Reproduction

in

Angiosperms

Introduction

In this section, we address **sexual reproduction in Phanerogams (plants with visible flowers).**

The transition fro

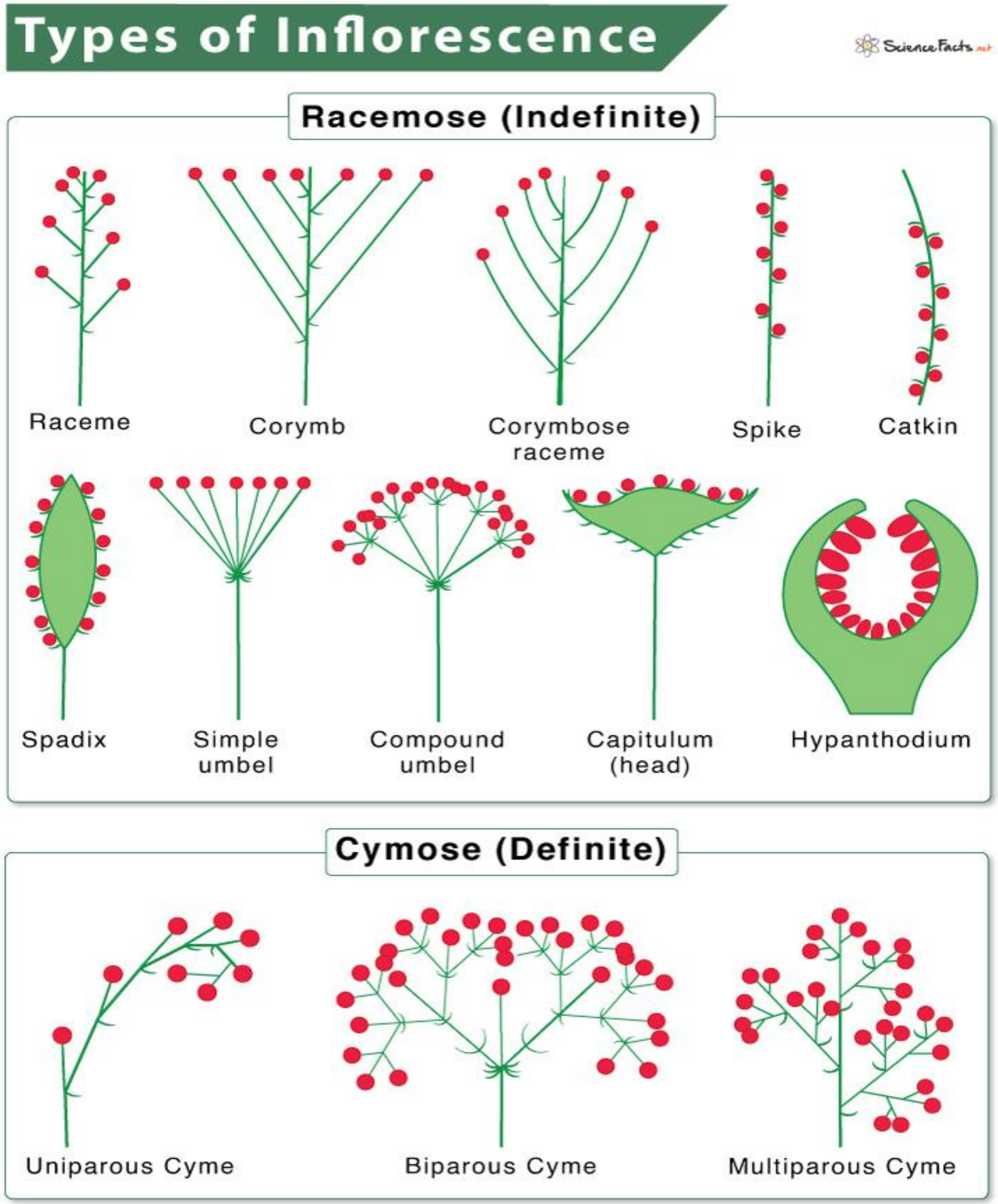
m vegetative state to sexual reproductive state depends on numerous factors:

- **Exogenous factors**: light rhythm (photoperiod) and temperature rhythm (thermoperiod)
- **Endogenous factors**: the concentration of certain hormones.

Floral Arrangement

In Angiosperms, flowers can be:

1. **Singular** (solitary or isolated flowers)
2. Grouped into multiple flowers called **inflorescences**.



Distribution of Sexes

The distribution of sexes among individuals and flowers determines two different categories:

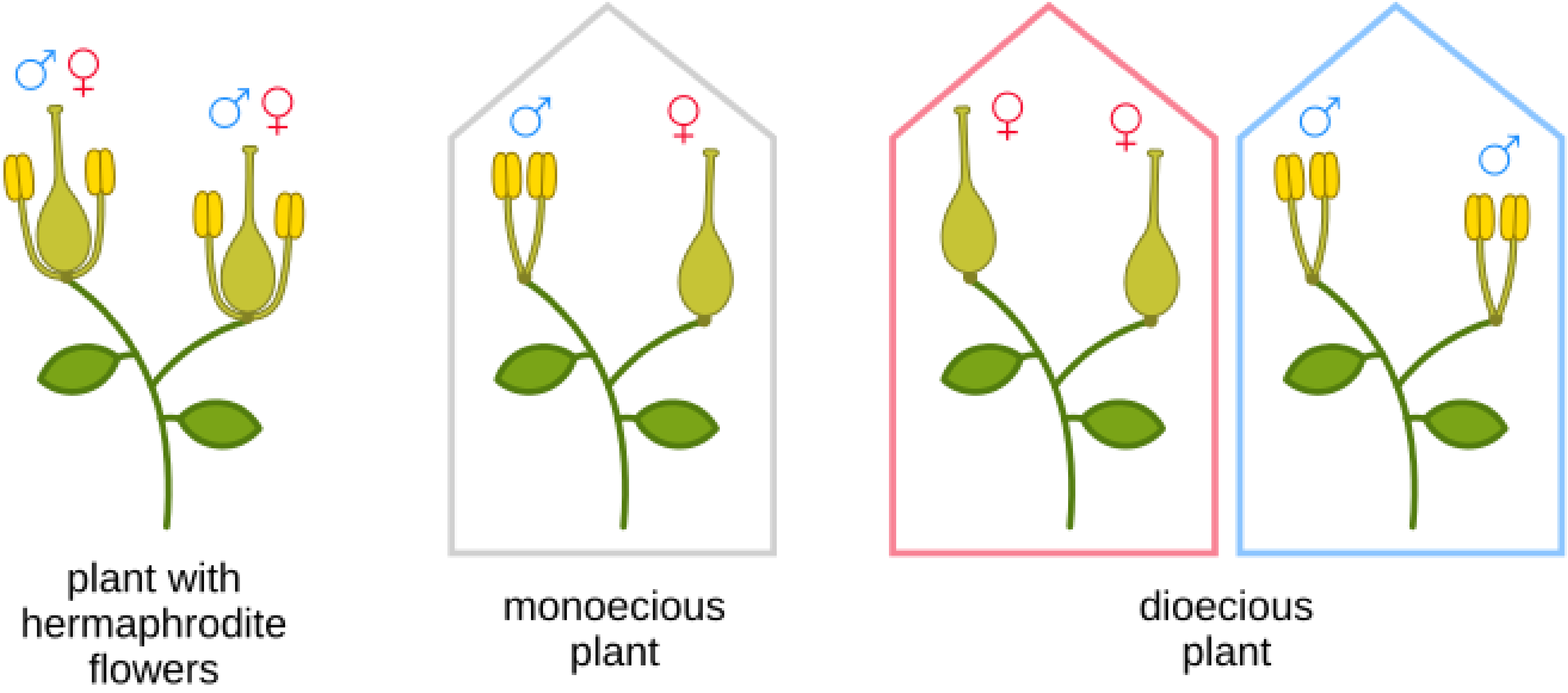
1. Monoecious Plants (Monoecy)

Male and female flowers are present on the same plant.

- **Hermaphroditic flowers**: The flower possesses both an androecium and a gynoecium (Angiosperms).
- **monoecious flowers:** The flower is either male or female but carried by the same plant (Gymnosperms).

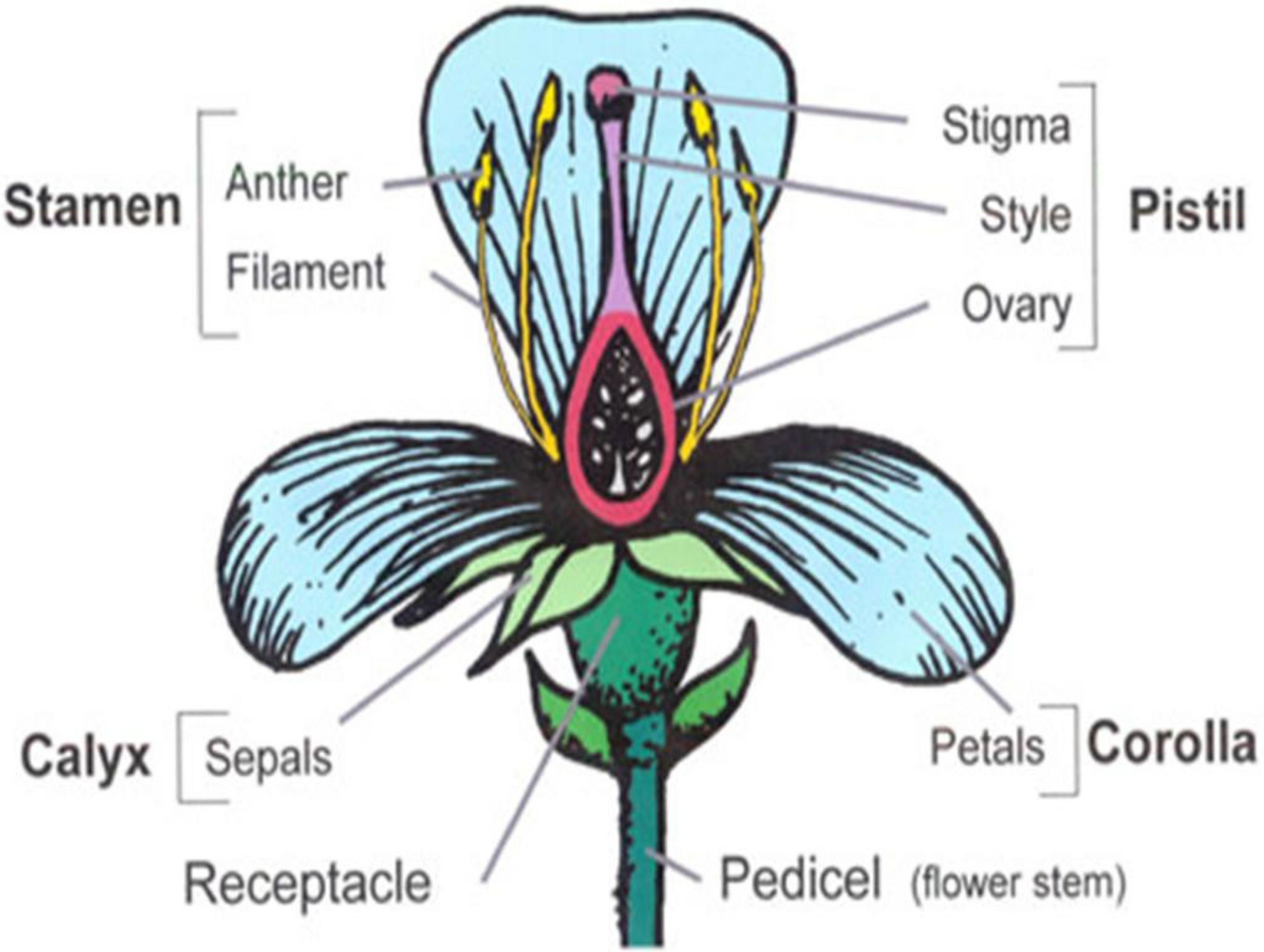
2. Dioecious Plants (Dioecy)

Male and female flowers are carried by separate plants ‘**monoecious flowers’**. This means there are male plants bearing only male flowers and female plants bearing only female flowers. Example: Date palm


plant with hermaphrodite flowers
monoecious plant
dioecious plant

Flower Structure

- A typical flower has four main parts—or whorls—known as:
- the calyx,
- corolla,
- androecium,
- and gynoecium



the calyx

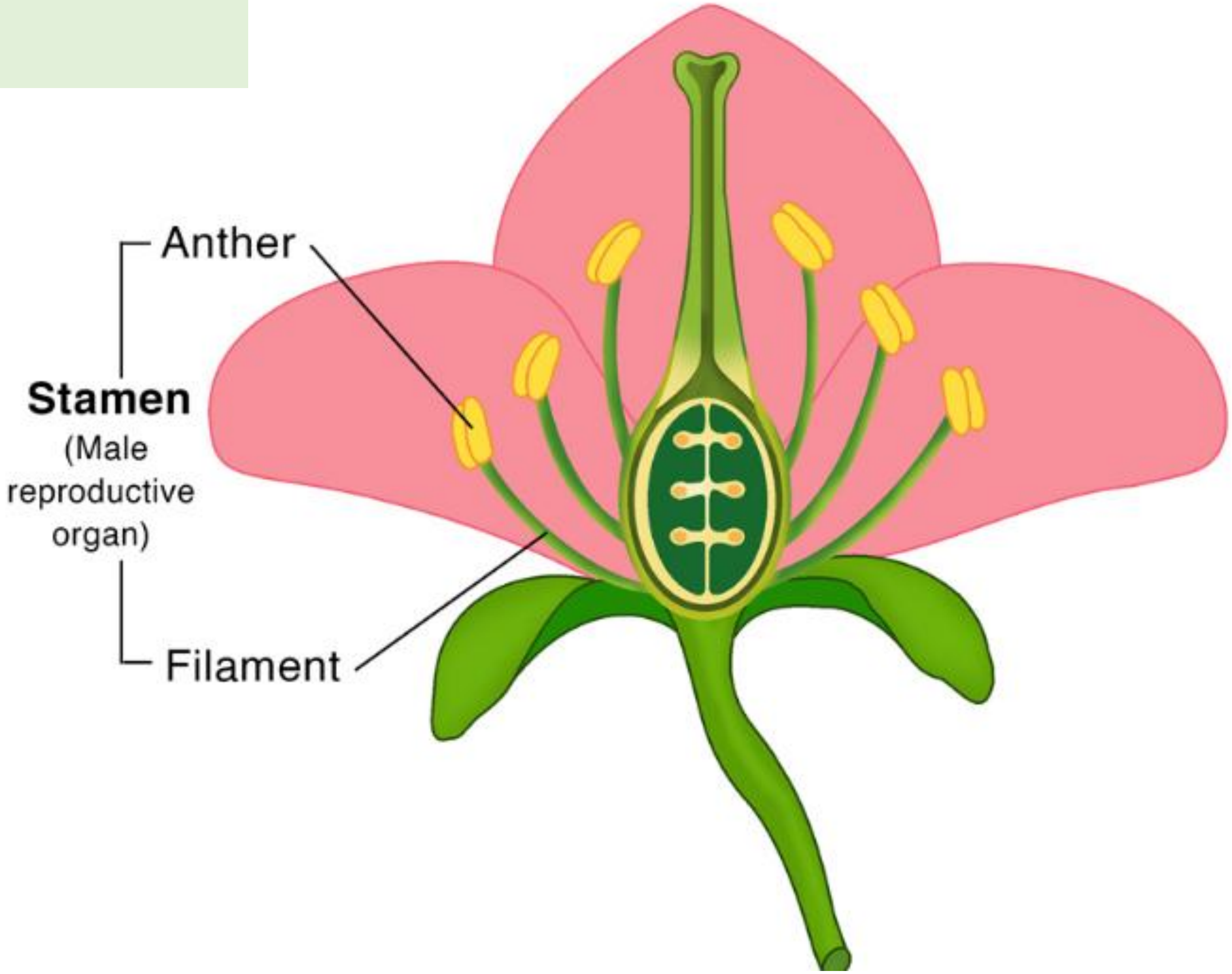
- **the calyx:** The outermost whorl of the flower has green, leafy structures known as **sepals.**
- The sepals help to protect the unopened bud.

the corolla

- **The corolla:** the second whorl is comprised of **petals**—usually , brightly colored.
- The number of sepals and petals varies depending on whether the plant is a monocot or dicot.
- In monocots, petals usually number three or multiples of three;
- in dicots, the number of petals is four or five, or multiples of four and five.
- the calyx and corolla are known as the **perianth**.

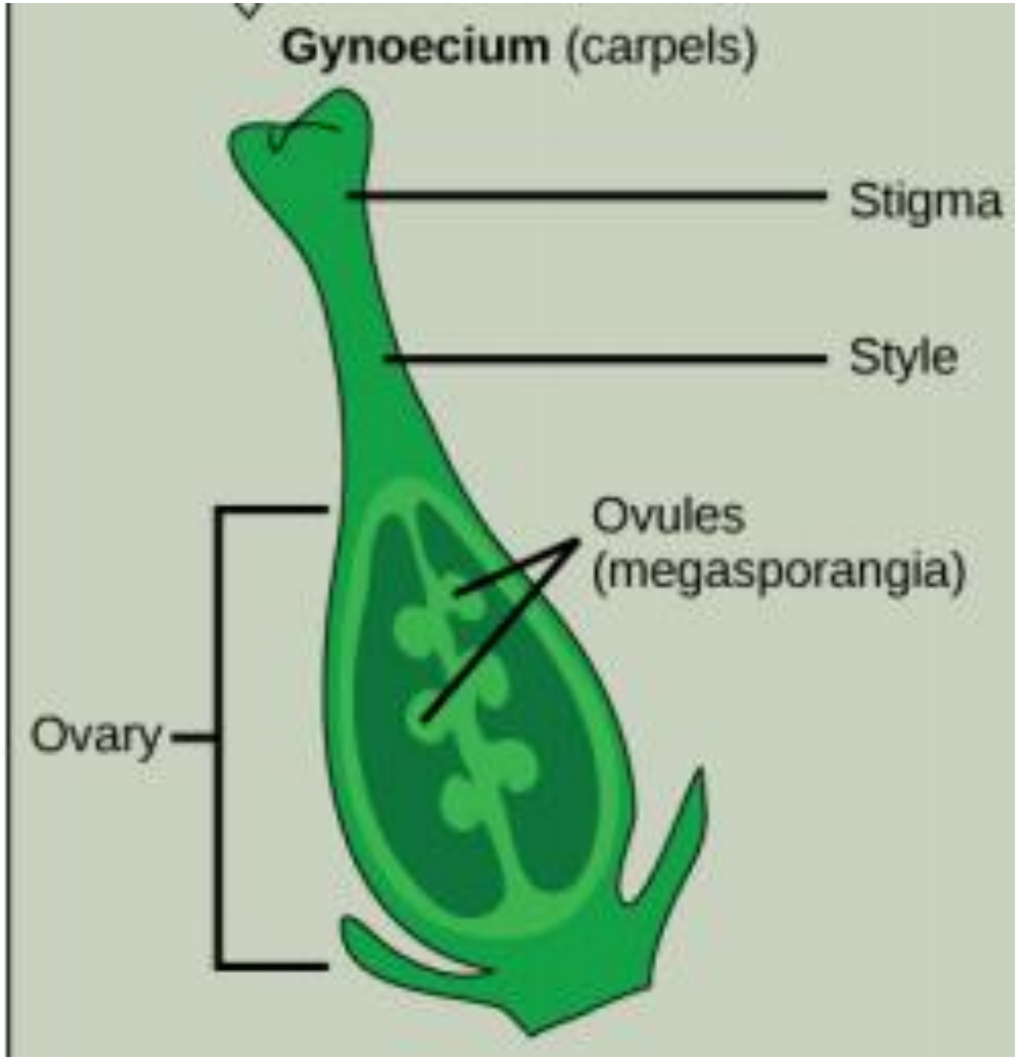
The androecium

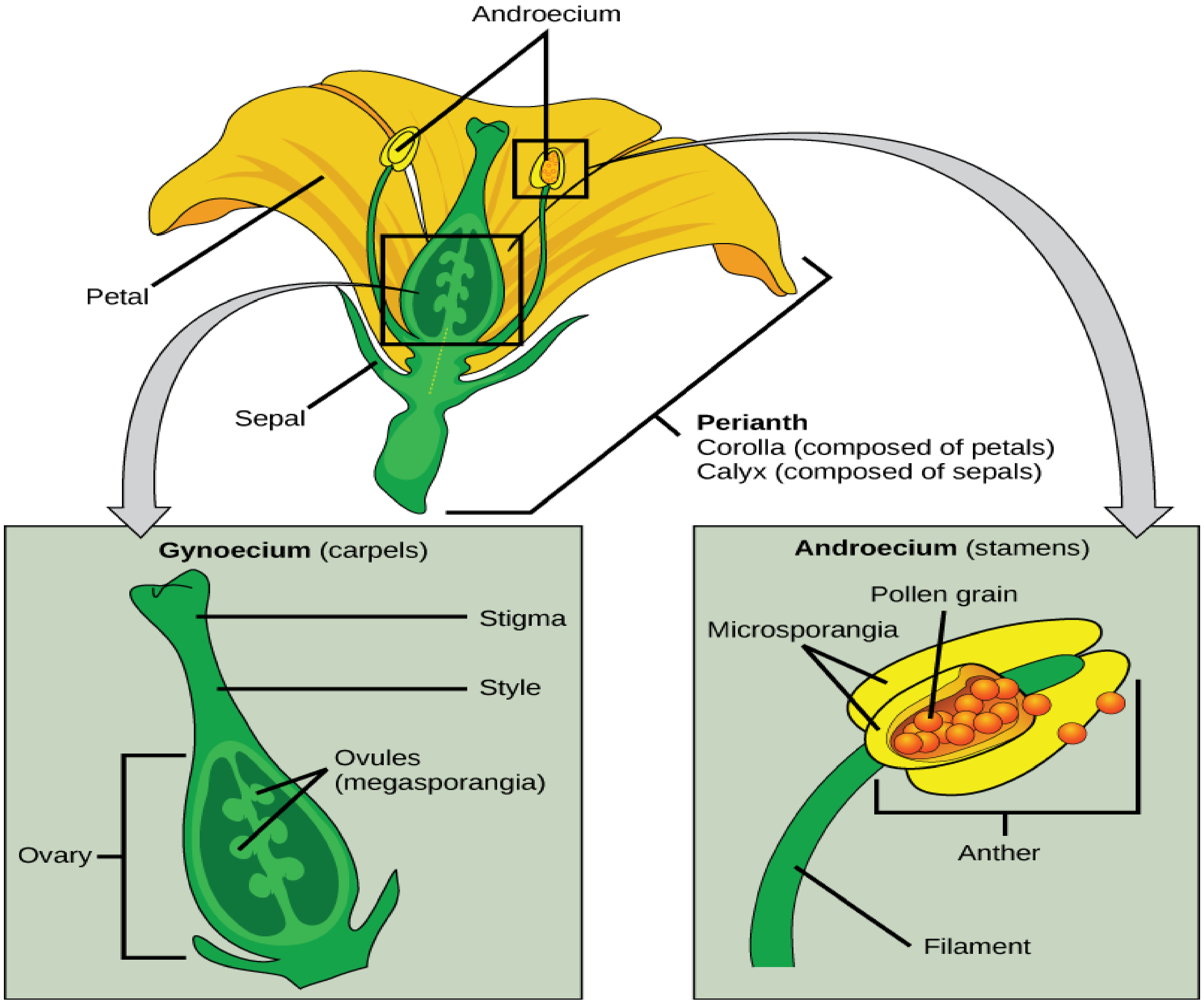
- **The androecium:** The third whorl contains the male reproductive structures.
- The androecium has **stamens**.
- **stamen** – the long and slender stalk called the **filament**, and the terminal generally bilobed structure called the **anther.**



the gynoecium

- **the gynoecium:** The innermost group of structures in the flower
- **The gynoecium** represents the **female reproductive part** of the flower.
- **The carpel (pistil)**is the individual unit of the gynoecium.
- It may consist of a **single pistil (monocarpellary)** or may have more than one pistil **(multicarpellary)**.
- The pistils may be fused together **(syncarpous)** or may be free **(apocarpous).**
- **Pistil = the stigma, style and ovary.**
- The stigma serves as a landing platform for pollen grains. The style is the elongated slender part beneath the stigma. The basal bulged part of the pistil is the ovary.

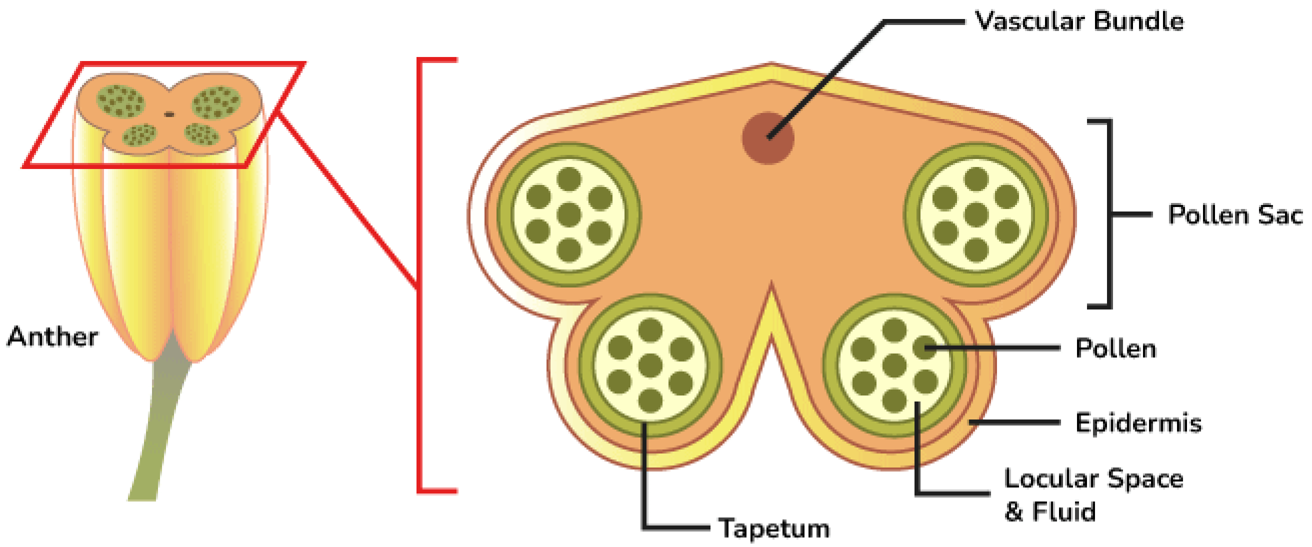



Androecium
Petal
Sepal
Perianth
Corolla (composed of petals)
Calyx (composed of sepals)
Gynoecium (carpels)
Stigma
Style
Ovules
(megasporangia)
Ovary
Androecium (stamens)
Pollen grain
Microsporangia
Anther
Filament

Mature anthere

Anther consists of **two anther lobes** connected by a tissue known as **connective**. Each anther lobe contains two pollen sacs or microsporangia. Mature anther contains **four pollen sacs (microsporangia)** having many pollen grains.

T.S of Anther



ANTHER DEHISCENCE

The dehiscence of the anther occurs due to the endothecium layer. The point where the endothecium layer breaks is known as the stomium. Pollen grains are released from the dehisced anther.

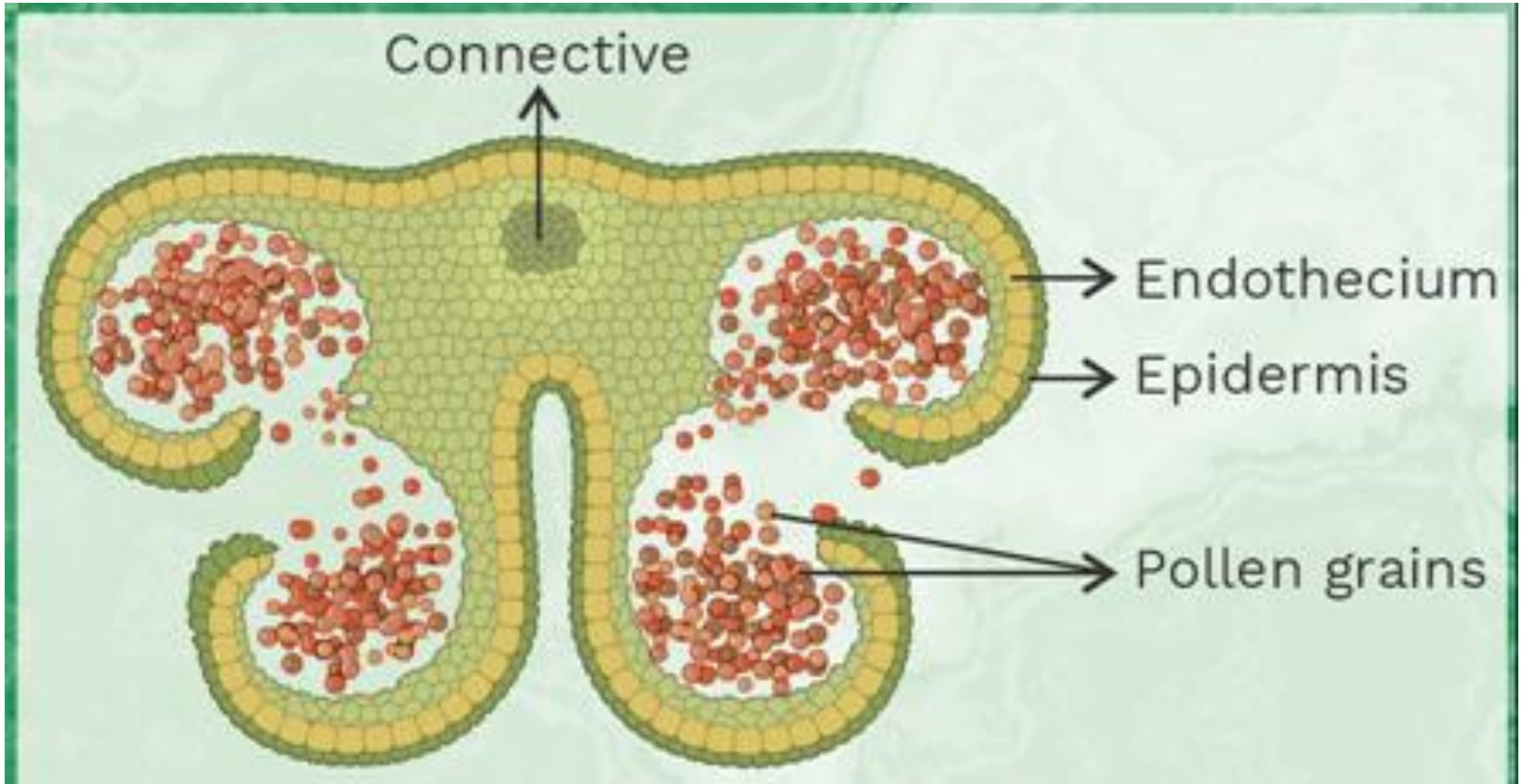
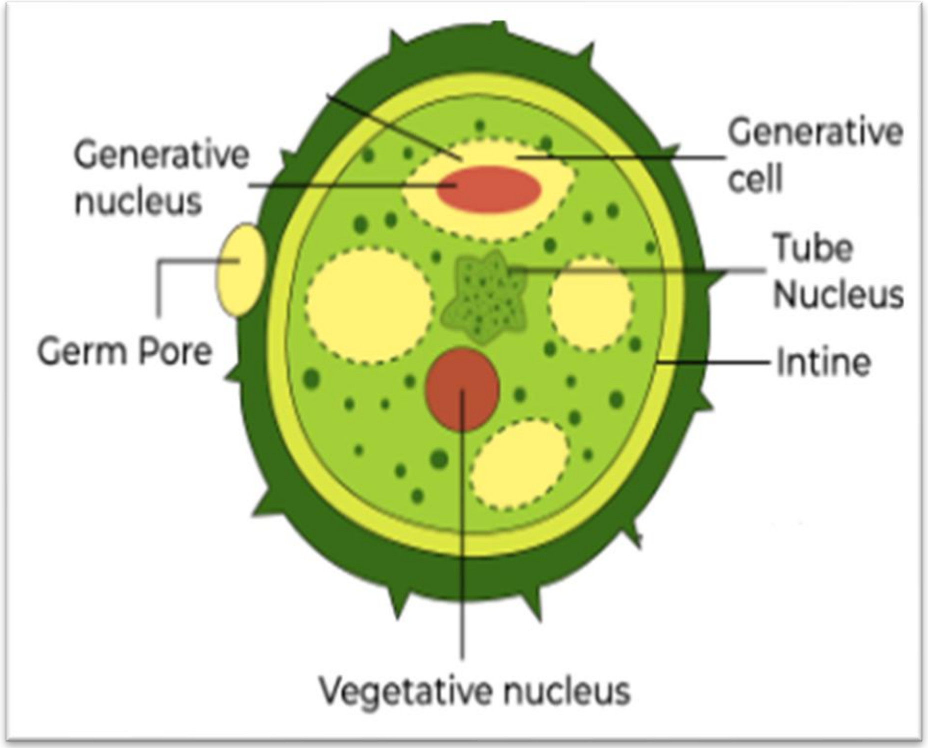


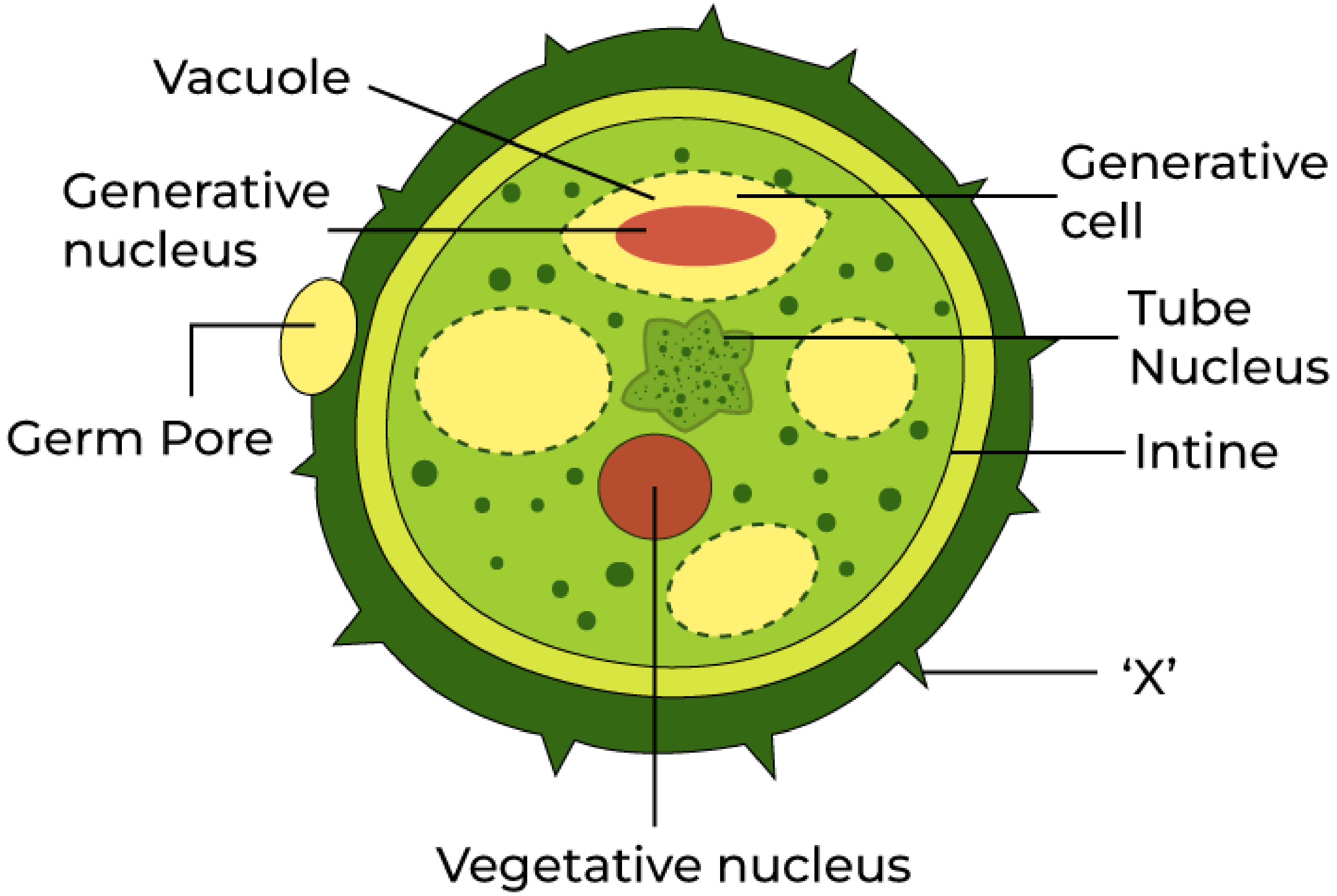
FIG. A MATURE DEHISCED ANTHER

Pollen grain structure

- **Pollen grains** are generally spherical measuring about 25-50 micrometers in diameter.
- It has a prominent two-layered wall. The hard outer layer called the **exine** is made up of **sporopollenin** . It can withstand high temperatures and strong acids and alkali.
- Pollen grain exine has prominent apertures called **germ pores.**
- The inner wall of the pollen grain is called the **intine.** It is a thin and continuous layer made up of cellulose and pectin.
- When the pollen grain is mature it contains two cells, **the vegetative cell and generative Cell.**



Structure of Pollen Grain



Ovule structure

- **The ovule** is a small structure attached to **the placenta** by means of a stalk called **funicle**.
- Each ovule has one or two protective envelopes called **integuments.**
- Integuments encircle the **nucellus** except at the tip where a small opening called the **micropyle**.
- Opposite the micropylar end, is the **chalaza**, representing the basal part of the ovule.
- In the nucellus, **female gametophyte** is present, also known as **embryo sac**.

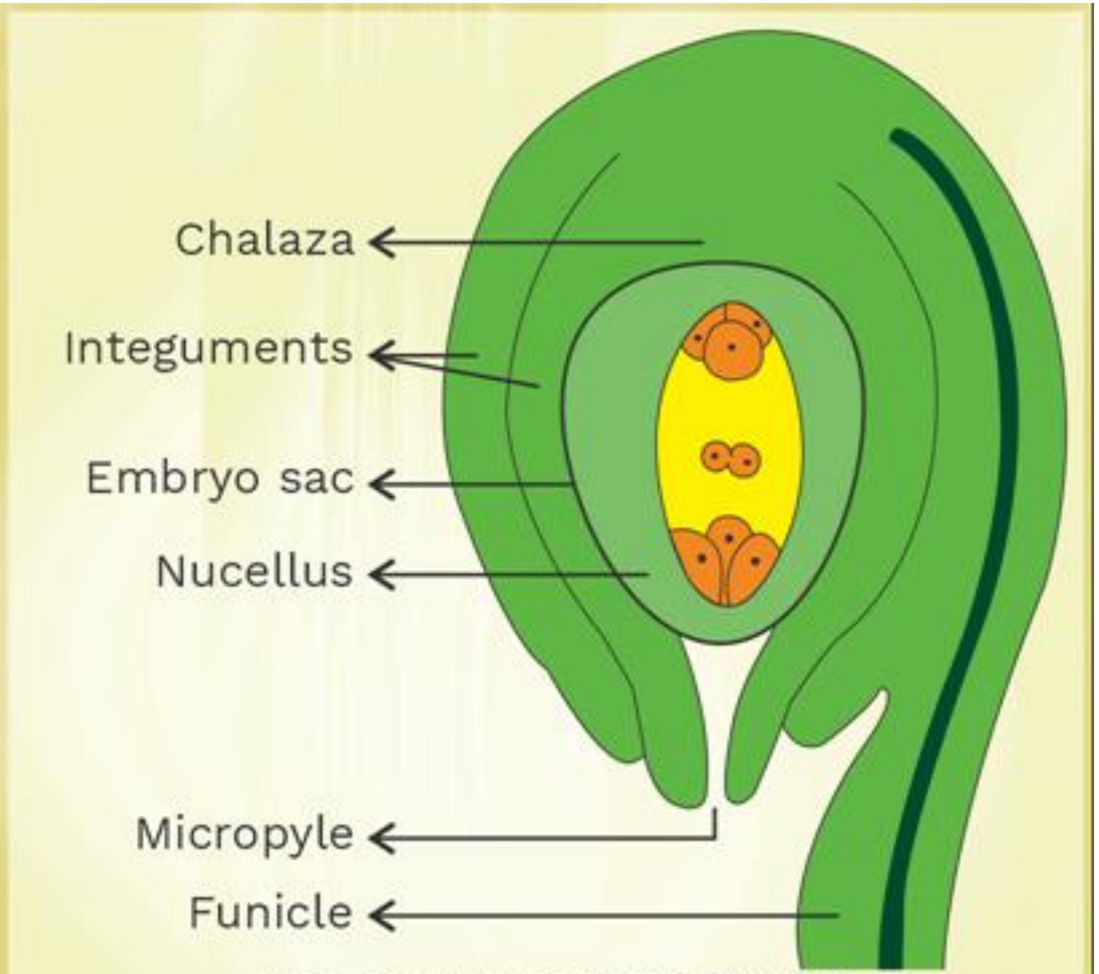


FIG. ANATROPOUS OVULE

Different Types of Ovules

The position of the ovule relative to the placenta varies. The different types of ovules are defined by considering the relative positions of three points of ovular morphology: the hilum, chalaza, and micropyle. There are three types of ovules:

- **Straight or orthotropous ovule**: hilum, chalaza, and micropyle are aligned along the axis of the ovule
- **Curved or campylotropous ovule:** the ovule is curved, the micropyle is on the side
- **Inverted or anatropous ovule:** the funicle is fused to the ovular body. The point of suture is called the raphe. The hilum is close to the micropyle. This is the most widespread type.

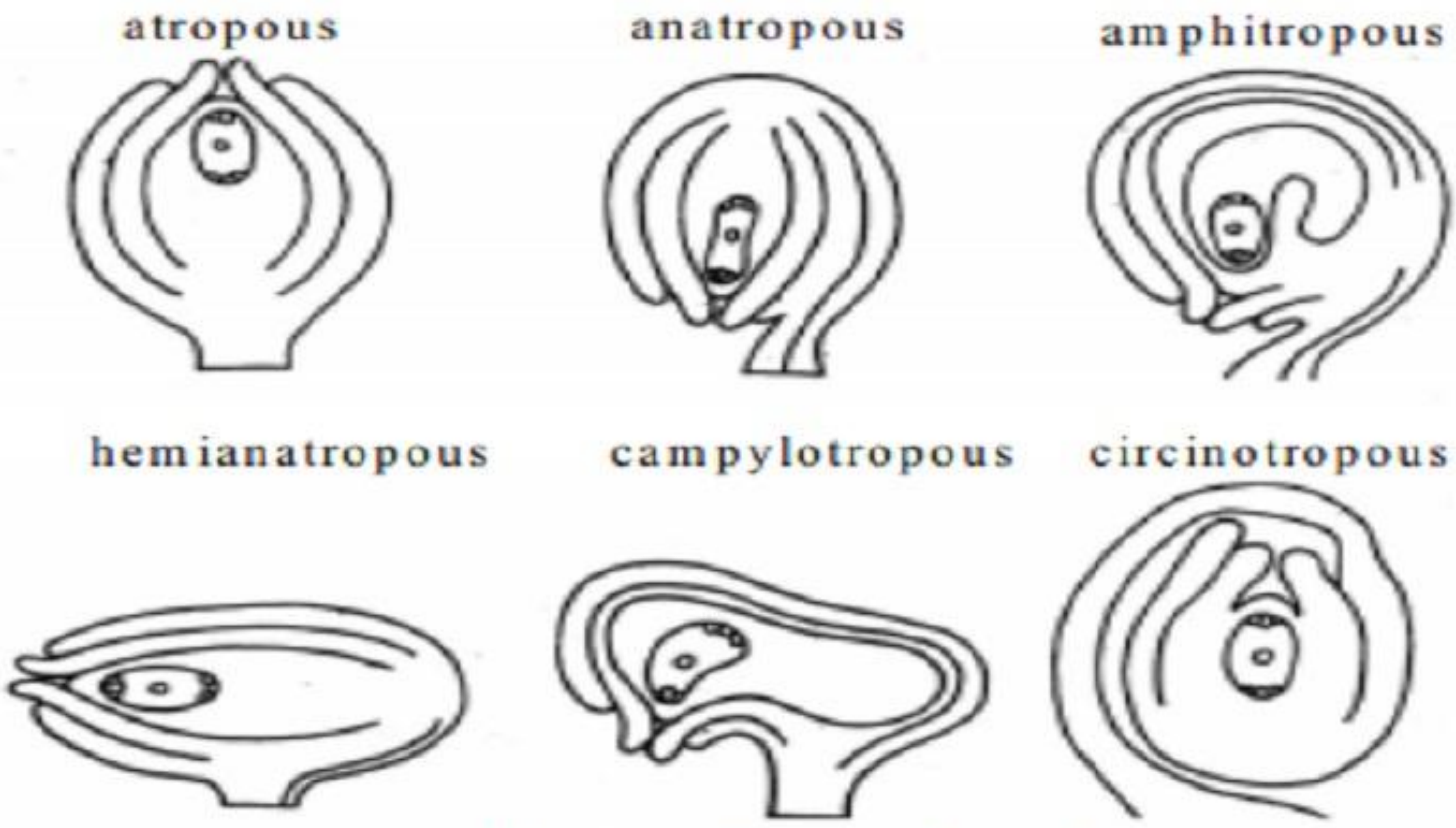
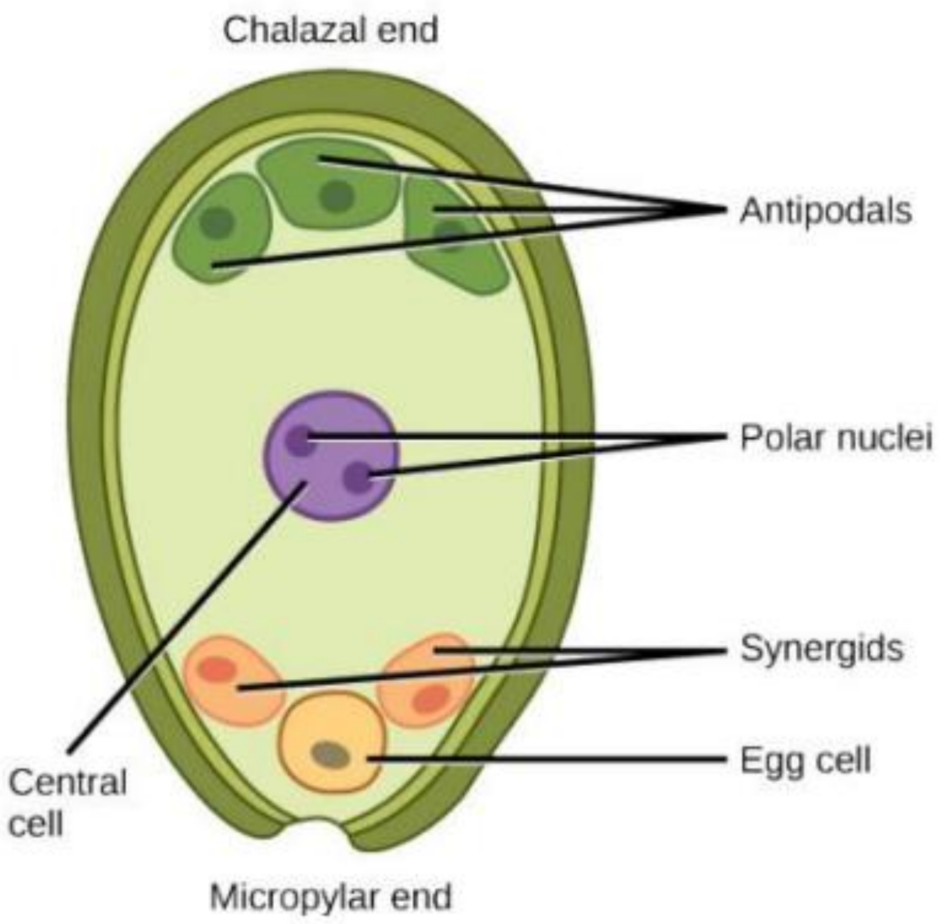


Fig. Types of ovules

Embryo sac struture

- Three cells are grouped together at the micropylar end and consist of **two synergids** and one **egg cell**.
- Three cells are at the **chalazal end** and are called the **antipodals**.
- The large central cell, has two **polar nuclei**.



Development of megaspore:

- In general, a single hypodermal cell of the nucleus differentiates to form the archesporium.
- It becomes more prominent due to its large size, denser cytoplasm and distinct nucleus and is called a **primary sprorogenous cell**.
- The primary sporogenous cell directly functions as a **megaspore mother cell**.
- The megaspore mother cell divides meiotically to form a **tetrad** of four haploid cells.
- The first division is always transverse to form **dyad cells.** The second division is also transverse to form a linear tetrad of four megaspores.
- Usually only one of the four megaspores is functional and forms the **embryo sac** or **female gametophyte**. The other three degenerate.

Development of female gametophyte or embryo sac:

- Megaspore represents the first stage of the female gametophyte and hence develops to form the female gametophyte.
- The female gametophyte is also called an embryo sac.
- The megaspore enlarges and its nucleus divides mitotically to form **two nuclei**.
- The two nuclei are pushed towards the opposite poles of the cell by a vacuole.
- Both the nuclei divide twice by mitosis to form eight nuclei, four at **micropylar end** and four at the **chalazal end.**
- This is followed by the cellular organization of the embryo sac.
- One nucleus from each pole moves towards the center of the embryo sac and fuses to form a **polar nucleus** or **secondary nucleus**.

- The remaining three nuclei at the micropylar end organize into **egg apparatus.** This egg apparatus consists of **two lateral synergids** and a median **large egg cell** or ovum or female gamete.
- Similarly, three nuclei from the chalazal end form the **antipodal cells.** In many plants, the antipodals are persistent and show a possible role in the nutrition of the embryo sac.
- A mature female gametophyte before fertilization has **seven nuclei**;
    - 3 in egg apparatus
    - 3 in antipodal cells
    - A diploid polar nucleus
- Antipodal cells and the cells in the egg apparatus haploid in nature.
- The formation and development of female gametophyte is followed by the fertilization of the egg cell and the secondary nucleus by the male gametes.

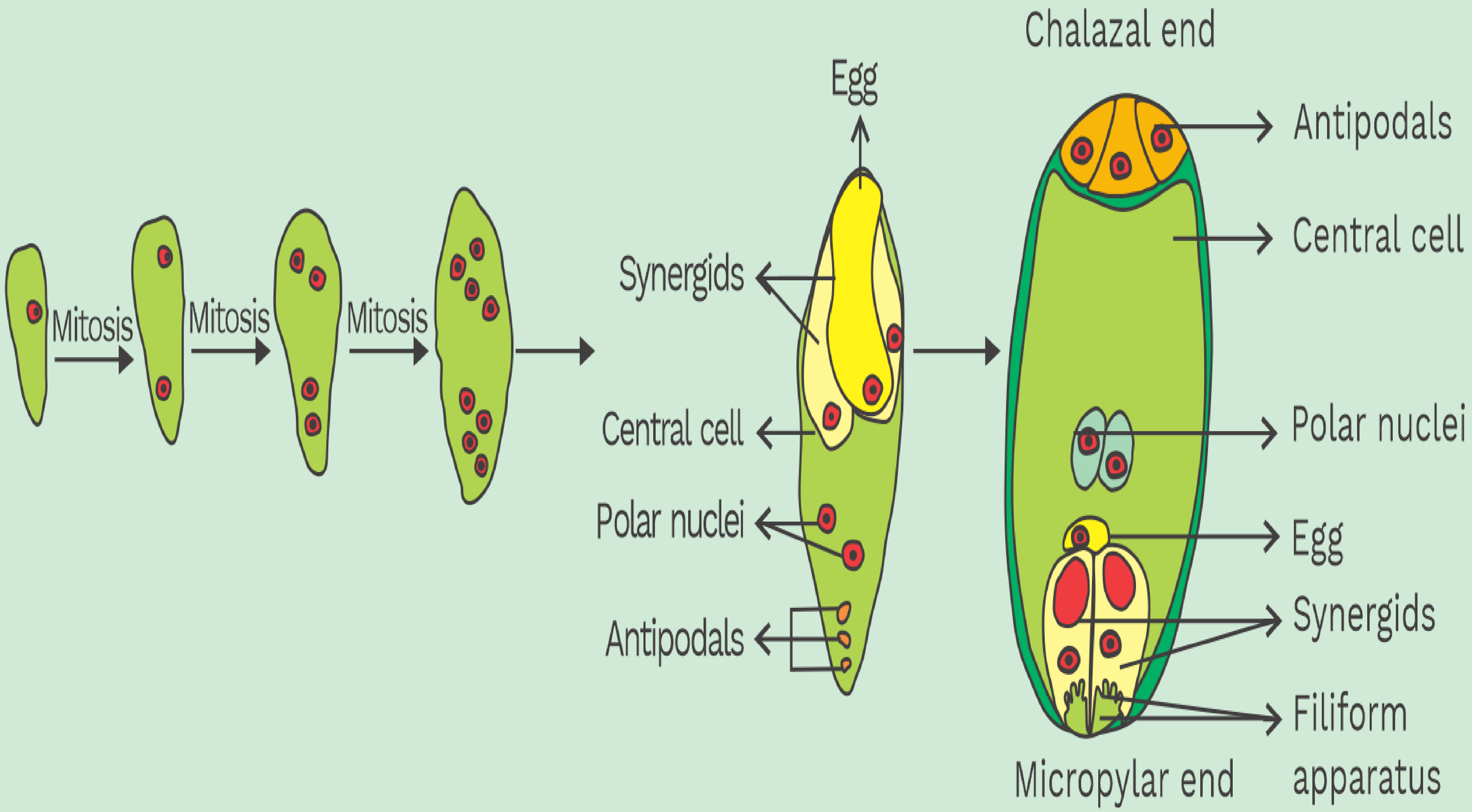
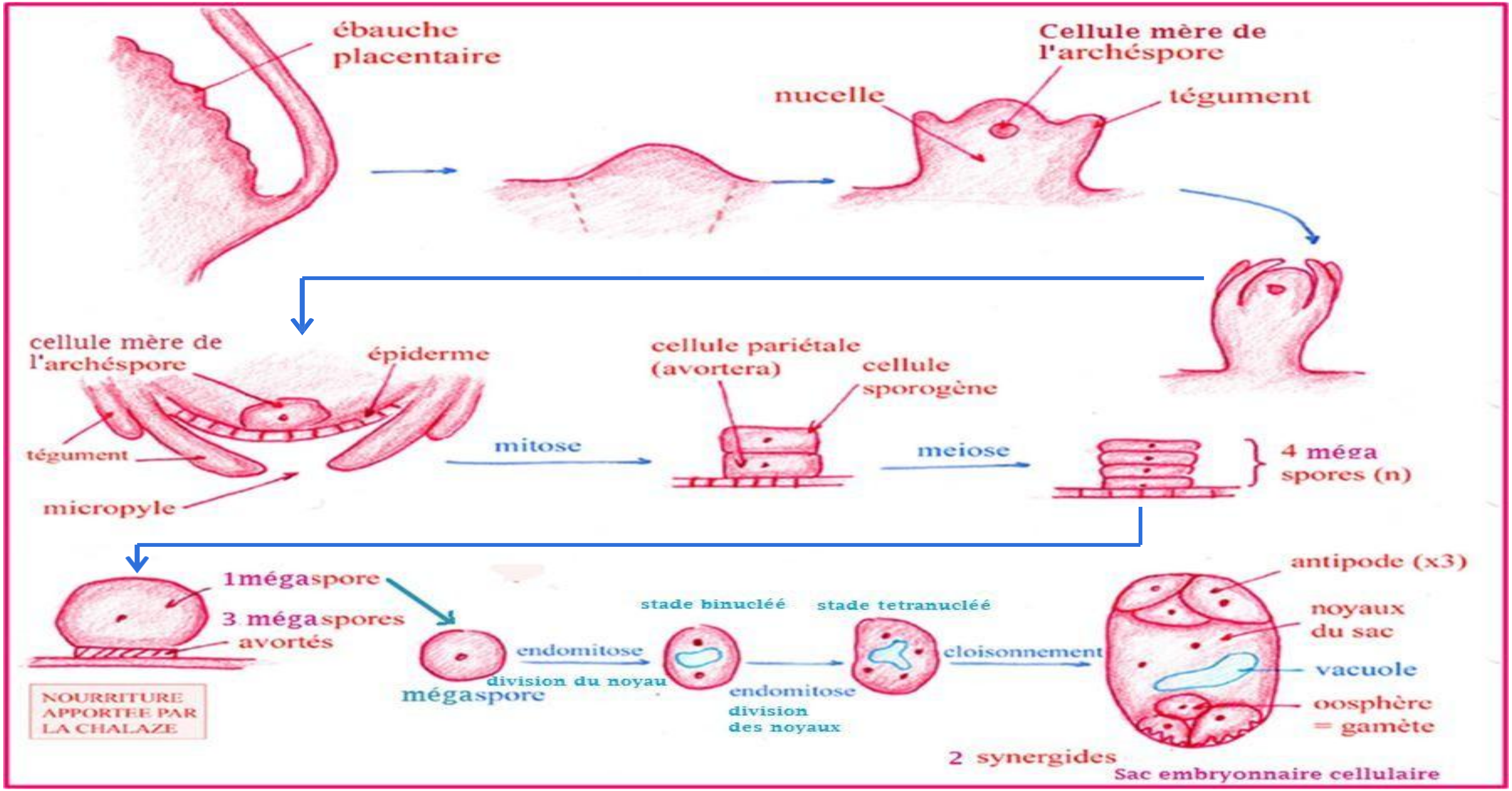
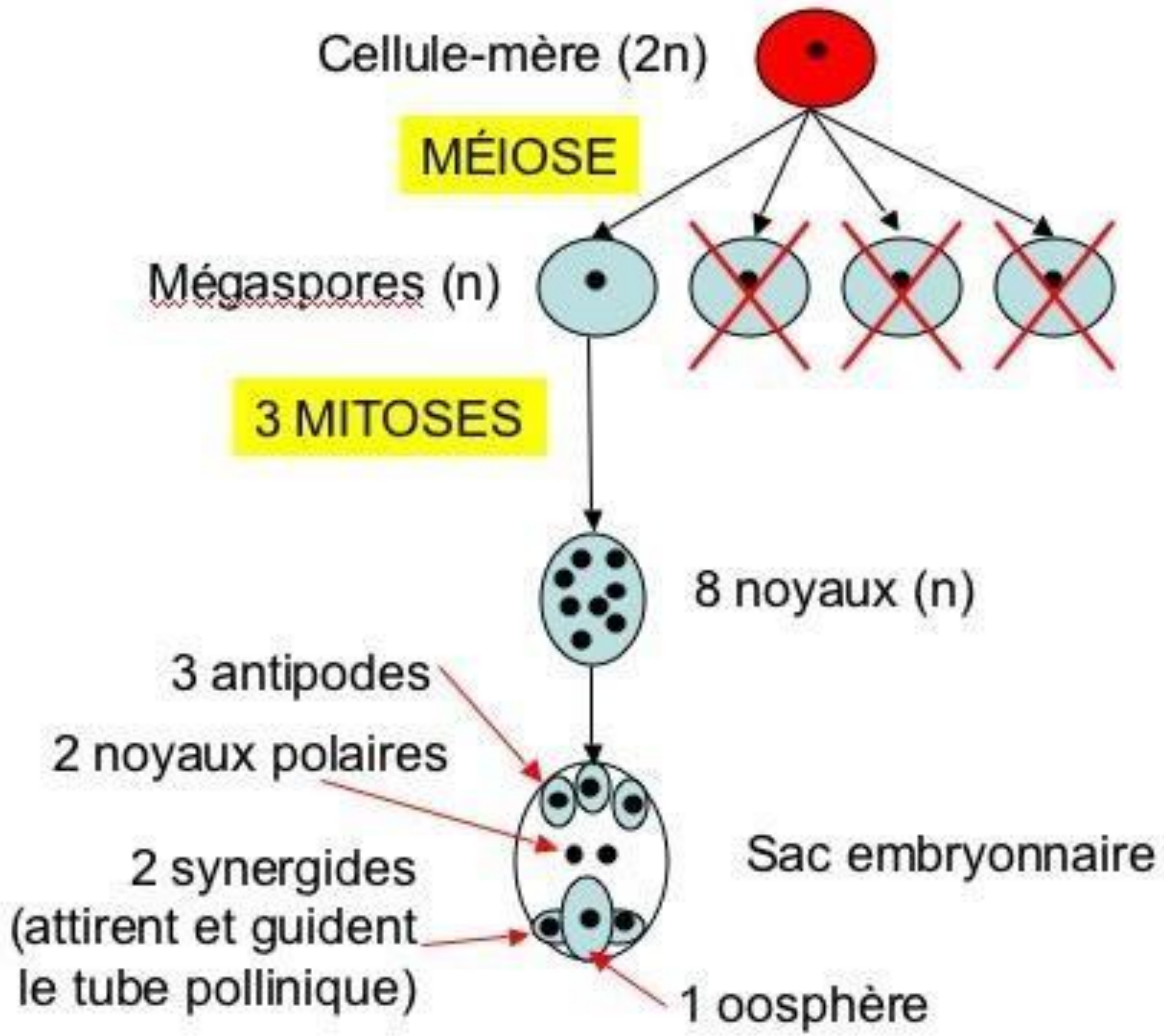


FIG. DEVELOPMENT OF EMBRYO SAC FROM FUNCTIONAL MEGASPORE



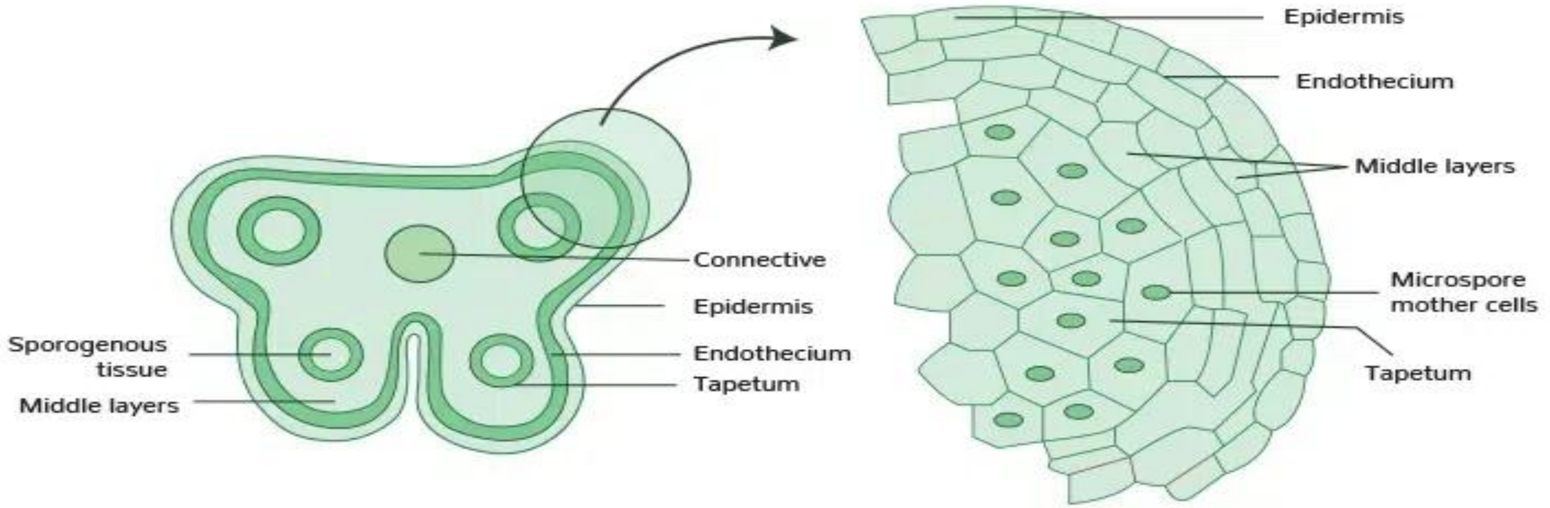
ébauche
placentaire
Cellule mère de
l'archéspore
nucelle
tégument
cellule mère de
l'archéspore
épiderme
tégument
tégument
micropyle
mitose
cellule pariétale
(avortera)
cellule
sporogène
meiose
4 méga
spores (n)
1mégaspore
3 mégaspores
avortés
NOURRITURE
APPORTEE PAR
LA CHALAZE
stade binucléé
stade tetranucléé
endomitose
division du noyau
mégaspore
endomitose
division
des noyaux
cloisonnement
antipode (x3)
noyaux
du sac
vacuole
oosphère
= gamète
2 synergides
Sac embryonnaire cellulaire

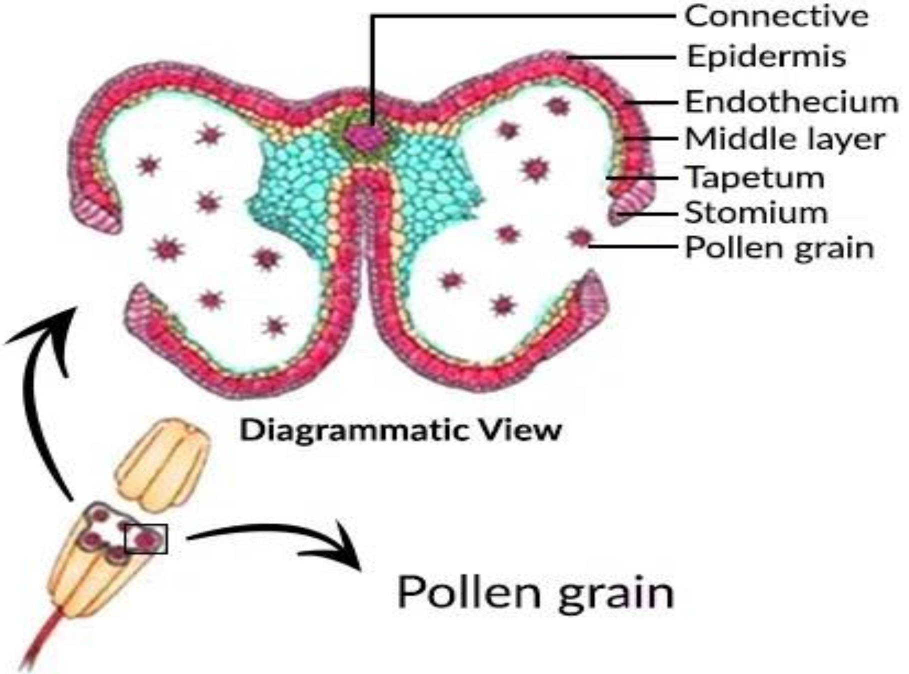

Cellule-mère (2n)
MÉIOSE
Mégaspores (n)
3 MITOSES
8 noyaux (n)
3 antipodes
2 noyaux polaires
2 synergides
(attirent et guident
le tube pollinique)
Sac embryonnaire
1 oosphère

Male Gametogenesis

- -Formation of male gametes (pollen grains) in the anther and females in the carpels.

Bilobed Anther - Structure of an Anther

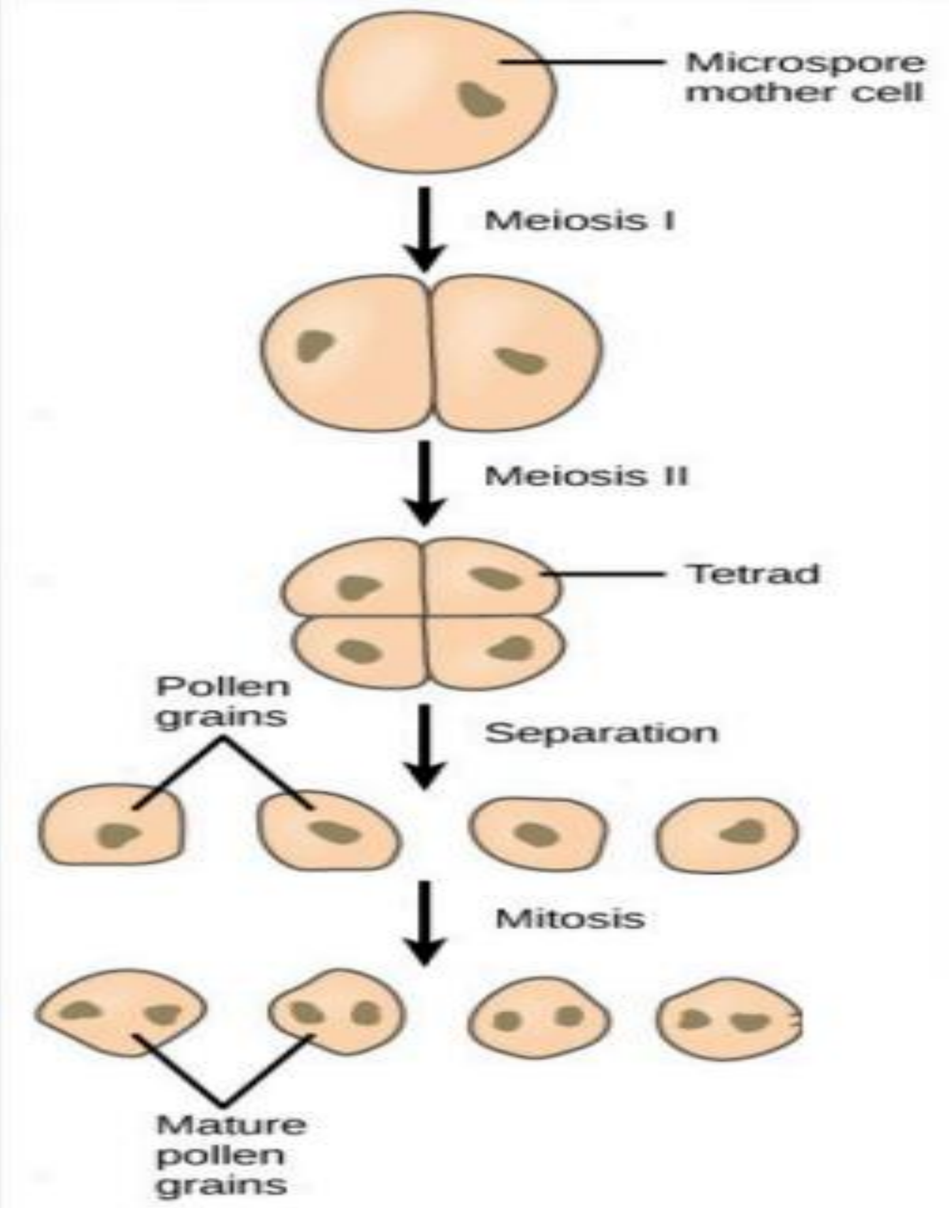




Development of male gametophyte (pollen grain)

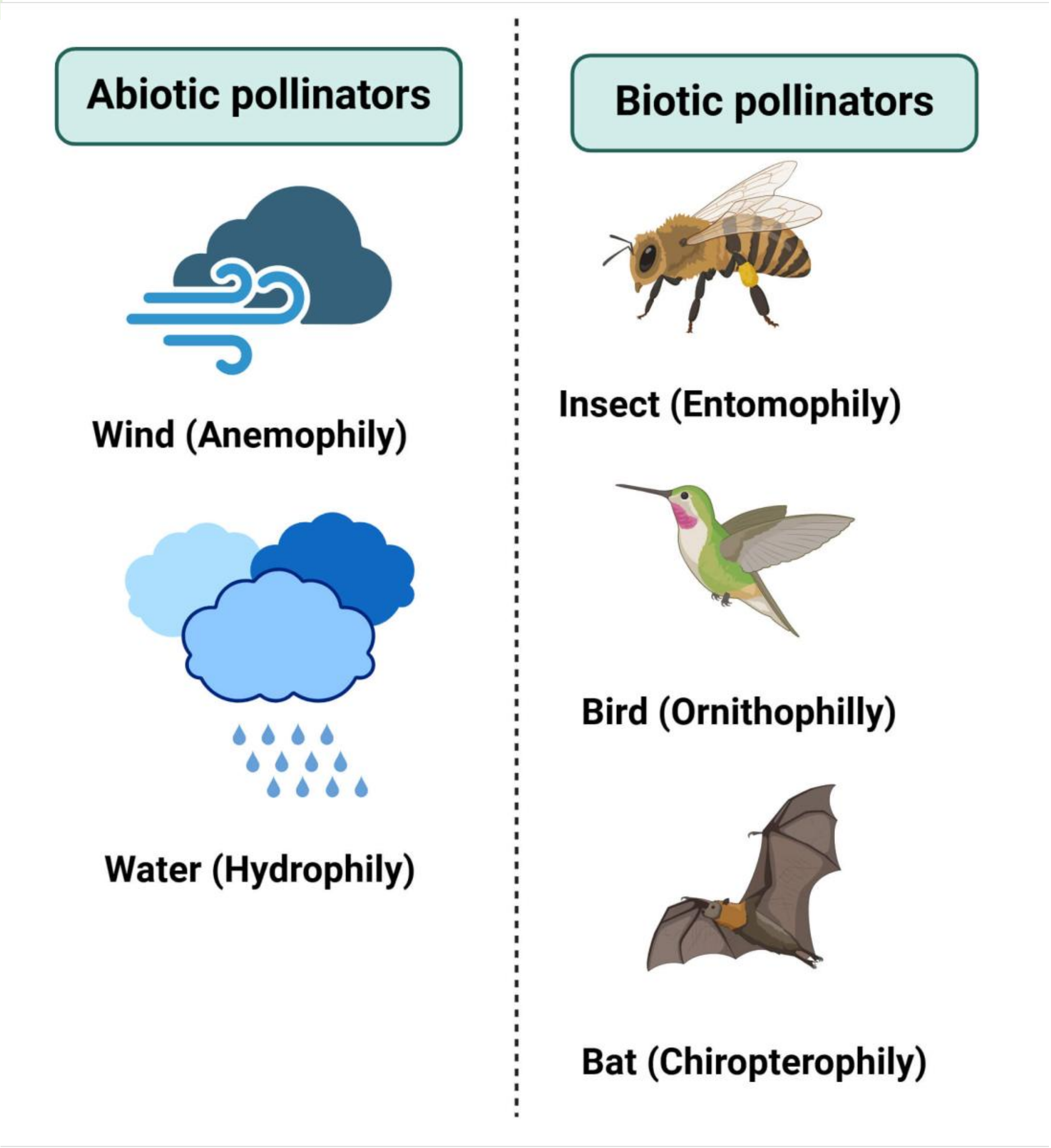
Within **the microsporangium (pollen sac),** the **microspore mother cell** which is **diploid** cell divides by meiosis to give rise to **four haploid microspores or pollen grains.**

- The single nucleus of the pollen grain divides by mitosis to form **two nuclei**: **tube nucleus** and **generative nucleus**.
- The cell wall is developed between the two to form unequal cells, a smaller generative cell and larger tube or vegetative cell.



Pollination

- The transfer of pollen grains from the anther to the stigma is called pollination .
- Pollen grains are immobile .
- They cannot reach the stigma by themselves .
- An external agent is required for this . It can be wind , water , animal , gravity or growth contact
- Pollination is of two types self pollination and cross pollination



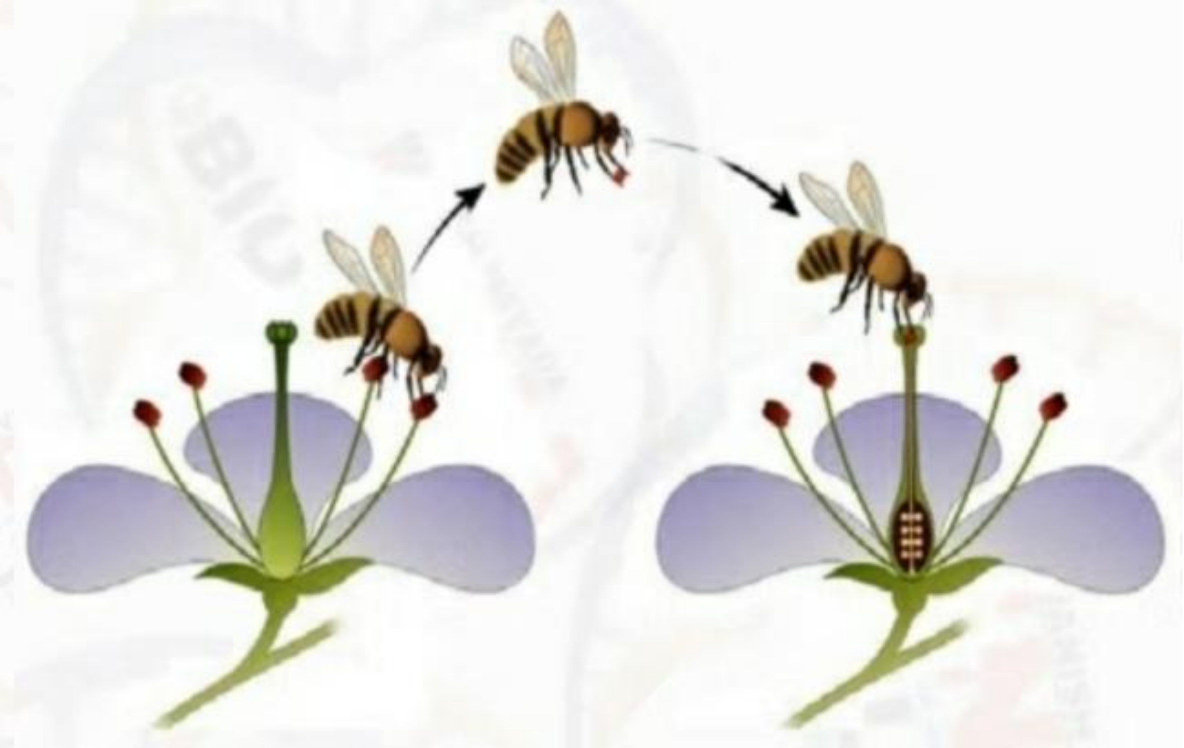
Pollination

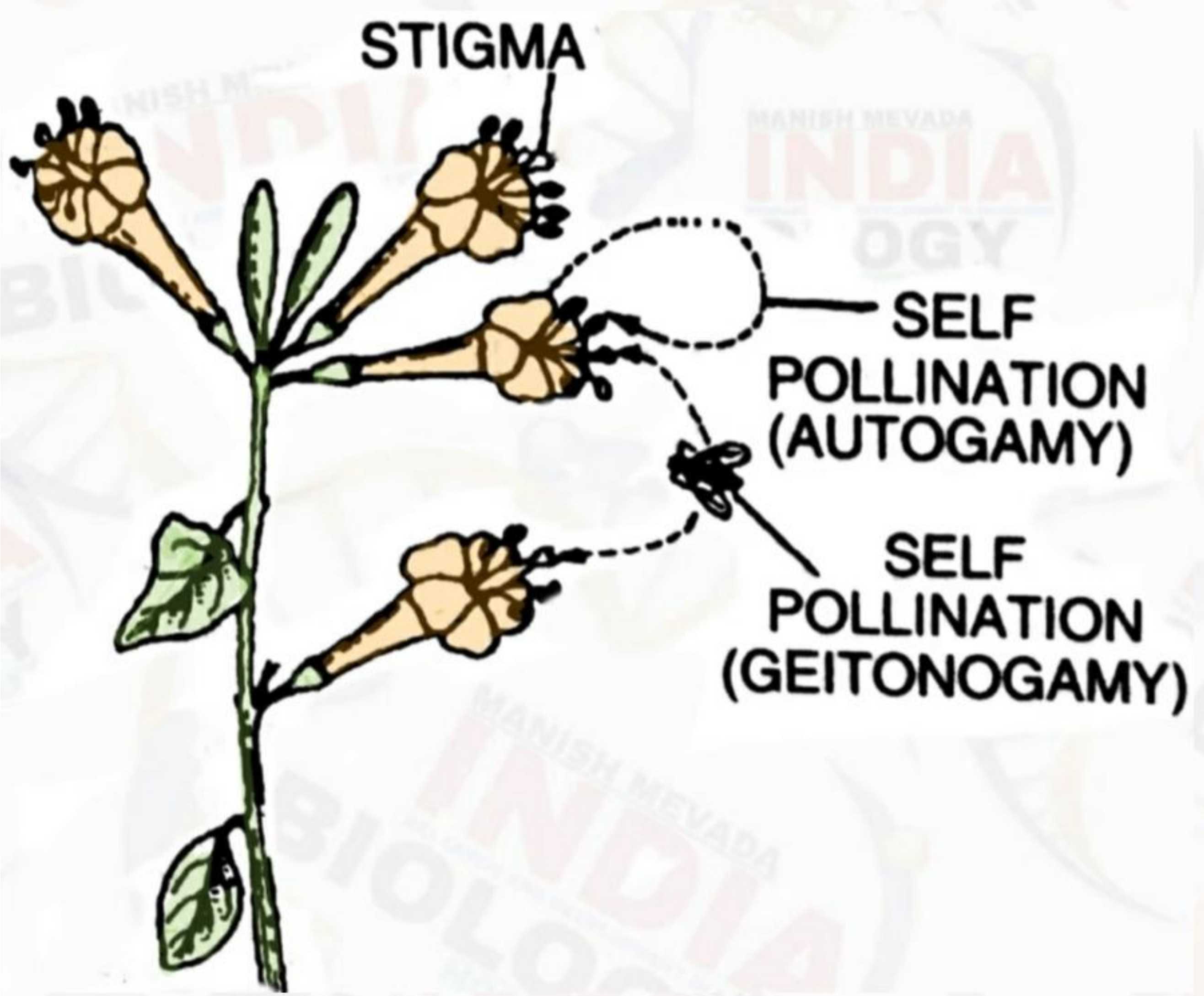
- Transfer of pollen grains from the anther to the stigma of a pistil.
- **Kinds of Pollination :** Depending on the source of pollen, pollination can be divided into three types.

a-Autogamy* (self-pollination) *: Transfer of pollen grains from the anther to the stigma of the same flower.

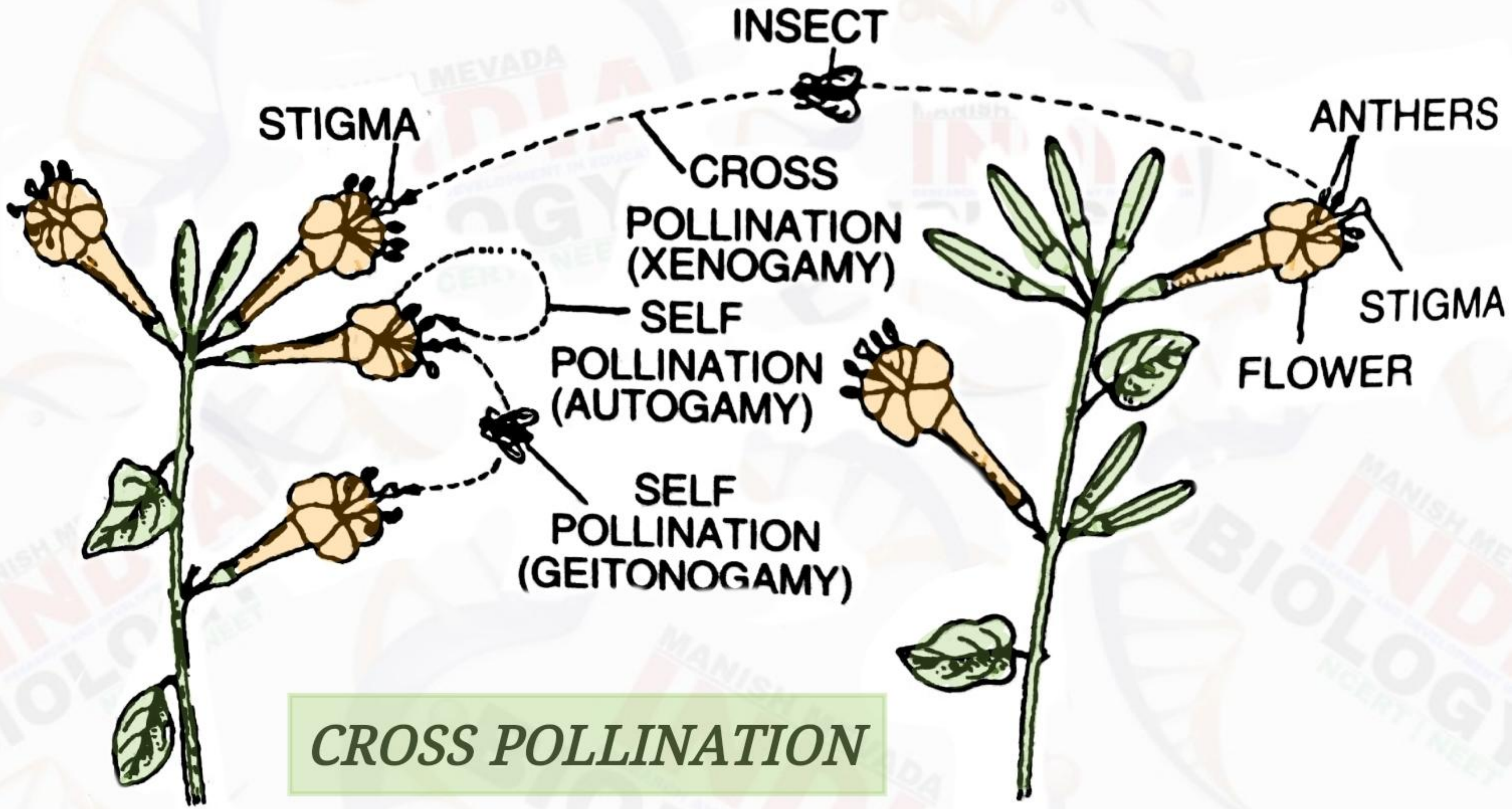
b-Geitonogamy – *Transfer of pollen grains from* the anther to the stigma of another flower of the same plant.

C-***Xenogamy*** – *Transfer of pollen grains from* anther to the stigma of a different plant.





SELF POLLINATION



CROSS POLLINATION

Pollinating Agents

Pollen grains are inert and their transport to a stigma is ensured by external pollinating agents.

- **Anemophilous plants**: wind-pollinated, referred to as anemogamy. 20% of Angiosperms are pollinated by wind, and their pollen grains are adapted to this.
- **Entomophilous plants**: insect-pollinated, referred to as entomogamy. Almost all remaining Angiosperm species are pollinated by animals, including birds but primarily insects.
- **Hydrophilous plants**: A small fraction is pollinated by water.

Pollen Germination

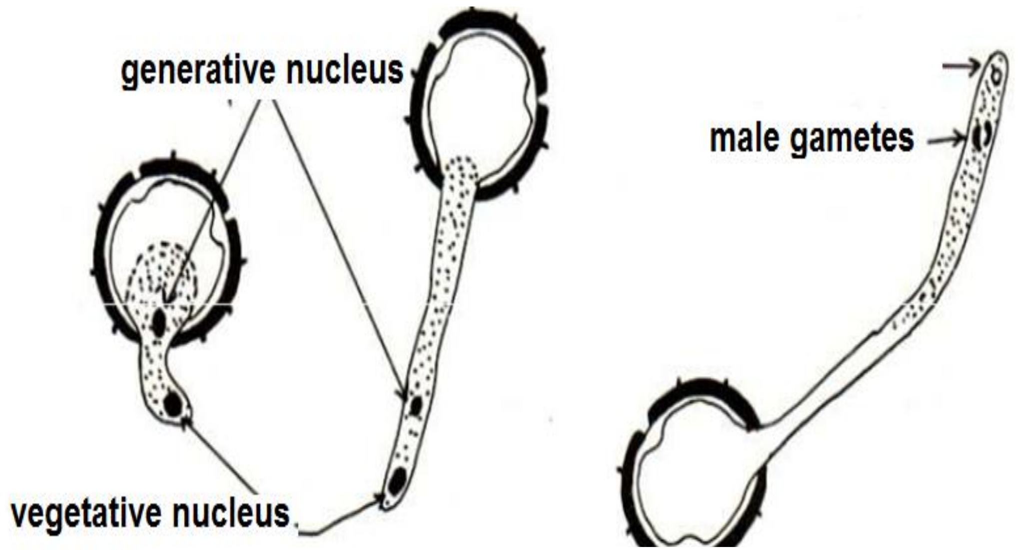
Germination of the Bicellular Pollen Grain

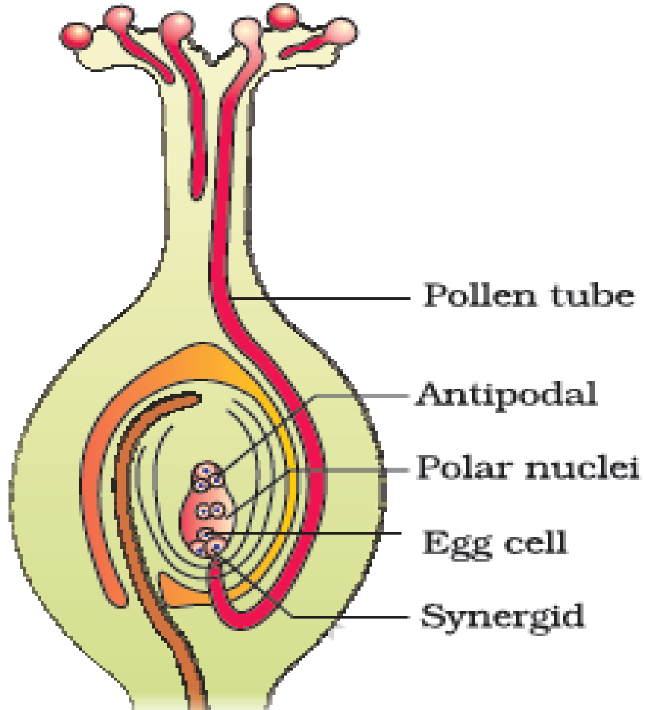
The end of male gametogenesis occurs after pollination. The dehydrated pollen grain that arrives at the stigma level is first recognized, then accepted.

An osmotic potential difference between the pollen grain and the receptive tissues of the pistil leads to a movement of water toward the pollen. The pollen grain is then hydrated, its size increases.

Double Fertilization

- the pollen grain germinates on the stigma to produce a pollen tube through one of the germ pores.
- The contents of the pollen grain move into the pollen tube.
- The generative nucleus divides by mitosis to form **2 male gametes.**
- Pollen tube grows through the tissues of the stigma and style and reaches the ovary.
- Pollen tube enters the ovule through the micropyle.





Double fertilisation

- After entering the ovule:
- One of the male gametes fuses with the egg cell = **syngamy.** This results in the **formation of a diploid cell, the zygote**.
- The other **male gamete** fuses with the two polar nuclei located in the center= **triple fusion.** to produce a **triploid primary endosperm nucleus (PEN).**
- Since two types of fusions, **syngamy** and **triple fusion** take place in an embryo sac the phenomenon is termed **double fertilisation**, an event unique to **flowering plants or angiosperms**

Double Fertilization

The pollen tube continues its elongation in the style. It crosses the nucellus, enters the ovule through the micropyle, and reaches the upper part of the embryo sac, i.e., the side of the gametic complex (oosphere + synergids).

It enters the embryo sac by pushing aside the synergids to approach the oosphere. At this moment, the tip of the tube lyses to release the 2 spermatozoa, one of which moves toward the oosphere and the other toward the polar nuclei.

This results in the formation of:

- **A principal zygote (2n)** by the fusion of the oosphere nucleus with the sperm nucleus
- **An accessory triploid zygote (3n)** by fusion of the second sperm nucleus with the 2 polar nuclei that have previously fused together

two zygotes are formed:

- A principal zygote and An accessory zygote, For this reason, we say that Angiosperms undergo double fertilization.

Embryogenesis

Embryogenesis means the formation of the embryo.

The 2 zygotes (principal zygote and accessory zygote) that result from double fertilization have different destinies.

Fate of the Diploid Principal Zygote (2n)

A few days after fertilization, the principal zygote undergoes a first mitosis and gives 2 superimposed cells:

- A basal cell close to the micropyle
- An apical or terminal cell on the chalaza side

the Basal Cell

It undergoes several transverse divisions to form a uniseriate multicellular filament called the suspensor, which allows not only the attachment of the embryo in the ovule but also its nutrition. It disappears at the maturity of the embryo.

the Apical or Terminal Cell

After several mitoses carried out in several planes, it forms the globular pro-embryo, which has axial symmetry. From this stage, embryo formation continues differently in Dicotyledonous Angiosperms and Monocotyledonous Angiosperms.

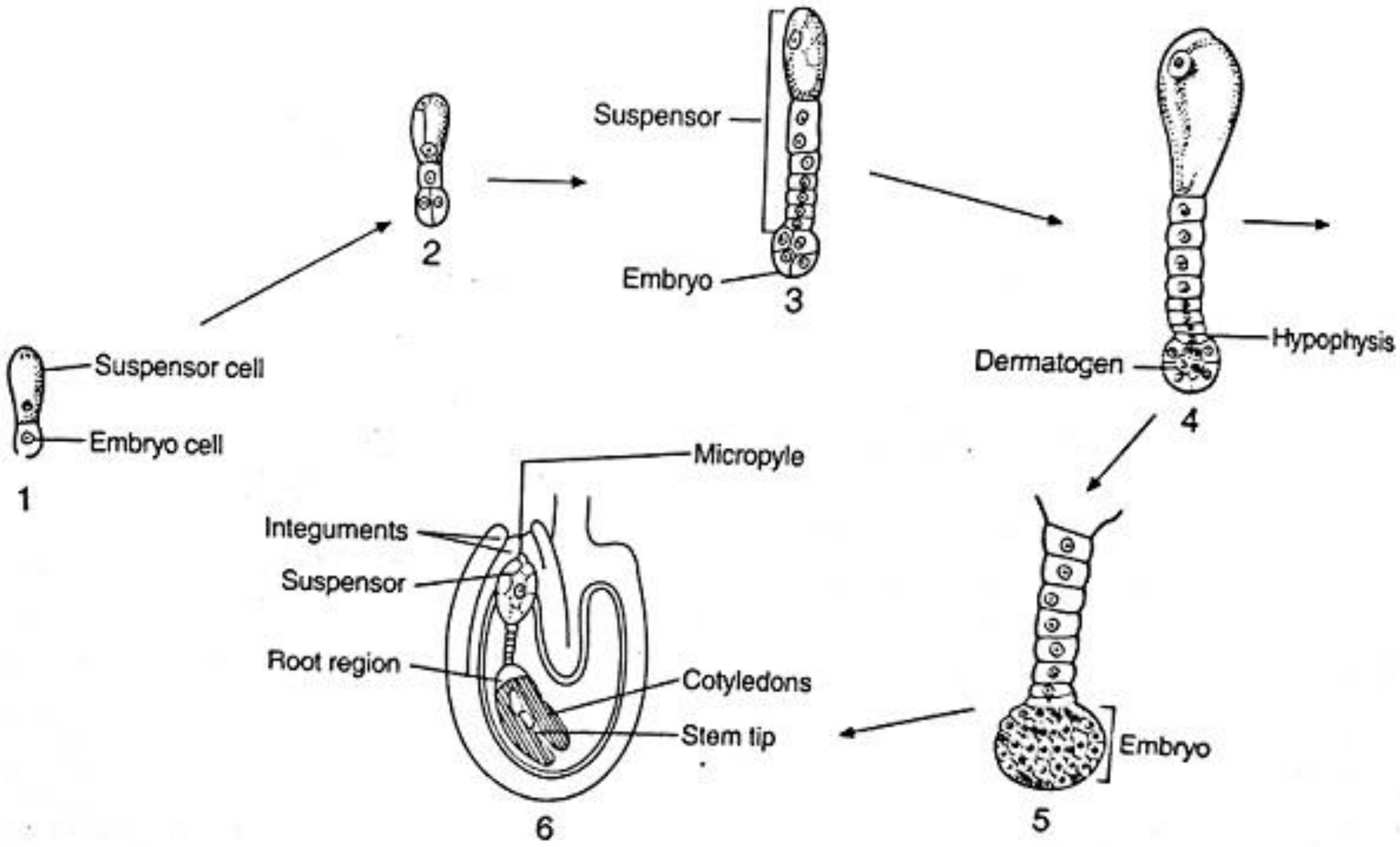
Formation of the Dicotyledonous Angiosperm Embryo

The globular pro-embryo undergoes numerous mitoses while changing symmetry, becoming bilateral by the uplifting of 2 lobes, called cotyledonary lobes, which later develop into 2 cotyledons. At this stage, the embryo of Dicotyledonous Angiosperms is cordiform (heart-shaped). Between the 2 lobes, 2 meristems are constituted:

- A caulinary meristem at the caulinary pole
- A radicular meristem at the radicular pole

Mitoses and differentiation of the different parts continue to constitute the definitive embryo or very young seedling composed at this stage of:

- 2 cotyledons
- The gemmule located between the cotyledons (constituted by the caulinary meristem, which will allow the formation of the leafy stem after germination of the seed)
- The radicle
- And the hypocotyl, located between the gemmule and the radicle, constituting the stemlet of the very young seedling



Suspensor cell
Embryo cell
1
2
Suspensor
Embryo
3
Hypophysis
Dermatogen
4
Embryo
5
Micropyle
Integuments
Suspensor
Root region
Cotyledons
Stem tip
6

Formation of the Monocotyledonous Angiosperm Embryo

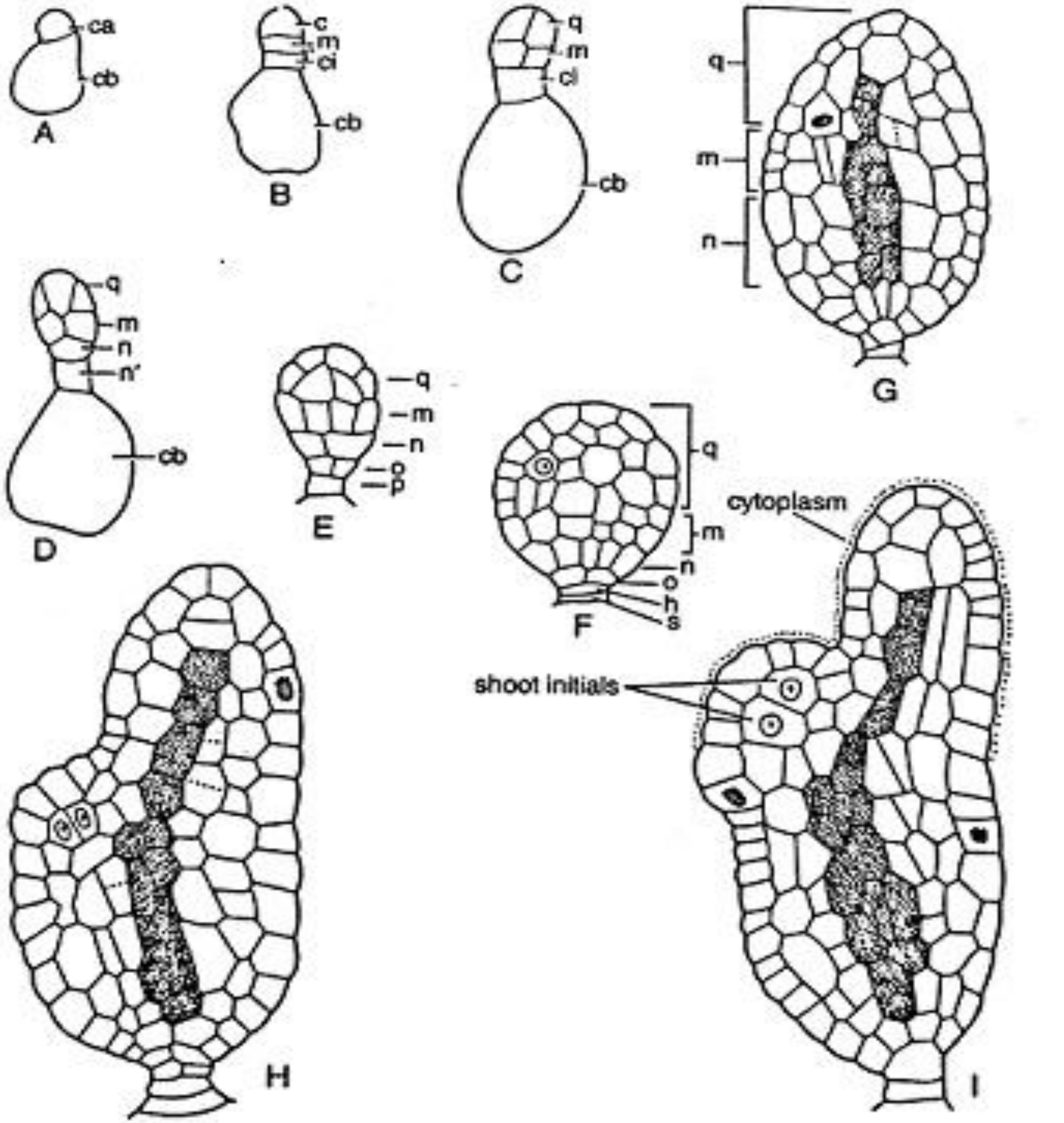
In Monocotyledons, the stages are identical to those of dicotyledonous Angiosperms up to the globular stage. From this stage of embryogenesis, there is an uplifting of a single cotyledonary lobe, which develops into a single cotyledon (the embryo does not pass through the cordiform stage at all).

The definitive embryo or very young seedling is therefore composed of:

- A single cotyledon
- A gemmule
- A radicle
- And the hypocotyl, located between the gemmule and the radicle

Fate of the Triploid Accessory Zygote (3n)

The accessory zygote is formed after the principal zygote; it undergoes much more rapidly numerous mitoses to quickly form a nutritive tissue called albumen, whose role is to ensure nutrition for the development of the embryo.



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Formation of the Seed

During the development of the embryo and albumen, the ovule develops considerably, increasing in volume.

The integuments and nucellus undergo the following transformations:

The Integuments

The walls of the cells that constitute the 2 integuments thicken and lignify to varying degrees depending on the species. They become the seed coat that ensures protection.

Transformation of the Nucellus

The transformation of the nucellus also varies according to species to constitute different types of seeds:

Albuminous Seeds

The nucellus is progressively destroyed until it completely disappears, digested by the albumen, which develops to become voluminous. The albumen then becomes a nutritive tissue. Examples: Castor or date seeds.

Ex albuminous Seeds

The nucellus completely disappears, digested by the albumen, which is itself completely digested by the embryo during its development. The latter then stores the nutritive substances in its cotyledons, which become very voluminous, occupying the entirety of the seed. Examples: Bean, pea, sunflower seeds, etc.

Seeds with Perisperm

The nucellus persists and transforms by enriching itself with reserves; it becomes a nutritive tissue called perisperm, which largely replaces the albumen, which is reduced because it is digested by the embryo during its development. Examples: Pepper, beet seeds...

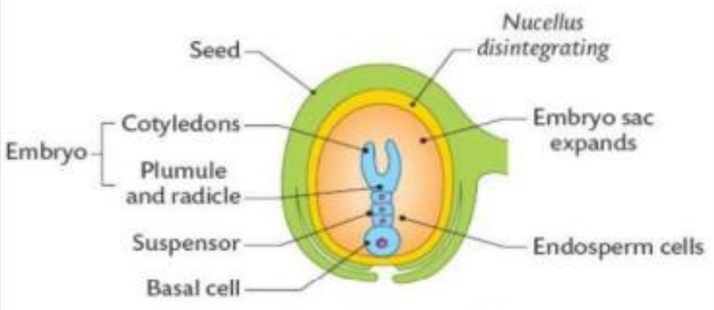
Types of Seeds

Non-endospermic/ Exalbuminous Seeds

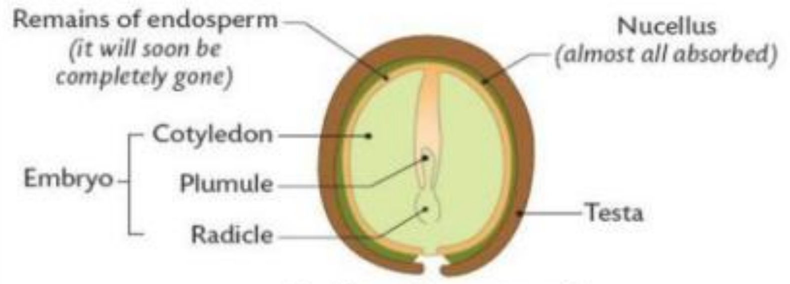
- The endosperm is completely consumed by the developing embryo.
- Examples: Gram, pea, groundnut

Endospermic/Albuminous Seeds

- The embryo does not consume all the endosperm and so, persists in the mature seed.
- Examples: Wheat, maize, barley



Albuminous seed



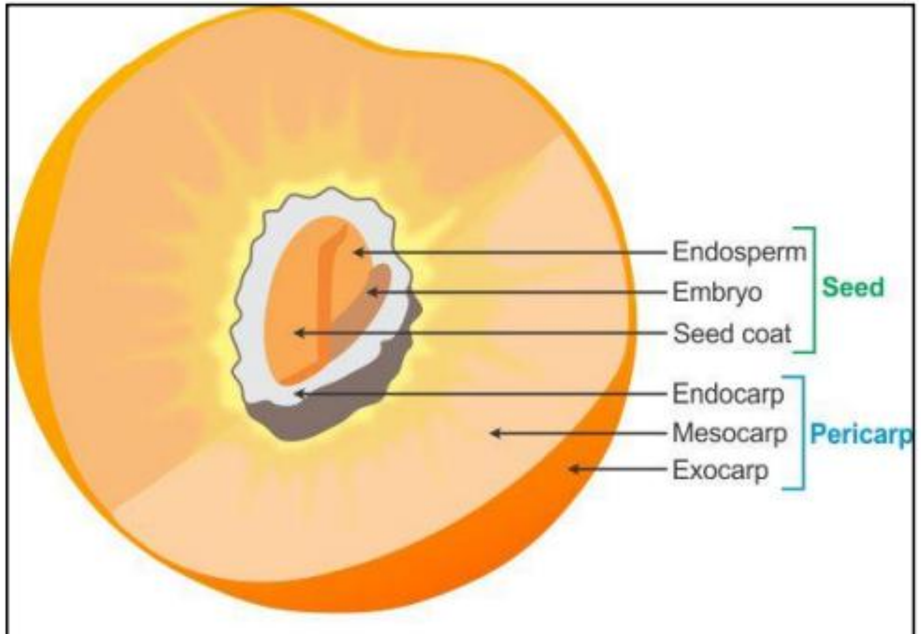
Exalbuminous seed

Formation of Fruits

Fertilization results in the transformation of ovules into seeds and the ovary into fruit under the action of different types of hormones (Auxin). Thus, the different tissues constituting the ovary—external epidermis, chlorophyllian parenchyma, and internal epidermis—transform to become the fruit constituted of the pericarp, which includes 3 parts:

- **Epicarp**: the outermost part of the fruit resulting from the transformation of the external epidermis
- **Mesocarp**: the central part resulting from the transformation of the chlorophyllian parenchyma (the flesh)
- **Endocarp**: the innermost part resulting from the transformation of the internal epidermis (the inner layer surrounding the seeds)

The fruit surrounds the seed.



Fruit

Types of Fruits

True Fruits	False Fruits	Parthenocarpic Fruits
Only the development of the ovary wall takes place.	Thalamus and other floral parts also proliferate along with the development of the ovary wall.	These are seedless fruits which develop without fertilisation.
Examples: Apple, cashew, strawberry	Example: Mango	Example: Banana