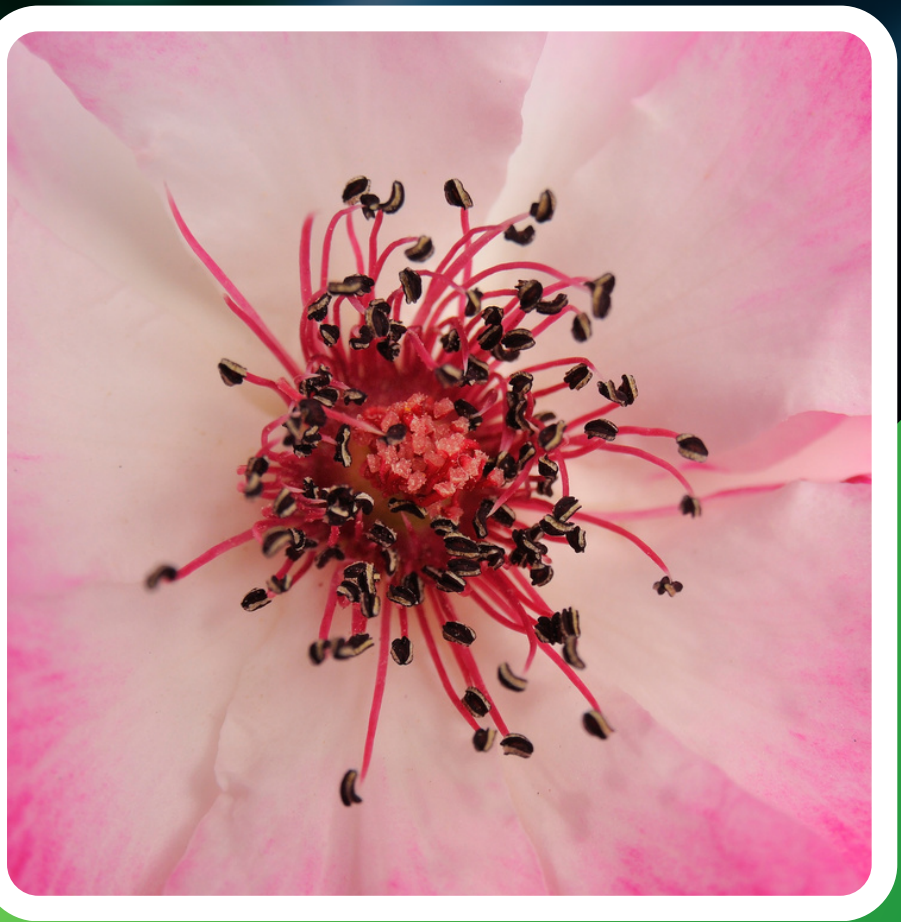
ALLEN CAREER INSTITUTE KOTA (RAJASTHAN)

path to success

PRE-MEDICAL

BIOLOGY

ENTHUSIAST | LEADER | ACHIEVER



STUDY MATERIAL

Sexual reproduction in flowering plants

ENGLISH MEDIUM

Copyright Statement

An introduction to Prof. Panchanan Maheshwari :-


PANCHANAN MAHESHWARI
(1904-1966)
[Father of Indian plant embryology]

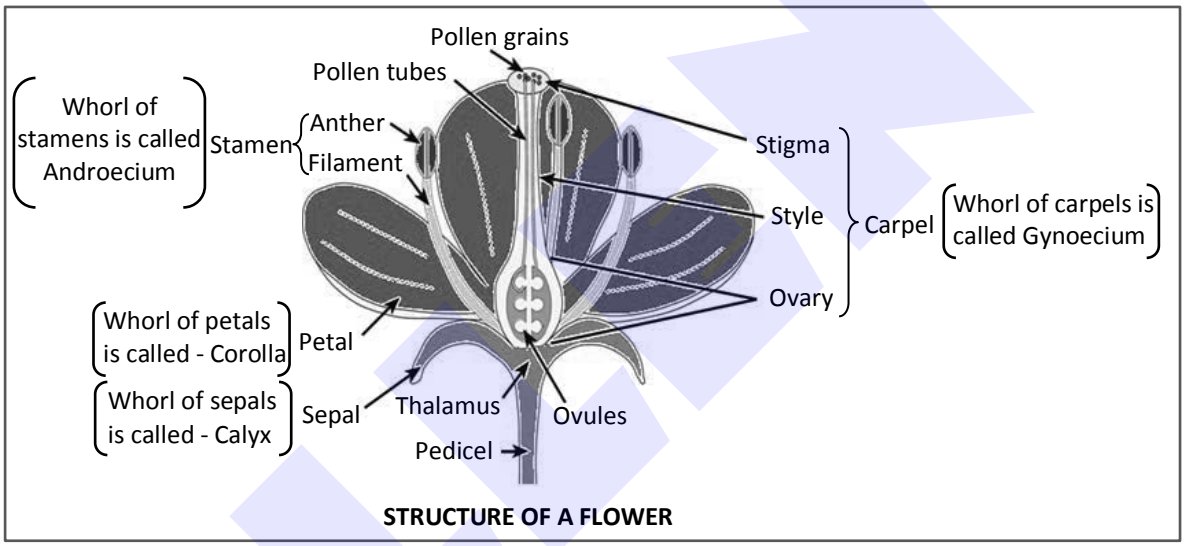
- He was born in November 1904 in **Jaipur (Rajasthan)** Panchanan Maheshwari rose to become one of the most distinguished botanist not only of India but of the entire world.
- He worked on embryological aspects and popularised the use of embryological characters in taxonomy.
- He established the Department of Botany, University of Delhi as an important centre of research in **embryology** and **tissue culture.**
- He also emphasised the need for initiation of work on artificial culture of immature embryos.
- He encouraged general education and made a significant contribution to school education by his leadership in bringing out the **very first textbooks of Biology** for Higher Secondary Schools **Published by NCERT in 1964.**
- **Prof. P. Maheshwari – Father of Indian plant Embryology**. He wrote a book – **'An Introduction to the Embryology of Angiosperms'**.

SEXUAL REPRODUCTION IN FLOWERING PLANTS

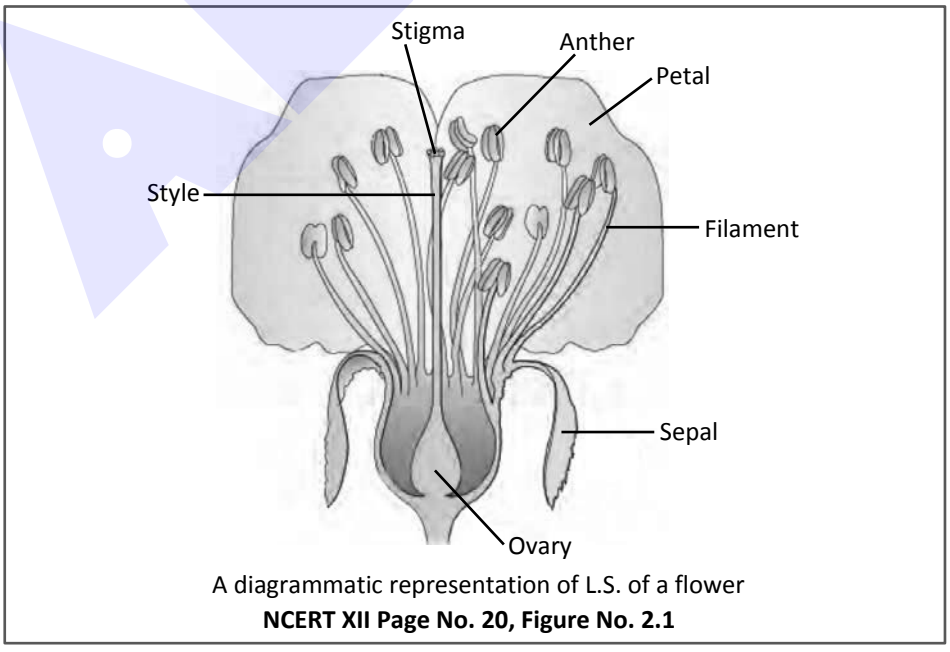
01. INTRODUCTION

- **Introduction**
- **Flower-A Fascinating Organ of Angiosperms**
- **Pre-Fertilisation : Structures and Events**
- **Double Fertilisation**
- **Post-Fertilization : Structures and Events**
- **Apomixis And Polyembryony**

- All flowering plants show sexual reproduction.
- Diversity of structures of the inflorescences, flowers and floral parts, shows an amazing range of adaptations to ensure formation of end products of sexual reproduction, the fruits and seeds.



STRUCTURE OF A FLOWER



A diagrammatic representation of L.S. of a flower

NCERT XII Page No. 20, Figure No. 2.1

02. FLOWER - A FASCINATING ORGAN OF ANGIOSPERMS

- **Floriculture – Science of cultivation, breeding and marketing of flowers.**
- Flowers are object of aesthetic, ornamental, social, religious and cultural values.
- Flowers are seat of sexual reproduction in angiosperms.
- To a biologist, flowers are morphological and embryological marvels and site of sexual reproduction.
- Most of the important angiospermic characters are found in ***Capsella*** (shepherd's purse) and it is easily available so it is considered as a "**Typical Angiosperm**". It is an annual plant and grows as a weed during the winter season in the field.
- **The main plant body** of the ***Capsella*** is a **sporophyte (diploid)** and it is differentiated into **root, stem and leaves**.
- ***Capsella* is a heterosporous** plant, it means two different types of spores are formed in the life cycle which are classified into two categories in which **male spores** are called **microspores** and **female spores** are called **megaspores**.
- **Flower is a modified shoot.**

MONOCARPIC AND POLYCARPIC PLANTS :

(i) Monocarpic plants :

- The plants in which **flowering** and **fruiting** takes place only **once** in the **whole life span** are called **monocarpic plants e.g. Annual & Biennial plants**.
- **Plants the annual and biennial types, show clearcut vegetative/juvenile, reproductive and senescent phases, but in the perennial species it is very difficult to clearly define these phases.**

(ii) Polycarpic plants :

- The plants in which **flowering** and **fruiting** takes place **many times** in their entire life span are known as **polycarpic plants e.g. Perennial plants**.

EXCEPTIONS :

- ***Bamboo*** and ***Strobilanthus kunthiana*** are **perennial** plants but they are the examples of **monocarpic** plants.
- **Bamboo species flower only once in their life time, generally after 50-100 years, produce large number of fruits and die.**
- ***Strobilanthus kunthiana* (Neelakuranji) flowers once in 12 years. It flowered during Sep.-Oct. 2006 and 2018. Its mass flowering transformed large tracks of hilly areas in Kerala, Karnataka and Tamilnadu into blue stretches and attracted a large number of tourists.**

03. SEXUAL REPRODUCTION

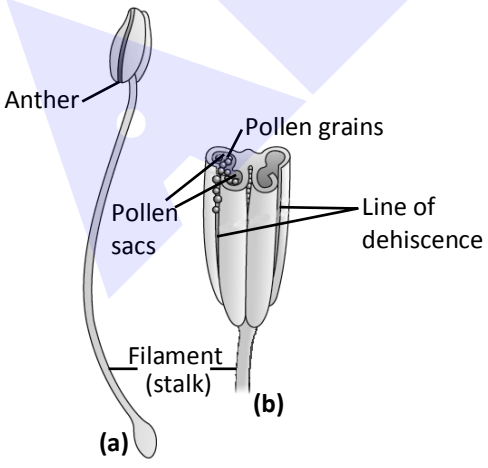
- Sexual reproduction involves the formation and fusion of gametes. It is a complex and slower process as compared to asexual reproduction.
- Events of sexual reproduction may be categorised into pre-fertilisation, fertilisation and post - fertilisation events.

(1) PRE-FERTILIZATION STRUCTURES AND EVENTS

- Pre-fertilization events include gametogenesis (means gamete formation) and gamete transfer.
- Much before the actual flower is seen on a plant, the decision that the plant is going to flower has taken place. Several hormonal and structural changes are initiated which lead to the differentiation and further development of the floral primordium. Inflorescences are formed which bear the floral buds and then the flowers. In the flower the male and female reproductive structures, the androecium and the gynoecium differentiate and develop.

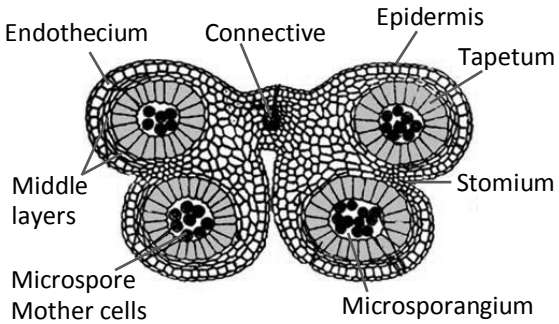
(A) MALE REPRODUCTIVE WHORL – ANDROECIUM :

- **Male reproductive organ is called androecium, consists of a whorl of stamens.**
- The number and length of stamens are variable in flowers of different species.
- **Stamen is equivalent to microsporophyll.**
- A typical stamen is differentiated into two parts -a long, thin stalk called the filament and the terminal generally bilobed structure called the anther.
- The proximal end of filament is attached to the thalamus or the petal.
- Anther and filament or two anther lobes are attached together with help of a region, called connective. **Connective contains vascular tissues**.
- A typical angiosperm anther is bilobed with each lobe having two theca i.e. they are dithecous. Often a longitudinal groove runs lengthwise separating the theca.



(a) A typical stamen;
(b) Three–dimensional cut section of an anther

NCERT XII Page No. 21, Figure No. 2.2



T.S. of anther, showing four microsporangia and anther walls

- The anther is consisting of four microsporangia located at the corners, two in each lobe.
- The microsporangia develop further and become pollen sacs, they extend longitudinally all through the length of an anther and are packed with pollen grains.
- **A typical anther** has four microsporangia i.e. **tetrasporangiate**.
- A typical anther is bilobed and tetrasporangiate.
- In ***Capsella***, which is member of the **cruciferae** or **brassicaceae**, **anthers are dithecous** and **tetrasporangiate** type.

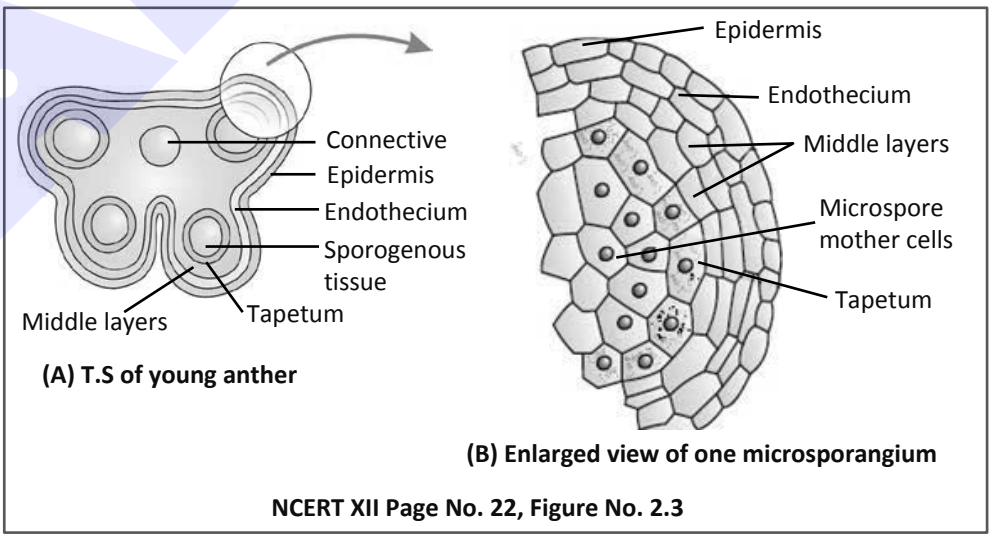
(i) STRUCTURE OF ANTHER :

- **In the transverse section of anther, it is seen almost tetragonal (4 sided)**

  Microsporangium is generally surrounded by four different wall layers.

  (a) Epidermis :- It is the outermost layer of anther. It is single celled thick layer. It forms the outermost **protective layer**.

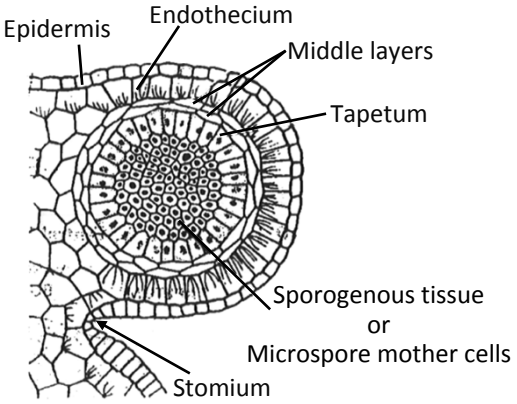
  (b) Endothecium (Fibrous layer) :- This layer is present below the epidermis. It is single celled thick layer. During the maturation of anther, various changes take place in different walls of cells of endothecium. The outer wall of these cells remain thin, but inner walls and radial walls become thick due to thickening of **α–cellulose fibers. Callose bands** are also present along the radial walls. At some places callose bands and fibrous thickenings are absent. These places are called **stomium**. The dehiscence of anther takes place only from these places. **Endothecium** becomes **hygroscopic in nature** due to presence of fibrous thickening. **Endothecium helps in dehiscence of anther.**



(A) T.S of young anther

(B) Enlarged view of one microsporangium

NCERT XII Page No. 22, Figure No. 2.3



T. S. of a young anther showing microsporangium

(c) **Middle layer** :- Middle layer consist of parenchymatous cells.This layer is one to three celled thick structure. Food is stored by **parenchymatous** cells of this layer.

- The outer three wall layers perform the function of protection and help in dehiscence of anther.

(d) **Tapetum** :- It is the innermost wall layer which acts as **nutritive layer**. This is single layered thick. The cells of tapetum possess dense cytoplasm and generally have more than one nucleus. The cells of the tapetum are initially diploid but they become **polyploid** and **multinucleate** due to **endomitosis and free nuclear divisions,** respectively.

- Tapetum absorbs food from the middle layers and **provides nutrition to the microspore mother cells or developing microspores**.

Functions of Tapetum :-

(1) **Tapetum provides nutrition to the sporogenous tissue / MMC or PMC and Developing pollen grains.**

(2) **Secretion of enzyme and hormone.**

(3) **Secretion of sporopollenin.**

(4) **Formation of pro-ubisch bodies.**
(Pro-Ubisch bodies + Sporopollenin → Ubisch bodies)

- **Ubisch body is mainly made up of a complex substance sporopollenin** which is a **polymer of carotenoids**.

(5) **Secretion of pollen-kitt substances.**

- **Pollen-kitt is made up of lipid and carotenoids.**

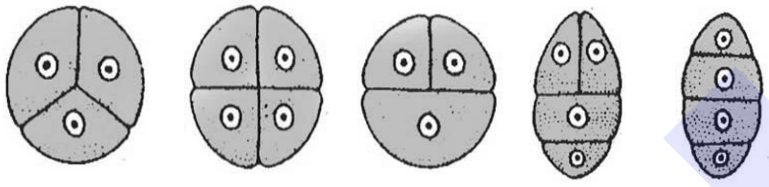
STRUCTURE OF MICROSPORANGIUM :

- In transverse section, a typical microsporangium appears near circular in outline.
- When the anther is young a group of compactly arranged homogenous cells called the sporogenous tissue occupies the centre of each microsporangium.
- **Pollen sacs :** Four pollen sacs are present in the anther. Inside the pollen sacs, **microspores (pollen grains)** are formed by the **meiotic division** of **microspore mother cells (pollen mother cells).**

- **As the each cell of sporogenous tissue is capable of giving rise to a microspore tetrad. Each one is a potential pollen mother cell or microspore mother cell (PMC)**

(ii) MICROSPOROGENESIS :

- **Microspore mother cell** or cell of sporogenous tissue divides to form four **haploid microspore** or pollen grain by **meiotic division** or **reduction division**. The process of formation of microspores from pollen mother cell by meiosis is called **microsporogenesis.**



POLLEN TETRADS OF ANGIOSPERMS

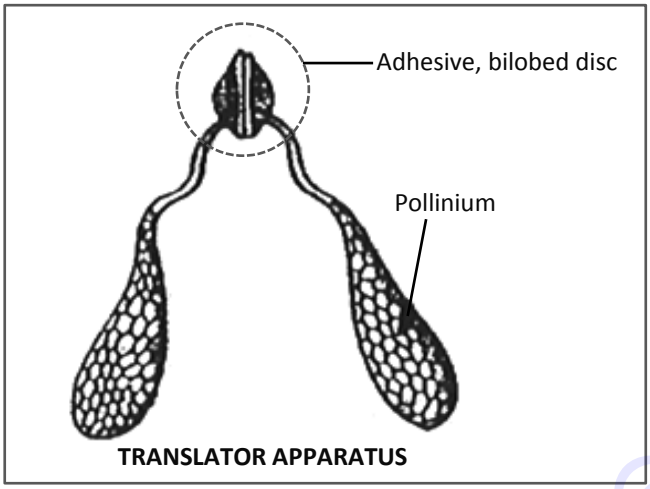
A Pollen grain tetrad

NCERT XII Page No. 23, Figure No. 2.5 (a)

- Microspore mother cell is surrounded by Callose layer.
- At the initial stage all **four microspores are attached together with the help of callose layer.** The microspore are arranged in a cluster of four cells - the microspore tetrad. After some time, this **callose layer is dissolved by callase enzyme**, which is secreted by tapetum.
- Many spherical bodies are formed inside the tapetal cells before their disintegration. These spherical bodies are known as Ubisch bodies.
- After the formation of ubisch body, the tapetum layer degenerates. Ubisch bodies participate in the formation of exine of the microspores inside the pollen sacs. Now thick walled microspores are called **pollen grains**.
- Inside each microsporangium thousands of microspores or pollen grains are formed that are released at the time of anther dehiscence.

Some facts about pollen grains –

(1) TRANSLATOR APPARATUS : In **Asclepiadaceae *(Calotropis)*** and **Orchidaceae** family, the pollen grains joined together to form bag like "Pollinium". Pollinium of ***Calotropis*** is constituent of **"Translator apparatus"**.



TRANSLATOR APPARATUS

(2) **AERO-ALLERGENS : Pollen grains** of many species which are present in the air **cause allergy** and bronchial afflictions – are called "aero allergens" e.g. ***Chenopodium, Parthenium (carrot grass), Sorghum*** and ***Amaranthus*****.** ["**Hay fever**" is caused by pollens of ***Ambrosia***.] In some people allergic pollens cause chronic respiratory disorders - asthama, bronchitis etc. ***Parthenium*** **that came into India as a contaminant with imported wheat has become ubiquitous in occurrence and cause pollen allergy.**

(3) **POLLEN TABLETS & SYRUPS :** Pollen grains are rich in nutrients. It has become a fashion in recent years to use pollen tablets as **food supplements.** In western countries, a large number of pollen products in the form of tablets and syrups are available in the market. Pollen consumption has been claimed to increase the performance of athletes and race horses.

Pollen Products

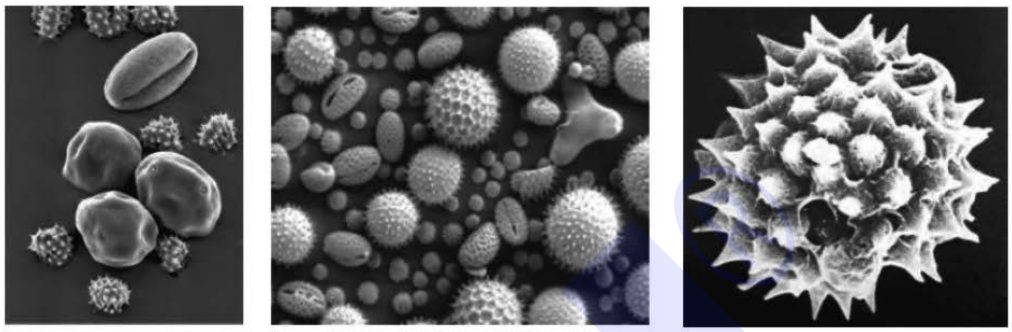
NCERT XII Page No. 24, Figure No. 2.6

(4) **LONGEST POLLEN :** ***Zostera*** **(sea grasses), Filiform pollen or filamentous pollen grain. Pollen grain long, ribbon like, without exine.**

(5) **VIABILITY OF POLLEN GRAINS :** In some cereals such as **rice and wheat, pollen grains lose viability within 30 minutes** of their release, and in some members of

rosaceae, leguminoseae and solanaceae, they maintain viability for months. The period for which pollen grains remain viable is highly variable and to some extent depends on the prevailing temperature and humidity.

(6) **POLLEN BANKS :** It is possible to store pollen grains of a large number of species for years in **liquid nitrogen (–196°C).** Such stored pollen can be used as **pollen banks,** similar to seed banks, in crop breeding programmes.



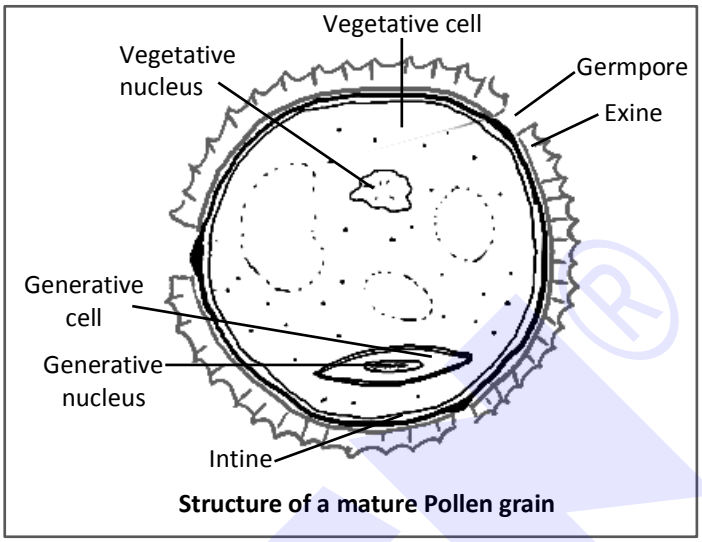
Scanning electron micrographs of a few pollen grains

NCERT XII Page No. 23, Figure No. 2.4

(iii) STRUCTURE OF POLLEN GRAIN :

- Pollen grains are **generally spherical,** measuring about **25-50 micrometers in diameter.**
- It has a prominent two layered wall. The **outer wall layer** is **thick, rigid** and **ornamented**, called **exine**. This layer is formed mainly by **sporopollenin**.
- **Sporopollenin is one of the most resistant organic material known. It is nonbiodegradable. It can withstand high temperatures, strong acids and alkali. No enzyme that degrades sporopollenin is so far known.**
- **Pollen grains are well preserved as fossils because of the presence of sporopollenin.**
- By the presence of fossils of pollen grains one can forecast the presence of **natural resources** like **petroleum**, **coals** etc. in the earth.
- The **inner wall of pollen grain** is **thin, continuous, soft** and **elastic** in nature. It is called **intine**. It is made up of **pectin** and **cellulose** or **pecto-cellulose.**
- The cytoplasm of pollen grain is surrounded by plasma membrane.
- At few places exine is usually absent or present in the form of thin layer. These places or prominent apertures are called **germ pores.** The intine comes out through the any one germ pore during the germination of pollen grain in the form of **pollen tube**.
- The exine exhibits a fascinating arrays of pattern and designs.
- The **number of germpore (aperture), structure** and **ornamentation** of exine is a significant feature of **taxonomy**.
- A detail study of pollen grains is called **palynology.**

- Three germpores are present in pollen grain of most of the dicots ***(Capsella)***. This type of pollen grains are called **tricolpate**. Only one germ pore is present in monocots and pollen grain is called **monocolpate.**
- The plants in which pollination takes place by **insects**, their pollen grains have **oily layer** around the pollen grain which is called **pollen-kitt.**



Structure of a mature Pollen grain

Functions of pollen kitt :-

(i) This oily layer protects the pollen grain from the harmful ultraviolet rays.

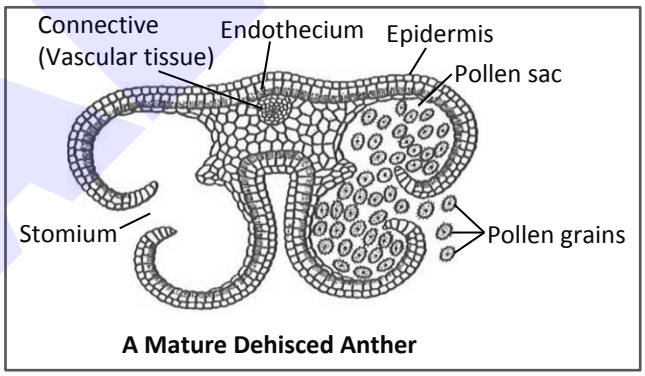
(ii) Its sticky surface helps to attach with the insects.

(iii) Its yellow colour attracts the insects. Pollen kitt is present on the pollens of *Capsella*.

(iv) DEHISCENCE OF ANTHER :

During the maturation of anther, various changes take place in the walls of anther.

- In the beginning, middle layer degenerates due to absorption of food by tapetum.



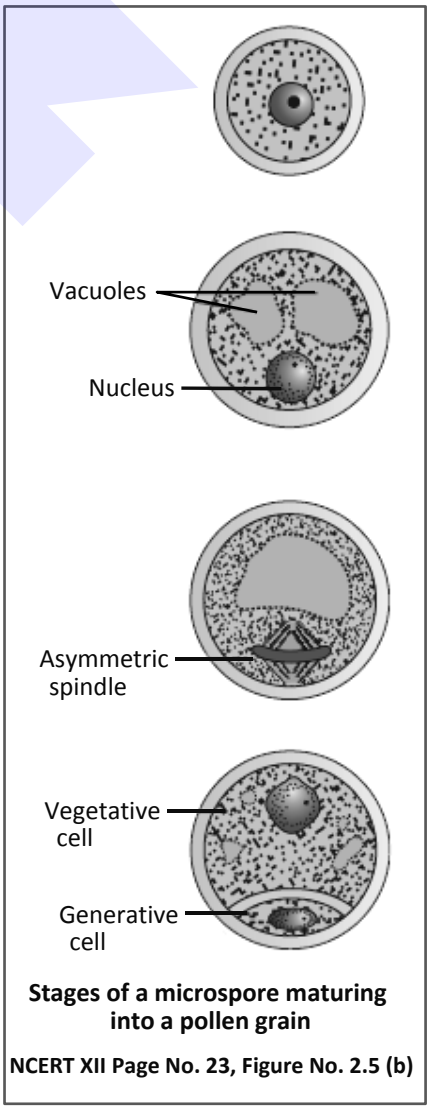
A Mature Dehisced Anther

- In a **mature anther** (at the time of dehiscence) only **two wall layers i.e. epidermis** and **endothecium** are present in the form of outer covering.
- The sterile tissues present between both the pollen sacs of each anther lobe degenerate. So both pollen sacs of the each anther lobe fuse together to form single pollen sac.

- Therefore, in the **mature anther** (at the time of dehiscence) only **two pollen sacs** are present.
- **Dehiscence** of anther takes place during the **dry season**. Loss of water takes place from the cells of endothecium in dry season.
- Walls of endothecial cells try to contract due to the loss of water but inner and radial walls do not contract due to presence of fibrous thickening whereas outer thin walls of endothecium cells contract and become concave or incurved.
- Incurving of outer walls exert pulling force or tension over the entire surface of anther. Due to pulling force or tension, thin walled stomial cells break off and dehiscence of anther takes place and pollen grains present in pollen sacs get released into the atmosphere.
- **Dehiscence** of anther in most of the **Angiosperms** is **longitudinal.** Dehiscence of anther of ***Capsella*** is **longitudinal.**

(v) MICRO-GAMETOGENESIS OR DEVELOPMENT OF MALE GAMETOPHYTE :

- In **flowering plants**, **microspore** or **pollen grain** is considered as **first cell** of **male gametophyte**. Partial development of pollen grain starts before dehiscence of anther (before pollination). Development of pollen also takes place at **mother place** [means inside pollensac of anther] it is called **in-situ development**.



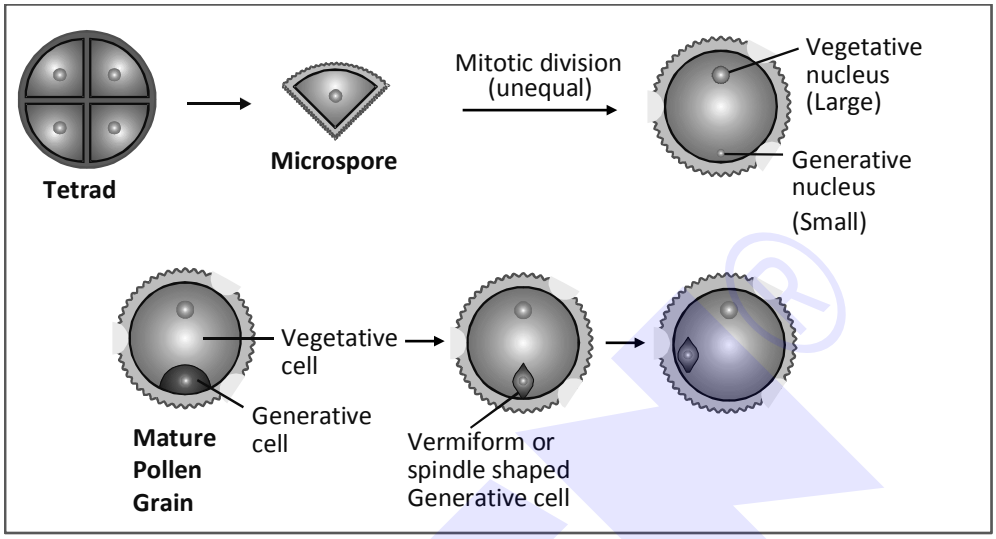
Stages of a microspore maturing into a pollen grain

NCERT XII Page No. 23, Figure No. 2.5 (b)

(a) Pre-pollination development :

- In the beginning of this process, nucleus of pollen grain divides by **unequal mitotic division**, resulting two unequal sized nuclei are formed. **Small nucleus** which is present near the wall is called **generative nucleus** and **large irregular shaped nucleus** which is present inside the cytoplasm is called **tube nucleus** or **vegetative nucleus**.
- Both the nuclei are surrounded by cytoplasm and it becomes dense, then followed by **unequal cytokinesis**, resulting **two cells of unequal size** are formed.
- **Larger cell** in which **large irregular shaped nucleus** is present is known as **vegetative cell** or **tube cell.** It has abundant food reserves and **smaller cell** in which **small nucleus** is present, called **generative cell**.

- When the pollen grain is mature it contains two cells (VC and GC) This stage of pollen grain is called **partially developed male gametophyte or mature pollen grain**.
- Now generative cell changed into **vermiform** or **spindle shaped** structure with dense cytoplasm and detached from the wall and enters inside the vegetative cell and floats in the cytoplasm of the vegetative cell.



- **In over 60% of angiosperms, pollen grains are shed at 2 celled stage. In the remaining species the generative cell divides mitotically to give rise to the two male gametes before pollen grains are shed (3 celled stage)**

(b) Post-pollination development :

- Further **development of pollen grain** takes place on the **stigma** of carpel after pollination.
- Pollens absorb moisture and sugar content from the stigma. Due to this volume of cytoplasm increased. It exerts pressure on the both outer layers. Because of this pressure intine comes out through any one germpore in the form of tube like structure which is called **pollen tube**.
- First of all **vegetative nucleus** enters into the pollen tube and assumes **terminal** [tip] position. The spindle shaped generative cell now enters into the pollen tube.
- Inside the pollen tube, **generative** cell divides **mitotically** to form two **non motile male gametes**. Now **male gametophyte** becomes **three celled structure** in which **one vegetative cell** and **two male gametes** are present.
- This **three celled stage represents the mature male gametophyte of Angiosperm.**
- **Male gametophyte of angiosperms is highly reduced and completely depends on sporophyte.**
- **Development of male gametophyte is *In-situ, Ex-situ* and *In-vivo*.**
- The pollen grain represents the male gametophyte/The pollen grain represents the male gametophytic generation.
- **For the formation of mature pollen grain from microspore mother cell or pollen mother cell, one meiotic and one mitotic divisions are required. For the formatation of mature male gametophyte, one meiotic and two mitotic divisions are required from microspore mother cell.**

BEGINNER'S BOX — MALE REPRODUCTIVE ORGAN

1. What would be the ploidy of the cells of tetrad?

(1) Haploid (2) Diploid (3) Polyploid (4) Triploid

2. To some extent viability of pollen grains depends on :-

(1) Temperature (2) Humidity (3) Both (1) and (2) (4) Light

3. The microsporangia develop further and become pollen sacs. In anther these pollen sacs extends

(1) Transversely

(2) Longitudinally

(3) Obliquely

(4) Sometimes transversely and sometimes longitudinally

4. Due to which of the following substance pollen grains are well preserved as fossils

(1) Pollen kitt (2) Callose (3) Sporopollenin (4) Pecto cellulose

5. Which of the following pollen structure exhibits a fascinating array of patterns and designs (Sculpturing pattern)?

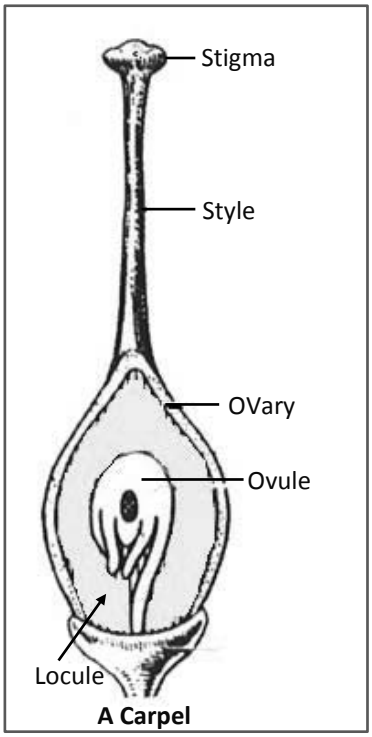
(1) Germ pores (2) Exine (3) Intine (4) Tapetum

(B) FEMALE REPRODUCTIVE WHORL-GYNOECIUM :

- **Gynoecium is the female reproductive organ (or part) of flower.**
- The **unit** of gynoecium is called **carpel**.
- Gynoecium may consist of a single pistil (monocarpellary) or more than one pistil (muticarpellary)
- **Carpel is equivalent to megasporophyll**.

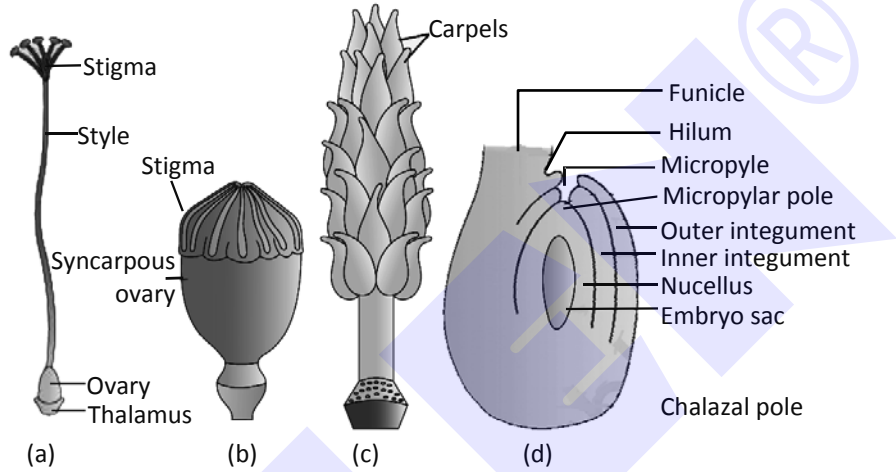
  The **carpel** or pistil is differentiated into **three** distinct regions-

  (i) Stigma (ii) Style (iii) Ovary
- The free end of the carpel which serves as landing platform for pollen grains is called **stigma**.
- A long (elongated), narrow tubular structure is present in between the stigma and ovary called **style**.
- The basal swollen [bulged] part of the carpel is called **ovary**. Ovarian cavity (locule) is present inside the ovary.



A Carpel

- The ovules are also known as integumented **megasporangia** which are borne on a cushion-like tissue called **placenta** in the ovarian cavity. The placenta is located inside the ovarian cavity.
- Arising from the placenta are the megasporangia, commonly called ovules.
- The number of ovules in an ovary may be **One (In Wheat, Paddy, Mango)** or **more than one** ovules **(In papaya, water melon, orchids).**
- **Apocarpous gynoecium (free carples) - Rose, lotus, *Michelia*.**
- **Syncarpous gynoecium (fused carpels) - *Papaver*, *Hibiscus***



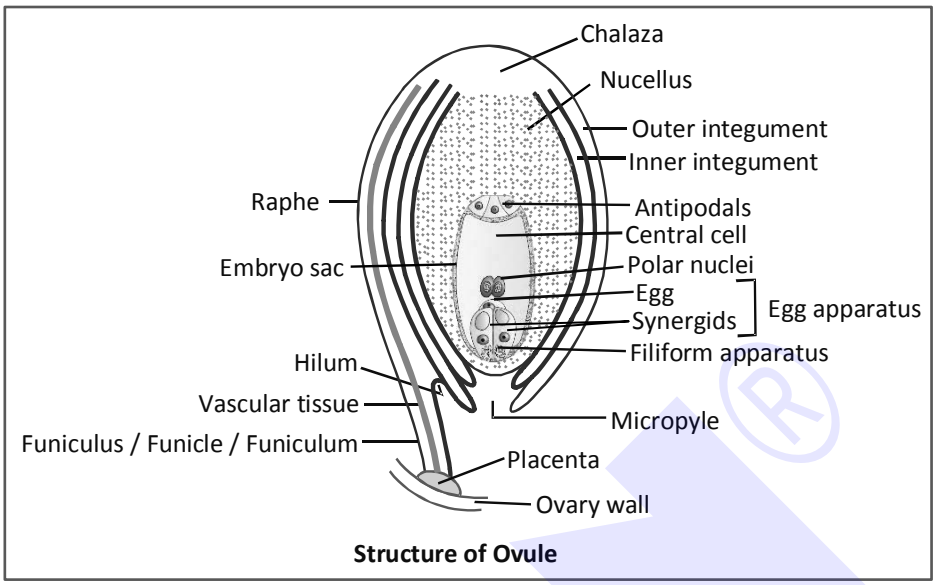
(a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed);
(b) Multicarpellary, syncarpous gynoecium (pistil) of *Papaver* ;
(c) A multicarpellary, apocarpous gynoecium of *Michelia* ;
(d) A diagrammatic view of a typical anatropous ovule

NCERT XII Page No. 25, Figure No. 2.7

(i) STRUCTURE OF OVULE OR MEGASPORANGIUM :

- **Ovule is also known as** integumented **megasporangium.**
- Each ovule is attached to the placenta by means of a thin stalk called **funicle** (or **funiculus/funiculum)**
- The body of the ovule fuses with funicle in the region called hilum. Thus, hilum represents the junction between ovule and funicle.
- The main region of the ovule is composed of mass of parenchymatous cells (with abundent reserve food materials) which is called **nucellus**. **Nucellus** is the **main part of ovule**. Located in the nucellus is the embryosac or female gametophyte.
- The nucellus is covered by **one** or **two** coats or protective envelops which are called **integuments**.

- Integuments encircle the ovule except at the tip where a small opening called the micropyle is organised.



Structure of Ovule

- In ovule of most of the plants, funicle is attached to the main body of ovule for some distance (at lateral side) to form a ridge like structure known as ***Raphe*****.**
- Vascular tissues are present inside the funiculus which supply food material from the placenta to the body of ovule.
- Opposite the micropylar end, is the **Chalaza,** representing the basal part of the ovule.
- Occasionally in some seeds such as black pepper, beet and castor remnants of nucellus are also persistent. This **residual, persistent nucellus** is the **perisperm**.

SPECIAL INTEGUMENTS –

(i) **ARIL** – It is the **type of third integument** which develops from funicle at the **base** of the ovule. e.g. **Litchi.**

(ii) **CARUNCLE** – It is formed due to the proliferation (out growth) of outer integuments over the micropyle. e.g. ***Ricinus communis*** **(castor)**. It is made up of sugary contents, it helps in absorption of water during germination of seeds and dispersal of seeds occurs by ants which is called **myrmecochory**.

TYPES OF OVULES ON THE BASIS OF INTEGUMENTS :

(i) **UNITEGMIC –** A single integumented ovule is called unitegmic ovule - example - members of Gamopetalae and most of the gymnosperms.

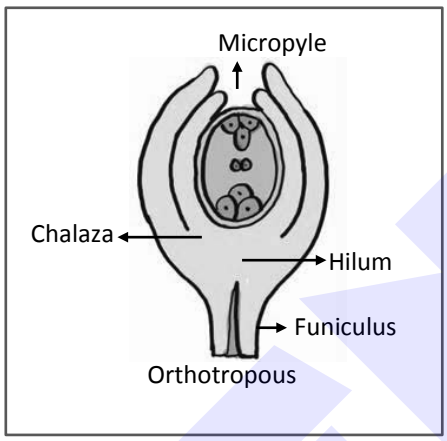
(ii) **BITEGMIC –** Two integumented ovule is called bitegmic ovule. Example - In most of Angiosperms [members of polypetalae-*Capsella* and monocots].

(ii) TYPES OF OVULES

There are different **types of ovules in Angiosperms** on the **basis of relationship** of the **micropyle, chalaza** and **hilum** with body of the ovule and **orientation on the funiculus**:

(a) Atropous or orthotropous ovule :

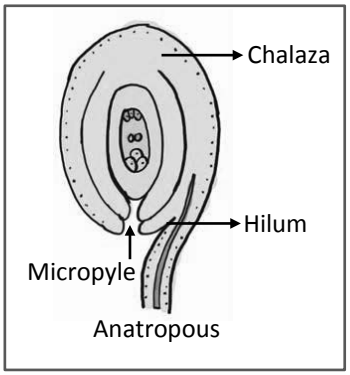
The body of ovule is upright in position. The **micropyle, chalaza** and **hilum** lie in one **straight** line, so **this type of ovule is called straight or upright ovule.**



Example :- ***Polygonum*** and in **gymnosperms**. It is the **most primitive and most simplest type of ovule.** In this type of ovule raphe is absent.

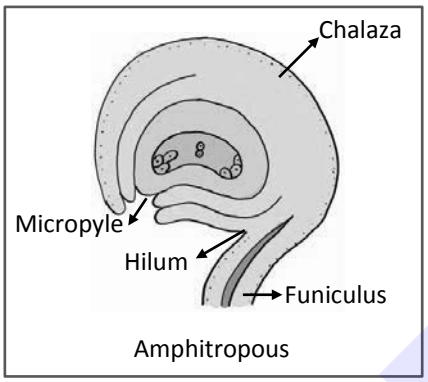
(b) Anatropous ovule :

In this type, the body of the ovule completely turned at **180^0 angle**, due to unilateral growth of funiculus, so **it is also called inverted ovule**. The hilum and micropyle lie side by side very close to each other. This type of ovule is found in **80% families** of **Angiosperms** but not in ***Capsella***. In this ovule micropyle is facing downward **condition**. This is the **most common type of ovule of angiosperms** it is considered as a **"typical ovule" of Angiosperms**. **It is also called resupinate ovule**. eg. Members of **malvaceae, cucurbitaceae, solanaceae, compositae** family.



(c) Amphitropous ovule :

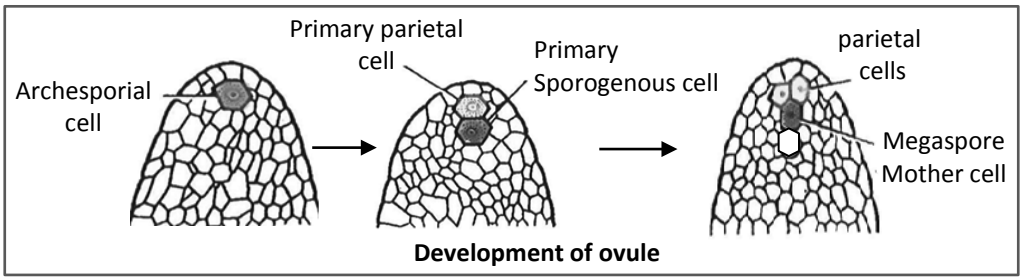
In this type of ovule, **curvature** is effective in the nucellus and due to this effect of nucellus, embryo sac becomes **horse shoe shaped.** Micropyle comes close to the hilum.



Eg. ***Lemna*, Poppy (*Papaver*).**

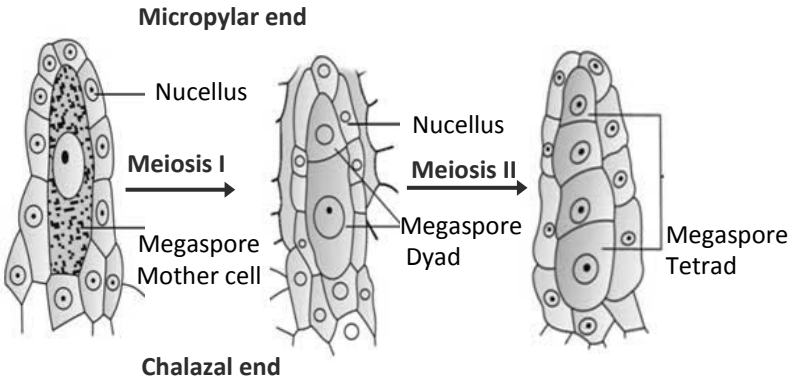
(iii) DEVELOPMENT OF OVULE :

- During the development of ovule, in the beginning of this process, **nucellus** develops from the **placenta** in the form of a small rounded out growth like structure. At this stage, all the cells of nucellus are undifferentiated, homogenous and meristematic and finally they become parenchymatous. This mass of cells is surrounded by single layer of epidermis.
- Any **one hypodermal** cell of nucellus differentiates and increases in size. It becomes different from rest of the cells due to presence of distinct nucleus. It is called **archesporial cell**.
- Archesporium (Archesporial cell) divides mitotically to form **a primary parietal cell** and **primary sporogenous cell**.
- The primary sporogenous cell directly acts as a **megaspore mother cell** (At micropylar region). i.e. a single MMC is differentiated in the micropylar region of nucellus during ovule development.
- MMC is large cell with dense cytoplasma and a prominent nucleus. MMC divides **meiotically** to form, four haploid **megaspores**.



Development of ovule

(a) MEGASPOROGENESIS :



Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores.

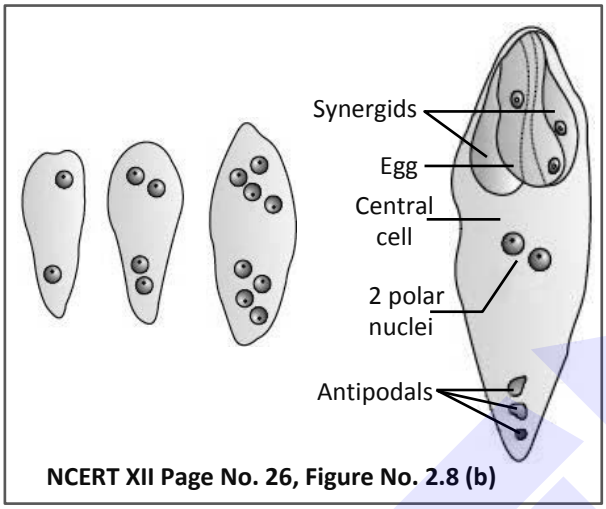
NCERT XII Page No. 26, Figure No. 2.8 (a)

- **The process of formation of megaspores from megaspore mother cell (MMC) is called megasporogenesis.**
- The four haploid megaspores are generally arranged in **linear tetrad.**
- In **most of angiosperms *[Capsella]*, chalazal megaspore remains functional.**
- In a majority of flowering plants the lower most or chalazal **megaspore** remains **functional** out of four megaspores and the **other three** which lie towards the micropyle degenerate.
- The functional megaspore produces female gametophyte (embryo sac).
- This method of embryo sac formation from a single megaspore is termed monosporic development.
- **Ploidy of the cells :** Nucellus (2n), MMC (2n), Functional megaspore (n), Female gametophyte (n).

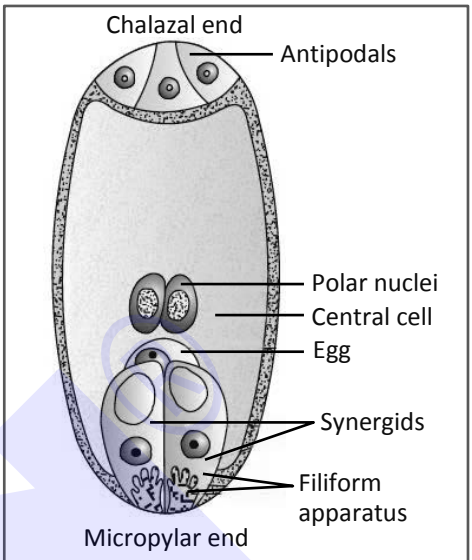
(b) DEVELOPMENT OF EMBRYOSAC (FEMALE GAMETOPHYTE) OR MEGAGAMETOGENESIS :-

- **Megaspore** is the **first** cell of the **female gametophyte**. This megaspore grows in size and obtains nutrition from the **nucellus**.
- The nucleus of the functional megaspore divides mitotically to form two nuclei. Each nucleus moves towards the opposite pole forming the 2-nucleate embryo sac.
- Two more sequential mitotic nuclear divisions result in the formation of the 4-nucleate and later the 8-nucleate stages of the embryo sac.
- **It is of interest to note that these mitotic divisions are strictly free nuclear, that is, nuclear divisions are not followed immediately by cell wall formation.**

- Out of the four, one nucleus from each pole migrates towards the centre [one nucleus from chalazal side and one nucleus from micropylar side]. They are known as **polar nuclei**. Both polar nuclei are present in the centre.



NCERT XII Page No. 26, Figure No. 2.8 (b)



A Mature Embryo-Sac
NCERT XII Page No. 26, Figure No. 2.8 (c)

- After the 8-nucleate stage, cell walls are laid down leading to the organisation of the typical female gametophyte or embryo sac.
- **Six of eight nuclei are surrounded by new cell walls and organised into cells.**
- **Three cells** are formed towards the **micropyle** end in which one cell is large and more distinct out of three cells. This is called **egg cell** and remaining **two smaller** cells are known as **synergids**. These three cells are collectively known as **egg-apparatus**. [1 Egg cell + 2 Synergids]
- The three cells are formed toward the chalazal end are called **antipodals or antipodal cells**.
- Both the polar nuclei are present in the large central cell. **Polar nuclei are present below the egg apparatus in central cell.** Just before the process of fertilization they unite or fuse together in the centre to form **secondary nucleus** or definitive nucleus. It is **diploid in nature [2n]** and one in number.
- **After 3 mitosis in megaspore, seven celled and eight nucleated structure is formed. This eight nucleated and seven celled structure is called female gametophyte or embryo-sac of angiosperms. This type of embryo-sac is known as "polygonum type" because it was discovered by Strasburger in *Polygonum* plant.**
- ***Polygonum* type of embryo-sac is most common type of embryo-sac of angiosperms *[Capsella]*. Most of the embryo-sacs (Including *Polygonum* type of embryo-sac) develop from single megaspore so it is also known as monosporic embryo-sac development.**

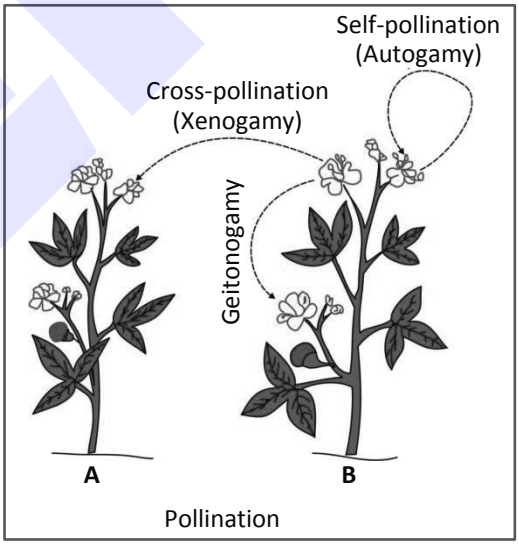
- **The synergids have fingers like structures (special cellular thickenings) at the micropylar tip called filiform apparatus**. With the help of these structures, synergids absorb food from the nucellus and transfer it to the embryosac. Filiform apparatus also secrete **chemicals** which attract and guide the pollen tube into the synergid.

Golden Key Points

- Multicarpellary, syncarpous gynoecium is found in *Papaver and Hibiscus.*
- Multicarpellary, apocarpous gynoecium is found in rose, lotus and *Michelia*.
- Megaspore mother cell is situated at micropylar region or micropylar end.
- Generally functional megaspore is situated towards chalazal end.
- Polar nuclei are situated below the egg apparatus in the large central cell.

(C) POLLINATION:

- "**Pollination** is defined as the process of transfer of pollen grains from anther to the stigma."
- In flowering plant both types of gametes (male gamete and female gamete) are non motile and brought together for fertilization by pollination.
- Flowering plants have evolved an amazing array of adaptation to achieve pollination. They make use of external agents to achieve pollination.



(I) Kinds of pollination

Pollination is of different types :- On the basis of source of pollen.

(i) AUTOGAMY OR SELF POLLINATION :

- If the pollen grains are transferred from an anther to the stigma of the **same flower** then it is called **self pollination** or **autogamy**.
- In a normal flower which opens and exposes the anthers and stigma, complete autogamy is rather rare. Autogamy in such flowers requires synchrony in pollen release and stigma receptivity and also the anther and the stigma should lie close to each other so that self pollination can occur.
- Continued self pollination results in inbreeding depression.

(ii) GEITONOGAMY :

- When, pollination takes place in between the **two flowers** of the **same plant** then it is called **geitonogamy**.
- From the **genetical point** of view geitonogamy is **similar to self pollination (Autogamy) because pollen grains come from the same plant** and all flowers of the same plant are genetically identical.
- But **functionally or ecologically**, it is considered as **cross pollination involving a pollinating agent.**

(iii) XENOGAMY OR CROSS POLLINATION OR ALLOGAMY :

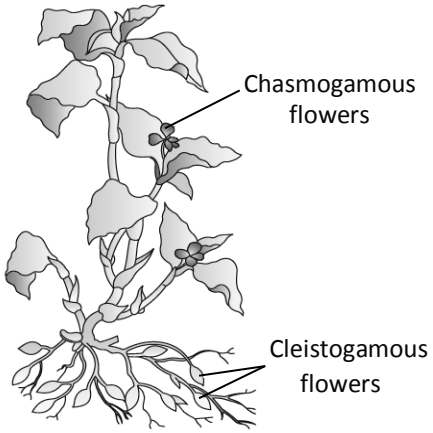
- Transfer of pollen grains from anther to stigma of different plant.
  When the pollination takes place in between the two different flowers of **two different plants** of the same species then it is called **xenogamy**.
- This is **real or true cross pollination. Genetically,** as well as **ecologically**, it is **cross pollination**.
- This is the only type of pollination in which genetically different types of pollen reaches to the stigma.

MONOECIOUS PLANTS : If both male and female flowers are present on same plant but flowers are unisexual Eg. **castor, cucurbits, coconut** and **maize**. **It prevents autogamy but not geitonogamy.**
DIOECIOUS PLANTS : If male and female flowers are present on different plants and flowers are unisexual. Eg. **Papaya, date palm. It prevents both autogamy and geitonogamy.**

Contrivances or Adaptations for Self Pollination :

(a) Bisexuality – Majority of flowering plants produce hermaphrodite (bisexual) flowers. eg. **pea**

Self pollinated flowers
NCERT XII Page No. 28, Figure No. 2.9 (a)



Commelina plant
NCERT XII Page No. 28, Figure No. 2.9 (c)

(b) **Homogamy** :- When both the sex organs of a flower mature at the same time (synchrony in pollen release and stigma receptivity). It is called **homogamy**. It increases chances for self pollination. E.g. ***Pea***

(c) **Cleistogamy :**

- In some plants bisexual flowers are formed which never open throughout the life. Such flowers are called **cleistogamous flowers**, such as ***Commelina, Viola*** **(Common pansy)**, ***Oxalis.***
- All the above plants have two types of flowers. One type of flowers are **cleistogamous** and another are **chasmogamous flowers** which are similar to flowers of other species with exposed anthers and stigma.
- **Cleistogamous flowers produce assured seed set even in the absence of pollinators.**
- **In cleistogamous flowers the anthers and stigma lie close to each other. When anthers dehisce in the flower buds, pollen grains come in contact with the stigma to effect pollination thus cleistogamous flowers are invariably autogamous as there is no chance of cross pollen landing on the stigma.**
- Cleistogamy is advantageous as well as disadvantageous.

(d) **Bud pollination:-** This pollination occurs in bud stage before the opening of flowers. e.g. **wheat, rice.**

Contrivances or Adaptations for Cross Pollination (Outbreeding devices)

(a) **Unisexuality :-** In some plants, flowers are unisexual to prevent self-polination. Examples – **Date palm, *papaya (Carica)***.

(b) **Dichogamy** :- **In many plants pollen release and stigma receptivity are not synchronised. Either the pollen is released before the stigma becomes receptive or stigma becomes receptive much before the release of pollen.**

Dichogamy is of two types –

- **Protandry** :- In protoggny, pollens are released before the stigma becomes receptive. **Many plants of Angiosperms** are cross pollinated only because of **protandrous condition**.

  Protandrous condition is found in most of the angiosperms.
- **Protogyny** :- In protogamy stigma becomes receptive much before the release of pollen.

(c) **Chasmogamy or Anthesis** :- Opening [blooming] of the floral bud in the form of a flower is called **anthesis**. Chasmogamous flowers have exposed anthers and stigma.

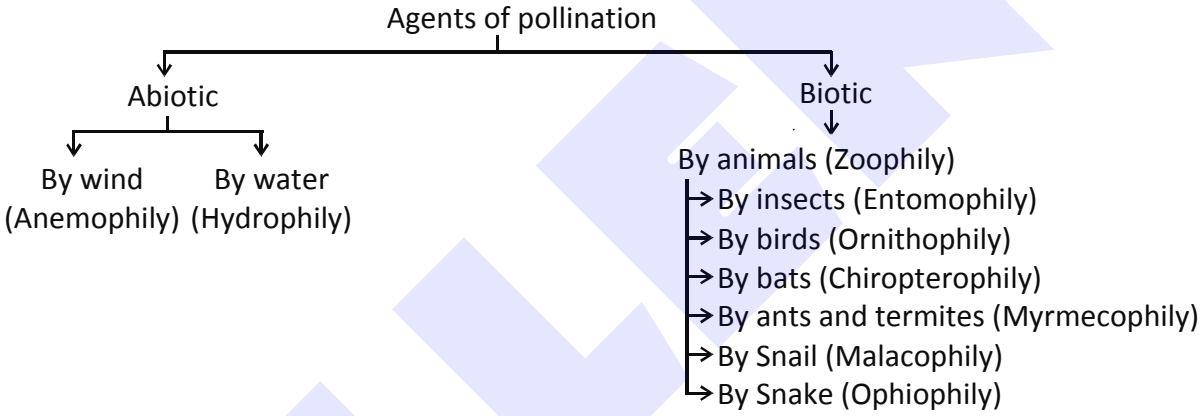
(d) **Heterostyly** :- **In some plants anther and stigma are placed in different positions so that the pollen can not come in contact with the stigma of same flower.** Due to this reason, self pollination is not possible in these plants e.g. *Primula*.

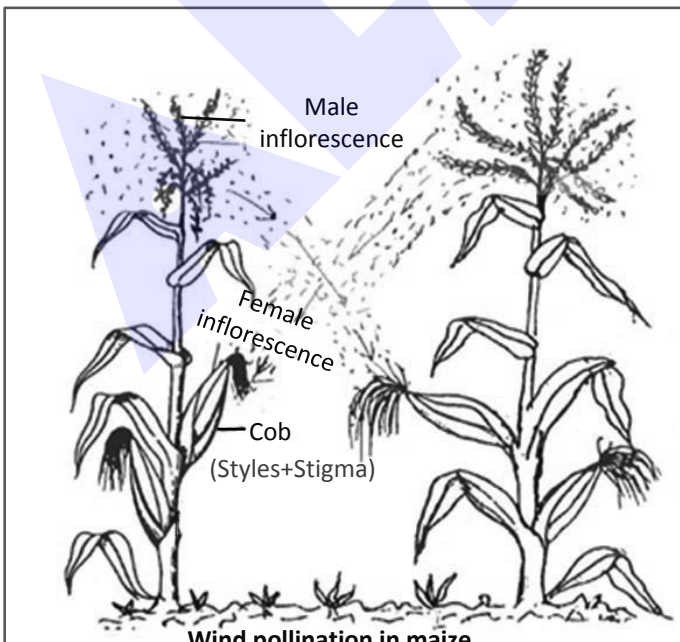
(e) **Self sterility or Self incompatibility** :- This is a genetic mechanism and **prevents self pollen (from the same flower or other flower of the same plant) from fertilising the ovules by inhibiting pollen germination or pollen tube growth in the pistil.** e.g. tobacco.

AGENTS OF POLLINATION

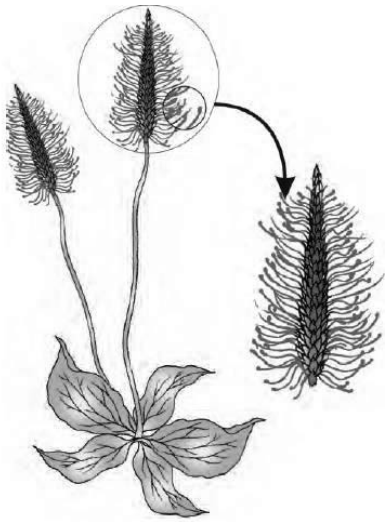
Plants use two abiotic (wind and water) and one biotic (animals) agents to achieve pollination.

Majority of plants use biotic agents for pollination.





Wind pollination in maize



A wind pollinated plant showing compact inflorescence and well exposed stamens

NCERT XII Page No. 29, Figure No. 2.10

ABIOTIC AGENTS :

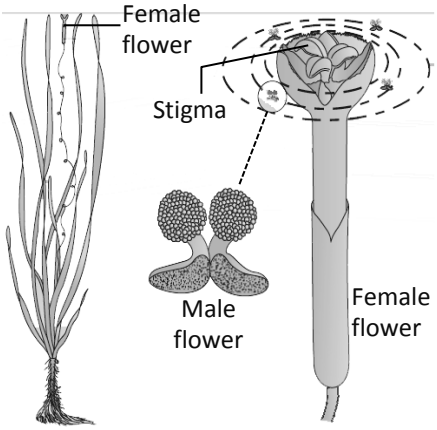
- Only a small proportion of plants use abiotic agents.
- Pollen grains coming in contact with stigma is a chance factor in both wind and water pollination. To compensate for this uncertainties and associated loss of pollen grains, the flowers produce enormous amount of pollen grains when compared to the number of ovules available for pollination.
- Both wind and water pollinated flowers are not very colourful and do not produce nectar.

(A) ANEMOPHILY :

- When the pollen grains are transferred from one flower to the another flower through the wind then it is called **anemophily** and flower is known as **anemophilous flower**.
- The anemophilous plants produce **enormous amount of pollen grains**.
- The pollen grains are very **small, light weight** and **dry** (non-sticky).
- Stigma is large often **hairy or feathery to easily trap air borne pollen grains** and **mucilagenous (Sticky)**.
- **They often possess well exposed stamens** so that the pollens are easily dispersed into wind currents.
- **Sulphur shower** is related to pollen grains of Pinus at the time of pollination.
- Winged pollen grains are found in *Pinus.*
- Anemophilous flowers are **neither attractive** nor with **fragrance.** They do not have nectar glands. Anemophilous flowers are generally unisexual.
- Maximum loss of pollen grains takes place in this type of pollination. It is completely **non directional process**.
- **Wind pollinated flowers often have a single ovule in each ovary and numerous flowers are packed into an inflorescence eg. corn cob. The tassels is styles and stigmas which wave in the wind to trap pollen grains.**
- **Pollination by wind is more common amongst abiotic pollinations.**
- **Wind pollination is quite common in grasses.**

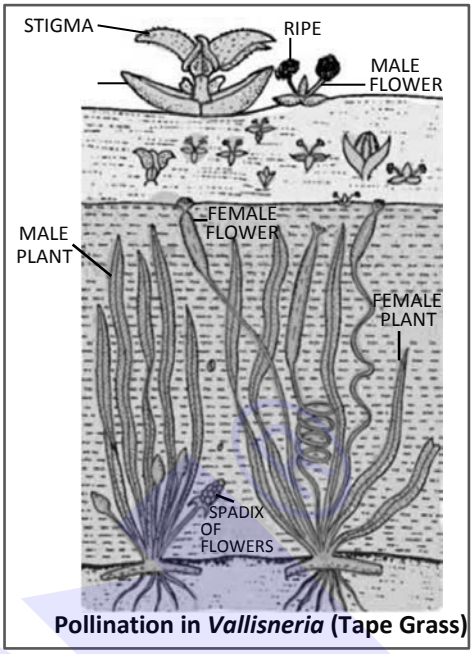
  E.g. - **gymnosperms, maize (corn), sugarcane, *bamboo*, coconut, *Cannabis*, grasses, date palm, papaya.**

(B) HYDROPHILY :



Pollination by water in *Vallisneria*

NCERT XII Page No. 30, Figure No. 2.11 (a)



Pollination in *Vallisneria* (Tape Grass)

- When the pollination brings about by water then it is known as hydrophily.
- **Not all aquatic plants use water for pollination.**
- **Pollination by water is quite rare in flowering plants and is limited to about 30 genera, mostly monocotyledons.**
- Hydrophily is of **two types**.

(i) Epihydrophily :

- When the pollination takes place on the surface of water then it is called **epihydrophily** e.g. *Vallisneria*.
- ***Vallisneria*** is a dioecious plant and flowers are unisexual.
- **Pedicel** (Stalk) of female flowers are long and coiled. But at maturity due to uncoiling they also reach the water surface.
- The male flowers or pollen grains are released on to the surface of water due to bursting in inflorescence of male plant.
- They are carried passively by water currents and some of them are eventually reach the female flower and the stigma.
- All activities of ***Vallisneria*** take place inside the water except pollination.

(ii) Hypohydrophily :

- When the pollination takes place inside the water then it is called **hypohydrophily**. e.g. ***Zostera*** (Sea grasses), ***Hydrilla.***

- **In seagrass *Zostera* female flowers remain submerged in water and the long ribbon like pollen grain are released inside the water and they are carried passively inside the water, some of them reach the stigma and achieve pollination.**

- ***Vallisneria* and *Hydrilla* are fresh water plants, while *Zostera* is a marine water plant.**
- **In most of the water pollinated species, pollen grains are protected from wetting by a mucilaginous covering.**

(C) ZOOPHILY :

- When the **pollination** brings about by **animals** then it is called **zoophily**.
- Majority of flowering plants use a range of animals as pollinating agents. Bees, butterflies, bettles, wasps, ants, moths, birds and bats are common pollinating agents.
- **Among the animals, insects, particularly bees are the dominant biotic pollinating agents.**
- **Larger animals such as some primates (Lemurs), arboreal (tree-dwelling) rodents, or even reptiles (Gecko lizard and garden lizard) have also been reported as pollinators in some species.**
- Generally in zoophillous plants, flowers are **large, attractive** and **nectar glands** are present. Often flowers of animal pollinated plants are specifically adapted for a particular species of animals.

(i) ENTOMOPHILY :

- The pollination which takes place with the help of **insects** is known as **entomophily**. Most of insect pollination **(80%)** occurs only by **honey bees**.
- Favourable colour of **honey bees** is **yellow**, but they are blind to red colour.
- Majority of insect pollinated flowers are large, colourful, fragrant and rich in nectar, when the flowers are small, a number of flowers are clustered into an inflorescence to make them conspicuous.
- **Night flowering plants** are pollinated by **moths**. **They are highly scented. Their flowers are generally white coloured**
- **The flowers pollinated by flies and beetles secrete foul odour to attract these animals.**

- The **pollen grains** of insect pollinated flowers are **sticky** due to presence of **pollen kitt**.
- Most of entomophilous plants are ornamental plants. **Ornamental plants** utilize their maximum energy in this pollination and develop different types of **adaptation** for attraction of insects. Their flowers are attractive. Animals are attracted to flowers by colour and/or **fragrance** .
- e.g. **Lemon, coriander, onion, lobia, apple, pear, sunflower (asteraceae family) and *Salvia* (labiatae family), cucumber, cotton, tobacco and *Brassica, Eucalyptus*.**

Cross pollinated flowers

NCERT XII Page No. 28, Figure No. 2.9 (b)

Note :-

(1) Some of the flowers have attractive **bract** i.e. bright and colourful like petals, are called **petaloid bract**. e.g. **Bougainvillea**.

(2) In ***Yucca*** plant pollination occurs by ***Pronuba yuccasela*** moth (***Tegeticula*** moth)

(3) In **tallest flower of *Amorphophallus* (the flower itself is about 6 feet in height),** process of pollination is same as ***Yucca*** as also provides space (safe place) for laying eggs.

Yucca

(4) **In species of *Ficus (Fig)*** pollination occurs by ***Blastophaga* wasp** (insect)**.**

- **Floral rewards : To sustain animals visits, the flowers have to provide rewards to the animals. Nectar and pollen grains are usual floral rewards. In some species floral rewards are in providing safe places to lay eggs. eg. *Yucca, Amorphophallus***
- **Pollen / Nectar robbers : Many insects may consume pollen or the nectar without bringing about pollination, such floral visitors are referred to as pollen / nectar robbers.**

(5) In ***Rafflesia*** (foul odour like rotten meat), the **pollination** is brought about by **carrion flies (Entomophily)**.

(6) ***Nymphaea* (water lily), water hyacinth, *Nelumbo* or *Nelumbium (lotus)*** are also **entomophilous** plants while they are **hydrophytes.**

Note :- In water lily and water hyacinth pollination take place by **insects** or wind.

(ii) ORNITHOPHILY :-

When the process of **pollination** takes place by **birds** (sun bird and humming bird) then it is called **ornithophily**.

e.g. ***Bignonia*** plant, ***Callistemon*** **(bottle brush),** ***Bombax*** [silk cotton tree], ***Butea monosperma*****.**

Humming bird

(iii) CHIROPTEROPHILY :-

If the **pollination** brings about by **bats** **(*Pteropus*)** then it is called **chiropterophily.** The chiropterophilous flowers are big in size, usually dull coloured, night blooming with plenty of nectar.

e.g. ***Anthocephalus kadamba, Kigelia, Adansonia.***

SOME EXTRA POINTS

(1) **Mango** is pollinated by wind or insect **(mainly by insect).**

(2) **Rose is pollinated by insect** (Red or orange species are pollinated by birds)

(3) **Banana** is pollinated by bats or birds **(mainly by bats)**

(4) In **some plants** pollination occurs by **snake** which is called **"ophiophily".**
eg. *Santalum* (sandal)

BEGINNER'S BOX — FEMALE REPRODUCTIVE ORGAN AND POLLINATION

1. Which flowers are small and unattractive :

(1) Zoophilous (2) Anemophilous (3) Entomophilous (4) Ornithophilous

2. Which of the following is monoecious plant?

(1) Papaya (2) Date palm (3) *Vallisneria* (4) *Cucurbita*

3. Choose the number of diploid structures in the list given below with respect to angiosperms :-

Pollen grains, nucellus, perisperm, endosperm, embryo-sac, megaspore

(1) Two (2) Three (3) Four (4) One

4. Select the odd one with respect to cells of embryo-sac :-

(1) Pollen grains (2) Antipodal cells (3) Synergids (4) Egg cell

5. A multicarpellary, apocarpous gynoecium is found in :-

(1) *Hibiscus* (2) *Michelia* (3) *Papaver* (4) All

(2) FERTILIZATION

The fusion of male gamete with female gamete is called fertilization. This process is completed in the following steps :-

(A) GERMINATION OF POLLEN GRAINS :

- After pollination, **pollen grains** germinate on the **stigma**. They absorb moisture and sugar contents from stigma and swell up. The intine of pollen grain grows out through the any one germ pore of exine, in the form of tube like out growth which is called **pollen tube.**
- Pollen tube develops from vegetative cell (tube cell).
- **One pollen tube develops in *Capsella* and most of Angiosperms it is called monosiphonous condition, but more than one pollen tubes develop in Malvaceae and Cucurbitaceae family. It is called polysiphonous condition.**
- **Pollen tube produces enzymes which digest the tissue of the stigma and solid style.**
- When the pollen tube comes down from the stigma into the style, first of all vegetative nucleus enters, into the pollen tube then it is followed by generative cell. The tube nucleus occupies the terminal position in pollen tube. The vegetative nucleus (tube nucleus) controls the growth of the pollen tube. Mean while, the generative cell divides mitotically to form **two male gametes.**
- **Both of the male gametes** are **non motile.**
- **Boron and calcium elements (mainly Boron) are essential for the growth of pollen tube.**
- **Best temperature for growth of pollen tube is 20–30^{0}C.**
- **Pollen tube shows apical growth.**
- **Pollen tube shows chemotropic movement towards synergid due to Ca-B-inositol sugar complex.**
- **Longest pollen tube is found in *Zea mays* (Maize).**
- **The solid style, has a core of transmitting (transmission) tissue while in hollow style the stylar canal is lined by glandular cells.**

POLLEN - PISTIL INTERACTION :

- **Pollination does not guarantee the transfer of right type of pollen (compatible pollen of the same species as the stigma). Often, pollen of the wrong type, either from other species or from the same plant (if it is self - incompatible) also land on the stigma.**
- **The pistil has the ability to recognise the pollen whether it is of the right type (compatible) or of the wrong type (incompatible). If it is of right type the pistil accepts the pollen and promotes post pollination events (Fertilization). If the pollen is of wrong type, the pistil rejects the pollen by preventing pollen germination on the stigma or the pollen tube growth in the style.**
- **The ability of the pistil to recognise the pollen is the result of a continuous dialogue between pollen grain and the pistil. This dialogue is mediated by chemical components of pollen interacting with those of the pistil.**
- **All the events from pollen deposition on the stigma until pollen tube enters the ovule are together referred to as pollen pistil interaction. It is mediated by chemical components of pollen and pistil. Pollen pistil interaction is a dynamic process involving pollen recognition followed by promotion or inhibition of the pollen.**
- **It is only in recent years that botanist have been able to identify some of the pollen and pistil components and interactions leading to the recognition, followed by acceptance or rejection. The knowledge gained in this area would help the plant breeder in manipulating pollen - pistil interaction, even in incompatible pollinations to get desired hybrids.**

(B) ENTRY OF POLLEN TUBE INTO THE OVULE :

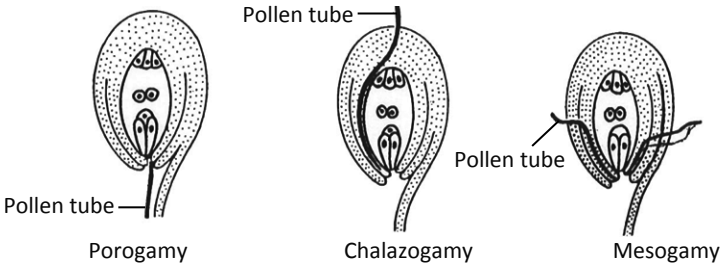
Finally, the pollen tube enters in the ovary at that time, ovule becomes mature. Pollen tube generally enters in ovule through the micropyle.

A mature ovule in which embryo sac has also matured, has three paths for the entry of pollen tube:-

(i) Porogamy :- In this, pollen tube enters into the ovule directly through the micropyle. It is found in most of angiosperms *[e.g. Capsella].*

(ii) Chalazogamy :- In this method, the pollen tube enters into the ovule through the chalaza. e.g. *Casuarina*.

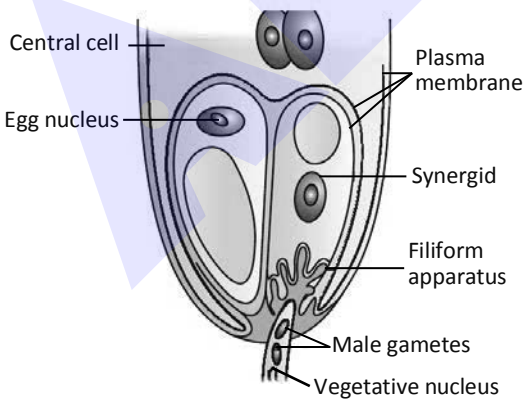
(iii) Mesogamy :- In this method, pollen tube enters into the ovule either through the funiculus or integuments *eg. Cucurbita.*



Various methods of entry of pollen tube into the ovule

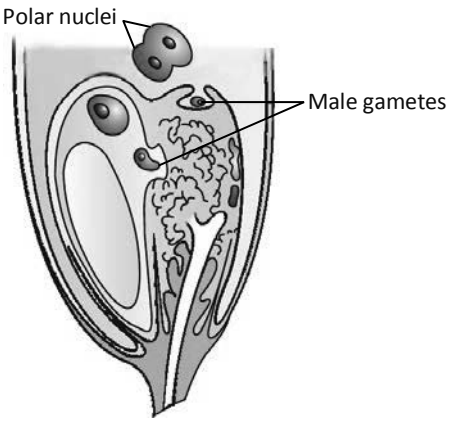
(C) ENTRY OF POLLEN TUBE INTO THE EMBRYO-SAC :

- Pollen tube can enter into the ovule through the any passage but inside embryosac, it enters only through the **egg apparatus** cell (i.e. synergid). After the entrance inside the ovule, it grows towards the egg apparatus because synergid cells secrete the chemicals with the help of filiform apparatus which attract the pollen tube and guide the pollen tube.
- Any one synergid starts degenerating when the pollen tube comes near the egg apparatus. The pollen tube enters into the embryosac through the degenerating synergid.
- When tip of the pollen tube enters into the embryosac, vegetative nucleus (tube nucleus) degenerates.
- The tip of the pollen tube swells and burst **[Due to endosmosis]** after reaching inside the embryosac.
- The pollen tube releases all contents including both male gametes inside the cytoplasm of degenerating synergid of embryosac.



Enlarged view of an egg apparatus showing entry of pollen tube into a synergid

NCERT XII Page No. 32. Figure No. 2.12 (d)

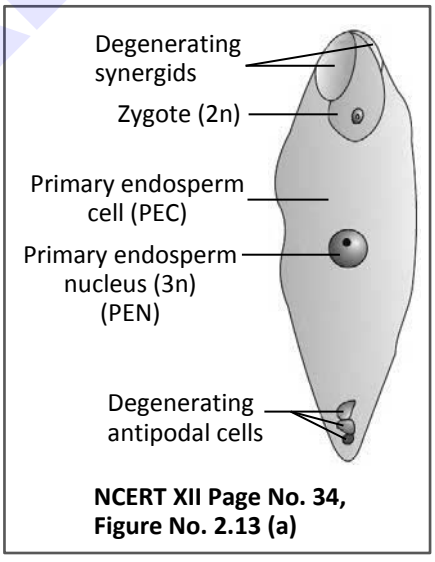


Discharge of male gametes into a synergid and the movements of the sperms (male gametes), one into the egg and the other into the central cell

NCERT XII Page No. 32. Figure No. 2.12 (e)

(D) FUSION OF GAMETES :

- During fertilization both polar nuclei of the central cell fuse together to form a **diploid nucleus,** which is known as **secondary nucleus** or **definitive nucleus**.
- Out of two, **one male gamete** moves towards the egg cell and fertilize the **egg cell** to form a **diploid zygote**. This fusion is known as **syngamy.** This is **true fertilization** process. **Syngamy leads to formation of a specialised cell called zygote (2n).**
- **Syngamy was discovered by Strasburger in *Monotropa* plant.**
- The **second male gamete** move towards secondary nucleus & get fused with **diploid secondary nucleus.** This fusion is known as **triple fusion** or vegetative fertilization resulting formation of a triploid (3n) structure. It is called **primary endosperm nucleus (PEN).**
- **Since two types of fusions, syngamy and triple fusion take place in an emrbyo sac, the phenomenon is termed double fertilization**.
- **Double fertilization was discovered by "Nawaschin" in *Lilium* and *Fritillaria* plants.**
- **Double fertilization and triple fusion is the specific or universal characteristic of angiosperm. Double fertilization is an event unique to flowering plants.**
- **Five haploid nuclei participate in double fertilization.**
- **Three gametes participate in double fertilization**
- **A zygote is formed by true fertilization (syngamy) which develops into an embryo.**
- **Triploid primary endosperm nucleus (PEN) is formed in PEC by triple fusion.**
- **The central cell after triple fusion becomes the primary endosperm cell (PEC) and develops into the endosperm which is used as nutrition for growing embryo.**
- **Antipodal cells and remaining synergid** degenerate after the fertilization. At this time, zygote obtains food from degenerating synergid and antipodal cells.
- The **fertilization** in which **non motile gametes** are carried to female gamete through **pollen tube** is known as "**Siphonogamy**".



NCERT XII Page No. 34, Figure No. 2.13 (a)

(3) POST-FERTILIZATION : STRUCTURES AND EVENTS

Following double fertilization, events of endosperm and embryo development, maturation of ovule(s) into seed(s) and ovary into fruit are collectively termed post-fertilization events.

(A) DEVELOPMENT OF ENDOSPERM :

- **Endosperm development precedes embryo development.**
- **The PEC divides repeatedly and forms a triploid endosperm tissue.**
- **The cells of this tissue are filled with reserve food materials and are used for nutrition of the developing embryo.**
- The endosperm is of **following types** on the basis of **development** :-

(i) NUCLEAR ENDOSPERM OR FREE NUCLEAR ENDOSPERM :

- This type of development of endosperm is found in most of the dicots (In members of polypetalae) & in most of the monocots.
- Such type of endosperm develops by **free nuclear divisions** in PEC.
- The PEN undergoes successive nuclear divisions to give rise to free nuclei. Thus a **multinucleated endosperm** is formed. Later on cytokinesis (cell wall formation) takes place, so that endosperm becomes cellular at maturity.
- The number of free nuclei formed before cellularisation varies greatly.
- **The coconut water of tender coconut is free nuclear endosperm** (made up of thousands of nuclei).
- **This type of endosperm is the most common in angiosperms.**

(ii) CELLULAR ENDOSPERM :

- This type of endosperm is found in members of gamopetalae.
- During the development, each division of primary endosperm nucleus is followed by cytokinesis. So the endosperm remains cellular from the beginning.

SPECIAL POINTS :

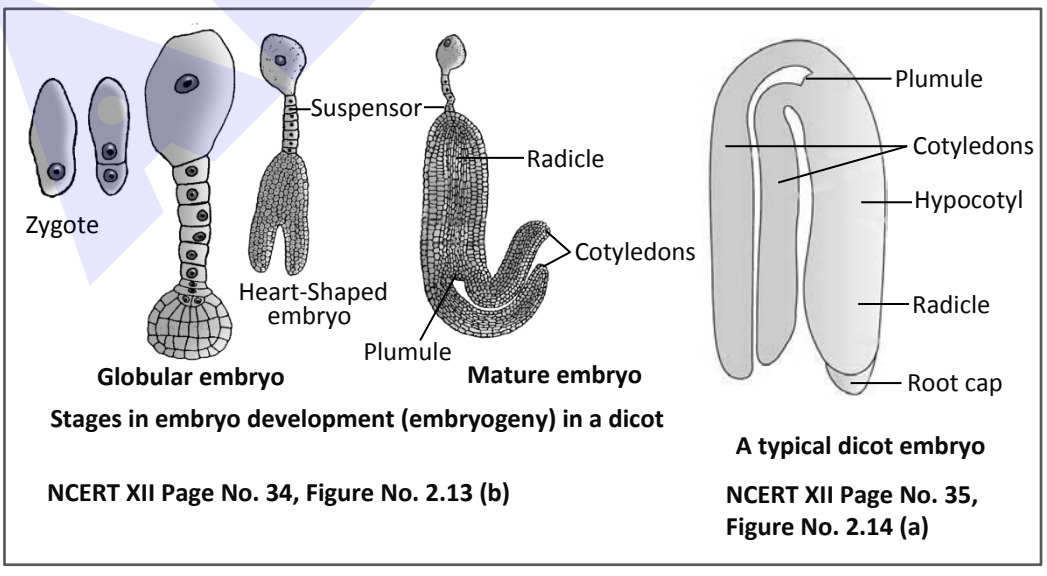
(a) The **drinking** portion (coconut water) is **nuclear** endosperm and **edible** portion (white kernel) is the **cellular endosperm** in **coconut**.

(b) Starchy endosperm is found in rice, wheat, maize etc.

(B) DEVELOPMENT OF EMBRYO IN DICOT :

- **The process of development of embryo from the zygote is called embryogenesis or embryogeny.**
- **Embryo develops at the micropylar end of the embryo sac where the zygote is situated.**

- **Most zygote divides only after certain amount of endosperm is formed. This is an adaptation to provide assured nutrition to the developing embryo.**
- The **first division** of Oospore is **transverse**, results two cells are formed. One cell lies towards **micropyle** is called **basal cell** or **suspensor cell**. The other cell lies towards chalaza is called **apical cell** or **terminal cell** or **embryonal cell**.
- The basal cell (suspensor cell) and embryonal cell divide simultaneously.
- **The embryonal cell divides by mitotic divisions to gives rise to the proembryo and subsequently to the globular, heart shaped and mature embryo.**
- The **suspensor** cell divides by transverse divisions forming a **6-10 celled** long filament like structure which is termed **suspensor**.
- **The main function of suspensor is to push the developing embryo into food laden endosperm** to provide nutrition.
- The **micropylar cell** of the **suspensor** swells up. This cell of suspensor is known as **haustorial-cell**.
- **A typical dicot embryo consists of an embryonal axis and two cotyledons.**
- Axis present between plumule and radicle is called **embryonal axis**. It is also called **Tigellum [main embryonal axis].**
- **The portion of embryonal axis above the level of cotylodons is known as epicotyl which terminates with the plumule or stem tip.**
- **The portion of embryonal axis below the level of cotyledons is known as hypocotyl. Hypocotyl terminates in the radicle or root tip. Root tip or radicle is covered by root cap.**



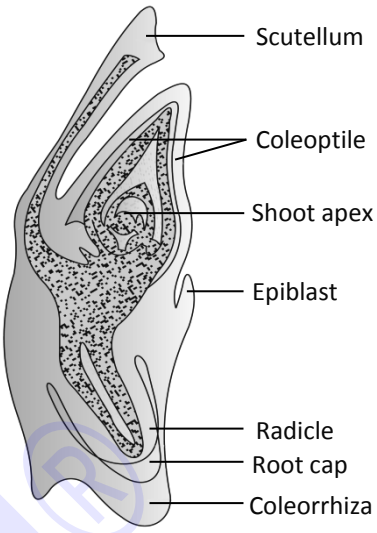
Stages in embryo development (embryogeny) in a dicot

NCERT XII Page No. 34, Figure No. 2.13 (b)

NCERT XII Page No. 35, Figure No. 2.14 (a)

(C) MONOCOT EMBRYO

Though the seeds differ greatly, the early stages of embryo development (embryogeny) are similar in both dicots and monocots.



L.S. of an embryo of grass

NCERT XII Page No. 35, Figure No. 2.14 (b)

GRASS EMBRYO

- **In the grass family the cotyledon is called scutellum (shield shaped) that is situated towards one side (lateral) of the embryonal axis.**
- **At its lower end, the embryonal axis has the radical and root cap enclosed in an undifferentiated sheath called coleorrhiza.**
- **The portion of the embryonal axis above the level of attachment of scutellum is the epicotyl.**
- **Epicotyl has a shoot apex and a few leaf primordia enclosed in a hollow foliar structure, the coleoptile.**

(D) ANGIOSPERMIC SEED

(i) STRUCTURE OF SEED :

- In angiosperms, the seed is the final product of sexual reproduction.
- Fertilized **ovule** is known as **seed.** In other words, **seed is a mature fertilized, integumented megasporangium (Ovule).**
- All the structures, which are present inside the seed coat are collectively termed as **kernel.**
- Typical mature seed is having **three main parts :**
  (1) Seed coat
  (2) Embryo [It is consists of Cotyledon(s) and embryonal axis]
  (3) Endosperm [may or may not be present]

Endosperm –

It is the nutritive tissue which may be present or absent in the seeds. The angiospermic seeds are classified into two categories on the basis of **presence** or **absence of endosperm** in seeds -

(a) NON ENDOSPERMIC SEEDS OR EX-ALBUMINOUS SEEDS OR NON ALBUMINOUS SEEDS :

Such type of seeds do not have an endosperm at maturity, therefore they are called **non endospermic** or **Ex-albuminous** seeds. The endospermic tissues are consumed during the development of embryo. The absorbed food materials from the endosperm is stored in cotyledons, that's why they become so large and fleshy

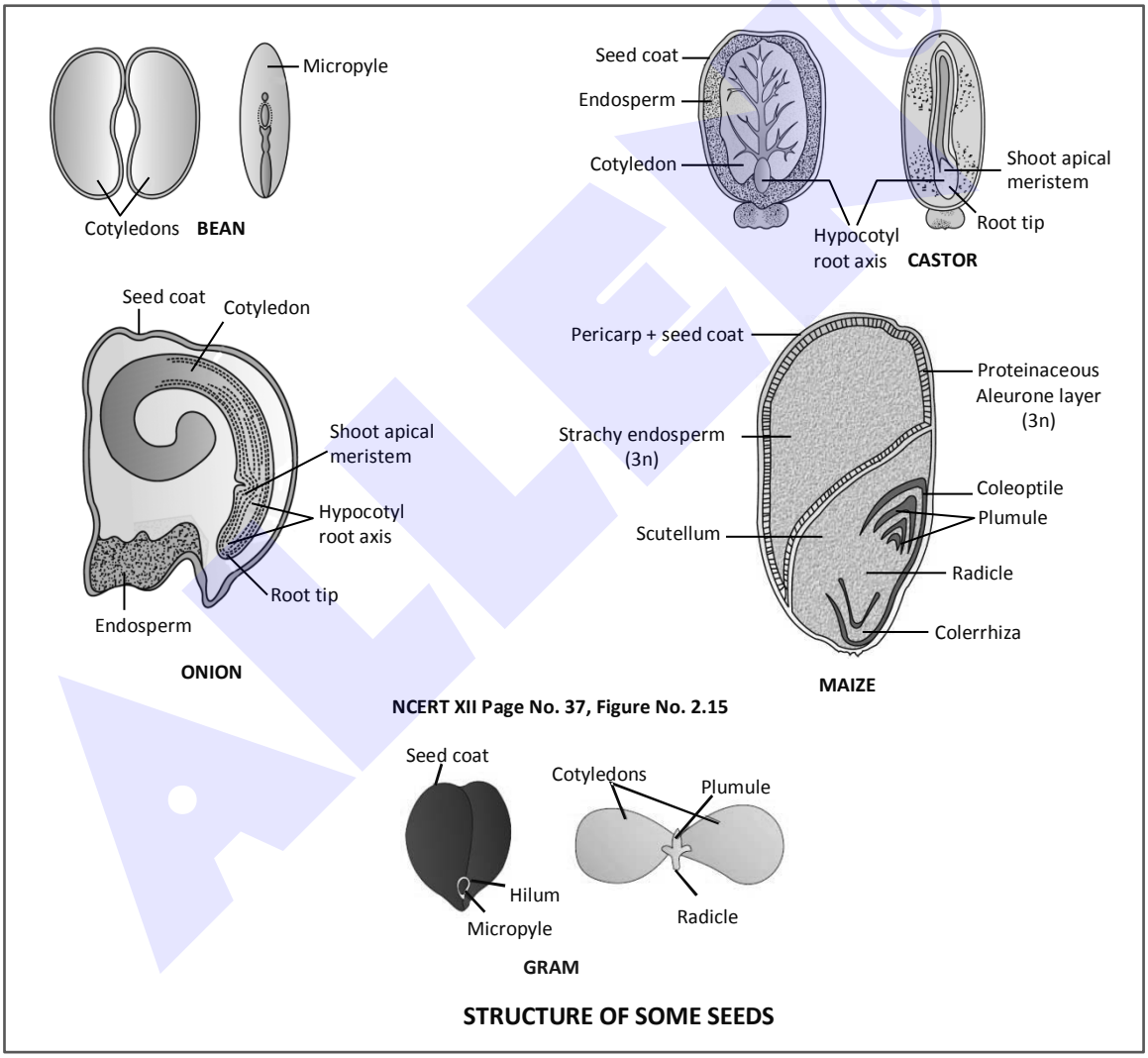
***Examples : Capsella* and most of dicotyledons. eg. gram, pea, bean, ground nut.** But in **castor, seeds are endospermic**.

(b) ENDOSPERMIC SEEDS OR ALBUMINOUS SEEDS :

These seeds retain a part of endosperm as it is not completely used up during embryo development.

In this type of seeds, **food** is stored in **endosperm**. The endospermic tissue in these seeds are utilized during the germination of seed and their cotyledons are thin and membranous

Examples : **Most of monocot seeds** e.g. **wheat, rice, coconut, barley** and **maize** etc. But in **orchid seeds are non-endospermic.**



NCERT XII Page No. 37, Figure No. 2.15

STRUCTURE OF SOME SEEDS

- After fertilization integuments of ovules harden as tough protective seed coats.
- The micropyle remains as a small pore in the seed coat. This facilitates entry of oxygen and water into the seed during germination.

- As the seed matures its water content is reduced and seeds become relatively dry (10-15% moisture by mass) The general metabolic activity of the embryo slow down. The embryo may enter a state of inactivity called dormancy, or if favourable conditions are available (adequate moisture, oxygen and suitable temperature), they germinate.
- As ovules mature into seeds, the ovary develops into a fruit i.e. the transformation of ovules into seeds and ovary into fruit proceeds simultaneously.

ADVANTAGE OF SEED

- Since reproductive processes such as pollination and fertilization are independant of water, seed formation is more dependable (reliable).
- Seeds have better strategies for dispersal to new habitat and help the species to colonise in other areas.
- Seeds provide nourishment to young-seedlings.
- Hard seed coat provides protection to the young embryo.
- Seed is product of sexual reproduction, so they generate new genetic combinations leading to variations.

(ii) FACTORS AFFECTING SEED GERMINATION :

(a) Moisture or water :

The **moisture** or **water** is the **most important** factor for germination of seed. As the seed matures its water content is reduced. Generally, the cells of embryo contain about **10-15% water** in **dormancy period**. The vital activities like growth and development is unable to continue in this less amount of water. For **active life** processes, **water** must be present about **75-90%.** The seed absorbs water and swell up to increase their size before germination. **Water is absorbed** through **seed coat** and **micropyle**.

(b) Oxygen [O_2] :

The process like **cell division, cell elongation** etc. of the embryo requires **energy**. This energy is released by the oxidation of organic substances. Oxygen is essential for oxidation process. The upper surface of soil contains sufficient amount of O_2. The healthy germination of seed does not take place in the absence or scarcity of oxygen in deep soil so, crop seed are sown in the soil by the farmers usually upto 5-7 c.m. deep.

(c) Temperature :

The **suitable temperature** is essential for germination of seed. The protoplasm and enzymes of the cell remains active at certain range of temperature. Most of seeds **do not germinate** in between the range of **0^0C to 5^0C** and above the **45^0C.** The **favourable range** of temperature is **20-25^0C** for germination of seed.

(d) Food or Nutrition :

The growing embryo requires [needs] nutrition during germination. The embryo depends upon stored food materials in **cotyledons** or **endosperm** in the germination period upto the formation of primary root from the radicle and first leaf from the plumule.

04. APOMIXIS

- **"Reproduction in which new individuals are formed without fusion of gametes** is called **asexual reproduction."**
- **Apomixis is a form of asexual reproduction that mimics sexual reproduction.**
- **Some species of Asteraceae and grasses have evolved a special mechanism, to produce seeds without fertilization, called apomixis.**

  [In Greek - Apo = without; mixis = mixing] Apomixis term was suggested by Winkler.
- The Apomixis is characterised by quick multiplication and production of genetically similar plants from the single parent. The offsprings formed by asexual reproduction are identical and are referred to as clones and each member of the clone is called **ramet**.
- **Agamospermy is included in apomixis.**

AGAMOSPERMY :

In this type of method **embryo** is formed without fertilization and meiotic division. It means plants belonging in this category propagate through **seeds** but the embryo formation does not involve meiosis and syngamy.

It occurs by following three methods :-

(i) DIPLOSPORY :

In this method **megaspore mother cell directly gives rise to an embryosac without meiosis**. This embryo sac is diploid.

Example : *Parthenium, Taraxacum (*Members of *Asteraceae)*

(ii) ADVENTIVE EMBRYONY :

In this method, an **embryo is formed from** any diploid cell **[Cell of nucellus or integuments]** of the **ovule**. This **diploid cell** behaves like a **zygote**. Adventive embryony derived from **Nucellus** can be seen in ***Citrus, Mangifera* (Mango), *Opuntia,*** *Onion* and from Integuments in *Spiranthus.*

Sporophytic budding : In this process some of the nucellar cells surrounding the embryosac start dividing, protrude into the embryosac and develop into embryos. It is adventive embryony.

(iii) APOSPORY :

- **Formation of gametophyte directly from sporophyte** without meiosis is called apospory.
- In this method **embryosac or female gametophyte is directly formed from** any diploid cell of the sporophyte i.e. **nucellus or integument** (except megaspore mother cell) without meiosis. In this gametophyte always remains diploid, e.g. *Hieracium, Ranunculus* and *Rubus*.

Significance of apomixis :-

- **Hybrid varieties of several of our food and vegetable crops are being extensively cultivated. Cultivation of hybrids has tremendously increased productivity. One of the problems of hybrids is that hybrid seeds have to be produced every year. If the seeds collected from hybrids are sown, the plants in the progeny will segregate and do not maintain hybrid characters. Production of hybrid seeds is costly and hence the cost of hybrid seeds become too expensive for the farmers. If these hybrids are made into apomicts, there is no segregation of characters in the hybrid progeny. Then the farmers can keep on using the hybrid seeds to raise new crop year after year and he does not have to buy hybrid seeds every year. Because of the importance of apomixis in hybrid seed industry, active research is going on in many laboratories around the world to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties.**

- **PARTHENOGENESIS :** Formation of embryo from unfertilized egg is called parthenogenesis. In this process haploid egg cell of female gametophyte is responsible to form a haploid embryo without fertilization.
- **APOGAMY :** In this process any haploid cell of female gametophyte except egg cell is responsible to form a haploid embryo without fertilization or Formation of sporophyte directly from gametophyte without fertilization is called apogamy.

  ***If both gametophyte and sporophyte are diploid in parthenogenesis and apogamy then it is called diploid parthenogenesis and diploid apogamy respectively.**
- **PARTHENOCARPY :** Formation of fruit from unfertilized ovary is known as pathenocarpy.

  In some of the Angiosperms, fruit is formed from the ovary without fertilization which is known as **parthenocarpic fruit.**

  In some fruits parthenocarpy is useless (If edible part is endosperm or seed). eg. **pomegranate (*Punica granatum*).**
- **POLYEMBRYONY :**

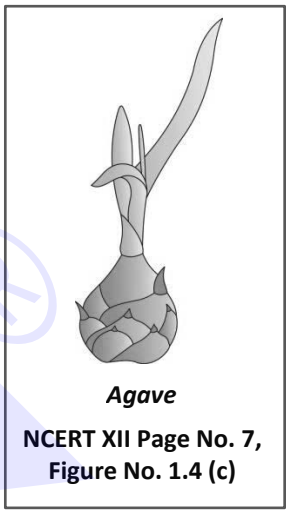
  When many embryos are present inside the single seed then it is called **polyembryony.** first of all, it was observed by **Leeuwenhoek** in ***Citrus*** **(Orange) seeds.** Polyembryony is commonly found in **Gymnosperms** but it is also found in some of angiospermic plants such as **orange, lemon** and ***Nicotiana*** etc.

  [**Adventive embryony** is also an example of **polyembryony** in which additional number of embryos are formed from **nucellus** or **integuments**]

VEGETATIVE REPRODUCTION /PROPAGATION

Plants belonging to this category are propagated by a part of their body other than a seed. The structural unit that is employed in place of seed for the propagation of new plants is called **propagule**. In **angiosperms** any part of the plants - **roots, stems** and **leaves** can be used for vegetative propagation.

Generally methods of vegetative propogation have been further divided into **two types**- natural and Artificial.



Agave

NCERT XII Page No. 7, Figure No. 1.4 (c)

(A) Natural vegetative propagation : It occurs by tuber, rhizome, corm, bulb and bulbils etc.

BULBILS :

- In some plants, **fleshy buds** are developed which are called **bulbils.** These buds form new plants.

  Example – ***Dioscorea (Wild Yam), Oxalis, Agave, Cycas.***

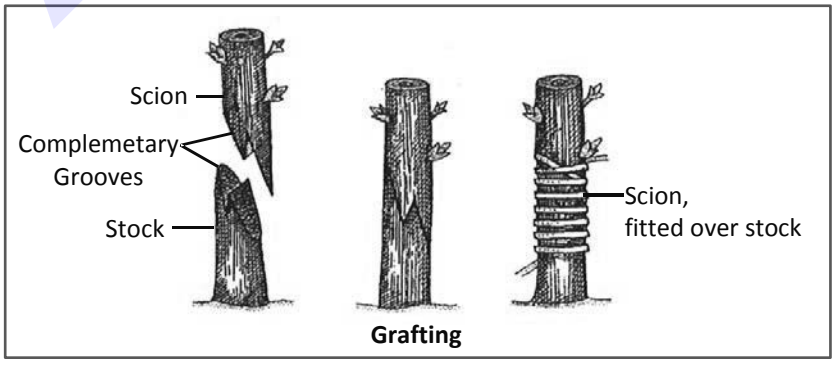
(B) Artificial propagation :

(i) By Cutting :- A cutting is separated portion of root, stem or leaf which is used for propagation. Some time the stem cuttings are treated with rooting hormone [IBA, IAA or NAA] for proper development of adventitious roots e.g., **sugar cane, Rose** (stem cutting). **[Favourable time for cutting - rainy season]**

(ii) By Grafting : -

Grafting is done between two closely related **dicotyledonous** plants having **vascular cambium**. The **root supported portion** of one plant is called **stock** which is joined with a **twig of another plant** called **scion**. Generally, the **root stock** belongs to **wild variety** which is resistant to disease & pest or having efficient root system. The **scion** is derived from the plant possessing **better characters**. e.g., **grafted mango, roses**

[Favourable time for grafting - spring season]



Grafting

Post Fertilization Changes

(1) Ovary → Fruit
(2) Ovule → Seed
(3) Ovary wall → Pericarp or fruit wall
(4) Integument → Seed coat (Tough and protective)
(5) Outer integument → Testa (Outer seed coat)
(6) Inner integument → Tegmen (Inner seed coat)
(7) Nucellus → Degenerates (Sometimes present in the form of perisperm)
(8) Synergids and antipodals → Degenerate
(9) Hilum of ovule → Hilum of seed (Scar on seed)
(10) Funiculus of ovule → Stalk of seed (may be left or broken)
(11) Micropyle of ovule → Micropyle of seed
(12) Chalaza of ovule → Chalaza of seed

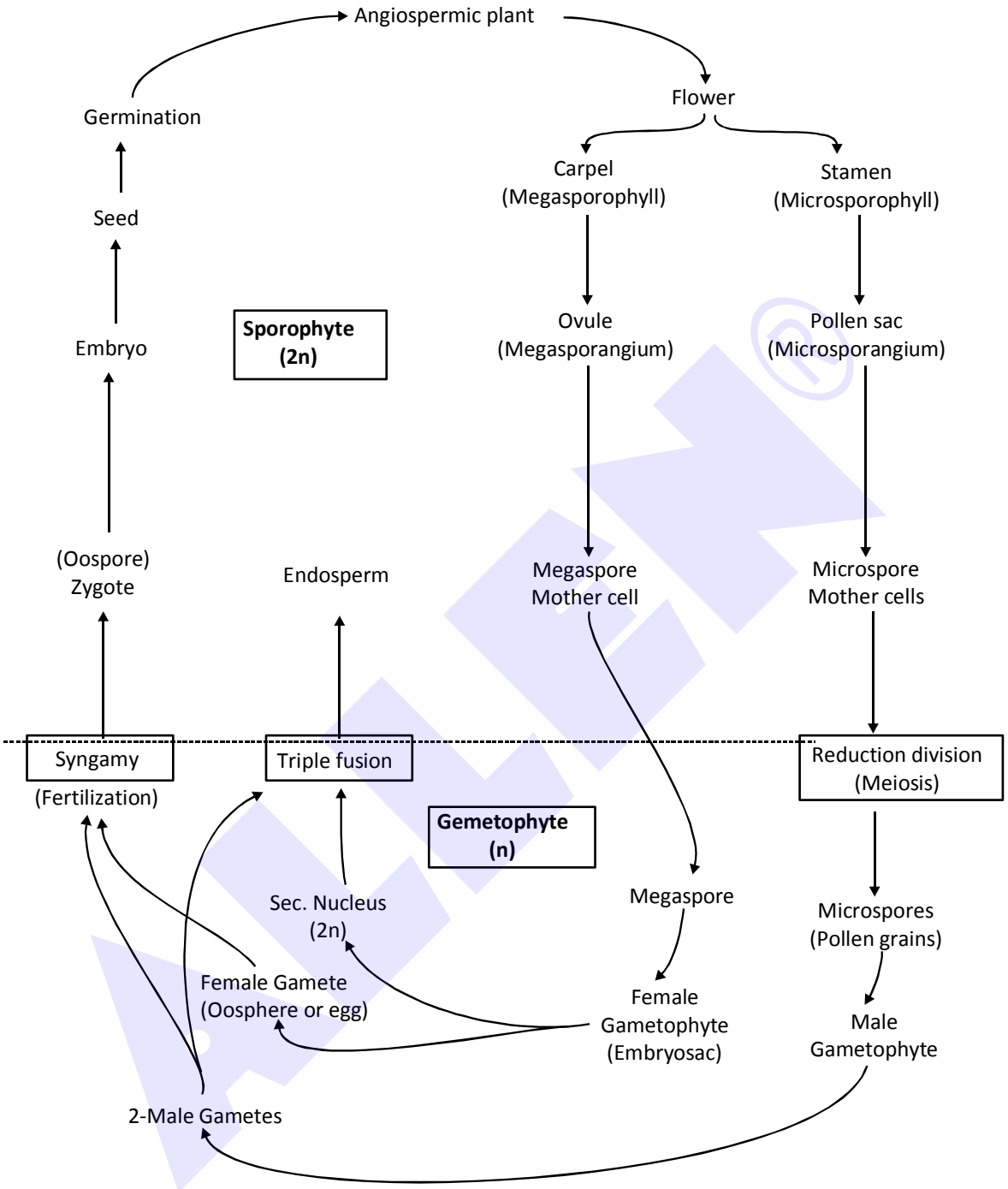
PLOIDY LEVEL OF DIFFERENT STRUCTURES/PARTS IN FLOWERING PLANT :-

SPOROPHYTE		
1.	Zygote	2n
2.	Embryo	2n
3.	Radicle	2n
4.	Plumule	2n
5.	Cotyledon	2n
6.	Nucellus, Perisperm	2n
7.	Integument, Seed coat	2n
8.	Microspore mother cell	2n
9.	Megaspore mother cell	2n
10.	Ovary wall, Fruit wall	2n
11.	Carpel	2n
12.	Sepal, Petal	2n
13.	Stamen, Anther	2n
14.	Leaf, Root, Stem	2n

GAMETOPHYTE		
1.	Microspore/Pollen grain	n
2.	Tube cell, Generative cell	n
3.	Male gamete, Female gamete	n
4.	Megaspore	n
5.	Embryosac	n
6.	Synergid	n
7.	Antipodals	n
8.	Egg cell	n
9.	2 Polar nuclei	n & n

1.	Secondary nucleus	2n
2.	Primary endosperm nucleus/cell	3n
3.	Endosperm	3n
4.	Aleurone layer	3n

1.	Stamen = Microsporophyll
2.	Carpel = Megasporophyll
3.	Pollen sac = Microsporangium
4.	Ovule = Integumented megasporangium
5.	Egg/Ovum = Female gamete
6.	Sperm/Male gamete = Microgamete
7.	Germinating pollen grain = Male gametophyte
8.	Embryo sac = Female gametophyte



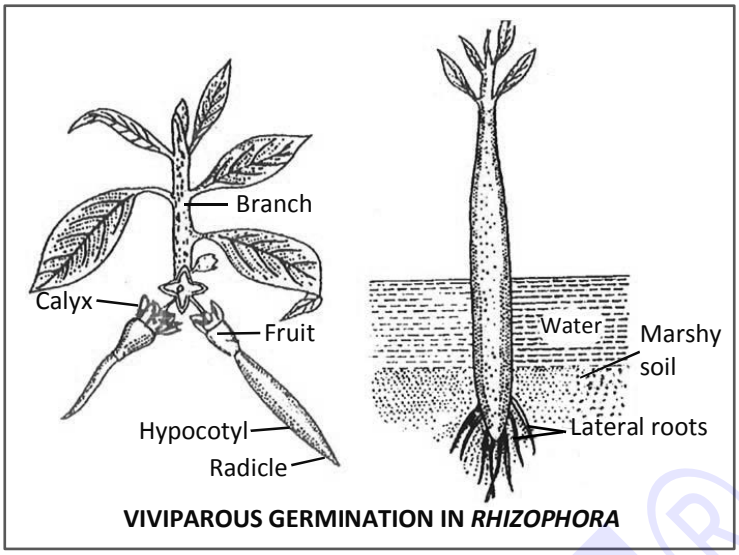
OUT LINE DIAGRAM OF LIFE CYCLE OF ANGIOSPERMS

SPECIAL POINTS

1. Highest amount of **fat** is found in endosperm of **coconut.**
2. **125 meiotic** divisions are essential for development of **100 grains of Wheat**.
3. **Two generations** are present in **Angiospermic seed.**
4. **Inside the mature seed embryo is the progenitor of the next generation.**
5. **Seeds of a large number of species live for several years. Some seeds can remain alive for hundreds of years. There are several records of very old yet viable seeds. The oldest is that of a lupine, *(Lupinus arcticus)* excavated from Arctic Tundra. The seed germinated and flowered after an estimated record of 10,000 years of dormancy. A recent record of 2000 years old viable seed is of the date plam, *(Phoenix dactylifera)* discovered during the archeological excavation at King Herod's palace near the Dead Sea.**
6. The seed of ***Cuscuta*** and ***Santalum*** lacks cotyledons.
7. Dormancy is absent in ***Mangrove*** plants like ***Rhizophora***.
8. **Orchid fruits contain thousands of tiny seeds. Similar is the case of fruits of some parasitic species such as *Orobanche* and *Striga*. Tiny seeds are also found in *Ficus*.**
9. **Dehydration and dormancy of mature seeds are crucial for storage of seeds. Seeds form basis of agriculture.**
10. You can easily study **pollen germination** by dusting some pollen from flowers such as **pea, chickpea**, ***Crotalaria*, balsam** and ***Vinca*** on a glass slide containing a drop of **sugar solution (about 10 per cent).** After about 15–30 minutes, observe the slide under the low power lens of the microscope. You are likely to see pollen tubes coming out of the pollen grains.
11. Water is a regular mode of transport for male gametes among the lower plants like algae, bryophytes and pteridophytes. It is believed that bryophytes and pteridophytes are limited in their distribution because of the need of water for the transport of male gametes and fertilisation.
12. **Viviparous germination or vivipary :**

    It is a **special type of seed germination** which is characteristic of **mangrove vegetation,** found in muddy, saline conditions, e.g., ***Rhizophora, Avicennia,*** etc. Here there is no resting period of embryo and germination occurs inside the fruit, while it is attached to the parent plant, i.e., **"in-situ germination".** This is called **viviparous germination** or **vivipary.**

    Viviparous germination is found in halophytes.



VIVIPAROUS GERMINATION IN *RHIZOPHORA*

BEGINNER'S BOX

FERTILIZATION, ENDOSPERM, EMBRYO, SEED ETC.

1. Endosperm may persist in mature seed in

(1) Pea (2) Castor (3) Groundnut (4) Bean

2. Syngamy results in the formation of :

(1) Zygote (2) Primary endosperm nucleus

(3) Endosperm (4) Ovary

3. Embryo develops at which end of embryo-sac?

(1) Micropylar end (2) Chalazal end (3) Funiculus (4) Outside the ovary

4. In mature seed how much amount of moisture is present

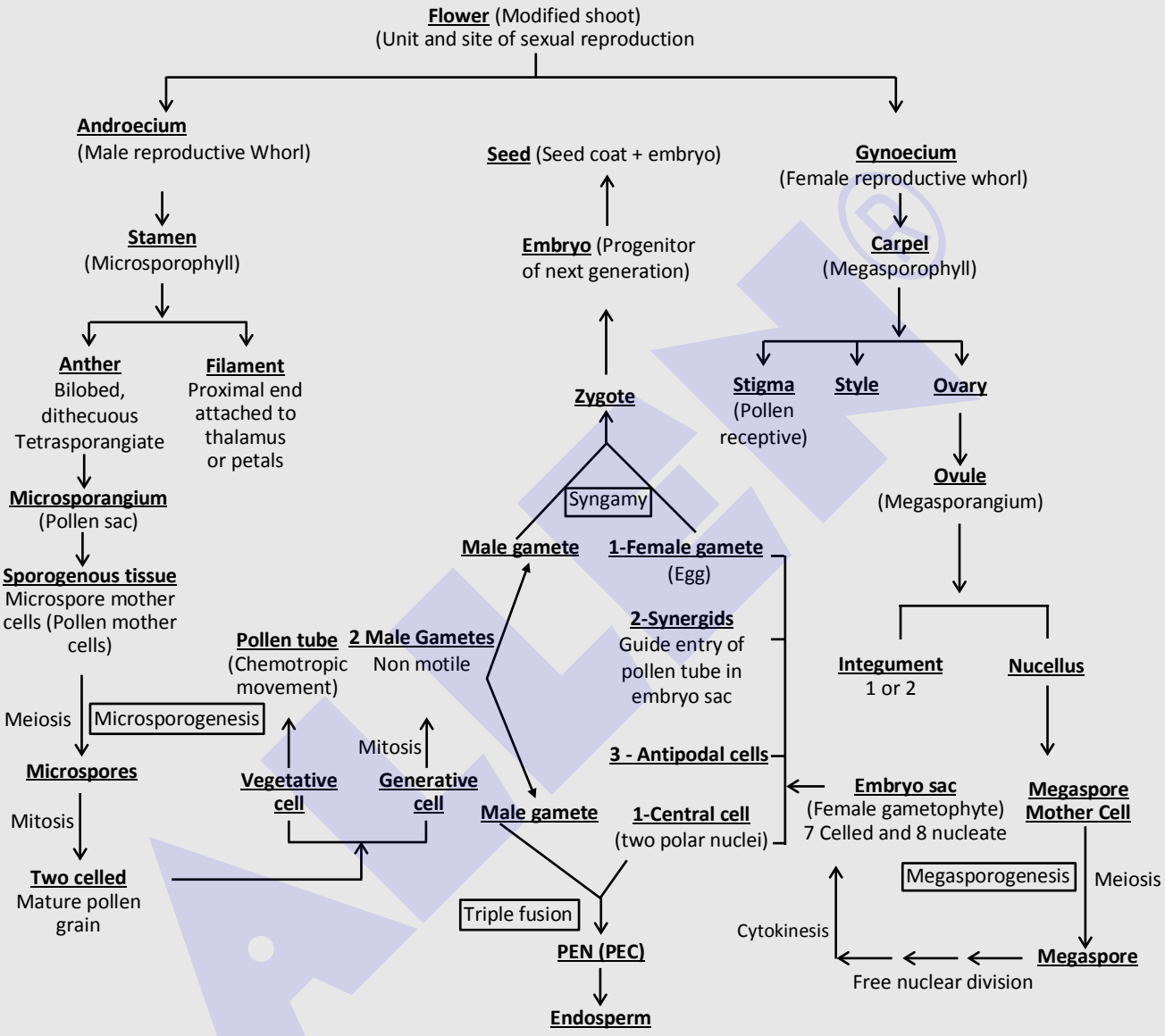
(1) 5-10 percent (2) 10-15 percent (3) 15-20 percent (4) 20-25 percent

5. An event unique to flowering plants is :

(1) True fertilisation (2) Double fertilisation (3) Embryogenesis (4) Pollination

★ Golden Key Points ★

- Pollen, pistil interaction is mediated by chemical components of the pollen interacting with those of the pistil.
- Endosperm is generally triploid in angiosperms.
- Many insects may consume pollen or the nectar without bringing about pollination. Such floral visitors are referred to as pollen/nectar robbers.
- Nucellar adventive embryony is found in ***Citrus*** and mango.



Pollination
- Autogamy (Genetically and functionally self pollination)
- Geitonogamy (Genetically self pollination and functionally cross pollination)
- Xenogamy (Genetically and functionally cross pollination)

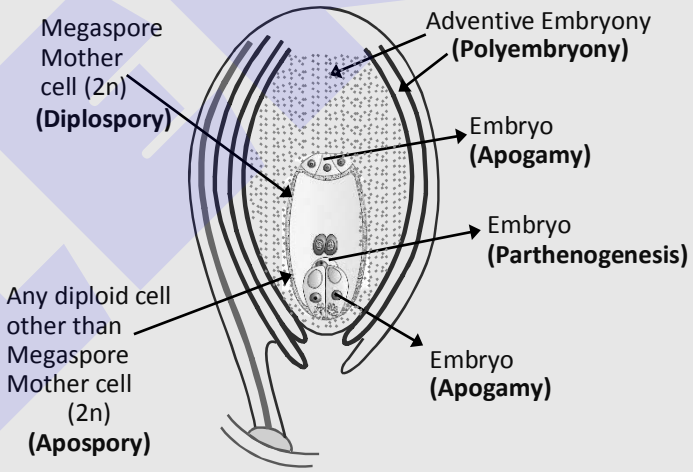
- **Contrivances of self pollination :** Bisexuality, Homogamy, Cleistogamy, Bud pollination.
- **Out breeding devices :** Unisexuality, Dichogamy, Chasmogamy, Self incompatibility, Heterostyly.
- **Floral rewards provided to pollinators :** Edible pollen, nectar and safe place for laying eggs.
- Self incompatibility is a genetic mechanism to prevent self fertilization.
- **Double fertilization :** Triple fusion + Syngamy.

- **Tapetum :** Provides nutrition of developing pollen grains
- **Nucellus :** Provides nutrition to developing female gametophyte or embryo sac
- **Endosperm :** Provides nutrition to developing embryo
- **Cotyledons :** Provides nutrition during seed germination

- Pollen tube enters into the embryo sac through degenerating synergid.
- Pollen tube discharges its content in cytoplasm of degenerating synergid.
- Endosperm development precedes the embryo development.
- Embryo consists of embryonal axis and cotyledon (s).
- Seeds are the end product of sexual reproduction.

Apomixis :

- A form of asexual reproduction which mimics the sexual reproduction.
- A type of reproduction without fusion of gametes.
- Apomictic seeds are genetically identical to each other and as well as of parents.
- Seeds can be produced without fertilization by apomixis.



Diplospory : Megaspore mother cell $\xrightarrow[\text{without meiosis}]{}$ Embryo sac.

Apospory : Nucellus or integuments (Any diploid cell of ovule other than MMC) $\longrightarrow$ Embryo sac

Parthenogenesis : Egg cell $\xrightarrow[\text{Without fertilization}]{}$ Embryo.

Apogamy : Synergid or Antipodal cell $\xrightarrow[\text{Without fertilization}]{}$ Embryo

BEGINNER'S BOX ANSWERS KEY

MALE REPRODUCTIVE ORGAN

Que.	1	2	3	4	5
Ans.	**1**	**3**	**2**	**3**	**2**

FEMALE REPRODUCTIVE ORGAN AND POLLINATION

Que.	1	2	3	4	5
Ans.	**2**	**4**	**1**	**1**	**2**

FERTILIZATION, ENDOSPERM, EMBRYO, SEED etc.

Que.	1	2	3	4	5
Ans.	**2**	**1**	**1**	**2**	**2**