Chapter 1: Reproduction in Lower and Higher Plants

Introduction to Reproduction

- **Definition**: Reproduction is the process of producing new individuals or offspring.
- **Significance**:
  - Essential for the continuation of a species.
  - Maintains continuity of life on Earth.
- **Types**:
  Reproduction methods are broadly categorized into:

1. **Asexual Reproduction**
2. **Sexual Reproduction**

1.1 Asexual Reproduction

- **Definition**: A method of reproduction that **does not involve the fusion of gametes (male and female cells)**.
- **Characteristics**:
  - Only **one parent** is involved.
  - Offspring are **genetically identical** to the parent (called **clones**).
  - Involves simple mitotic division.
  - No new genetic variation occurs.

Modes of Asexual Reproduction

1. Fragmentation

- Occurs in **multicellular organisms**.
- The organism breaks into **two or more fragments**.
- Each fragment grows into a **new individual**.
- **Example**: *Spirogyra* (a filamentous green alga).

2. Budding

- Common in unicellular organisms like **Protosiphon** and **Yeast**.
- Process:
  - Small outgrowths (buds) form on the parent under favourable conditions.
  - Buds separate to become new individuals.

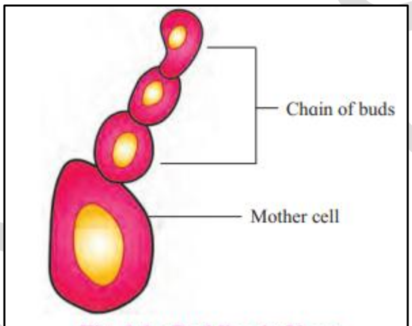

Fig. 1.1 : Budding in Yeast

3. Spore Formation

- Occurs in organisms like **Chlamydomonas**.
- Involves the production of **zoospores**.
- Zoospores are **motile, flagellated spores** that grow into new individuals.

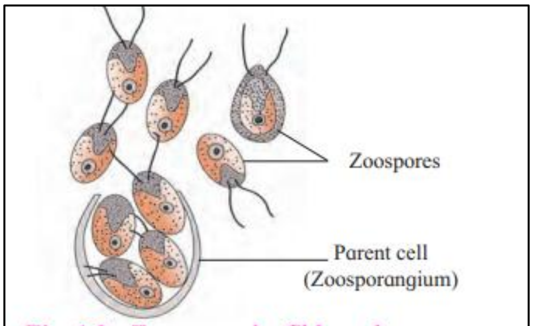

Fig. 1.2 : Zoospores in *Chlamydomonas*

Other Asexual Reproduction Methods

- **Binary Fission** – e.g., *Chlorella*, *Diatoms*, *Chlamydomonas*.
- **Conidia Formation** – e.g., *Penicillium*.
- **Gemma Formation** – e.g., *Marchantia*.

Vegetative Reproduction

- Plants can reproduce **asexually** through **vegetative parts** like roots, stems, and leaves.
- New plants formed by this method are **genetically identical to the parent plant** (clones).
- Some vegetative reproduction methods **do not occur naturally** and are used in **agriculture and horticulture** to:
  - Multiply stock plants.
  - Produce desired varieties.
  - Adapt to human needs.

Artificial Vegetative Propagation Methods:

a. Cutting

- A small piece of plant (stem, leaf, or root) with **one or more buds** is used.
- This method is simple and cost-effective.
- **Examples**:
  - Stem cutting: *Rose*, *Bougainvillea*
  - Leaf cutting: *Sansevieria*
  - Root cutting: *Blackberry*

b. Grafting

- **Two plants** are joined to form **one single plant**.
- The **Scion** (desired plant stem) is grafted onto a **stock** (rooted plant).
- **Used in fruit trees** like Apple, Pear, and Rose.
- **Bud grafting**: A single bud is joined to the stock.

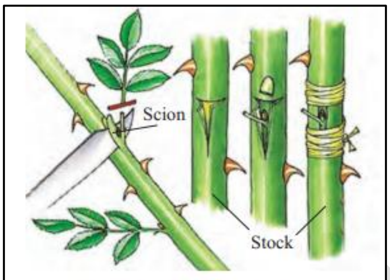

Fig. 1.3 : Grafting in Rose

  - Scion
  - Stock
  - Tied graft union

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c. Tissue Culture

- A modern technique where **small tissue pieces** are cultured to grow **many identical plantlets**.
- Used in **micropropagation**.
- Popular for mass-producing plants with **desirable traits**.

1.2 Sexual Reproduction

- Involves the **fusion of two gametes** (male and female).
- Common in most **mature flowering plants**.
- Leads to **genetic variation** in the offspring.

Role of the Flower

- Flower is the **reproductive organ** where sexual reproduction occurs.
- Function:
  - Produces **haploid gametes**.
  - Enables **fertilization**.
- A typical flower contains **four whorls**:

1. **Calyx**
2. **Corolla**
3. **Androecium** (male part)
4. **Gynoecium** (female part)

Events in Sexual Reproduction

1. **Meiosis** – to form haploid gametes.
2. **Fertilization** – fusion of gametes to form **diploid zygote**.
3. **Embryogenesis** – formation of the embryo from the zygote.

- Results in **genetically different offspring**.
- Leads to **diversity** and evolution in plants.

Phases of Sexual Reproduction

1. **Pre-Fertilization**
2. **Fertilization**
3. **Post-Fertilization**

Male Reproductive Part of Flower

- Known as **Androecium**.
- Made up of **stamens**, each consisting of:

- **Filament**
- **Anther** (pollen-producing part)
- **Connective**

Structure of Anther

- Typically:
  - **Di-thecous** (has two lobes)
  - **Tetrasporongiate** (each lobe has two pollen sacs)
- Contains **four pollen sacs** in total.
- Young anther contains:
  - **Sporogenous tissue** surrounded by epidermis.
  - These are **diploid** and divide meiotically to form **microspores/pollen grains**.

T.S. of Anther (Transverse Section)

- The primary cell (archesporial cell) divides into:
  - **Primary Parietal Cells** – form wall layers.
  - **Primary Sporogenous Cells** – form pollen/microspores.
- Wall layers of the anther (from outside to inside):

1. **Epidermis** – protective outermost layer.
2. **Middle Layers** – 1 to 2 layers of thin-walled cells.
3. **Endothecium** – radial, fibrous thickenings help in **dehiscence** (breaking open to release pollen).
4. **Tapetum** – innermost layer, rich in cytoplasm and nutrition. Nourishes developing microspores.

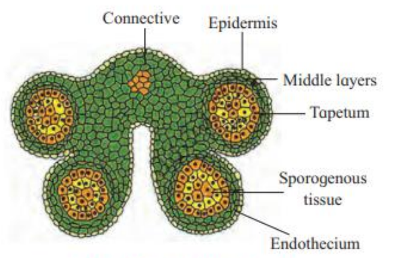

Fig. 1.4 : (a) T. S. of anther

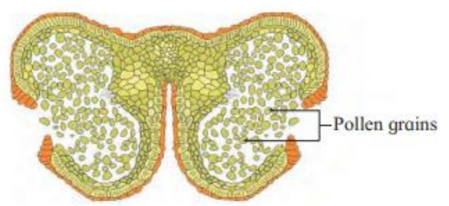

Fig. 1.4 : (b) Dehisced anther

1.3 Microsporogenesis

- Process by which **microspore mother cells** (MMC) divide **meiotically** to form **haploid microspores** or **pollen grains**.

Structure of a Microspore (Pollen Grain)

- Each pollen grain is:
  - **Non-motile**
  - **Haploid**
  - **Unicellular** (has a single nucleus)
- Surrounded by two-layered wall:

1. **Exine**:
   - Outer, **thick and resistant**.
   - Made of **sporopollenin** – very durable and **non-biodegradable**.
   - Sometimes has **sculpted patterns** or **germ pores** (thin areas for pollen tube emergence).
2. **Intine**:
   - Inner wall.
   - Made of **cellulose and pectin**.
   - Lies just below exine.

Development of Male Gametophyte

- Begins in the **pollen grain**.
- Undergoes **first mitotic division** to produce:
    1. **Vegetative cell**:
        - Large, food-rich, irregular shape.
        - Responsible for forming the **pollen tube**.
    2. **Generative cell**:
        - Small, thin-walled, and floats in the cytoplasm of the vegetative cell.
- **Second mitotic division**:
    - The **generative cell** divides again to form **two male gametes**.
    - Division may occur:
        - Inside the **pollen grain** or
        - Within the **pollen tube**.
    - Most **angiosperms** release pollen at the **2-celled stage** (vegetative + generative).

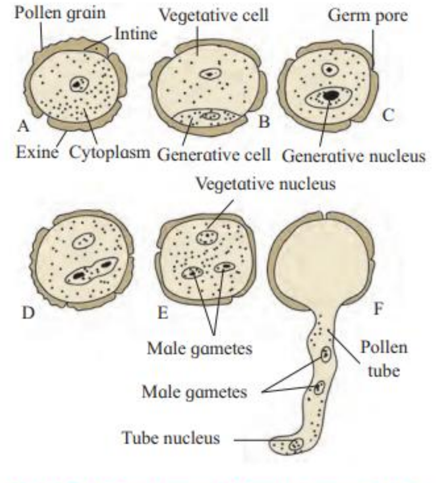

Fig. 1.5 : Development of male gametophyte

Female Reproductive Part: Gynoecium

- Also called **Pistil**.
- Made up of one or more **carpels**.
- Each carpel = **Megasporophyll**.

Types of Flowers:

1. **Apocarpous** – free carpels
   e.g., *Michelia*
2. **Syncarpous** – carpels fused together
   e.g., *Brinjal*

- Typical pistil has:
  - **Ovary**
  - **Style**
  - **Stigma**
- Based on **number of ovules** in ovary:
  - **Uniovulate** – one ovule e.g., paddy, wheat, mango)
  - **Multiovulate** – many ovules (e.g., tomato and lady's finger)

1.4 Structure of Anatropous Ovule

- **Most common type** in angiosperms.
- The **ovule**:
  - Develops inside **ovary**
  - Attached to **placenta** by **funiculus** (a stalk)
  - Junction = **hilum**
- **Nucellus** (main body) is protected by:
  - **Two integuments** (outer and inner)

- The **micropyle** is a small opening at the ovule's apex, opposite to **chalaza**.
- **Embryo sac** (female gametophyte) lies inside **nucellus**.

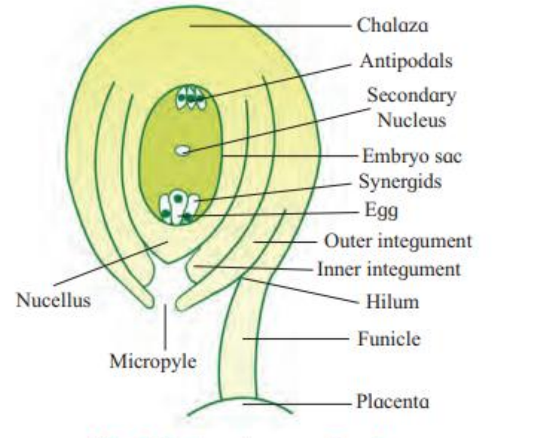

Fig. 1.6 : Anatropous Ovule

1.5 Megasporogenesis

Definition:

- It is the **process of forming haploid megaspores** from a diploid **megaspore mother cell (MMC)** via **meiosis**.
- The **MMC** is located in the **nucellus** (center of ovule near micropyle).

Development of Female Gametophyte

Step-by-step Process:

1. **MMC** undergoes **meiosis** to form **four haploid megaspores** in a linear arrangement.
2. Of the four, typically **only one (the functional megaspore)** remains; the rest **degenerate**.
3. Functional megaspore undergoes **three successive mitotic divisions**:
    - Results in **8 nuclei**:
        - **4 at micropylar end**
        - **4 at chalazal end**

- One nucleus from each pole migrates to the center and fuses to form **two polar nuclei**.

Structure of Embryo Sac (Mature Female Gametophyte):

- Consists of **7 cells and 8 nuclei**:
  - **1 Egg cell** (female gamete)
  - **2 Synergids** (with filiform apparatus – help guide pollen tube)
  - **3 Antipodal cells** (at chalazal end)
  - **1 Central cell** with **2 polar nuclei** (fuse to form **secondary/definitive nucleus**)

Called **monosporic development**, as the embryo sac develops from a **single megaspore**.

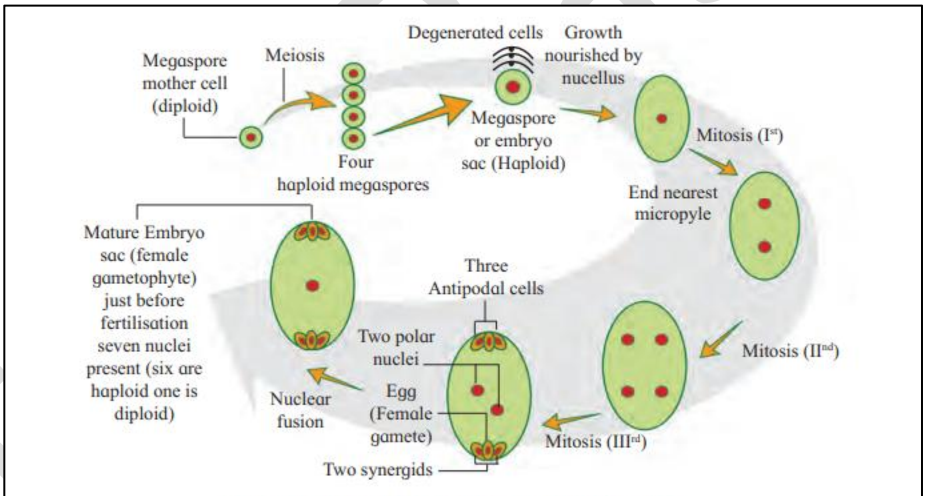

Fig. 1.7 : Development of female gametophyte

1.6 Pollination

📌 **Key Points:**

- **Pollination**: Transfer of **pollen grains** from **anther to stigma**.
- Angiosperms are **non-motile**, so they rely on **external agents** for pollination.

Types of Pollinating Agents:

1. **Abiotic**:
   - **Wind** (Anemophily)
   - **Water** (Hydrophily)
2. **Biotic**:
   - **Insects**, **birds**, **bats**, **snails**, etc.

Adaptations for Pollination:

- Flowers attract pollinators via:
  - **Color**
  - **Nectar**
  - **Fragrance**
- Non-motile gametes rely on vectors for fertilization.

Double fertilization is a key feature in angiosperms – **both male gametes** participate:

- One fuses with **egg cell**
- Another fuses with **polar nuclei**

Types of Pollination

Pollination can occur in **two main ways**:

1. **Self-pollination**
2. **Cross-pollination**

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1. Self-pollination (Autogamy)

◆ **Definition:**

- Pollination that occurs **within the same flower** or **between two flowers of the same plant**.

- Results in **inbreeding** or **selfing**.

◆ **Autogamy:**

- Self-pollination **within the same bisexual flower** using its own pollen.
- Offspring are **genetically identical** to parents.
- **Example**: *Clitoria*

Adaptations for Autogamy:

1. **Bisexuality**: Both male and female parts in one flower.
2. **Homogamy**: Stigma and anther **mature simultaneously**.
3. **Cleistogamy**:
    - Flowers do **not open**.
    - Pollination occurs **inside closed buds**.
    - **Example**: *Commelina benghalensis*
    - **Viola**, **Oxalis** produce both **chasmogamous** (open) and **cleistogamous** (closed) flowers.

Term to Remember:

- **Chasmogamous**: Flowers that open and expose sex organs.

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2. Geitonogamy

- Transfer of pollen from **one flower to another** of the **same plant**.
- Functionally similar to **cross-pollination**, but genetically resembles **self-pollination**.
- **Example**: *Cucurbita maxima*

3. Xenogamy (Cross-pollination or Outbreeding)

◆ **Definition:**

- Transfer of pollen to a **flower of a different plant** of the **same species**.

- Produces **genetically varied offspring**.
- Most flowering plants depend on xenogamy.
- Ensures **genetic diversity** and variation.

Pollination Agents

Classified into:

A. Abiotic Agents (non-living)

1. **Wind (Anemophily)**:
    - Examples: *Wheat*, *Rice*, *Maize*, *Grass*, *Palms*
    - Characteristics of wind-pollinated flowers:
        - **Small, colorless, scentless** flowers
        - **Light pollen grains**
        - Produce **large numbers** of pollen
        - **Feathery stigma** to trap pollen in wind

Adaptations in Wind-Pollinated Plants:

- **Long stamens** with **exserted filaments** and **versatile anthers** (help pollen release).
- **Exposed stamens and stigma** to catch airborne pollen.
- Produce **large quantities** of lightweight, dry pollen grains.
- Examples: *Maize*, *Grass*, *Wheat*, *Rice*, *Sugarcane*.

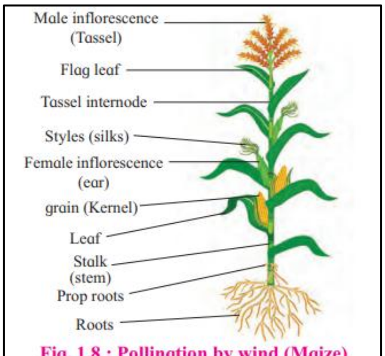

Fig. 1.8 : Pollination by wind (Maize)

2. Pollination by Water (Hydrophily)

◆ **Found in:**

- About **30 genera of monocots**.
- Examples: *Vallisneria*, *Zostera*, *Ceratophyllum*, etc.

◆ **Adaptations in Hydrophilous Flowers:**

- Flowers are **small and inconspicuous**.
- Pollen grains are:
  - **Long**, **ribbon-like**, **unwettable**
  - Sometimes **lack exine** for buoyancy
- No **nectar or fragrance** (unlike insect-pollinated flowers).

Types of Hydrophily:

1. Hypohydrophily:

- Pollination **underwater**.
- Pollen grains sink and reach the stigma.
- Example: *Zostera*

2. Epihydrophily:

- Pollination at the **surface of water**.
- Pollen grains **float** and reach female flower.
- Example: *Vallisneria* (submerged, dioecious, female flowers rise temporarily)

Interesting Facts:

- Pollen grain **specific gravity = water** (helps floating).

- Some aquatic plants are actually **wind-pollinated (anemophilous)** e.g., *Potamogeton*.
- Others are **entomophilous (insect-pollinated)** e.g., *Lotus*, *Water lily*, *Water hyacinth*.

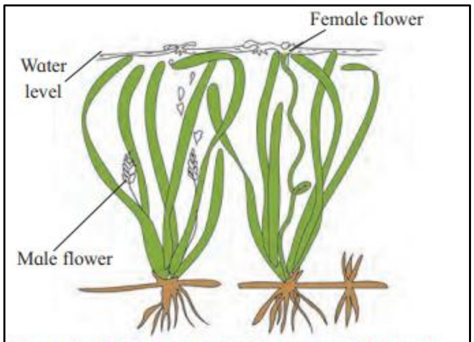

Fig. 1.9 : Male and female plants-*Vallisneria*

B. Biotic Agents (Living Organisms)

◆ **Definition:**

- Living agents like **insects, birds, bats, snails** help in pollination.
- About **80% of flowering plants** rely on **biotic pollination**.
- Biotic agents help:
  - Transfer pollen.
  - Maintain biodiversity.
  - Assist **crop reproduction** and **ecosystem stability**.

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1. Pollination by Insects (Entomophily)

Occurs in:

- *Rose*, *Jasmine*, *Cestrum*, etc.

Adaptations in Entomophilous Flowers:

- Flowers are **large**, **brightly coloured**.
- They **produce sweet scent (odour)**.

- Often have **nectar glands**.
- Plants have evolved **special mechanisms** to promote cross-pollination with the help of insect visitors.
- Example: **Lever mechanism or turn-pipe mechanism in *Salvia***.

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2. Pollination by Birds (Ornithophily)

Only a few bird species are specialized for pollination. Birds like **sunbirds and hummingbirds** visit flowers for nectar.

Examples of Ornithophilous Plants:

- ***Bombax***, ***Callistemon*** (Bottle Brush), ***Butea***

Adaptations in Ornithophilous Flowers:

- Brightly coloured, large, and showy flowers.
- Profuse, **dilute nectar** is secreted.
- **Sticky and spiny** pollen grains.
- Usually **lack fragrance** (birds rely on sight more than smell).

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3. Pollination by Bats (Chiropterophily)

- Bats can transport pollen over long distances (sometimes several kilometers).

Adaptations in Chiropterophilous Flowers:

- **Dull coloured**, but **strongly fragrant**.
- Secrete **abundant nectar**.
- Produce **large edible pollen grains**.

Examples of Bat-Pollinated Trees:

- *Anthocephalus* (Kadamb Tree)
- *Adansonia* (Baobab Tree / Gorakh Chinch)

- *Kigelia* (Sausage Tree)

Outbreeding Devices (Contrivances)

Plants have mechanisms to **prevent self-pollination** and **encourage cross-pollination** to maintain genetic diversity.

❖ **Importance:**

- Promotes evolutionary variation and natural selection.
- Prevents **inbreeding depression**.

Devices of Outbreeding:

1. Unisexuality:

- Plant produces either **male or female flowers**.
- Known as **dioecism**.
- Since flowers are unisexual, **self-pollination is avoided**.

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2. Dichogamy:

A mechanism where **anthers and stigmas mature at different times** in the same bisexual flower to avoid self-pollination.

Types:

1. **Protandry**:
   - **Androecium** (male part) matures earlier than the **gynoecium** (female part).
   - Example: *Sunflower*.
2. **Protogyny**:
   - **Gynoecium** matures earlier than the **androecium**.
   - Example: *Gloriosa*.

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3. Prepotency:

- Pollen grains from other flowers **germinate faster** on the stigma than pollen from the same flower.
- Example: *Apple*.

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4. Heterostyly (Heteromorphy):

- Seen in plants like *Primula* (Primrose).
- Flowers exist in **two or three forms**, where **stigmas and anthers are placed at different levels**.
    - This prevents self-pollination.
    - Pollens from one flower type pollinate only compatible flowers.

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5. Herkogamy:

- **Physical barrier** in bisexual flowers to prevent self-pollination.
- Male and female organs are spatially separated.
- Example: In *Calotropis*, the stigma is placed **below** the level of the anthers.

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6. Self-Incompatibility (Self Sterility):

- **Genetic mechanism**: Pollen of the same plant **fails to germinate** on its own stigma.
- Example: *Tobacco*, *Thea* (Tea).

1.8 Pollen–Pistil Interaction

Definition:

- Interaction between **pollen grains and stigma/style** of a flower.

- Includes events from **deposition of pollen** to **fertilization**.

Key Events:

- Pollen lands on stigma → enters style → reaches ovule (synergid) → **pollen-pistil interaction** occurs.
- Only the **right type of pollen** (compatible) is accepted.
- **Wrong type or incompatible pollen** is rejected.

Compatibility & Incompatibility:

- Controlled by **specific proteins** on the stigma surface.
- These proteins ensure:
    - **Compatible pollen** → allowed to germinate.
    - **Incompatible pollen** → rejected.

Pollen Tube Growth:

- Pollen absorbs water/nutrients from stigma.
- Germinates and produces pollen tube.
- Tube grows through style guided by chemical signals.
- Reaches embryo sac → fertilization.

Importance:

- Ensures **correct pollen** fertilizes the ovule.
- Prevents **wastage of reproductive effort**.
- Crucial for **sexual reproduction** and **seed formation**.

Role in Artificial Hybridization:

- **Artificial hybridization** relies on pollen-pistil interaction.

- Only desired pollen is used for fertilization.
- Techniques include:
    - Pollination control.
    - Use of **sucrose, boric acid** to enhance pollen germination.
    - Promotes tube growth in vitro.

1.9 Double Fertilization

Definition:

Double fertilization is a **unique and complex process** found only in **angiosperms (flowering plants)**.

- Discovered by **Nawaschin** in plants like *Lilium* and *Fritillaria*.

Process of Double Fertilization:

1. Pollen Tube Entry:

- Once the pollen grain lands on the stigma, it germinates forming a **pollen tube**.
- The tube travels through the **style**, enters the **ovary**, and finally reaches the **ovule**.
- The tube is guided to the ovule by chemical signals from the **synergids**.
- The usual entry of the pollen tube is through the **micropyle** → called **porogamy**.
- Rare types:
    - **Chalazogamy**: Entry through the **chalaza**.
    - **Mesogamy**: Entry through **integuments** or **middle parts**.

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2. Fusion Events:

- Pollen tube carries **two male gametes**.

- Enters ovule and discharges contents into one of the **synergids**.
- **One male gamete** fuses with the **egg cell** → forms **diploid zygote (2n)** → this process is called **syngamy**.
- **Second male gamete** fuses with two **polar nuclei** (central cell) → forms **triploid Primary Endosperm Nucleus (PEN)** → develops into **endosperm**.
    - This process is called **triple fusion**.

✔ **Double Fertilization = Syngamy + Triple Fusion**

Terms to Know:

Term	Description
Syngamy	Fusion of one male gamete with the egg → **diploid zygote**
Triple Fusion	Fusion of the second male gamete with two polar nuclei → **triploid PEN**
Endosperm	Triploid nutritive tissue formed after triple fusion
Porogamy	Entry of pollen tube through the micropyle
Chalazogamy	Entry through chalaza
Mesogamy	Entry through integuments/middle region

📌 **Diagrams (Important):**

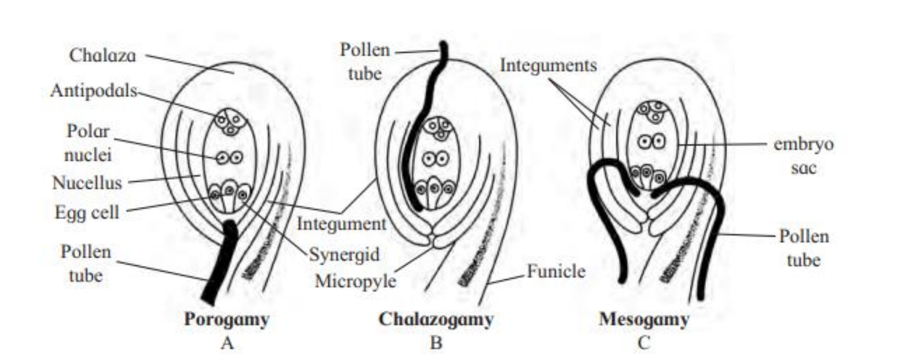


Fig. 1.12 : Entry of pollen tube into the ovule

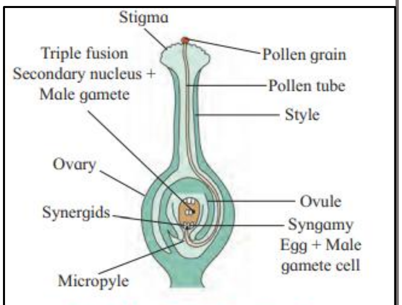


Fig. 1.13 : Double fertilization

Significance of Double Fertilization:

- **Exclusive to angiosperms**.
- Ensures that the **endosperm forms only if the egg is fertilized** → prevents wastage of resources.
- Results in:
  - **Diploid zygote (2n)** → develops into **embryo**.
  - **Triploid endosperm (3n)** → nourishes the developing embryo.
- **Double fertilization ensures efficient use of energy** and **enhances reproductive success** in flowering plants.
- **PEN develops into nutritive endosperm tissue**.
- **Restores diploid condition** by fusing haploid male and female gametes (syngamy).
- Facilitates **polyembryony** (formation of more than one embryo).

1.10 Development of Endosperm

- The **triploid primary endosperm nucleus** undergoes **repeated mitotic divisions** to form a tissue called **endosperm**.
- Post-fertilization: embryo and endosperm develop **simultaneously**.
- Other cells in the embryo sac degenerate soon.
- **Endosperm development triggers embryo formation**.

Types of Endosperm (Based on Mode of Development):

1. Nuclear Type:

- Most common type; found in **161 angiosperm families**.
- The PEN divides **mitotically** without cell wall formation.
- Many **free nuclei** are formed.

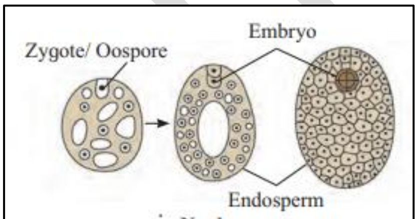
- A central **vacuole** pushes nuclei to the periphery.
- Later, **walls may develop** → multicellular endosperm.
- In some plants (e.g. wheat, sunflower, coconut), **cell wall formation remains incomplete**.
- Example: **Coconut** (outer part = cellular; inner part = free nuclear).

2. Cellular Type:

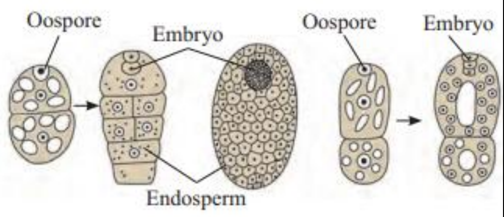
- Division of PEN is immediately followed by **cell wall formation**.
- Endosperm is cellular from the start.
- Found in **72 dicot families**.
- Examples: *Balsam*, *Petunia*, *Adoxa*.

3. Helobial Type:

- Found in **order Helobiales** (monocots).
- First division of PEN is **asymmetrical**, producing:
  - Small **chalazal cell**
  - Large **micropylar cell**
- Nuclei in each cell divide, forming **two chambers**.
- **Intermediate** between nuclear and cellular types.
- Example: *Asphodelus*



i. Nuclear



ii. Cellular iii. Helobial

1.11 Development of Embryo (Embryogenesis)

- The **zygote develops into embryo** through a process called **embryogenesis**.

- Embryo develops at the **micropylar end** of the **embryo sac**.
- Growth of embryo **is triggered only after** endosperm formation begins, ensuring nutrient supply.

Embryo Development in Angiosperms

Embryogenesis begins **after fertilization** and once **sufficient endosperm is formed** to support embryo growth.

Zygote Division and Proembryo Formation

- **Zygote** divides to form a **two-celled proembryo**:
    - **Micropylar cell** → larger cell, becomes **basal/suspensor initial**.
    - **Chalazal cell** → smaller cell, becomes **terminal/embryonal initial**.
- **Suspensor Initial Cell** divides **transversely** forming a **filamentous suspensor** (6–10 cells long).

Functions of Suspensor

- **Pushes the embryo** into the nutritive endosperm.
- **Micropylar end** of suspensor becomes enlarged and functions as a **haustorium**.
- The **lowermost cell** of suspensor is called **hypophysis**, which will contribute to root formation.

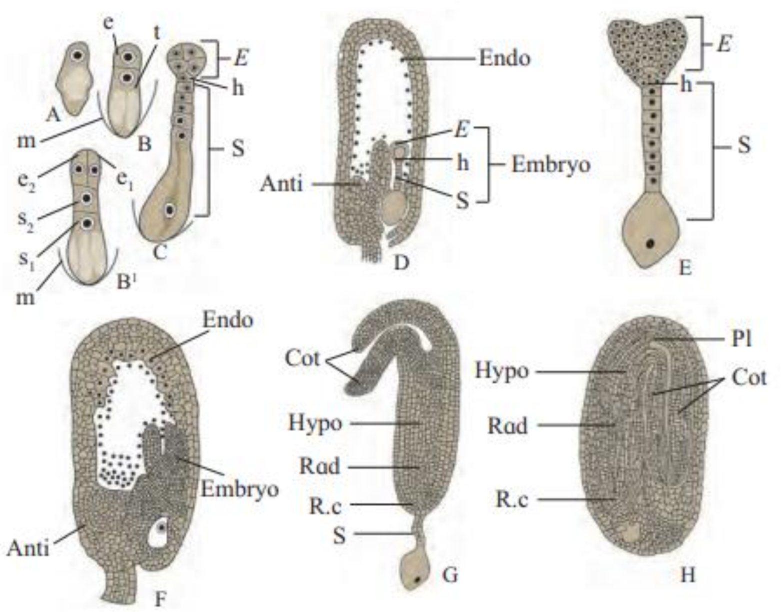
Embryo Initial Cell Development

- **Embryonal cell** (from chalazal end) divides three times **mitotically** to form an **octant** (8-cell structure).
- These cells divide **at right angles**.
    - **Lower four cells** → form **hypocotyl and radicle**.
    - **Upper four cells** → form **epicotyl, cotyledons**.

Development of Dicot Embryo (e.g., *Capsella*)

Stages:

1. **Zygote → Proembryo (2-celled)**.
2. **Formation of suspensor** (micropylar side).
3. **Octant stage → Globular stage → Heart-shaped** embryo (due to two cotyledons).
4. Embryo matures into **seed** with:
   - **Cotyledons**
   - **Radicle** (root)
   - **Hypocotyl**
   - **Plumule** (shoot apex)



A. Oospore. B. Two celled proembryo. e=embryonal initial; t=suspensor initial; m=Embryo sac membrane. B^1=4-celled I-shaped proembryo; e_1, e_2 are from embryonal initial; s_1, s_2 are from suspensor initial. C. Further development of embryo. S=Suspensor, h=Hypophysis; *E*=Embryonal mass D. L. S. of ovule Endo=Endosperm in free nuclear stage. Anti=Antipodal tissue. Embryo= Developing embryo E. Embryo showing further development of embryonic octants and hypophysis. F. L. S. of ovule. Endosperm becoming cellular. G. Embryo Cot=Cotyledons; Hypo=Hypocotyl; Rad=Radicle; R.c=Root-cap H. Mature seed. Pl=Plumule. Endosperm has been consumed almost completely.

Fig. 1.15 : Development of Dicot Embryo as in *Capsella*

🌾 Development of Monocot Embryo (e.g., grasses like maize)

- Process is **similar initially** to dicots:
  - Zygote → Proembryo → Suspensor → Embryo proper

- Later stages diverge in terms of **cotyledon number and arrangement**.

Monocot Embryo Characteristics:

- Has a **single cotyledon** called the **Scutellum** (found on lateral side).
- **Radicle** is protected by a **coleorhiza**.
- **Plumule** is enclosed by **coleoptile**.
- **Epiblast**: A small outgrowth next to scutellum (vestigial second cotyledon).

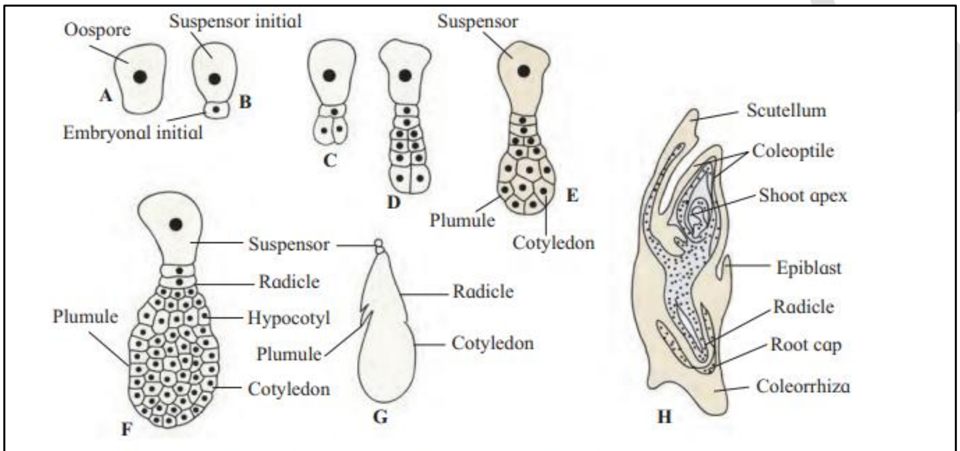


Fig. 1.16 : Development of Monocot (grass) Embryo

- In **monocots**, single cotyledon occupies the **terminal position**, and the **plumule is lateral**.
- The single cotyledon is known as the **scutellum**.
- **Protective sheaths**:
  - Around **plumule**: **Coleoptile**
  - Around **radicle**: **Coleorhiza**

Finally, the **ovule transforms into the seed**, and the **ovary transforms into the fruit**.

1.12 Seed and Fruit Development

Goal:

- The main aim of reproduction in plants is to ensure the **continuation of species** by producing **offspring** through seeds and fruits.

Seed Development

- Initiated by **fertilization**.
- After fertilization:
  - **Integuments** of the ovule → become the **seed coat**.
  - **Ovule** → becomes the **seed**.
  - **Ovary** → becomes the **fruit**.

Seed Structure:

- Seed has two coverings:
  - **Testa** (outer hard seed coat)
  - **Tegmen** (inner membrane)
- Sometimes the **nucellus** of the ovule persists in seeds (e.g. black pepper, beet) → becomes **perisperm** (remnant tissue).

Types of Seeds Based on Endosperm:

1. Endospermic / Albuminous Seeds:

- **Endosperm is retained** and stores food.
- Found in: **Castor**, **Coconut**, **Maize**, etc.
- Endosperm remains visible and fills a large part of seed.

2. Non-Endospermic / Exalbuminous Seeds:

- **Endosperm is absorbed** completely by embryo during seed development.
- Found in: **Pea**, **Bean**, etc.

- Cotyledons store food and become **first photosynthetic organs**.

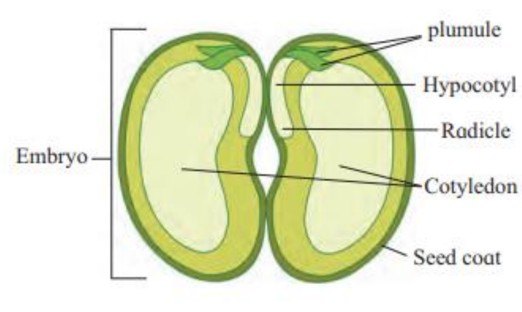


Fig. 1.17 : Bean seed (Dicot)

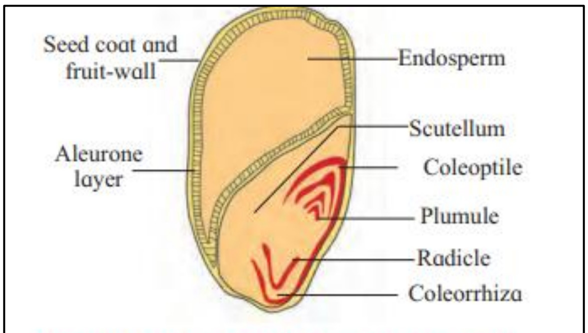


Fig. 1.18 : V. S. Maize grain (Monocot)

Additional Notes:

- **Micropyle**: Small pore on seed coat, allows **entry of water and oxygen** during germination.
- **Fruit formation**: Initiated by **hormones** released from developing seeds.
- **Ovary wall** develops into **pericarp** (fruit wall).

Pericarp Structure:

- **Pericarp** differentiates into three layers:
  - Found in **fleshy fruits** like **mango, coconut**.

Significance of Seed and Fruit Formation

1. **Fruits nourish the developing seeds.**
2. **Fruits protect seeds** when immature.
3. **Seeds are important propagating organs**, ensuring the survival and spread of plant species.
4. Seeds and fruits often have **special adaptations** for **dispersal**, aiding distribution.

Dormancy

- **Definition**: Temporary suspension of growth and metabolism in viable seeds, even under favourable conditions.
- Purpose: Helps survival during **adverse environmental conditions**.
- Causes: **Structural or physiological adaptations**.
- Dormancy ensures:
    - Seeds are **dispersed in time and space**.
    - Germination occurs under **optimal conditions** only.

Example of seed longevity:

Plant	Seed Longevity
Lupinus arcticus	10,000 years
Phoenix dactylifera (Date Palm)	2,000 years
Citrus	Viable for years
Striga, *Orobanche*	Viable and dispersed easily

1.13 Apomixis

- **Definition**: Formation of embryos **without fertilization** or meiosis; i.e., **asexual reproduction via seeds**.
- **No gamete fusion** (no syngamy), **no meiosis**.
- Embryo develops from ovule parts other than zygote.

Types of Apomixis:

1. Recurrent Apomixis:

- Embryo arises from **embryo sac or nucellus**.
- **No meiosis**, egg cell retains diploid state.
- Example: *Taraxacum* (dandelion).

2. Non-Recurrent Apomixis:

- Egg cell forms embryo **without fertilization**, but only for **one generation**.
- No contribution from pollen or male gamete.
- Used in **hybrid seed production**.
- Example: *Nicotiana*.

3. Adventive Embryony:

- Embryo develops from **nucellus or integument cells** (somatic tissue).
- Common in **mango**, **citrus**.
- A form of **polyembryony** (multiple embryos per seed).

1.14 Parthenocarpy

Definition:

- Coined by **Noll (1902)**.
- Parthenocarpy is the development of **fruit without fertilization**.

Natural Occurrence:

- Seen in fruits like **pineapple, banana, papaya, fig**, etc.
- In some plants, **unfertilized ovaries** produce **Auxin (IAA - Indole-3-Acetic Acid)** → causes fruit development **without seeds**.

Important Points:

- Parthenocarpic fruits are **seedless**, though they resemble normally produced fruits.
- Seedlessness is highly desired in commercial fruit production.

1.15 Polyembryony

Definition:

- Development of **more than one embryo** in a single seed.
- First observed by **Leeuwenhoek (1719)** in seeds of the **Citrus genus**.

Occurrence:

- Results in **multiple seedlings** from a single seed.
- Can be **true** or **false** depending on where the extra embryos originate.

Types of Polyembryony:

Type	**Description**	**Example**
Adventive Polyembryony	Additional embryos form from **diploid cells** (e.g. nucellus or integuments)	*Citrus*
Cleavage Polyembryony	**Zygote splits** into many parts which develop into embryos	Found in various angiosperms

- **True polyembryony**: More than one **zygote or embryo sac**.
- **False polyembryony**: Additional structures mimic embryos but don't develop into full plants.

Importance:

- Enhances **survival of species**.
- Useful in **horticulture** for producing **genetically identical seedlings**.

Thank You