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Introduction

Sexual Reproduction in Angiosperms

- All flowering plants reproduce sexually by forming and fusing gametes.
- Flowers are the specialized organs for sexual reproduction in angiosperms.
- Inflorescences, flowers, and floral parts show diverse structures adapted for fruit and seed formation.

Memory Aids

- Flowers = Sexual reproduction organs in angiosperms.
- Diversity ensures successful fruit and seed formation.

Quick Checkpoints

- What is the role of flowers in angiosperms?
- How do floral structures aid reproduction?

Flower

Structure and Function

- Flower is a modified shoot with determinate growth and condensed internodes.
- Four whorls on the receptacle: calyx, corolla, androecium, gynoecium.
- Calyx: outermost whorl, usually green sepals protecting the flower bud.
- Corolla: petals, often colorful to attract pollinators.
- Androecium: male reproductive part, consists of stamens (anther + filament).
- Gynoecium: female reproductive part, consists of carpels (stigma, style, ovary).
- Ovules inside ovary develop into seeds after fertilization.
- Thalamus (floral base) supports all floral parts.
- Floriculture is the cultivation of ornamental flowering plants.

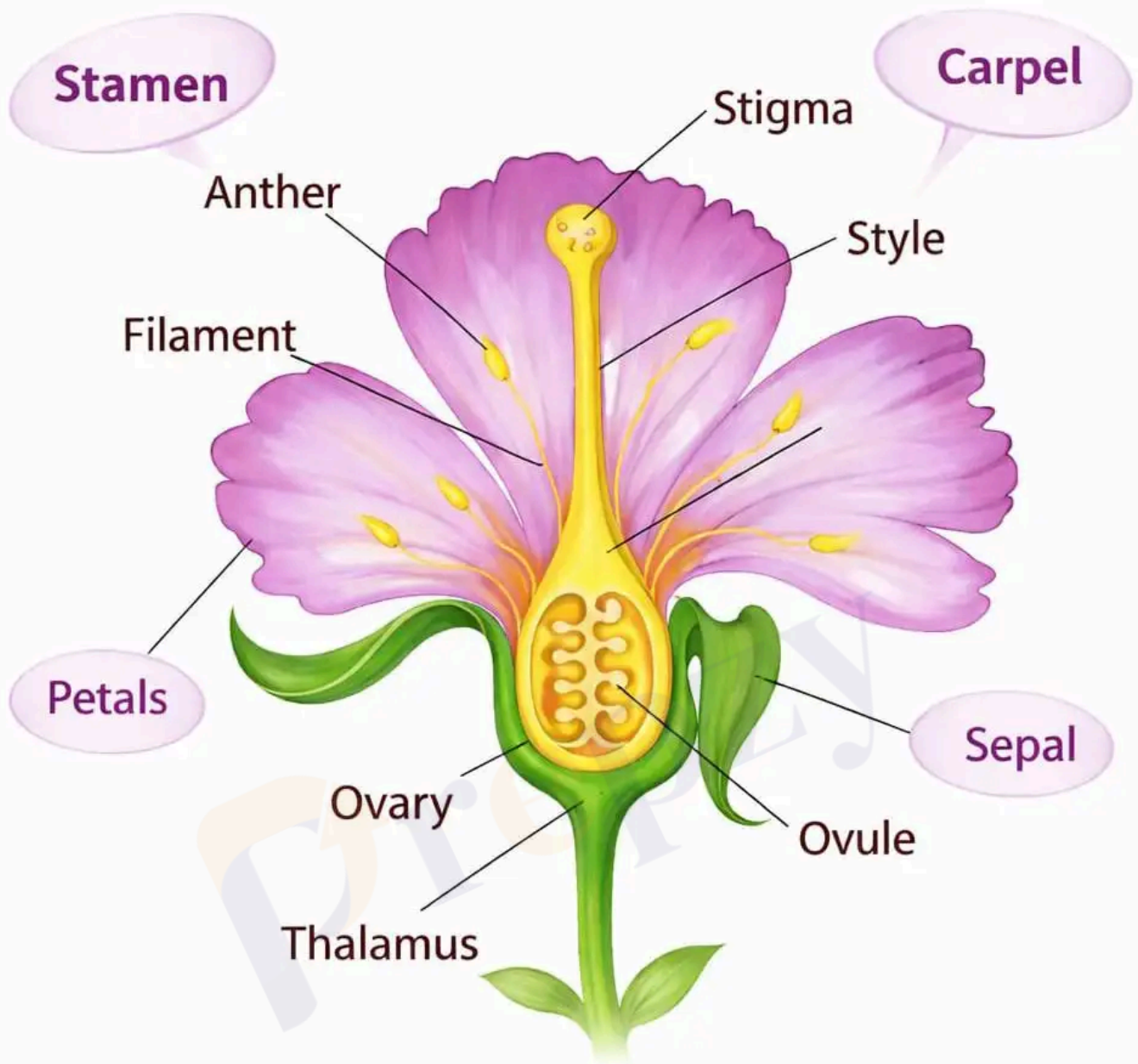


Fig: L.S. of a flower

Memory Aids

- Flower = Modified shoot with 4 whorls: C-C-A-G (Calyx, Corolla, Androecium, Gynoecium).
- Stamen = Anther + Filament (male).
- Carpel = Stigma + Style + Ovary (female).
- Floriculture = Flower cultivation.

Quick Checkpoints

- What are the four whorls of a flower?
- Which parts form the male and female reproductive organs?
- What is the function of the thalamus?
- Define floriculture.

Pre-fertilisation: Structures and Events

Overview

- Floral primordium differentiates under hormonal and structural changes.
- Inflorescences bear floral buds and flowers.
- Flower has male (androecium) and female (gynoecium) reproductive organs.
- Androecium: whorl of stamens (male organ).
- Gynoecium: female reproductive organ.

Memory Aids

- Androecium = Male stamens.
- Gynoecium = Female pistils.

Quick Checkpoints

- What initiates floral primordium development?
- Define androecium and gynoecium.

Stamen, Microsporangium and Pollen Grain

Structure and Function

- Stamen consists of filament and anther.
- Filament attaches proximally to thalamus or petal.
- Anther is bilobed, each lobe with two theca (ditheous).
- Longitudinal groove separates theca.
- Anther is tetragonal with four microsporangia (pollen sacs) at corners.
- Microsporangia develop into pollen sacs filled with pollen grains.

Memory Aids

- Ditheous anther = 2 theca per lobe.
- Tetragonal anther = 4 microsporangia.

Quick Checkpoints

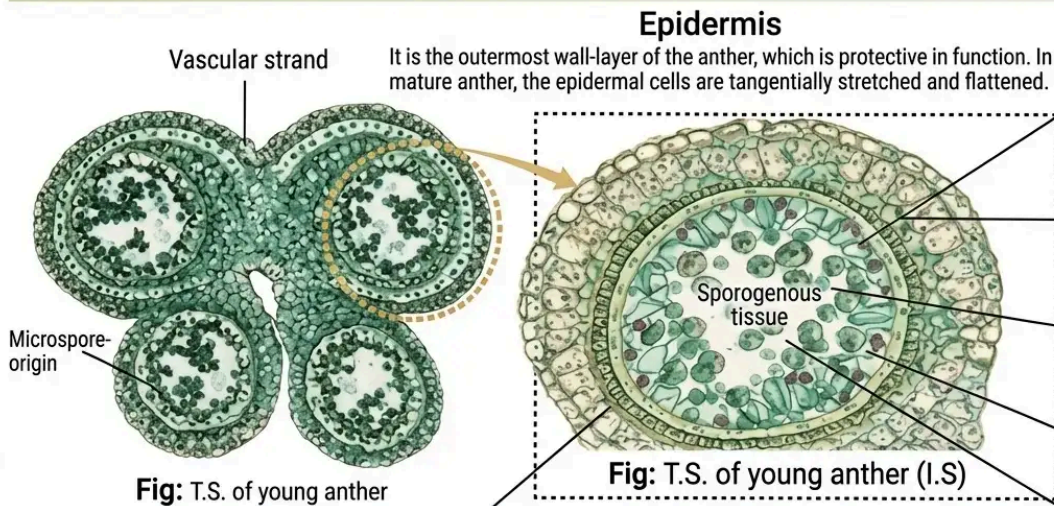
- What are the parts of a stamen?
- Describe the structure of an anther.

Structure of Anther

Layers and Functions

- Anther has 4 pollen sacs (microsporangia).
- Microsporangial wall has four layers: epidermis, endothecium, middle layers, tapetum.
- Outer three layers protect and aid anther dehiscence.
- Tapetum nourishes developing pollen.

Structure of Anther



Memory Aids

- Tapetum = innermost nourishing layer.
- Endothecium = fibrous bands for anther opening.

Quick Checkpoints

- List the layers of microsporangial wall.
- What is the role of tapetum?

Microsporogenesis

Process

- Sporogenous tissue cells undergo meiosis forming microspore tetrads.
- Each microspore separates and develops into pollen grain.
- Microsporogenesis = formation of microspores from pollen mother cell by meiosis.
- As anther matures and dehydrates, microspores dissociate.

Memory Aids

- Microsporogenesis = meiosis in anther producing microspores.

Quick Checkpoints

- Define microsporogenesis.
- What happens to microspore tetrads?

Pollen Grain

Structure and Development

- First cell of male gametophyte, spherical, 25–50 μm diameter.
- Initially uninucleate, becomes 2–3 celled at liberation.
- Wall (sporoderm) has two layers: outer exine (sporopollenin) and inner intine.
- Exine is thick, sculptured or smooth, resistant to decay.
- Thin areas in exine are germ pores (circular) or germinal furrows (elongated).
- Intine is thin, elastic; forms pollen tube during germination.
- Nucleus divides mitotically into vegetative (tube) cell and generative cell.
- Vegetative cell: large, food-rich, irregular nucleus.
- Generative cell: small, spindle-shaped, floats in vegetative cytoplasm.
- 60% angiosperms shed pollen at 2-celled stage; generative cell divides later.
- Pollen causes allergies; viability varies by species and conditions.
- Pollen can be stored in liquid nitrogen for breeding (pollen banks).
- Used as nutrient supplements (pollen tablets).

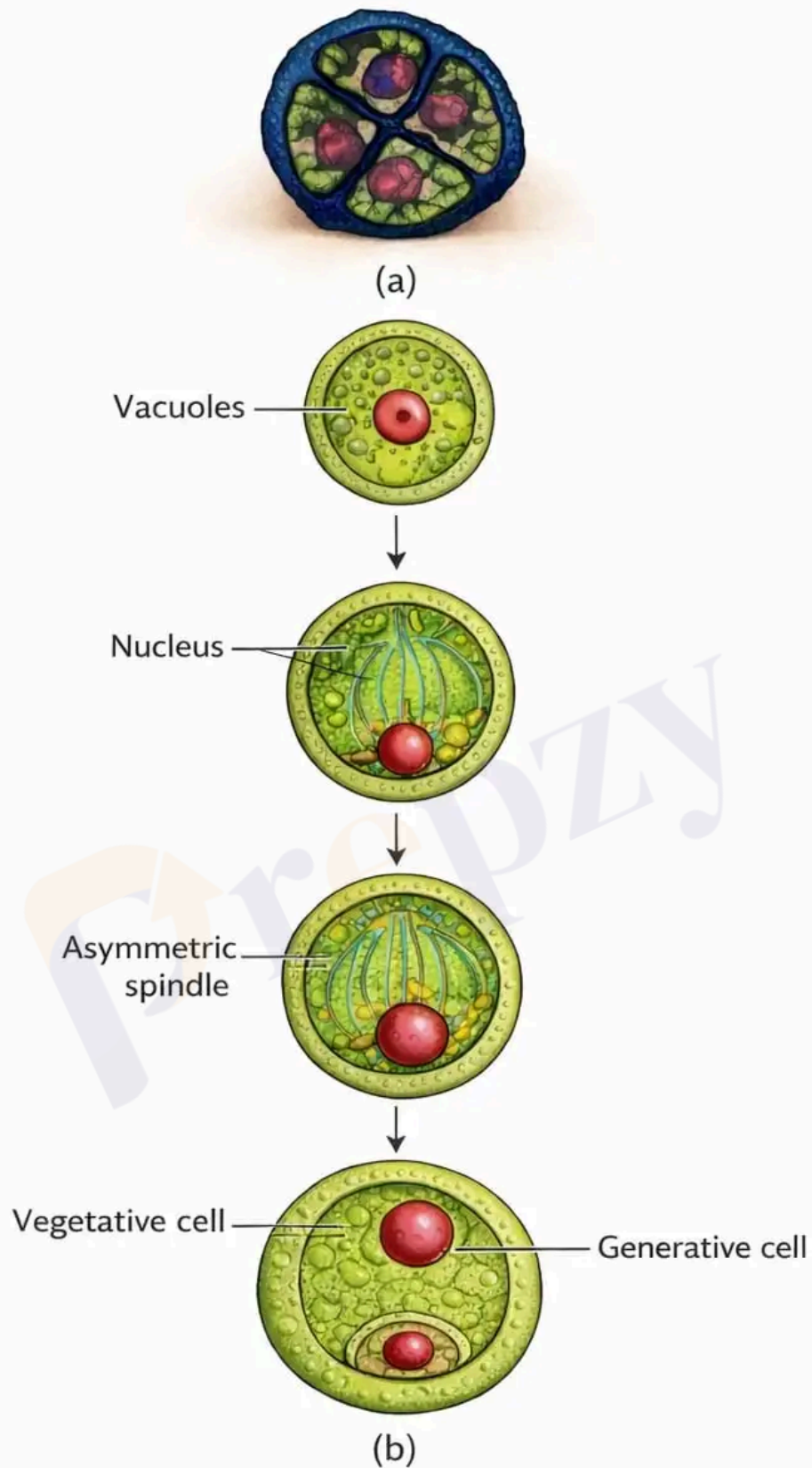


Fig.: (a) Enlarged view of a pollen grain tetrad.
(b) Stages of a microspore maturing into a pollen grain.

Memory Aids

- Exine = sporopollenin, tough outer layer.
- Intine = inner elastic layer.
- Vegetative cell = tube cell; generative cell = male gamete precursor.

Quick Checkpoints

- What is sporoderm?
- Describe the two cells in mature pollen grain.
- Why is pollen viable for different durations?

Pistil, Megasporangium and Embryo Sac

Gynoecium Structure

- Gynoecium = female reproductive part; single (monocarpellary) or multiple pistils (multicarpellary).
- Multiple pistils may be fused (syncarpous) or free (apocarpous).
- Each pistil has stigma (receptive), style (stalk), and ovary (swollen base).
- Ovary contains locules and placenta bearing ovules.
- Ovule number varies: one (wheat, mango) to many (papaya, orchids).

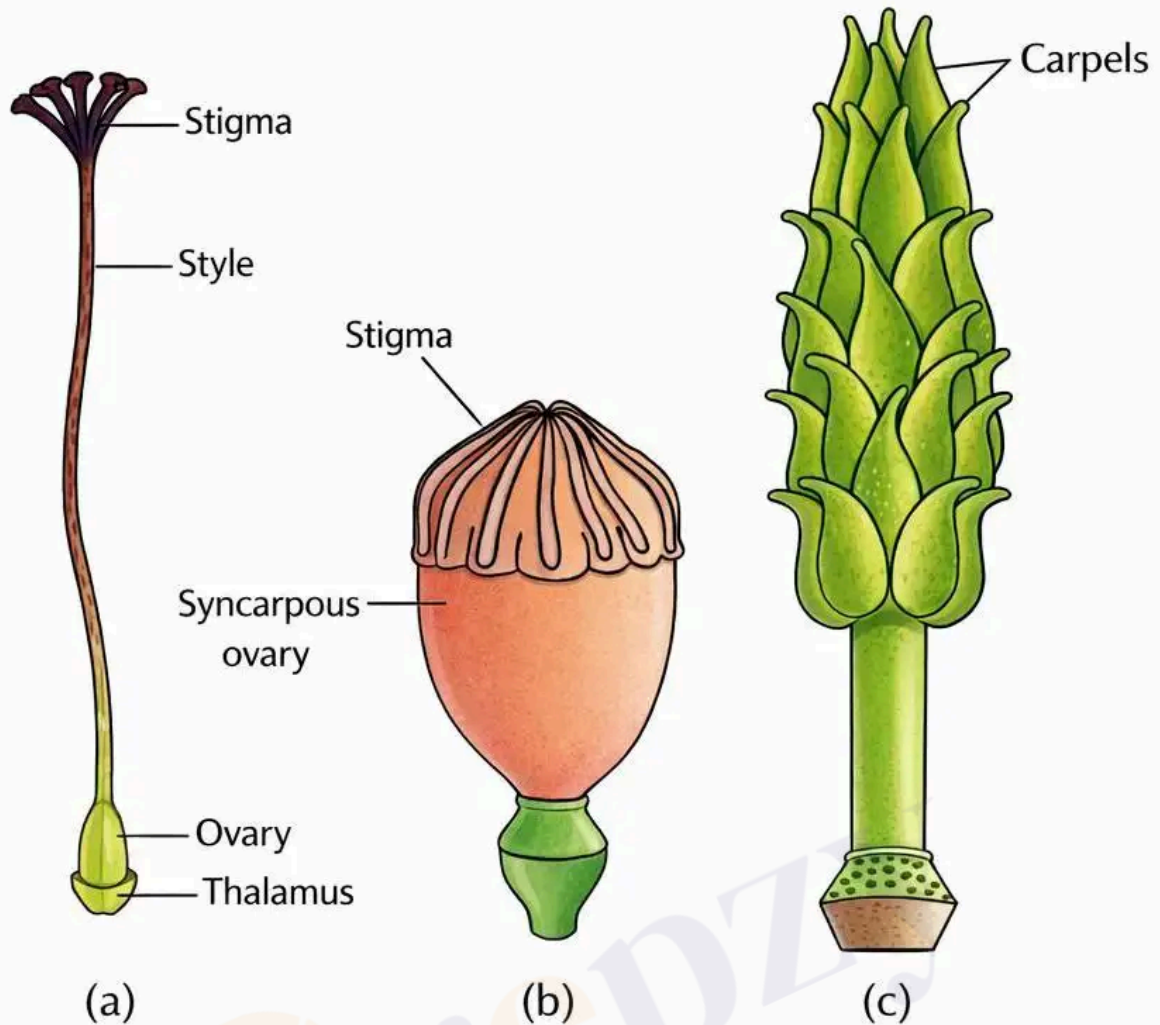


Fig.: (a) A dissected flower of *Hibiscus* showing pistil (other floral parts have been removed); (b) Multicarpellary, syncarpous pistil of *Papaver*; (c) A multicarpellary, apocarpous gynoecium of *Michelia*.

Memory Aids

- Syncarpous = fused pistils; Apocarpous = free pistils.
- Stigma = pollen receptor; Style = pollen tube path; Ovary = ovule container.

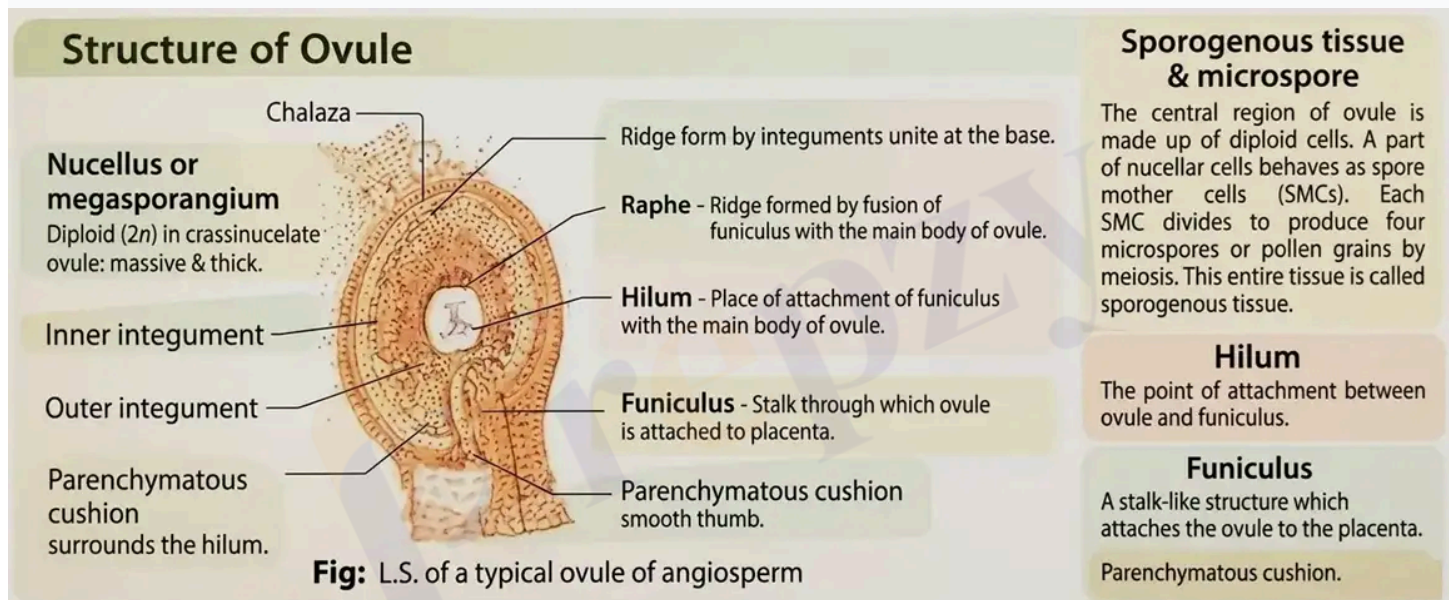
Quick Checkpoints

- Define syncarpous and apocarpous pistils.
- What are the parts of a pistil?

The Megasporangium

Ovule Structure

- Ovule = integumented megasporangium developing into seed after fertilisation.
- Attached to placenta by funicle (stalk).
- Hilum = junction of ovule and funicle.
- Integuments (one or two) surround nucellus (food-rich tissue).
- Micropyle = small opening at tip of ovule.
- Chalaza = basal part opposite micropyle.
- Contains embryo sac (female gametophyte).



Memory Aids

- Unitegmic ovule = single integument (Gamopetalae).
- Bitegmic ovule = two integuments (Polypetalae, monocots).
- Ategmic ovule = no integuments (e.g., *Santalum album*).
- Tritegmic ovule = three integuments (rare, e.g., *Asphodelus*).

Quick Checkpoints

- What is funicle and hilum?
- Differentiate unitegmic and bitegmic ovules.

Megasporogenesis

Process

- Megaspore mother cell (MMC) in nucellus undergoes meiosis.
- Produces four haploid megaspores in linear tetrad.
- Upper three megaspores degenerate; lowermost becomes functional megaspore.
- Functional megaspore develops into embryo sac.

Memory Aids

- Megasporogenesis = meiosis in ovule forming megaspores.

Quick Checkpoints

- Define megasporogenesis.
- What happens to the four megaspores?

Female Gametophyte

Embryo Sac Formation

- Functional megaspore forms female gametophyte (embryo sac) by mitosis.
- Monosporic development: embryo sac from single megaspore.
- Nucleus divides to 2-, 4-, then 8-nucleate stages without cell walls (free nuclear).
- Two polar nuclei fuse to form diploid secondary nucleus.
- Chalazal end: 3 antipodal cells.
- Micropylar end: egg apparatus with 2 synergids and 1 egg cell (oosphere).
- Synergids have filiform apparatus guiding pollen tube.
- Egg fertilizes to form zygote; synergids and antipodals degenerate post-fertilisation.
- Mature embryo sac is 8-nucleate, 7-celled.

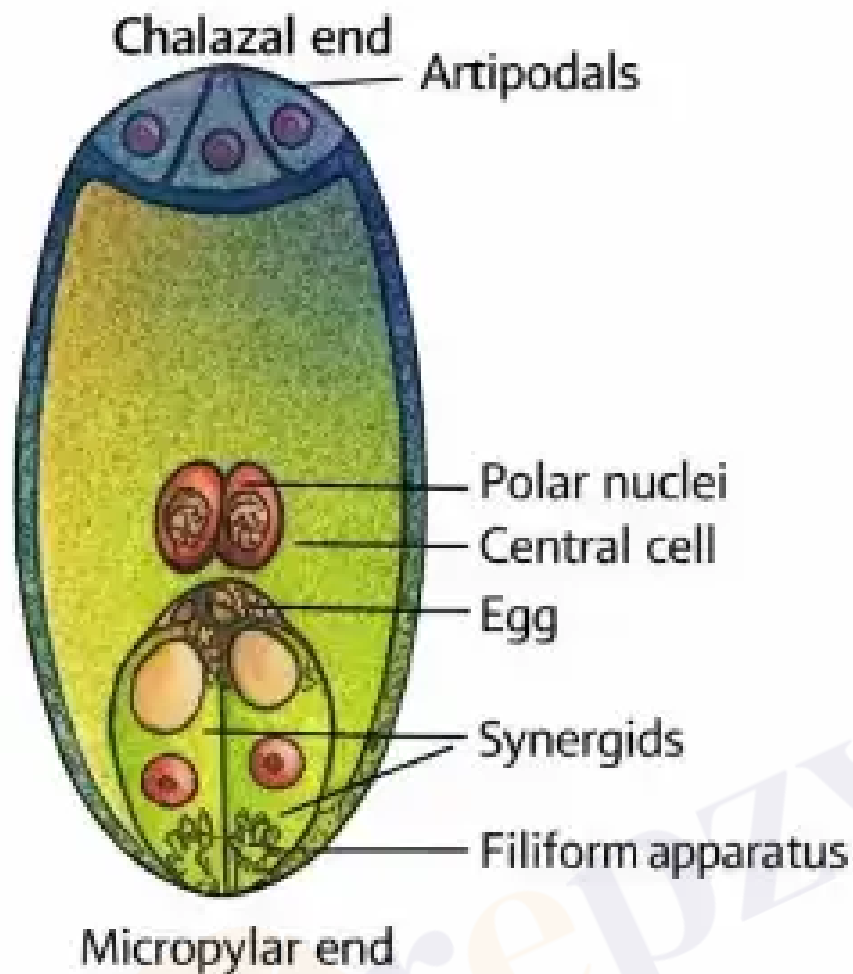


Fig.: A diagrammatic representation of the mature embryo sac

Memory Aids

- Embryo sac = female gametophyte, 8 nuclei, 7 cells.
- Filiform apparatus guides pollen tube.

Quick Checkpoints

- What is monosporic development?
- Name the cells of the embryo sac.

Pollination

Definition and Types

- Pollination: transfer of pollen from anther to stigma of same or different flower of same species.
- Two types: Self-pollination and Cross-pollination.
- Self-pollination: pollen to stigma of same flower or genetically similar flower.
- Autogamy: pollen to stigma of same flower.
- Geitonogamy: pollen to stigma of different flower on same plant (ecologically cross-pollination).

Memory Aids

- Autogamy = same flower; Geitonogamy = different flower, same plant.

Quick Checkpoints

- Define autogamy and geitonogamy.
- What are contrivances for self-pollination?

Cross Pollination

Mechanisms

- Cross pollination (allogamy/xenogamy): pollen transfer between different plants of same species.
- Contrivances to prevent self-pollination:
- Dicliny (unisexual flowers): monoecious (same plant, different flowers) or dioecious (separate plants).
- Self-sterility: pollen cannot fertilize same flower stigma.
- Dichogamy: male and female organs mature at different times.
- Protandry: anthers mature first (e.g., sunflower).
- Protogyny: carpels mature first (e.g., mustard).

- Heterostyly: flowers with different anther and stigma lengths.
- Herkogamy: physical barrier between androecium and gynoecium (e.g., *Calotropis*).

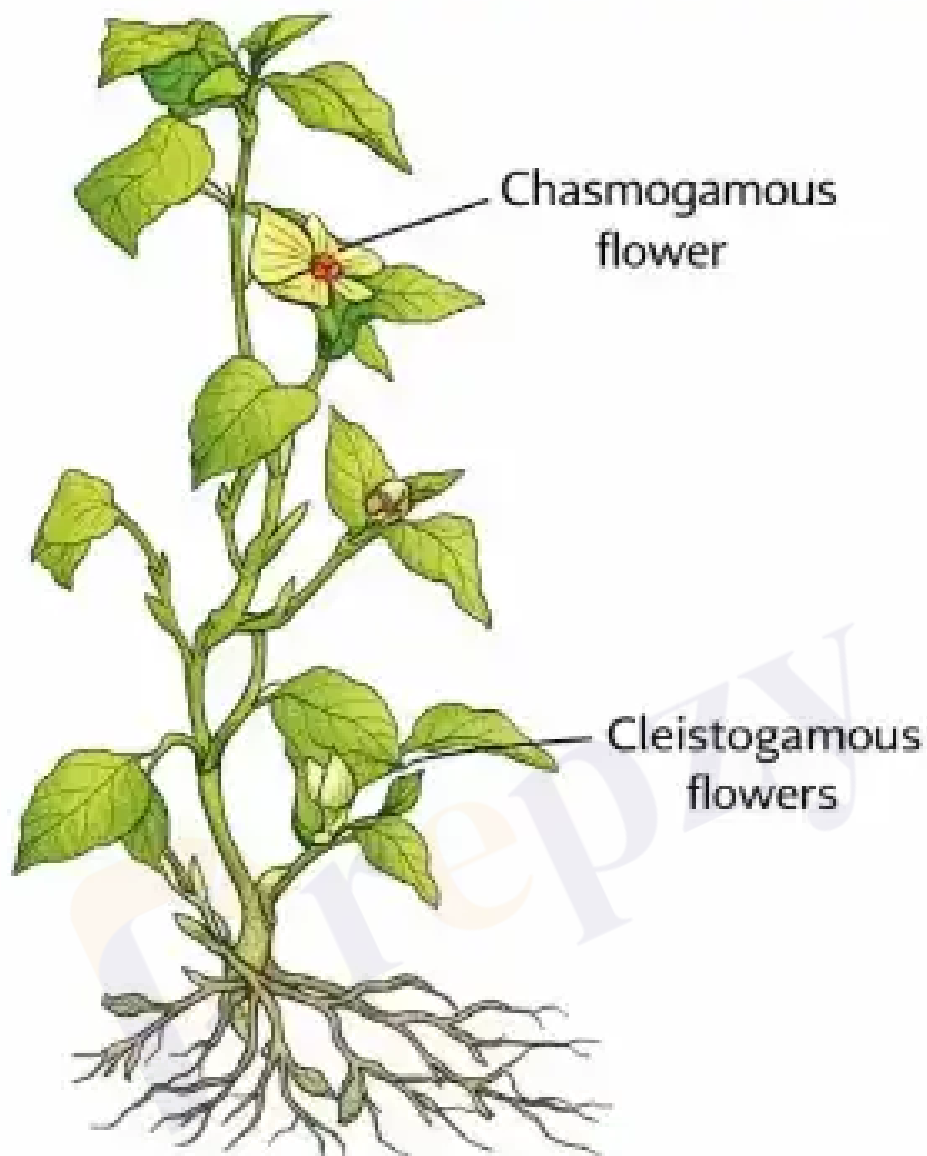


Fig.: A plant showing chasmogamous and cleistogamous flowers

Memory Aids

- Dicliny = unisexual flowers.
- Dichogamy = temporal separation of maturity.
- Herkogamy = physical barrier to self-pollination.

Quick Checkpoints

- What is dichogamy? Name its types.
- Explain heterostyly and herkogamy.

Types of Pollination

Abiotic Agents

- Anemophily: pollination by wind.
- Characteristics: non-showy flowers, no scent/nectar, exerted stamens and stigmas, dry small pollen, feathery stigmas.
- Examples: maize, grasses, mulberry, date palm.
- Hydrophily: pollination by water.
- Flowers are small, inconspicuous, odourless, nectarless, often waxy.
- Pollen is small, light, non-sticky, coated with wax.
- Stigma is sticky but unwettable.
- Types: Hypohydrophily (underwater, e.g., *Ceratophyllum*), Epihydrophily (surface, e.g., *Vallisneria*).

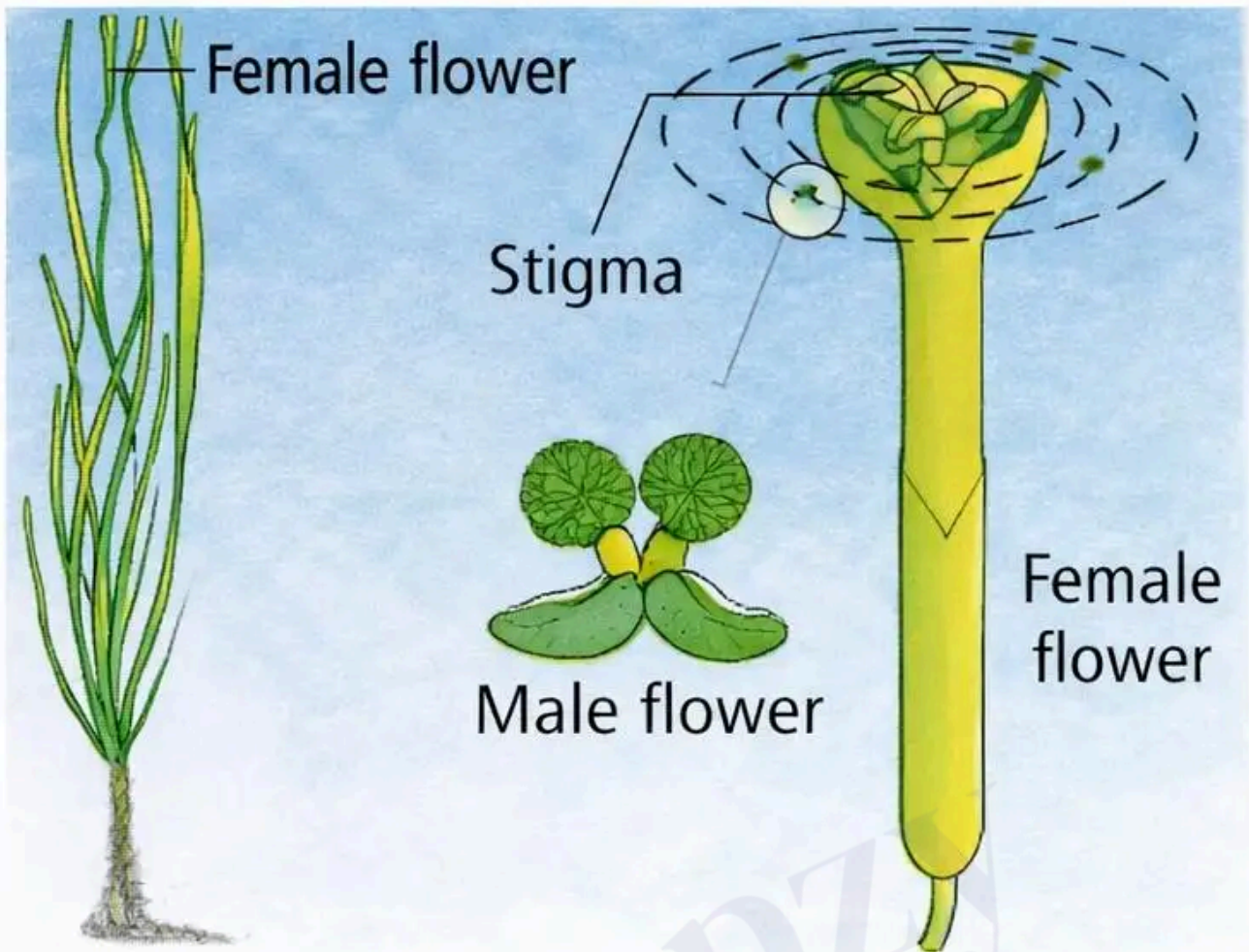


Fig.: Pollination by water in *Vallisneria*

Memory Aids

- Anemophily = wind, dry pollen, feathery stigma.
- Hydrophily = water, waxy pollen, sticky stigma.

Quick Checkpoints

- Define anemophily and hydrophily.
- Differentiate hypohydrophily and epihydrophily.

Biotic Agents

- Entomophily: pollination by insects.
- Flowers produce nectar, edible pollen, are fragrant and brightly coloured.
- Pollen grains are spiny, heavy, sticky (pollenkitt).
- Ornithophily: pollination by birds.
- Flowers are large, bright, odourless, with tubular or cup-shaped corollas, produce mucilaginous nectar.
- Chiropterophily: pollination by bats.
- Flowers are dull-coloured, strong fruity smell, abundant nectar and pollen.
- Other types: malacophily (snails), myrmecophily (ants).

Memory Aids

- Entomophily = insect pollination, nectar and scent.
- Ornithophily = bird pollination, bright and nectar-rich.
- Chiropterophily = bat pollination, dull and smelly.

Quick Checkpoints

- What are features of entomophilous flowers?
- Describe ornithophily and chiropterophily.

Pollen-Pistil Interaction

Process and Importance

- Pollination may deposit incompatible pollen.
- Stigma identifies compatible pollen via pollen-pistil interaction.
- Stigma surface has glandular papillae; types: dry (no exudate) and wet (with exudate).
- Exudates contain sugars, amino acids, proteins, mucopolysaccharides.
- Pollen tube secretes enzymes to digest stigma tissues.
- Pollen tube grows chemotropically guided by calcium-boron-inositol sugar complex.
- Tube enters embryo sac via synergid.

- Interaction regulates pollen acceptance or rejection, aiding breeding.
- Artificial hybridisation uses emasculation (removal of anthers) and bagging to prevent unwanted pollen.
- Unisexual flowers do not require emasculation; bagging before stigma receptivity is done.

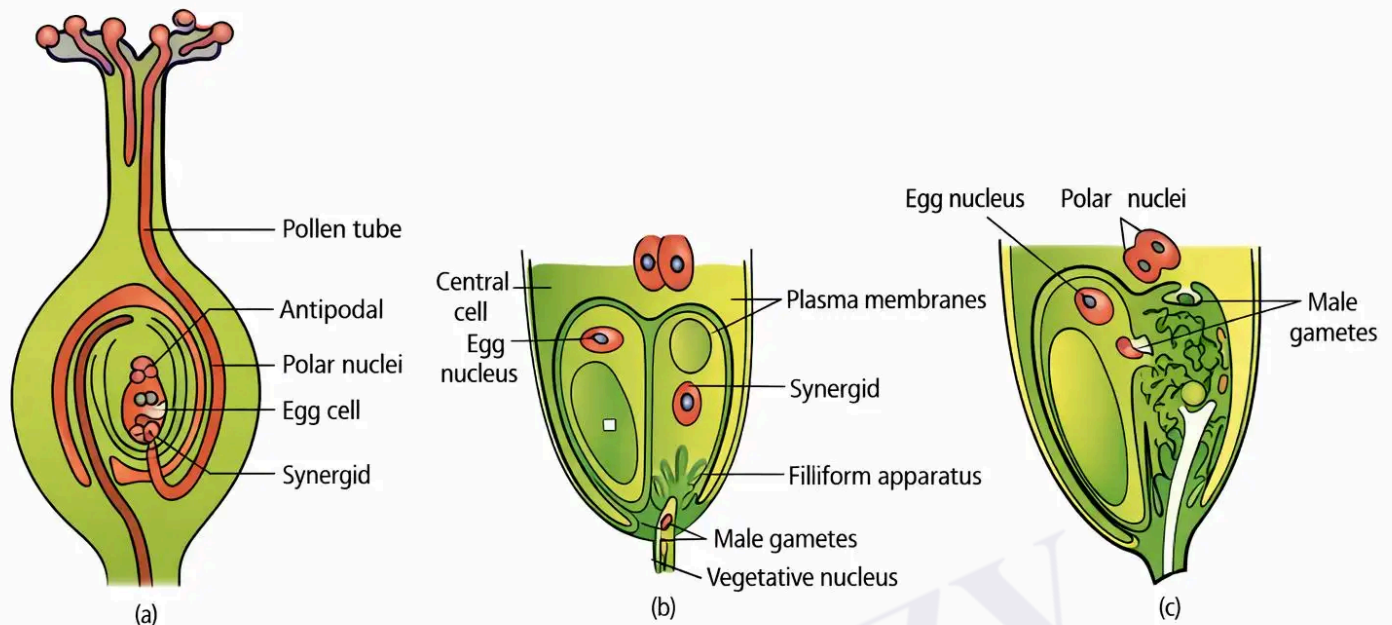


Fig.: (a) L.S. of pistil showing path of pollen tube growth; (b) Enlarged view of an egg apparatus showing entry of pollen tube into a synergid (c) Discharge of male gametes into a synergid and the movements of the sperms, one into the egg and the central cell.

Memory Aids

- Emasculation = anther removal to prevent self-pollination.
- Bagging = covering flowers to avoid contamination.
- Pollen-pistil interaction = compatibility check.

Quick Checkpoints

- What is emasculation and why is it done?
- How does pollen tube reach the embryo sac?

Double Fertilisation

Process and Types

- Fertilisation: fusion of male and female gametes.
- After pollination, pollen grain germinates on stigma, producing pollen tube via germ pore (siphonogamy).
- Pollen grains are usually monosiphonous (one tube per grain) but can be polysiphonous (multiple tubes per grain, e.g., Malvaceae).
- Pollen tube enters ovule through micropyle (porogamy, e.g., *Lilium*), chalaza (chalazogamy, e.g., *Juglans*, *Casuarina*), or integuments (mesogamy, e.g., *Cucurbita*, *Populus*).
- Regardless of entry, pollen tube enters embryo sac via micropylar region.
- Inside embryo sac, one male gamete fuses with egg forming zygote ($2n$) - syngamy or generative fertilisation.
- Second male gamete fuses with two polar nuclei forming triploid primary endosperm nucleus - triple fusion or vegetative fertilisation.
- Zygote develops into embryo; primary endosperm nucleus develops into endosperm.
- Syngamy and triple fusion together are called double fertilisation.
- Discovered by S.G. Nawaschin (1898) in *Fritillaria* and *Lilium*.

Memory Aids

- Siphonogamy = pollen tube formation.
- Monosiphonous = one tube; Polysiphonous = many tubes.
- Porogamy = micropyle entry; Chalazogamy = chalaza entry; Mesogamy = integument entry.
- Syngamy = zygote formation; Triple fusion = endosperm formation.
- Double fertilisation = syngamy + triple fusion.

Quick Checkpoints

- What is siphonogamy?
- Difference between monosiphonous and polysiphonous pollen grains?
- Routes of pollen tube entry into ovule?
- Define syngamy and triple fusion.

- What forms the primary endosperm nucleus?
- Who discovered double fertilisation and in which plants?

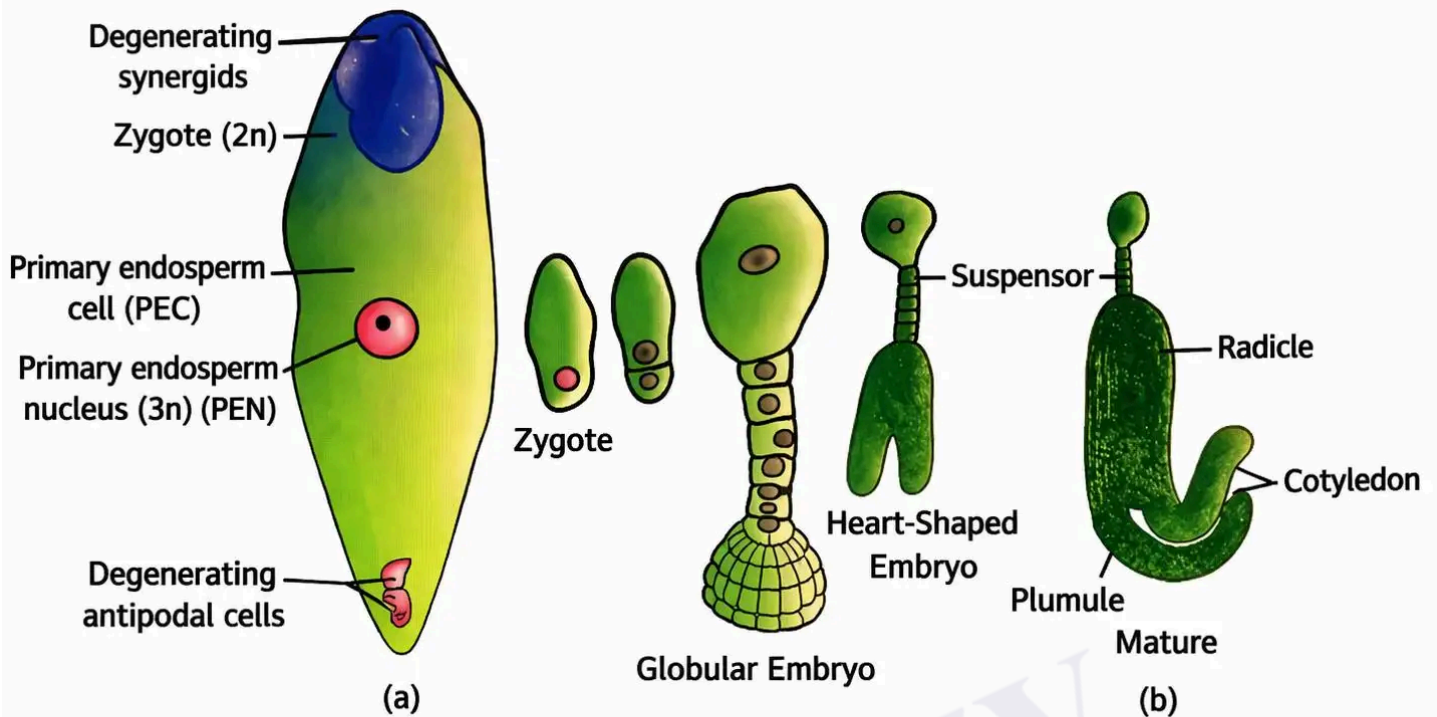


Fig.: (a) Fertilised embryo sac showing zygote and Primary Endosperm Nucleus (PEN);
(b) Stages in embryo development in a dicot [shown in reduced size as compared to (a)]

Embryo Development Stages

- Fertilized embryo sac contains zygote and primary endosperm nucleus.
- Zygote grows into globular embryo stage.
- Embryo develops into heart-shaped stage showing early organ formation.
- Mature embryo forms radicle (root), plumule (shoot), cotyledons (seed leaves), and suspensor (nourishment).
- Each stage marks key steps in seed plant development.

Memory Aids

- Globular stage = embryo shape formation.
- Heart-shaped stage = organ initiation.
- Radicle = future root; Plumule = future shoot.
- Suspensor = embryo nourishment.

Quick Checkpoints

- What does the primary endosperm nucleus develop into?
- Sequence of embryo development stages?
- Functions of radicle, plumule, and suspensor?

Post-Fertilisation Events

Overview

- Occurs after double fertilisation.
- Includes development of endosperm and embryo.
- Maturation of ovule into seed and ovary into fruit.

Memory Aids

- Post-fertilisation = seed + fruit formation.

Quick Checkpoints

- What events follow double fertilisation?
- Which structures mature into seeds and fruits?

Endosperm

Development and Types

- Develops before embryo.
- Primary endosperm cell divides to form triploid tissue.
- Cells store food for embryo nutrition.
- Free-nuclear stage: multiple nuclei without cell walls.
- Cellular stage: cell walls form around nuclei.

- Example: Coconut water is free-nuclear endosperm; white kernel is cellular endosperm.
- Endosperm may be consumed by embryo (non-endospermic seeds) or persist in mature seed (endospermic seeds).

Memory Aids

- Endosperm = embryo food reserve.
- Free-nuclear = many nuclei, no walls.
- Cellular = nuclei enclosed in cells.

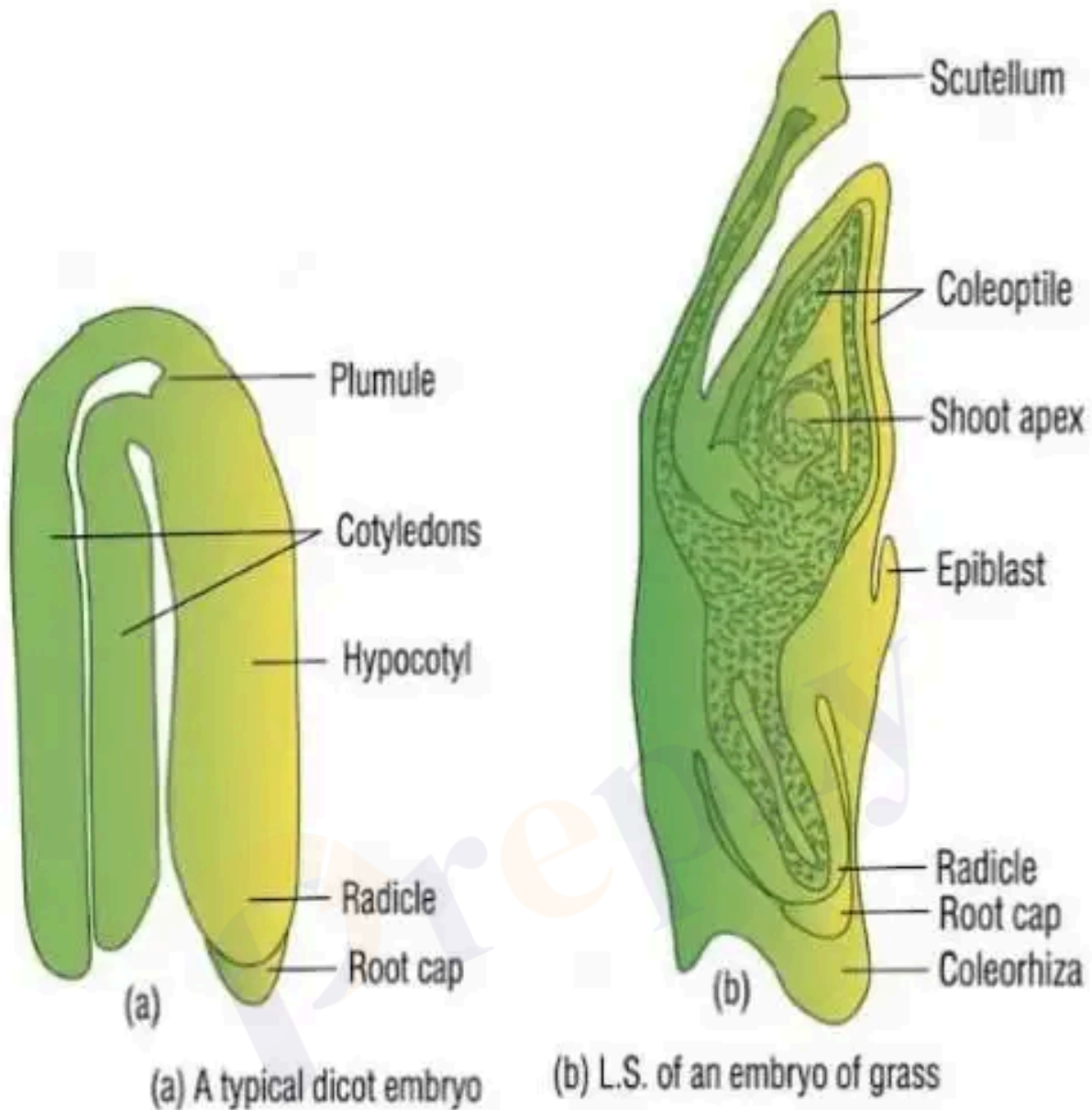
Quick Checkpoints

- What is the ploidy of endosperm?
- Difference between free-nuclear and cellular endosperm?
- Examples of endospermic and non-endospermic seeds?

Embryo

Structure and Development

- Develops at micropylar end of embryo sac.
- Zygote divides after some endosperm forms for nutrition.
- Stages: proembryo → globular → heart-shaped → mature embryo.
- Dicot embryo: embryonal axis + two cotyledons.
- Embryonal axis parts: epicotyl (above cotyledons), hypocotyl (below cotyledons), radicle (root tip with root cap).
- Monocot embryo: one cotyledon called scutellum.
- Monocot embryonal axis: radicle with root cap in coleorhiza; epicotyl with shoot apex and leaf primordia in coleoptile.



Memory Aids

- Dicot = 2 cotyledons; monocot = 1 cotyledon (scutellum).
- Epicotyl = shoot tip; hypocotyl = stem base; radicle = root tip.
- Coleoptile and coleorhiza protect shoot and root in monocots.

Quick Checkpoints

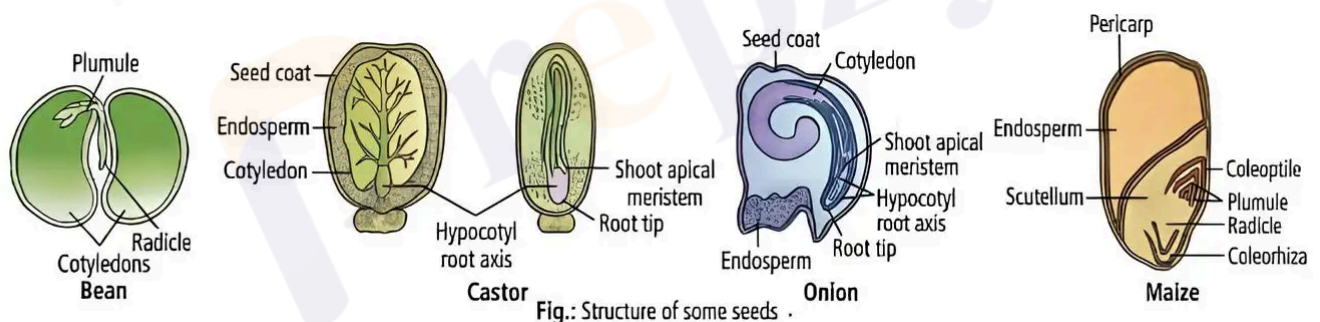
- Where does embryo develop in the ovule?

- What are the stages of embryo development?
- Differences between dicot and monocot embryos?

Seed

Structure and Features

- Seed = fertilised ovule; final product of sexual reproduction in angiosperms.
- Components: seed coat, cotyledons, embryo axis.
- Cotyledons store food reserves; seeds may be albuminous or non-albuminous.
- Perisperm: persistent nucellus in some seeds (e.g., black pepper).
- Seed coat formed from integuments; micropyle allows water and oxygen entry.
- Seed water content reduces at maturity; embryo enters dormancy or germinates if conditions are favorable.
- Viability: ability to germinate over time; affected by storage conditions.
- Loss of viability due to food exhaustion, embryo damage, or enzyme denaturation.



Memory Aids

- Seed = fertilised ovule with embryo and food reserve.
- Dormancy = embryo inactivity until favorable conditions.
- Viability depends on storage and seed condition.

Quick Checkpoints

- What are the main parts of a seed?
- Difference between albuminous and non-albuminous seeds?

- Factors causing loss of seed viability?

Fruit

Definition and Types

- Fruit develops from fertilised ovary and surrounding tissues.
- False (pseudocarpic) fruit: flesh from ovary and other parts (e.g., apple, strawberry).
- True (eucarpic) fruit: develops only from ovary (e.g., mango).
- Pericarp: fruit wall with epicarp (skin), mesocarp (fleshy part), endocarp (inner layer around seeds).
- Fruit types: simple, aggregate, composite (multiple).
- Simple fruit: from monocarpellary or syncarpous ovary.
- Aggregate fruit: from apocarpous ovary.
- Composite fruit: from inflorescence.
- Parthenocarpy: fruit formation without fertilisation; seedless fruits (e.g., banana); induced by hormones.

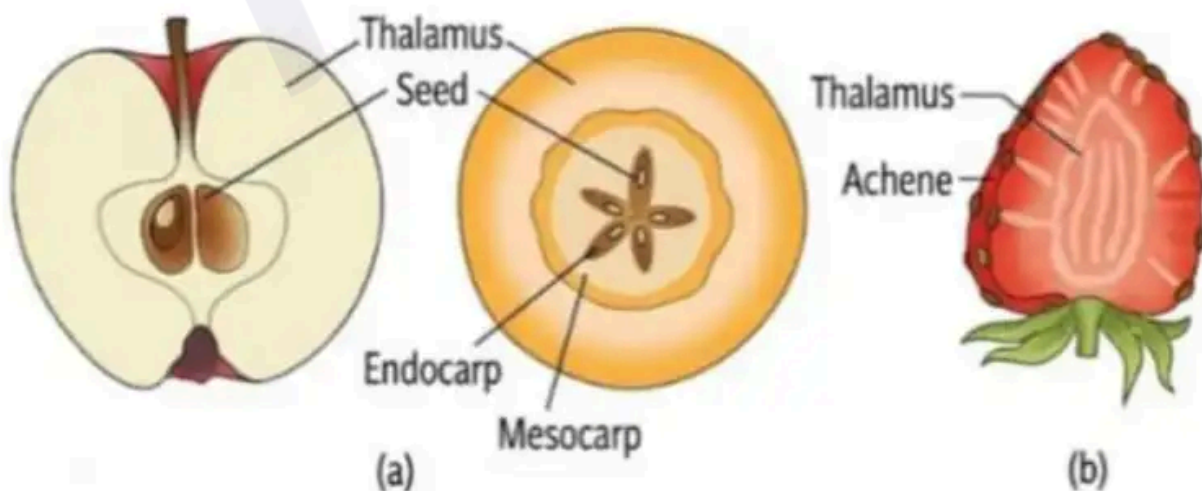


Fig.: False fruits of (a) apple and (b) strawberry

Memory Aids

- False fruit = ovary + other flower parts.
- True fruit = ovary only.
- Parthenocarpy = seedless fruit formation.

Quick Checkpoints

- What is the difference between true and false fruits?
- What are the layers of pericarp?
- Define parthenocarpy and give examples.

Apomixis and Polyembryony

Apomixis

- Formation of new individuals without gamete formation or fusion.
- Asexual reproduction mimicking sexual reproduction.

Polyembryony

- Presence of more than one embryo in a seed.
- Examples: *Citrus*, onion, groundnut.
- Simple polyembryony: multiple embryos from fertilisation of more than one egg.
- Adventive polyembryony: extra embryos formed by sporophytic budding.

Memory Aids

- Apomixis = Asexual reproduction without gametes.
- Polyembryony = Multiple embryos in one seed.
- Simple polyembryony = Multiple eggs fertilised.
- Adventive polyembryony = Embryos from sporophyte cells.

Quick Checkpoints

- What defines apomixis?
- Which plants show polyembryony?
- Difference between simple and adventive polyembryony?
- How does adventive polyembryony occur?

Prepzy