# REPRODUCTION IN ORGANISMS

It is a process by which living organisms give rise to new individuals of the same kind (species).

It is one of the fundamental life characteristics that involves transmission of the genetic material from parents to offspring; thus giving rise to a new generation of the same species. The process therefore ensures perpetuation of such characteristics over generations.

**IMPORTANCE OF REPRODUCTION**

- The fundamental essence of reproduction is to ensure continuity of life through giving rise to new members that replace those dying of old age, diseases, predation etc.
- It allows for increase in number of organisms during favourable environmental conditions.
- It leads to genetic variation among organisms that reproduce sexually.
- May involve development of resistant stages for survival of un favourable conditions
- Reproduction leads to formation of spores, seeds or larvae which are important for dispersal

**There are two types of reproduction**

- sexual reproduction
- A sexual reproduction

**A SEXUAL REPRODUCTION**

This is the production of new individuals from a single organism without fusion of gametes.

The process does not involve use of gametes and therefore does not lead to variation (which allows for change of organisms), offspring tend to closely resemble their parents forming a clone of identical organisms. Unlike sexual reproduction which requires two parents, asexual reproduction involves only one organism for a parent as no gamete fusion takes place.

**NB:** Asexual reproduction does not lead to variation since only one parent is involved and there is no gamete production. Asexually produced offspring are identical to each other and are known as clones. Any differences among such offspring are due to random mutations or environmental factors.

A clone is a group of identical offspring from a single parent.

**TYPES OF ASEXUAL REPRODUCTION**

Asexual reproduction occurs in 5 major forms in different organisms. These include

- Fission
- Budding
- Fragmentation
- Sporulation
- Vegetative propagation

**FISSION**

This occurs in unicellular organisms and involves division/splitting of a cell into two or more daughter cells that are identical to the parent cell. The formation of two daughter cells is called binary fission while formation of more than two daughter cells is called multiple fission.

**Binary fission** involves replication of DNA then division of the nucleus (for eukaryotic organisms) which leads to division of the whole cell. Two identical daughter cells are formed and develop into individual organisms.

This form of asexual reproduction is so rapid and population size grows similarly. It occurs in unicellular organisms like bacteria and protists like amoeba, paramecia, and euglena.

**Multiple fission** involves repeated division of the nucleus followed by division of the whole cell into many daughter cells. The cell undergoing multiple fission enlarges and is known as a schizont; while the process of multiple division is called schizogony.

Multiple fission is common in plasmodium.

**BUDDING**

This is when an organism develops an outgrowth/protrusion (called a bud) which eventually detaches and grows into an independent organism.
During budding, the parent nucleus divides into two and one passes the outgrowth which undergoes further development. This occurs in unicellular fungi like yeast and cnidarians like hydra and sponges.
Unlike binary fission where the daughter cells are of equal sizes, the new organism develops from a bud which is smaller than the parent cell. The bryophyllum plants, this has small plantlets called bulbils which upon germination detaches and grows independently.

**FRAGMENTATION**

This is when an organism breaks down into two or more parts that develop into independent organisms
It occurs in filamentous algae (spirogyra) and flat worms like tape worms and planaria.

**SPORULATION (SPORE FORMATION)**

This is when organisms reproduce by means of **spores**. A spore is a single haploid cell that is capable of directly growing into a new organism. It consists of a nucleus and a thin cytoplasm. They are resistant to harsh conditions and can germinate when conditions are favourable.
Sporulation occurs in all groups of fungi like rhizopous (bread mould), all groups of algae and fungi, protoctistans, bacteria and green plants. Lower plants like mosses and ferns basically reproduce by means of spores. Higher plants produce microspores (Pollen grains) in pollen sacs and megaspores (embryo sacs) in ovules. Bacterial spores are mainly formed as protective structures needed to survive harsh conditions like dry conditions and extreme temperatures. These spores remain dormant in such situations only to resume activity when conditions become favourable.
In addition to survival and reproduction, pollen grains are also means of dispersal given their small size that they can easily be carried around by wind or insects. The only challenge is the limited food reserves that may be depleted before finding a suitable substrate for germination.

**Sporulation in rhizopus**

The bread moulds are saprophytic fungi that consists of a highly branched body (mycelium) comprised of tiny filamentous threads called hyphae. Some hyphae grow vertically upwards forming sporangiophore which bear spore-producing bodies called sporangia (singular sporangium) inside which numerous spore are produced. When mature, the sporangium bursts to release the spores which grow into new moulds once they land on suitable substrates.

**VEGETATIVE PROPAGATION**

This is when a vegetative part of a plant is detached and develops into a new plant. These plant parts are usually large and specialised with small buds which can develop into new plants. In many cases these parts are succulent, swollen with food reserves and resistant to harsh conditions. This increases survival of the plant species as these organs grow into new plants when environmental conditions become favourable. The resistant structures are capable of surviving harsh conditions for a long period of time and are known as perennating organs. These are commonly underground stems.

**COMMON METHODS OF VEGETATIVE PROPAGATION**

**Modified leaves;** this commonly occurs in bryophyllum plants where leaves carry tiny plantlets called bulbils in the notches along the margin. These bulbils can grow into new independent plants when conditions permit.
**Bulbs;** are short underground stems surrounded by fleshy leaves (store food) and thin scale leaves on the outside. They have many adventitious roots with one or more buds. Each bud is capable of developing into an independent plant producing a new bulb at the end of the season.
Examples of such plants include Onions and garlic
**Stem tubers;** Are rounded underground stems swollen with stored food. They have scale leaves with axillary buds each capable of developing into a new plant. In this process, adventitious roots develop from the tubers to absorb water from the soil

**Rhizomes;** Are horizontally growing underground stems. They have scale leaves, nodes and axillary buds. When conditions are favourable, a rhizome develops adventitious roots below and shoots up into new pants. Rhizomes are also important for storage of food and water.
Couch grass, canna lilly and ginger can reproduce vegetatively by use of such rhizomes.
**Corms;** Are thick vertically growing underground stems swollen with food reserves.
It has protective scale leaves, nodes, terminal and axillary buds capable of developing into new plants.
During favourable conditions, corms develop adventitious roots which absorb water and growth resumes. This method is commonly used by cocoyam.
**Root tubers;** these are usually swollen adventitious roots containing stored food, e.g. sweet potatoes. These contain buds from the base of the old stem which are capable of growing into new plants.
**Swollen tap roots**; these are commonly found in roots, swollen with stored food. The roots carry several terminal buds and lateral buds with small adventitious roots which absorb water and growth resumes.
**NB:** Although it is not typical of roots to bear buds, swollen adventitious roots and tap roots carry axillary buds as remains from the old stem that forms part of the root. These are capable of growth into new plants hence vegetative propagation.
***Stolons,*** the stem grows diagonally upwards and then bends over to the ground, producing adventitious roots at the tip. The apical bud continues growing into a new shoot which also bends over to the ground and the process continues.
Examples include black berries
***Runners*** are horizontal stems growing along the soil surface form the parent plant. New plants develop along the nodes of this stem and adventitious roots grow. The runners eventually dry when the new plants become established.
Examples of runners include straw berry and the creeping butter cap
***Suckers*** initially grow underground and emerge and develop into new plants.
**NB:** Although the rhizomes, corms, stem tubers, swollen tap roots and bulbs are underground structures that are also important for survival of harsh conditions (perennating organs) and storage of food and water, stolons, runners and suckers are just creeping stems but can be used for vegetative propagation since they can also give rise to new plants.
The plants may have be able to reproduce by flowers (during favourable conditions) but only the swollen roots survives harsh conditions like winter and germinate into new plants when conditions become favourable.
**Artificial Techniques of Vegetative Reproduction**
**Stem cuttings;** this is when small portions of the plant are cut and planted, developing into new plants. This is commonly done with cassava and rose plants
**Layering;** the terminal end of the stem is cut and inserted into the soil to resume growth into new plants. This is done in sweet potatoes
**Grafting;** a growing part of the plant is cut and inserted onto another plant to resume growth. This method allows for combination of good qualities from different species or different varieties of the same species into a single plant.
During grafting, the plant part that provides a root system is called a **stock** while the one that is inserted onto the stock is called the **scion.** This is commonly done for fruits like passion fruits, oranges etc.
**Tissue culturing (Cloning);** it involves placing a mitotically active cell of the cambium into a culture solution to allow it grow into a full plant. The method may also be applied to animals. The cell from the organism is placed in a culture solution where it under goes mitosis to grow into a full organism. Such organisms are genetically (and virtually) phenotypically identical to the parent unless significant mutations occur during growth.
It may also involve cell hybridisation where the protoplasm or nuclei of 2 cells may be combined to grow into a single organism.

This method of propagation is important in agriculture to rapidly multiply plants of great agricultural importance. Such plants grow at the same time which makes harvesting easy. They also maintain useful characteristics of the parental plant. Cloned cells can also be used to investigate the impact of hormones, drugs and antibodies in the lab. The disadvantage of clones is that in case of disease outbreak, resistant forms hardy exist because they are genetically identical.

**Advantages of asexual reproduction**

- ❖ New organisms are identical to the parents. This maintains advantageous characteristics over generations.
- ❖ Only one organism is involved which eliminates external factors associated with pollination and fertilisation.
- ❖ Offspring mature faster as compared to those produced sexually.
- ❖ The process is so rapid that very many organisms are produced
- ❖ Offspring don't require parental care
- ❖ Enable plants which don't have viable seeds e.g. bananas and pine apples to reproduce

**Disadvantages of asexual reproduction**

- ❖ Offspring are identical which prevents variation among organisms. This is because gene mixing does not occur since one parent is involved.
- ❖ It may lead to overcrowding due to faster rates of reproduction
- ❖ Diseases from parents are usually passed from parents to offspring
- ❖ Asexual reproduction results into progressive decrease in hybrid vigour of offspring. Offspring are progressively weaker than their parents.
- ❖ Undesirable characters are always passed from parents to offspring

**NB:** The above advantages and disadvantages also apply to vegetative propagation, parthenogenesis and other means of asexual reproduction.

## SEXUAL REPRODUCTION

This is the formation of new organisms by fusion of male and female gametes to form zygote

The fusion of male and female gametes to form a zygote is known as fertilization. This type of reproduction mainly occurs in animals and flowering plants but also occurs in some non-flowering plants and some fungi where two different organisms are involved; the male produces sperms while he female produces ova. Organisms with separate male and female individuals are described as **unisexual organisms;** as in humans and most other animals

Some species are capable of producing both male and female gametes by the same organism. These are termed as **hermaphrodites/bisexual organisms.** They commonly include protozoa like paramecia Platyhelminthes like tape worms (Taenia), earth worms, and molluscs like snails. It also occurs in some fish, birds, lizards and most flowering plants. It is an adaptation to slow-moving or solitary organisms where finding a mate may not be easy; as in plants and internal parasites.

Although such organisms are capable of self-fertilisation; adaptations commonly occur to promote cross fertilisation and minimise self-fertilisation. Cases of genetic self-incompatibility (When sperms cannot fertilise ova of the same organism), a number of structural adaptations as in f lowering plants, and production of sperms and ova in the same organism but at different times. In such cases hermaphroditism serves to ensure that any two organisms can mate successfully hence increasing the chances of reproduction.

**Forms of sexual reproduction**

There are three forms of sexual reproduction; basing on the kinds of gametes produced

- ✓ Primitive organisms like algae produce gametes that are structurally (morphologically identical). This is called isogamy
- ✓ Some organisms produce non-identical gametes; a condition known as anisogamy

- ✓ Organisms produce non identical gametes where one is much smaller and motile. This is termed as oogamy.

**Parthenogenesis (Virgin origin)**

Parthenogenesis is a modified form of sexual reproduction in which a gamete develops into a new individual without fertilisation taking place. It is a form of reproduction eggs develop into adults without being fertilised. Such parthenogenetic eggs may be produced by mitosis (diploid) or by meiosis (haploid).

**Haploid parthenogenesis** is when haploid gametes are formed by meiosis and develop into new individuals without being fertilised. It occurs in many insects like ants, bees and wasps

In both of these cases, offspring are genetically identical to the parent (Mother).

In bees, the queen produces eggs by meiosis; and may lay them fertilized or unfertilised. Fertilised eggs develop into diploid females. These once fed on royal jelly grow into fertile females (Queens) while those fed on pollen and honey grow into sterile females (workers). The unfertilised eggs grow by parthenogenesis into fertile haploid fertile males (drones) and these produce haploid gametes by mitosis. This is what is called haploid parthenogenesis

**Diploid parthenogenesis;** occurs when diploid eggs are produced by meiosis and grow into new individuals without fertilization. This commonly occurs in Aphids where females produce diploid eggs that develop within the female until they hatch and young ones are released viviparously. Each of the young ones is fertile and capable of reproduction. This commonly occurs in summer to allow for rapid reproduction as the food is readily available.

Other organisms capable of parthenogenesis include plants (like bananas, pine apple and seedless varieties of oranges and grapes), flat worms, rotifers, and a variety of vertebrates like fishes, lizards, snakes and birds.

In plants, parthenogenesis is stimulated by presence of a high level of auxins that occurs in the ovaries. Parthenogenesis can be artificially induced in tomatoes, peas and sweet peppers by addition of a high level of auxins (or even Gibberellins).

## LIFE CYCLES

The term life cycle refers to the developmental stages through which an organism passes from one generation to the next generation.

The complexity of life cycles varies greatly among organisms. In plants and algae, two generations which differ in morphology and mode of reproduction occur in the life cycle of the same organism. This is known as **alternation of generations**.

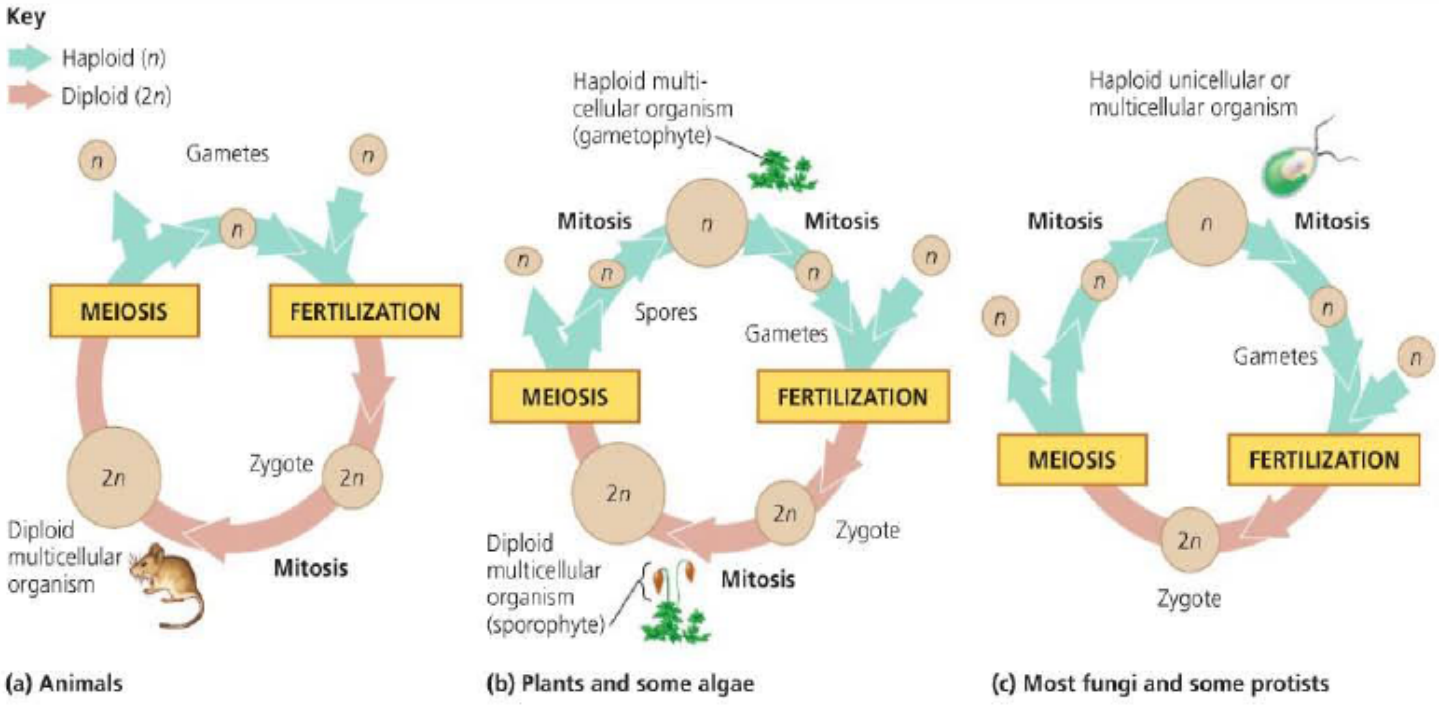
The term alternation of generations refers to the occurrence multicellular sporophyte and gametophyte forms in the life cycle of the same organism. These forms commonly differ in structure (Morphology) and mode of reproduction.

A sporophyte is a multicellular diploid generation that produces spores by meiosis. A spore is a single haploid cell capable of directly growing into a new organism. Unlike the zygote; spores are not formed by fusion of two cells.

A gametophyte is a multicellular haploid generation that produces gametes by mitosis. A gamete is a single haploid cell that fuses with another gamete to form a zygote; which then grows into a new organism.

**General form of alternation of generations**

In the sporophyte generation, meiosis occurs to produce haploid cells called spores, which unlike gametes divide by mitosis to grow into a multicellular haploid generation called the gametophyte. Cells of the gametophyte produce haploid gametes by mitosis. Fusion of two haploid gametes at fertilization results into a diploid zygote which divides by mitosis to grow into the next sporophyte generation.




▲ **Figure 13.6 Three types of sexual life cycles.** The common feature of all three cycles is the alternation of meiosis and fertilization, key events that contribute to genetic variation among offspring. The cycles differ in the timing of these two key events.

Alternation of generations occurs in all terrestrial plants and algae. Some animals show alternation of sexual and asexual forms (generations); this is better termed as **Metagenesis.** Both the sexual and asexual forms are diploid and the only haploid forms are the gametes.

**Alternation of generations in bryophytes (E.g. Liverworts and Mosses).**

Bryophytes include classes; liverworts like Pellia and Marchantia, and mosses like Funaria.

**Life cycle**

Bryophytes show alternation of generations between the gametophyte and sporophyte generations; with the gametophyte generation being dominant; and produce gametes by **mitosis**. Male gametophytes have **antheridia** which produce **antherozoids (sperms)** by mitosis while female gametophytes have **archegonia** which produce ova by mitosis.

When mature; the antheridium absorbs water and bursts; releasing antherozoids in a film of water; these by means of flagella swim towards and into the archegonium (being attracted by sucrose); and fuse with the ovum; forming a diploid zygote.

The zygote grows by mitosis; into a diploid sporophyte; which is dependent on the gametophyte. The sporophyte carries a capsule containing spore mother cells; which undergo meiosis to form haploid spores.

When mature; the capsule bursts to release the spores; which grow into a filamentous structure called **protonema**. This has numerous buds which grow into gametophytes; and the cycle repeats.

**Alternation of generations in pteridophytes**

These commonly include ferns; also called filicinophytes

Pteridophytes show alternation of generations between the gametophyte and sporophyte generations; with the sporophyte generation being dominant. The sporophyte undergoes meiosis in the sporangia; on the underside of the fronds to form haploid spores. Mature sporangia rapture to release the spores which grow by mitosis into haploid gametophytes. The gametophyte is a thin heart-shaped layer of cells called **prothalus**; which

produces antheroids in the antheridium and ova in the archegonia by mitosis.
At maturity, the antheridium releases antheroids into a film of water; and they swim towards the archegonium in response to chemicals. Antheroids fuse with the ovum to form a diploid zygote which grows by mitosis into a diploid sporophyte. This is initially dependant on the gametophyte until roots and leaves are developed, and the cycle repeats.
Comparing alternation of generations in bryophytes and pteridophytes

**SIMILARITIES**

- ✓ Both need water for fertilization.
- ✓ Both reproduce by means of spores.
- ✓ In both, gametes are produced by mitosis.
- ✓ The sporophyte is dependant onto the gametophyte
- ✓ Spores by meiosis.
- ✓ Flagellated spermatozoids [motile].
- ✓ Grow in damp moist habitats

**DIFFERENCES**

| BRYOPHYTES | PTERIDOPHYTES |
|---|---|
| Gametophyte is dominant. | Sporophyte is dominant. |
| Sporophyte is fully dependent on gametophyte. | Sporophyte is partly dependant on the gametophyte. |
| Zygote grows into a protonema | Zygote grows into a prothalus |
| Antheridium and archegonium occur on separate gametophytes. | Antheridia and archegonia occur on the same gametophyte |
| Biflagellate sperms. | Multi flagellate sperms. |

**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 increases chances of a species since the different generations are interdependent

**Sexual reproduction in spirogyra (a non-flowering plant)**

Spirogyra is a green filamentous algae found in fresh waters like lakes and ponds. The plant consists of elongated cells joined end to end to form a long threadlike filaments (hence the name filamentous algae).
It commonly reproduces asexually by fragmentation of these cells that develop into independent plants. It is also capable of sexual reproduction by a process called conjugation.

**Conjugation in spirogyra**

During conjugation, two filaments lying close to each other develop outgrowths called protuberances, which grow towards each other until they meet. On meeting, the cell walls dissolve to form a continuous tube called the conjugation tube joining the two filaments. The protoplasm passes from the cell of one filament into the other filament via the conjugation tube, their nuclei fuse to form a zygote. This develops a thick resistant wall and is known as the zygospore; which lays dormant till conditions become favourable. The zygospore germinates into a new filament.

**Sexual reproduction in *Rhizopus stolonifer***

A saprophytic fungus commonly known as the bread mould, usually reproduce by asexually by means of spores. The fungus can also reproduce sexually by use of spores.

**Sexual reproduction in rhizopus**

The process starts two hyphae of different mating types (+ and -) develop outgrowths with swollen tips which develop cross walls to separate them from the rest of the hyphae. The tips eventually meet and the cross walls dissolve, allowing their nuclei to fuse into a zygote. This develops a thick resistant covering to form a zygospore which dries and falls off as a dormant structure. When conditions become favourable, the zygopore germinates into a short hypha which spreads numerous spores. These are spores are of different types and are called sexual spores unlike the asexual spores which are all identical.

**SEXUAL REPRODUCTION IN FLOWERING PLANTS**

Flowering plants are called angiosperms; they are the most advanced plants (higher plants) and reproduce sexually by means of flowers

A flower is the reproductive part of the plant, having a male part (androecium) and a female part (gynoecium).

**Assignment**

**Define the following terms as used with flowers**

**TERMS USED IN FLOWERS**

*Parts of the flower*

✓ Whorls. The parts of a typical flower are arranged in groups of four main floral parts called whorls.

| Floral part (whorl) | Description and function |
|---|---|
| **Calyx** | Comprises of a group of small leaf-like structures called sepals. These protect the flower while still in a bud. |
| **Corolla** | Is comprised of a group of petals. They are usually scented and brightly colored to attract insect pollinators. |
| **Androecium** | Is a collection of stamens. These form the male part of the flower |
| **Gynoecium** | This is the female part of the flower. It comprises of one or more pistils (carpels) |

**NB:** Some flowers occur in close association with foliage leaves, such leaves are referred to as **bracts.** E.g. in banana inflorescent and bougainvillea.

✓ Inflorescence. Is a group of flowers borne on the same stock

✓ Sepals. These are usually green and protect the young flower bud. A flower whose sepals are free is said to be **polysepalous** e.g. morning glory while a flower with fused sepals is **gamosepalous** e.g. hibiscus

✓ Petals. They are often brightly colored and scented to attract insect pollinators. A flower whose petals are free is said to be **polypetalous** e.g. hibiscus while a flower with fused sepals is **gamopetalous** e.g. morning glory

✓ Perianth, in some flowers, the petals and sepals are identical and are collectively referred to as the ***perianth.***

✓ Androecium. Is the male part of a flower that consists of the stamens. Each stamen comprises of the **filament** at the top of which is the **anther** head containing pollen grains. These are the male reproductive cells in plants and are equivalent to sperms in human beings.

✓ Gynoecium/pistil. Is the female part of the plant that comprises of the carpels. One carpel consists of the ovary, style and the stigma.

- ✓ Accessory parts. These are parts of the flower that are not involved directly in sexual reproduction. For example petals, sepals, pedicel.
- ✓ Essential parts of the flower are those parts that are directly involved in sexual reproduction. These are the stamens and the pistil.
- ✓ Receptacle. This is the enlarged tip of the pedicel from which the floral parts are attached.

***Distribution and sexes***

- ✓ Complete flower is a flower on which all the four main floral parts are present
- ✓ Incomplete flower is a flower on which one or more main floral parts are missing
- ✓ Bisexual flowers-Both stamens and pistils are present (hermaphrodite/perfect flower)
- ✓ Unisexual flowers-possess either the stamens or the pistils but not both (imperfect). If only stamens are present the flower is described as a ***staminate flower,*** if only the pistils are present it is a ***pistillate flower.***
- ✓ Monoecious plant is a plant having both staminate and pistillate flowers on the same plant e.g. cucumber and maize
- ✓ Dioecious plants-have staminate and pistillate flowers on separate plants.

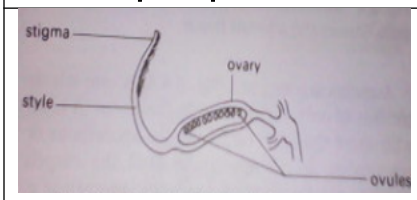
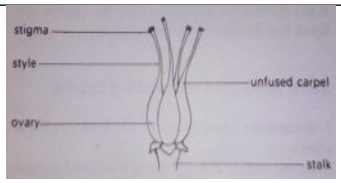
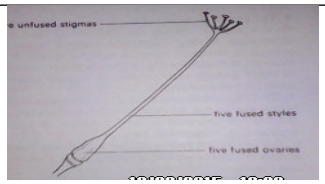
***Flower symmetry***

- ✓ Regular flowers (actinomorphic). Flowers with a regular symmetry can be divided into two or more equal parts. The floral parts are arranged radially around the receptacle and are of similar size and shape. E.g. hibiscus.
- ✓ Irregular flowers (zygomorphic). These are flowers which cannot be divided into more than two similar parts, e.g. crotalaria, pea/bean flowers, genea grass etc

***Description of the gynoecium (pistil)***

The gynoecium is the female part of the flower and consists of one or more carpels.

- ✓ Monocarpous pistil is one which consists of only one carpel, e.g. crotalaria flowers
- ✓ Apocarpous pistil is one with many but free (separate) carpels, e.g. bryophyllum and rose flowers
- ✓ Syncarpous pistil is one with many but fused carpels. E.g. hibiscus has five fused carpels

| Monocarpous pistil | Apocarpous | Syncarpous |
|---|---|---|
|   |   |   |

***Position of the ovary;***

The position of the ovary in relation to other floral parts may vary among different flowers; **Superior ovary** is one which is located above the point of attachment of the petals as in bean flower (**crotalaria**), tomato, orange etc. An **inferior ovary** is found below the point of attachment of petals, e.g. bananas and guava flowers.

**Alternation of generations in flowering plants**

Angiosperms also show alternation of generations with the **sporophyte being dominant**. The whole plant forms the sporophyte with 2 forms of gametophytes which are greatly reduced in size and fully dependant on the sporophyte. The male gametophytes are the **pollen grains** while the female gametophyte is the **embryo sac**. Both gametophytes occur within flowers which are the reproductive organs of angiosperms. Specifically, pollen grains (male gametophytes) are produced within the anthers of the stamen while the embryo sac (Female gametophytes) are produced within the ovary.

## GAMETOGENESIS IN PLANTS

Gametogenesis refers to the process by which male and female gametes are formed. The process of sperm formation is called **spermatogenesis** while **oogenesis** is the process of formation of the ovum.

**Formation of male gametes**

In angiosperms, the male gametes are produced within the **pollen sacs** of the anthers; usually four occur in each anther. The pollen sacs (microsporangia) enclose a mass of diploid **pollen mother cells**, each of which divides by meiosis to form a **tetrad of haploid cells** (microspores). The nucleus of each cell divides by mitosis to form a **pollen tube nucleus** and a **generative nucleus**. Each cell develops a thick resistant wall; consisting of a thin inner layer called the **intine** and a thick pitted outer layer called the **exine**. This is a mature pollen grain and forms the male gametophyte.

After pollination; the generative nucleus divides by **mitosis** to form **two male nuclei**. These are the male gametes.

**Draw and label**

**NB:** The role of the pollen grain is to provide means of protecting and transferring the male gametes from one place to another.

**Formation of female gametes**

The ovary contains a swollen body called **nucellus**; which is enclosed by the inner and outer **integuments** with a small opening called **micropyle**. The nucellus encloses a diploid **spore mother** cell (embryo sac mother cell). This divides by meiosis to form a **tetrad** of haploid cells; three of which degenerate; and one (Nearest to the micropyle) enlarges (grows) into a **megaspore** (Embryo sac). The nucleus divides by **mitosis** to form two nuclei; which migrate to opposite poles. Each nucleus undergoes **two successive mitotic divisions** forming 4 haploid cells. Two nuclei, one from each pole move to the centre and fuse to form a **diploid polar nucleus** while the remaining nuclei are separated by cell walls. The three cells at the pole opposite to the micropyle are called **antipodal cells** and these perfume no further role. Nearest to the micropyle one cell forms the **eggs cell** (Ovum) while the remaining two are the **synergids**. These have no further function and usually degenerate.

At this stage, the embryo sac forms a **mature gametophyte**; containing 7 nuclei, one of which is diploid.

## POLLINATION

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

***Types of pollination***

- Self-pollination is the transfer of pollen grains from anthers to the stigma of the same flower
- Cross pollination is the transfer of pollen grains from the anthers of one flower to the stigma of another flower but of the same species (type)

***Agents of pollination***

These are mainly wind and insects, but may also include other animals like birds, bats and man (vanilla)

**NB:** Self-pollination is a form of **inbreeding** and leads to formation of poor quality offspring, while cross pollination usually results into combination of features from different parents. Plants have therefore evolved different mechanisms **to prevent self-pollination and promote cross pollination as follows;**

✓ **Dioecism** (having separate male and female plants) which makes self-pollination is impossible. E.g.

pawpaw

- ✓ Some plants have **monoecious flowers** (have separate male and female flowers on the same plant) like in maize and coconut which increases chances of cross pollination
- ✓ For plants with bisexual flowers, anthers and stigmas may mature at different times e.g. cow peas which minimizes self-pollination. This is known as **dichogamy. Protandry** is when the anthers (Androecium) matures first while **Protogyny** is when the stigmas (Gynoecium) mature first.
- ✓ In some flowers, anthers are found hanging outside the petals which makes self-pollination impossible.
- ✓ Stigmas in some flowers grow above the anther heads making self-pollination very unlikely
- ✓ Some flowers are self-incompatible; they cannot be fertilized by own/self-pollen grains which prevents self-pollination.

***Sq. outline the features that promote self-pollination in plants***

- ✓ Flowers remain enclosed by petals till fertilization is complete e.g. garden peas
- ✓ The anthers being located above the stigma
- ✓ Bisexual (hermaphroditic) flowers
- ✓ Anthers and stigmas that ripen at the same time
- ✓ Stamens are located close to the pistil
- ✓ Flowers being self-compartible.

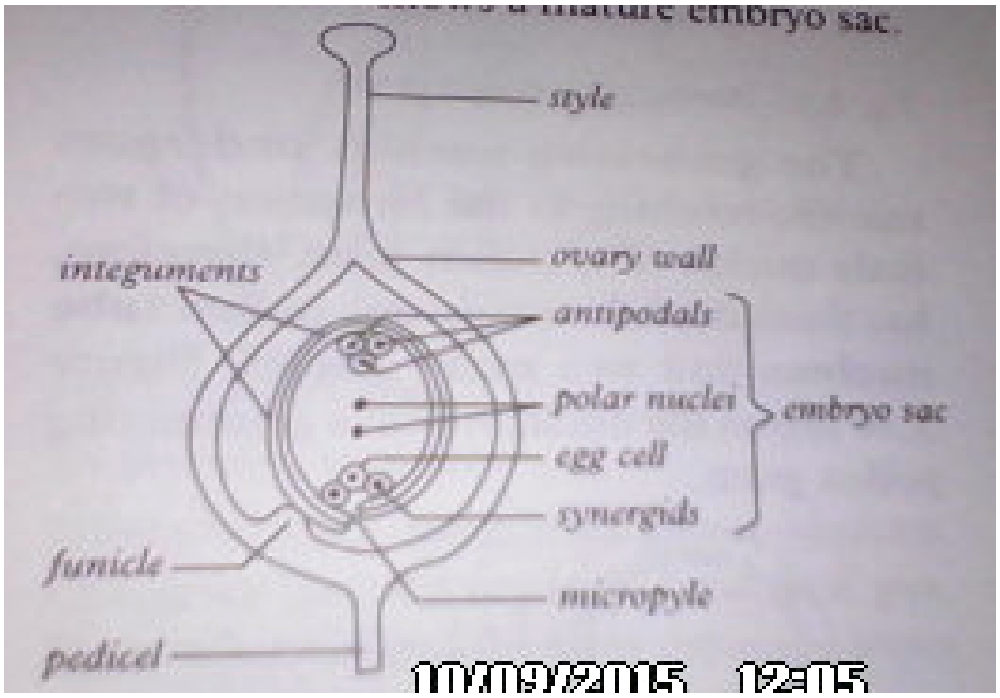
**SQ**. Give the advantages of each of the two types of fertilisation over the other.

**Comparing insect and wind-pollinated flowers**

| **Wind pollinated** | **Insect pollinated** |
|---|---|
| Small making them less conspicuous | Relatively large and conspicuous |
| Petals are often dull-coloured | petals are brightly coloured |
| Lack scent or nectar | Are scented with nectar |
| Anthers are loosely attached to the filaments (easily shaken off by wind) | Anthers are firmly attached to the filament. Usually enclosed in petals |
| Produce large quantities of smooth pollen grains | Smaller quantities of sticky pollen grains |
| Have feathery stigmas to trap pollen grains | Have smooth stigmas |
| Anthers found hanging outside the petals | Anthers enclosed within the flower |

After pollination, the pollen grains on the stigma germinate into a pollen tube through the style down the ovary where fertilization occurs.

**The process of fertilization in plants**




When a **mature** pollen grain lands on a mature stigma (pollination); it absorbs the sucrose solution from the stigma and germinates into a pollen tube that grows towards the ovary through the style. Growth is controlled by the pollen tube nucleus at the tip of the pollen tube; being attracted by the chemicals secreted by the embryo sac (Positively chemotropic).

The pollen tube nucleus is closely followed by the generative nucleus; which divides by mitosis to form two haploid male nuclei.

On reaching the micropyle, the pollen tube nucleus **disintegrates** and the pollen tube bursts; letting the two male nuclei into the ovule. One of the two male nuclei fuses with the **Ovum** (**egg cell nucleus)** to form a **diploid zygote** while the other fuses with the **secondary nucleus (polar nuclei)** to form a triploid endospermic nucleus. This is known as **double fertilization** and only occurs in angiosperms (flowering plants).

The zygote undergoes mitotic cell division to develop into the embryo enclosed into the seed while the ovary develops into the fruit. The seed lies dormant and germinates into a new plant when conditions become favourable for germination.

**NB:** A series of events occur following fertilisation leading to formation of fruits and seeds. These include the following:

- ✓ The petals, stamens and styles wither (dry) and fall off
- ✓ The ovules develop into seed
- ✓ Integuments fuse and develop into the seed coat/testa
- ✓ The ovary develops into the fruit
- ✓ Ovary walls develop into the pericarp of the fruit
- ✓ The endospermic nucleus develops into the endosperm, which persists only in endospermic seeds like maize. In non-endospermic seeds it is suppressed by cotyledons which take on the role of food storage.
- ✓ The micropyle persists as a small hole in the testa
- ✓ The hilum is a scar on the testa that marks the point of attachment of the seed to the fruit

- ✓ The zygote undergoes mitotic cell division to form the embryo. This comprises of the plumule, radicle and the cotyledons

**SEED AND FRUIT DISPERSAL**

Dispersal refers to the spreading of seeds/fruits from the parent plant to colonize new areas. Agents of seed and fruit dispersal include wind, water, animals and explosive mechanism (Self dispersal)

**Wind dispersal**

This is when the seeds are blown away from their parent plant by wind

***Adaptations of seeds for wind dispersal***

- ✓ Possess parachute-like hair in form of a pappus, which increase buoyancy of the seed in air as in tridax and cotton seeds
- ✓ In some seeds the testa is drawn into wing-like structures which increase the surface area over which wind blows. E.g. jacaranda and Nandi flame seeds
- ✓ Wind dispersed seeds are small and light which enables them to be blown over long distances
- ✓ Some of them possess a **censor mechanism** e.g. tobacco. In these plants; the fruit splits in such a way that seeds are exposed and can easily be blown away by wind
- ✓ The seeds and fruits are loosely attached to their stalks so that they can easily be blown away by wind

***Adaptations of seeds to dispersal by water*** **(common example is the coconut fruits)**

- ✓ These seeds are light to easily float on water
- ✓ They contain air spaces which makes the fruit buoyant in water as in coconuts
- ✓ They usually possess water-proof epicarps which protect the seeds from getting soaked in water
- ✓ Possession of tough fibrous pericarps which do not easily decompose when exposed to water

***Adaptations to animal dispersal***

Such animals include birds, bats, humans etc.

- ✓ Possession of hooks and spines so as to stick onto animals bodies as they pass by e.g. black jack
- ✓ Some are covered by sticky hairs as in desmodium to easily attach onto the fur of animals
- ✓ Possession of good scent to attract animals to eat up the fruit and end up discarding the seeds over long distances e.g. jack fruit, mangoes etc.
- ✓ These fruits are usually brightly coloured and succulent to attract animals to eat them and disperse the seeds for example oranges, sweet bananas
- ✓ Some possess hard or slimy coverings to protect them against digestive enzymes. Animals eat them up and pass them out with faeces at reasonable distances from the parental plants like guavas, passion fruit seeds.
- ✓ Animal dispersed fruits have a pleasant taste which attracts animals to eat them like oranges, paw paws etc.
- ✓ They are usually large and conspicuous so that they can easily be seen by animals

***Explosive mechanism***

This is also known as self-dispersal mechanism. The dry pericarp splits forcefully as a result of tension exerted on the sutures of a dry pod, and the two halves twist outwards throwing the seeds away from the parent plant. E.g. beans, peas, castor oil and balsam fruits.

**Significance/importance of dispersal**

- ✓ It reduces competition for light, water and nutrients
- ✓ It prevents overcrowding hence reduces the chances of disease spread among plants
- ✓ Dispersal enables the plant species to colonize new habitats
- ✓ It increases chances of survival of the species as seeds are spread far from the parent plant

**Advantages of reproduction by means of seeds**

- ✓ The process of fertilisation is independent of water, making such plants adapted for survival on land
- ✓ The seed protects the embryo from damage hence increasing chances of survival
- ✓ Seeds have adaptations that ensure dispersal of the embryo
- ✓ Seeds store food for the embryo. This is commonly in the endosperm for endospermic seeds or in the cotyledons for non-endospermic seeds
- ✓ Ability to remain dormant for some time to survive un favourable conditions
- ✓ Seeds are physiologically sensitive to favourable conditions and germinate when conditions are favourable
- ✓ Being products of sexual reproduction, seeds are associated with genetic variation leading to better plant varieties.

**Disadvantages of reproduction by means of seeds**

- ✓ Seeds are liable to being eaten by animals due to their food reserves.
- ✓ They are relatively large which makes dispersal more difficult
- ✓ Seeds contain a limited food store which may be insufficient for the growing embryo
- ✓ Seed formation relies more on external agents of pollination and dispersal which reduces the degree of success
- ✓ Successful reproduction requires a very large number of cells as many are eaten by animals

**NB:** Advantages and disadvantages of seed production depends on the comparison with spores or vegetative propagation.

## SEXUAL REPRODUCTION IN ANIMALS

All higher animals reproduce sexually; including all vertebrates and some invertebrates. Sexual reproduction involves fusion of male and female gametes to form a zygote, this may occur from outside the body (external reproduction) or from within the body (internal fertilisation).

Sexual reproduction in almost all animals involves courtship which leads to mating and if this is successful it results into fertilisation. Courtship involves a series of behaviour aimed at inducing another organism of the opposite sex into mating. This may involve use of noise, smell (Scent), colourations, dance displays etc.

Comparing internal and external fertilisation

| **Internal fertilisation** | **External fertilisation** |
|---|---|
| Occurs inside the body | Occurs outside the body |
| Increases chances of fertilisation | Associated with lower chances of fertilisation |

| | |
|---|---|
| Requires fewer sperms | Requires a large quantity of sperms due to wastage |
| Occurs in fish and amphibians | Occurs in all mammals, birds and reptiles |
| Increases chances of survival if the embryo is retained inside the mother's body | Reduces the chances of survival of the embryo |

**Definition of terms**

Terms associated with reproductive patterns:

- ✓ **Fertilisation**: The fusion of male and female gametes to form a zygote. Internal fertilisation occurs within the body of the female while external fertilisation occurs outside the body of the female.
- ✓ **A zygote** is a single diploid cell that is capable of developing into a new organism
- ✓ **Oviparity:** this is when eggs are fertilised from within the body but laid and develop from outside the body**.** E.g. In birds.
- ✓ **Ovoviviparity:** This is when eggs are fertilised internally and retained into the body of the female until when they hatch and the young ones are released from the body. As in aphids. The young ones are nourished by the nutrients stored in the egg yolk.
- ✓ **Viviparity:** Eggs are fertilised from within the body and retained to develop into a foetus which is produced alive. During development, the growing embryo is nourished by nutrients from the mother's blood until an advanced level of development. E.g. In mammals.
- ✓ **Gametogenesis:** it refers to the process of formation of mature gametes in the body of the organism
- ✓ **Spermatogenesis:** Is the process of formation of male gametes in the organism.
- ✓ **Oogenesis:** Is the process of formation of female gametes in the organism.
- ✓ **Menopause:** It is a period when ovulation and menstruation cease in human females.

**Sexual reproduction in bony fish**

Bony fish show external fertilization and external development.

Reproduction in fish starts with courtship for the male to attract the female to the nest. The female lays eggs and the male shed sperms onto them to be fertilised externally (from outside the body). The eggs later hatch into very small fish called fry which develop into mature fish.

Some fish species don't show parental care at all, they simply lay the eggs onto the waters to develop on their own. This greatly decreases the chances of survival as many are eaten by predators. Some fish species like tilapia show an advanced level of parental care. They construct a nesting ground at the bottom of the water body. Females carry their eggs into the mouth for incubation and protection from predators (Mouth brooding). The male swims off to find other females.

**SEXUAL REPRODUCTION IN AMPHIBIANS**

Just like fish, amphibians (Toads and frogs) show external fertilization on and external development. In most cases, mating is done as a communal activity.

During reproduction, the male frog finds a suitable breeding site like a pond or other places, and attracts female frogs into the territory by courtship.

During mating, the female frog carries the male on the back until it releases eggs into water and the male instantly sheds sperms onto the eggs to be fertilised externally. The eggs hatch into fish-like creatures with a tail and are called tadpoles which grow into new adult frogs.

**NB:** After fertilisation, the eggs are surrounded by a jelly-like protective layer which protects them from drying out. This layer holds the eggs together in a mass called **frogspawn,** this attaches to rocks and weeds so that they are not carried away by water currents.

**SEXUAL REPRODUCTION IN BIRDS**

They reproduce sexually by means of eggs which are fertilised internally but complete their development

externally. The male bird usually establish a territory into which the females are attracted by courtship which leads to mating. Fertilisation takes place in the oviduct where the egg becomes surrounded by a jelly-like layer of proteins called albumen (egg white), and an outer shell of calcium carbonate.

The eggs are incubated usually by the female bird (sits on the eggs to maintain them at body temperature) for several weeks usually 3 (21 days) for domestic fowl. This is called the gestation period. The eggs then hatch into chicks which are shown parental care until mature enough to sustain themselves.

**Internal structure of bird's egg (draw)**

**Function of parts**

- Shell: Hard deposited with calcium to protect the inner structures of the egg. It is porous (has tinny pores) to allow free exchange of gases with outside environment.
- Albumen: Jelly-like mixture containing proteins like albumins. It provides proteins to the growing embryo. It also provides water and mineral salts to the embryo
- Yolk: This is a store and source of proteins and fats to the growing embryo.
- Germinal disc: This develops into the embryo of the egg that develops into the chick after fertilisation.
- Chalaza: It is a rope-like structure made of proteins. It stabilises the yolk and the embryo in the albumen.
- Air space: Provides space for air storage in the egg.

**SEXUAL REPRODUCTION IN MAMMALS**

This is the most advanced group of vertebrates; comprised of endothermic animals characterised with fur all over the body and mammary glands. Mammals are the only vertebrates were both fertilisation and development occur inside the body (Viviparus) and show the highest level of parental care. After birth, the young one is fed on milk produced by specialised mammary glands during a period called lactation. It is the only group of organisms which have sex form leisure.

**Difference between sexual and asexual reproduction**

| Sexual reproduction | A sexual |
|---|---|
| Involves fertilization | Does not involve fertilization |
| Involves gamete formation | there is no gamete formation |
| Involves two organism of different sexes | only one organism is involved |
| Introduces genetic variability | there is no genetic variability |
| Hybrid vigor not maintained | Maintains hybrid vigor |
| Depends on external mechanism to bring gametes together | No external mechanisms are involved |
| Few offspring are usually produced | Many offspring's are usually produced |
| A slower method of reproduction | Faster method or reproduction |

**SEXUAL REPRODUCTION IN MAN**

In man (humans, sexual reproduction occurs only in sexually mature individuals. This is when the gonads (testes and ova) together with other relevant organs like penis, vagina, uterus etc. are fully developed

Sexual maturity in man begins at **puberty** (the period when sexual organs attain full development and become active), a period of growth leading to adolescence. During this period, the body experiences significant physical, physiological and behavioural changes called **secondary sexual characteristics.** They are responsible for the big differences between male and female human beings and occur as a result of hormones released by the brain and sex organs. The changes occur between 11-16 years in boys and usually earlier in girls.

**THE MALE REPRODUCTIVE SYSTEM**

The male reproductive system consists of a pair of **testes** enclosed in the scrotal sac, a number of ducts, accessory glands and the penis

The testis is an **oval-shaped gland** (Compound tubular). It is internally divided into several **lobules**, each

containing a highly coiled series of **seminiferous tubules** (50cm) embedded in a connective tissue of specialised cells **called Leydig cells (Interstitial cells)**. The seminiferous tubules are lined by **germinal epithelial cells** that undergo meiosis to produce sperm cells (Male gametes) while the Leydig/Interstitial cells produce **testosterone**-the male sex hormone.

After formation in the testis, sperms move to the **epididymis** via the **vasa efferentia** (Short straight tubules) where **concentration** occurs by absorption of excess fluids (secreted by seminiferous tubules). The epididymis is also a region for **maturation** and **storage** of the sperm cells (Spermatozoa).

During ejaculation; sperms are released into the **sperm duct** (Vas deferens; plural vasa deferentia) which conveys them to the urethra.

**NB:** The epithelia linings of the seminiferous tubules contain large cells called **sertoli cells (Nurse Cells)** which provide nutrients and protection to growing sperm cells during **spermiogenesis**.

The parts of the reproductive system that are directly involved in sperm production are the **primary sex organs**. These are specifically the testes

**Accessory** (Secondary) sex organs are parts of the reproductive system that are not directly involved in sperm production. These include the penis, vasa differentia and the associated glands.

The **penis** is the copulatory organ used to deposit sperms into the vagina

The **sperm duct** passes over sperms from the epididymis into the urethra

The glands include:

The **prostate gland** which secretes an alkaline fluid to neutralise the acids of the vagina which would reduce sperm mobility

The **Cowper's gland** (Bulbourethral gland) which produces a milky alkaline fluid that neutralises any urine that may be remaining in the urethra.

**Seminal vesicles** secrete a mucous **nutrient-rich** fluid which nourishes sperms during swimming. It provides fructose for respiration to produce energy for swimming of the sperms.

**Structure of the male reproductive system**

**NB:** In mammals, sperm production occurs favourably at a temperature of 2 to $3^0$C below the core body temperature. Testes are held outside the general body core to provide a lower temperature favourable for sperm production. Temperature is also maintained by the **counter-current exchange** of heat by the **spermatic artery and vein** to prevent warming up of the testes. The distance of the testes from the body core can be adjusted by contraction and relaxation of the **dartos muscle** of the scrotum depending on the core body temperature.

The combination of the sperm duct and the spermatic artery and vein is termed as the **spermatic cord.**

**Roles of the male reproductive system**

- To produce sperms (male gametes)
- Deposit sperms into the female reproductive system.
- It also produces hormones like testosterone which is responsible for the male secondary sex characteristics

**NB**: Semen is a protein and carbohydrate-rich fluid in which sperms swim into the female reproductive system. About $3cm^3$ of semen in a normal ejaculation contain 10% sperms, 20% prostate secretion and 60% seminal vesicle secretions and other substances. It contains about $10^8$sperms per cc.

**The process of sperm formation (Spermatogenesis) in man**

Spermatogenesis occurs in three main phases, which include multiplication phase, growth phase and maturation phase.

During multiplication, the primordial germ cells of the seminiferous tubules undergo repeated mitosis to form a mass of diploid cells called spermatogonia. The spermatogonium grows and enlarges to form the primary spermatocyte which undergoes the first meiotic division to form the secondary spermatocytes (Haploid).

These undergo the second meiotic division to form spermatids.
These are embedded by their heads into large sertoli cells, where they grow and differentiate into functional spermatozoa. This process is called spermiogenesis. Mature and functional sperm cells are released into the lumen of the seminiferous tubules and taken to the epididymis for storage.

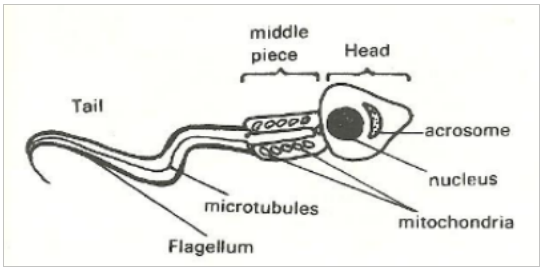
**Illustration**

**NB:** Spermiogenesis is the process by which early spermatids grow and differentiate into functional sperm cells; being nourished by the sertoli cells

**Structure of the sperm cell**

**The Sperm**

A sperm is a minute, motile male gamete produced by the testes. It consists four major regions as shown in the diagram below.




**Functions of each part**

**Head;** this contains the nucleus and the acrosome embedded in the cytoplasm. The nucleus contains a haploid set of chromosomes form the father. The acrosome contains hydrolytic enzymes that digest the layers of the ovum for the sperm to penetrate during fertilisation.

**Neck;** this contains a pair of centrioles lying at right angles to each other. From one of the centrioles radiate microtubules that extend the entire length of the tail. They are termed as the **axil filament** responsible for the beating action of the tail.

**Middle piece;** this contains numerous closely packed mitochondria that provide energy for swimming of the sperm from the vaginal tract to the oviduct where fertilisation takes place.

**Tail;** This beats back and forth to propel the sperm as it swims to the oviduct where fertilisation takes place.

**Hormonal control of spermatogenesis**

The process of process of spermatogenesis is controlled by hormones from the Pituitary gland and the Hypothalamus.

At puberty, the Hypothalamus produces the **Gonadotrophin** Releasing Hormone (GnRH), which stimulate the anterior Pituitary gland to release two hormones; Follicle Stimulating Hormone (FSH) and Luteinising Hormone (LH)/ Interstitial Cell Stimulating Hormone (ICSH). The FSH stimulates spermatogenesis by stimulating the Sertoli cells to cause maturation of spermatozoa from spermatids. LH stimulates the Leydig Cells (interstitial cells) to release Testosterone, which stimulates spermatogenesis and development of secondary male sex characteristics.

Higher levels of Testosterone inhibit further secretion of the GnRH which inhibits release of FSH and LH. This inhibits spermatogenesis. Low levels of Testosterone promote production of the GnRH which stimulates release of FSH and LH.

***Describe the male secondary sex characteristics as promoted by Testosterone.***

**THE FEMALE REPRODUCTIVE SYSTEM**

It consists of a pair of ovaries joined to the uterus by the fallopian tubes (Oviduct). The germinal epithelial linings of the ovary undergo meiosis continuously to form female gametes (Ova). The ovary also produces female sex hormones like oestrogen and progesterone

The inner linings of the oviduct contain ciliated epithelial tissues whose cilia propel the ovum towards the uterus. It is where fertilisation takes place.

The uterus is a muscular sac where development takes place. It consists of three layers of muscles.

The serous coat forms the outermost protective layer of the uterus.

The myometrium is the middle layer that is the thickest of all. It consist of bundles of smooth muscles that are sensitive to oxytocin during child birth.

The myometrium is the innermost layer that contains numerous blood vessels. It is a soft and smooth layer whose thickness varies during the menstrual cycle.

The lower entrance of the uterus is called the cervix. It consists of strong circular muscles that separate the uterus from the vagina. The cervix remains closed during gestation.

The vagina is the birth canal of the system. It is also receives the penis during copulation. This consists of thick linings of non-keratinised stratified epithelium.

On the outside, the female reproductive system consists of the clitoris and the vulva. The vulva consist labial folds of membrane; the labia majora on the outside and the labia minora on the inside. These membranes contains vestibular glands that release mucus during sexual stimulation for lubrication of the penis during sexual intercourse.

The clitoris is an erectile structure that is homologous to the penis of the male. It is important for sexual stimulation

**The diagram below shows the female reproductive system**

**Gametogenesis in human females (Oogenesis)**

Unlike in males where gametogenesis starts at puberty; gametogenesis in females starts early during embryonic development and completed only after fertilisation. At birth a human female has millions of growing gametes in the ovaries.

During embryonic development, the primordial germ cells of the ovary undergo repeated mitosis to form diploid cells called oogonia. The oogonia grow and enlarge to form primary oocytes; each surrounded by a layer of granulosa cells forming primary follicles. The primary oocytes remain at prophase I of the first meiotic division until birth.

At puberty, Follicle Stimulating Hormone stimulates one primary oocyte per month to resume growth. It completes the first meiotic division to form the secondary oocyte and the first polar body. The secondary oocyte undergoes the second meiotic division up to prophase II, until after ovulation. Fertilisation stimulates completion of the second meiotic division; forming an ootid (Ovum) and the second polar body.

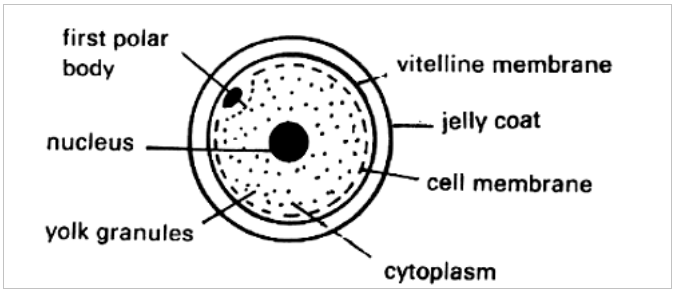
**NB:** The polar bodies have no advanced function in fertilisation and development of the embryo, they finally degenerate. Their primary role is to take up excess chromosomes to ensure that the daughter cells remain haploid. Their small size is due to uneven distribution of the cytoplasm during cytokinesis such that the resultant ovum is large in size.

At maturity, the ovum enclosed by a follicle of granulosa cells is called the graafian follicle. This is ready for release from the ovary during ovulation.

After ovulation, the follicle is transformed into a corpus luteum; which starts secreting progesterone hormone.

**The ovum (0.2 mm)**

It is an oval non motile gamete produced by the ovary. It is much larger than the sperm and surrounded by a thin protective membrane called Zona pellucida and a layer of granulosa cells called the corona Radiata. These protect the ovum until fertilisation takes place.




**Differences between sperms and ovum**

| SPERM | OVUM |
|---|---|
| - It is small | it is large |
| - It is motile | it is non-motile |
| - It has tail | has no tail |
| - Has no York | has a yolk granules |
| - Has acrosome | as no acrosome |
| -It is elongated in shape | It is oval shaped |

**Comparing spermatogenesis and oogenesis**

Similarities

- ✓ Both processes occur in gonads
- ✓ Both processes involve meiosis
- ✓ In both cases, haploid gametes are produced
- ✓ Spermatogenesis and oogenesis involve the same stages; multiplication, Growth and maturation

**Differences**

| Spermatogenesis | Oogenesis |
|---|---|
| Occurs in testes | Occurs in the ovary |
| Starts at puberty | Occurs throughout life |
| Occurs in form of a series of continuous stages | Involves a series of interrupted stages |
| Involves equal division of the cells during meiosis | There is un even division of cells during meiosis |
| Does not involve formation of polar bodies | Involves formation of polar bodies |
| All daughter cells develop into functional gametes | Only one daughter cell forms a functional gamete |

**Hormonal control of oogenesis**

When the ovum is released by the ovary, the uterus would have prepared by increasing in thickness of the myometrium by the addition of new layers of cells for the ovum to sink. However, if it does not get fertilized, the new layers of cells disintegrate and unwanted cells, mucus, and some blood passes out through the cervix and vagina. This is a process referred to as menstruation, this process takes place once in about 28days.

**Role of female sex hormones in menstrual cycle**

After menstruation, the **hypothalamus** releases **GnRH** which stimulates the **anterior pituitary gland** to release small amounts of **FSH** and **LH**.

FSH stimulates development of a follicles in the ovary, only one of which grows into a Graafian follicle. It also stimulates the granulosa cells of the follicle to produce **oestrogen** promotes repair of the uterine walls in preparation for pregnancy and **inhibits further** release of FSH by the Pituitary Gland by negative feedback. Oestrogen reaches its **peak** (Surge levels) on day 13, stimulating release of more LH by the Pituitary gland by positive feedback.

Levels of LH increase rapidly reaching a peak (Surge) on day 14; and cause ovulation (Release of a mature

ovum from the graafian follicle); and conversion of the remains into the corpus luteum. It also stimulates the corpus luteum to release progesterone and small amounts of oestrogen.
Progesterone maintains the thickness of the endometrium in preparation for implantation and inhibits further release of FSH and LH by the Pituitary gland.
In case fertilisation does not take place, the corpus luteum degenerates, levels of progesterone fall. This makes the blood capillaries of the endometrium to constrict leading to menstruation. Decrease in progesterone levels stops the inhibitory effect of progesterone on the pituitary gland; release of FSH and LH hormone resumes and the cycle repeats.
In case of fertilisation; the zygote under goes repeated mitosis to form a blastocyst which secretes the Human Chorionic Gonadotrophin (HCG). This maintains the corpus luteum; which continues secreting progesterone and oestrogen that maintain pregnancy.

**Copulation, Fertilisation and Pregnancy**

Copulation (coition) refers to the insertion of an erect penis into the vagina; it is also called **sexual intercourse.**
For copulation to take place successfully the penis must be fully erect and this occurs due to sexual arousal of the male which activates the parasympathetic nervous system. This stimulates the widening of the arterioles supplying blood to the erectile tissues of the penis. The blood occupies up all spaces making the penis large, hard and stiff. Now it can be inserted into the vagina.
During copulation, the in and out movement of the penis increases the tactile stimulation of sensory receptors of the penis. These send the sensory impulses to the epididymis, vas deferens and the associated glands to contract and release sperms in a fluid mixture called semen into the vagina through the urethra. This process is known as **ejaculation** (the release of semen through the urethra of an erected penis due to rhythmic contraction of the urethra)
Ejaculation occurs at the climax of sexual stimulation and the associated sensation (feeling) is called **orgasm** and leads to sexual satisfaction.
During ejaculation, the semen containing sperms are deposited close to the cervix of the female, these swim towards the oviducts through the uterus so as to meet the ovum ready for fertilisation. This movement is aided by the tails present on the sperm cells and contraction of the uterine walls to push the sperms upwards. These sperms can stay viable for 72 hours (3 days) waiting for the ovum to be released from the ovaries.

**FERTILISATION**

This refers to the fusion of the sperm and egg nucleus to form a diploid zygote. It occurs when sperms meet a mature ovum in the oviduct. The process of fertilisation involves the following stages.
**Capacitation:** This involves the removal of the outer membrane of glycoproteins and cholesterol from the membrane of the sperm head to make it weaker and more permeable. This makes the membrane more permeable to calcium ions which increases the beating action of the tail and promoting the acrosome reaction.
**Acrosome reaction:** When the sperm head makes contact with the ovum; and recongnises the receptors on the membrane of the ovum; the outer membrane of the sperm and the acrosome membrane raptures to release hydrolytic enzymes mainly hyaluronidase and proteases. These breakdown the protective layers of the ovum; to allow the sperm penetrate; and the nucleus enters into the ovum
**Cortical reaction:** Immediately after penetration; the lysosome (Cortical granules) in the outer region of the ovum fuse with the zona pellucida; and release their enzymes. They make it thicken and harden to form a fertilisation membrane which prevents polyspermy. (Fusion of the same ovum with more than one sperms). The enzymes also destroy the protein receptors on the membrane to prevent recognition by other sperms.
**Fertilisation:** Penetration stimulates the secondary oocyte to complete the second meiosis forming an ovum

and the second polar body; the polar body degenerates while the ovum nucleus fuses with the sperm nucleus to form a diploid nucleus. The resultant cell is called a zygote. This is known as fertilisation, also called conception in man.

**NB:** Later in about week 10 of embryo development; the placenta is fully developed and starts secreting progesterone and oestrogen; the corpus luteum then degenerates. Degeneration of the corpus luteum before establishment of the placenta is a common cause of miscarriage. HCG is excreted in urine where it can be detected using common early strip test for pregnancy within 2 weeks after fertilisation.

**Twins:**

In some cases, two ova may be released at the same time and if both are fertilised, two babies develop and are called twins. These twins are genetically different as they are formed from different ova and sperms and are therefore physically different (non-identical twins).

In some rare cases, the ovum may split completely very soon after fertilisation. This gives two embryos which develop into two babies that are genetically and physically identical and are called identical twins. This is because they are formed from the same ovum and sperm.

**IMPLANTATION**

This is the embedding of a fertilized ovum (zygote) into the walls of the uterus where further growth and development takes place.

Fertilisation takes place in the oviduct, the zygote moves by a combination of peristalsis and the beating action of cilia towards the oviduct. In the process, the zygote undergoes a series of mitotic cell divisions without increase in size; forming a hollow ball of cells; a process called **cleavage**. The cells become progressively smaller and are termed as **blastomeres.** They are retained within the zona pellucida forming a spherical ball of called the blastocyst with a central cavity called **blastocoel**; filled with a fluid from the oviduct.

The outermost layer of the blastocyst is called the **trophoblast**. Trophoblastic cells thicken at one point forming an inner mass of cells called the **inner cell mass**. This level is reached in about 5 days.

Upon reaching the oviduct, the zona pellucida breaks down; allowing the cells of the trophoblast to get into contact with cells of the endometrium and absorb nutrients. Trophoblastic cells multiply rapidly and differentiate into the inner and outer layers of cells; and sinks into the endometrium. This is known as **implantation**. The outer layer develops numerous villi that grow into the endometrium; providing a large surface area for exchange of materials between the blastocyst and maternal blood. Between the trophoblastic villi are spaces called lacunae, filled with maternal blood.

**NB:** After implantation; the woman is now considered pregnant and the developing cell is called an embryo.

**PREGNANCY (GESTATION PERIOD)**

Gestation period refers to that period of time between fertilisation and birth. It is a period of development of the zygote to the embryo and then a foetus.

For humans during this period, the following body changes may be experience

- ✓ Morning and evening fever
- ✓ Vomiting
- ✓ Increased heart beat rate
- ✓ Weight gain
- ✓ Loss of appetite
- ✓ Increased body temperature
- ✓ Enlargement of mammary glands
- ✓ Laziness
- ✓ Mood swings
- ✓ Constant spitting
- ✓ Ceasation of menstrual periods

- ✓ Increased sex libido (sex urge); though it may decrease in some females

**Embryo development**

During development, of the embryo is enclosed by four membranes called **extra-embryonic membranes**. These are the **Chorion**, **amnion**, **allantois** and the **yolk sac.**

The Chorion is the outermost membrane; which develops from trophoblastic cells of the blastocyst. Initially it is used for exchange of materials with maternal blood; a role that is later taken up by the **placenta**.

Two cavities appear within the inner cell mass; leading to formation of two membranes; the **amnion**, and the **yolk sac**; beneath which is the embryo disc-which grows into the embryo. The yolk sac has no significant function in mammals; but in birds and reptiles (Reproduce by means of cleidoic eggs); it is the site for absorption of nutrients from the yolk.

The amnion forms a thin protective membrane that encloses the embryo. The amnion also secretes the amniotic fluid into the amniotic cavity. This fluid protects the embryo from mechanical shock and provides support to the growing embryo.

Later the fourth membrane called the Allantois develops from the hind gut of the embryo. It grows outwards and comes into contact with the chorion. At the point of contact; a richly vascularises structure called the **Allanto-choiron** which grows into the placenta.

**SQ**. Describe the changes under-gone by the extra embryonic membranes during development of the embryo.

**The placenta**

It is a point of close association between maternal and fetal circulation; that provides a site for exchange of materials between maternal blood and that of the foetus. It is he only organ that consists of tissues from two different organisms, the mother and the foetus.

The fetal side of the placental consists of connective tissue cells of the chorion; in form of numerous projections called **choronic villi**. These provide a large surface area across which materials are exchanged. The villi contain numerous mitochondria and pinocytic vesicles. They also carry a **highly branched network** of blood capillaries derived from the **umbilical artery** and the **umbilical vein**.

The maternal side of the placenta consists of numerous projections of the endometrium. Between these projections and the chorionic villi are spaces called lacunae; filled with blood from the uterine arterioles. This blood bathes the chorionic villi in a **counter-current** flow and drains into the uterine venules.

The placenta only forms in **eutherians** (Hence the name placental mammals) after 12 weeks of pregnancy.

**Functions of the placenta**

The placenta is a small organ but has a wide variety of roles. The placenta works as a link, a barrier and/or an endocrine organ.

**The placenta as a link:**

- ✓ Provides a site for exchange of materials between maternal and fetal blood. These are mainly nutrients like glucose, amino acids, fatty acids and oxygen from maternal blood into the foetus and wastes from the foetus into the mother's blood
- ✓ It allows passage of antibodies from maternal blood into the foetus to provide immunity

**The placenta as a barrier:**

- ✓ Prevents entry of toxic substances from maternal blood into the foetus
- ✓ Protects the foetus from entry of pathogens from maternal blood into the foetus
- ✓ Protects the fetal circulatory system from the high blood pressure of the mother which would be dangerous to the foetus.
- ✓ Prevents mixing of the fetal blood with maternal blood which would be lead to agglutination if their blood groups are not compatible.
- ✓ It also excludes maternal hormones from the fetus as these would affect the growth and development of the foetus.

**The placenta as an endocrine organ** produces a number of hormones as summerised in the table below.

| Placental Hormone | Functions |
|---|---|
| Progesterone | ✓ Maintains thickness of the endometrium<br>✓ Relaxes muscles of the myometrium (Prevents contraction); thus preventing miscarriage<br>✓ Stimulates development of mammary glands<br>✓ Inhibits release of FSH, preventing development of more follicles<br>✓ Inhibits release of prolactin hence inhibits lactation |
| Oestrogen | ✓ Increases sensitivity of the myometrium to oxytocin<br>✓ Stimulates growth of the myometrium of the uterus<br>✓ Stimulates development of mammary gland ducts<br>✓ Inhibits release of FSH<br>✓ Inhibits release of prolactin |
| Human placental Lactogen (HPL) | ✓ Stimulates growth and development of mammary glands<br>✓ Promotes effects of progesterone and oestrogen on mammary glands |
| Human Chorion Gonadotrophin (HCG) | Maintains the activity of the corpus luteum to continue secreting porgesteron. This applies up to week 12 when this role is taken over by the placenta. The level of HCG then decreases. |

**NB:** During pregnancy, progesterone and oestrogen are secreted in gradually increasing amounts first by the corpus luteum and later by the placenta. In the last three months of pregnancy, oestrogen secretion increases faster than that of progesterone. Just prior to birth, the level of progesterone decreases while oestrogen increases.

**NB:** At the placenta; the blood of the mother never comes into direct contact with that of the foetus. Exchange of materials is restricted to diffusion, active transport and pinocytosis.

| Mechanism | Materials exchanged |
|---|---|
| Osmosis | Water |
| Simple diffusion | Respiratory gases (Oxygen and carbon dioxide), Nitrogenous wastes (Urea) and some mineral ions like sodium, potassium and calcium |
| Facilitated diffusion | Glucose |
| Active transport | Most nutrients like Amino acids, Vitamins, lipids and, mineral ions like Sodium, potassium, iron and Calcium. |
| Pinocytosis | Antibodies |

**Adaptations of the placenta for its function**

- ✓ It is richly supplied with blood capillaries which transport materials to maintain a steep diffusion gradient, leading to more diffusion.
- ✓ Placental capillaries are arranged in a counter-current exchange to allow for maximum exchange of materials
- ✓ It has numerous villi and microvilli that provide a large surface area for exchange of materials
- ✓ The villi of the fetal part occur in close proximity with maternal villi. This reduces the diffusion distance hence allowing for faster diffusion of materials
- ✓ Presence of numerous mitochondria that provide energy for active transportation of materials

- ✓ It is semi permeable thus allowing only some molecules to cross from maternal blood while preventing others which may be harmful to the growing embryo.
- ✓ It also contains secretory cells which produce a number of placental hormones that regulate growth of the embryo

**Diagram showing blood circulation to and from the foetus**

**Child birth (Parturition)**

The process of child birth is known as **Parturition**. Normally; the process occurs at the end of gestation.

At the end of gestation; the level of **progesterone** falls below that of **oestrogen**. This breaks the inhibition of oxytocin; allowing the posterior pituitary gland to release **oxytocin**. Oxytocin stimulates **rhythmic contraction** of the uterine walls; which stimulates release of more oxytocin to cause stronger contraction; following a **positive feedback**. The cervix dilates gradually; due to relaxation of muscles; leading to rapture of the chorion and the amnion; releasing the amniotic fluid through the vagina.

The contractions originate from the top of the uterus, and spread downwards. Contractions progressively increase in strength, duration and frequency; until the baby is pushed through the dilated cervix and then vagina.

The umbilical cord is tied twice and cut between the ties, to completely separate the baby from the mother

The placenta detaches from the uterus and gradually pushed out through the vagina with extra embryonic membranes as the after birth.

**Milk ejection reflex**

Immediately after birth; the suckling of the baby stimulates the **sensory receptors** in the nipple; to send impulses to the hypothalamus; which in turn stimulates release of oxytocin from the posterior pituitary gland. Oxytocin causes contraction of the **myoepithelial** tissues around the alveoli; leading to milk let down (Flow of milk).

**NB:** During pregnancy; progesterone inhibits milk production. Decrease in the level of progesterone breaks the inhibition; and prolactin stimulates milk production (Lactogenesis). After birth; oxytocin stimulates the release of the produced milk (Lactation).

Milk basically contains fat, lactose, and proteins casein and lactalbumin. In addition; the first milk after birth contains antibodies which contribute to passive immunity of the new borne.

**Prenatal circulatory system.**

Before birth; blood supply to the lungs and digestive system do not function; as exchange of gases and supply of nutrients are performed by the placenta. Oxygenated blood flows from placenta via **the umbilical vein**; by-passes the liver via the **Ductus venosus** into the inferior venacava. Some of the blood in the ductus venosus flows directly through the liver before joining the inferior venacava. Blood flowing into the right atrium is a mixture of oxygenated and deoxygenated blood. Some blood from the right atrium is pumped into the right ventricle and then pumped to into the pulmonary artery. This blood by-passes the lungs via the **ductus arteriosus** that links to the aorta. Most of the blood from the right atrium passes through the **foramen ovale** into the right atrium. It then flows to the right ventricle which pumps it via the aorta to general body circulation. The deoxygenated blood reaches the umbilical artery; which delivers it to the placenta for oxygenation; and the cycle repeats.

**NB:** During fetal circulation; blood pressure is highest in the pulmonary artery; and this determines the direction of blood flow.

**Changes in fetal circulation after birth**

After birth, a number of changes occur in the circulatory system in adaptation to life outside the uterus. These include:

The baby takes in the **first breath**; leading to **inflation** of the lungs which **reduces the pressure** in the

pulmonary artery; leading to constriction and closure of the **ductus arteriosus**; such that blood flows into the lungs. Tying the umbilical vessels increases the amount of blood in the aorta which increases the pressure in the left ventricle and atrium. This leads to closure of the **foramen ovale**. The ductus venosus also constricts and closes; which increases blood flow to the liver and intestines.

The other change is the replacement of **fetal haemoglobin**; whose affinity for oxygen is higher; with **adult haemoglobin**; whose affinity is relatively low.

**NB:**

Fetal haemoglobin consists of 2 alpha polypeptide chains along with 2 gamma chains. In adult haemoglobin, the gamma chains are replaced with beta chains.

In some few individuals; the foramen ovale may completely fails to close; leading to a situation called "Hole in the heart". This is treated by surgery.

In case the blood pressure in the aorta exceeded that of the right ventricle; blood would flow backward into the ductus arteriosus in the fetus.

**Birth control methods**

| Method | Examples | Advantage | Disadvantage |
|---|---|---|---|
| Sterilisation | Vasectomy. It involves cutting and tying of the vas deferentia that carry sperms from testes during ejaculation | No artificial appliances involved<br>It is a very effective method<br>It is cheap as no extra cost is involved after the operation | It is irreversible |
| | Tubal ligation. This refers of the tying of the fallopian tubes to prevent sperms from meeting the ova | No artificial appliances involved<br>It is a very effective method<br>It is cheap as no extra cost is involved after the operation | It is irreversible |
| Prevention of ovulation | Oral contraceptives. They are in form of drugs containing synthetic oestrogen and progesterone | Very reliable if taken regularly | |
| | Injection contraceptives; they contain oestrogen and progesterone | Very reliable if taken regularly | Irregularity of menstruation |
| | Implants; it is placed under the skin to | It is a very reliable method | Irregularity of |

| | | | |
|---|---|---|---|
| | release oestrogen and progesterone | | menstruation |
| Prevention of implantation | Use of pills; These are taken after sexual intercourse. It blocks the action of progesterone which would maintain the pregnancy | It can be used closely before or after sexual intercourse | It is not recommended for regular use |
| | Intra-uterine Device (Loop/coil). It is a loop of plastic or copper wire inserted into the womb to prevent implantation | Does not require further action after application. This makes it cheaper | It must be inserted by a technical person<br>May be displaced during sexual intercourse<br>It may also be rejected by the body |
| Prevents sperm form meeting with the egg | Diaphragm (Cap). It is a dome –shaped sheet of thin rubber that is inserted around the cervix. It may be used with a spermicide | It is very reliable if used with a spermicide.<br>It is available for all kinds of women | It must be required prior to sexual intercourse<br>Must be fitted by a trained person |
| | Use of condoms. They include both male and female condoms that prevent the egg from meeting the sperm | It is a reliable method | Reduces enjoyment during sexual intercourse |
| | Spermicides. They are creamy jelly or foam that is inserted in the vagina | It is an effective method | It is better used with other methods<br>They occasionally cause discomfort |
| Natural Methods | Rhythm method. Refraining from sex during fertile days of the cycle | It does not come with any side effects<br>No applications required | It is a less reliable method |