Sexual Reproduction in Flowering Plants

Flower = reproductive shoot of angiosperms.

Important events :

(1) Pre-fertilisation - gamete formation & transfer

(2) Double fertilisation - syngamy + triple fusion

(3) Post-fertilisation - embryo + endosperm + seed + fruit

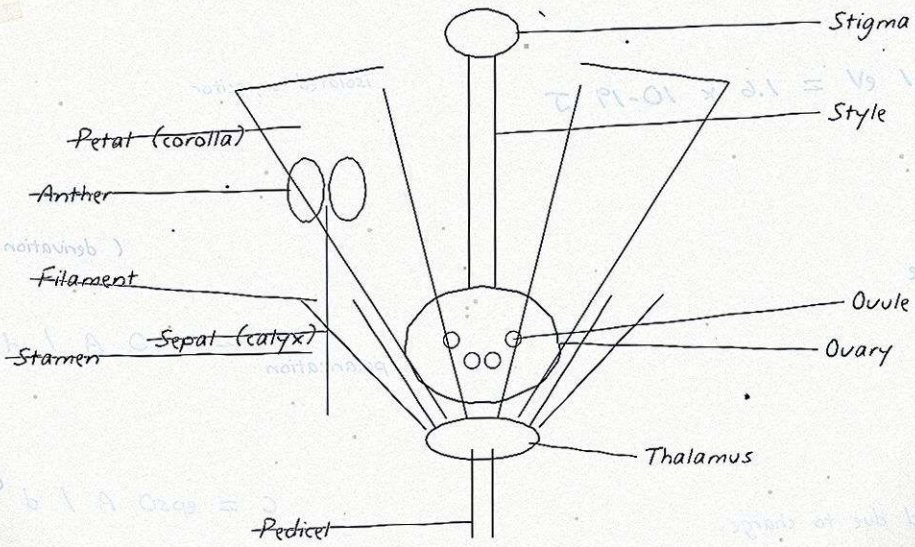


Fig. L.S. of typical angiosperm flower

Flower Types & Symmetry

Based on Sex

Bisexual (perfect) - both stamens + carpels

Eg. hibiscus*, mustard

Unisexual - only one sex present

Eg. cucurbita, papaya, maize

Based on Plant

Monoecious - M and F flowers on SAME plant (maize,

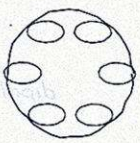
Dioecious - M and F on DIFFERENT plants (papaya, d

Based on Symmetry

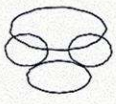
Actinomorphic (radial) - mustard, datura, chilli

Zygomorphic (bilateral) - pea, bean, cassia, gulmohar

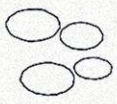
Asymmetric - ~~rare~~ canna (uneven, no symmetry)



Actinomorphic



Zygomorphic



Asymmetric

Floral Parts (4 whorls)

Calyx (sepals) - protective, green, lowermost

Corolla (petals) - attractive, coloured, 2nd whorl

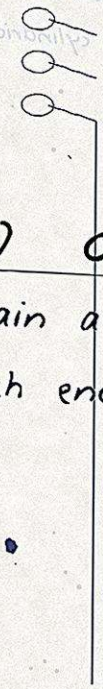
Androecium (stamens) + Gynoecium (carpels) - reprod.

Inflorescence

Cluster of flowers borne on a single branch / shoot.
Two main types :

(1) Racemose (open / indefinite)

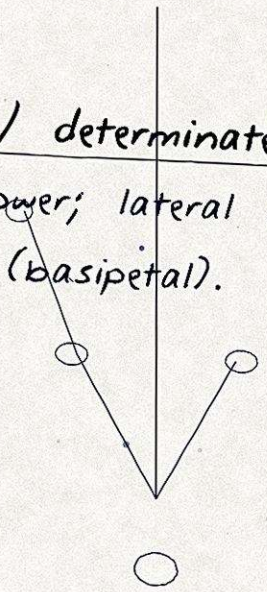
Main axis grows continuously; flowers in acropetal succession (older below, younger above).



Raceme

(2) Cymose (closed / determinate)

Main axis ends in a flower; lateral branches continue, each ending in a flower (basipetal).



Cyme

Examples Table

Racemose	Mustard, Radish, Larkspur, Lupin
Spike	Achyranthus, Adathoda
Catkin	Mulberry, Acalypha
Spadix	Banana, Maize, Colocasia
Umbel	Coriander, Carrot
Cymose	Bougainvillea, Calotropis, Jasmine, Hibiscus

Stamen & Microsporangium

Stamen Structure

Each stamen = filament + anther.

Anther typically bilobed; each lobe = 2 microsporangia.

A typical anther = DITHECOUS, TETRASPORANGIATE.

T.S. of Anther

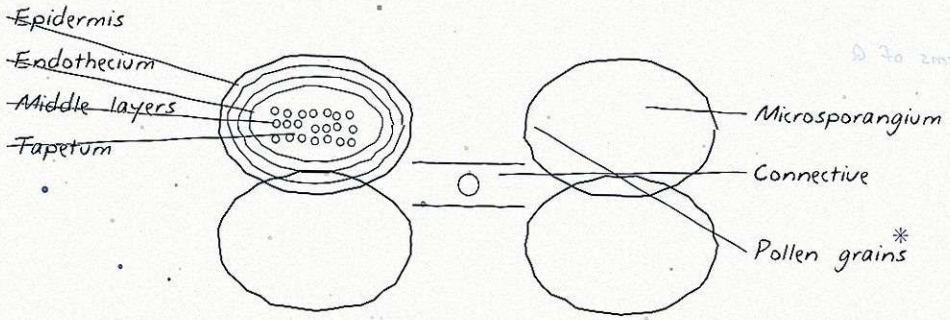


Fig. T.S. of bilobed dithecous anther

Wall Layers - Outer to Inner

(i) Epidermis - protective

(ii) Endothecium - fibrous, helps in dehiscence

(iii) Middle layers (2-3) - short-lived, ephemeral

(iv) TAPETUM - innermost; nourishes pollen.

Cells often POLYPLOID & multinucleate.

Tapetum secretes ~~intine~~ sporopollenin + Ubisch bodies.

First 3 layers PROTECT + help anther dehiscence.

Microsporogenesis (detailed)

Formation of haploid microspores from diploid Microspore Mother Cell (MMC) via meiosis.

Sporogenous Tissue

Compactly arranged homogenous cells in centre of young microsporangium - develop into MMC / PMC.

Meiotic Sequence - PMC to Pollen

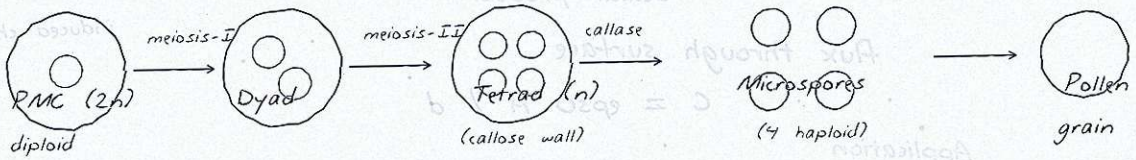


Fig. Microsporogenesis (PMC -> 4 microspores)

Callase Enzyme

Dissolves the callose wall of the tetrad, releasing 4 individual microspores into the locule.

Microspore Maturation

After release, microspore develops a complex wall : Exine + Intine, with germ pore - becomes pollen grain.

Pollen Grain - Structure

Pollen grain = male gametophyte (microspore).

Size : 25-50 micrometer; usually spherical.

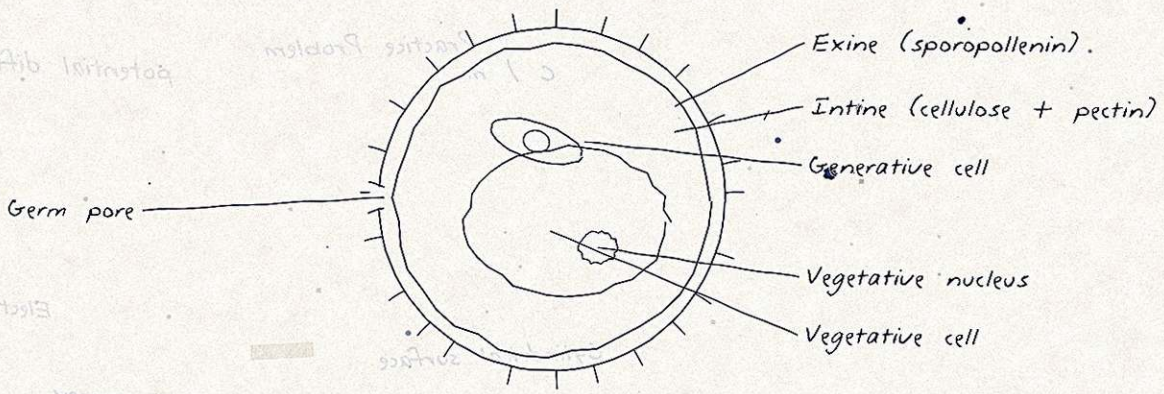


Fig. Mature 2-celled pollen grain

Sporopollenin

Highly resistant biopolymer in exine.

Resists high temp + strong acids/alkalis + enzymes.

Hence pollen fossils are well-preserved (palaeontology).

Germ Pores

Apertures in exine where sporopollenin is absent.

Pollen Biology

Number of Cells in Mature Pollen

60 % angiosperms - shed in 2-celled stage (vegetative cell + generative cell)

40 % angiosperms - shed in 3-celled stage (vegetative cell + 2 male gametes)

Eg. of 3-celled : Grasses (Poaceae), Compositae

Pollen Viability

Time during which pollen remains capable of germinating on a compatible stigma :

Rice, wheat	30 min
Some Rosaceae	few hours
Some legumes	few days
Datura, citrus	months (cryo)

Pollen Storage

Stored in liquid N at -196 deg C in POLLEN BANKS.

Used in plant breeding and germplasm conservation.

Pollen Allergy

Pollen of some plants ~~cause hayfever~~ causes allergies :

Eg. Parthenium (carrot grass) - hay fever, asthma.

Parthenium hysterophorus - alien invader, common in roadsides; major allergen in India.

Pollen as Food / Supplement

Pollen rich in protein, oils, vitamins.
Used in west as TABLETS / SYRUPS by athletes, race horses, etc. to enhance performance.

Pistil / Carpel

Each carpel = Stigma + Style + Ovary.

MONOCARPELLARY - one carpel (e.g. pea)

MULTICARPELLARY - many carpels

SYNCARPOUS - carpels fused (papaver)

APOCARPOUS - carpels free (rose, lotus)

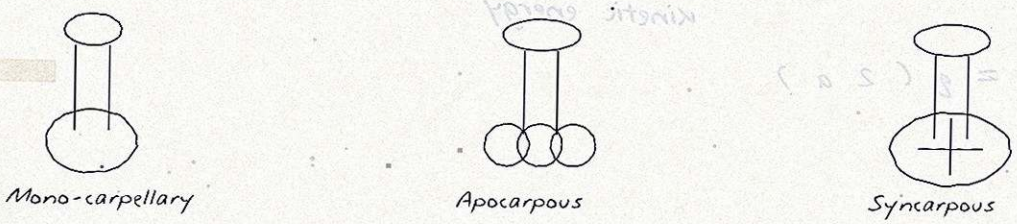


Fig. Three types of carpel arrangement

Stigma Types

DRY - no surface secretion (cereals)

WET - surface sticky / oily (lily, tobacco)

Megasporangium (Ovule)

Ovule = small structure inside ovary attached to placenta via funicle.

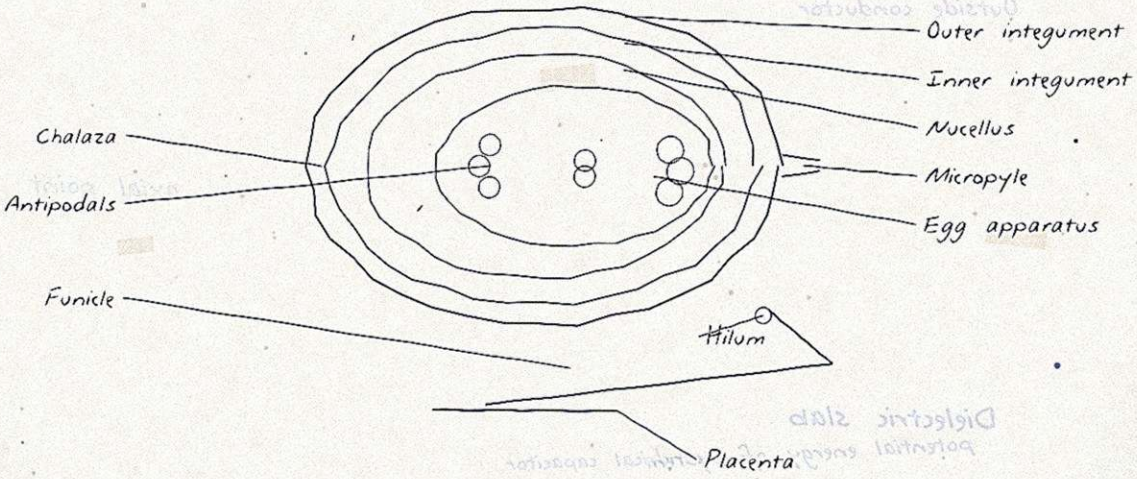


Fig. L.S. of anatropous ovule

Important Definitions

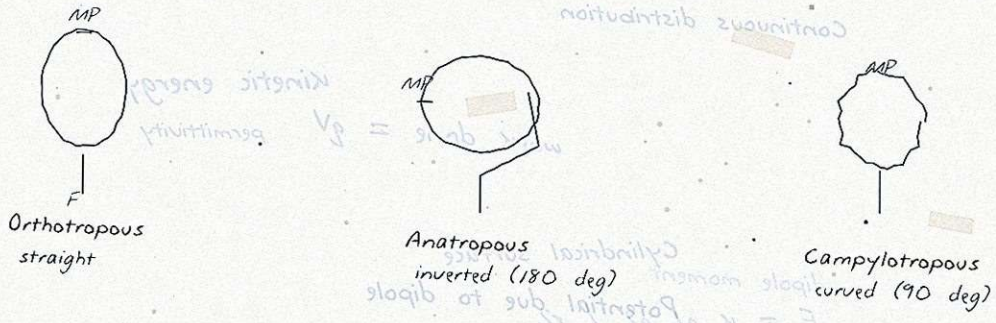
Funicle - stalk attaching ovule to placenta

Hilum - junction of funicle with the ovule body

Chalaza - basal opposite end of ovule

Micropyle - small pore through integuments

Types of Ovule (orientation)



Most Common Type

ANATROPOUS - in 80 % of angiosperms.

Body of ovule turned ~~90~~ 180 deg so micropyle* aligns with fu

Megasporangium / Nucellus

Mass of nutritive cells inside the ovule.

One cell differentiates as MMC -> Megaspore.

Cells surrounding nucellus = integuments (1 or 2).

Unitegmic - one (Gamopetalae)

Bitegmic - two (Polypetalae)

Position of Placenta

Megasporogenesis

Formation of haploid megaspores from MMC by meiosis.

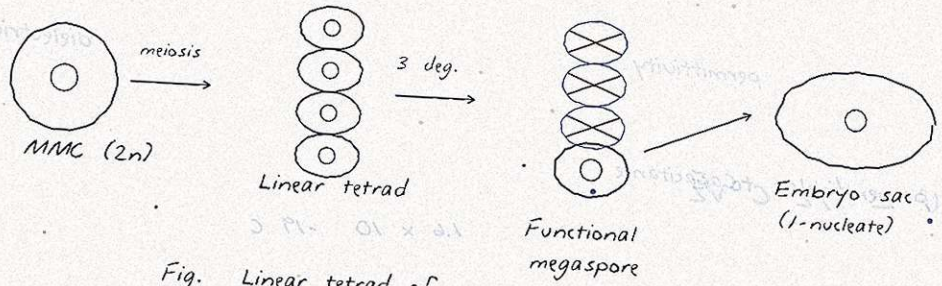


Fig. Linear tetrad of megaspores; 3 die, 1 survives

Polygonum Type Embryo Sac (most common)

MONOSPORIC - only ONE megaspore is functional.

Develops by THREE successive MITOTIC divisions :

(1) 1st mitosis -> 2 nuclei (binucleate)

(2) 2nd mitosis -> 4 nuclei (4-nucleate)

(3) 3rd mitosis -> 8 nuclei (8-nucleate)

Then cell walls form -> 7-celled, 8-nucleate sac.

Final Layout

Micropylar end : egg apparatus (1 egg + 2 synergids)

Centre : central cell + 2 polar nuclei

Chalazal end : 3 antipodals

Mature Embryo Sac

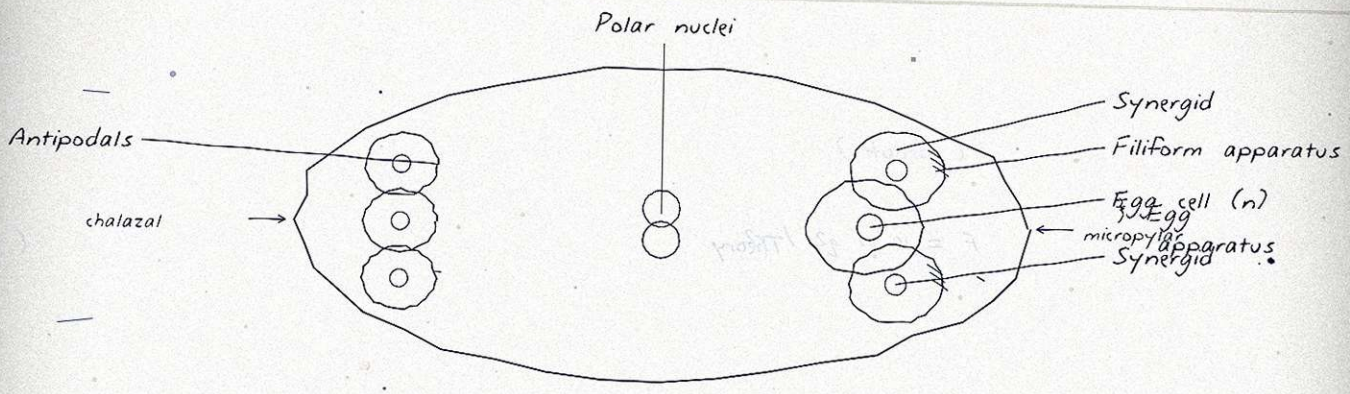


Fig. Mature embryo sac (7-celled, 8-nucleate)

Functions of Each Cell

Synergids - guide pollen tube via filiform apparatus (chemo-attractant secretion)

Egg - fuses with one male gamete -> Zygote (2n)

Central cell - fuses with another male gamete -> Primary Endosperm Nucleus, PEN (3n)

Antipodals - ~~egg~~ accessory, degenerate later.

Polygonum / Other Types

Bisporic, tetrasporic types occur but are rare.

Pollination

Transfer of pollen from anther to stigma.
Key event preceding fertilisation.

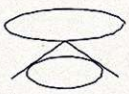
Three Kinds

1. Autogamy - self-pollination within same flower
2. Geitonogamy - between 2 flowers of SAME plant
   Genetically autogamy, ecologically cross-poll..
3. Xenogamy - from DIFFERENT plant of same species
   True cross-pollination.

Cleistogamy & Chasmogamy

Cleistogamous - flowers never open. Self-pollinated.
(Eg. Viola, Oxalis, Commelina, Arachis)
Chasmogamous - open flowers, both autogamy and xenogamy possible.

Cleistogamous (closed)



Chasmogamous (open)

Agents of Pollination

ABIOTIC : Wind (Anemophily), Water (Hydrophily)
BIOTIC : Insects, Birds, Bats, Snails (rarely)

Pollinating Agents - Details

Anemophily (Wind)

Features : light, non-sticky, dry, dusty pollen.
Stigma large + feathery + sticky to trap.
Eg. maize, grasses, coconut, pinus, mulberry.

Hydrophily (Water)

Rare; mostly monocots in fresh water.
Eg. Vallisneria - female flower reaches surface, pollen float on water (epi-hydrophily)
Eg. Zostera, Hydrilla - hypo-hydrophily.

Entomophily (Insects)

80 % flowering plants. Pollen + nectar = reward.
Flowers large, brightly coloured, fragrant, with nectar / pollen as food.
Eg. sunflower, rose, marigold; Yucca + moth (mutualism)
Special : Amorphophallus - ~~sweet~~ bad smell, attracts flies.

Ornithophily (Birds)

Bombax (silk cotton), Bottle-brush. Birds = sunbird, hummingbird, crow.

Chiropterophily (Bats)

Adansonia (baobab), Kigelia - night-blooming pale flowers.

Outbreeding Devices

Promote cross-pollination + prevent inbreeding depression. Five common devices :

(1) Pollen Release / Stigma Receptivity

NOT synchronised - pollen released before / after stigma becomes receptive. Eg. maize, sunflower.

(2) Anther & Stigma Position

Placed at different heights -> Herkogamy.
Eg. Hibiscus, Gloriosa.

(3) Self-Incompatibility

Genetic mechanism - same-genotype pollen rejected.
Pollen germinates but tube growth blocked in style.
Eg. Brassica, Petunia, Theobroma.

(4) Unisexual Flowers

Eg. cucurbits (monoecious - same plant)
papaya, date palm (dioecious - separate plants)

(5) Heterostyly

Two flower types - PIN (long style, short stamens) + THRUM (short style, long stamens). Eg. Primula.

Inbreeding Effects

Pollen-Pistil Interaction

All events from pollen deposition on stigma to entry into ovule. Pistil's safety check.

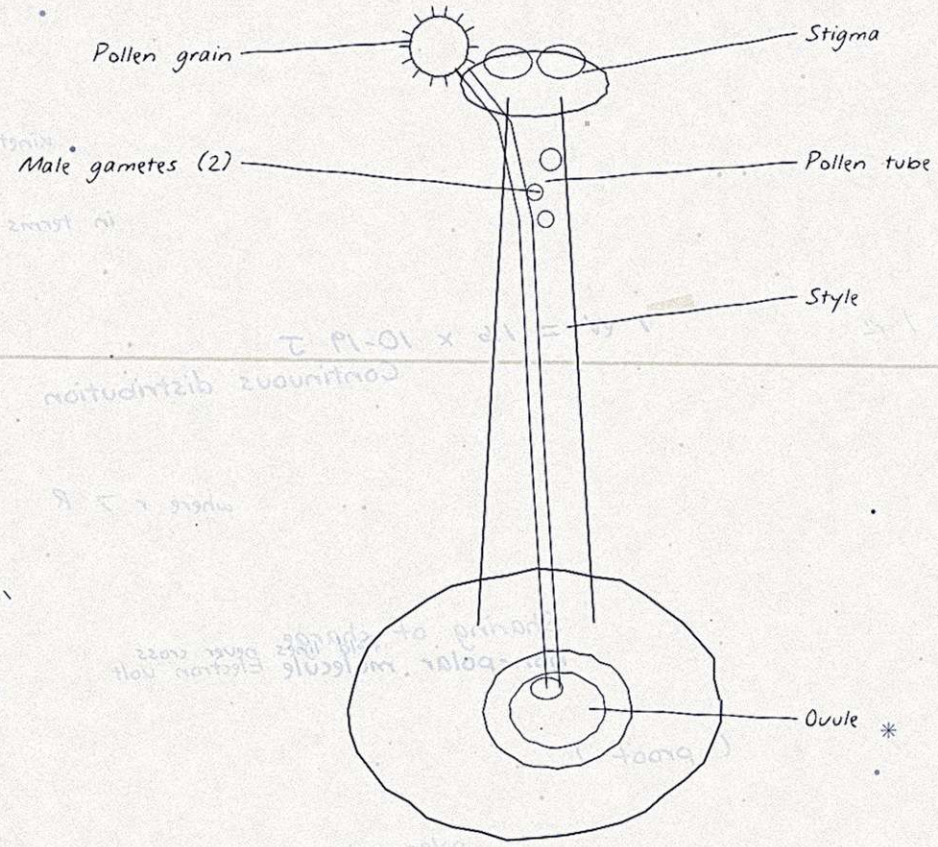


Fig. Pollen tube growth from *stigma to ovule

Compatibility Check

Pistil tests pollen on ~~colour~~ surface chemistry.

Compatible -> tube grows; incompatible -> blocked.

Generative Cell Division

Artificial Hybridisation

Crop improvement technique used by plant breeders.

Goal - make superior progeny with desired traits.

Steps

1. Emasculation - remove anthers from bisexual flower BEFORE they release pollen (bud stage).
2. Bagging - cover with butter-paper bag to prevent contamination by unwanted pollen.
3. Pollination - dust mature pollen from male parent on receptive stigma; re-bag.
4. Tag + wait for seeds to mature.

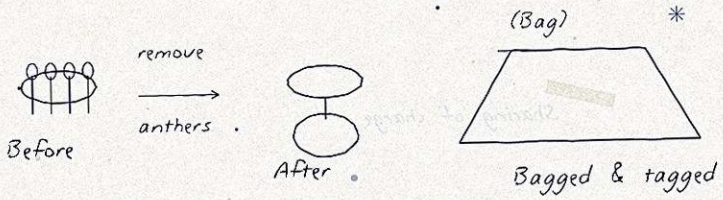


Fig. Emasculation + bagging steps

Compatibility Issues

Sometimes incompatibility blocks fertilisation - use embryo rescue + tissue culture.

Hybrid vigour = ~~inbreeding~~ heterosis.

Eg. Hybrid corn produces 2x yield of parents.

Double Fertilisation

Unique to angiosperms. Discovered by S.G. Nawaschin (1898).
Pollen tube enters ovule through ~~chalaza~~ micropyle (porogamy).

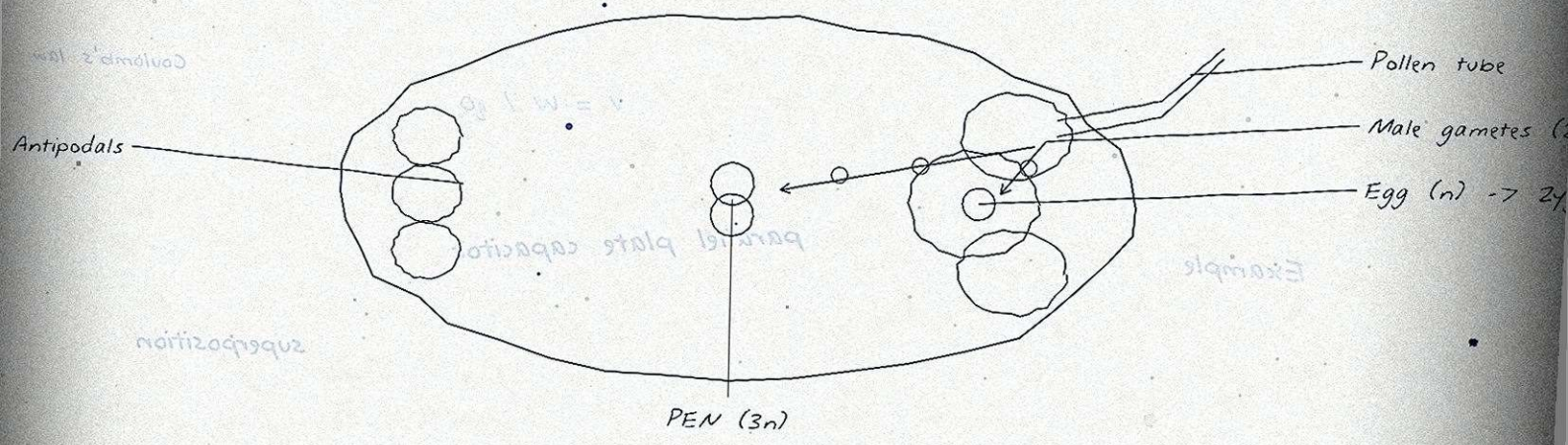


Fig. Two male gametes -> two fusions

Two Fusions

Syngamy : male gamete + egg -> Zygote (2n)
Triple fusion : male gamete + 2 polar nuclei
-> Primary Endosperm Nucleus (3n)

Hence the Name

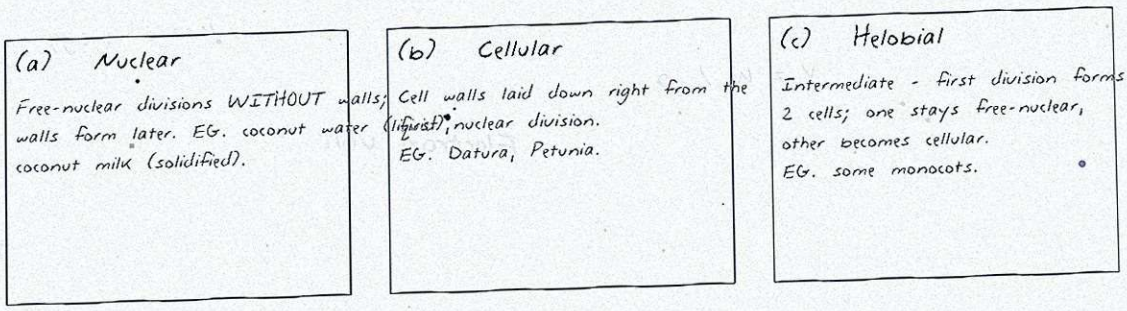
TWO fusion events in single embryo sac
=> DOUBLE fertilisation (only in angiosperms).

Endosperm (3n)

Develops from Primary Endosperm Cell (PEC) = central cell + PEN (3n).

FUNCTION - nourishes the developing embryo.

Three Types of Endosperm Development



Endospermic vs Non-endospermic

Endospermic (Albuminous) - endosperm persists in seed

Eg. castor, maize, coconut, wheat, rice

Non-endospermic ~~(monocot)~~ (Exalbuminous) - endosperm us up; food stored in cotyledons.

Eg. pea, gram, bean, groundnut.

Special Endosperm

Coconut water = liquid free-nuclear endosperm.

Embryo Development (Dicot)

Starts at micropylar end of embryo sac.

Zygote -> proembryo -> globular -> heart-shaped -> torpedo -> mature embryo.

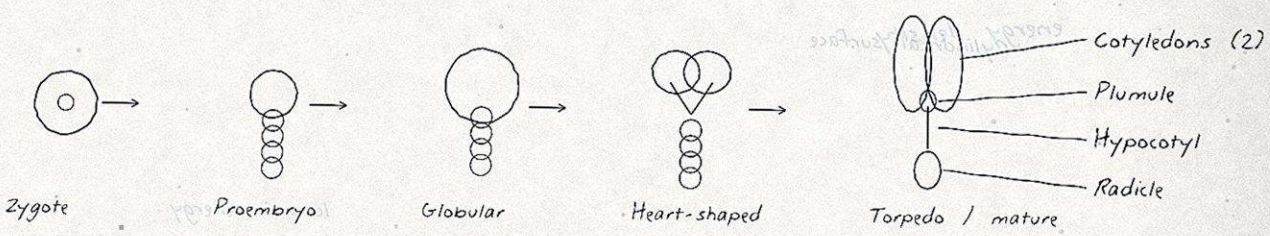


Fig. Embryo stages in dicot

Suspensor

Short string of cells that pushes the proembryo into endosperm - ensures nutrient supply.

Dicot Embryo Parts

Embryo axis = plumule (shoot tip) + radicle (root tip)

Hypocotyl = region below cotyledons

Epicotyl = region above cotyledons

2 Cotyledons = food storage

Monocot Embryo (Maize) & Seed

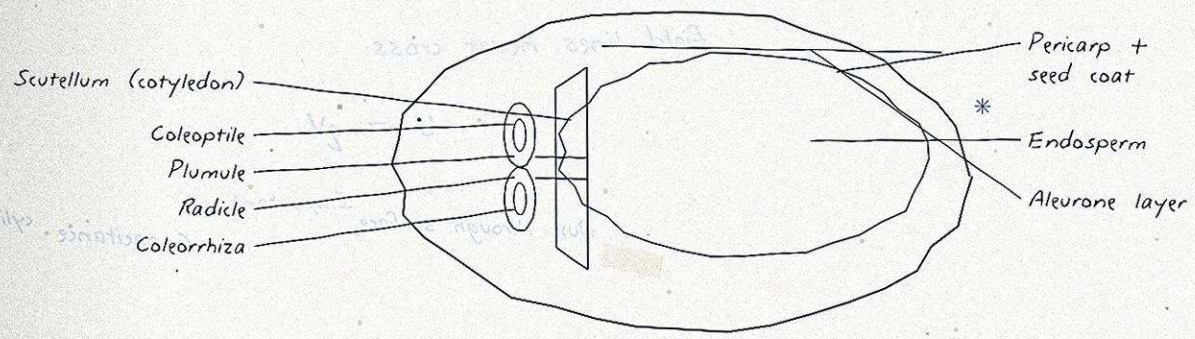


Fig. L.S. of monocot (maize) grain

Monocot vs Dicot Embryo

Feature	Dicot	Monocot
Cotyledons	2	1 (scutellum)
Plumule cover	absent	coleoptile
Radicle cover	absent	coleorrhiza
Endosperm at maturity	often used up	present

Seed & Fruit

Ovule -> Seed ; Ovary -> Fruit

True fruit (ovary only) ; False fruit (thalamus +)

Apomixis & Polyembryony

Apomixis

Asexual reproduction that MIMICS sexual reproduction.
Seeds form WITHOUT fertilisation.
Common in some Asteraceae & grasses.
Important for hybrid seed industry - ~~each crop~~ maintains hybrid vigour through generations (no segregation).

Types of Apomixis

1. Diplospory - embryo sac from MMC w/o meiosis
2. Apospory - embryo sac from a nucellar cell
3. Adventive embryony - from nucellus / integuments
   Eg. Citrus, Mango.

Polyembryony

Occurrence of MORE THAN ONE embryo in a single seed.
First described by Antony van Leeuwenhoek (1719) in Citrus seeds.
Common Eg. Orange, lemon, mango, mustard, onion.

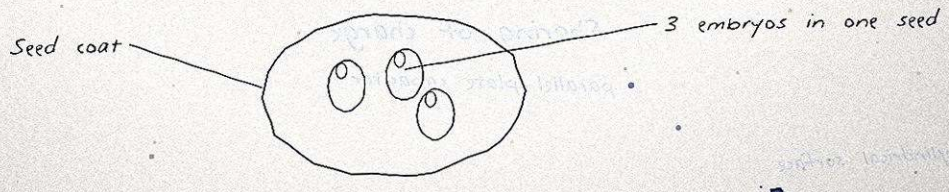


Fig. Polyembryonic seed (Citrus)