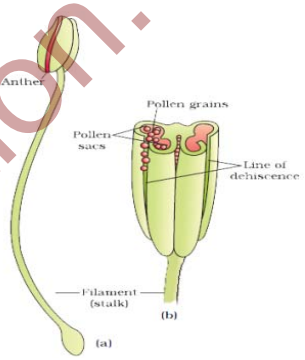
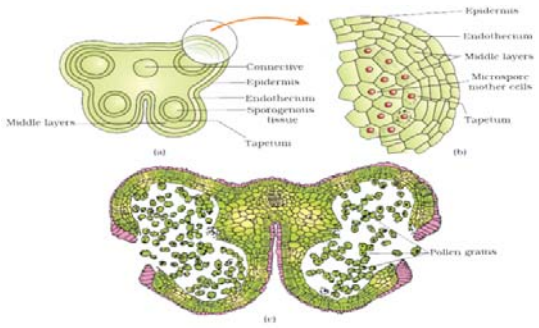
Sexual Reproduction in Flowering Plants

* Flowers are morphological and embryological marvels and sites of sexual reproduction.
* Study of cultivation of flower yielding plants is called as Floriculture.
* Androecium and Gynoecium are important structures of Flower associated with sexual reproduction.
* Embryology is branch of Botany associated with androecium, gynoecium and processes involved in sexual reproduction of flowering plants.
* The decision to form flowers is taken well before the actual flower is seen on the plant.
* Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium.



Stamen, Microsporangium and Pollen Grain

* A typical stamen has two main parts. They are the stalk known as filament and the terminal and usually bilobed structure the anther. The filament and anther are attached at point known as connective. The filament is attached to the petal or thalamus with its proximal end.



* The anther usually has two lobes separated by a deep longitudinal groove. Each lobe is called as theca. Anthers are dithecous in plants like *Datura* and monothecous in *Hibiscus*.
* Bilobed anther is tetragonal structure with four microsporangia located at the corners.
* Every lobe has two locules and each locule is a microsporangium. The two microsporangia are separated by a shallow grove and extended longitudinally throughout the length of anther. The microsporangium is filled with microspores.

Structure of Microsporangium

* A normal microsporangium is usually circular in outline and has an anther wall and microsporogenous tissue

* Another wall has epidermis, endothecium, middle layers and tapetum from periphery to inside.
* **Epidermis** is the outermost layer of anther wall consisting of more or less similar rectangular cells. Cells of the epidermis present between two microsporangia of the same theca are smaller, thin walled and form the **Stomium**. It shows the signs of degeneration at the time of meiosis in microspore mother cells.
* Endothecium is present between epidermis and middle layers and has radially elongated cells with fibrous thickenings made of α-cellulose. It is hygroscopic. At the time of anther maturation its cells contract and help in the breakage of theca at stomium.
* Middle layers are present between endothecium and tapetum and 1-5 layered. It stores food materials in the form of starch. It is ephemeral and degenerated during the development of anther.
* Tapetum is the innermost layer of anther wall and completely surrounds the sporogenous tissue.It has thin walls, prominent nuclei and dense cytoplasm. It provides nourishment to the developing sporogenous tissue. More than one nucleus of tapetal cells are formed due to free nuclear divisions.
* Sporogenous tissue is homogenous and present at the center of microsporangium surrounded by tapetum.
* During the development of anther, the cells of sporogenous tissue divide mitotically and form microspore mother cells, which undergo meiosis to form haploid microspores. It is called as **microsporogenesis**. Each microspore mother cell forms four haploid microspores in tetrads.With the maturation and dehydration of anther, the pollen grains of tetrad are separated and liberated individually. Every microsporangium has thousands of microspores.

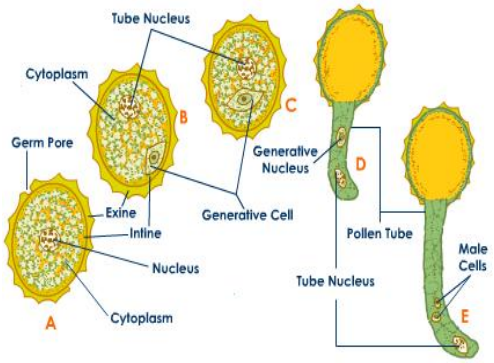
Pollen grain or Microspore

* It represents the male gametophyte of Spermatophytes. It is the first cell of male gametophyte.
* It is of different sizes, shapes, architectures, colors etc.
* It is usually spherical with 25-50µ in diameter.
* It has double layered wall consisting of outer exine and inner intine and a protoplast.
* Exine is denser than intine and made of one of the most resistant biological materials known as Sporopollenin. It is resistant to high temperatures, acids and bases. Due to this pollen is well preserved even in fossils. So far no enzyme that degrades pollen is known.

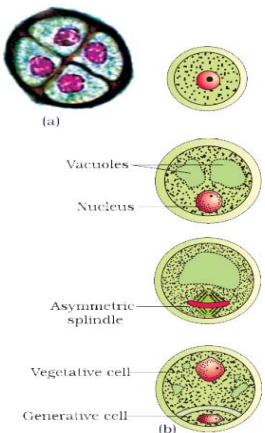
* Exine has various types of ornamentations.
* Exine has depressions known as germ pores. These may be one or many in number. Through these pores the pollen tube emerges out at the time of germination.
* Intine is thin, pectocellulosic and uniformly thickened and forms the wall of pollen tube.
* Protoplast has a cell membrane which surrounds the dense cytoplasm with the prominent nucleus with oil reserves and distinct vacuoles.
* Pollen grains of some plants cause allergy which leads to chronic respiratory disorders like asthma, bronchitis. One such plant whose pollen causes allergy is *Parthenium* or Carrot grass. It was accidentally imported into India as contaminant in wheat.
* Pollen is rich in nutrients. It is given in the form of syrups or tablets to athletes and race horses to improve their performance.
* The viability of pollen dependent on the species of the plant, temperature and humidity to which it is exposed. It is upto 30 minutes in grasses like Wheat and Paddy, few months in plants of Solanaceae, Rubiaceae and Leguminosae etc.
* Pollen is stored in Pollen banks for future use in crop improvement at liquid nitrogen at -196^0C.

Development of Male gametophyte

* Microspore is the first cell of male gametophyte. It starts dividing in the microsporangium itself. It divides periclinally, mitotically and unequally and forms two unequal cells. The larger one is vegetative cell or tube cell and the smaller one is generative cell or male gamete mother cell.
* Generative cell is lense shaped or spindle shaped and vegetative cell has irregularly shaped nucleus.
* The generative cell detaches from the parental cell wall and floats freely in the cytoplasm of vegetative cell. At this 2-celled stage, the pollen grains are released in 60% of angiosperms. In remaining angiosperms it is released at 3-celled stage (vegetative cell and 2 male gametes).



* The pollen is carried to stigma by various agents like wind, water and animals.
* After dialogue between the pollen and stigma, the pollen grains absorb the stigmatic secretions by imbibition and it

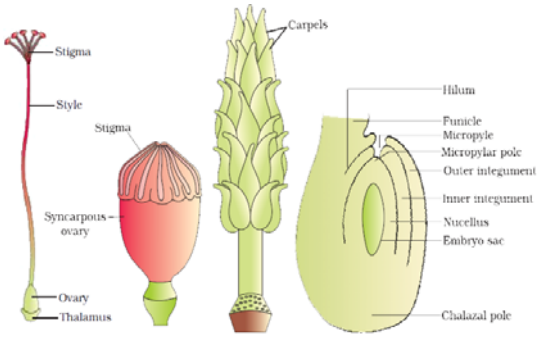


germinates. During this, the intine comes out as tube like structure through germ pore. It is known as pollen tube.

* Pollen germination requires Ca and B. Auxins promote the germination. Growth of pollen tube is apical and chemotropic.
* At the beginning, the apex of the pollen tube has vegetative nucleus and behind to it is generative cell. Eventually, the position is reversed and later the generative cell divides mitotically and forms two male gametes which do not have cell wall. Male gametes are also formed when the pollen grain is on the stigma and yet to germinate and even after the entry of pollen tube into the embryosac.
* The pollen tube travels through the stylar tissue and seeks entry into ovule of ovary either through micropyle or chalaza or integuments or funicle.
* It enters into the embryosac through one of the synergids that have filiform apparatus.
* The growth of pollen tube is stopped after the entry into embryosac and the two male gametes are discharged into the synergid due to dissolution or formation of pore in the pollen tube wall either terminally or sub-terminally.
* Since pollen tube acts as male gamete carrier, fetilisation of spermatophytes is described as Siphonogamy.
* Pollen grains are usually monosiphonous i.e. form only one pollen tube. Some times as in Malvaceae and Cucurbitaceae they are polysiphonous. Rarely pollen tube is branched.

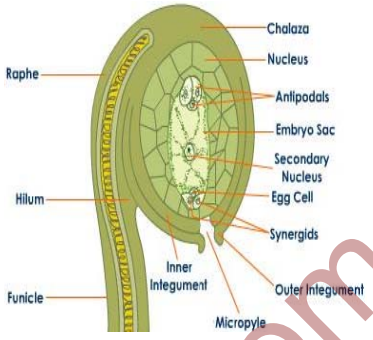
The Pistil, Mega sporangium and Embryo sac

The Pistil

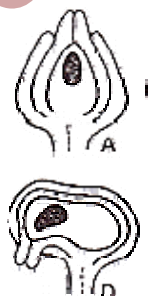


* It is female reproductive part consisting of one (**monocarpellary** as in *Dolichos*) or more than one carpels (**multicarpellary** as in *Michelia*) or megasporophylls. These many carpels may be free (**Apocarpous**) as in *Michelia* and *Annona* are united (**Syncarpous**) as in *Papaver* and *Hibiscus*.
* Pistil has three parts. These are the basal swollen part ovary, slender elongated part style and pollen receptive distal end called Stigma.
* Ovary has one or more than one cavities known as locules.
* Ovary has ovules or megasporangia arranged in different patterns in different species of pants.
* Number of ovules may be one as in Wheat, Paddy and Sunflower or many as in Cucurbits like Water melon, Orchids and Papaya.

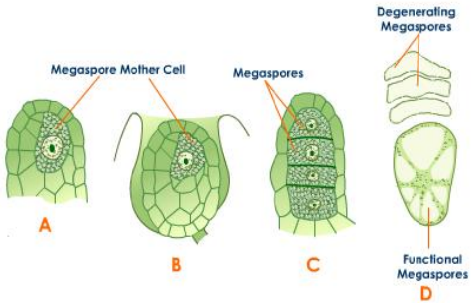
Ovule or Mega sporangium



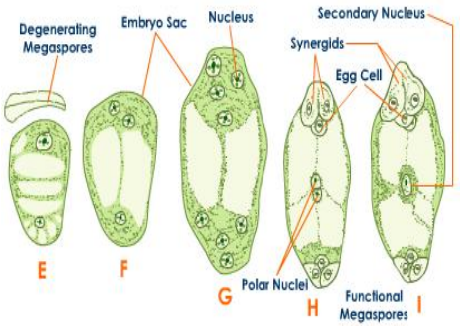
* It is integumented megasporangium.
* It is present in all spermatophytes. It is exposed in Gymnosperms and concealed in Angiosperms.
* It is formed from placental tissue of ovary.
* It has a stalk named **Funiculus** with which it is attached to the placenta and a body.
* Body and funiculus join at a point known as **Hilum**.
* Body of the ovule has a diploid mass of nutritive tissue known as Nucellus. It provides food to the megaspore mother cell and female gametophyte during their development.



* The protective coverings present around the nucellus are called as **Integuments**. These are outer integument and inner integument. Integuments are absent in **Ategmic** ovules as in Parasites like *Loranthus*, **Unitegmic** ovules have one integument as in Gamopetalae members like *Helianthus* and *Datura* and **Bitegmic** ovules have two integuments as in Monocots and Polypetalae membe
* Within the nucellus, an embryosac or female gametophyte is embedded which is formed from megaspore.
* The narrow passage left uncovered by the integuments at the distal end of ovule is called **Micropyle**.
* Ovules are of various types based on their degree of curvature of ovule body on the funiculus.



* In **Orthotropous** ovules, micropyle, nucellus, chalaza and funiculus are aligned in the same plane. Ex: Polygonum
* In **Anatropous** ovule, the ovule body is curved on the funiculus at an angle of 180^0 and its micropyle lies nearer to the funiculus as in Sunflower family.
* In **Campylotropous** ovule, the ovule body is placed perpendicularly to the funiculus and it bends in such a way that micropyle lies nearer to the funiculus. The embryosac may be slightly curved. Such ovules are seen in Bean family (Fabaceae).



Mega sporogenesis

* It is formation of megaspores from megaspore mother cells upon reduction division. One of the cells of nucellus at the micropylar region gets differentiated into larger cell with prominent nucleus and dense cytoplasm. It is megaspore mother cell.
* This megaspore mother cell undergoes reduction division and forms 4 haploid megaspores in a linear tetrad. This formation is called as megasporogenesis.

Female gametophyte

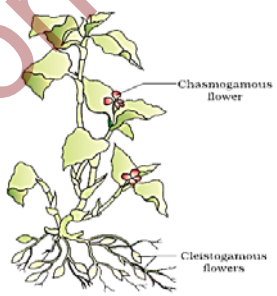
* In the megaspore tetrad, the three megaspores formed towards the micropyle degenerate and the lower one is functional. The functional megaspore gives rise female gametophyte.
* Functional megaspore enlarges in size and its nucleus undergoes a free nuclear division and forms two nuclei. One nucleus migrates towards the micropyle and called Primary micropylar nucleus and the other one migrates towards the chalazal end and called Primary chalazal nuclei. Both the primary nuclei undergo two generations of divisions and form four nuclei at each pole.
* Out of four nuclei at each pole one nucleus migrates towards the center. These nuclei are called Polar nuclei.
* Around the nuclei of respective pole, cell walls are formed to form a 7 celled 8 nucleated structure called embryo sac. Such embryo sac formed from a single megaspore is called as Monosporic embryo sac and first discovered in *Polygonum*.
* In the embryo sac, the group of three cells formed towards the micropylar region is called as Egg apparatus. It has a larger cell called **egg** which is flanked by two **synergids**. Each synergid has an cell extension in the form of finger like structure called **filiform apparatus** which secretes some chemical substances and guides the pollen tube into the embryo sac. Egg cell is the fertile cell of embryo sac. The three cells towards the chalazal end are called as antipodals. The largest cell of embryo sac is present between the egg apparatus and antipodals. It is called central cell and has two polar nuclei. At maturity the embryo sac is 7-celled and 8-nucleated.

Pollination

* This process helps in bringing non-motile male gametes to the site of female gamete present in the embryo sac for fertilization. It is prerequisite for fertilization.
* In Gymnosperms the pollen grains are directly deposited on the ovule and known as **Direct pollination**. In angiosperms it is indirect because the pollen grains are deposited on the stigma and later reach the

ovule present in the ovary. It is called **Indirect Pollination**.

* If the pollen grains are deposited on the stigma of same flower it is Autogamy or Self-pollination, and deposited on the stigma of some other flower of the same species it is Cross pollination.
* Based on the source of pollen pollination is divided into three types
  1. Autogamy 2. Geitonogamy and 3. Xenogamy.
* In **Autogamy**, the pollen grains are deposited on the stigma of same flower. For this the flower should be bisexual and there should be synchrony in pollen receptivity of stigma and pollen release. Anthers and stigma must be close enough for this purpose.
* Plants like *Viola* (Pansy), *Oxalis* and *Commelina* produce two types of flowers. These are **Cleistogamous** flowers and **Chasmogamous** flowers.
* **Chasmogamous** flowers open and expose their anthers and stigma. Cleistogamous flowers are not opened.
* In **cleistogamous** flowers the anthers and stigma are very closely placed and during anther dehiscence the pollen grains come in contact with stigma to effect pollination. These flowers are invariably autogamous and do not require pollinators. Seed set is ensured.



* **Geitonogamy** is deposition of pollen grains on the stigma of some other flower present on the same plant. It is functionally cross pollination but genetically self-pollination as the pollen belongs to the same plant.
* **Xenogamy** is deposition of pollen grains on the stigma of another flower present on another plant belonging to the same species. It is genetically and functionally cross pollination.
* Geitonogamy and Xenogamy are types of **Crosspollination**.

Agents of Pollination

* These are abiotic (wind and water) and biotic (Animals) agents.
* Plants are mostly pollinated by biotic agents.

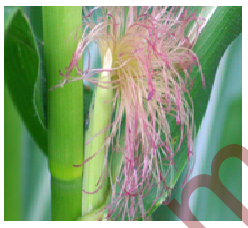
Abiotic agents

* Pollination by abiotic agents is a chance factor. To overcome this, the flowers produce large amounts of pollen compared to the number of ovules available for pollination.
* Flowers are not attractive. They neither emit scent nor produce nectar as rewards.

Anemophily

* It is pollination by wind and more common than hydrophily.

* It is common in grasses
* Inflorescence has several flowers which are not attractive.
* Anthers are versatile. Perianth is not well developed.
* Pollen grains are light and non-sticky.
* Stamens are well exposed and so that the pollen is easily dispersed into wind currents.
* The stigmas are feathery.
* Usually the ovary has single ovule as in grasses.
* In plants like maize the female flowers have elongate styles which hang into the air as clusters to catch wind borne pollen as in maize.



Hydrophily

* In is pollination by water.
* It is rare and seen only in 30 genera mostly belonging to monocots.
* All hydrophytes are not hydrophilous but all hydrophilous plants are hydrophytes.
* It is of two types known as **Epihydrophily** and **Hypohydrophily**.
* **Epihydrophily** is shown by plants like *Vallisneria* and Hydrilla which are freshwater forms.
* In Vallisneria, the female flowers have elongated stalk which helps in bringing the female flower to the level of water.
* The male flowers are detached from the male inflorescence and freely float on the surface of water. It is carried to the female flower by water currents and when it comes in contact with the female flower, the pollen grains are ducted on the stigma and pollination is facilitated.
* **Hypohydrophily** or underwater pollination is shown by Zostera. It is commonly called as sea grass and marine plant.
* The female flowers are submerged in water and the pollen grains are released inside the water.
* The pollen grains are long, ribbon like and passively carried inside the water. The pollen grains lack exine and protected by mucilage covering from wetting.

Biotic agents

* Pollination by biotic agents is called as Zoophily. These are **Entomophily**, **Ornithophily** (pollination by birds such as sunbirds, humming birds)**Chiropterophily** (pollination by bats),**Malacophily** (pollination by Snails), **Herpetophily** (pollination by reptiles like lizards)**Therophily** (pollination by mammals), **Sminthophily** (Rodents), **Eutherophily**(Marsupials), **Metatherophily** (Placentales) and **Ophiophily** (Snakes).
* Animal pollinated plants are adapted for a particular species of animal.

Entomophily

* The biotic agents are Bees, Butterflies, Flies, Beetles, Wasps, Ants, and Moths.
* These plants have large, colorful, fragrant, nectar rich flowers.
* If the flowers are small they are clustered into inflorescence.
* Flowers visited by flies and Beetles emit foul smell.
* Nectar and pollen are the rewards offered by flowers to the insects to sustain main visits of the pollinator.
* Pollen grains are sticky and when come in contact with the animal they are stuck to the animal body.
* In plants like Amorphophallus, the spathe of spadix inflorescence which is of 6 feet height provides safe place to insects to lay eggs.
* The moth Pronuba yuccacella and the flowers of plant Yucca show symbiotic relationship without which both cannot complete their life cycle. The moth lays eggs in the ovary of flower during which it pollinates the flowers. The larvae come out of the eggs as seeds are forming in the fruits.
* Many insects may consume pollen and nectar without pollinating the flowers. Such insects are called as Pollen/Nectar robbers.

Out breeding devices

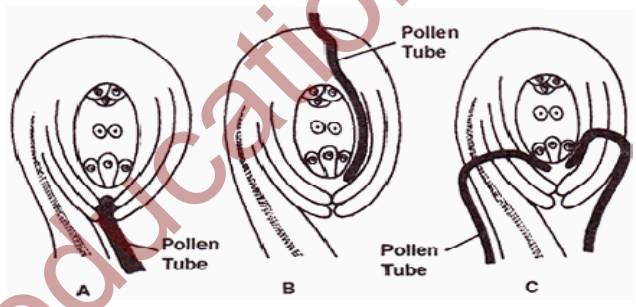
* In hermaphrodite flowers, if self-pollination takes place, it leads to decrease in the quality of the plant and it is known as inbreeding depression. To avoid this, flowering plants developed many devices of adaptations or contrivances to promote cross pollination. These devices are Dicliny, Dichogamy, Herkogamy, Heterostyly, Self-sterility etc.
* Production of unisexual flowers is known as **Dicliny** or **Unisexuality**. Plant with unisexual flowers may be Monoecious or Dioecious. In such plants, cross pollination is inevitable. In monoecious plants, autogamy is prevented but geitonogamy or xenogamy takes place (Castor and Maize). In dioecious plants, xenogamy only occurs and there is no chance for autogamy or geitonogamy (Papaya).

* **Dichogamy** is maturation of androecium and gynoecium at different intervals in a bisexual flower. In this pollen release and stigma receptivity are not synchronized. It is protandry and protogyny.
* In **Protandry** androecium matures earlier than gynoecium.
  E.g. Sunflower
* In **Protogyny** stigma is receptive earlier than pollen release and by the time pollen is released, the stigma loses the receptivity.
  E.g. *Datura*, *Solanum*.

* In **Herkogamy**, the stigma and anthers are positioned in different directions or different heights so that the stigma and anther do not come in contact with each other. **Ex:** *Hibiscus, Gloriosa*
* In **Heterostyly**, the styles are of different heights indifferent flowers of the same species. **Ex:** *Primula*
* In **Self-sterility** of **Self-incompatibility**, inhibition of pollen germination pollen tube growth when pollen deposited on the stigma of same flower.
  Ex: *Abutilon*. This is a genetic mechanism

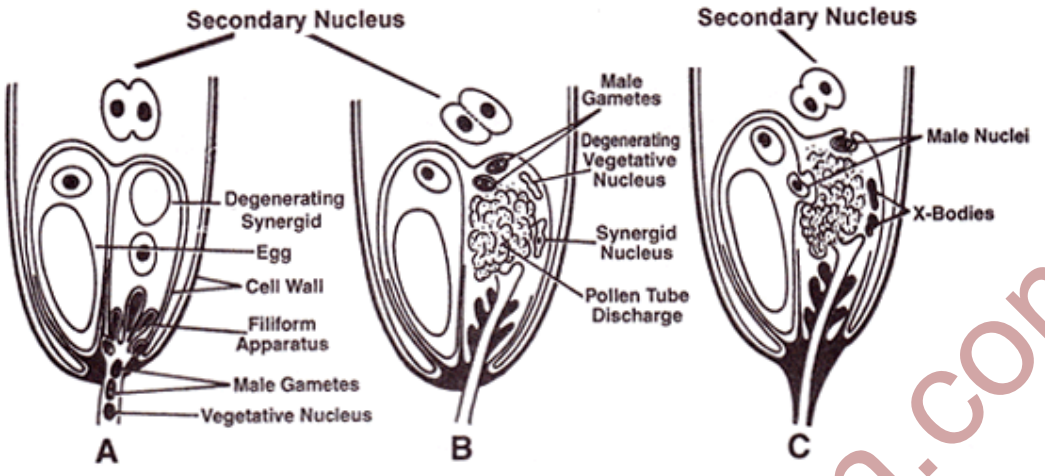
Pollen-Pistil Interaction

* The sum of events that occur from the deposition of pollen on the stigma till the pollen tubes enter into the ovule is called as **Pollen-Pistil interactions**. The knowledge obtained in the area is useful in manipulating pollen-pistil interaction even in incompatible pollinations to get desirable hybrids.



* The pistil can recognize the pollen whether it belongs to some other species or same species. If it is of same species it can distinguish whether it belongs to the same flower or different flower.
* There is continuous dialogue between the pollen and pistil. It is mediated by some chemical substances of pollen interacting with the pistil. This interaction leads to recognition of pollen to accept or reject the pollen. If it accepts, the pollen grains germinate otherwise the pollen germination or pollen tube growth can be inhibited.
* In compatible pollination, the pollen grains germinate on the stigma and produce a pollen tube through one of the germ pores. The contents of the pollen grain move into the tube.

* The pollen tube grows through the style and reaches the ovary.



* In plants which release pollen in two celled stage with generative cell and vegetative cell, the generative cell divides in the pollen tube and forms two male gametes.
* In those plants in which the pollen grains are released at 3-celled stage, the pollen tube carries the two male gametes right from the beginning and reaches the ovary.
* The pollen tube enters the ovary and later into the ovule either through micropyle (Porogamy), or Chalaza (Chalazogamy) or through the integuments (Mesogamy).
* Pollen tube enters into the embryosac through filiform apparatus of synergids.
* Pollen germination and formation of pollen tubes can be studied by dusting pollen on a slide with 10% sucrose solution and observing them under microscope after 15-30 minutes.

Artificial Hybridisation

* In is one of the methods of crop improvements.
* In this the pollen of desired male parent is place over the stigma of female parent to bring about cross pollination and eventually cross fertilization to get hybrid seed.
* The anthers of bisexual flowers of female parent are removed and the process is called **Emasculation**. It avoids self-pollination. This need not be done in case of unisexual flowers.
* The emasculated flowers are covered with polythene or butter paper bags to avoid unwanted cross pollination and process is called as **Bagging**. For unisexual flowers bagging is done when the flowers are in bud stage.
* When the stigma of female parent attains receptivity, the pollen of male parent is collected and kept over the stigma and again rebagged to allow for the development of fruits.

Double fertilisation

* The pollen tube, after seeking entry into the synergid of embryo sac, releases the two male gametes into it due to breakage of pollen tube wall or formation of pore in the pollen tube wall.
* One of the male gametes moves towards the egg cell and its haploid nucleus fuses with the haploid nucleus of egg cell to form diploid zygote. It is called as **Syngamy** or **Zygotic** fertilisation. The other nucleus fuses with the two polar nuclei and fuses with them to form Primary Endosperm Nucleus. It is called as **Triple fusion** or Vegetative fertilization.
* Since two types of fusions occur in the embryo sac, the phenomenon is called as **Double fertilization**. It is seen in only Angiosperms.
* The central cell is called Primary Endosperm Cell after fertilization and develops into endosperm. Similarly the zygote develops into embryo.

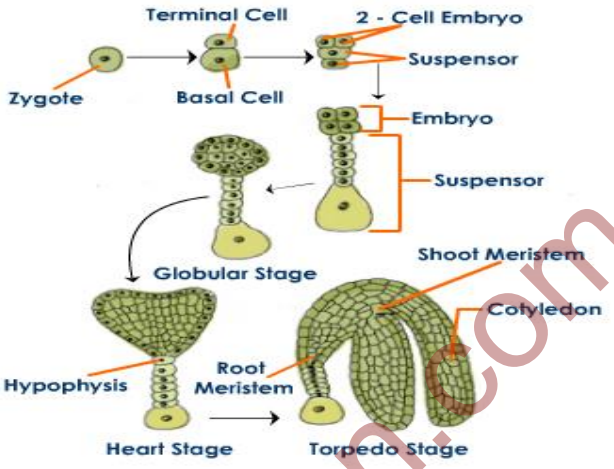
Post-fertilisation: Structures and Events

* The changes such as development of endosperm, embryo, maturation of ovules into seeds and ovary into fruit together called as Post-fertilisation events. The other structures of flower wither off.

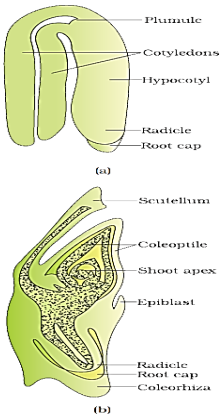
Endosperm

* It is developed earlier than embryo because it has to provide nourishment to the developing embryo.
* Primary endosperm nucleus of Endosperm mother cell divides and forms several triploid nuclei. Around these nuclei cell walls are developed to form triploid endosperm. Endosperm formed in such method is called as free nuclear endosperm which is the most common type of endosperm in angiosperms. The number of free nuclei formed before cellularization differs enormously.
* In Coconut, the coconut milk is free nuclear endosperm and the coconut meat is solid endosperm.
* In some plants the endosperm is totally consumed by the time the seed is totally developed. Such seeds are called as **Endospermic** or **Albuminous** seeds. Ex: Pea, Groundnut, Beans.
* In some plants endosperm is retained even after seed maturation. Such seeds are described as **Endospermic** or **Albuminous** seeds.
  Ex: Castor, Coconut, Cereals. In these plants endosperm is used during seed germination.

Embryo



* It is developed from zygote only after formation of certain amount of endosperm. This assures nutrition to zygote for embryo development.
* Though the seeds among the angiosperms differ greatly, the early stage of development in both dicots and monocots is same.
* The zygote divides and forms a few celled **Proembryo**, a multicellular **Globular** stage, **Heart** stage and ultimately the **mature** embryo.
* A dicot embryo consists of an axis known as **Tigellum** two which two dorsiventrally flattened fleshy structures with food reserves known as **Cotyledons** are inserted laterally. The portion of tigellum present above the cotyledons is called as **Epicotyl** and below cotyledons as **Hypocotyl**.
* The epicotyl terminates into Plumule or Stem tip (First apical bud of shoot) and hypocotyl into Radicle or Root tip. The root tip is covered with root cap.

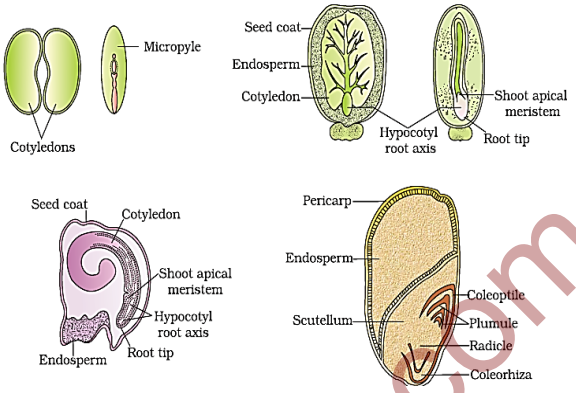


* **Monocotyledonous** embryo has only one cotyledon. The only cotyledon of grass plants embryo present on one side of embryonal axis is called as **Scutellum**. The axis has epicotyl with **Plumule** and few leaf primordial at the end and hypocotyl with **Radicle** at the end. The epicotyl and hypocotyl are covered by membranous coverings known as **Coleoptile** and **Coleorhiza** respectively. The outermost layer of endosperm rich in proteins is called as **Aleurone layer**.The lateral outgrowth of coleorhiza is called Epiblast.
* The left over nucellus present in some seeds is called as **Perisperm**. Ex: Black Pepper, Beet root.

Structure of Dicot Seed

* It has a covering called Seed coat differentiated into outer Testa and inner Tegmen.
* The **Hilum** is a scar on the seed coat through which it is connected to fruit. The small pore present above the hilum is called **Seed pore** or **Micropyle** is present.

* A seed with seed coat is called as Kernel. The kernel has an embryo with two usually fleshy cotyledons and an embryonal axis. At one end of embryonal axis there is **radicle** and at the other end **plumule**. In some seeds such as castor, endosperm is present around the embryo. In Bean, gram and pea endosperm is absent.



Structure of Monocot Seed

* Usually monocot seeds are endospermic but orchids are non-endospermic.
* In the seeds of cereals such as Maize, the seed coat is thin and fused with the pericarp. The endosperm is massive and full of food reserves. The outermost covering of endosperm separates the embryo from rest of the endosperm. It is called **Aleurone** layer.
* The embryo is small and situated in a groove at one end of endosperm. It has one large and shield shaped cotyledon called **Scutellum** and short axis with plumule covered by **coleoptile** and radicle covered by **coleorhiza**.

Significance of Seed and Fruit

* Seeds are the driest structures of Plant. The integuments of the ovule become tough seed coat with outer testa and inner tegmen. The seed has a pore through which the water and gases seek entry at the time of germination.
* As the seeds mature the water content recedes and seeds become relatively dry (10 – 15% of water). The metabolic activity of seed gradually decreases and the embryo enters into a state of inactivity called Dormancy. If favourable conditions such as availability of oxygen and water, it germinates and forms seedling.
* Fruit is an adaptation meant for dispersal of seeds. Coconut fruit floats after detached from the plant, *Martynia* (Tiber Claw plant) attaches to the fur of animals and seeds of Guava and Figs are eaten by birds which are not digestible but their seed coat is softened for quick germination. The fruits attract the animals by providing food for the dispersal of seeds.
* The seeds of Orchids are microscopic and many in number in each fruit. These seeds weigh 0.81 micrograms. The seeds of *Lodoicea maldivica* are the largest seeds with 30 cm long and 90 cm in perimeter weigh about 18 kg.
* Seeds offer several advantages to angiosperms. These have better adaptive strategies for dispersal to new habitats and help the species to colonize in new areas. Since they have enough food reserves, young seedlings are nourished till

they perform photosynthesis on their own. The hard seed coat provides protection to the embryo. Since seeds are products of sexual reproduction, they form new genetic combinations that lead to variations.

* Seed is basis for out agriculture. Less water content and dormancy of seeds is important for storage which can be used as food throughout the year and also to raise the crop in the next season.
* The ability of seed to germinate and give rise seedling is called as Seed viability. It varies from species to species. Some seeds lose viability within few months. Some have viability for years together. The seeds of Lupine, *Lupinus arcticus* has 10,000 years of seed viability. Date palm, *Phoenix dactylifera* has 2000 years viability.
* A fruit of Orchids, Orobanche and Striga consists of thousands of tiny seeds. The tiny seed of *Ficus*, upon germination gives raise a massive plant.

Apomixis, Parthenocarpy and Polyembryony

* In some species of Asteraceae and Grasses, seeds are formed without fertilisation by a mechanism called **Apomixis**. It is a type of asexual reproduction that resembles sexual reproduction. Apomictic seed are formed from diploid egg cells which in return formed without meiosis during megasporogenesis and subsequent embryo sac development. Apomixis is assured reproduction in the absence of pollinators in extreme environments.
* Formation of more than one embryo in a seed is called **Polyembryony**. In plants like Citrus, the diploid cells of nucellus protrude into the embryo sac and develop into embryos. These embryos are in different sizes and can be called as clones as they have same genetic nature except the sexually formed embryo.
* Formation of fruit without fertilization is called **Parthenocarpy**. Such fruits do not have seeds. Ex: Grapes, Banana. Parthenocarpy may be induced or natural. This phenomenon is applied for commercial production of seedless fruits.
* **Productivity** of crop is increased by using hybrid varieties. Hybrid seed has to be produced a fresh every year. If the seed are collected from hybrid plant and sown in the next season, the productivity may decrease due to segregation of characters. Production of hybrid seed is costly and such seed is expensive to farmers. If these seeds are made apomictic, the farmers can keep on using the hybrid seeds to raise the crop every year as there is no segregation of characters. Research is going on different laboratories to produce apomictic hybrid seeds by transferring apomictic genes.