

Chapter 1: Sexual Reproduction in Flowering Plants

1. Introduction & Structure of Flower

Flower: Flower is a modified shoot and it is the site of sexual reproduction in angiospermic plants. Flowers are morphological and embryological marvels of angiosperms.

- Flowers are involved only in angiospermic plants for sexual reproduction.
- They hold aesthetic, social, religious, ornamental, and cultural value in human life.
- They symbolise important human feelings such as love, affection, happiness, grief, and mourning.
- **Floriculture:** The cultivation of different species of flowers in fields is called floriculture.

A flower has four whorls attached to a central axis called the **Thalamus**:

Type	Whorl Name	Individual Unit	Function / Description
Accessory Organs	Calyx	Sepal	Outermost green whorl; protects flower in bud stage. (5–7 in number)
	Corolla	Petal	Brightly coloured whorl; attracts insects for pollination. (5–7 in number)
Reproductive Organs	Androecium	Stamen	Male reproductive organ. Consists of Anther, Connective, and Filament.
	Gynoecium	Pistil / Carpel	Female reproductive organ. Consists of Stigma, Style, and Ovary.

Perianth (Tepals): When Calyx and Corolla are not distinct, they are collectively called Perianth (e.g., Sunflower, Onion, Marigold).

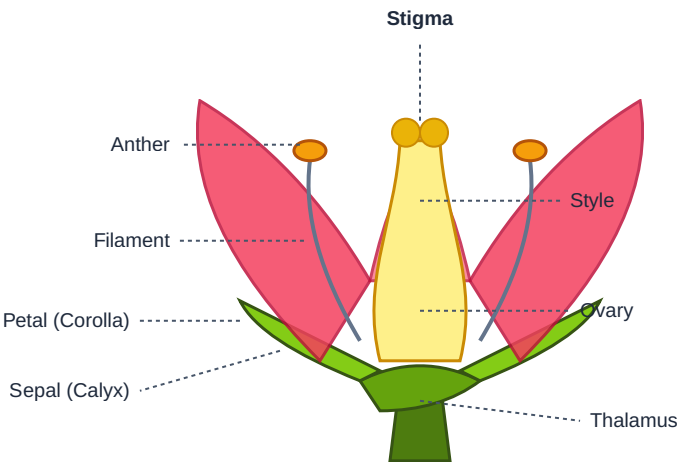


Figure 1.1: Schematic Diagram of a Typical Flower

2. Male Reproductive Unit: Stamen, Anther & Microsporangium

Pre-fertilisation involves two main steps: **Gametogenesis** (formation of gametes) and **Transfer of Gametes**.

Structure of Anther

Anther is the terminal, fertile part of the stamen. It is typically **bilobed**, and each lobe has two chambers (theca), making it **Dithecous** (containing 4 microsporangia/pollen sacs in total). The lobes are connected by sterile vascular tissue called **Connective**.

Wall Layers of Microsporangium:

1. **Epidermis**: Outermost single-layered protective covering.
2. **Endothecium**: Provides protection and helps in dehiscence of anther.
3. **Middle Layers**: 1–3 layered, short-lived, protective in nature.
4. **Tapetum**: Innermost layer. Functions include:
 - Provides nourishment to developing microspores/pollen grains.
 - Secretes **Sporopollenin** (extremely resistant organic material for Exine).
 - Secretes **Callase enzyme** to separate microspore tetrads.
 - Forms **Pollenkit** around insect-pollinated pollen grains.

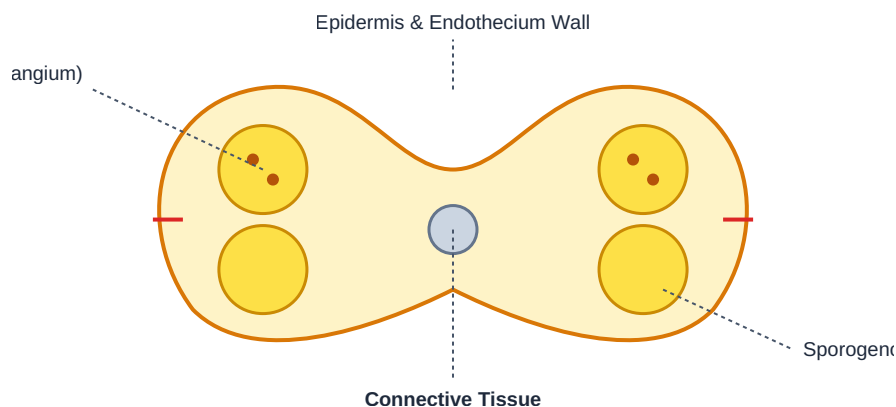


Figure 1.2: Transverse Section (T.S.) of a Mature Anther

Microsporogenesis

The process of formation of microspores from a Pollen Mother Cell (PMC) / Microspore Mother Cell (MMC) through **meiosis** is called **Microsporogenesis**.

MMC (2n) → [Meiosis] → Microspore Tetrad (n) → [Callase action] → 4 Pollen Grains (n)

Pollen Grain (Male Gametophyte)

Pollen grains represent the male gametophyte. They are spherical, measuring 25–50 micrometers in diameter. They possess two wall layers:

- **Exine**: Hard outer layer made of **Sporopollenin** (most resistant organic material). It has small pores called **Germ pores** where sporopollenin is absent.
- **Intine**: Thin, continuous inner layer made of **cellulose and pectin**.

A mature pollen grain contains 2 cells:

1. **Vegetative Cell (Somatic cell):** Bigger, abundant food reserve, large irregular nucleus. Helps form the pollen tube.
2. **Generative Cell (Reproductive cell):** Small, spindle-shaped, floats in the cytoplasm of vegetative cell. Divides mitotically to form **2 male gametes**.

In ~60% of angiosperms, pollen is shed at the **2-celled stage**. In remaining species, the generative cell divides to give 3-celled pollen before shedding.

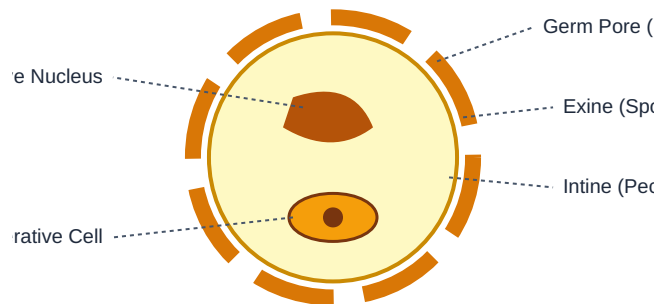


Figure 1.3: Structure of a Mature 2-Celled Pollen Grain

Pollen Viability & Economic Importance:

- **Pollen Allergy:** Pollen of *Parthenium* (carrot grass) causes severe allergies and respiratory disorders like asthma and bronchitis.
- **Pollen Products:** Rich in nutrients; used as pollen tablets/syrups for athletes and race horses.
- **Pollen Storage:** Stored in liquid nitrogen at **-196°C** in pollen banks for crop breeding.
- **Viability Duration:** 30 minutes in rice and wheat; several months in Leguminosae, Solanaceae, and Rosaceae.

3. Female Reproductive Unit: Pistil & Megasporangium (Ovule)

The Gynoecium represents the female reproductive organ. It can be **Monocarpellary** (1 pistil) or **Multicarpellary** (many pistils). Multicarpellary gynoecium can be:

- **Syncarpous:** Pistils fused together (e.g., *Papaver somniferum*, Mustard).
- **Apocarpous:** Pistils are free (e.g., *Michelia*).

Structure of Ovule (Anatropous Ovule)

An ovule consists of the following key structures:

- **Funicle:** Stalk attaching ovule to placenta.
- **Hilum:** Junction point between ovule body and funicle.
- **Integuments:** Protective envelopes (outer and inner integuments).
- **Micropyle:** Small opening at the tip where integuments are absent.
- **Chalaza:** Basal part of the ovule, opposite to micropyle.
- **Nucellus:** Central mass of parenchymatous tissue containing reserve food.

- **Embryo Sac (Female Gametophyte):** Located inside nucellus.

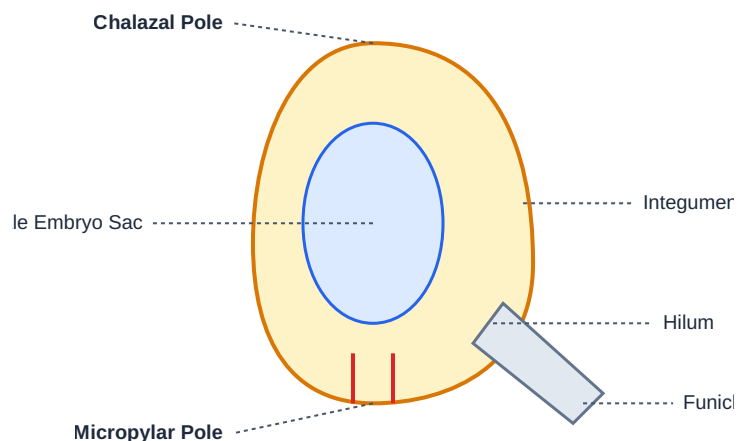


Figure 1.4: Structure of a Typical Anatropous Ovule

Megasporogenesis & Female Gametophyte Development

Megasporogenesis: Process of formation of megaspores from Megaspore Mother Cell (MMC).

MMC (2n) → [Meiosis] → 4 Megaspores (n) → [3 Degenerate] → 1 Functional Megaspore (n)

Monosporic Embryo Sac (7-Cellled, 8-Nucleated Stage):

The functional megaspore nucleus undergoes 3 successive free-nuclear mitotic divisions (1 → 2 → 4 → 8 nuclei), resulting in an 8-nucleated, 7-celled Embryo Sac:

- **Egg Apparatus (3 cells at Micropylar end):** Consists of **1 Egg Cell** (female gamete) and **2 Synergid cells** with filiform apparatus to guide pollen tube.
- **Antipodal Cells (3 cells at Chalazal end):** Provide nourishment and later degenerate.
- **Central Cell (1 large cell in center):** Contains **2 Polar Nuclei**.

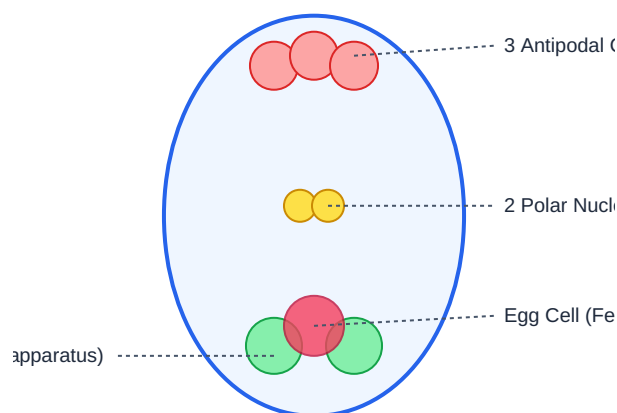


Figure 1.5: Mature 7-Cellled, 8-Nucleated Embryo Sac

4. Pollination: Types & Agents

Pollination is the transfer of pollen grains from anther to the stigma of a flower.

Types of Pollination

Category	Type	Description & Key Features
Self Pollination	Autogamy	Transfer of pollen within the <i>same flower</i> . Requires synchrony and close proximity of anthers and stigma. • <i>Chasmogamous</i>: Flowers open with exposed organs. • <i>Cleistogamous</i>: Flowers do not open at all (e.g., <i>Oxalis</i>, <i>Commelina</i>, <i>Viola</i>); guarantees seed set without pollinators.
	Geitonogamy	Transfer of pollen between <i>different flowers of the same plant</i> . Functionally cross-pollination (requires agent), genetically self-pollination.
Cross Pollination	Xenogamy	Transfer of pollen between <i>flowers of two different plants of same species</i> . Brings genetically varied pollen grains to stigma.

Pollinating Agents

- **Abiotic Agents:**
 - **Wind (Anemophily):** Pollen light, non-sticky; stamens well exposed; stigmas feathery/hairy. Common in grasses. Single ovule per ovary.
 - **Water (Hydrophily):** E.g., *Vallisneria*, *Hydrilla*, *Zostera*. Long stalk in female flowers of *Vallisneria* reaches water surface; pollen protected by mucilage. (Note: Water hyacinth and water lily use wind/insects).
- **Biotic Agents (Animals/Insects):**
 - **Entomophily (Insects):** Flowers large, colorful, fragrant, rich in nectar. Pollen grains are sticky.
 - **Ornithophily (Birds), Chiropterophily (Bats), Myrmecophily (Ants).**
 - **Egg-laying Safe Havens:** E.g., 6-foot tall flower of *Amorphophallus* and *Yucca* plant with moth.

5. Pollen-Pistil Interaction & Double Fertilisation

Pollen-Pistil Interaction: Dynamic process starting from pollen deposition on stigma to its entry into ovule. Pistil recognizes compatible pollen, promotes germination forming pollen tube carrying 2 male gametes through germ pore down the style into micropyle.

Artificial Hybridisation: Key method in plant breeding involving:

- **Emasculation:** Removal of anthers from bisexual flower bud before dehiscence using forceps.
- **Bagging:** Covering emasculated flower with butter paper bag to prevent unwanted pollen contamination.

Double Fertilisation (Unique to Angiosperms)

Upon entering embryo sac, pollen tube releases 2 male gametes into synergid:

1. Syngamy (1st Fertilisation):

Male Gamete (n) + Egg Cell (n) → Diploid Zygote (2n) → Embryo

2. Triple Fusion (2nd Fertilisation):

Male Gamete (n) + Secondary Polar Nuclei (2n) → Primary Endosperm Nucleus / PEN (3n)

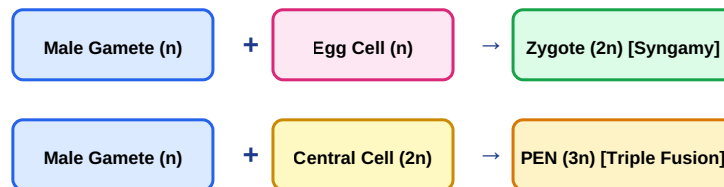


Figure 1.6: Flowchart of Double Fertilisation Events

6. Post-Fertilisation Structures & Events

Post-fertilisation involves 4 major events:

1. Development of Endosperm from PEN (3n).
2. Development of Embryo from Zygote (2n).
3. Maturation of Ovule into Seed.
4. Maturation of Ovary into Fruit.

1. Endosperm Development

Triploid tissue filled with reserve food to nourish developing embryo. Types of endosperm:

- **Free Nuclear Endosperm:** PEN undergoes repeated nuclear divisions without wall formation (e.g., tender coconut liquid).
- **Cellular Endosperm:** Wall formation occurs immediately after nuclear divisions (e.g., white kernel of coconut).
- **Helobial Endosperm:** Intermediate form between nuclear and cellular.

2. Embryo Development (Embryogeny)

Zygote divides at micropylar end. Stages: **Zygote** → **Proembryo** → **Globular Embryo** → **Heart-shaped Embryo** → **Mature Embryo**.

Dicot Embryo Parts	Monocot Embryo Parts
• Embryonal Axis with 2 Cotyledons. • Epicotyl: Above cotyledon level; ends in Plumule (shoot tip). • Hypocotyl: Below cotyledon level; ends in Radicle (root tip) with Root Cap.	• Single Cotyledon called Scutellum (lateral side). • Coleoptile: Protective sheath covering Epicotyl / Plumule. • Coleorhiza: Undifferentiated sheath covering Radicle / Root cap.

3. Seed & Fruit Formation

- **Seed Coat:** Formed from ovule integuments. Outer layer = **Testa**, Inner layer = **Tegmen**.
- **Perisperm:** Persistent remnant of nucellus in seeds (e.g., Black Pepper, Beet).
- **Non-Albuminous (Ex-albuminous) Seed:** Endosperm completely consumed during development (e.g., Pea, Groundnut, Beans).
- **Albuminous Seed:** Retains residual endosperm (e.g., Wheat, Maize, Castor, Sunflower).
- **Fruit Types:**
 - **True Fruit:** Develops strictly from fertilized ovary (e.g., Mango, Mustard, Orange).
 - **False Fruit:** Thalamus contributes to fruit formation along with ovary (e.g., Apple, Strawberry, Cashew).
 - **Parthenocarpic Fruit:** Develops without fertilisation; seedless (e.g., Banana).

7. Special Mechanisms: Apomixis, Polyembryony & Outbreeding Devices

- **Apomixis:** Production of seeds without fertilisation (mimics sexual reproduction, e.g., Asteraceae and Grasses). Diploid egg cell develops directly into embryo without meiosis and fertilisation.
- **Polyembryony:** Presence of more than one embryo in a seed (e.g., Citrus/Orange, Mango).
- **Seed Longevity & Dormancy:**
 - *Lupinus arcticus* (Lupine) seed germinated after **10,000 years** of dormancy from Arctic Tundra.
 - *Phoenix dactylifera* (Date Palm) seed germinated after **2,000 years** of dormancy (discovered at King Herod's palace near Dead Sea).
- **Outbreeding Devices:** Mechanisms to prevent self-pollination (autogamy) and promote cross-pollination:
 1. Non-synchronous pollen release and stigma receptivity.
 2. Anther and stigma placed at different positions.
 3. **Self-incompatibility:** Genetic barrier inhibiting pollen germination/tube growth on stigma of same plant.
 4. Unisexual flowers (Dioecy prevents both autogamy and geitonogamy).