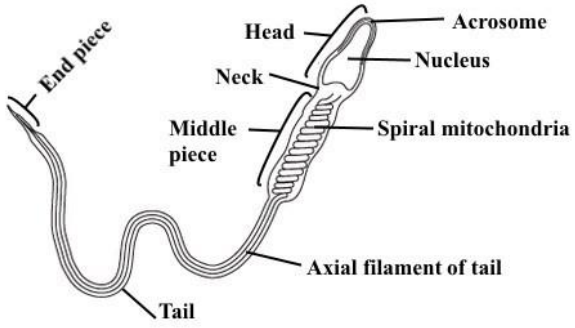
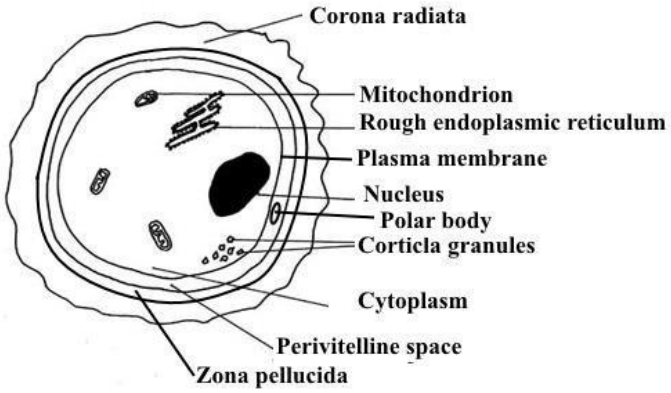
Similarities:

- Both begin with diploid germinal epithelial cells
- Mitosis and meiosis are involved in both
- Both yield haploid gametes
- Both occur in gonads

Differences:

Spermatogenesis	*Oogenesis*
• Occurs in seminiferous tubules in testes of males.	• Occurs in ovaries of females
• Begins only at puberty.	• Begins during embryonic development. A baby girl is born with the set number of primary oocytes already in prophase stage of 1st meiotic division.
• It is a continuous process and occurs all the time	• It is a discontinuous process, only one egg matures in about 28 days.
• During growth phase, primary spermatocyte shows only double the increase	• Primary oocyte may show the increase of about four to eight times.
• Four spermatids are formed from one primary spermatophyte	• Only one ovum is formed from one primary oocyte.
• Equal cytoplasmic divisions during meiosis I and meiosis II and no formation of polar bodies.	• There is unequal cytoplasmic division during meiosis I and meiosis II and resulting into formation of polar bodies.
• All stages are completed and sperms are formed in the testes only	• The secondary oocyte leaves the ovary and final second meiotic division at fertilization in the fallopian tube.
• Male gamete or sperm is comparatively very small.	• Female gamete is very large comparatively.
• Spermatid undergoes spermiogenesis to become sperm.	• No such stage after the formation of ootid or ovum
• Takes a longer time to complete	• Takes a shorter time to complete

Structure of human male and female gametes

Male gamete	*Female gamete*
	

Functions of the parts of gametes

Human spermatozoon:

Acrosome: Contains hydrolytic enzymes which facilitate the penetration of the egg membranes prior to fertilization.

Nucleus: Contain a haploid set of chromosomes, which on fusion with the egg restores the diploid state of organisms.

Mitochondria: They complete aerobic to release ATP required for contraction of filaments during the sperm's movement.

Tail piece (Flagellum): Enables motility of the sperm.

Human ovum:

Yolky cytoplasm: Contains fat and protein which nourish the developing embryo.

Cortical granules (lysosomes): Contain enzymes that alter the structure of vitelline membrane to prevent polyspermy at fertilization, to avoid upsetting the diploid state of the zygote.

Vitelline membrane: Undergoes structural changes that prevent polyspermy at fertilisation

Nucleus: Contains 23 chromosomes that complete meiosis II at fertilization to provide female haploid nucleus

Polar body: Contains 23 chromosomes, but is non-functional and degenerate

Hormonal control of spermatogenesis in humans.

- Interaction of hormones from the hypothalamus and anterior pituitary gland working together controls spermatogenesis.
- From the hypothalamus, **gonadotrophin-releasing hormone (GnRH)** stimulates the anterior pituitary gland to secrete two gonadotrophins (gonad stimulating hormones), i.e. **follicle stimulating hormone (FSH)** and **luteinising hormone (LH)/interstitial cell stimulating hormone (ICSH).**
- **FSH** stimulates spermatogenesis by causing sertoli cells to complete the development of spermatozoa from spermatids.
  FSH also causes sertoli cells to release a peptide hormone **inhibin** that specifically inhibits **FSH** secretion.
  LH (ICSH) stimulates the leydig cells (interstitial cells) of the testes to secrete **testosterone.**
- **Testosterone** stimulates the growth and development of germinal epithelial cells (spermatogonia) to form sperm, and also works with **FSH** to stimulate the sertoli cells.
- However, increased **testosterone** level inhibits the secretion of **GnRH** and **LH.**

The general name for male sex hormones is **androgens** (e.g. testosterone), while **oestrogens** are the female sex hormones. Both androgens and oestrogens are present in male and female mammals, but in different proportions so that the degree of 'maleness' or 'femaleness' is variable depending upon the balance between the levels of androgens and oestrogens in the body.

a) (i) Distinguish between oestrous and menstrual cycles.

ii) Outline the four main phases of the menstrual cycle

b) Describe the hormonal, physiological and structural changes that occur during the human menstrual cycle.(hormonal control of menstrual cycle)

a) (i) **Oestrous cycle:** series of hormone controlled changes in the non-primate reproductive cycle characterized by females experiencing a period of heightened sexual excitement just before ovulation.

Menstrual cycle: series of hormone controlled changes in the primate female reproductive system that result in monthly discharge of blood and uterine materials when fertilization fails.

ii) **The four main phases of the menstrual cycle:**

–Follicular phase

-Ovulation

-Luteal phase

-Menstruation

HORMONAL CONTROL OF MENSTRUAL CYCLE

At puberty (about 12 years) the hypothalamus:

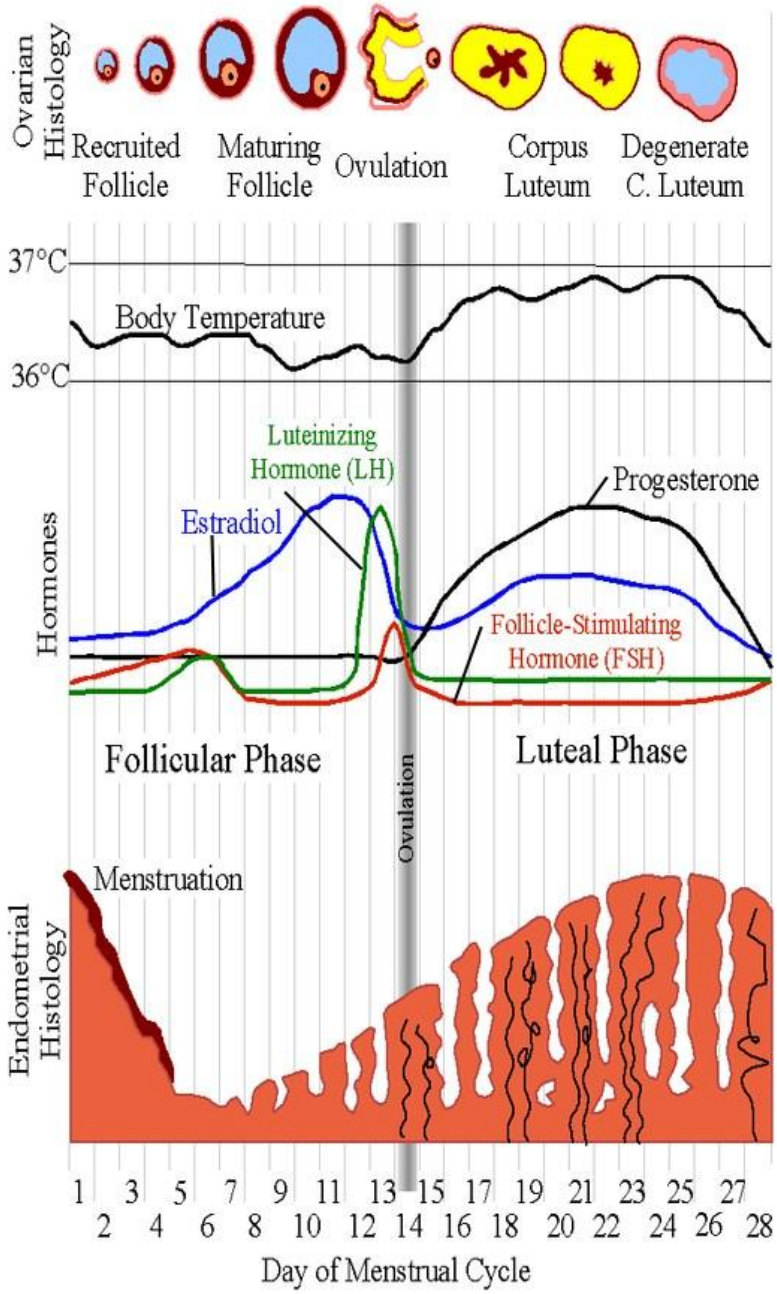
1) Secretes **Gonadotrophin-releasing hormone (GnRH)** which stimulates the anterior pituitary to secrete **follicle stimulating hormone (FSH).**
2) **FSH** stimulates:
   - The development of primary follicles in the ovary
   - The secretion of **oestrogen.**
3) **Oestrogen:**
   - Causes the repair and healing of the uterine wall following menstruation.
   - Inhibits the secretion of **FSH.**
   - Causes the secretion of **LH** from the anterior pituitary.
4) **LH** stimulates:
   - **Ovulation** i.e. Meiosis I resumes in the primary oocyte to form polar body and secondary oocyte, which is released by rupturing of Graafian follicle.
   - The remains of Graafian follicle to develop into **corpus luteum** (yellow body),
   - The **corpus luteum** to secrete **progesterone** and o**estrogen**.
5) **Progesterone:**
   - Causes increased thickness (muscularisation) and vascularization of the uterus.
   - Inhibits the release of **LH** and **FSH** by negative feedback.

   Decreased level of **FSH** prevents development of Graafian follicles, hence secretion of **oestrogen** stops.

   Decreased level of **LH** prevents ovulation, hence the corpus luteum degenerates and **progesterone** decreases.

   The sudden decrease of progesterone level in blood completes menstrual cycle, as the hypothalamus resumes the secretion of **GnRH**.

   GnRH stimulates the anterior pituitary to secrete **FSH** as menstruation occurs, characterized by breakdown and shedding of endometrial materials.



Briefly explain the following processes and state the significance of each.
(a) Sperm capacitation (b) Acrosome reaction (c) Fast block (d) Cortical reaction

Process	***Explanation***	***Significance of the process***
Sperm capacitation	The process of activation of mammalian sperm to fertilise the egg, during which the acidity and enzymes in the female genital tract cause perforation of the sperm head by removal of cholesterol and glycoprotein to allow entry of Ca^{2+} and the release of acrosome enzymes.	Entry of Ca^{2+} increases the beating activity of the sperm tail and also promotes acrosome reaction to enable sperm penetrate the egg.

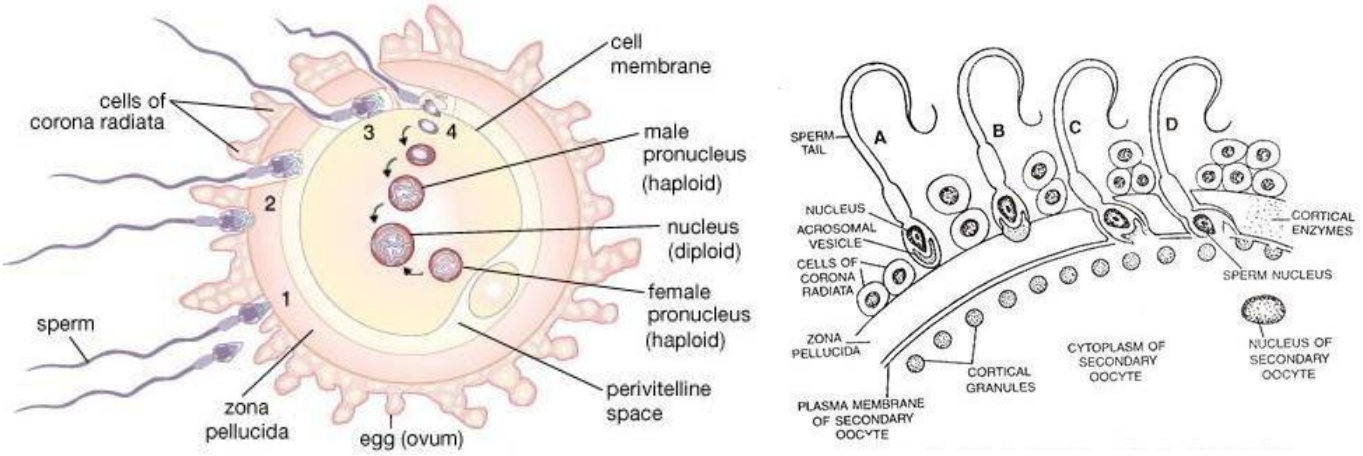
Acrosome reaction	A process that occurs in the sperm head on making contact with a secondary oocyte, during which the cell and acrosome membranes rupture to release hydrolytic enzymes e.g. hyaluronidase and proteases.	Enables sperm head to penetrate the egg membranes.

Fast block	A process during which contact of the **first sperm** with the egg membrane is instantly followed by an electrical potential change in the egg membrane to prevent entrance of more than one sperm.	Prevents entrance of more than one sperm into the egg (polyspermy) that would upset the diploid state of the embryo.
Cortical reaction	A process that occurs following sperm penetration of the secondary oocyte during which lysosomes (cortical granules) fuse with the plasma membrane and release their contents, causing the vitelline membrane to harden and form the **fertilization membrane** to prevent **polyspermy**	Formation of fertilization membrane prevents multiple sperm entry into the egg (polyspermy) that would upset the diploid state to cause death of mammalian embryo.

Outline the events which lead to fertilization of an egg by a sperm.

Fertilization is the fusion of sperm and egg nuclei to form a diploid zygote.

- On entering the vagina, sperm spend about 7 hours being **capacitated**, after which they move towards the oviducts, aided by muscular contractions of the uterus and oviducts, and lashing of tail.
- A spermatozoon comes into contact with the oocyte by random movement.
- Acrosome enzymes hydrolyse a path in the granulosa layer of egg until the sperm head makes contact with zona pellucida.
- Sperm acrosome membrane ruptures to release hydrolytic enzymes (**acrosome reaction)** and the acrosomal filament pierces through the oocyte membranes up to the plasma membrane of the oocyte.
- An electrical potential change in the oocyte membrane occurs **(fast block),** followed by fusion of cortical granules with plasma membrane to discharge their contents **(cortical reaction),** which creates an osmotic gradient that draws water into the space between the plasma membrane and vitelline membrane.
- The two membranes are lifted away and the vitelline membrane hardens (**fertilization membrane)** to block polyspermy.
- While the sperm tail is lost and disintegrates, the nucleus expands and is now known as **pronucleus.**
- Entry of a sperm stimulates completion of second meiotic division of the secondary oocyte to form the second polar body, which disintegrates, and an egg. The haploid **male and female pronuclei** fuse to form a **diploid zygote**, which divides immediately by mitosis to form two diploid cells.



Outline the events that occur in the egg immediately following the entry of the spermatozoon.

- Sperm acrosome membrane ruptures to release hydrolytic enzymes and the acrosomal filament pierces through the oocyte membranes up to the plasma membrane of the oocyte.
- An electrical potential change in the oocyte membrane occurs followed by fusion of cortical granules with plasma membrane to discharge their contents which creates an osmotic gradient that draws water into the space between the plasma membrane and vitelline membrane.
- The two membranes are lifted away and the vitelline membrane hardens to block polyspermy.
- While the sperm tail is lost and disintegrates, the nucleus expands and is now known as **pronucleus.**
- Entry of a sperm stimulates completion of second meiotic division of the secondary oocyte to form the second polar body, which disintegrates, and an egg.
- The haploid **male and female pronuclei** fuse to form a **diploid zygote**, which divides immediately by mitosis to form two diploid cells.

a) What is meant by negative feed back

b) Briefly explain how negative feedback operates in the control of:

i) Testicular hormone secretion

ii) The menstrual cycle

c) What hormonal controlled changes occur in the endometrium during the menstrual cycle? (Effect of ovarian hormones on the endometrium during the menstrual cycle)

a) A mechanism in which the effect of deviation from the normal condition triggers a response that eliminates its deviation in order to reduce further corrective action of the control system once the set point value has been reached.

b) (i)-The hypothalamic hormone, **gonadotrophin-releasing hormone (GnRH)** stimulates the anterior pituitary gland to secrete both **follicle stimulating hormone (FSH)** and **luteinising hormone (LH).**

-FSH stimulates spermatogenesis by causing sertoli cells to complete the development of spermatozoa from spermatids.

FSH also causes sertoli cells to release a peptide hormone **inhibin** that specifically inhibits **FSH** secretion.

-**LH** stimulates leydig cells of the testes to secrete **testosterone.**

- Testosterone stimulates the growth and development of spermatogonia to form sperm, also inhibits the secretion of **LH** by feeding back, both directly at the anterior pituitary gland and indirectly by reducing **GnRH** release**.** ii) -The hypothalamic **Gonadotrophin-releasing hormone (GnRH)** stimulates the anterior pituitary to both **FSH** and **LH.**

-FSH stimulates the secretion of **oestrogen** in the ovary.

-Oestrogen in increased levels inhibits **FSH** secretion and causes secretion of **LH** from the anterior pituitary. -**LH** stimulates ovulation and development of **corpus luteum,** which secretes **progesterone** and also continues to secrete o**estrogen**.

-**Progesterone** inhibits the release of **LH** and **FSH** thus arresting development of any further follicles**.**

c) Hormonal control of changes in the endometrium during the menstrual cycle

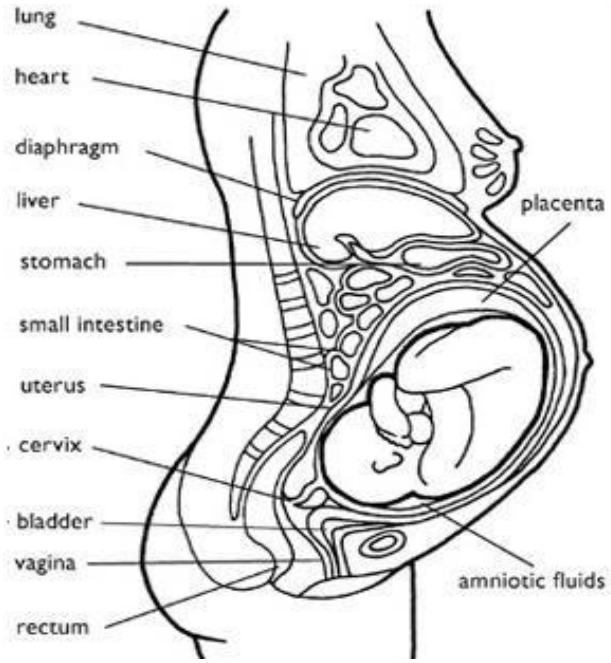
-During the follicular phase, oestrogen (estradiol) from the ovary causes the uterine endometrium to repair and heal.

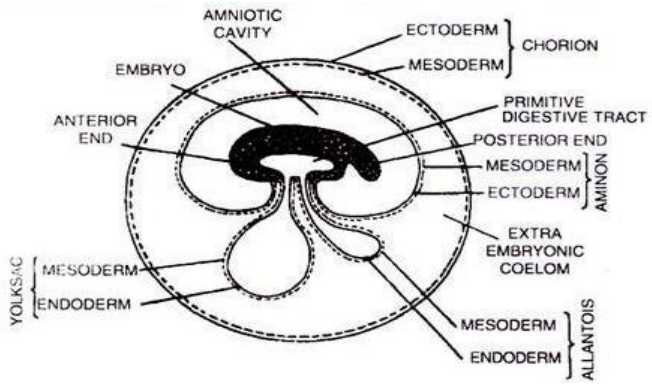
-During the luteal phase, progesterone secreted by the corpus luteum in the ovary causes the endometrium to become highly muscular and vascular.

-As the corpus luteum degenerates, the rapid fall in oestrogen and progesterone levels at the end of the cycle causes the endometrium to be sloughed off in menstruation.

PREGNANCY (GESTATION)

This is the period between conception (fertilisation) and birth.





Highlights of human pregnancy

30 hours after fertilization**: f**irst cleavege

3-4 Days after Conception:

(i) The zygote, now called **morula** arrives at the uterus after a 4 inch journey through the fallopian tube.

(ii) In the uterus the morula burrows itself into the endometrium (inner lining of uterus).

(iii) The outside cells of the morula eventually grow to form the placenta.

6-7 Days after Conception

The morula, now called **blastocyst** attaches to the uterus, causing some women to feel **implantation cramps.**

7-9 Days After Conception

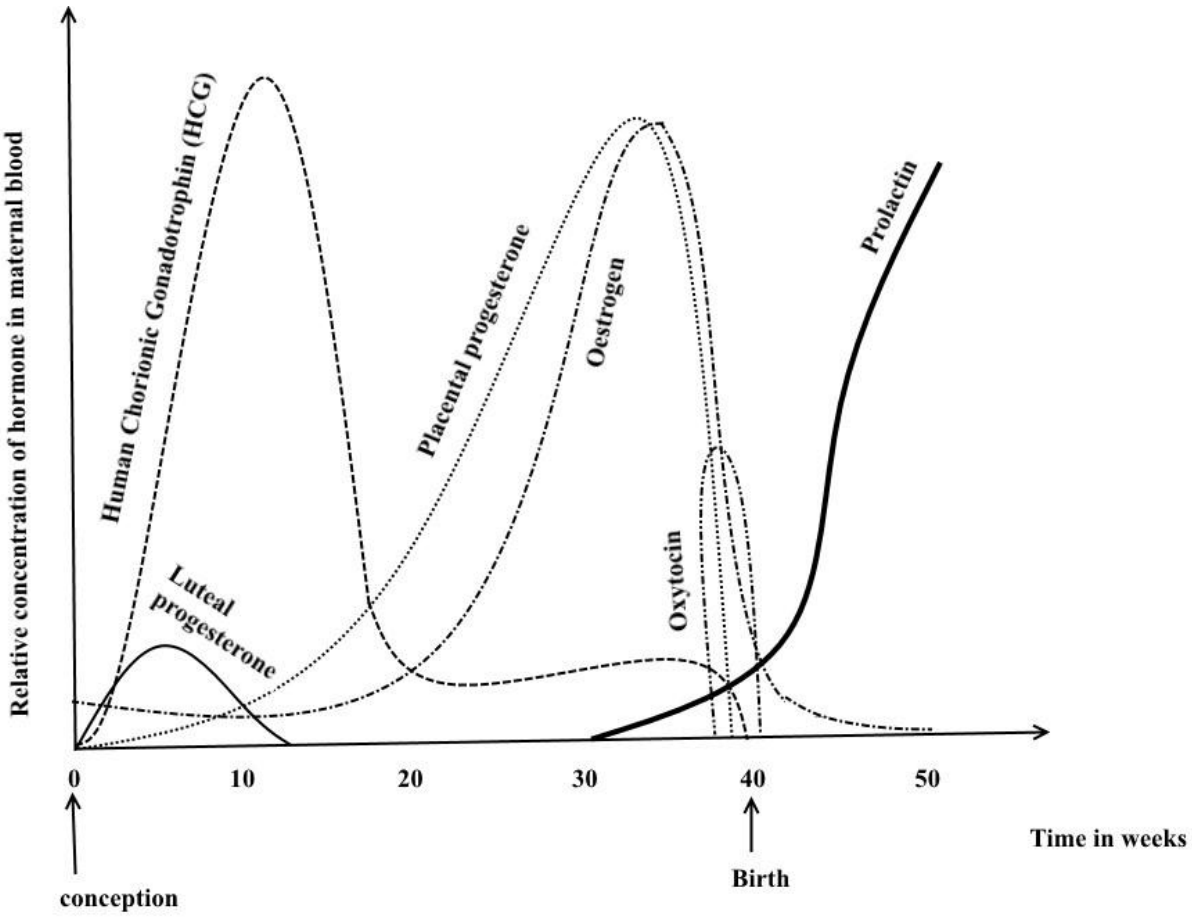
(i) **Pregnancy** tests can detect the levels of **HCG** (human Chorionic Gonadotropin) hormone in the body.

(ii) **HCG**, a protein hormone, is first produced in the second week of gestation to prevent menstruation and is most concentrated at 8 weeks gestation. Levels gradually decline after the 8th week.

Duration	Major events
2 weeks	Most women can test positive for HCG urine pregnancy tests, at 95% accuracy.
3 weeks	Baby-in-the-making is a ball of cells called a **blastocyst. Gastrulation** occurs.
4 weeks	Organogenesis
5 weeks	Heart begins to beat – at twice the rate of adults.
6 weeks	Facial features (e.g. **eyes and nostrils**) begin to form, and little buds appear where arms and legs will develop
8 weeks	Arms and legs are growing, as well as a **nose** and **upper lip** are formed. Notochord degenerates.
9 weeks	**Eyes** have developed, though eyelids are still fused and shut.
10 weeks	The embryo has become a **foetus**. Vital organs – such as **kidneys, intestines, brain, and liver** – are starting to function. Tiny **fingernails** and **toenails** are forming.
11 week	Foetus is almost fully formed. **Bone templates** are formed, **external genitalia** are developing.
12 week	Baby's heartbeat can be felt.
14 week	Kidneys can release urine into the amniotic fluid.
15 weeks	Baby can see light that filters in from outside the womb, even though the eyelids are still shut

16 weeks	Baby's sex can be detected.
19 weeks	Baby can hear mother's heartbeat and sounds that come from outside the body, such as father's voice.
23 weeks	Baby's sense of movement has developed, so s/he can feel the motion if mother dances.
27 weeks	Baby can "practice breathing" by inhaling and exhaling amniotic fluid, and also open and close eyes.
34 weeks	Baby is now considered full-term, lungs can work fine if born now.
40 weeks	Baby is due and fully ready for life outside the womb.

Hormonal control of pregnancy
Changes in hormonal concentration during pregnancy



EXPLANATION FOR OBSERVATIONS

Hormone	Observations (Description)	Explanation
HCG (pregnancy hormone)	(a) Concentration very low at conception, (b) HCG Concentration increases rapidly at about 1 - 2 weeks after fertilization to a maximum at about 10 - 11 weeks of gestation. (c) HCG concentration decreases rapidly to a minimum at about 19 – 20 weeks, and remains relatively constant after the 20th week until about 40th week when it drops to zero.	(a) Before conception, HCG is secreted by the anterior pituitary and functions in a Luteinizing Hormone-like manner to promote ovulation and progesterone production during the menstrual cycle. (b) At implantation, trophoblast cells secrete HCG to: (i) Maintain the corpus luteum. (ii) Stimulate the corpus luteum to continue secreting oestrogen and progesterone. (iii) Cause the blockage of any immune or macrophage action by mother on foreign invading placental cells. (iv) Cause uterine growth parallel to fetal growth. (v) Suppress any contractions by uterine wall during the course of pregnancy. (vi) Cause growth and differentiation of the umbilical cord (c) As the embryo grows, the placenta increases in size causing increased secretion of progesterone, which takes over some of the roles of HCG causing its secretion to decreases. A decrease in HCG causes degeneration of corpus luteum. At the 40th week the foetus is expelled therefore HCG secretion stops.
Progesterone "pro-gestational" hormone		
(a) Luteal progesterone	There is a slight rise to a maximum at about 4-6 weeks after conception followed by a rapid decrease thereafter to zero at 11 – 12 week.	Corpus luteum secretes luteal progesterone after ovulation, to ensure that the lining of the uterus stays intact and provides a nourishing environment for the egg to implant and develop. Without luteal progesterone, the lining of the uterus would slough off, ending the pregnancy.
(b) Placental progesterone	(i) Absent at conception. (ii) Concentration increases first slowly upto about 8-10 weeks, then rapidly to a maximum just before birth (40th week).	As the corpus luteum and ovaries become inactive in the later stages of pregnancy, progesterone secretion is by the placenta. As the pregnancy progresses, there is increased growth of the placenta, causing increased secretion of placental progesterone which: (i) Inhibits contraction of the myometrium (promotes relaxation) (ii) Increases mucus secretion in the cervix of the womb, forming a protective plug (promotes glandular activity in uterus) (iii) Stimulates growth of maternal part of placenta. (iv) Stimulates enlargement of the uterus. (v) Inhibits FSH release, thus prevents ovulation and menstruation. (vi) Causes enlargement of the breasts and growth of mammary glands.

		NB: After a meal, progesterone levels drop greatly (about 50%), explaining why blood test should be done early morning and before eating.
Oestrogen	(i) Concentration very low at conception (ii) Concentration remains relatively constant from conception to about 12 weeks. (iii) Concentration increases rapidly after 12 weeks to a maximum just before birth.	After ovulation, **Oestrogen** is initially secreted by the corpus luteum up to 12 weeks, hence the low and constant concentration. Afterwards, placenta takes over oestrogen secretion, therefore increased growth of the placenta causes increased secretion of oestrogen which: (i) Inhibits secretion of FSH (Follicle Stimulating Hormone) and LH (Lutenising hormone), both of which are involved in ovulation. (ii) Causes growth of the uterus and increases the sensitivity of the uterus to the hormone **oxytocin** which is involved in the processes of **birth** and **lactation**. (iii) Inhibits the secretion of prolactin, and thus inhibits lactation during pregnancy. (iv) Stimulates the development of mammary glands in preparation for lactation after the baby has been born. (v) Causes softening and relaxing of the ligament of the pelvic girdle.
Prolactin and Oxytocin	(i) Not secreted until after the 30th week. (ii) Prolactin secretion starts at about 31-32 weeks and increases, first slowly up to about 42 week then rapidly thereafter.	High levels of oestrogen and progesterone inhibit the secretion of **Prolactin** from the **anterior lobe of pituitary gland** and **Oxytocin** from the **posterior pituitary** until birth. When levels of Oestrogen and Progesterone decrease after birth, **prolactin** causes lactation. Towards parturition (birth), high levels of oestrogen promote uterine contractions and increased sensitivity of uterine wall to **oxytocin**, which causes the uterine muscle (myometrium) to contract.
Relaxin	Relaxin peaks during the 14 weeks of the first trimester and at delivery	Causes increased: (i) Relaxation of ligaments, softening of cervix and inhibition of muscle contractions. (ii) Cardiac output, renal blood flow, and arterial compliance.

a) Give an account of the role of the placenta as an endocrine organ in mammals.

b) How is a placenta suited for providing the developing foetus with nutrients?

a) The role of the placenta

As an endocrine organ:

It secretes various hormones which control development of the foetus:

- **HCG (human chorionic gonadotrophin)** causes the corpus luteum to continue secreting progesterone and oestrogen necessary for endometrial development for the first 3-4 months of pregnancy.
- **Oestrogen** prevents ovulation and menstruation, stimulates growth of mammary glands and increase in uterine muscle cells, and increases myometrium sensitivity to oxytocin
- **Progesterone** also stimulates growth of mammary glands, inhibits the contraction of uterine muscles and inhibits the release of **prolactin** (a hormone that stimulates milk production).

Relaxin hormone relaxes the connective tissue in pelvic girdle to enlarge the cervix in preparation for birth.

As a non-endocrine organ

- Digested food and other nutrients are transported through umbilical vein to link up with the foetal blood
- Waste foetal products diffuse from umbilical artery to maternal blood.
- Oxygen diffuses from umbilical vein to the foetal blood while carbondioxide moves in opposite direction.
- Antibodies cross the placenta from mother to foetus hence providing means by which **passive immunity** is acquired.
- It serves as a barrier to the transfer of solutes and blood components from maternal to foetal circulation.
- It prevents direct contact of maternal and foetal blood systems enabling them to operate at different pressures

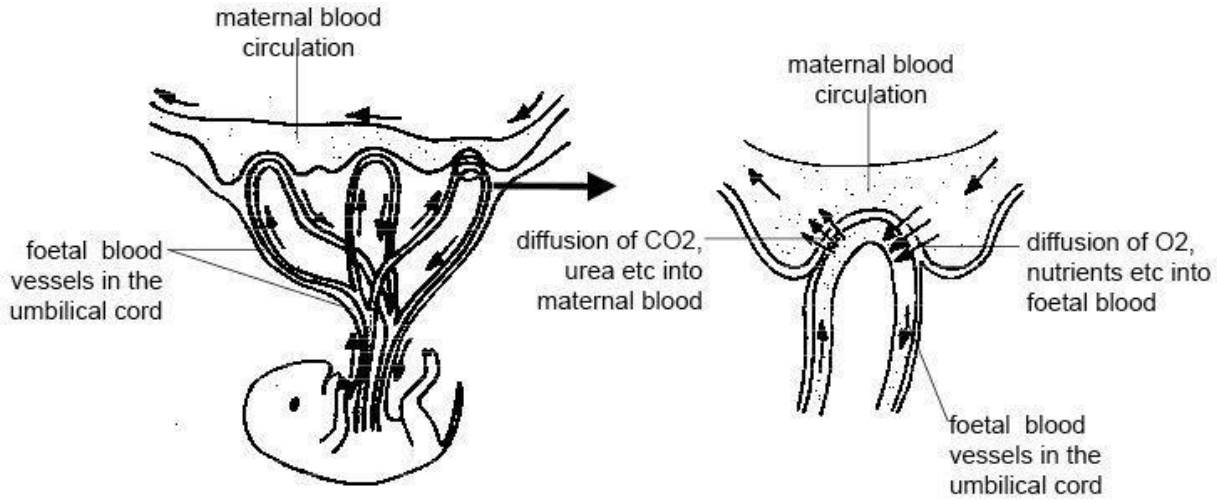
b) **How placenta is suited for providing the developing foetus with nutrients:**

-The finger-like projections which grow into the endometrium increase the surface area for exchange of substances.

-Closeness of maternal and foetal blood vessels facilitates faster diffusion of substances.

-Continuous flow of blood at the placenta ensures replacement of substances to maintain diffusion gradients for easy diffusion of these materials.

-Chorionic villi cells contain numerous mitochondria to provide energy required for active transport.



THE BIRTHING PROCESS (PARTURITION)

The time leading up to the normal birthing process is generally 266 days (38 weeks) - from conception to birth. However, only about 5% of births occur on the actual due date.

Outline the stages in the process of parturition (birth)

-The onset of birth is triggered by decreased progesterone and increased oestrogen levels during the last stages of pregnancy.

-The posterior pituitary produces **Oxytocin,** which causes contraction of the uterus that increase in force and frequency.

-Cervix dilates to allow passage of baby's head into the vagina while embryonic membranes rupture.

-Foetus is expelled in down face position, followed by afterbirth (umbilical cord and placenta) expulsion.

a) Distinguish between contraception and birth control.

Contraception: use of methods which act to prevent fertilization of an egg by sperm.

Birth control: a wide range of methods that prevent development of egg into foetus, whether it is already fertilized or not.

b) Give an outline of birth control methods in man

Birth control methods

Method	***How it works:***
Barriers preventing sperm from reaching egg cell	-Inserted on erect penis or into vagina before sexual intercourse
a) Condom (for males and females)	
b) Diaphragm (cap)	-Inserted into vagina before sexual intercourse
c) Spermicide	-Cream, foam or gel placed into vagina to kill sperm

Hormones that interfere with ovulation or implantation a) Pill b) Morning after pill (emergency pill)	-Combination of oestrogen and progesterone prevents ovulation and implantation -Used within 48 hours after sex.
Behavioural a) Rhythm method b) Penis withdrawal (coitus interruptus)	Sex is avoided during ovulation period Penis is withdrawn from vagina before ejaculation occurs
. Surgical a) Vasectomy (males) b) Ligation of oviducts	Sperm duct is cut and tied permanently -Both oviducts are cut and tied permanently
Other e.g. intra-uterine device (IUD), plastic or copper device	Prevents implantation

INFERTILITY

Infertility is the failure of a couple to conceive a pregnancy after trying to do so for at least one full year.

Primary infertility is when pregnancy has never occurred.

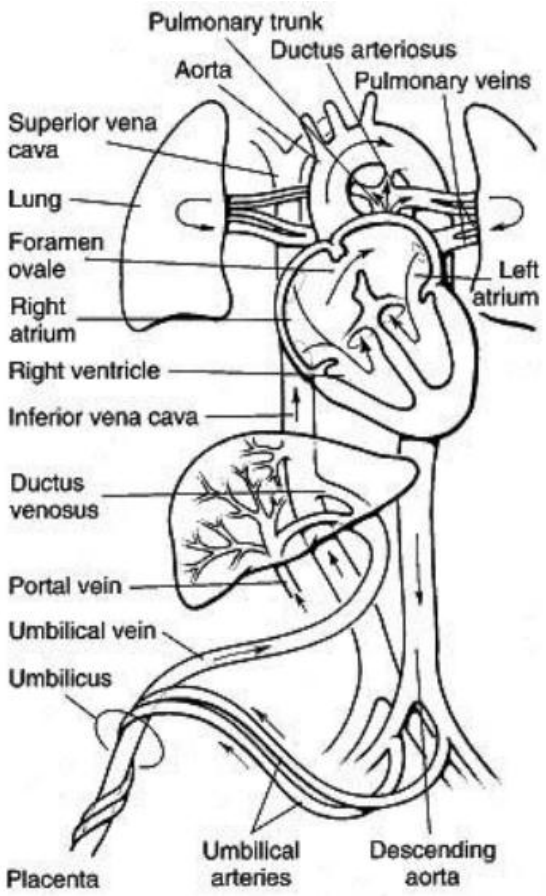
Secondary infertility is when one or both members of the couple have previously conceived, but are unable to conceive again after a full year of trying.

Main causes of infertility

a) Male problems: 35%
b) Ovulation problems: 20%
c) Tubal problems: 20%
d) Endometriosis: 10% (abnormal location of uterine tissue outside of the uterus)
e) Cervical factors: 5%.

1) **Complex changes** in the **hypothalamus, pituitary gland** and **ovaries** can cause **hormone imbalance** to cause ovulation disorders. It's the most common cause of female infertility.
2) **Excess physical or emotional stress** can disrupt the pattern of secretion of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) and affect ovulation – evidenced by irregular or absent periods.
3) **Excessive overweight** or **underweight** can disrupt the pattern of secretion of FSH and LH and affect ovulation.
4) **Auto-immune response** - the body mistakenly attacks ovarian tissues.
5) **Premature loss of eggs** from the ovary due to **genetic problems** or environmental insults such as chemotherapy causing ovulation failure, as well as a decreased estrogen secretion below 40 years.
6) **Too much prolactin** secretion which reduces oestrogen production and may cause infertility due to pituitary malfunction or medications taken for another disease.
7) **Damage or blockage of fallopian tubes** hence preventing sperm from getting to the egg or block the passage of the fertilized egg into the uterus.
8) **Implantation failure** due to fibroids/tumors, inflammation, abnormally shaped uterus, cervical narrowing.
9) Sometimes the cervix can't produce the best **type of mucus** to allow the sperm to travel through the cervix into the uterus.
10) **Low sperm count:** less than 5 million sperm per ml of semen
11) **Impotence:** failure of the penis to erect or ejaculate

CHANGES THAT OCCUR IN BLOOD AND FOETAL CIRCULATION AT BIRTH



Before birth:

- Foetal haemoglobin has a higher affinity for oxygen than adult haemoglobin to facilitate diffusion of oxygen from the mother.
- In the foetus, blood bypasses the lungs via the **ductus arteriosus**, which connects the pulmonary artery to the aorta.
- Blood also bypasses the lungs, which are functionless by going through the **foramen ovale** connecting the two atria of the foetal heart.
- Blood from the left atrium passes into the left ventricle and into the aorta, which supplies blood to the body and the umbilical artery.
- Pressure in the foetal circulatory system is greatest in the pulmonary artery and this determines the direction of blood flow through the foetus and placenta

After birth:

- In a few weeks of life, foetal haemoglobin is replaced by adult haemoglobin since it is less suitable as a means of gaseous exchange with air
- At birth when the baby takes the first breath, there is increased partial pressure of oxygen in its blood together with the nervous reflexes occurring in its body results in the closure of ductus arteriosus.
- As a result of this, most of the blood vessels and the opening of pulmonary circulation results in the blood pressure in the left atrium exceeding that of the right atrium, causing the foramen ovale to close with the aid of a valve in its passage.
- Blood then passes from the right ventricle and pulmonary artery to the lungs.

Note: sometimes the mechanism which results in the closure of foramen ovale fails. This is the reason why some children called **blue babies** bear a hole in the heart, where a portion of blood continues to bypass the lungs resulting in inadequate oxygenation of the tissues.

If blood pressure were highest in the aorta, blood would flow in the reverse direction along the ductus arteriosus.

Extra embryonic membranes associated with the human foetus

1. **Chorion:** It completely surrounds the foetus and is the foetal contribution to the placenta.
2. **Amnion:** Forms a fluid filled **amniotic cavity** that cushions the foetus from shock and mechanical damage.
3. **Yolk sac:** Contains little or no yolk, it is a temporary site for **red blood cell** formation.
4. **Allantois:** Derived from embryonic hind gut, it contributes blood vessels that form the umbilical cord.

a) What are the main features of reproduction in birds?
b) How are birds suited for reproduction on land?
c) Compare embryo development in birds and mammals.
d) State the forms of parental care provided by mammals.

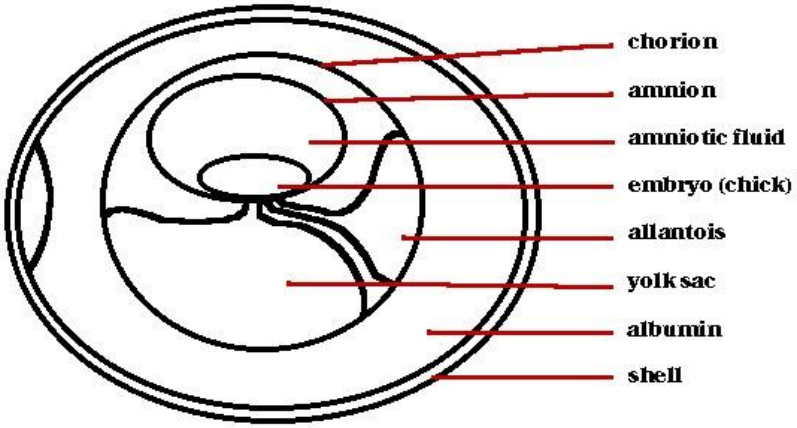
a) Some of the main features of reproduction in birds

i) Fertilization is internal
ii) Mating is preceded by elaborate courtship displays
iii) Hard shelled eggs **(cleidoic/amniotic eggs)** are laid in the external environment

iv) Eggs are incubated usually by the mother as the embryo develops
v) Newly hatched young ones are fed and cared for by the parents

b) ***How birds are suited for reproduction on land***

i) Production of hard-shelled eggs for protection from mechanical damage
ii) Fertilization is internal to avoid drying up of eggs and wastage of gametes
iii) Newly hatched young ones are fed and cared for by the parents e.g. nest building, brooding etc.
iv) Zygote develops within the **amniote (cleidoic egg),** which provides the embryo with a fluid-filled cavity in which it can develop on land.



c) Comparison of embryo development in birds and mammals.

Similarities:

- Both contain yolk sac
- In both the embryo is surrounded by **extra-embryonic membranes,** which develop from tissues outside the embryo
- In both the embryo is cushioned in the fluid-filled amniotic cavity
- Embryo development is preceded by internal fertilization in both
- Allantois is involved in gaseous exchange.

Differences:

Embryo development in birds	***Embryo development in mammals.***
• Yolk sac is well developed nourish the foetus	• Yolk sac is poorly developed since the foetus derives nourishment from the mother.
• Allantois is a depository organ for nitrogenous wastes e.g. uric acid.	• Nitrogenous wastes e.g. urea diffuse into maternal blood.
• Embryo is protected from damage by an outer shell.	• Outer shell is lacking around the developing embryo.
• Yolk sac transfers digested food to the embryo.	• Digested food is transferred by placenta.
• Allanto-chorion is lacking.	• There is a developed allanto-chorion

c) Forms of parental care provided by mammals:

- Protection from predators
- Feeding
- Provision of shelter
- Training of offspring.