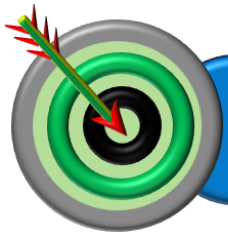
Chapter
01

Sexual Reproduction in Flowering Plants



OBJECTIVES

- INTRODUCTION
- FLOWER – A FASCINATING
- PRE-FERTILISATION: STRUCTURES
- DOUBLE FERTILISATION
- POST-FERTILISATION: STRUCTURES
- APOMIXIS AND POLYEMBRYONY

INTRODUCTION

Sexual reproduction in flowering plants (angiosperms) is a complex and highly specialized process that ensures genetic variation and species continuity. Flowers, the reproductive structures of angiosperms, exhibit diverse forms, colors, and fragrances to attract pollinators and facilitate reproduction. The process involves the formation of male and female gametes, pollination, fertilization, and ultimately the development of fruits and seeds. Various adaptations in floral structures and reproductive mechanisms enhance the efficiency of sexual reproduction, making it a vital aspect of plant survival and evolution.

1.1 FLOWER - A FASCINATING ORGAN OF ANGIOSPERMS

Flowers have been an integral part of human life since ancient times, serving aesthetic, ornamental, social, religious, and cultural purposes. They symbolize emotions such as love, affection, happiness, grief, and mourning. Flowers are widely cultivated in homes and gardens for their beauty and fragrance.

Common Ornamental Flowers- Some commonly grown ornamental flowers include:

1. **Rose** (*Rosa*) – Symbol of love and admiration.
2. **Marigold** (*Tagetes*) – Bright and cheerful, used in decorations.
3. **Hibiscus** (*Hibiscus rosa-sinensis*) – Grown for its large, vibrant flowers.
4. **Orchid** (*Orchidaceae*) – Valued for its exotic and intricate blooms.
5. **Lily** (*Lilium*) – Represents purity and elegance.

Flowers in Social and Cultural Celebrations- Flowers also play a significant role in social and cultural traditions. Some flowers commonly used in celebrations include:

1. **Jasmine** (*Jasminum*) – Used in religious rituals and weddings.
2. **Lotus** (*Nelumbo nucifera*) – Sacred in many cultures, symbolizes purity.
3. **Tulsi Flowers** (*Ocimum sanctum*) – Important in Hindu religious practices.
4. **Sunflower** (*Helianthus annuus*) – Represents positivity and vitality.
5. **Chrysanthemum** (*Chrysanthemum morifolium*) – Associated with festivals and memorial ceremonies.

Flowers as Reproductive Structures

From a biological perspective, flowers are fascinating structures that serve as the sites of sexual reproduction in flowering plants (angiosperms). They are composed of various parts that work together to facilitate reproduction.

Key Reproductive Parts of a Flower

A flower consists of several components, but the two primary reproductive structures are:

1. **Androecium (Stamens)** – The male reproductive part, where pollen grains containing male gametes develop.
2. **Gynoecium (Carpel/Pistil)** – The female reproductive part, where ovules containing female gametes are formed.

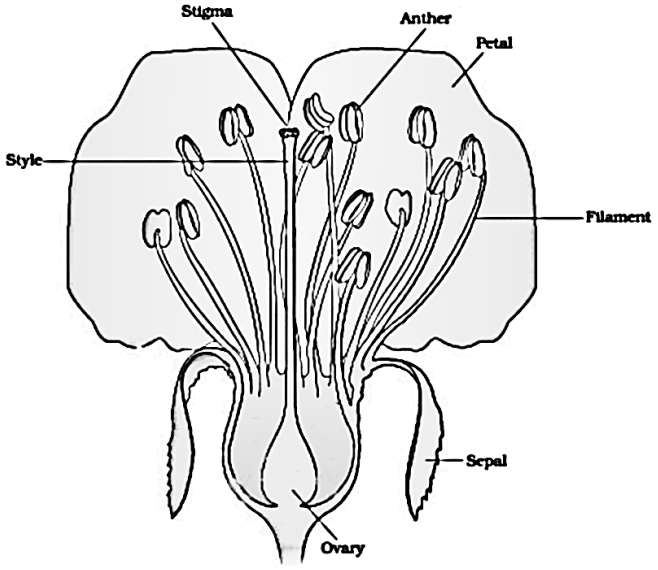


Fig.: A diagrammatic representation of L.S. of a flower

1.2 PRE-FERTILISATION: STRUCTURES AND EVENTS

Before a flower becomes visible on a plant, the process of flowering is already determined. Various **hormonal and structural changes** trigger the **differentiation and development of the floral primordium**. This leads to the formation of **inflorescences**, which produce **floral buds** that eventually bloom into flowers.

Within the flower, the **male and female reproductive structures** develop:

- **Androecium** – The male reproductive organ, consisting of a **whorl of stamens**.
- **Gynoecium** – The female reproductive organ, responsible for producing ovules.

These reproductive structures play a vital role in **sexual reproduction**, ensuring the continuation of plant species.

1.2.1 Stamen, Microsporangium and Pollen Grain

1. Structure of a Stamen

A typical stamen consists of two main parts:

Filament: A long, slender stalk that attaches to the **thalamus** or **petal** of the flower.

Anther: A terminal, generally bilobed structure containing **pollen sacs**.

The **number and length of stamens** vary among different plant species. By collecting stamens from different flowers and observing them under a dissecting microscope, variations in **size, shape, and attachment of anthers** can be studied.

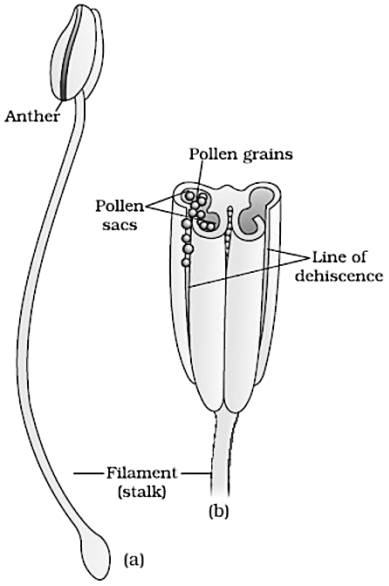


Fig.: (a) A typical stamen; (b) Three–dimensional cut section of an anther

2. Structure of a Microsporangium

A typical **angiosperm anther** is bilobed, with **each lobe containing two theca** (dithecous structure).

A longitudinal groove separates the two theca. In a transverse section (T.S.), the anther appears as a tetragonal structure, consisting of four microsporangia at the corners (two in each lobe).

As the anther develops, the **microsporangia** mature into **pollen sacs**, extending throughout the anther length and containing **pollen grains**.

Wall Layers of Microsporangium

The microsporangium is surrounded by **four distinct wall layers**:

1. **Epidermis** – The outer protective layer.
2. **Endothecium** – Aids in **anther dehiscence**.
3. **Middle Layers** – Provide additional protection.
4. **Tapetum** – The innermost layer, which **nourishes developing pollen grains**.
    - Tapetal cells have **dense cytoplasm** and are often **bi-nucleate** (due to nuclear division without cytokinesis).

At an early stage, the center of each microsporangium contains **compactly arranged homogeneous cells** known as **sporogenous tissue**.

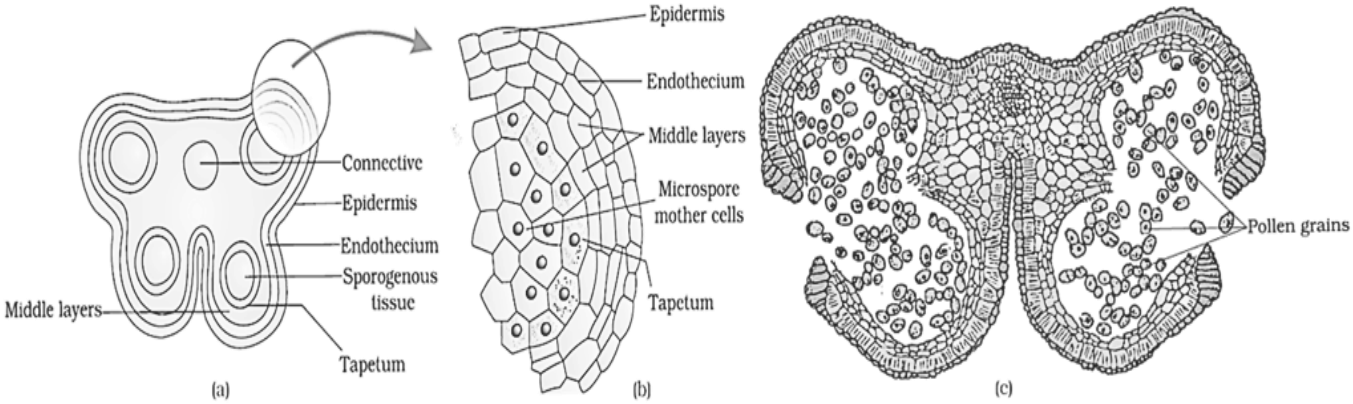


Fig.: (a) Transverse section of a young anther; (b) Enlarged view of one microsporangium showing wall layers; (c) A mature dehisced anther

3. **Microsporogenesis: Formation of Microspores**

Microsporogenesis is the process where **sporogenous tissue undergoes meiosis** to form **haploid microspore tetrads**. Each cell of the **sporogenous tissue** acts as a **pollen mother cell (PMC)**, undergoing **meiotic division** to produce **four microspores** (tetrads).

Initially, microspores remain attached in a **tetrad**, but later, as the anther matures and dehydrates, the microspores **separate and develop into pollen grains**. Each **microsporangium** produces **thousands of pollen grains**, released upon **anther dehiscence**.

4. **Structure and Development of Pollen Grain**

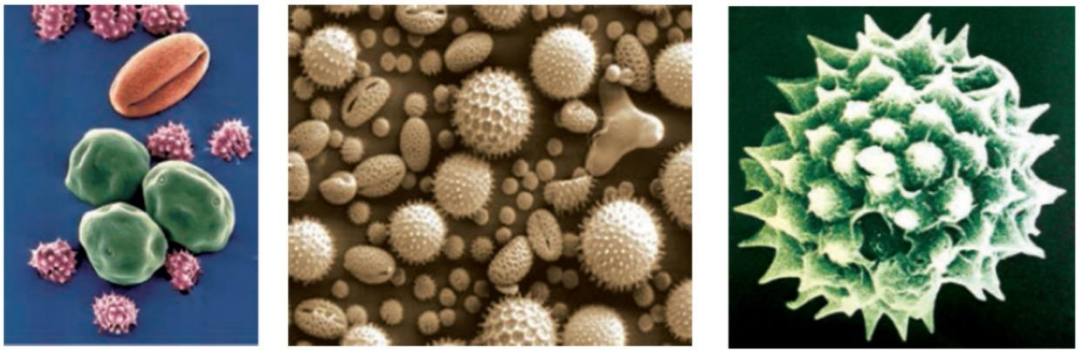


Fig.: Scanning electron micrographs of a few pollen grains

Pollen grains are **male gametophytes** and appear as a **yellow powder** in flowers like **Hibiscus**.

Structural Features

- **Shape & Size**: Spherical, measuring **25-50 µm in diameter**.
- **Wall Layers**:
  1. **Exine (Outer Layer)**: Composed of **sporopollenin**, the most **resistant organic material** known.
     - It withstands **high temperatures, strong acids, and alkalis**.
     - It contains **germ pores** (areas without sporopollenin), facilitating **pollen tube formation**.
     - Due to sporopollenin, **pollen grains are well-preserved as fossils**.
  2. **Intine (Inner Layer)**: Thin and continuous, made of **cellulose and pectin**.
- **Cytoplasmic Contents**: Enclosed by a **plasma membrane**.

Cellular Composition

1. **Vegetative Cell**
   Larger, with **abundant food reserves**.
   Contains a **large, irregular nucleus**.
2. **Generative Cell**
   Smaller, spindle-shaped, with **dense cytoplasm and a single nucleus**.
   In **60% of angiosperms**, pollen grains are released at the **2-celled stage**.
   In the remaining **40%**, the **generative cell undergoes mitosis** to produce **two male gametes (3-celled stage)**.

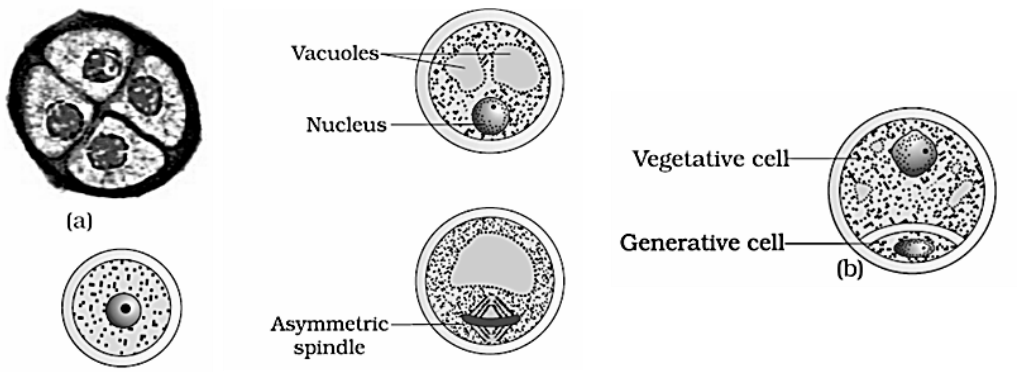


Fig.: (a) Enlarged view of a pollen grain tetrad; (b) stages of a microspore maturing into a pollen grain

5. **Pollen Allergies and Economic Importance**

Pollen Allergies

- Pollen grains from certain plants cause **severe allergies** and **respiratory disorders** such as **asthma and bronchitis**.
- **Parthenium (Carrot Grass)**, introduced as a **wheat contaminant**, is a major **allergenic plant** in India.

Pollen as a Nutritional Supplement

- Pollen grains are **rich in nutrients** and used as **dietary supplements**.
- **Pollen tablets and syrups** are commercially available.
- Some studies suggest pollen **enhances athletic and racehorse performance**.

Fig.: Pollen products

6. **Pollen Viability and Storage**

- **Pollen viability varies** depending on **species, temperature, and humidity**.
- In **rice and wheat**, pollen viability lasts **only 30 minutes**.
- In **Rosaceae, Leguminosae, and Solanaceae**, pollen remains viable for **months**.
- Pollen grains can be **stored in liquid nitrogen (-196°C)** for years, creating **pollen banks** similar to **seed banks**.
- Stored pollen is useful for **crop breeding programs** and **artificial fertilization**.

Critical Thinking

1. **Sporopollenin Importance**
   - Protects **pollen grains from harsh environmental conditions**.
   - Enables **pollen fossilization**, aiding **paleobotanical studies**.
2. **Why Tapetal Cells are Bi-nucleate**
   - Provides **more nutrients** for microspore development.
   - Helps synthesize **sporopollenin and pollen wall materials**.
3. **Function of Germ Pores**
   - Serve as exit points for **pollen tube formation**.
   - Ensure **successful fertilization** by aiding sperm movement.

TOPIC CENTRIC EXERCISE -01

Q1. **Microsporogenesis occurs in the:**
(a) Ovary (b) Anther
(c) Style (d) Stigma

Q2. **The process of formation of microspores from a pollen mother cell is called:**
(a) Megasporogenesis (b) Microsporogenesis
(c) Gametogenesis (d) Embryogenesis

Q3. **Microspores are produced in groups of:**
(a) Two (b) Four
(c) Eight (d) Six

Q4. The protective layer around the pollen grain is called:
(a) Intine (b) Exine
(c) Cuticle (d) Epidermis

Q5. Each pollen mother cell undergoes:
(a) Mitosis (b) Meiosis
(c) Both mitosis and meiosis (d) No division

1.2.2 The Pistil, Megasporangium (ovule) and Embryo sac

1. The Pistil and Its Structure

The **gynoecium** represents the **female reproductive part** of a flower. It may consist of:

- **A single pistil** (*monocarpellary* condition)
- **More than one pistil** (*multicarpellary* condition)- When multiple pistils are present, they can be:
  Syncarpous (fused together) – e.g., *Papaver*
  Apocarpous (free pistils) – e.g., *Michelia*

Each pistil consists of **three main parts**:

1. **Stigma** – The receptive surface for pollen grains, serving as a landing platform.
2. **Style** – The elongated stalk connecting the stigma to the ovary.
3. **Ovary** – The basal swollen part that contains the **ovarian cavity (locule)** where ovules (megasporangia) are present.

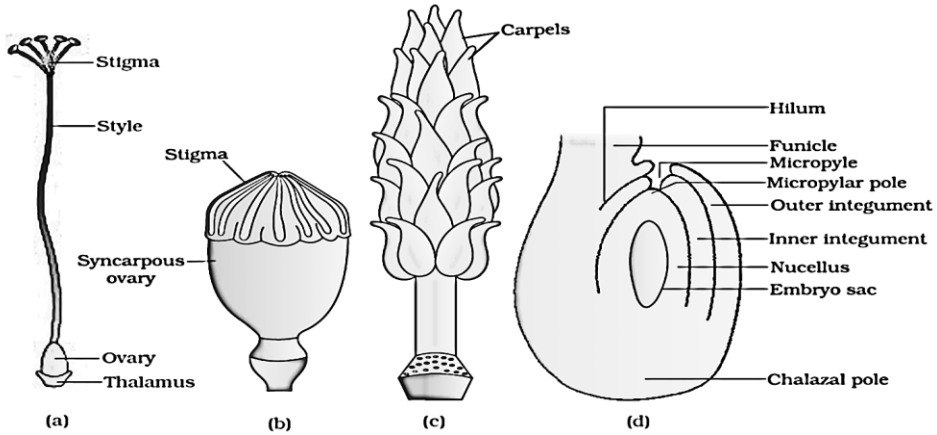


Fig. 1.7 (a) A dissected flower of Hibiscus showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of Papaver; (c) A multicarpellary, apocarpous gynoecium of Michelia; (d) A diagrammatic view of a typical anatropous ovule

2. Structure of the Ovule (Megasporangium)

The ovule is a small structure that arises from the **placenta** inside the ovary. The number of ovules varies across plant species:

- **Single ovule** – e.g., *wheat, paddy, mango*
- **Multiple ovules** – e.g., *papaya, watermelon, orchids*

A typical angiosperm ovule consists of the following parts:

1. **Funicle** – A stalk that attaches the ovule to the placenta.
2. **Hilum** – The junction between the ovule and the funicle.
3. **Integuments** – Protective layers surrounding the ovule, except at one opening called the **micropyle**.
4. **Micropyle** – A small pore at the tip of the ovule that allows sperm entry during fertilization.
5. **Chalaza** – The basal region opposite the micropyle.
6. **Nucellus** – The central mass of cells inside the integuments that contains stored nutrients.
7. **Embryo Sac** – Also called the **female gametophyte**, which develops from a megaspore and houses the egg cell for fertilization.

3. Megasporogenesis: Formation of the Megaspore

Megasporogenesis is the process by which a **megaspore mother cell (MMC)** undergoes meiosis to produce **four haploid megaspores**.

- The **MMC** is a large, prominent cell located in the **micropylar region** of the ovule.
- The meiotic division results in four megaspores, but typically, only **one remains functional**, while the other three degenerate.
- The single **functional megaspore** develops into the **female gametophyte (embryo sac)** through **monosporic development**.

4. Development of the Female Gametophyte (Embryo Sac)

The functional megaspore undergoes **three rounds of mitotic division** to form an **8-nucleate, 7-celled embryo sac**:

1. The **first mitotic division** forms two nuclei, which migrate to opposite poles, forming a **2-nucleate stage**.
2. A second mitotic division results in a **4-nucleate stage**.
3. A third mitotic division results in an **8-nucleate stage**, followed by cell wall formation, leading to the development of the mature embryo sac.

5. Structure of the Embryo Sac

A mature **angiosperm embryo sac** consists of **7 cells with 8 nuclei**, organized as follows:

1. **Egg Apparatus (3 cells at the micropylar end)**:
   - **1 Egg Cell** – Fertilized by the male gamete to form the **zygote**.
   - **2 Synergids** – Assist in pollen tube guidance via **filiform apparatus**.
2. **Central Cell (1 large cell in the center)**:
   - Contains **two polar nuclei**, which fuse with a male gamete to form the **triploid endosperm nucleus** after fertilization.
3. **Antipodal Cells (3 cells at the chalazal end)**:
   - Function remains uncertain, but they may provide **nutrition** to the embryo sac.

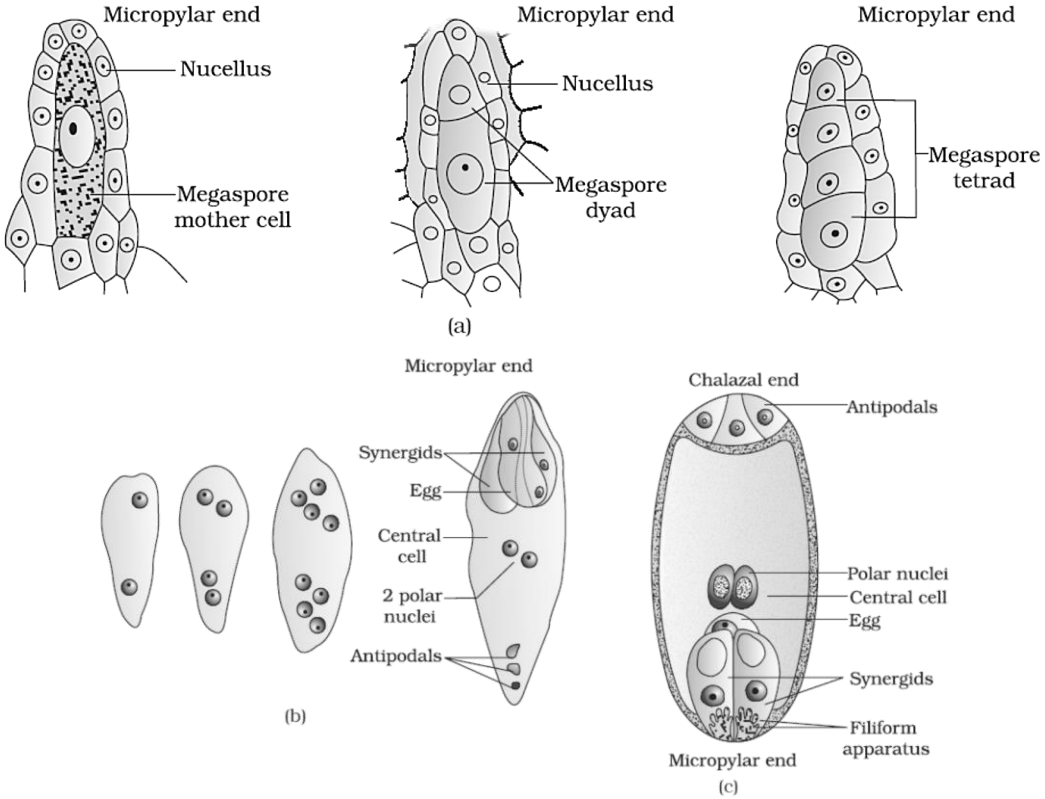


Fig. 1.8 (a) Parts of the ovule showing a large megaspore mother cell, a dyad and a tetrad of megaspores; (b) 2, 4, and 8-nucleate stages of embryo sac and a mature embryo sac; (c) A diagrammatic representation of the mature embryo sac.

6. Significance of the Embryo Sac Development

- The **egg cell** participates in **syngamy** (fusion with sperm to form the zygote).

- The **central cell** contributes to **triple fusion**, forming the triploid **primary endosperm nucleus**, which develops into the **endosperm** to nourish the developing embryo.
- The **synergids** help in **pollen tube entry**, ensuring efficient fertilization.
- The **monosporic development** is the most common pattern of embryo sac formation in **angiosperms**.

Monosporic Development in Plants

Monosporic development is a type of female gametophyte formation in flowering plants where only one functional megaspore out of the four produced during meiosis develops into the embryo sac. The other three megaspores degenerate. This process occurs in most angiosperms, including *Polygonum* (Polygonum-type), which is considered the most common type of embryo sac development. The functional megaspore undergoes three successive mitotic divisions to form an eight-nucleate, seven-celled structure, including the egg cell, synergids, central cell, and antipodal cells.

TOPIC CENTRIC EXERCISE -02

Q1. The process of formation of megaspores from a megaspore mother cell is called:
(a) Megasporogenesis (b) Microsporogenesis
(c) Gametogenesis (d) Syngamy

Q2. Megasporogenesis occurs in the:
(a) Anther (b) Ovule
(c) Style (d) Stigma

Q3. A typical angiosperm ovule is:
(a) Monosporic (b) Bisporic
(c) Tetrasporic (d) Trisporic

Q4. The functional megaspore divides to form:
(a) Pollen grains (b) Embryo sac
(c) Endosperm (d) Zygote

Q5. How many nuclei are present in a mature embryo sac?
(a) 2 (b) 4
(c) 8 (d) 12

1.2.3 Pollination

Pollination is the transfer of pollen grains from the anther to the stigma of a pistil, enabling fertilization in flowering plants. Since both male and female gametes are non-motile, pollination serves as the mechanism to bring them together. Plants have evolved various adaptations to facilitate pollination, often relying on external agents.

Types of Pollination

Based on the source of pollen, pollination is categorized into three types:

1. **Autogamy (Self-Pollination)**:
   - Pollen is transferred from the anther to the stigma of the same flower.
   - True autogamy is rare in open flowers as it requires synchronization between pollen release and stigma receptivity.
   - Some plants, such as *Viola* (pansy), *Oxalis*, and *Commelina*, produce cleistogamous flowers, which remain closed and ensure self-pollination.
   - Cleistogamous flowers guarantee seed production even in the absence of pollinators, but they limit genetic diversity.
   - **Advantages**: Assured seed-set, no dependency on pollinators.
   - **Disadvantages**: Lack of genetic variation may lead to inbreeding depression.
2. **Geitonogamy**:
   - Pollen is transferred from the anther of one flower to the stigma of another flower on the same plant.

- Functionally, it resembles cross-pollination as it requires a pollinating agent, but genetically, it is similar to autogamy since the pollen comes from the same plant.
- Often facilitated by wind, insects, or other pollinators.

3. **Xenogamy (Cross-Pollination)**:
   - Pollen is transferred from the anther of one plant to the stigma of another plant of the same species.
   - This is the only form of pollination that introduces genetic variation, which enhances adaptability and survival. Requires external pollinating agents such as wind, water, or animals.

(a) **(b)** **(c)**

Fig.: (a) Self-pollinated flowers; (b)Cross pollinated flowers; (c) Cleistogamous flowers

Agents of Pollination

Plants use both **abiotic (wind and water)** and **biotic (animals)** agents for pollination.

Abiotic Pollination

1. **Wind Pollination (Anemophily)**:
   - Common in grasses and some trees.
   - Requires light, non-sticky pollen that can be carried by wind.
   - Flowers are usually small, with well-exposed stamens and feathery stigmas for effective pollen capture.
   - Examples: Corn, wheat, and grasses.
   - **Additional Features**:
     - Large quantities of pollen produced to compensate for random dispersal.
     - Flowers often lack fragrance and nectar since they do not need to attract pollinators.

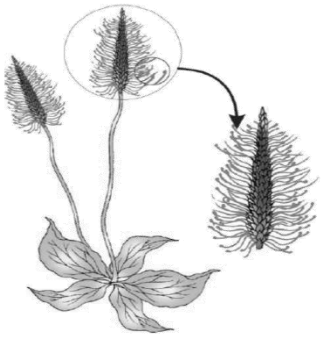


Fig.: A wind-pollinated plant showing compact inflorecence and well exposed stamens

2. **Water Pollination (Hydrophily)**:
   - Rare in flowering plants, occurring in about 30 genera, mainly monocots.
   - Common in aquatic plants such as *Vallisneria*, *Hydrilla*, and *Zostera*.
   - Pollen grains are carried by water currents or released underwater and have mucilaginous coverings to prevent wetting.
   - Most aquatic plants, like water lilies, are pollinated by insects or wind rather than water.
   - **Types**:
     - **Epihydrophily** (pollination occurs on the water surface, e.g., *Vallisneria*).
     - **Hypohydrophily** (pollination occurs underwater, e.g., *Zostera*).

Biotic Pollination

1. **Insect Pollination (Entomophily)**:
   - The most common type of pollination, carried out by bees, butterflies, flies, beetles, wasps, ants, and moths.
   - Flowers are typically large, colorful, fragrant, and nectar-producing to attract pollinators.
   - Some flowers, like those pollinated by flies and beetles, produce foul odors to attract these insects.
   - Example: Sunflower, rose, and mango.
   - **Specialized Relationships**:
     - *Amorphophallus* (Titan arum) attracts carrion flies with its foul smell.
     - *Yucca* plant relies on yucca moths, which pollinate the plant while laying eggs in its flowers.

2. **Bird Pollination (Ornithophily)**:
   - Carried out by birds such as hummingbirds and sunbirds.
   - Flowers are usually tubular, brightly colored (red, orange, or yellow), and rich in nectar.
   - Example: Hibiscus and coral tree.
   - **Adaptations**:
     - Stiff floral structures to support bird perching.
     - No scent production, as birds rely on visual cues rather than smell.
3. **Bat Pollination (Chiropterophily)**:
   - Flowers are usually large, pale-colored, and bloom at night.
   - They produce strong fragrances and large amounts of nectar.
   - Example: Baobab and agave.
   - **Characteristics**:
     - Sturdy flowers to withstand bat movement.
     - High nectar production to attract nocturnal pollinators.
4. **Other Pollinators**:
   - Some plants are pollinated by tree-dwelling rodents, lemurs, and even reptiles like geckos and lizards.
   - Example: Certain species of *Yucca* rely on a mutualistic relationship with moths for pollination and reproduction.

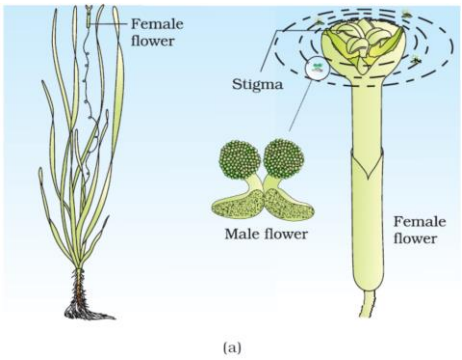


Fig.: (a) Pollination by water in *Vallisneria*; (b) Insect pollination

Outbreeding Devices in Plants

Most flowering plants produce hermaphroditic flowers, increasing the chances of self-pollination. However, self-pollination over generations can lead to inbreeding depression, reducing genetic diversity. To counteract this, plants have evolved mechanisms to promote cross-pollination:

Temporal Separation (Dichogamy)	Spatial Separation (Herkogamy)	Self-Incompatibility	Unisexual Flowers (Monoecy and Dioecy)
The timing of pollen release and stigma receptivity is different.	The anther and stigma are positioned differently to prevent self-pollination.	A genetic mechanism that prevents self-pollen from fertilizing the ovules.	**Monoecious plants**: Male and female flowers are present on the same plant, preventing autogamy but allowing geitonogamy (e.g., maize, castor).
If pollen is released before the stigma is receptive, it is called **protandry**.	Example: *Caryophyllaceae* flowers exhibit herkogamy.	It inhibits pollen germination or pollen tube growth in the pistil.	**Dioecious plants**: Male and female flowers are on different plants, preventing both autogamy and geitonogamy (e.g., papaya, date palm).
If the stigma is receptive before pollen release, it is called **protogyny**.		Example: Brassicas and tobacco.	

Pollen-pistil Interaction:

Pollination ensures the transfer of pollen from the anther to the stigma, but successful fertilization depends on whether the pollen is compatible with the pistil. Pollen-pistil interaction is a selective process where the pistil recognizes and either accepts or rejects the pollen, ensuring only the right type of pollen results in fertilization.

Recognition of Pollen by the Pistil

- The pistil can differentiate between **compatible** and **incompatible** pollen.
- The interaction between pollen and pistil is mediated by **chemical signals** that help in recognition.
- If the pollen is **compatible**, the pistil promotes its germination, leading to fertilization.
- If the pollen is **incompatible**, the pistil **rejects** it by preventing either germination or pollen tube growth.
- Self-incompatibility is a genetic mechanism that prevents self-pollination and encourages cross-pollination.

Post-Pollination Events

After pollination, if the pollen is accepted, the following events take place:

1. **Pollen Germination**
   - The pollen grain absorbs nutrients from the stigma and forms a **pollen tube** through one of its germ pores.
   - The vegetative cell enlarges and forms the pollen tube, while the generative cell divides into **two male gametes** (if not already divided).
2. **Growth of the Pollen Tube**
   - The pollen tube grows through the style, guided by **chemical signals from the ovule**.
   - The tube carries the **two male gametes** toward the ovule.
   - The **filiform apparatus** (a specialized structure in synergids) directs the pollen tube toward the egg apparatus.
3. **Entry into the Ovule**
   - The pollen tube enters the ovule through the **micropyle** and penetrates one of the synergids.
   - The synergids help guide the pollen tube, ensuring that the sperm cells are delivered correctly.
4. **Fertilization (Double Fertilization)**
   - One male gamete fuses with the **egg cell** to form a **zygote (2n)**, which develops into an embryo.
   - The second male gamete fuses with the **two polar nuclei** to form the **triploid endosperm (3n)**, which serves as the food reserve for the developing embryo.
   - This process is unique to **angiosperms** and is called **double fertilization**.

Significance of Pollen-Pistil Interaction

- Prevents **wastage of pollen** by rejecting incompatible pollen.
- Ensures **genetic diversity** by promoting cross-pollination.
- Plays a vital role in **plant breeding** and the development of hybrid crops.

Factors Affecting Pollen-Pistil Interaction

1. **Compatibility** – Whether the pollen belongs to the same species and is genetically acceptable.
2. **Pollen Viability** – The pollen should be mature and viable for successful germination.
3. **Stigma Receptivity** – The stigma should be receptive at the time of pollination.
4. **Environmental Conditions** – Factors like humidity, temperature, and wind speed affect pollen tube growth.

Applications of Pollen-Pistil Interaction

- **Hybrid Seed Production** – Used in creating hybrid crops with improved yield, disease resistance, and stress tolerance.
- **Controlled Pollination** – Used in genetic studies and plant breeding programs.
- **Overcoming Incompatibility** – Scientists manipulate pollen-pistil interaction to overcome barriers in crossbreeding.

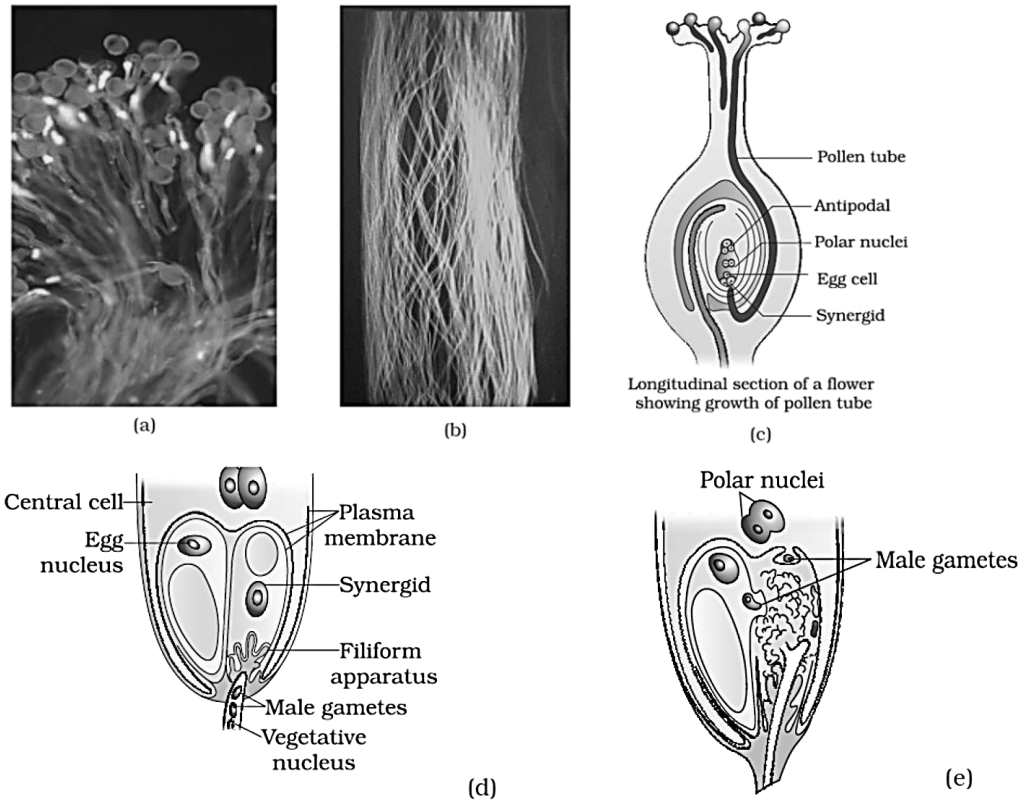


Fig.: (a) Pollen grains germinating on the stigma; (b) Pollen tubes growing through the style; (c) L.S. of pistil showing path of pollen tube growth; (d) enlarged view of an egg apparatus showing entry of pollen tube into a synergid; (e) Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the other into the central cell

Artificial Hybridisation

Artificial hybridization is a technique used in **crop improvement programs** to combine desirable traits from different plant species or varieties. This is achieved by controlling pollination through **emasculation and bagging techniques**.

Steps of Artificial Hybridization

A. Emasculation

- If the female plant has **bisexual flowers**, the **anthers are removed** before they mature (before dehiscence) to prevent self-pollination.
- This is done using forceps and ensures that only desired pollen fertilizes the stigma.

B. Bagging

- After emasculation, the flower is covered with a **bag made of butter paper** or similar material.
- This prevents unwanted pollen from contaminating the stigma.
- The bag remains until the stigma **becomes receptive**.

C. Pollination with Desired Pollen

- When the stigma becomes receptive, the bag is removed, and **mature pollen grains** from the chosen male parent are dusted on the stigma.
- The flower is then **rebagged** to prevent contamination.

D. Development of Hybrid Fruits

- The fertilized flowers are left to develop into **hybrid fruits and seeds** with desirable traits.

If the Female Parent Has Unisexual Flowers

- **No emasculation is needed** because the male and female flowers are separate.
- The female flower bud is **bagged before it opens**.
- When the stigma becomes receptive, pollination is carried out with the desired pollen, followed by **rebagging**.

Importance of Artificial Hybridisation

- Helps in **producing high-yielding varieties**.
- Increases **disease resistance** and **stress tolerance** in crops.
- Allows for the combination of **desirable traits** from different plants.

TOPIC CENTRIC EXERCISE -03

Q1. Which type of pollination occurs within the same flower?
(a) Xenogamy (b) Geitonogamy
(c) Autogamy (d) Hydrophily

Q2. What is the main advantage of self-pollination?
(a) Genetic variation (b) Assured seed production
(c) Dependence on pollinators (d) Increased disease resistance

Q3. Which mechanism prevents self-pollination by genetic incompatibility?
(a) Dichogamy (b) Herkogamy
(c) Self-incompatibility (d) Monoecy

Q4. Which plant relies on moths for pollination?
(a) Mango (b) Yucca
(c) Corn (d) Wheat

Q5. What is the primary purpose of emasculation in artificial hybridization?
(a) To remove female reproductive structures
(b) To prevent self-pollination
(c) To protect the flower from insects
(d) To encourage cross-pollination naturally

1.3 DOUBLE FERTILISATION

Double fertilization is a unique reproductive process **exclusive to angiosperms (flowering plants)**. It involves the fusion of two male gametes with two different cells in the embryo sac, leading to the formation of both a **zygote (2n)** and a **triploid endosperm (3n)**. This phenomenon ensures efficient resource allocation and successful seed development.

Process of Double Fertilization

1. **Entry of Pollen Tube into the Embryo Sac**
   - After **pollination**, the pollen grain germinates on the stigma and produces a **pollen tube**.
   - The pollen tube grows through the **style** and reaches the ovule via the **micropyle**.
   - Upon entering the embryo sac, the pollen tube **discharges two male gametes** into one of the **synergid cells**.
   - The **filiform apparatus** in the synergids guides the pollen tube to ensure precise delivery of male gametes.
2. **Syngamy: Fusion of Male Gamete with Egg Cell**
   - One of the **haploid (n) male gametes** moves toward the **haploid (n) egg cell**.
   - The two nuclei fuse, forming a **diploid (2n) zygote**.
   - This process is called **syngamy**, a critical step leading to embryo development.
3. **Triple Fusion: Formation of Endosperm**
   - The second **haploid (n) male gamete** moves toward the **central cell**, which contains **two haploid (n) polar nuclei**.
   - All three nuclei (one from the male gamete and two from the central cell) fuse, forming a **triploid (3n) primary endosperm nucleus (PEN)**.
   - Since this involves **fusion of three haploid nuclei**, it is called **triple fusion**.
   - The central cell, after triple fusion, becomes the **primary endosperm cell (PEC)**, which later develops into **endosperm**, a nutritive tissue that supports embryo growth.
4. **Formation of Embryo and Endosperm**
   - The **zygote (2n)** undergoes mitotic divisions and develops into an **embryo**, which will eventually grow into a new plant.

- The **primary endosperm nucleus (3n)** undergoes multiple divisions, forming the **endosperm**, which serves as a storage tissue for the developing embryo.
- The endosperm provides essential nutrients such as **starch, proteins, and lipids**, ensuring proper seed development.

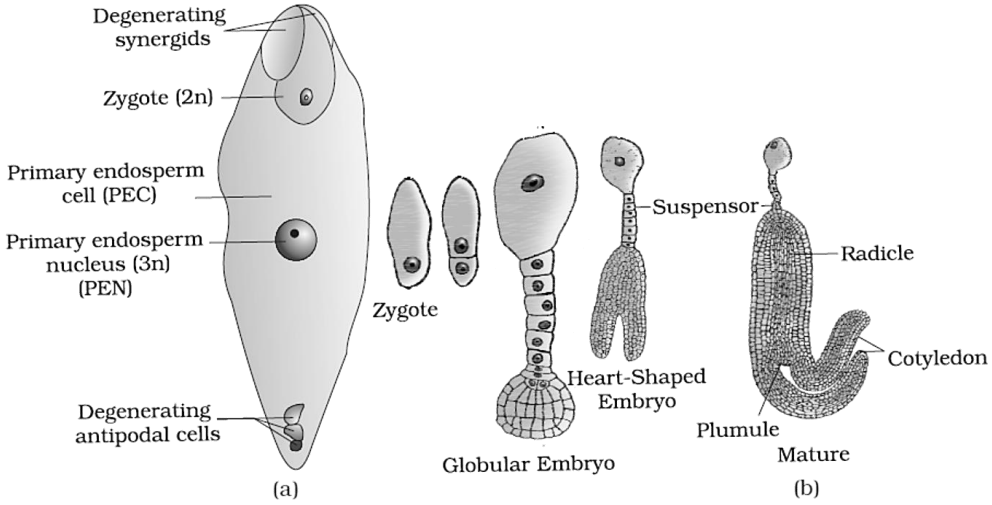


Fig.: (a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN);
(b) Stages in embryo development in a dicot [shown in reduced size as compared to (a)]

Significance of Double Fertilization

1. **Unique to Angiosperms** – This process is exclusive to flowering plants and is absent in gymnosperms.
2. **Efficient Resource Utilization** – Endosperm formation occurs **only after fertilization**, preventing wastage of nutrients in unfertilized ovules.
3. **Enhanced Seed Viability** – The **endosperm nourishes the embryo**, ensuring better survival and germination.
4. **Agricultural Importance** – Many **cereal grains (wheat, rice, maize)** rely on endosperm as a primary food source.
5. **Genetic Variation** – The involvement of multiple nuclei in fertilization promotes genetic diversity in offspring.

Comparison Between Syngamy and Triple Fusion

Feature	Syngamy	Triple Fusion
Definition	Fusion of a male gamete with the egg cell	Fusion of a male gamete with two polar nuclei
Nucleus Formed	Diploid (2n) Zygote	Triploid (3n) Primary Endosperm Nucleus (PEN)
Function	Leads to embryo formation	Leads to endosperm formation
Type of Fertilization	Sexual fertilization	Accessory fertilization

1.4 POST-FERTILISATION: STRUCTURES AND EVENTS

After fertilisation in flowering plants, several changes occur in the ovule and ovary, leading to the formation of seeds and fruits. The major post-fertilisation events include the **development of the endosperm and embryo**, **maturation of the ovule into a seed**, and **transformation of the ovary into a fruit**. These processes ensure the successful propagation of plant species.

1.4.1 Endosperm

Endosperm development occurs **before embryo development** to provide nutrients for the developing embryo. The **primary endosperm cell (PEC)**, formed after triple fusion, undergoes multiple divisions to form the **endosperm tissue**, which serves as a food reserve.

Types of Endosperm Development

There are three major types of endosperm formation:

1. **Nuclear Endosperm** (Most common)
   - The **primary endosperm nucleus (PEN)** undergoes repeated mitotic divisions **without cytokinesis**, resulting in **free nuclei**.
   - Later, **cell walls** form around these nuclei to develop into a **cellular endosperm**.
   - **Example:** Coconut water (free nuclear endosperm) and coconut kernel (cellular endosperm).
2. **Cellular Endosperm**
   - The **primary endosperm nucleus** undergoes **immediate cytokinesis**, forming **cell walls at each division**.
   - The endosperm is cellular from the beginning.
   - **Example:** Datura, Petunia.
3. **Helobial Endosperm**
   - Occurs in monocots. The first division results in **two unequal cells**:
     - **One cell undergoes free nuclear divisions** (like nuclear endosperm).
     - **The other cell remains undivided** or divides slowly.
   - **Example:** Asphodelus.

Fate of Endosperm in Seeds

- **Completely consumed by the embryo → Non-albuminous seeds** (e.g., Pea, Groundnut, Beans).
- **Partially consumed, some remains in the seed → Albuminous seeds** (e.g., Wheat, Maize, Barley, Castor).
- **Persistent nucellus (Perisperm) remains in seed** → Found in **Black Pepper, Beet**.

1.4.2 Embryo

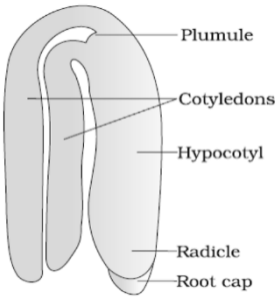
The **zygote (2n)**, formed after syngamy, develops into an **embryo**. The **process of embryo development is called embryogeny**. This occurs in a **systematic sequence**:

1. **Zygote → Proembryo**
2. **Proembryo → Globular Stage**
3. **Globular Stage → Heart-Shaped Stage**
4. **Heart-Shaped Stage → Mature Embryo**

Structure of a Dicot Embryo

A typical **dicot embryo** consists of:

- Embryonal Axis
- Two Cotyledons
- Epicotyl → Region above cotyledons; terminates in plumule (shoot tip).
- Hypocotyl → Region below cotyledons; terminates in radicle (root tip).
- Radicle is covered by a root cap.



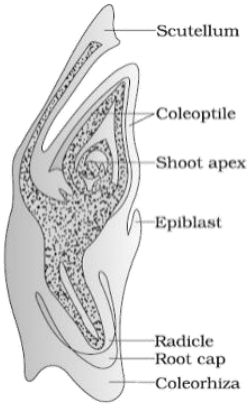
(a) A typical dicot embryo

Structure of a Monocot Embryo

- Possesses **only one cotyledon**, called the **scutellum** (in grasses).
- **Coleoptile** → A protective sheath covering the shoot apex.
- **Coleorhiza** → A protective sheath covering the root apex.

Why Does the Embryo Develop After the Endosperm?

- The **embryo needs nutrition** during early development.
- **Endosperm formation ensures the availability of food** before embryo growth begins.



(b) L.S. of an embryo of grass

TOPIC CENTRIC EXERCISE -04

Q1. The first division of the zygote is:
(a) Mitotic
(b) Meiotic
(c) Asymmetric
(d) Both (a) and (c)

Q2. The suspensor in the embryo is responsible for:
(a) Anchoring the embryo
(b) Nourishing the embryo
(c) Storing food
(d) Dividing cells

Q3. The cotyledons are:
(a) Leaves of the embryo
(b) Food storage structures
(c) Part of the endosperm
(d) Part of the seed coat

Q4. The embryonic axis above the cotyledons is the:
(a) Radicle
(b) Plumule
(c) Root cap
(d) Epicotyl

Q5. The embryonic root is known as the:
(a) Plumule
(b) Radicle
(c) Endosperm
(d) Seed coat

1.4.3 Seed

In **angiosperms**, seeds are the final product of sexual reproduction. A seed is essentially a **fertilised ovule** enclosed within a protective seed coat.

Parts of a Seed

1. **Seed Coat** → Protective outer layer (formed from ovule integuments).
2. **Embryo** → Consists of the **radicle, plumule, and cotyledons**.
3. **Cotyledons** → Stores nutrients for the developing embryo.

Types of Seeds

- **Non-Albuminous (Exalbuminous) Seeds**
  - Endosperm is **completely consumed** by the embryo.
  - **Examples:** Pea, Groundnut, Beans.
- **Albuminous Seeds**
  - Endosperm is **partially consumed** and remains in the mature seed.
  - **Examples:** Wheat, Maize, Barley, Castor.
- **Seeds with Persistent Nucellus (Perisperm)**
  - **Examples:** Black Pepper, Beet.

Seed Dormancy and Germination

- **Dormancy**: Some seeds enter a **resting phase** where metabolic activities slow down.
- **Germination**: When conditions are favorable (moisture, oxygen, temperature), the embryo resumes growth.
- **Micropyle**: A tiny opening in the seed coat that allows **water and oxygen** to enter during germination.

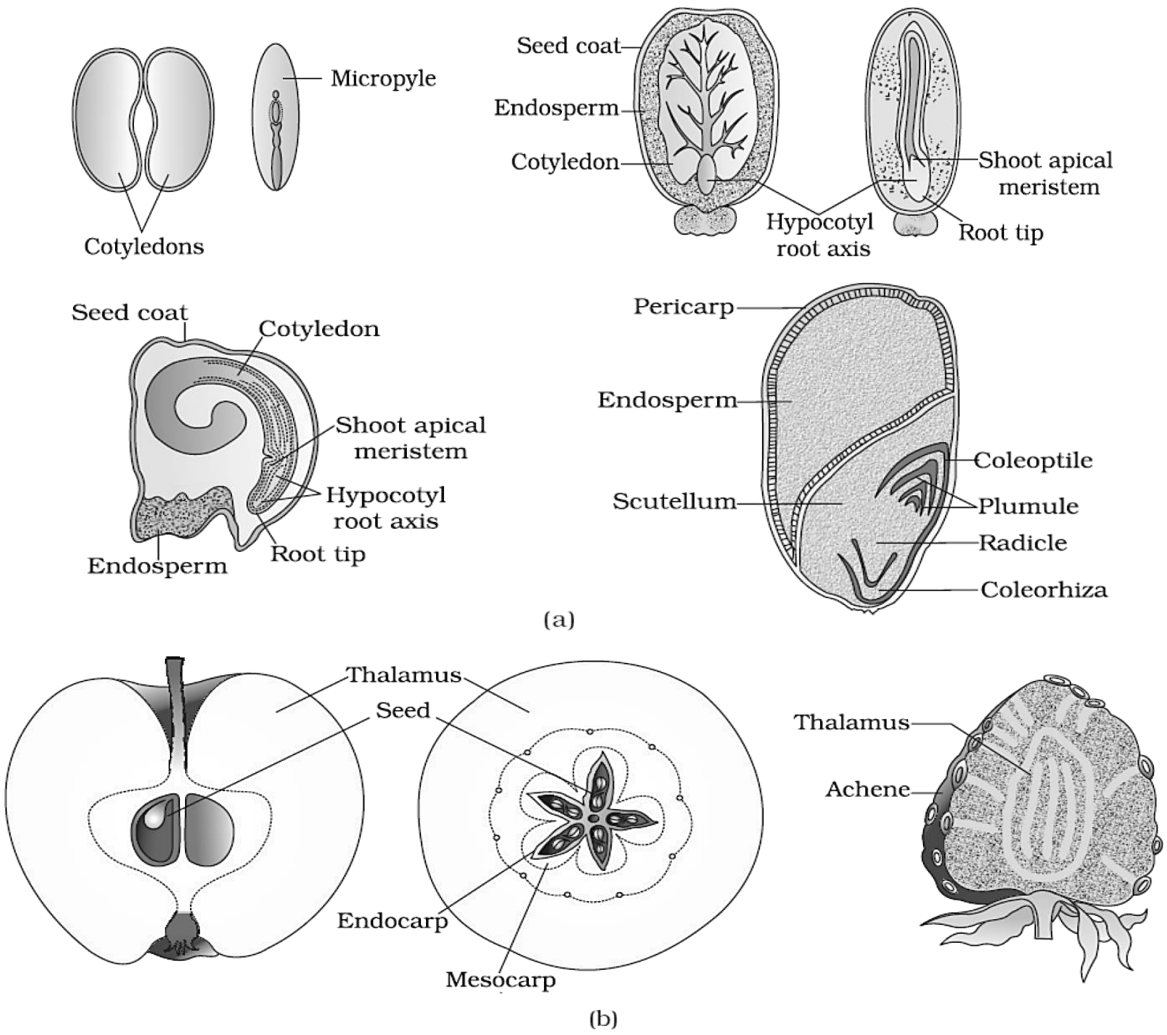


Fig.: (a) Structure of some seeds. (b) False fruits of apple and strawberry

1.4.4. Fruit Development

As seeds mature, the ovary develops into a fruit. The transformation of an ovary into a fruit occurs simultaneously with seed formation.

Types of Fruits

- **True Fruits** → Develop **only from the ovary** (e.g., Mango, Tomato, Guava).
- **False Fruits** → Develop **from the ovary and other floral parts (e.g., thalamus)** (e.g., Apple, Strawberry, Cashew).
- **Parthenocarpic Fruits** → Develop **without fertilisation**, resulting in seedless fruits (e.g., Banana).

Advantages of Fruits

- Protect the seeds inside.
- Aid in seed dispersal through wind, water, or animals.
- Prevent premature germination by enclosing the seeds.

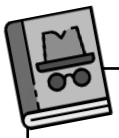
Importance of Seeds

- Ensure species survival by allowing dispersal to new areas.
- Provide food storage for the young plant until it can perform photosynthesis.
- Genetic Variation: As products of sexual reproduction, seeds promote diversity and adaptation.
- Essential for Agriculture: Seeds can be stored and used to grow crops in later seasons.

Seed Viability

- Some seeds remain viable **only for a few months**.
- Others can survive **for years or even centuries**!

- **Oldest Viable Seeds**:
  - Lupinus arcticus (10,000 years old, Arctic Tundra).
  - Phoenix dactylifera (Date Palm) (2,000 years old, Dead Sea excavation).



Clue Finder

- Endosperm develops first to support the embryo.
- Seeds are fertilised ovules that contain an embryo and stored food.
- Fruits develop from ovaries and aid in seed dispersal.
- Dormancy ensures survival, and germination allows growth under favorable conditions.

1.5 APOMIXIS AND POLYEMBRYONY

Apomixis: A Unique Mode of Asexual Reproduction

Apomixis is a form of asexual reproduction that mimics sexual reproduction but occurs without fertilization. It enables the formation of seeds without the fusion of gametes, leading to the production of genetically identical offspring (clones) of the parent plant. This phenomenon is observed in certain species of Asteraceae, Poaceae (grasses), Citrus, and Mango.

Polyembryony: Occurrence of Multiple Embryos in a Seed

Polyembryony refers to the presence of more than one embryo within a single seed. This phenomenon can arise due to:

- **Zygotic Polyembryony** – Multiple embryos develop from the zygote due to cleavage or budding.
- **Adventive Polyembryony** – Embryos arise from **nucellar or integumentary cells**, which bypass fertilization and give rise to independent embryos.
- **Apomictic Polyembryony** – Apomictic processes lead to multiple embryos, as seen in **Citrus and Mango**.
  In many species, especially in **Citrus**, a single seed may contain multiple embryos of different sizes and shapes. If you extract and examine an orange seed, you can often observe multiple embryos within the seed coat.

Genetic Nature of Apomictic Embryos

Since apomictic embryos are produced without fertilization, they retain the exact genetic makeup of the parent plant, making them clonal in nature. Thus, apomictic embryos can be called clones.

Significance of Apomixis in Hybrid Seed Production

Hybrid crop varieties are extensively cultivated because of their higher yield, disease resistance, and better adaptability. However, one major drawback of hybrids is that their seeds cannot be used for planting the next season. When hybrid seeds are sown, their progeny exhibits genetic segregation, meaning the desirable hybrid characteristics are lost in the subsequent generation. This forces farmers to purchase new hybrid seeds every year, making cultivation costly.

Apomixis offers a **revolutionary solution** to this problem:

- **No Genetic Segregation** – Apomictic seeds produce offspring **identical** to the parent, preserving the hybrid characters for multiple generations.
- **Cost Reduction** – Farmers can reuse seeds from hybrid plants, eliminating the need to buy new hybrid seeds each year.
- **Increased Agricultural Productivity** – Apomixis ensures a stable, uniform crop yield with desirable traits across successive generations.

Due to its potential benefits in agriculture, **extensive research is being conducted worldwide** to understand the genetic control of apomixis and incorporate apomictic genes into hybrid crops.

TOPIC CENTRIC EXERCISE -05

Q1. Seed formation begins after:
(a) Pollination (b) Fertilization
(c) Double fertilization (d) Germination

Q2. A seed consists of:
(a) Zygote and cotyledons (b) Embryo, seed coat, and endosperm
(c) Endosperm only (d) Seed coat only

Q3. The outer covering of a seed is the:
(a) Endosperm (b) Seed coat
(c) Embryo (d) Radicle

Q4. Non-albuminous seeds lack:
(a) Endosperm (b) Seed coat
(c) Cotyledons (d) Embryo

Q5. Albuminous seeds retain:
(a) Endosperm (b) Seed coat
(c) Cotyledons (d) Embryo

Differences between apomixis and polyembryony:

Feature	Apomixis	Polyembryony
Definition	Formation of seeds without fertilization (asexual reproduction).	Occurrence of multiple embryos in a single seed.
Fertilization	No fertilization occurs.	Fertilization may or may not occur.
Genetic Nature	Produces genetically identical offspring (clones).	Embryos may be genetically identical or different, depending on the type.
Types	Includes parthenogenesis, apospory, diplospory, and adventive embryony.	Includes zygotic, adventive, and apomictic polyembryony.
Examples	Seen in some grasses, Asteraceae, Citrus, and Mango.	Found in Citrus, Mango, and some gymnosperms like Pinus.

Solved Examples

Ex: 1- A typical angiosperm anther is _____ with each lobe having _____ theca i.e. they are _____
(a) Bilobed, two, dithecous
(b) Dithecous, two, bilobed
(c) Bilobed, four, dithecous
(d) Dithecous, four, bilobed

Sol. (a): Angiosperm anthers are bilobed and each lobe has two thecae (pollen sacs), making them dithecous.

Ex: 2- Pollen grain represents –
(a) Male gametophyte (b) Male sporophyte
(c) Female gametophyte (d) Female sporophyte

Sol. (a): The pollen grain is the male gametophyte, which produces male gametes.

Ex: 3- Pollen grains can be used in form of tablets as food supplements because-
(a) They are rich in nutrients
(b) They increase the performance of athletes
(c) They are only useful in animals
(d) Both (a) and (b)

Sol. (d): Pollen is nutrient-rich and can enhance athletic performance, hence used as supplements.

Ex: 4- An ovule generally has _____ embryo sac formed from a megaspore.
(a) Single (b) Two
(c) Three (d) Four

Sol. (a): Typically, only one functional megaspore forms a single embryo sac in the ovule.

Ex: 5. **Typical embryo sac of angiosperm at maturity is –**
(a) 8 celled, 8 nucleate (b) 7 celled, 8 nucleate
(c) 8 celled, 7 nucleate (d) 7 celled, 7 nucleate
Sol. **(b):** The mature embryo sac has 7 cells and 8 nuclei including 2 polar nuclei in the central cell.

Ex: 6. **Genetically different type of pollen is brought to stigma by-**
(a) Autogamy only (b) Geitonogamy only
(c) Xenogamy only (d) More than one options
Sol. **(c):** Xenogamy involves transfer of pollen from one plant to another genetically distinct plant.

Ex: 7. **Inbreeding depression is a result of-**
(a) Self-fertilization followed by cross-fertilization
(b) Cross-fertilization followed by self-fertilization
(c) Continued cross-fertilization
(d) Continued self-fertilization
Sol. **(d):** Prolonged self-fertilization leads to expression of harmful recessive traits causing depression.

Ex: 8. **Endosperm tissue is-**
(a) Haploid (b) Diploid
(c) Triploid (d) Tetraploid
Sol. **(c):** Fusion of two polar nuclei with a male gamete forms triploid endosperm in angiosperms.

Ex: 9. **Micropyle plays role of-**
(a) Stalk for seed
(b) Scar of stalk
(c) Facilitating entry of water into seed
(d) Facilitating escape of seed metabolites
Sol. **(c):** Micropyle allows water absorption into the seed during germination.

Ex: 10. **The oldest yet viable seed found is –**
(a) Lupinus from arctic tundra
(b) Phoenix from arctic tundra
(c) Lupinus from king Herod's palace
(d) Phoenix from king Herod's palace
Sol. **(a):** Lupinus arcticus seeds over 10,000 years old were found viable in arctic tundra.

Exercise-01 Level -01

1. The reproductive structures in angiosperms are contained in the:
(a) Leaf (b) Stem
(c) Flower (d) Root

2. The male reproductive organ of a flower is called:
(a) Gynoecium (b) Calyx
(c) Androecium (d) Corolla

3. Which part of the stamen contains pollen grains?
(a) Anther (b) Filament
(c) Style (d) Ovary

4. Which of the following is the female reproductive part of a flower?
(a) Androecium (b) Gynoecium
(c) Petal (d) Sepal

5. Which substance makes up the exine of pollen grains?
(a) Cellulose (b) Sporopollenin
(c) Lignin (d) Hemicellulose

6. The intine layer of the pollen grain is composed of:
(a) Cellulose and lignin (b) Cellulose and pectin
(c) Sporopollenin (d) Cutin

7. Pollen viability refers to:
(a) The ability of pollen to germinate
(b) The longevity of pollen
(c) The ability to attract pollinators
(d) The development of the pollen tube

8. In most angiosperms, pollen grains are:
(a) One celled (b) Two celled
(c) Three celled (d) Four celled

9. Which part of the anther produces pollen?
(a) Endothecium (b) Tapetum
(c) Microsporangium (d) Exine

10. In angiosperms, the process of pollen transfer from anther to stigma is called:
(a) Fertilization (b) Pollination
(c) Germination (d) Seed dispersal

11. Which type of pollination occurs between flowers of the same plant?
(a) Xenogamy (b) Autogamy
(c) Geitonogamy (d) None

12. Self-pollination refers to:
(a) Transfer of pollen from one plant to another
(b) Transfer of pollen from anther to stigma of the same flower
(c) Transfer of pollen from one flower to another on the same plant
(d) No transfer of pollen

13. Pollination by insects is called:
(a) Anemophily (b) Entomophily
(c) Hydrophily (d) Zoophily

14. In hydrophyllous plants, pollination occurs through:
(a) Wind (b) Water
(c) Insects (d) Birds

15. Pollination by birds is termed as:
(a) Ornithophily (b) Entomophily
(c) Anemophily (d) Zoophily

16. What is the outermost layer of pollen grain called?
(a) Endothecium (b) Intine
(c) Exine (d) Tapetum

17. Which part of the pollen grain helps in pollen tube formation?
(a) Exine (b) Intine
(c) Endothecium (d) Tapetum

18. The process of double fertilization in angiosperms involves:
(a) Fusion of one male gamete with the egg and another with the central cell
(b) Two male gametes fusing with two eggs
(c) Two male gametes fusing with one egg
(d) Only one male gamete participating

19. In a typical embryo sac, the egg apparatus consists of:
(a) One egg cell and two synergids
(b) Two egg cells and one synergid
(c) Three egg cells
(d) Two synergids only

20. Antipodal cells are located in the:
(a) Center of the embryo sac
(b) Micropylar end
(c) Chalazal end
(d) Ovary wall

21. The central cell in the embryo sac has:
(a) One nucleus (b) Two polar nuclei
(c) Three nuclei (d) No nucleus

22. The embryo sac is also known as:
(a) Megasporangium
(b) Female gametophyte
(c) Microsporangium
(d) Ovule

23. The structure that develops into the seed is the:
(a) Ovule (b) Ovary wall
(c) Embryo sac (d) Stigma

24. The product of double fertilization includes:
(a) Only embryo
(b) Endosperm and embryo
(c) Only endosperm
(d) None of the above

25. Triple fusion leads to the formation of:
(a) Embryo (b) Zygote
(c) Endosperm (d) Synergids

26. Which of the following structures is diploid after fertilization?
(a) Synergid (b) Zygote
(c) Endosperm (d) Antipodals

27. The ploidy level of the endosperm in angiosperms is:
(a) Haploid (b) Diploid
(c) Triploid (d) Tetraploid

28. Ovules are attached to the placenta by a stalk called:
(a) Hilum (b) Funicle
(c) Integument (d) Nucellus

29. The outer covering of the ovule is known as:
(a) Micropyle (b) Integument
(c) Nucellus (d) Funicle

30. In a mature ovule, the egg apparatus consists of:
(a) One egg cell and two synergids
(b) One egg cell and three antipodals
(c) Two egg cells and one synergid
(d) One egg cell and one antipodal

31. What is the name of the opening in the ovule through which pollen tube enters?
(a) Chalaza (b) Funicle
(c) Micropyle (d) Integument

32. Synergids are located near the:
(a) Chalaza (b) Micropyle
(c) Funicle (d) Integument

33. Antipodal cells are:
(a) Haploid (b) Diploid
(c) Triploid (d) Two celled

34. The male gametophyte in angiosperms is represented by:
(a) Pollen grain (b) Ovule
(c) Embryo sac (d) Synergids

35. Megasporogenesis results in the formation of:
(a) Pollen grains (b) Microspores
(c) Megaspores (d) Synergids

36. The functional megaspore in angiosperms develops into:
(a) Embryo sac (b) Ovule
(c) Nucellus (d) Endosperm

37. Which part of the flower develops into the fruit?
(a) Ovary (b) Ovule
(c) Stigma (d) Anther

38. The seed is formed from the:
(a) Ovule (b) Ovary
(c) Pollen grain (d) Anther

39. Which of the following plants show cleistogamous flowers?
(a) Pea (b) Viola
(c) Hibiscus (d) Mustard

40. Self-incompatibility is a genetic mechanism that prevents:
(a) Cross-pollination (b) Self-pollination
(c) Both self- and cross-pollination
(d) Double fertilization

41. Pollen tube germinates:
(a) Before pollination
(b) After pollination in air
(c) On stigma (d) On biotic pollinator

42. Triple fusion occurs in the:
(a) Egg cell (b) Central cell
(c) Synergid (d) Antipodal cell

43. The pollen tube releases sperm cells into the:
(a) Micropyle (b) Central cell
(c) Egg apparatus (d) Antipodal cells

44. Syngamy results in the formation of a:
(a) Triploid cell (b) Diploid zygote
(c) Haploid embryo (d) Tetraploid cell

45. Endosperm development in angiosperms is generally:
(a) Nuclear (b) Cellular
(c) Both (d) None

46. Which of the following plant not exhibit apomixis?
(a) Mango (b) Citrus
(c) Grass (d) Rice

47. Apomixis results in:
(a) Formation of seed without fertilization
(b) Normal fertilization
(c) Formation of embryo from zygote cells
(d) Formation of gametes without meiosis

48. Polyembryony refers to:
(a) Development of more than one embryo in a single seed
(b) Development of multiple embryos from different eggs
(c) Development of multiple embryos from different ovules
(d) Formation of several seeds in one ovule

49. Endosperm development precedes embryo development in:
(a) Gymnosperms (b) Angiosperms
(c) Algae (d) Bryophytes

50. Parthenocarpic fruit is-
(a) Strawberry (b) Tomato
(c) Banana (d) Apple

Exercise-02 Level -02

1. Read the following statements:
I. Microsporogenesis occurs in the anther.
II. Microsporogenesis produces pollen grains.
III. Microsporogenesis involves meiosis.
IV. Microsporogenesis is a type of mitosis.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

2. Read the following statements:
I. Microsporogenesis begins with the formation of sporogenous cells.
II. Sporogenous cells give rise to microspore tetrad.
III. Microspore tetrad form microspore mother cells.
IV. Microspore mother cells produce pollen grains directly.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

3. Read the following statements:
I. Microspore mother cells undergo meiosis I to form dyads.
II. Dyads undergo meiosis II to form tetrads.
III. Tetrads are composed of four microspores.
IV. Microspores are haploid.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

4. Read the following statements:
I. Microsporogenesis occurs in the sporogenous tissue.
II. Microsporogenesis produces microspores.
III. Microspores develop into pollen grains.
IV. Pollen grains are diploid.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

5. Read the following statements:
I. Cytoplasm of pollen grain is surrounded by cell membrane.
II. Pollen grain membrane is two layered.
III. Pollen grain possess germ pore with continuous sporopollenin.
IV. Pollen grain is never fossilised.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

6. Read the following statements:
I. Pollen grain is two celled in many angiosperms.
II. Pollen grain is covered by outer exine and inner intine.
III. Pollen grain has bigger generative cell.
IV. Pollen grain has smaller vegetative cell.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

7. Read the following statements:
I. Each cell of sporogenous tissue can give rise to microspore mother cell.
II. Microspore dissociates from each other after maturation.
III. Microsporangium has several thousand of microspores.
IV. Pollen grains are released from the anther after dehiscence.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

8. Read the following statements:
I. Microsporogenesis produces haploid microspores.
II. Microspores develop into haploid pollen grains.
III. Pollen grains contain diploid cells.
IV. Pollen grains germinate to form the pollen tube.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

9. Read the following statements:
I. The pistil is the female reproductive organ.
II. The pistil consists of stigma, style, and ovary.
III. The ovary contains ovules.
IV. The ovules produce pollen grains.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

10. Read the following statements:
I. The ovule is the megasporangium.
II. The ovule contains megaspores.
III. Megaspores develop into embryo sacs.
IV. Embryo sacs produce seeds.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

11. Read the following statements:
I. The embryo sac is haploid.
II. The embryo sac contains egg cell, synergids, and antipodals.
III. The embryo sac is formed through meiosis.
IV. The embryo sac develops only into endosperm.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

12. Read the following statements:
I. The ovule is attached to the placenta.
II. The ovule contains a micropyle.
III. The ovule contains a chalaza.
IV. The ovule produces seeds.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

13. Read the following statements:
I. The stigma is the receptive surface.
II. The style connects the stigma to the ovary.
III. The ovary contains ovules.
IV. The ovary produces pollen grains.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

14. Read the following statements:
I. The embryo sac contains 8 nuclei.
II. The embryo sac contains 7 cells.
III. The embryo sac contains egg cell, synergids, and antipodals.
IV. The embryo sac produces embryo.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

15. Read the following statements:
I. Hilum is junction between funicle and ovule.
II. The ovule produces haploid megaspores.
III. Megaspores develop into female gametophyte.
IV. Embryo sacs produce seeds directly.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

16. Read the following statements:
I. The placenta is the region of ovule attachment.
II. Integument encircle nucellus except micropyle.
III. The ovule contains only a chalaza.
IV. The ovule produces male gametophyte.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

17. Read the following statements:
I. Pollination is the transfer of pollen from anther to stigma.
II. Pollination occurs in both gymnosperms and angiosperms.
III. Pollination is essential for fertilization.
IV. Pollination occurs only through wind.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

18. Read the following statements:
I. Agents of pollination include insects, wind, and water.
II. Insects are the most important pollinators.
III. Wind pollination occurs in grasses and conifers.
IV. Water pollination occurs in all aquatic plants.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

19. Read the following statements:
I. Outbreeding devices promote cross-pollination.
II. Outbreeding devices include self-incompatibility and heterostyly.
III. Outbreeding devices increase genetic diversity.
IV. Outbreeding devices are present in all flowering plants.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

20. Read the following statements:
I. Self-pollination occurs in bisexual flowers.
II. Self-pollination reduces genetic diversity.
III. Cross-pollination promotes genetic diversity.
IV. Cleistogamy is a type of self-pollination.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

21. Read the following statements:
I. Heterostyly is a type of outbreeding device.
II. Heterostyly promotes cross-pollination.
III. Heterostyly prevent xenogamy.
IV. Heterostyly is same as self-incompatibility.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

22. Read the following statements:
I. Pollination by insects is called entomophily.
II. Pollination by wind is called anemophily.
III. Pollination by water is called hydrophily.

IV. Pollination by birds is called ornithophily.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

23. Read the following statements:

I. Continuous self- pollination result in inbreeding depression.
II. Self-incompatibility prevents autogamy.
III. Self-incompatibility promotes cross-pollination.
IV. Self-incompatibility occurs in all flowering plants.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

24. Read the following statements:

I. Cleistogamy is a type of self-pollination.
II. Cleistogamy occurs in Viola.
III. Cleistogamy promotes genetic diversity.
IV. Cleistogamy reduces seed production.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

25. Read the following statements:

I. Pollen-pistil interaction involves recognition between pollen and stigma.
II. Pollen germination occurs on the stigma.
III. Pollen tube growth is controlled by the style.
IV. Pollen-pistil interaction is unnecessary for fertilization.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

26. Read the following statements:

I. Compatible pollen-pistil interaction leads to pollen germination.
II. Incompatible pollen-pistil interaction prevents pollen germination.
III. Self-incompatibility is a type of incompatible pollen-pistil interaction.
IV. Pollen-pistil interaction is controlled by multiple genes.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

27. Read the following statements:

I. Pollen tube growth is influenced by chemical signals.
II. Pollen tube growth is influenced by physical barriers.
III. Pollen tube growth is necessary for fertilization.
IV. Pollen tube growth occurs in the anther.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

28. Read the following statements:

I. Monoecious plants as castor prevent autogamy.
II. Maize plant donot exhibit autogamy.
III. Papaya is a dioecious plant.
IV. Dioecy prevent both autogamy and geitonogamy.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

29. Read the following statements:

I. Pollen-pistil interaction involves cell-cell recognition.
II. Pollen-pistil interaction involves molecular signaling.
III. Pollen-pistil interaction controls fertilization.
IV. Pollen-pistil interaction is unnecessary for seed formation.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

30. Read the following statements:

I. Double fertilization occurs in flowering plants.
II. One sperm fuses with egg cell to form zygote.
III. Other sperm fuses with diploid secondary nucleus.
IV. Double fertilization produces two zygotes.

Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

31. Read the following statements:
I. Endosperm is a triploid tissue.
II. Endosperm develops from triple fusion.
III. Endosperm provides nutrition to developing embryo.
IV. Endosperm is formed before fertilization.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

32. Read the following statements:
I. Embryo development begins with zygote formation.
II. Zygote undergoes several cell divisions.
III. Embryo sac contains embryo and endosperm.
IV. Embryo development occurs in anther.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

33. Read the following statements:
I. Triple fusion forms primary endosperm nucleus.
II. Primary endosperm nucleus develops into endosperm.
III. Endosperm is a storage tissue.
IV. Endosperm is absent in flowering plants.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

34. Read the following statements:
I. Embryo development involves differentiation.
II. Embryo development is known as embrogeny.
III. Embryo development forms radicle and cotyledon.
IV. Embryo development occurs at micropylar end.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

35. Read the following statements:
I. Double fertilization ensures genetic diversity.
II. Double fertilization increases seed production.
III. Double fertilization forms zygote and endosperm.
IV. Double fertilization occurs in all plants.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

36. Read the following statements:
I. Endosperm is a nutritive tissue.
II. Endosperm develops from triple fusion.
III. Endosperm provides nutrition to developing embryo.
IV. Endosperm is triploid.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

37. Read the following statements:
I. Embryo sac contains 8 nuclei.
II. Embryo sac contains 7 cells.
III. Embryo sac forms zygote and endosperm.
IV. Embryo sac is diploid.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

38. Read the following statements:
I. Seeds are formed from ovules.
II. Seeds contain embryo and endosperm.
III. Seeds provide nourishment to developing embryo.
IV. Seeds are produced in gymnosperms and angiosperms.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

39. Read the following statements:
I. Fruits develop from ovary.
II. Fruits protect seeds from desiccation.
III. Fruits attract dispersal agents.
IV. Fruits are produced only in angiosperms.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

40. Read the following statements:
I. Pericarp is the outer layer of fruit.
II. Pericarp is derived from ovary wall.
III. Pericarp provides protection to seeds.
IV. Pericarp is edible in all fruits.
Choose the correct option:

(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

41. Read the following statements:
I. Fruits develop from one ovary.
II. True fruits develop from fertilisation.
III. False fruits develop from other than ovary.
IV. Parthenocarpic fruits develop from thalamus.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

42. Read the following statements:
I. Seeds are dispersed through wind.
II. Seeds are dispersed through water.
III. Seeds are dispersed through animals.
IV. Seeds are not dispersed.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

43. Read the following statements:
I. Groundnut is dry fruit.
II. Guava is fleshy fruit.
III. Cashew is true fruit.
IV. Strawberry is false fruit.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

44. Read the following statements:
I. Seed dormancy prevents premature germination.
II. Seed dormancy is broken by light.
III. Seed dormancy is broken by temperature.
IV. Seed dormancy is permanent.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

45. Read the following statements:
I. Perisperm is persistent nucellus
II. Perisperm is present in beet.
III. Perisperm is present in all plants.
IV. Perisperm is seed part.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

46. Read the following statements:
I. Fruits are classified into true and false.
II. True fruit develop from fertilisation.
III. False fruits are also called parthenocarpic.
IV. Parthenocarpic fruit donot need fertilisation.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

47. Read the following statements:
I. Apomixis is a form of asexual reproduction.
II. Apomixis occurs in flowering plants.
III. Apomixis involves formation of seeds without fertilization.
IV. Apomixis produces genetically diverse offspring.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

48. Read the following statements:
I. Polyembryony occurs in gymnosperms.
II. Polyembryony occurs in angiosperms.
III. Polyembryony involves formation of multiple embryos.
IV. Polyembryony results in genetically identical offspring.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

49. Read the following statements:
I. Apomixis is a mechanism to bypass sexual reproduction.
II. Apomixis ensures seed production without pollination.
III. Apomixis promotes genetic diversity.
IV. Apomixis occurs in all flowering plants.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

50. Read the following statements:
I. Hybrid crop increase productivity.
II. Hybrid seeds need to be produced every year.
III. Hybrid seed maintain hybris character after being sown.
IV. Hybrid show segregation after made into apomicts.
Choose the correct option:
(a) All correct
(b) I, II, and III are correct, IV is incorrect
(c) I, II, and IV are correct, III is incorrect
(d) I and II are correct, III and IV are incorrect

Exercise-03 Level -03

Assertion & Reason Based Questions

1. **Assertion (A):** Flowering plants exhibit a high degree of variability.
Reason (R): Sexual reproduction in flowering plants involves meiosis and fertilization, leading to genetic diversity.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

2. **Assertion (A):** Pollen grains are produced in large numbers.
Reason (R): Pollen grains are haploid and produced through meiosis to ensure genetic diversity.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

3. **Assertion (A):** Flowers have a specific arrangement of sepals, petals, stamens, and carpels.
Reason (R): This arrangement ensures efficient pollination and fertilization.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

4. **Assertion (A):** Double fertilization is unique to flowering plants.
Reason (R): Double fertilization ensures the formation of endosperm and embryo.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

5. **Assertion (A):** Endosperm is a nutritive tissue.
Reason (R): Endosperm provides nutrients to the developing embryo.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

6. **Assertion (A):** Fruits develop from the ovary.
Reason (R): Fruits protect seeds and aid in dispersal.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

7. **Assertion (A):** Seeds are formed from ovules.
Reason (R): Seeds contain embryo and endosperm.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

8. **Assertion (A):** Apomixis is a form of asexual reproduction.
Reason (R): Apomixis bypasses sexual reproduction and ensures seed production without fertilization.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

9. **Assertion (A):** Polyembryony occurs in some flowering plants.
Reason (R): Polyembryony results in multiple embryos from a single zygote.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

10. **Assertion (A):** Pollination is essential for fertilization.
Reason (R): Pollination transfers pollen from anther to stigma.

(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

11. **Assertion (A):** Self-incompatibility prevents self-pollination.
Reason (R): Self-incompatibility promotes genetic diversity.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

12. **Assertion (A):** Embryo sac contains 8 nuclei.
Reason (R): Embryo sac is the female gametophyte.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

13. **Assertion (A):** Zygote develops into embryo.
Reason (R): Embryo develops from fertilized egg cell.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

14. **Assertion (A):** Endosperm develops from triple fusion.
Reason (R): Endosperm is triploid.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

15. **Assertion (A):** Seed dormancy prevents premature germination.
Reason (R): Seed dormancy ensures seed survival.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

16. **Assertion (A):** Seed germination happens in adequate moisture condition.
Reason (R): Favourable condition helps to break seed dormancy.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

17. **Assertion (A):** Polyembryony increases seed yield.
Reason (R): Polyembryony results in multiple seedlings.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

18. **Assertion (A):** Cleistogamy is a type of self-pollination.
Reason (R): Cleistogamy ensures seed production.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

19. **Assertion (A):** Pollen-pistil interaction involves recognition.
Reason (R): Pollen-pistil interaction ensures compatible mating.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

20. **Assertion (A):** Double fertilization ensures genetic diversity.
Reason (R): Double fertilization involves fusion of one male gamete and one egg cell.
(a) Both A and R are correct, and R is the correct explanation of A.
(b) Both A and R are correct, but R is not the correct explanation of A.
(c) A is correct, but R is incorrect.
(d) A and R are incorrect.

Statement Based Questions

21. **Statement I:** The pollen grains are produced in the anther lobes of the stamen.
Statement II: Each anther lobe contains only one pollen sac.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

22. **Statement I:** The exine layer of pollen grains is made up of sporopollenin.
Statement II: Sporopollenin can not easily degrade under natural conditions.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

23. **Statement I:** In angiosperms, microsporogenesis takes place inside the pollen sacs.
Statement II: Microsporogenesis leads to the formation of female gametophytes.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

24. **Statement I:** The pollen grain in most species is two-celled when it is released from the anther.
Statement II: In all species, pollen grains are released in a three-celled stage.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

25. **Statement I:** The embryo sac is the female gametophyte in flowering plants.
Statement II: The embryo sac is haploid.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

26. **Statement I:** In a typical angiosperm ovule, the megaspore mother cell undergoes meiosis to form four megaspores.
Statement II: Out of all four megaspores, only one develop into embryo sacs.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

27. **Statement I:** The process of double fertilization in angiosperms involves two fertilization events.
Statement II: Double fertilization produces one zygote and one triploid endosperm.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

28. **Statement I:** The antipodal cells in the embryo sac are involved in nourishing the developing embryo.
Statement II: Antipodal cells degenerate after fertilization.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

29. **Statement I:** The integuments of the ovule develop into the seed coat after fertilization.
Statement II: The seed coat is a part of the embryo.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

30. **Statement I:** Pollen grains are haploid structures.
Statement II: Pollen grains are formed by meiosis in the pollen mother cell.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

31. **Statement I:** Apomixis is a form of asexual reproduction in plants.
Statement II: Apomixis requires pollination for seed formation.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

32. **Statement I:** Endosperm development precedes embryo development in flowering plants.
Statement II: The endosperm provides nutrition to the developing embryo.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

33. **Statement I:** The zygote is the first cell of the sporophytic generation.
Statement II: The zygote go through by mitosis for further development.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

34. **Statement I:** The micropyle is the opening through which the pollen tube enters the ovule.
Statement II: After fertilization, the micropyle remains closed.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

35. **Statement I:** Seeds formed by apomixis are genetically identical to the parent plant.
Statement II: Apomixis is a result of the fusion of male and female gametes.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

36. **Statement I:** Double fertilization is unique to angiosperms.
Statement II: Double fertilization involves the fusion of two sperm cells with the egg cell.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

37. **Statement I:** Pollination is necessary for fertilization in flowering plants.
Statement II: Pollination is the fusion of male and female gametes.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

38. **Statement I:** Synergids assist in the guidance of the pollen tube into the embryo sac.
Statement II: The synergids do not degenerate after fertilization.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

39. **Statement I:** In double fertilization, one sperm cell fuses with the egg to form the zygote.
Statement II: The second sperm cell fuses with the antipodals to form the endosperm.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

40. **Statement I:** Endosperm provides nutrition to the developing embryo in seeds.
Statement II: In monocot seeds, the endosperm is completely consumed by the developing embryo.
(a) Statement I is correct but Statement II is incorrect.
(b) Statement II is correct but Statement I is correct.
(c) Both statements are correct.
(d) Both statements are incorrect.

Match up Based Questions

41. Match the following columns:

Column-I		Column-II	
A.	Formation of pollen grains	I.	Megaspore mother cell
B.	Formation of megaspore	II.	Microspore mother cell
C.	Double fertilization	III.	Fusion of two sperm cells
D.	Endosperm development	IV	Triploid tissue

(a) A-II, B-I, C-III, D-IV
(b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II
(d) A-IV, B-III, C-I, D-II

42. Match the following columns:

Column-I		Column-II	
A.	Embryo sac development	I	Megasporogenesis
B.	Pollen grain development	II	Microsporogenesis
C.	Embryo formation	III	Embryogenesis
D.	Endosperm development	IV	Endospermogenesis

(a) A-II, B-III, C-IV, D-I (b) A-I, B-II, C-III, D-IV
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

43. Match the following columns:

Column-I		Column-II	
A.	Self-incompatibility	I	Ensures seed production
B.	Cleistogamy	II	Asexual reproduction
C.	Polyembryony	III	Promotes genetic diversity
D.	Apomixis	IV	Multiple embryos from one zygote

(a) A-II, B-III, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

44. Match the following columns:

Column-I		Column-II	
A.	Pollination	I	Emergence of radicle and cotyledon
B.	Fertilization	II	Spread of seeds away from parent plant
C.	Seed dispersal	III	Transfer of pollen from anther to stigma
D.	Seed germination	IV	Fusion of sperm and egg cells

(a) A-II, B-III, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

45. Match the following columns:

Column-I		Column-II	
A.	Microspore	I	Female gametophyte
B.	Megaspore mother cell	II	Nutritive tissue
C.	Embryo sac	III	Diploid cell
D.	Endosperm	IV	Haploid male gametophyte

(a) A-II, B-III, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

46. Match the following columns:

Column-I		Column-II	
A.	Flower structure	I	Self, cross
B.	Fruit types	II	Sepals, petals, stamens, carpels
C.	Seed types	III	True, False, parthenocarpic
D.	Pollination types	IV	Monocot, dicot

(a) A-II, B-III, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

47. Match the following columns:

Column-I		Column-II	
A.	Embryo development	I	Growth of ovary
B.	Seed dormancy	II	Emergence of seedling
C.	Seed germination	III	Formation of radicle and cotyledon
D.	Fruit development	IV	Prevention of premature germination

(a) A-II, B-III, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

48. Match the following columns:

Column-I		Column-II	
A.	Banana	I	Dry fruit
B.	Apple	II	Parthenocarpic fruit
C.	Mango	III	False fruit
D.	Groundnut	IV	Flashy fruit

(a) A-II, B-III, C-IV, D-I
(b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II
(d) A-IV, B-III, C-I, D-II

49. Match the following columns:

Column-I		Column-II	
A.	Microsporogenesis	I	Formation of microspores
B.	Megasporogenesis	II	Formation of megaspores
C.	Embryogenesis	III	Formation of embryo
D.	Endospermogenesis	IV	Formation of endosperm

(a) A-II, B-III, C-IV, D-I (b) A-I, B-II, C-III, D-IV
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

50. Match the following columns:

Column-I		Column-II	
A.	Seed formation	I	Transfer of pollen from anther to stigma
B.	Fruit formation	II	Fusion of sperm and egg cells
C.	Pollination	III	Ovary growth and development
D.	Fertilization	IV	Embryo and endosperm development

(a) A-II, B-III, C-IV, D-I (b) A-III, B-IV, C-II, D-I
(c) A-III, B-I, C-IV, D-II (d) A-IV, B-III, C-I, D-II

Exercise-04 Previous Year Questions

1. Given below are two statements: One is labelled as **Assertion (A)** and the other is labelled as **Reason (R).**

Assertion (A): A typical unfertilised, angiosperm embryo sac at maturity is 8 nucleate and 7-celled.

Reason (R): The egg apparatus has 2 polar nuclei.

In the light of the above statements, choose the **correct** answer from the options given below: **(2025)**

(a) **A** is true but **R** is false
(b) **A** is false but **R** is true
(c) Both **A** and **R** are true and **R** is the correct explanation of **A**
(d) Both **A** and **R** are true but **R** is **NOT** the correct explanation of **A**

2. Given below are two statements: One is labelled as **Assertion (A)** and the other is labelled as **Reason (R).**

Assertion (A): Both wind and water pollinated flowers are not very colourful and do not produce nectar.

Reason (R): The flowers produce enormous amount of pollen grains in wind and water pollinated flowers.

In the light Othe above statements, choose the **correct** answer from the options given below: **(2025)**

(a) **A** is true but **R** is false
(b) **A** is false but **R** is true
(c) Both **A** and **R** are true and **R** is the correct explanation of **A**
(d) Both **A** and **R** are true but **R** is **NOT** the correct explanation of **A**

3. How many meiotic and mitotic divisions need to occur for the development of a mature female gametophyte from the megaspore mother cell in an angiosperm plant? **(2025)**

(a) 1 Meiosis and 3 Mitosis
(b) No Meiosis and 2 Mitosis
(c) 2 Meiosis and 3 Mitosis
(d) 1 Meiosis and 2 Mitosis

4. Given below are two statements: One is labelled as **Assertion (A)** and the other is labelled as **Reason (R)**.

Assertion (A): Cells of the tapetum possess dense cytoplasm and generally have more than one nucleus.

Reason (R): Presence of more than one nucleus in the tapetum increases the efficiency of nourishing the developing microspore mother cells.

In light of the above statements, choose the **most appropriate** answer from the options given below: **(2025)**

(a) A is true but R is false
(b) A is false but R is true
(c) Both A and R are true and R is the correct explanation of A
(d) Both A and R are true but R is NOT the correct explanation of A

5. Match List I with List II:

List I	List II
A. Scutellum	I. Persistent nucellus

B. Non-albuminous seed	II. Cotyledon of Monocot seed
C. Epiblast	III. Groundnut
D. Perisperm	IV. Rudimentary cotyledon

Choose the option with all **correct matches**:
(2025)

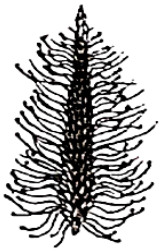
(a) A–IV, B–III, C–I, D–II
(b) A–II, B–IV, C–III, D–I
(c) A–II, B–III, C–IV, D–I
(d) A–IV, B–III, C–II, D–I

6. Identify the set of correct statements: **(2024)**

A. The flowers of Vallisneria are colourful and produce nectar
B. The flowers of waterlily are not pollinated by water
C. In most of water-pollinated species, the pollen grains are protected from wetting.
D. Pollen grains of some hydrophytes are long and ribbon like
E. In some hydrophytes, the pollen grains are carried passively inside water.

Choose the correct answer from the options given below:
(a) A, B, C and D only
(b) A, C, D and E only
(c) B, C, D and E only
(d) C, D and E only

7. Identify the correct description about the given figure: **(2024)**



(a) Water pollinated flowers showing stamens with mucilaginous covering
(b) Cleistogamous flowers showing autogamy
(c) Compact inflorescence showing complete autogamy
(d) Wind pollinated plant inflorescence showing flowers with well exposed stamens.

8. Large, colourful, fragrant flowers with nectar are seen in **(2023)**

(a) Wind pollinated plants
(b) Insect pollinated plants
(c) Bird pollinated plants
(d) Bat pollinated plants

9. What is the function of tassels in the corn cob? **(2023)**

(a) To protect seeds
(b) To attract insects
(c) To trap pollen grains
(d) To disperse pollen grains

10. In angiosperm, the haploid, diploid and triploid structures of a fertilized embryo sac sequentially are: **(2023)**

(a) Synergids, antipodals and Polar nuclei
(b) Synergids, Primary endosperm nucleus and zygote
(c) Antipodals, synergids, and primary endosperm nucleus
(d) Synergids, Zygote and Primary endosperm nucleus

11. **Assertion A:** In gymnosperms the pollen grains are released from the microsporangium and carried by air currents.
Reason R: Air currents carry the pollen grains to the mouth of the archegonia where the male gametes are discharged and pollen tube is not formed.
In the light of the above statements, choose the correct answer from the options given below:
(2023)

(a) Both A and Rare true but R is NOT the current explanation of A
(b) A is true but R is false
(c) A is false but R is true
(d) Both A and R are true and R is the correct explanation of A

12. Transfer of pollen grains from anther of one flower to stigma of another flower of same plant is known as: **(2023)**

(a) Geitonogamy (b) Xenogamy
(c) Autogamy (d) Cleistogamy

13. In angiosperms the correct sequence of events in formation of female gametophyte in the ovule is:

(A) 3 successive free nuclear divisions functional megaspore.
(B) Degeneration of 3 megaspores.
(C) Meiotic division in megaspore mother cell.
(D) Migration of 3 nuclei towards each pole.
(E) Formation of wall resulting in seven celled embryosac.

Choose the correct answer from the options given below: **(2023)**

(a) (A), (B), (C), (D), (E)
(b) (C), (E), (A), (D), (B)
(c) (B), (C), (A), (D), (E)
(d) (C), (B), (A), (D), (E)

14. The residual persistent part which forms the perisperm in the seeds of beet is **(2022)**
(a) Integument (b) Calyx
(c) Endosperm (d) Nucellus

15. In general the egg apparatus of embryo sac in angiosperm consists of **(2022)**
(a) One egg cell, two synergids, two antipodal cells, two Polar nuclei
(b) One egg cell, two synergids, three antipodal cells, two Polar nuclei
(c) One egg cell, two synergids, two antipodal cells, three Polar nuclei
(d) One egg cell, three synergids, two antipodal cells, two Polar nuclei

16. **Statement I:** Cleistogamous flowers are invariably autogamous
Statement II: Cleistogamy is disadvantageous as there is no chance for cross pollination.
In the light of the above statements, choose the correct answer from the options given below: **(2022)**
(a) Both Statement I and Statement II are correct
(b) Both Statement I and Statement II are incorrect
(c) Statement I is correct but Statement II is incorrect
(d) Statement I is incorrect but Statement Il is correct

17. Identify the incorrect statement related to Pollination: **(2022)**
(a) Pollination by water is quite rare in flowering plants
(b) Pollination by wind is more common amongst abiotic pollination
(c) Flowers produce foul odours to attract flies and beetles to get pollinated
(d) Moths and butterflies are the most dominant pollinating agents among insects

18. A typical angiosperm embryo sac at maturity is: **(2021)**
(a) 7- nucleate and 8-celled
(b) 7- nucleate and 7-celled
(c) 8- nucleate and 8-celled
(d) 8-nucleate and 7-celled

19. The term used for transfer of pollen grains from anthers of one plant to stigma of different plant which, during pollination, brings genetically different types of pollen grains to stigma, is: **(2021)**
(a) Geitonogamy (b) Chasmogamy
(c) Cleistogamy (d) Xenogamy

20. In some members of which of the following pairs of families, pollen grains retain their viability for months after release? **(2021)**
(a) Poaceae ; Leguminosae
(b) Poaceae ; Solanaceae
(c) Rosaceae ; Leguminosae
(d) Poaceae ; Rosaceae

21. The plant parts which consist of two generations one within the other: **(2020)**
1. Pollen grains inside the anther
2. Germinated pollen grain with two male gametes
3. Seed inside the fruit
4. Embryo sac inside the ovule
(a) (1), (2) and (3)
(b) (3) and (4)
(c) (1) and (4)
(d) (1) only

22. In water hyacinth and water lily, pollination takes place by: **(2020)**
(a) Water currents only
(b) Wind and water
(c) Insects and water
(d) Insects or wind

23. The body of the ovule is fused within the funicle at: **(2020)**
(a) Micropyle (b) Nucellus
(c) Chalaza (d) Hilum

24. Which of the following is incorrect for wind-pollinated plants? **(2020 Covid Re-NEET)**
(a) Many ovules in each ovary
(b) Flowers are small and not brightly coloured
(c) Pollen grains are light and non-sticky
(d) Well exposed stamens and stigma

25. In some plants thalamus contributes to fruit formation. Such fruits are termed as **(2020 Covid Re-NEET)**
(a) Aggregate fruits
(b) True fruits
(c) Parthenocarpic fruit
(d) False fruits

Answer keys

TOPIC CENTRIC EXERCISE 01 : Answer Key

1. (b)	**2.** (b)	**3.** (b)	**4.** (b)	**5.** (b)

TOPIC CENTRIC EXERCISE 02: Answer Key

1. (a)	**2.** (b)	**3.** (a)	**4.** (b)	**5.** (c)

TOPIC CENTRIC EXERCISE 03 : Answer Key

1. (c)	**2.** (b)	**3.** (c)	**4.** (b)	**5.** (b)

TOPIC CENTRIC EXERCISE 04: Answer Key

1. (d)	**2.** (b)	**3.** (a)	**4.** (d)	**5.** (b)

TOPIC CENTRIC EXERCISE 05 : Answer Key

1. (c)	**2.** (b)	**3.** (b)	**4.** (a)	**5.** (a)

Exercise-01 Level -01 Answer Key

1. (c)	**6.** (b)	**11.** (b)	**16.** (c)	**21.** (b)	**26.** (b)	**31.** (c)	**36.** (a)	**41.** (c)	**46.** (d)
2. (c)	**7.** (b)	**12.** (b)	**17.** (a)	**22.** (b)	**27.** (c)	**32.** (b)	**37.** (a)	**42.** (b)	**47.** (a)
3. (a)	**8.** (b)	**13.** (b)	**18.** (a)	**23.** (a)	**28.** (b)	**33.** (a)	**38.** (a)	**43.** (c)	**48.** (a)
4. (b)	**9.** (c)	**14.** (b)	**19.** (a)	**24.** (b)	**29.** (b)	**34.** (c)	**39.** (b)	**44.** (b)	**49.** (b)
5. (b)	**10.** (b)	**15.** (a)	**20.** (c)	**25.** (c)	**30.** (a)	**35.** (c)	**40.** (b)	**45.** (c)	**50.** (c)

Exercise-02 Level -02 Answer Key

1. (b)	**6.** (d)	**11.** (b)	**16.** (d)	**21.** (d)	**26.** (a)	**31.** (b)	**36.** (a)	**41.** (b)	**46.** (c)
2. (b)	**7.** (a)	**12.** (a)	**17.** (b)	**22.** (a)	**27.** (b)	**32.** (b)	**37.** (b)	**42.** (b)	**47.** (b)
3. (a)	**8.** (c)	**13.** (b)	**18.** (b)	**23.** (b)	**28.** (a)	**33.** (b)	**38.** (a)	**43.** (c)	**48.** (a)
4. (b)	**9.** (b)	**14.** (a)	**19.** (b)	**24.** (c)	**29.** (b)	**34.** (a)	**39.** (a)	**44.** (b)	**49.** (c)
5. (d)	**10.** (a)	**15.** (b)	**20.** (a)	**25.** (b)	**30.** (b)	**35.** (b)	**40.** (b)	**45.** (d)	**50.** (d)

Exercise-03 Level -03 Answer Key

1. (a)	**6.** (b)	**11.** (b)	**16.** (a)	**21.** (a)	**26.** (c)	**31.** (a)	**36.** (a)	**41.** (a)	**46.** (a)
2. (b)	**7.** (a)	**12.** (b)	**17.** (a)	**22.** (c)	**27.** (c)	**32.** (c)	**37.** (a)	**42.** (b)	**47.** (b)
3. (b)	**8.** (b)	**13.** (a)	**18.** (a)	**23.** (a)	**28.** (d)	**33.** (c)	**38.** (b)	**43.** (c)	**48.** (a)
4. (a)	**9.** (b)	**14.** (b)	**19.** (a)	**24.** (a)	**29.** (a)	**34.** (a)	**39.** (a)	**44.** (b)	**49.** (b)
5. (a)	**10.** (a)	**15.** (a)	**20.** (a)	**25.** (c)	**30.** (c)	**35.** (a)	**40.** (a)	**45.** (d)	**50.** (d)

Exercise-04 Previous Year Questions

1. (a)	**4.** (c)	**7.** (d)	**10.** (d)	**13.** (d)	**16.** (a)	**19.** (d)	**22.** (d)	**25.** (d)
2. (d)	**5.** (c)	**8.** (b)	**11.** (b)	**14.** (d)	**17.** (d)	**20.** (c)	**23.** (d)	
3. (a)	**6.** (c)	**9.** (c)	**12.** (a)	**15.** (b)	**18.** (d)	**21.** (c)	**24.** (a)	