Unit 12 · Sexual Reproduction

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Embryology (Units 11–12 together): 5 of 75 marks; 1 MCQ (knowledge) and 1 short question (4 marks: knowledge 2, higher ability 2)
- **The paper:** Botany 37 + Zoology 38; each part: MCQs × 1 (5 Botany, 6 Zoology) · 4 short × 4 · 2 long × 8; one OR in each short and long group; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ: the second male gamete fuses with the polar nuclei; short: development of a monocot embryo with diagrams (3 + 1)
- **MCQ (1 mark)**
  - gynoecium; tapetum nourishes pollen; four microsporangia
  - two male gametes; zygote → embryo
  - blocked micropyle stops tube entry; autogamy keeps a pure line
  - zygote 2n, endosperm 3n
- **Short (in parts)**
  - microsporogenesis; microgametogenesis
  - embryo sac: structure, development with a diagram
  - self vs cross; why cross is better for evolution; bat flowers
  - double fertilization with a diagram; endosperm
  - an ovule from a figure: label, which part 3n, which the zygote
  - the suspensor in monocots and dicots

Key terms

Calyx, corolla: accessory whorls; **androecium** (stamens), **gynoecium** (pistil): essential whorls.

Microsporogenesis: MMC (2n) → meiosis → 4 microspores (n) in the anther.

Microgametogenesis: microspore → male gametophyte (pollen grain).

Megasporogenesis: MMC (2n) → meiosis → 4 megaspores in the ovule.

Megagametogenesis: functional megaspore → embryo sac.

Tapetum: innermost anther wall layer; nourishes pollen.

Sporopollenin: exine's resistant substance.

Pollination: transfer of pollen from anther to stigma.

Autogamy: same flower; **geitonogamy**: another flower, same plant; **xenogamy**: another plant.

Cleistogamy: flowers never open.

Dichogamy: anthers and stigma ripen at different times (**protandry**, **protogyny**).

Siphonogamy: male gametes carried in a pollen tube.

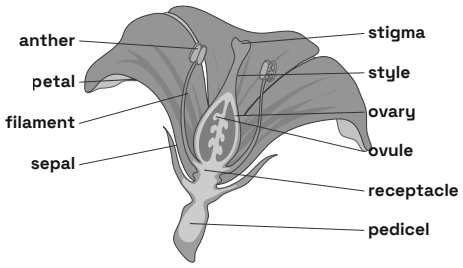
Porogamy: tube enters by the micropyle; **chalazogamy**, **mesogamy**: other ways (aporogamy).

Syngamy: male gamete + egg → zygote (2n).

Triple fusion: male gamete + 2 polar nuclei → primary endosperm nucleus (3n).

The flower

- **calyx** (sepals, protect bud); **corolla** (petals, attract); **androecium** (stamens: anther + filament); **gynoecium** (carpels: stigma, style, ovary with ovules)
- sexual reproduction: **gametogenesis** → **pollination** → **fertilization** → **seed and fruit**



Parts of a flower.

Microsporogenesis and pollen

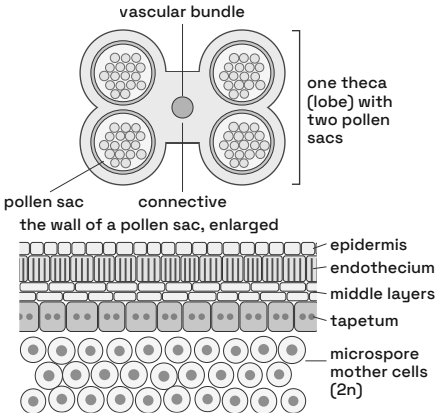
Anther

- **bilobed**; joined by the **connective** (vascular bundle)
- each lobe a **theca** → **dithecous**; 2 pollen sacs per theca → **4 microsporangia** (tetrasporangiate)
- opens at the **stomium**; mallows monothecous

Wall of the microsporangium (outside in)

1. **epidermis**: protects
2. **endothecium**: **fibrous thickenings** → **dehiscence**
3. **middle layers**: 1–3, store food, crushed
4. **tapetum**: large cells, **multinucleate**/polyploid; **nourishes** pollen, frees tetrads, makes exine material, **pollenkitt**

- centre: **sporogenous tissue** → MMCs; early tapetum breakdown → male sterility



The anther in section.

- MMC (2n) → **meiosis** → **microspore tetrad** (n) → separate → pollen grains

Pollen grain: 25–50 μm

- **exine**: **sporopollenin**; resists acid, alkali, heat, enzymes → fossils; species pattern
- **intine**: cellulose, pectin
- **germ pores**: intine grows out as the **pollen tube** (grasses 1, many dicots 3)

Microgametogenesis

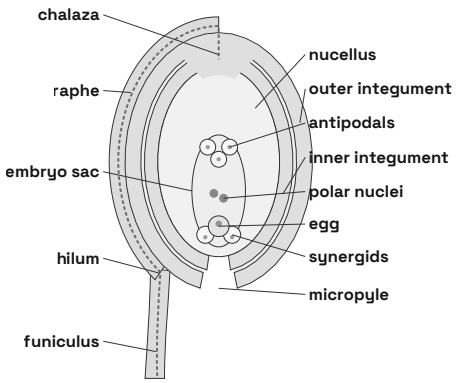
1. microspore enlarges; vacuole pushes nucleus to the side
2. **unequal mitosis** → large **vegetative (tube) cell** + small **generative cell** (floats inside it)
3. **> 60%** shed **2-celled**; generative cell divides in the tube
4. ~40% (wheat, rice, mustards) shed **3-celled**

- mature male gametophyte: **3 cells**: tube cell + **2 male gametes** (n, no flagella)

Megasporogenesis and the embryo sac

Ovule: on the **placenta** by the **funiculus**; **hilum**

- **nucellus** (embryo sac inside); **integuments** (1–2, future seed coat); **micropyle**; **chalaza**
- **anatropous**: turned round, micropyle near hilum, **raphe** (commonest); **orthotropous**: straight (*Polygonum*, black pepper)



An anatropous ovule.

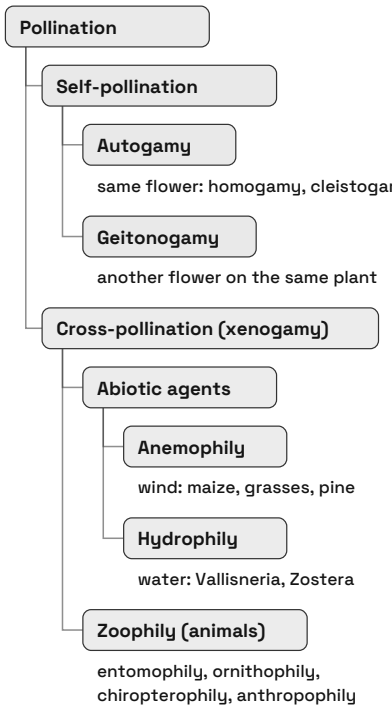
1. **archesporial cell** under the nucellus surface, micropylar end
2. → **MMC (2n)** directly or after cutting off a wall cell
3. **meiosis** → **linear tetrad** of megaspores
4. **3 degenerate**; **chalazal** one functional → **monosporic**, *Polygonum* type (Strasburger, 1879)

Megagametogenesis

1. functional megaspore enlarges
2. mitosis → 2 nuclei to the poles
3. two more mitoses → **4 + 4 = 8 nuclei**, **free nuclear**
4. **one from each pole** → middle: **2 polar nuclei**
5. walls form → **7 cells**

- **micropylar end**: **egg** + 2 **synergids** (**egg apparatus**); synergids' **filiform apparatus** guides the tube
- **chalazal end**: 3 **antipodals**
- **central cell**: 2 polar nuclei (may fuse → **secondary nucleus**, 2n)
- **7-celled, 8-nucleate**; 1 meiosis + 3 mitoses

Pollination



Kinds of pollination.

Self-pollination

- **autogamy**: same flower; helped by **homogamy** (ripen together: wheat, rice, pea, tomato) and **cleistogamy** (closed flowers: *Commelina*, *Viola*, *Oxalis*)
- **geitonogamy**: another flower, same plant; needs an agent; genetically self (maize, cucumber)

	Self	Cross
pollen from	same flower or plant	another plant
agent	not always needed	always
variation	little	much
pure lines	kept	lost
pollen	little wasted	much wasted
flowers	plain	showy, scented, nectar (or much pollen)
seed	almost certain	less certain
evolution	little	helps

Self: advantages: pure line; economical; no pollinator needed; no showy parts; seed sure
Self: disadvantages: little variation; less adaptable; **inbreeding depression**; unwanted characters kept; little evolution

Cross-pollination (xenogamy): only source of new genes; needs an agent

- **dioecy** (papaya, date palm, spinach)
- **dichogamy**: **protandry** (sunflower, coriander), **protogyny** (custard apple)
- **self-incompatibility** (tea, cabbage, apple, pear)
- **herkogamy**: barrier of form

Anemophily (wind): grasses, maize, walnut, birch, oak, conifers

- small, no color, scent, nectar
- huge amounts of **light, dry, smooth** pollen
- anthers on **long filaments** hanging out
- **large feathery** stigmas (maize silks)
- one ovule per ovary; dense inflorescences

Hydrophily (water): rare, ~30 genera; *Vallisneria*, *Hydrilla*, *Zostera*

- water hyacinth, lotus: insect-pollinated, not hydrophilous
- pollen with **mucilage**; *Vallisneria*: male flowers float to females on the surface; *Zostera*: thread-like pollen under water

Zoophily (animals): ~9 in 10 flowering plants; big colored petals, scent, nectar; **sticky, spiny** pollen

- **entomophily** (insects): bee flowers blue, yellow, purple, **nectar guides** (UV); mustard, sunflower, apple
- **ornithophily** (birds): **red, orange, tubular**, much dilute nectar, **no scent**; simal, *Erythrina*, laliguras
- **chiropterophily** (bats): open at **night**, large, pale, strong musty smell, much nectar; *Kigelia*, baobab
- **anthropophily** (people): vanilla by hand, date palm, apple in China
- also snails (malacophily), lizards, rodents; **no snake pollination** (ophiophily is wrong)

Cross: advantages: self-sterile plants seed; **variation**; evolution; adaptability; new varieties; **hybrid vigor**; recessives hidden
Cross: disadvantages: wasteful; depends on agents; unwanted characters in; varieties not kept pure; costly attractions; seed less certain

Double fertilization

- stigma checks pollen; compatible grain absorbs water, sugars → **pollen tube** down the style
- tube nucleus at the tip; generative cell → 2 male gametes: **siphonogamy** (mosses, ferns: **zoidogamy**)

1. **entry into ovule**: **porogamy** (micropyle); **aporogamy**: **chalazogamy** (*Casuarina*), **mesogamy** (*Cucurbita*)
2. **entry into embryo sac**: guided by the **filiform apparatus** into a **synergid** (degenerates); tip bursts, 2 male gametes released
3. **syngamy**: male gamete + **egg** → **zygote (2n)** → embryo
4. **triple fusion**: second male gamete + **2 polar nuclei** → **PEN (3n)** → **endosperm**

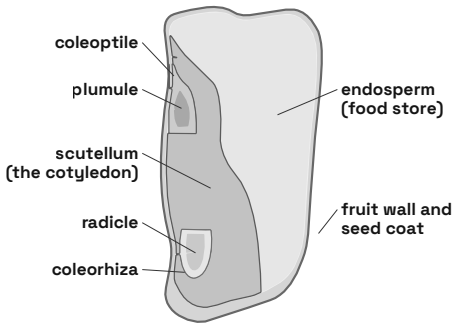
- syngamy + triple fusion = **double fertilization**; only in angiosperms; synergid, antipodals degenerate

Before	After
zygote	embryo
PEN	endosperm
integuments	seed coat (testa, tegmen)
micropyle	seed's pore
funiculus	stalk; hilum scar
ovule	seed
ovary	fruit
ovary wall	pericarp

Embryogenesis

Monocot

1. zygote → transversely → small **terminal** + large **basal** cell
2. **basal cell** → **suspensor**; often one large **vesicular** cell, degenerates
3. **terminal cell** → 2: tip cell → **single cotyledon + plumule** (plumule pushed into a lateral notch); middle cell → **hypocotyl + radicle**, a few suspensor cells
4. grasses: cotyledon = **scutellum** (absorbs endosperm food); plumule in **coleoptile**, radicle in **coleorhiza**



Development of a monocot embryo.

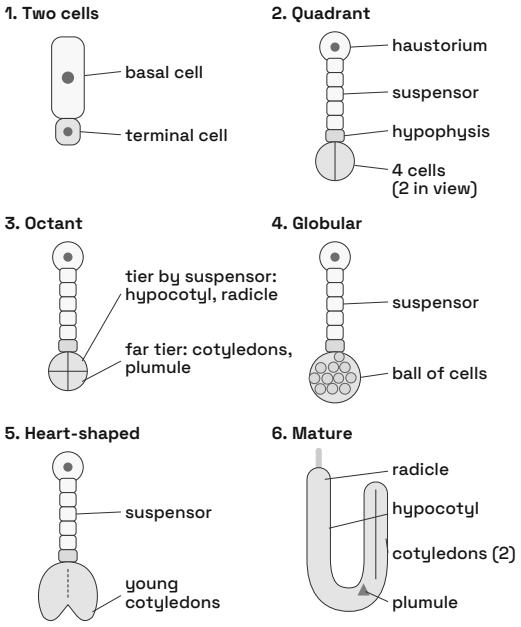
Dicot (*Capsella bursa-pastoris*)

1. zygote → large **basal** (micropylar) + small **terminal** (chalazal)

2. basal → **suspensor** of **6–10 cells**; micropylar cell = **haustorium**; cell next to embryo = **hypophysis** → **radicle tip, root cap**
3. terminal → 2 vertical divisions (**quadrant**) → 1 transverse (**octant**, 2 tiers of 4)

- tier next to suspensor (**hypobasal**) → hypocotyl + radicle
- far tier (**epibasal**) → **2 cotyledons + plumule**

1. **globular** stage; outer layer = epidermis
2. **heart-shaped** (cotyledon bulges)
3. **torpedo**; horseshoe in *Capsella*



Development of a dicot embryo, *Capsella*.

	Monocot	Dicot
suspensor	often 1 vesicular cell	6–10 cells, haustorium, hypophysis
cotyledons	1 (scutellum)	2
plumule	lateral notch	between cotyledons, terminal
sheaths	coleoptile, coleorhiza	none

Endosperm

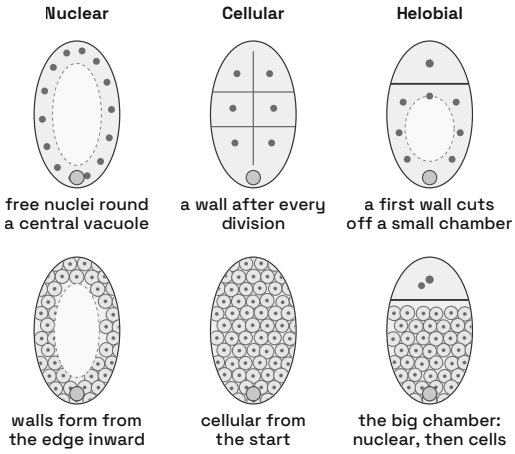
- from **PEN (3n)**; stored starch, oils, proteins; starts **before** the embryo divides

Nuclear (commonest): free nuclear divisions, vacuole, walls later from the edge

- maize, wheat, rice, *Capsella*
- **coconut**: water = free-nuclear endosperm; white flesh = cellular endosperm

Cellular: wall after every division, cellular from the start; *Petunia*, *Datura*, *Impatiens*

Helobial: first division → **large micropylar + small chalazal** cell; micropylar goes nuclear, chalazal divides little; monocots (*Eremurus*)



Three kinds of endosperm development.

- **non-endospermic** (exalbuminous): embryo uses it up, food in cotyledons; pea, gram, bean, groundnut
- **endospermic** (albuminous): maize, wheat, rice, castor, coconut

COMMON MISTAKES

✗ Each anther lobe has two thecae
✓ each lobe **is** a theca with **two pollen sacs**.

✗ The endothecium nourishes pollen
✓ the **tapetum**; endothecium opens the anther.

✗ The micropylar megaspore survives
✓ usually the **chalazal** one.

✗ The embryo sac has 8 cells
✓ **7 cells, 8 nuclei**.

✗ Geitonogamy is cross-pollination
✓ genetically **self**.

✗ All water plants are hydrophilous
✓ lotus, water hyacinth are insect-pollinated.

✗ Snakes pollinate flowers
✓ no plant is snake-pollinated.

✗ The second male gamete fuses with the antipodals
✓ with the **polar nuclei** (triple fusion).

✗ Endosperm is diploid
✓ **triploid** (3n); zygote 2n.

✗ Coconut water is cellular endosperm
✓ **free-nuclear**; the flesh is cellular.