What is meant by the term reproduction?

- It is the production of a new generation of individuals of the same species, during which there is transmission of genetic material from parents to their offspring to ensure continued survival of a species.
- OR: Formation of separately existing individuals of the same species by existing organisms

Types of reproduction: Sexual and Asexual

Distinguish between sexual and asexual reproduction

- **Asexual reproduction** is the production of offspring (new individuals) from a single organism without the formation of gametes. The offspring (referred to as **clone**) are genetically identical to each other and to their parent, except when and if mutation occurs.
  Cloning is the process by which an organism reproduces asexually to give individuals in a population genetically identical to each other and to their parent.

- **Sexual reproduction** is the production of offspring by the fusion of haploid male and female gametes (fertilization) to form a diploid zygote, which develops into the mature organism.

Compare sexual and asexual reproduction

Similarities:
- In both mitosis is involved
- Both produce offspring
- In both there is transmission of genetic material from parents to their offspring

Differences:

Sexual reproduction	Asexual reproduction
-Involves fertilization to form diploid zygote	-No zygote formation
-Offspring show genetic variability	-Offspring are usually identical to each other and to their parents; i.e. a clone
-Population numbers increase slowly	-Population numbers increase rapidly
-May involve one or two parents	-Always involves only one parent
-It is a less rapid process	- it occurs rapidly in favourable conditions
-Offspring mature slower	-Offspring mature faster
-Occurs among all living organisms	-Occurs mainly among plants and simpler animals
-Male and female gametes produced by gametogenesis	-No game formation

Give an account of the various forms of asexual reproduction

The five major ways by which asexual reproduction occurs are:

a) Fission:

It is the division of the cell by mitosis into two or more equal sized daughter cells identical to the parent cell. **Binary fission** ('splitting into two') occurs in bacteria, amoeba, paramecium while **multiple fission** (**schizogony**) - 'splitting into many' occurs in plasmodium (a malaria parasite) immediately after infection as the parasite (merozoites) enters the liver and again as they invade the red blood cells.

b) Sporulation (spore formation):

Is the formation of small unicellular bodies called spores by cell divisions in organisms, which detach from the parent plant and grow into new organisms under favourable conditions. It occurs in fungi e.g. *rhizopus*, bacteria, mosses, ferns, Liverworts, algae and amoeba.

What is a spore?
A haploid reproductive cell, usually unicellular, capable of developing into an adult without fusion with another cell.

c) Fragmentation:
This is the breaking of a single organism into two or more genetically identical pieces, each of which is capable of regenerating into a new individual. It occurs in <u>sponges, spirogyra, cnidarians, flatworms</u>.

d) Budding:
This involves the parent cell forming an out growth (a small bulge), which increases in size and finally drops off (detaches) to become an independent organism. It occurs in <u>flat worms</u> *e.g. tapeworms*, <u>yeast</u>, <u>hydra, obelia, bryophyllum.</u>

e) Vegetative propagation:
This is asexual reproduction in which a part of flowering plant <u>other than the flower</u> detaches itself to develop into a new individual plant. Parts of the plant such as root, stem, or leaf specialized to give rise to new individuals are called **propagules** and may also act as **organs of perennation.**

i)What are perennating organs?
ii) Explain the role played by perennating organs to the plants.
i) These are parts of flowering plants specialised for vegetative propagation as well as food storage, enabling plants bearing them to survive adverse (unfavourable) environmental conditions e.g. cold or dry periods. The food manufactured by photosynthesis in aerial green leaves is translocated and subsequently stored *as starch* in rhizomes, corms, stem and root tubers, *or as glucose* in onion bulb.

ii) During unfavourable conditions, the plant remains dormant but when conditions normalise, starch is hydrolysed to sugar and translocated to the young buds, enabling early growth, sprouting, and photosynthesis when there is little competition for nutrients from other species.

Distinguish between organs of vegetative propagation and organs of perennation in plants.
Organs of vegetative progation are the parts of the flowering plant other than the flower, such as root, stem, or leaf specialized for developing into new individuals when detached. Examples: rhizomes *e.g. ginger, couch grass, canna lily and spear grass*; corms *e.g. coco-yam (mayuni), crocus and gladiolus*; stem tubers *e.g. Irish potato, yams*; root tubers *e.g. sweet potato, dahlia*; bulbs *e.g. onion, garlic, tulip*, swollen taproots *e.g. carrot, turnip*; stolons *e.g. blackberry*; runners *e.g. straw berry, oxalis*

Organs of perennation are plant parts specialised for storing the food used to develop into new individuals, enabling plants bearing them to survive adverse environmental conditions like drought. Examples: rhizomes, corms, stem and root tubers, bulbs, swollen tap roots.
Summarily, organs of perennation also double as organs of vegetative propagation, **<u>but not all</u>** *organs of vegetative propagation function as perennating organs.*

Specialised organs of vegetative propagation must have buds, which only occur on stems. Explain why root tubers (swollen adventitious roots) e.g. sweet potato, dahlia and cassava, and swollen taproots e.g. carrot and turnip are used as organs of vegetative propagation yet roots lack buds.

Root tubers and swollen taproots must bear a small part of old stem if they are to act as organs of vegetative propagation. The swollen root together with buds at the base of old stem form organs of vegetative propagation and perennation.

Artificial propagation methods in plants

- **Cutting:**

A piece of root *e.g. of lemon and tamarind*, or stem *e.g. sugarcane and cassava*, or a complete leaf is dipped in rooting mixture composed of plant hormones, and allowed to grow in a rooting composite or soil.

- **Layering:**

Involves pegging down of stem of runners *e.g. strawberry* into the soil to induce development of adventitious roots, after which the new daughter plants are detached from the parent plants by cutting.

- **Grafting and budding:**

It is the insertion of a stem or bud of one plant, the **scion** onto another closely related plant, the **stock,** ensuring that vascular tissues are in contact. It propagates lemons, apples, roses, hibiscus, and oranges.

Grafting in plants is not hampered by rejection, as is the case in animals.

Comparison of advantages and disadvantages of natural vegetative propagation

Advantages	Disadvantages
-It is a rapid means of reproduction and spread -Offspring are genetically identical, preserving good strains. -Perrenating organs enable survival in adverse conditions -Their dispersal and spread is independent of external agents hence the process is faster. -Plants are less affected by environmental factors - Females pass all of their genes to the offspring	-Leads to overcrowding and competition for nutrients, unless separated artificially. -New varieties cannot be produced, except by mutation resulting into reduced vigour & strength -Diseases typical of a species are rapidly transmitted and can decimate a crop -

Outline the process of sporulation in amoeba.

-It starts when the nucleus of a single cell of amoeba divides repeatedly and each unit is enclosed in a bit of cytoplasm, but all are encased by one cell membrane.

-Some residual cytoplasm may be left which is discarded.

-The new nuclei with cytoplasm are surrounded by spore case (cyst) to withstand unfavourable conditions

-The spores formed are released by bursting of the cell membrane.

What is parthenogenesis?

Parthenogenesis ("virgin origin") is:

- The development of an embryo from an unfertilized egg or one in which the male and female nuclei fail to unite following fertilisation

What is the exact meaning of the following? Give an example in each case.

a) Diploid parthenogenesis / ameoitic parthenogenesis:

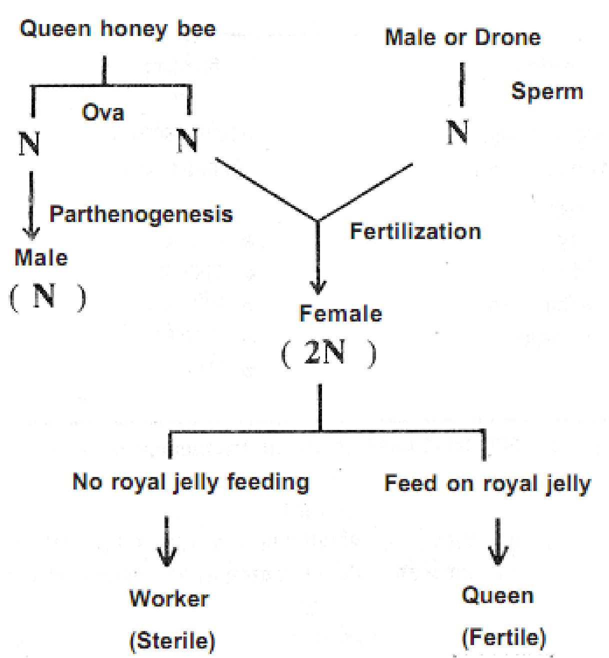
This is the development of embryo from unfertilized diploid eggs that formed by mitosis instead of meiosis, resulting into diploid offspring, which are clones of the parent. It occurs in Aphids, during which large numbers of wingless females are formed without necessitating the presence of males, in flatworms, rotifers, crustaceans.

b) Haploid parthenogenesis / meiotic parthenogenesis:

This is the development of embryo from unfertilized haploid eggs that formed by meiosis and may develop directly into haploid offspring. It occurs in honeybees, wasps, ants, whiptail lizards.

In honeybees, the queen bee can either fertilise the eggs as she lays them or allows them to pass unfertilised. Fertilised eggs become diploid females (fertile queens or sterile workers), and unfertilised eggs develop to become fertile haploid males (drones). In whiptail lizards of American southwest, meiosis is severely modified to yield a clone of only females

Summary of parthenogenesis in honeybees



c) Apomixis:

It is the formation of plant embryo from an unfertilised haploid egg cell or from a diploid embryo sac mother cell or from a diploid cell in the ovule without fertilisation. It occurs in potatoes and citruses.

d) Parthenocarpy:

This is fruit development without fertilisation, usually induced by auxins e.g. in apples

Give the major advantages of parthenogenesis

- It avoids the problem in some animals of bringing together males and females at the right moment for successful fertilization.
- Produces a large number of organisms in a short time. *E.g. in whiptail lizards all the parthenogenetic offspring are females, which all produce eggs, yet only half of the bisexual population are egg-laying females.*
- It eliminates in each generation all lethal genes that thrive in homozygous state

Major disadvantage of parthenogenesis:

-During sudden environmental changes, parthenogenetic species have limited capacity to shift gene combinations to adapt to the new conditions

SEXUAL REPRODUCTION

The role of sexual reproduction compared

Advantages	Disadvantages
- Brings about genetic variability in a population by recombining parental characteristics, enabling a species to adapt to the changing environmental conditions -During the life cycle of the organism, resistant stages develop enabling survival of adverse conditions - The formation of spores, seeds or larvae, which may be used to disperse offspring and so, reduce intraspecific competition. -It leads to increased numbers of a population	- May result into lethal combination of genes - In some animals, it is difficult to bringing together males and females at the right moment for successful fertilization. - It relies so much on external agents hence reducing chances of occurrence -It is a slower method of reproduction. -There is wastage in production of males, many of which fail to reproduce & thus consume resources that could be applied in the production of females -Females only pass half of the genes to the offspring because the genome is halved at meiosis

Out line the ways through which variation can arise in a population

i) During fertilization when male and female gametes with different genotypes fuse to form a zygote.

ii) Mutations during which there is alteration in gene structure and sequence.

iii) During meiosis by crossover during prophase I and also during random segregation of chromosomes on the metaphase plate

iv) By the effects of the environment where the organisms live.

What are the main characteristics / features of sexual reproduction?

-It involves production of gametes by two separate parents, a process called gametogenesis. **Isogametes** are identical though dissimilar genetically, **Anisogametes** (heterogametes) differ slightly in size. Some species exhibit **oogamy**, the gametes greatly differ in size and activity

-It involves fertilisation (syngamy), the union of male and female gametes

-Bacteria reproduce by conjugation.

Define the term life cycle.

It is the progressive sequence of changes an organism goes through from fertilization till death.

What is meant by alternation of generations?

It is the occurrence within the life cycle of an organism two or more distinct forms (generations), a haploid gametophyte and diploid sporophyte generations, which differ from each other in appearance, method of reproduction and genetic constitution.

a) Give an account of alternation of generations in a named bryophyte or pteridophyte/Filicinophyte

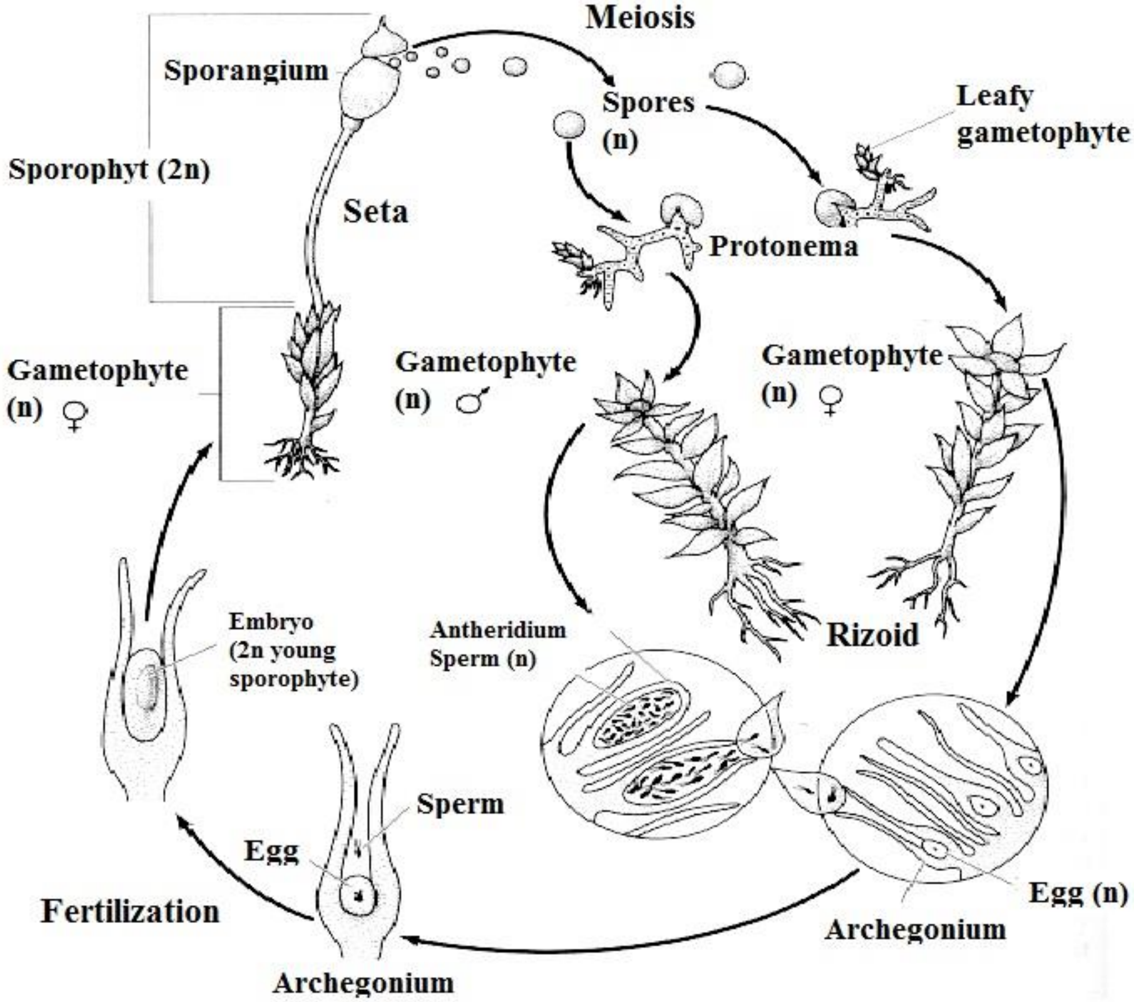
b) Compare alternation of generations in a named bryophyte and pteridophyte.

c) Discuss the significance of alternation of generations to the life cycle of plants.

a) **<u>Alternation of generations (lifecycle) of a moss e.g. *Funaria*</u>** <u>– a bryophyte:</u>

- A moss e.g. *Funaria* consists of two distinct forms in its life cycle, the haploid gametophyte, which is the <u>dominant</u> and <u>sexual</u> stage, and the diploid sporophyte, which is the <u>asexual</u> and less conspicuous stage.
- A gametophyte may bear both sex organs, the <u>antheridia</u> (sperm producing) and <u>archegonia</u> (egg producing) or they may be borne on separate gametophyte plants.
- On maturing, the antheridia shed sperms, antherozoids that are aided by rain-splash to reach the open neck of archegonia, and the attracted by <u>chemicals</u> e.g. sucrose enables them to reach the archegonia.
- The haploid antherozoids fuse with the haploid eggs (ospheres) to form diploid zygotes (oospores).
- The zygotes develop into diploid sporophytes, which remain attached and surviving on the gametophytes.
- At maturity the sporophyte produces haploid spores by meiosis within a spore capsule, which splits open when dry and the spores are dispersed by wind.
- On landing on moist soil;, each spore germinates into a green filamentous <u>protonema</u> which produces buds that grow into new haploid gametophyte.

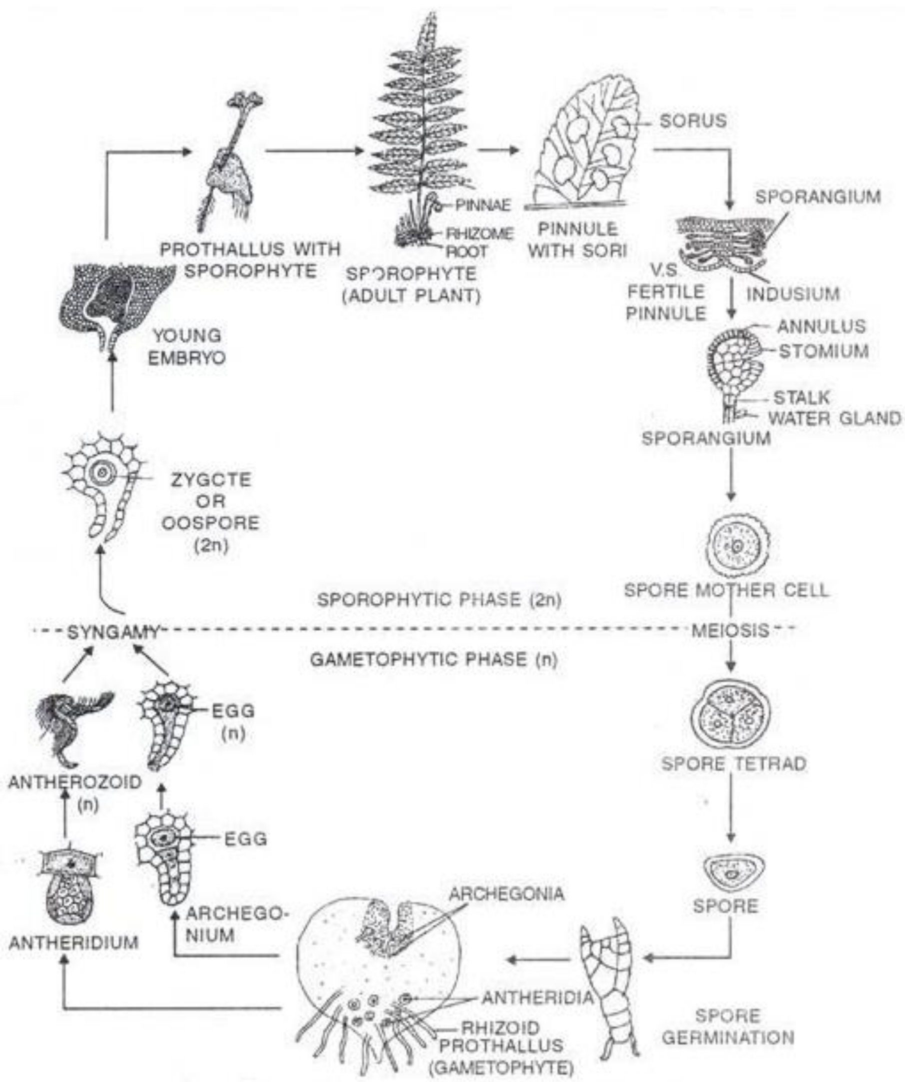
Lifecycle of Funaria



<u>Alternation of generations (lifecycle) of a common fern</u> <u>- a Pteridophyte / Filicinophyte:</u>

- A common fern (*Dryopteris)* consists of two distinct forms in its life cycle, the diploid sporophyte, which is the <u>dominant</u> and <u>asexual</u> stage, and the haploid gametophyte, which is the <u>sexual</u> and less conspicuous stage.
- Diploid spore mother cells inside sporangia divide by meiosis to produce haploid spores
- When mature, the protective covering (indusium) shrinks and the exposed sporangium wall begins to dry out.
- The walls rupture and the spores are discharged from the sporangium.
- If moisture is present, each spore germinates into <u>heart-shaped prothallus</u> (gametophyte), anchored to the soil by rhizoids.
- At the underside, the prothallus bears antheridia and archegonia that produce haploid sperms and eggs by mitosis respectively.
- After rupture of antheridia, the ciliated sperms swim through water to fertilise eggs at the base of archegonia, and the diploid zygotes formed grow into young sporophytes, which remain supported on the prothallus till self-supporting.

Lifecycle of Dryopteris



b) **Comparison of alternation of generations in a moss e.g. *Funaria* and common fern**

<u>Similarities:</u>

In both:

-There is one dominant stage and the other stage is relatively inconspicuous.
-A moist or aquatic environment is required.
-Male gametes from the antheridia are brought into contact with eggs by some mechanisms.
-The gametophytes bear sperm producing antheridia and egg producing archegonia.
-Cases the spores are formed in specialized spore-bearing sporangia.
-There is a dispersal mechanism for scattering spores.
-Sporophytes are diploid and gametophytes are haploid.
-Spores are produced by meiosis and gametes by mitosis
-There is sexual and asexual reproduction
-Male gametes are motile while eggs are non-motile

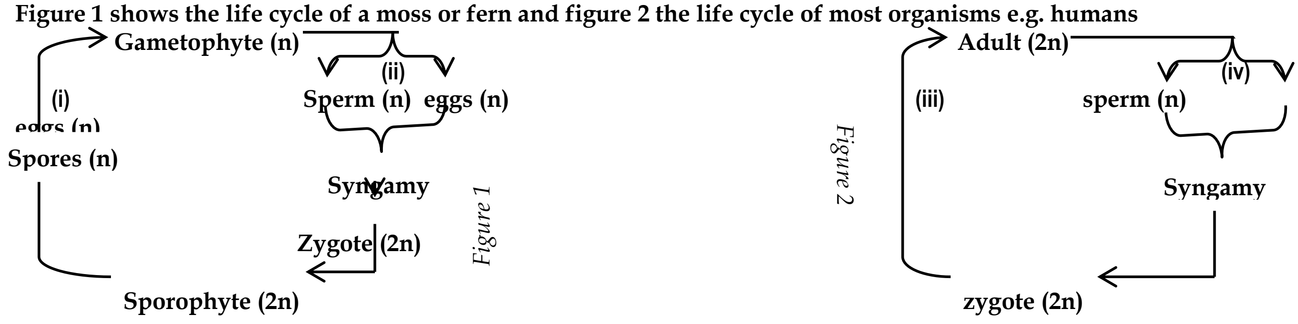
Differences between alternation of generations in a moss and common fern

Alternation of generations in a moss e.g. *Funaria*	**Alternation of generations in a Common fern**
- Sporophyte is dependent upon the gametophyte nutritionally	- Sporophyte is a self supporting plant
-Each spore germinates first into protonema, which transforms into gametophyte	-Each spore germinates directly into gametophyte
- Gametophyte is the dominant generation	-Sporophyte is the dominant generation
- Both male and female reproductive organs may be borne on same or separate gametophyte plants	- Both male and female reproductive organs are borne on the same gametophyte (prothallus)
-Majorly depends on water for plant growth, transference of sperms, support and spore dispersal and spore germination	- Dependence on water is less, mainly for swimming of sperms and germination of spores

c) ***The significance of alternation of generations to the life cycle of plants***

- It enable exploitation of different habitats in the ecosystem by the different generations
- Promotes rapid multiplication of species since spores are enormously produced
- Enables plants to cope better with adverse environmental conditions for survival
- It reduces chances of extinction of a species since the different generations are interdependent
- Brings abut genetic variability by meiosis during spore formation
- Mitosis during gamete formation maintains the plant genome by producing haploid gametes

Figure 1 shows the life cycle of a moss or fern and figure 2 the life cycle of most organisms e.g. humans



Which processes shown by arrows represent meiosis in both cycles?

A. (i) and (iii)
B. (ii) and (iv)
C. (i) and (iv)
D. (ii) and (iii)

COMPARISON OF PLANT FEATURES IN DIFFERENT PHYLA

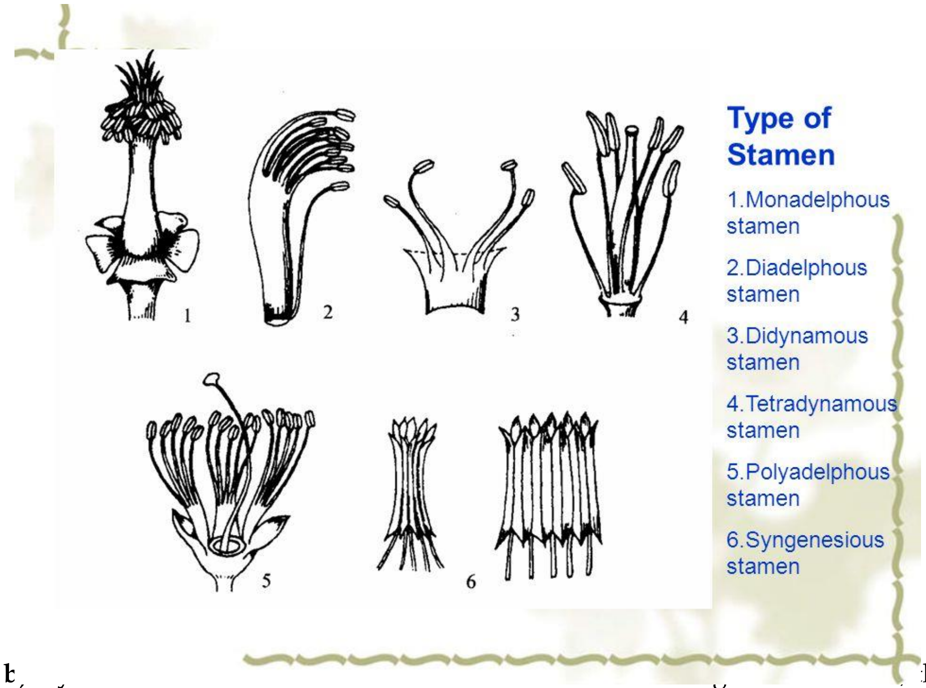
Features	Bryophyta	Pteridophyta	Gymnosperms	Angiosperms
Dominnant phase	Gametophyte	Sporophyte	Sporophyte	Sporophyte
Ploidy of main plant body	Haploid	Diploid	Diploid	Diploid
Differentiation of body	Thallus and rhizoids	Roots, stem and leaves	Roots , stem and leaves	Roots, stem and leaves
Vascular bundles	Absent	Present	Present	Present
Nature of spores	Homospores	Homospores or heterospores	Heterospores	Heterospore
Seed and its coverings	Seed absent	Seed absent	Seed naked without covering	Seed with coverings
Flower	Absent	Absent	Absent	Present

GENERALIZED DESCRIPTION OF THE ESSENTIAL ORGANS OF FLOWERS

Essential organs are those which directly take part in reproduction i.e. androecium and gynoecium while the **accessory/non-essential organs** are those which assist but do not directly take part in reproduction i.e. corolla and calyx.

a) Androecium: It is the collective name for the male sex organs of a flower, the stamens, each of which consists of the filament, a stalk supporting the anther head at the tip, and the connective, containing vascular strand. Various terms are used to describe stamens.

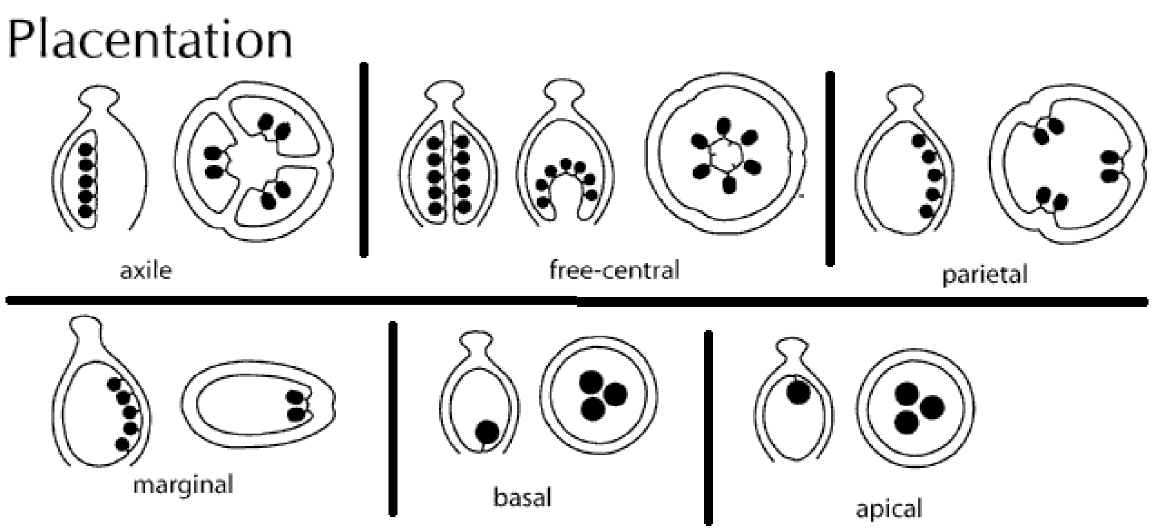
i) Gynandrous – stamens attached to pistils
ii) Versatile – the filament is attached to the anther at the middle, so that the anther is loose and can oscillate *e.g. maize and most grasses*
iii) Adnate – anthers placed on filament along lengthwise direction of filament *e.g. michelia*
iv) Basifixed – filament attached to the base of the anther e.g. radish
v) Dorsifixed – the tip of the filament is attached to the back of the anther (about the middle region) e.g. passionflower.
vi) Staminode - infertile / sterile stamens
vii) Epipetalous – stamens attached on corolla
viii) Syngeneceous – a condition in which filaments free, but all anthers are fused
ix) Synandrous – stamens are united completely by both filaments and anthers *e.g. cucumber*
x) Adelphous – anthers free, filaments united
xi) Monoadelphous - anthers free, filaments united but in just one bundle *e.g. hibiscus*
xii) Diadelphous - anthers free, filaments fused to form two bundles *e.g. sweet pea, bean*
xiii) Polyadelphous - anthers free, filaments united to form many bundles.



b ... he <u>carpels</u>, each of which consists of the <u>ovary,</u> which is a swollen base, <u>stigma,</u> at the top and <u>style</u>, which links stigma to ovary. Stigma may have one or more lobes, hairy, feathery, sticky, rough etc.

Internally, ovary may be <u>monocarpellary</u> (single carpel), <u>bicarpellary</u> (two carpels), <u>pentacarpellary</u> (five carpels), etc. depending on the number of mainly chambers observed when cut or stigma lobes.

<u>Placentation</u> (pattern of ovule arrangement) may be **<u>marginal</u>** *e.g. in beans*, **<u>parietal</u>** *e.g. in pawpaw, passion fruits and some cucumber*, <u>axile</u> *e.g. in oranges and lemons*, **<u>free central/central</u>** *e.g. in green pepper*, **<u>basal</u>** <u>(at base)</u> *e.g. in mango*, **<u>Apical</u>** <u>(at apex)</u> *e.g. avocado*



A carpel is described as:

i) Monocarpous – if it consists of only one carpel

ii) Apocarpous – if there are many carpels that are entirely separate from one another e.g. in rose.

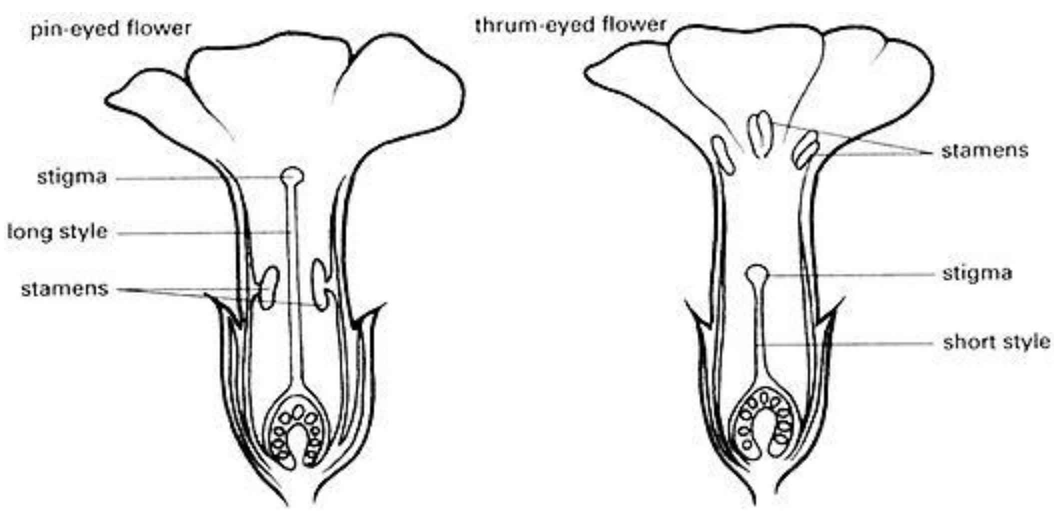
iii) Syncarpous – when all its carpels or at least their ovaries are fused e.g. in hibiscus.

With reference to plants, distinguish between the following, giving examples.
Monoecious, dioecious, and polygamous species
Dichogamy, Protandry and Protogyny
Heterostyly and self-sterility

Monoecious species: are species in which individual plants bear separate male and female flowers e.g. maize, oak, sycamore, coconut, date palms, castor oil, pumpkin
Dioecious species: are species in which individual plants bear either only male or only female flowers, so that there are different sexes of the plant e.g., pawpaw and asparagus.
Polygamous species: are species in which individual plants bear three types of flowers: bisexual, male and female e.g. mango
Dichogamy: failure of the stamens and pistil to ripen at the same time in a hermaphrodite flower.
Protandry: it is the ripening of the stamens before the carpel in a hermaphrodite flower e.g. in sunflower, white deadnettle, salvia, and dandelion *(mainly insect pollinated flowers)*.
Protogyny: ripening of carpels earlier than the stamens e.g. in arum lilies, and wild varieties of: wheat, barley, and oats. *(Mainly wind pollinated flowers). NB: protandrous flowers are more common than protogynous ones.*
Heterostyly: it is a condition in which the style length is different in various flowers of an individual plant, so that pollen from a different flower only can bring about effective pollination. e.g. primrose, has two types of flowers that differ in length of style, with the pin-eyed flower having stamens situated below the stigma while in the thrum-eyed flower they are situated above.

Self-sterility/genetic self-incompatibility: a condition, which results when the pollen and stigma recognize each other as being genetically related and pollen tube growth is either blocked or retarded. e.g. in clover and pears.
Self-incompatibility is controlled by the *S* (self-incompatibility) locus, which bears many alleles e.g. S_1, S_2, S_3, that regulate recognition responses between the pollen and stigma.
In gametophytic self-incompatibility, if any of the *S* alleles in the stigma matches with any pollen *S* allele, then the growth of that particular pollen tube with the allele which matches stops before it reaches the embryo sac, but other pollen tubes with alleles that don't match continue growing. Gametophytic self-incompatibility is determined by the haploid pollen genotype e.g. in petunias.
In sporophytic self-incompatibility, if any allele in the stigma matches with either of the pollen parent *S* alleles, then not even a single haploid pollen germinates. Sporophytic self-incompatibility recognizes the genotype of the diploid pollen parent, not just the haploid pollen genotype e.g. in broccoli.

Drawings showing Heterostyly in primrose



In a species, self-sterility is controlled by multiple alleles S_1, S_2 and S_3.
a) Assuming that self-sterility occurs if the pollen grain and the style tissue have an allele in common, what proportion of the pollen grains from a plant with the genotype S_1S_2 would be capable of successfully germinating on a plant with:
i) Genotype S_2S_3? ii) Genotype S_1S_2?
Explain your answers in (i) and (ii) above.
b) What type of self-incompatibility is exhibited in (a) above?
c) Give three other factors which promote outcrossing in plants.

a) (i) Only ½ or 50% of the pollen grains (those with the allele S_1) would be capable of germinating

A plant of genotype S_1S_2 produces ½ of its pollen with allele S_1 that does not match with either of the alleles S_2 and S_3 of the style tissue, hence would germinate, while the rest of pollen are of allele S_2 which matches with allele S_2 of the style tissue, germination would be inhibited.

ii) 0% or none of the pollen grains germinates. Both alleles S_1 and S_2 would match with those of the style tissue and germination would be inhibited.

c) Dioeciousness (Dioecism), Monoeciousness (Monoecism), Dichogamy and Heterostyly

a) State the physiological adaptations of flowers to pollination
b) Explain the mechanisms which limit inbreeding / promote outcrossing in plants
c) What are the consequences of self pollination and cross pollination

Pollination is the transfer of pollen grains from the anthers to the stigma of the flower.

Self-pollination – pollen from the anthers is transferred to the stigma of the flower on the same plant.

Cross-pollination - pollen from the anthers is transferred to the stigma of another flower on a different plant but of the same species. Based on agents, wind pollination is categorized as follows:

i) Anemophily (wind pollination). Anemophilous flowers exhibit many features (check page 12)

ii) Entomophily (insect pollination). Characteristics of entomophilous flowers are given on page 12.

iii) Hydrophily (water pollination). In hydrophilous flowers, pollen grains have same specific gravity as that of water to enable floating in water at any depth.

iv) Ornithophily (bird pollination). Ornithophilous flowers are tubular shaped, brightly coloured, with plenty of nectar, and generally odourless.

v) Chiropterophily (bat pollination). Chiropterophilous flowers emit strong scent and open after dusk, have long stalks and produce large quantities of nectar.

*a) **Adaptations of flowers to self-pollination:***

Physiological	Morphological
-Stamens and carpels mature at the same time -Hermaphrodite flowers may not open petals - Hermaphrodite flowers may remain under ground -Pollen is released onto the stigma by matured anthers before the petal opens. -Pollen is compatible with the tissues of style, thus allowing for their germination	-Flowers are reduced and inconspicuous -Stamens are situated above the stigma or the anther is close to the stigma -stigma often coiled to touch ripe anthers -Style and filaments coil on one another -Flowers failing to open e.g. in commelina

Adaptations of flowers to cross-pollination:

Physiological	Morphological
-Stamens ripen before carpel (protandry *e.g. in salvia, deadnettle and dandelion*) or carpel ripens earlier (protogyny) -Self incompatibility due to chemicals prevents germinating of pollen on the stigma of the same flower (self-sterility) -It is genetically controlled by self-incompatibility genes e.g. in pears pollen only becomes functional if the stigma surface on which it is has a different genetic composition.	-Dioecious flowers have either stamens or pistil -Stamens situated below the stigma . -Hermaphrodite (bisexual) flower containing both sex organs. -Production of nectar to attract insects. -Hanging of stamens or whole flower downwards so that falling pollen drops clear of that plant.

b) ***Mechanisms which limit inbreeding (self-pollination) in plants***

- Dioeciousness, all flowers on the plant being either male or female e.g. pawpaw
- Monoeciousness, having separate male and female flowers on the same hermaphrodite plant.
- Heterostyly (differing style length), structure of the flower e.g. when a stigma is protected from coming into contact with its own pollen or stigma being taller than the anthers.
- Dichogamy, Stamens ripening before carpel (protandry) or carpel ripening earlier (protogyny).
- Self incompatibility due to chemicals prevents germinating of pollen on the stigma of the same flower

c) ***Consequences/effects of self-pollination (inbreeding) and cross-pollination (out breeding)***

Consequences of self-pollination (inbreeding)	*Consequences of cross-pollination (out breeding)*
It promotes homozygosity i.e. transmission of genotype in the population, resulting into decreased fertility, reduced resistance to disease, thereby reducing evolutionary potential of the species in the long run.	It promotes genetic diversity, resulting into hybrid vigour, causing increased resistance to diseases, high yield, and earlier maturity, thereby providing greater evolutionary potential.

Comparison of the advantages and disadvantages of self and cross pollination:

Advantages	*Type of pollination*	*Disadvantages*
-It is reliable especially where members of a species are rare and far apart -It is the only means where pollinating agents are unreliable e.g. mountain tops lack insects, and during harsh climate. -It is not wasteful of pollen grains	*Self-pollination*	It promotes homozygosity i.e. transmission of genotype in the population, resulting into decreased fertility and reduced resistance to disease
It encourages genetic variation, increasing the hybrid vigour	*Cross-pollination*	It is wasteful of pollen grains since pollinating agents are not very efficient

a) Give one ecological importance of each of the following structural arrangements in plants.

i) Monoeciousness

-It allows self-fertilization for continuity of species where plants of that species are few or separated by long distance

ii) Dioeciousness

- It encourages genetic variation, thereby increasing the hybrid vigour since it allows cross-pollination

b) Explain why

i) In dioecious plants, male plants are usually associated with dry soils while female plants are associated with moist soils.

-Pollen production does not require much water, while seed formation and fruit ripening require much water.

ii) Nearly all dioecious plants are wind pollinated

It may not be possible to have animal pollinators bring in pollen from the same plant species, which would reduce chances of fertilization.

OR: It is therefore much easier for wind to bring in pollen from same plant species to increase chances of fertlisation

c) Suggest two reasons why dioecious plants (those with separate sexes)are rarer than monoecious plants, despite the advantages of cross-pollination.

-Half of the individuals in dioecious plants do not produce seeds, whereas all individuals in monoecious plants bear seeds.

-A lot of pollen is wasted in dioecious plants because the male and female plants are not necessarily together.

d) Why is dioecism (separate sexes) common in animals than in plants?

-There is less wastage of gametes in animals than in plants because males and females can move about.

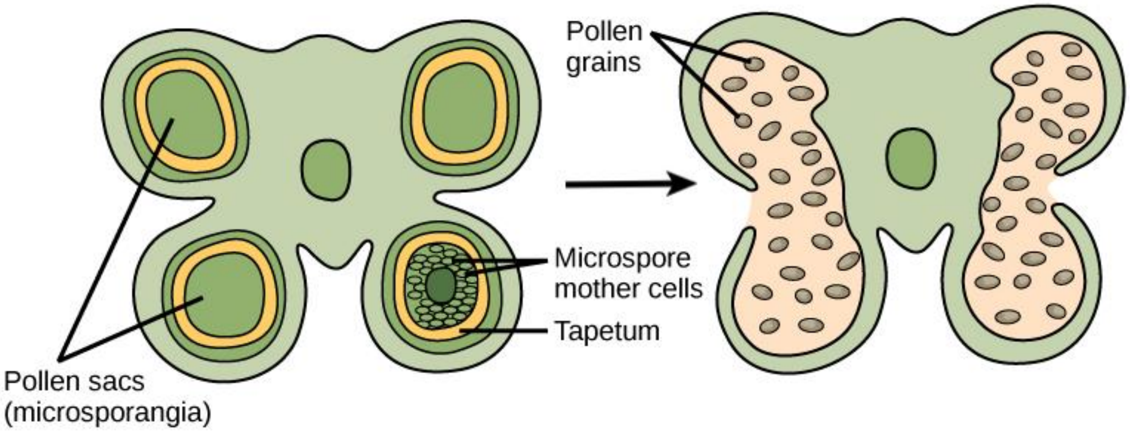
Comparison of wind pollinated (anemophilous) and insect pollinated (entomophilous) flowers

Wind pollinated flowers e.g. guinea grass, maize, rice	*Insect pollinated flowers e.g. crotalaria, sunflower, coffee, etc*
-Inconspicuous flowers, small and reduced in size. Petals may be absent or dull coloured if present. -No nectar and not scented -Pollen produced in large quantity, light, smooth, small and may have wing-like extensions. -Anthers are large and versatilily attached to filament. -Stamens hang outside the flower to release pollen. -stigmas are large, feathery or branched to trap pollen. -Stigmas hang out side the flower. -Flowers often unisexual, having male and female reproductive parts on separate flowers.	-Conspicuous flowers, large with brightly coloured petals, and often held in inflorescence if they are tiny and inconspicuous. -Produce nectar and or scent to attract insects. -Less in quantity, sticky, relatively heavy, and large pollen is produced. -Anthers are small and basifixedly or dorsifixedly attached to filament. -Stamens are confined within the flower. -Stigma relatively small, glandular, and sticky. -Stigma lies inside the corolla. -Flowers bisexual, enclosing reproductive organs e.g. stamens and carpels.

Describe the significant events that lead to the production and release of gametes in flowering plants.

- Gamete formation in plants occurs in the anther (male gametes) and ovary (female gametes).
- The pollen grains, formed in the anthers, contain and transport the male gamete while the ovules, formed in the ovary contain the female gamete (egg/ovum).

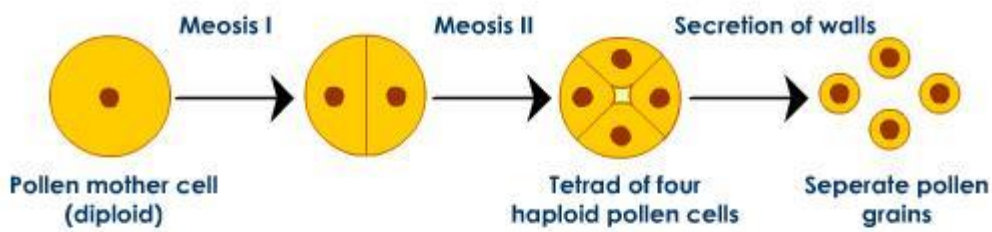
Transverse section of male gamete producing organs in flowering plants

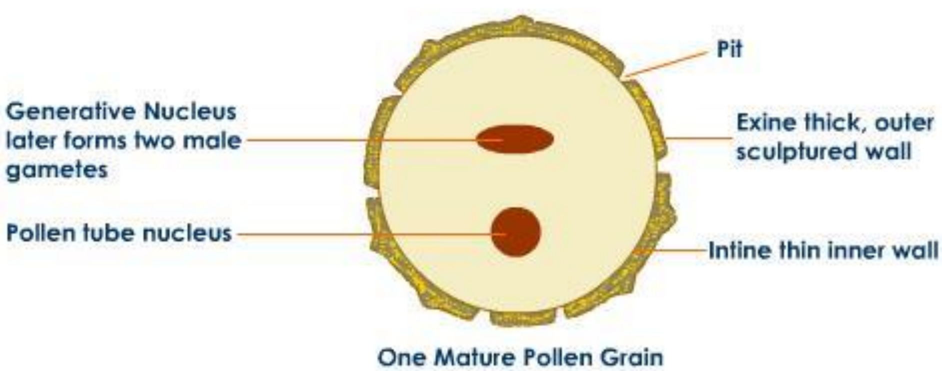


Production and release of male gametes:

- Repeated mitotic divisions occur within the sporogenous tissue, producing a mass of swollen cells, the microspore mother cells.
- Mitosis stops and each micro spore mother cell divides by meiosis to form a tetrad of haploid microspores, each of which gives rise to a pollen grain.
- Each pollen grain develops a hard resistant, sculptured outer wall, the exine and an inner cellulose wall, the intine.
- The single haploid pollen grain nucleus divides by mitosis form a pollen tube nucleus and the generative nucleus.
- When the pollen grains mature, the walls between each pair of pollen sacs breakdown and the anther lobe rupture longitudinally along the line of weakness to release pollen grains.

Diagrams illustrating the production of male gametes in plants

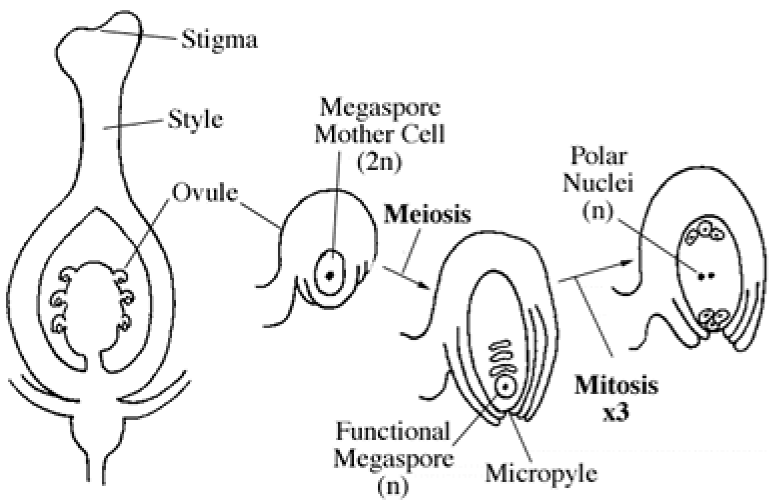




Production of female gametes:

- Each ovary develops one or more ovules, which contain a mass of cells, the nucellus, which is completely surrounded by two integuments, except at a small pore called micropyle.
- One cell of the nucellus develops into a diploid embryo sac mother cell.
- The embryo sac mother cell divides meiotically to give four haploid megaspore cells, only one of which develops to form the embryo sac while the three degenerate. *(In terms of development, the embryo sac is the equivalent to the pollen grain of the male)*
- The embryo sac nucleus divides mitotically to form two nuclei, which migrate to opposite poles, from where each divides mitotically to form four haploid nuclei at each pole.
- One nucleus from either end of the sac move to the centre and fuse to form a diploid primary endosperm nucleus.
- The remaining six nuclei each gets enclosed in a thin cell wall, and one of the three nuclei near the micropyle becomes the female gamete (egg nucleus).
- The remaining two nuclei near the micropyle, the synergids disintegrate while the three nuclei at the opposite end to the micropyle become the antipodal cells.
- Thus, a mature embryo sac contains a total of 7 nuclei, comprised of: two synergids, three antipodal cells, and diploid primary endosperm nucleus.

Diagrams illustrating the production of female gametes in plants



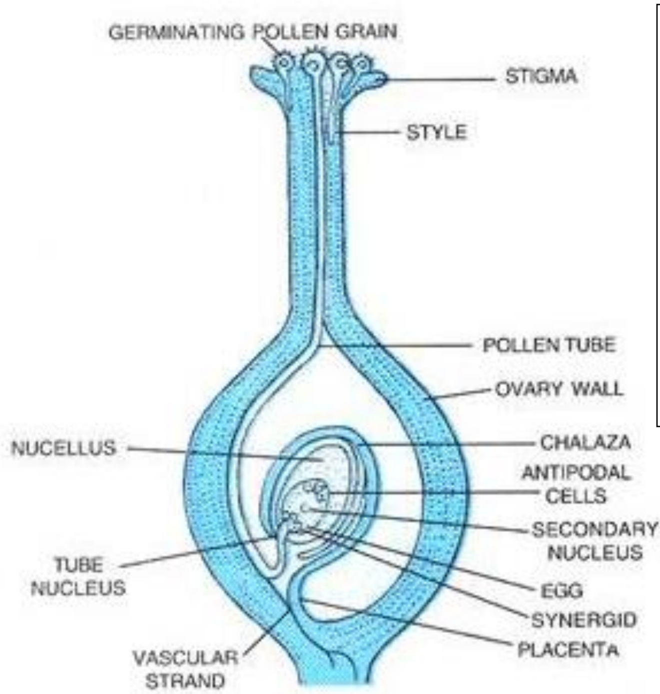
State the main features of embryo sac development in flowering plants

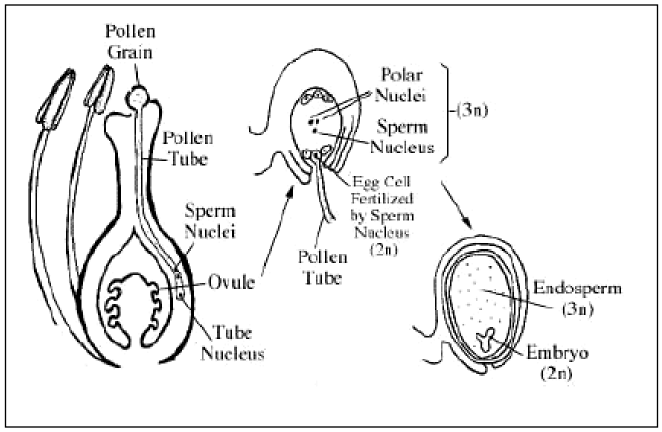
- Mitosis occurs three times
- There is formation of diploid nucleus by fusion of two male nuclei
- Produces six haploid cells
- Forms antipodal, synergid and egg cells.

a) Describe the events, which occur in the flower from pollination to fertilization.
b) What are the results of fertilization in a flower?
c) Explain what is meant by double fertilisation in relation to flowers.

a) -When a ripe pollen grain lands on the right stigma, it absorbs water, the outer wall (exine) breaks open and the inner wall (intine) germinates to form a pollen tube.
-The tube nucleus is positioned at the tip of the growing pollen tube controlling growth while the 2 male nuclei (2 sperms) formed by mitosis from the generative nucleus follow closely behind.
-The pollen tube tip pierces the stigmatic surface and penetrates the style tissue via intercellular spaces.
-Chemical substances in the style and embryo sac enable the unidirectional rapid growth of the pollen tube towards the ovary.
-After reaching the ovary, the pollen tube grows towards the ovule and usually enters through the micropyle, chalaza, or integuments.
-The pollen tube then penetrates the embryo sac, bursts open and the tube nucleus degenerates.
-The first fertilization occurs when one sperm fuses with the egg to form a diploid zygote, while the second fertilization occurs when another sperm fuses with the diploid secondary nucleus to form a triploid primary endosperm nucleus. This double fertilization is unique to only flowering plants.

Diagrams illustrating fertilisation in flowering plants





b) Summary of the results of fertilization in a flowering plant

Before fertilisation	*After fertilisation the parts become*	*Function of part formed after fertilisation*
Zygote	Embryo	
Ovule	Seed	Protects embryo
Ovary	Fruit	Protects seeds and enables their dispersal
Integuments: (a) outer (b) inner	Testa/seed coat Tegmen	Offer protection to the seed
Ovary wall	Fruit wall/pericarp	Offers protection to fruit contents
Triploid primary endosperm nucleus	Endosperm	Acts as food store in some seeds e.g. cereals like maize, wheat, castor oil
Micropyle	Micropyle	For entry of water and oxygen at germination
Nucellus	Disappears	
Calyx	Wither away or may persist	

Petals, stigma, style & stamens	They dry and fall off	

c) Double fertilization: is a unique process occurring only in flowering plants in which one male nucleus fuses with the functional egg nucleus to form a diploid zygote while another male nucleus fuses with the diploid secondary nucleus to form a triploid primary endosperm nucleus simultaneously.

a) What are the advantages and disadvantages of propagation by seed?
b) Explain how the science of palynology (pollen analysis) can provide information about past climate and human activities of a particular period of time.

a) Advantages:
- Enable plants to be better adapted for land environment since water is less required for sexual reproduction
- Embryo is protected within the seed
- There is food reserve for embryo growth in the cotyledon or endosperm
- Seeds are easy to store
- Seeds are easy to disperse and transport
- Allows for mixing of genes which increases the hybrid vigour
- There is increased resistance to diseases
- Plants mature early
- There is tolerance to unfavourable conditions

Disadvantages:
- Seeds are easily destroyed by pests
- Seeds have limited food reserves
- Requires selection of suitable seeds
- Needs technical knowing
- Initial inputs are expensive
- Dispersal may not be easy because of the large size of seeds usually

b) -The highly sculptured pattern of the exine (outer wall) of pollen grain is specific to plant species or genus.
-Since the exine has a waterproof lining resistant to decay, pollen grains last for a longtime in the sediments.
-The pollen from successive layers of sediments can be extracted and analysed by radiocarbon dating to establish the climatic history e.g. past temperature. Human interference with the natural vegetation is also reflected in the pollen record e.g. absence of pollen from trees in some areas would indicate forest clearance.

VERTEBRATE REPRODUCTIVE TERMINOLOGY

a) Oviparity: animals deposit fertilized eggs in the external environment for development e.g. in all birds some reptiles and some fish.
b) 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
c) 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
d) Internal fertilization: is where fusion of male and female gametes occurs inside the body of the female animal.
e) External fertilization: is where fusion of male and female gametes occurs outside the body of the female animal.
f) Isolecithal eggs (Gr. *Isos*, equal, + *lekithos*, yolk): eggs with very little yolk that is evenly distributed in the egg e.g. human eggs.
g) Mesolecithal eggs (Gr. *mesos*, middle, + *lekithos*, yolk): eggs with moderate amount of yolk concentrated in the vegetal pole e.g. in amphibians.
h) 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.
i) Cleidoic eggs: shelled eggs e.g. eggs of birds, reptiles
j) Gametogenesis: the series of transformations that result into the formation of mature gametes.
k) Spermatogenesis: the series of transformations that result into the formation of male gametes.
l) Oogenesis: the series of transformations that result into the formation of female gametes.
m) 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)

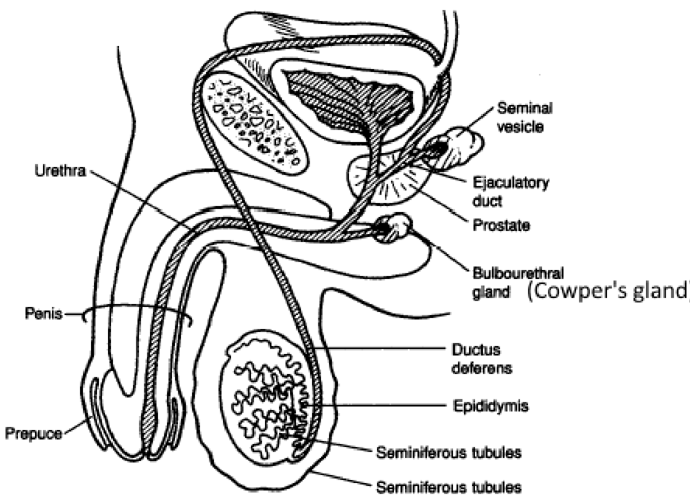
Secondary sex organs (accessory organs): organs associated with testes or ovaries which play some roles in reproduction but other than gamete production and hormone secretion. E.g. penis, prostate, seminal vesicles, sperm duct in males, and fallopian tubes, uterus, vagina, mammary glands in females.

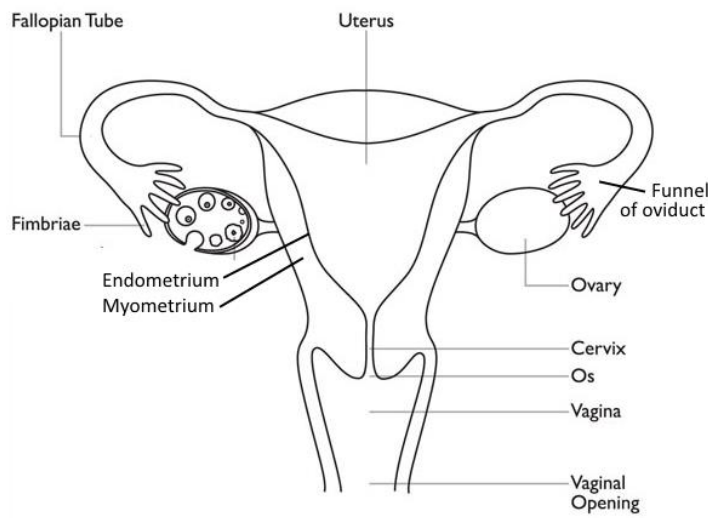
Primary sex organs	Secondary sex organs
-Produce gametes -Secrete sex hormones -Development is under the control of FSH and LH	-Do not produce gametes - Do not secrete sex hormones -Development is under the control of Oestrogen and progesterone in females and testosterone in males

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)

a) Describe the structure of the human reproductive systems.

b) State the functions of the different parts of human reproductive systems.

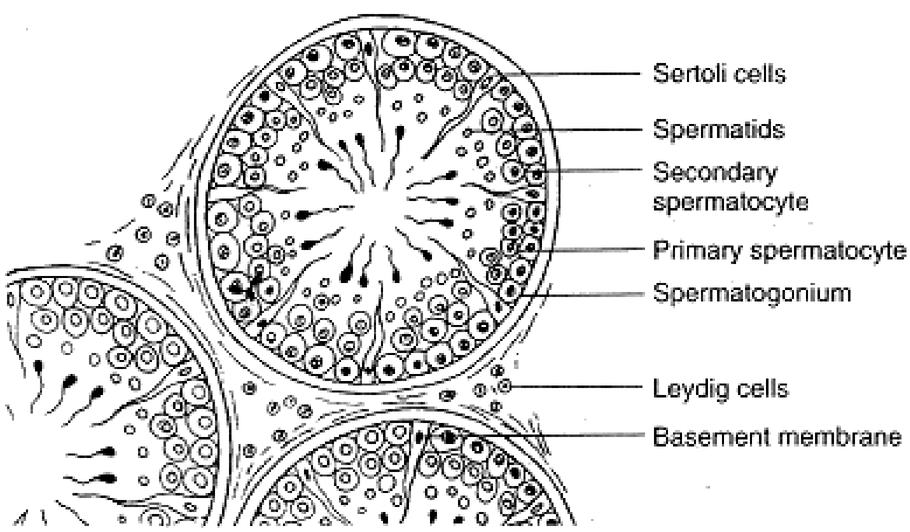


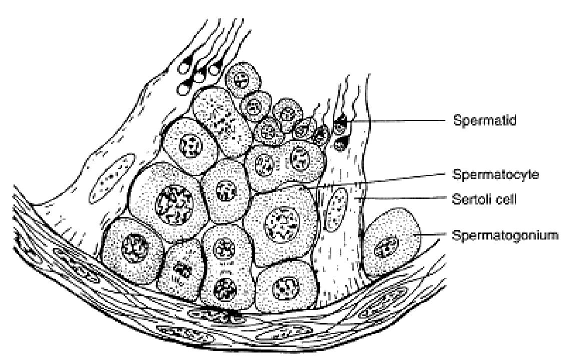


b) Functions of parts of the human reproductive systems

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** **Oviducts (Fallopian tubes)**	-The finger-like projections sweep the egg into oviduct. -Walls are muscular and lined with ciliated epithelium for moving egg from ovary towards uterus.
Testes	-Contain seminiferous tubules that produce sperm. -Produce the male sex hormone testosterone.	**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.		
Note: *Semen is 1% sperm, 20% fluid from prostate gland, 60% fluid from seminal vesicles and the rest other substances*		***Note:*** *The clitoris contains erectile tissue and nerves, and is homologous to the glans penis of males*	





Describe the main events during Spermatogenesis and development of ova in humans

Spermatogenesis:
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.
Spermiogenesis	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.

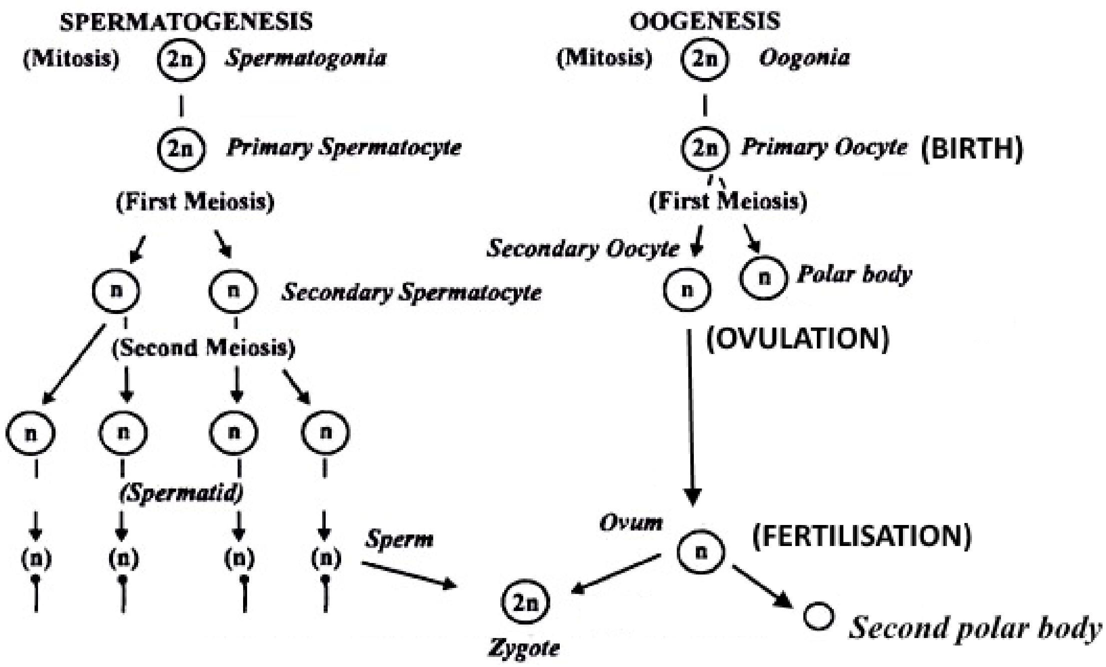
Functions of sertoli (sustentacular) cells:
i) Provide nourishment to developing spermatids.
ii) Phagocytise (eat off) the cytoplasm of spermatids.
iii) Secrete a fluid that carries spermids through the tubules.
iv) Phagocytise foreign particles that invade the tubules.

Oogenesis:

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 <u>**ootid (ovum)**</u> and <u>**second polar body.**</u> -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

<u>Note:</u> 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.



Explain the 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.

Compare spermatogenesis and oogenesis in humans

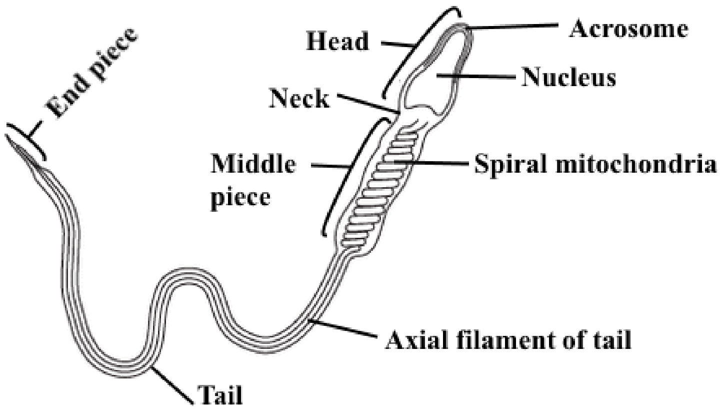
Similarities:

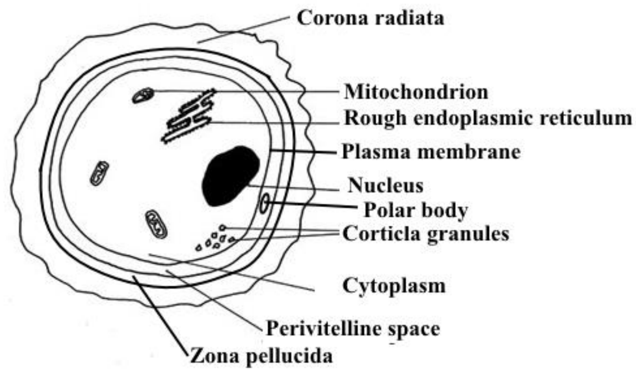
- Both begin with diploid germinal epithelial cells
- Mitosis and meiosis are involved in both
- Both yield haploid gametes
- Both occur in gonads

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

a) Describe the structure of human male and female gametes
b) State the functions of the parts of gametes
c) Compare male and female gametes in humans





b) Functions of the parts of gametes

Human spermatozoon			*Human ovum*	
Part	**Function**		**Part**	**Function**
Acrosome	-Contains hydrolytic enzymes which facilitate the penetration of the egg membranes prior to fertilization.		**Yolky cytoplasm**	Contains fat and protein which nourish the developing embryo.
Nucleus	Contain a haploid set of chromosomes, which on fusion with the egg restores the diploid state of organisms.		**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.
Mitochondria	They complete aerobic to release ATP required for contraction of filaments during the sperm's movement.		**vitelline membrane**	Undergoes structural changes that prevent polyspermy at fertilisation
Tail piece (Flagellum)	Enables motility of the sperm.		**Nucleus**	Contains 23 chromosomes that complete meiosis II at fertilization to provide female haploid nucleus
Centriole	-One of a pair produces microtubules that form the axial filament of flagellum. -The function of the other centriole is not clearly known.		**Polar body**	Contains 23 chromosomes, but is non-functional and degenerate

Outline the 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)

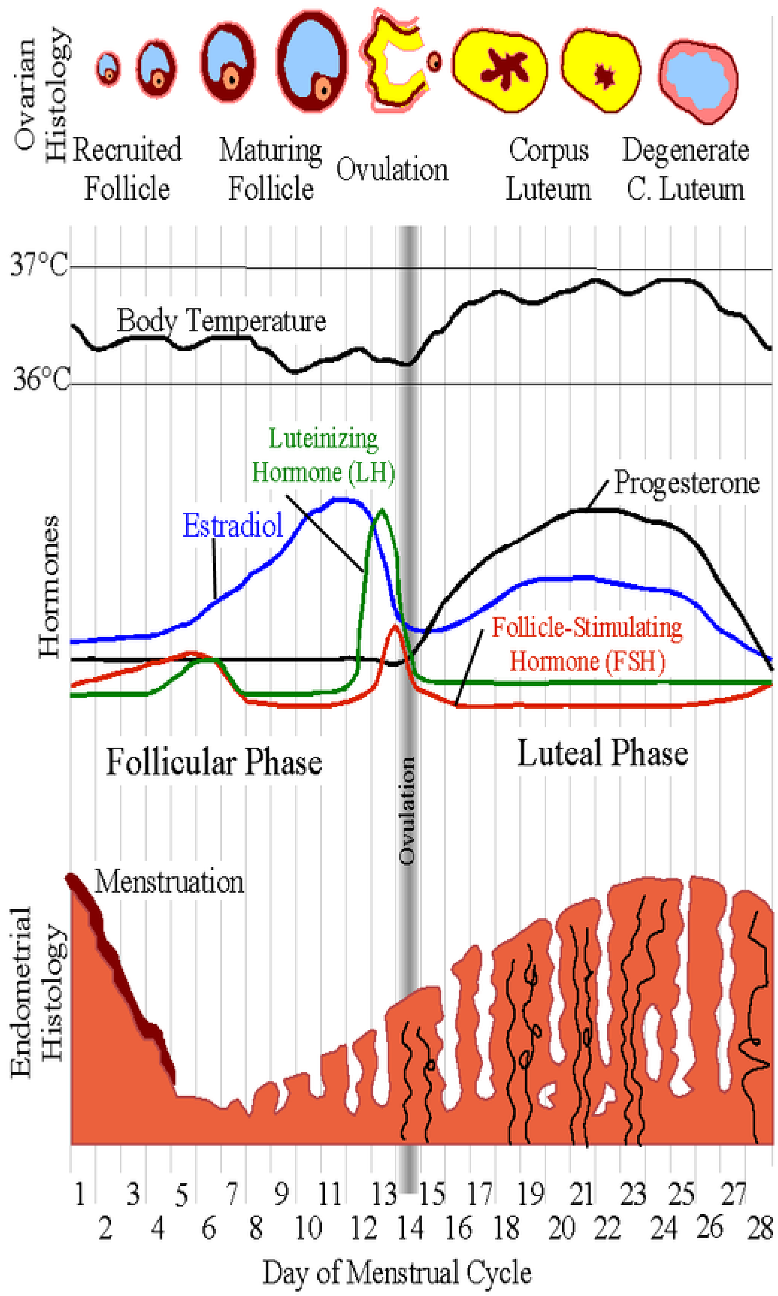
a) (i) **Oestrous cycle:** series of hormone controlled changes in the non-primate reproductive cycle characterized by females experiencing a period of heightened sexual excitement just before ovulation.

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

b) **HORMONAL CONTROL OF MENSTRUAL CYCLE**

The hormonal, physiological and structural changes that occur during the menstrual cycle are as follows:	
Phase	*Changes*
Follicular phase	-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: (i) The development of primary follicles in the ovary (ii) The secretion of **oestrogen.** **3. Oestrogen:**
Ovulation	(i) Causes the repair and healing of the uterine wall following menstruation. (ii) Inhibits the secretion of **FSH.** (iii) Causes the secretion of **LH** from the anterior pituitary.
Luteal phase	**4. LH** stimulates: (i) **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. (ii) The remains of Graafian follicle to develop into **corpus luteum** (yellow body), (iii) The **corpus luteum** to secrete **progesterone** and o**estrogen**.
Menstruation	**5. Progesterone:** (i) Causes increased thickness (muscularisation) and vascularization of the uterus. (ii) 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.

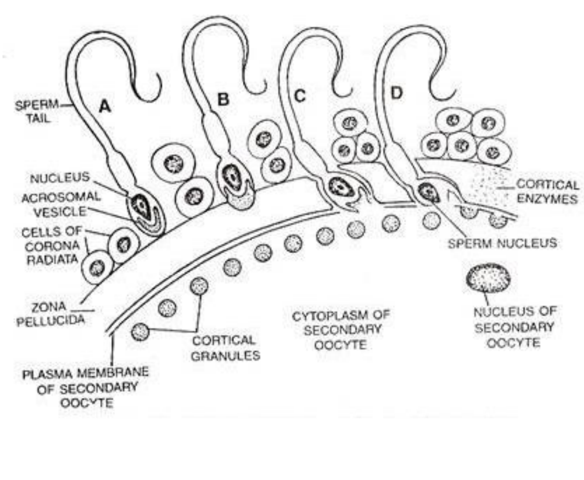
Outline the events which lead to fertilization of an egg by a sperm.

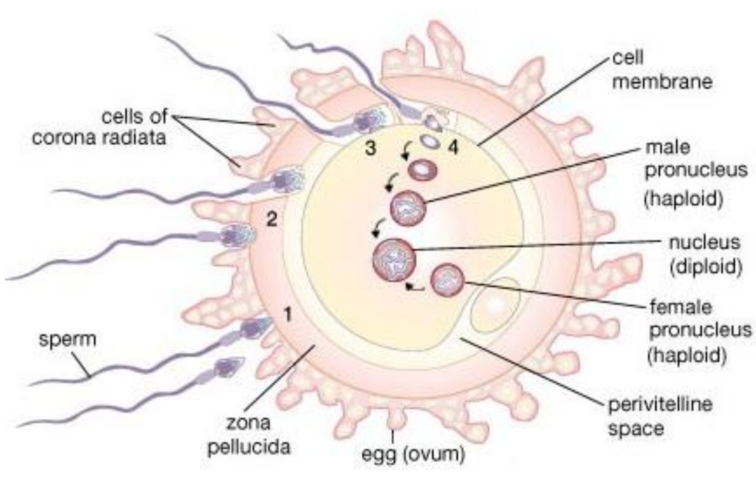
Fertilization is the fusion of sperm and egg nuclei to form a diploid zygote.

- 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.

After their release, how long do sperm and secondary oocyte remain viable for fertilization?

Approximately 48 hours for sperm and about 10-15 hours for secondary oocyte. Therefore to result in pregnancy, sexual intercourse must occur no more than 48 hours before or 15 hours after ovulation





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.**
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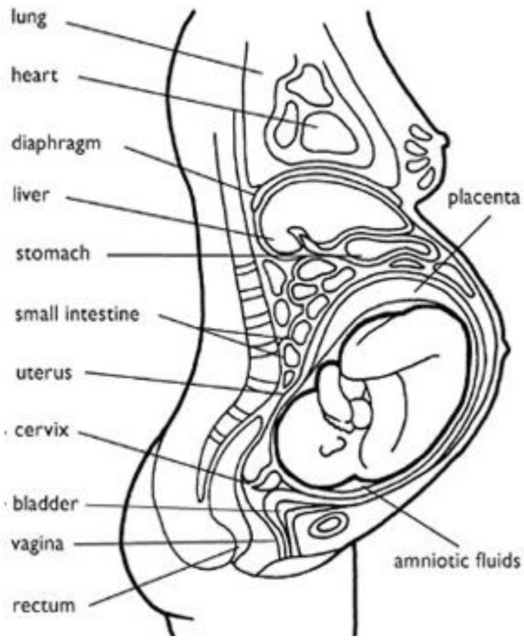
a) What is meant by negative feed back
b) Briefly explain how negative feed back operates in the control of:
i) Testicular hormone secretion
ii) The menstrual cycle
c) What hormonal controlled changes occur in the endometrium during the menstrual cycle?
(Effect of ovarian hormones on the endometrium during the menstrual cycle)

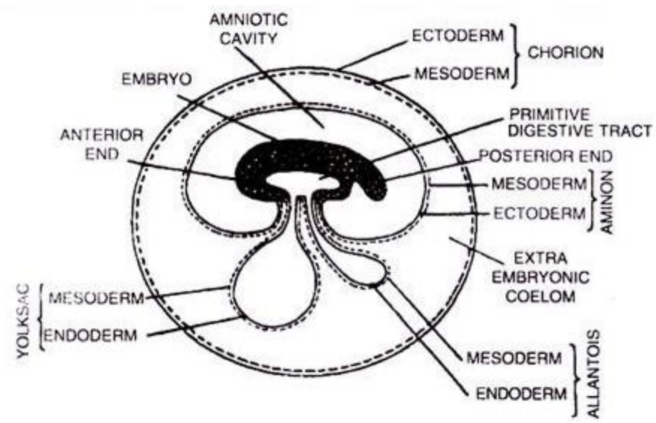
a) A mechanism in which the effect of deviation from the normal condition triggers a response that eliminates its deviation in order to reduce further corrective action of the control system once the set point value has been reached.

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.

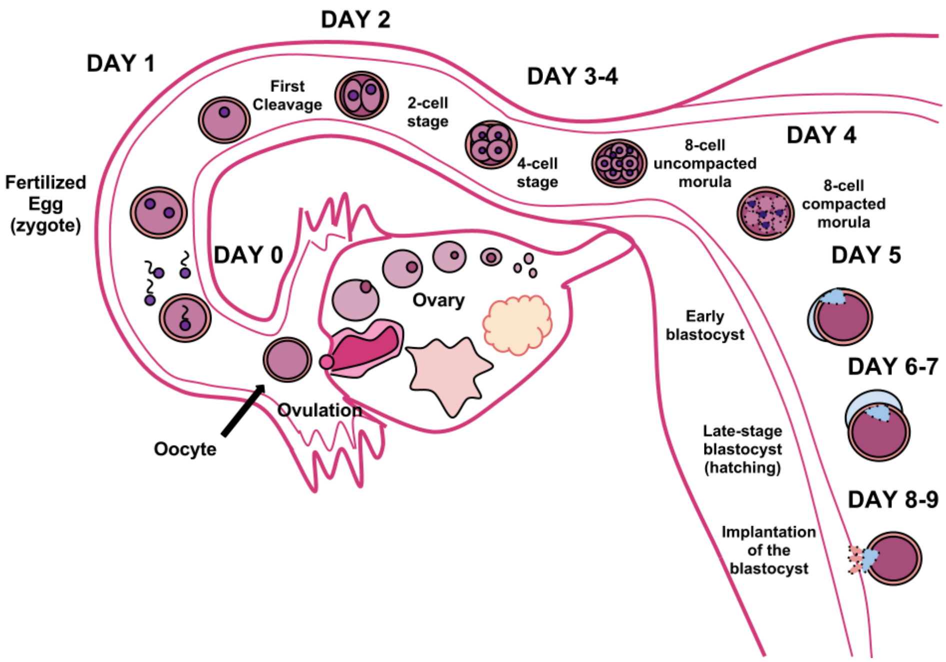
PREGNANCY (GRAVIDITY OR GESTATION): The period between conception (fertilisation) and birth.

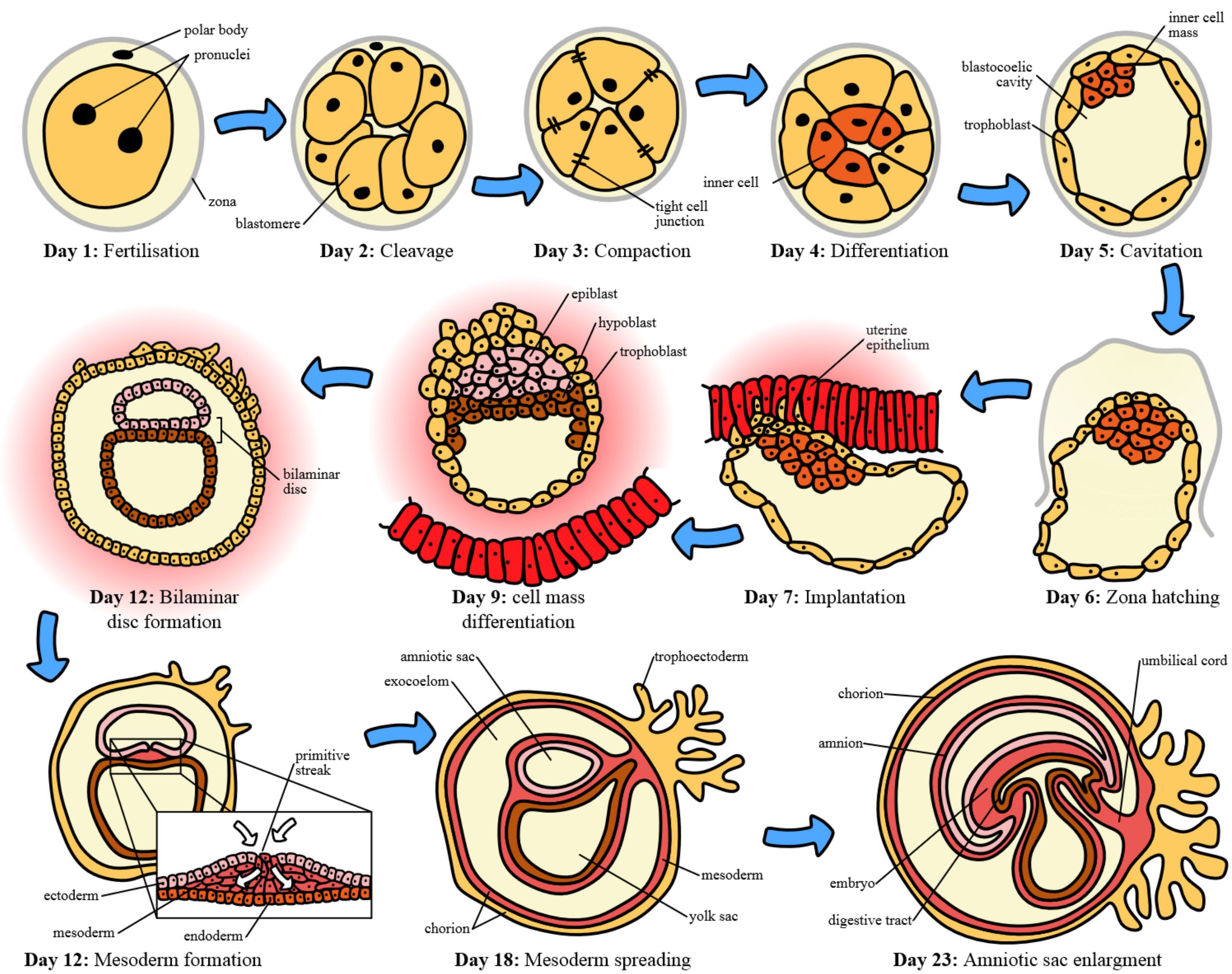




HIGHLIGHTS OF HUMAN PREGNANCY
30 hours after fertilisation – first cleavege
3-4 Days after Conception:
(i) The zygote, now called **morula** arrives at the uterus after a 4 inch journey through the fallopian tube.
(ii) In the uterus the morula burrows itself into the endometrium (inner lining of uterus).
(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.

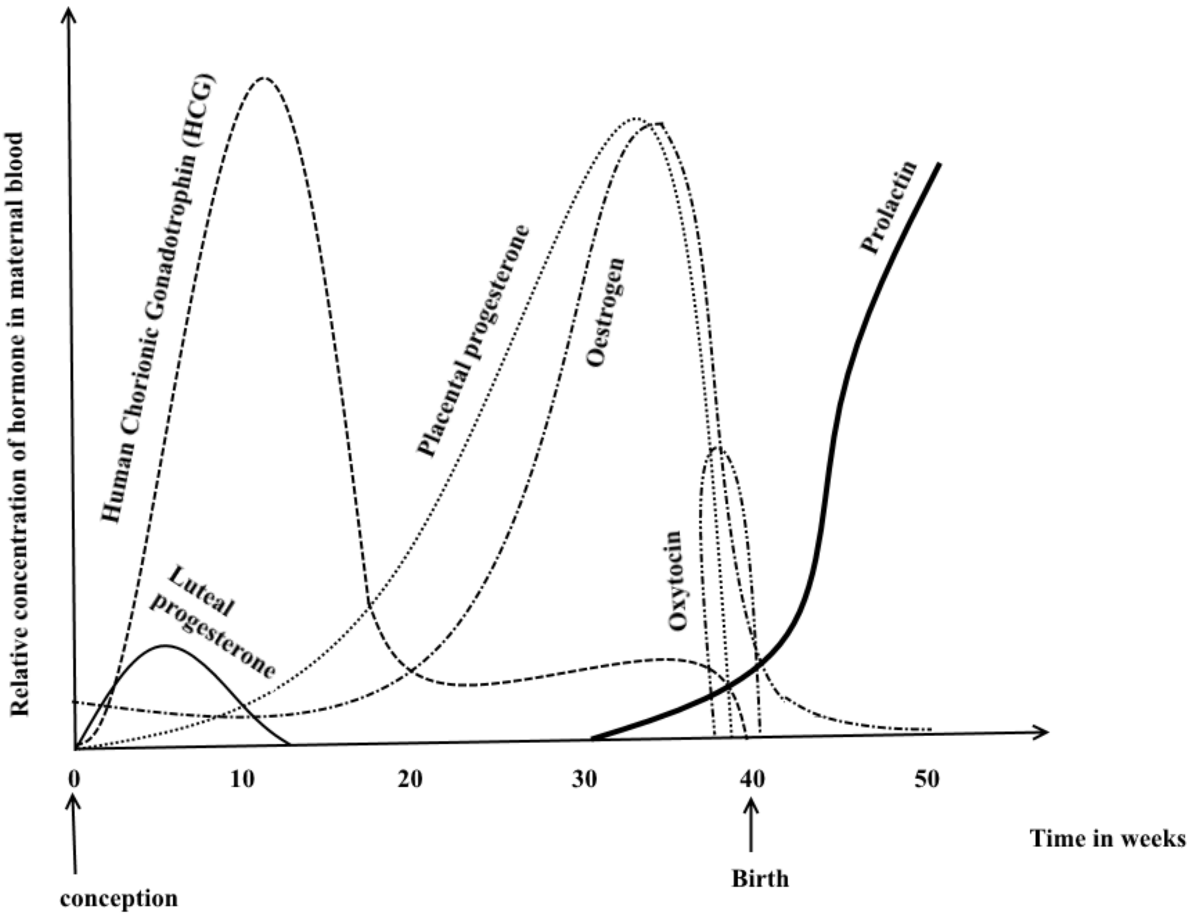
Duration	Major events
2 weeks	Most women can test positive for HCG urine pregnancy tests, at 95% accuracy.
3 weeks	Baby-in-the-making is a ball of cells called a **blastocyst. Gastrulation** occurs.
4 weeks	Organogenesis
5 weeks	Heart begins to beat – at twice the rate of adults.
6 weeks	Facial features (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.


DAY 2
DAY 1
First Cleavage
2-cell stage
DAY 3-4
4-cell stage
8-cell uncompacted morula
DAY 4
8-cell compacted morula
Fertilized Egg (zygote)
DAY 0
Ovary
DAY 5
Early blastocyst
DAY 6-7
Ovulation
Oocyte
Late-stage blastocyst (hatching)
DAY 8-9
Implantation of the blastocyst


polar body
pronuclei
zona
blastomere
tight cell junction
inner cell
inner cell mass
blastocoelic cavity
trophoblast
Day 1: Fertilisation
Day 2: Cleavage
Day 3: Compaction
Day 4: Differentiation
Day 5: Cavitation
epiblast
hypoblast
trophoblast
uterine epithelium
bilaminar disc
Day 12: Bilaminar disc formation
Day 9: cell mass differentiation
Day 7: Implantation
Day 6: Zona hatching
primitive streak
ectoderm
mesoderm
endoderm
amniotic sac
exocoelom
trophoectoderm
mesoderm
yolk sac
chorion
umbilical cord
chorion
amnion
embryo
digestive tract
Day 12: Mesoderm formation
Day 18: Mesoderm spreading
Day 23: Amniotic sac enlargment

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?
c) Outline the transport mechanisms involved in the exchange of substances between mother and developing foetus.

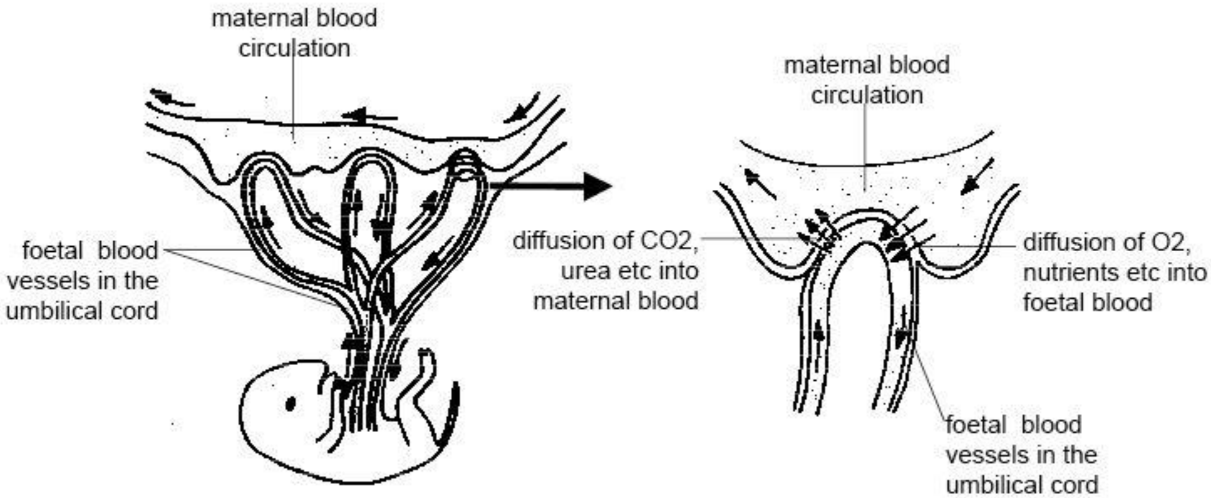
a) The role of the placenta

As an endocrine organ	*Non-endocrine role*
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.	• 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

c) Transport mechanisms involved in the exchange of substances between mother and foetus

Mechanism	*Substances moving*
Osmosis	Water
Simple diffusion	-Respiratory gases (oxygen and carbondioxide) -Nitrogenous wastes (urea) from the foetus -Ions (of sodium, potassium, calcium) to a small extent diffuse.
Facilitated diffusion	-Glucose
Active transport	-Ions (of sodium, potassium, calcium) largely move by active transport -Amino acids -Iron -Vitamins



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.

b) Give an outline of birth control methods in man

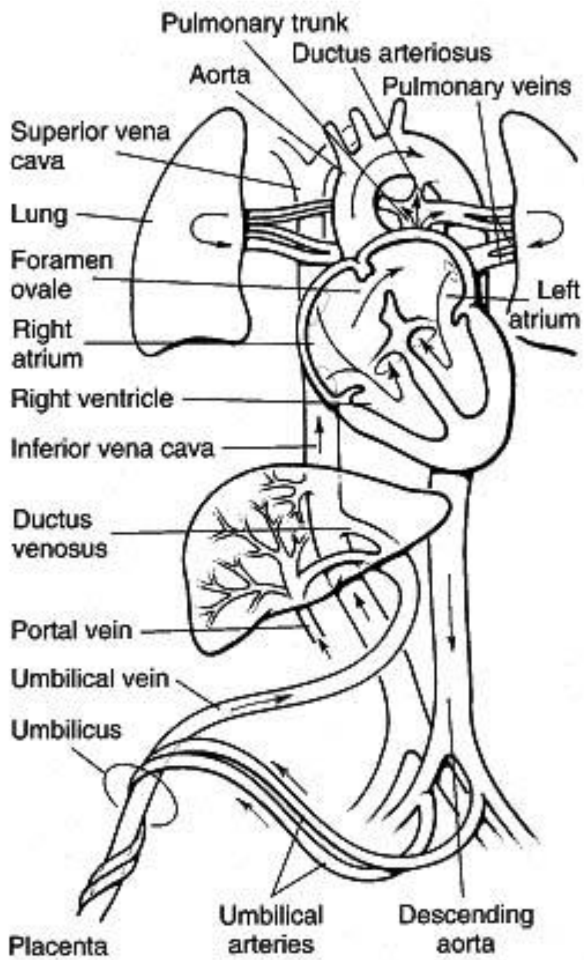
Contraception: use of methods which act to prevent fertilization of an egg by sperm

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

Birth control methods

Method	***How it works***
1. Barriers preventing sperm from reaching egg cell	
a) Condom (for males and females)	-Inserted on erect penis or into vagina before sexual intercourse
b) Diaphragm (cap)	-Inserted into vagina before sexual intercourse
c) Spermicide	-Cream, foam or gel placed into vagina to kill sperm
2. Hormones that interfere with ovulation or implantation	
a) Pill	-Combination of oestrogen and progesterone prevents ovulation and implantation
b) Morning after pill (emergency pill)	-Used within 48 hours after sex.
3. Behavioural	
a) Rhythm method	-Sex is avoided during ovulation period
b) Penis withdrawal (coitus interruptus)	- Penis is withdrawn from vagina before ejaculation occurs
4. Surgical	
a) Vasectomy (males)	-Sperm duct is cut and tied permanently
b) Ligation of oviducts	-Both oviducts are cut and tied permanently
5. Other e.g. intra-uterine device (IUD), plastic or copper device	-Prevents implantation

CHANGES THAT OCCUR IN BLOOD AND FOETAL CIRCULATION AT BIRTH



INFERTILITY

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

(i) Primary infertility: pregnancy has never occurred.

(ii) Secondary infertility: 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

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.

What major change would occur in the foetal circulation 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

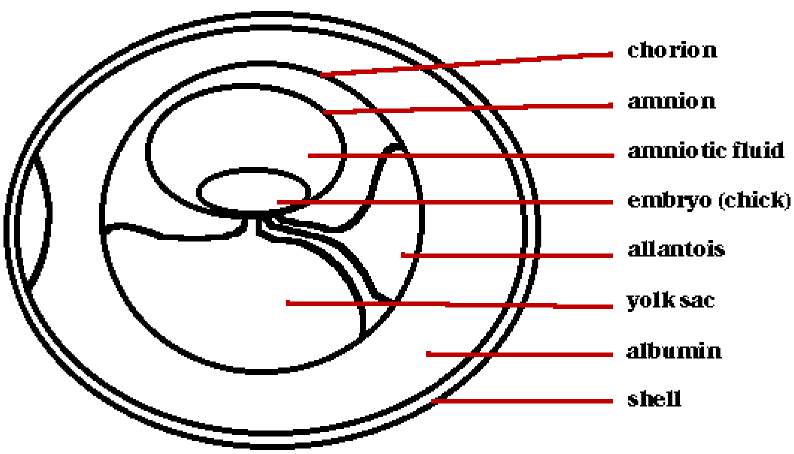
1. Chorion: It completely surrounds the foetus and is the foetal contribution to the placenta.
2. Amnion: Forms a fluid filled **amniotic cavity** that cushions the foetus from shock and mechanical damage.
3. Yolk sac: Contains little or no yolk, it is a temporary site for **red blood cell** formation.
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 e.t.c. **(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:

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

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:

(i) Protection from predators (ii) Feeding (iii) Provision of shelter (v) Training of offspring.