Collegedunia NCERT Notes

The Ultimate 12th NCERT Revision Guide for Class 12 Biology

Full-colour diagrams | 2026-27 / New NCERT

Chapter 1: Sexual Reproduction in Flowering Plants

Also see for this chapter: NCERT Solutions | Formula Sheet | Exemplar Solutions

Contents

1 Flower: A Fascinating Organ of Angiosperms

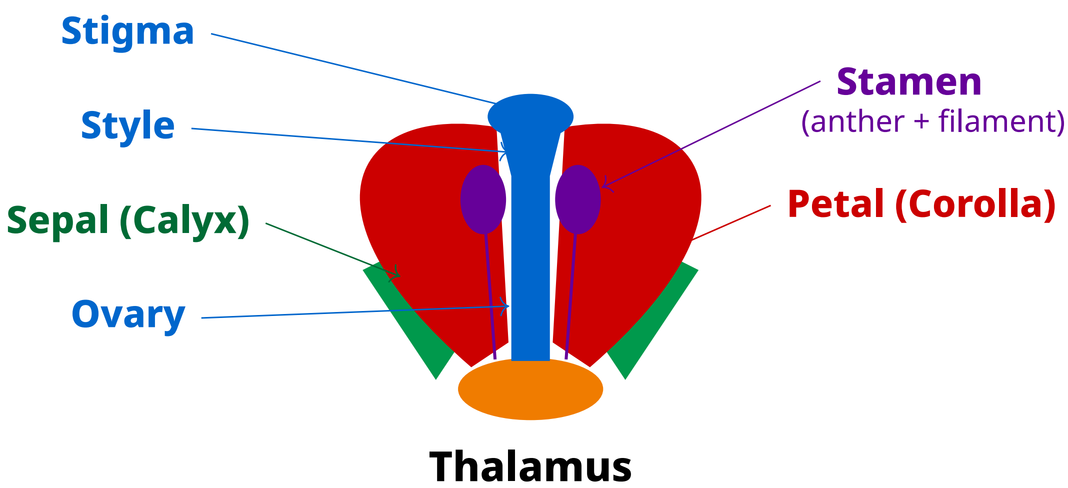
The flower is the reproductive shoot of an angiosperm. Beyond its aesthetic and cultural roles, it is the site where male and female gametes are produced, brought together by pollination, and fused by fertilisation to give rise to the next generation. Every floral whorl has a specific role: sepals protect the bud, petals attract pollinators, stamens (androecium) produce pollen, and the carpel (gynoecium) houses the ovule.

1.1 The four whorls of a typical flower

A typical bisexual flower has four whorls arranged on the thalamus, from outside in: calyx (sepals), corolla (petals), androecium (stamens), and gynoecium (carpels). The androecium and gynoecium are the essential reproductive whorls; the calyx and corolla are accessory.

Reproductive vs Accessory Whorls

Essential whorls (produce gametes): Androecium (microspores → male gametes), Gynoecium (megaspores → female gametes).
Accessory whorls (support reproduction): Calyx (protection), Corolla (pollinator attraction).



Longitudinal view of a typical bisexual flower showing the four whorls.

Key Takeaway

Stamen = filament + anther; the anther produces pollen. Carpel = stigma + style + ovary; the ovary contains ovules that mature into seeds. Memorise these two trios — the rest of the chapter unpacks them.

Whorls outside-in: CCPP

Calyx → **C**orolla → Andro**e**cium → Gyno**e**cium. Read it as "**Cat Calls Pretty Pet**": outermost protection, then attraction, then male, then female. A bisexual flower has all four; if any one is missing, it is incomplete.

1.2 Pre-, syn- and post-fertilisation events

Sexual reproduction in flowering plants happens in three phases:

- **Pre-fertilisation events**: formation of male and female gametophytes; pollination.
- **Fertilisation (syngamy)**: fusion of male and female gametes. In angiosperms, this is the unique *double fertilisation*.
- **Post-fertilisation events**: development of zygote into embryo, primary endosperm cell into endosperm, ovule into seed, and ovary into fruit.

The big picture

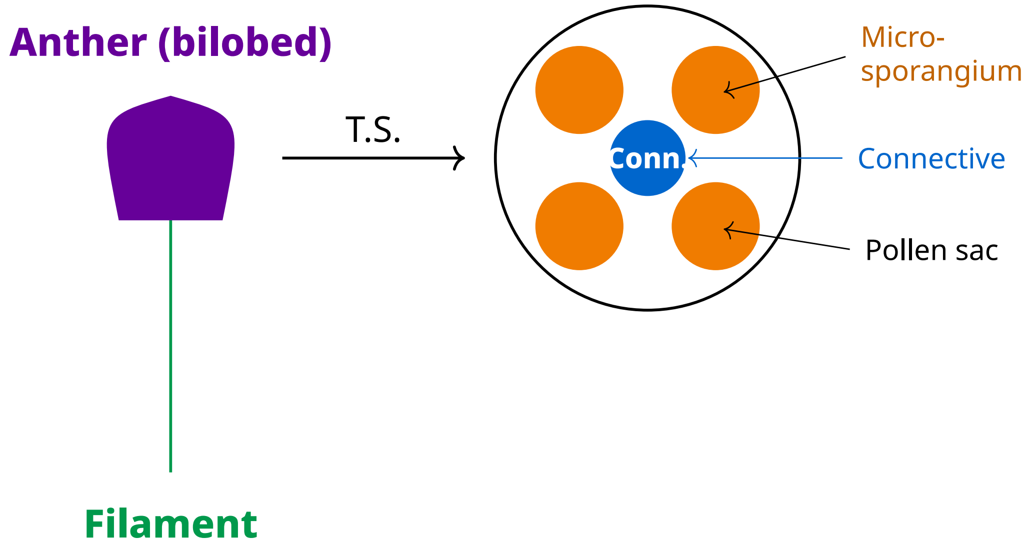
Pollination delivers pollen to stigma. Fertilisation fuses gametes. Everything before pollination is *gametogenesis*; everything after fertilisation is *development*. Most NCERT-level questions ask you to map a structure to its phase.

2 Pre-fertilisation: Structures and Events

This section covers gametogenesis (microsporogenesis and megasporogenesis), the structure of the pollen grain and embryo sac, and pollination.

2.1 Stamen, microsporangium and pollen grain

A stamen has a long, slender **filament** attached to the thalamus and a bilobed **anther** at the tip. Each anther lobe is dithecous, so a typical anther has four microsporangia at the corners — two per lobe.



A typical stamen (left) and transverse section of an anther (right) showing the four microsporangia.

In a transverse view, each microsporangium is bordered by four wall layers from outside in: **epidermis**, **endothecium**, **middle layers**, and the innermost **tapetum**. The outer three protect the sporangium and assist dehiscence at maturity. The tapetum nourishes the developing pollen — its cells are dense, multinucleate, and have a high RNA and protein content.

Anther wall layers

Outer → Inner: **Epidermis** → **Endothecium** → **Middle layers** (1–3) → **Tapetum**.
The tapetum is the *nutritive* layer; the inner three protect and assist dehiscence.

Anther wall mnemonic: EEMT

Every **E**xcellent **M**icrosporangium **T**hrives. Epidermis → Endothecium → Middle layers → Tapetum. The tapetum is at the heart of the sporangium because pollen is its precious cargo.

When the anther is young, a compact mass of sporogenous cells fills the centre of each microsporangium. These cells undergo meiosis to produce **microspore tetrads**; each tetrad has four haploid microspores. As the anther dehydrates, the microspores separate and mature into **pollen grains**.

Microsporogenesis at a glance

Sporogenous cell (2n) $\longrightarrow$ tetrad of 4 haploid microspores (by meiosis) $\longrightarrow$ pollen grains.

Each anther releases thousands of pollen grains — each grain is the result of one meiosis somewhere in the lineage.

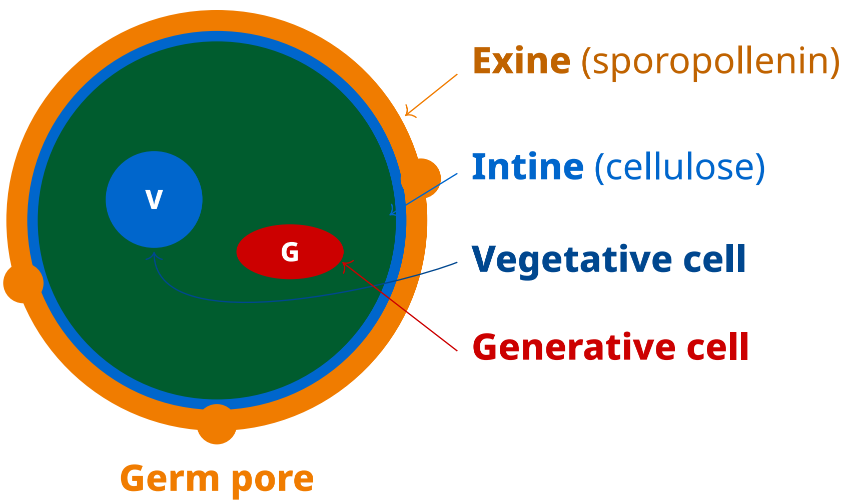
2.2 Pollen grain — structure

A mature pollen grain is small (typically 25–50 μm), spheroidal, and has a two-layered wall. The hard outer layer is the **exine** and the thin inner layer is the **intine**.

- **Exine**: made of **sporopollenin**, one of the most resistant organic materials known. Survives high temperature, strong acids, alkalis and enzymes. Has unsealed gaps called **germ pores** where sporopollenin is absent.
- **Intine**: a thin continuous wall of cellulose and pectin.

Pollen wall composition

Exine = sporopollenin (highly resistant); contains germ pores.
Intine = cellulose + pectin (thin, continuous).
The pollen tube emerges through a germ pore where the exine is interrupted.



Internal structure of a mature 2-celled pollen grain.

When the pollen grain is shed at the 2-celled stage, it contains a larger **vegetative cell** (abundant food reserves, irregular nucleus) and a smaller **generative cell** (spindle-shaped, dense cytoplasm). In some 60% of angiosperms, pollen is shed at this 2-celled stage; in the remaining 40%, the generative cell divides mitotically to give two male gametes before pollen shedding (the **3-celled stage**).

Sporopollenin in exam questions

Sporopollenin is the most resistant organic material known — neither high temperature, strong acid, strong alkali, nor enzymes degrade it. That is why pollen grains are preserved as fossils for millions of years. If a question asks "which biomolecule resists every chemical degradation", the answer is *sporopollenin*.

Pollen allergy and Parthenium

Inhaled pollen of *Parthenium* (carrot grass) and several grasses cause severe asthma and chronic bronchitis in sensitive people. Aeropalynology — the study of airborne pollen — is the science that links these allergens to seasonal respiratory illnesses.

2.3 Pollen viability and applications

Pollen viability — the duration for which a pollen grain remains capable of fertilisation — varies widely. Rice and wheat pollen lose viability within 30 minutes of release; *Rosaceae*, *Leguminosae* and *Solanaceae* members keep their pollen viable for months. For long-term storage, pollen is preserved in liquid nitrogen at $-196°$C — a **pollen bank**, much like a seed bank for breeders.

Pollen viability rule

The richer the food reserves of the pollen and the thicker its exine, the longer it stays viable. Wind-pollinated grasses produce vast quantities of short-lived pollen; insect-pollinated species produce fewer, longer-lived grains.

Pollen products

Pollen tablets and pollen-based health supplements are marketed because pollen is protein-rich. Some athletes and racehorse trainers use them, though clinical evidence is limited.

2.4 Pistil, megasporangium (ovule) and embryo sac

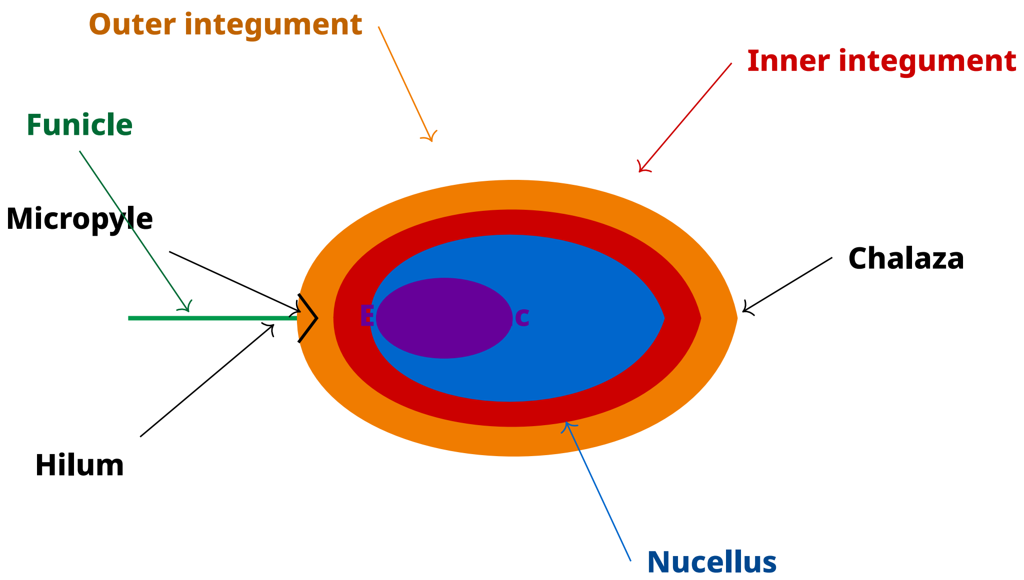
The gynoecium is made of one or more **pistils** (carpels). A pistil with three regions — **stigma**, **style**, and **ovary** — is the female reproductive unit. The stigma receives pollen, the style is a slender tube the pollen tube grows through, and the ovary contains one or more ovules.

- **Apocarpous**: many free pistils (e.g. *Michelia*, lotus).

- **Syncarpous**: pistils fused into one structure (e.g. tomato, papaver).

Ovule (megasporangium) anatomy

A typical ovule has: **funicle** (stalk), **hilum** (attachment point), **integuments** (1 or 2 protective coats), **micropyle** (gap in integuments), **chalaza** (basal end opposite micropyle), **nucellus** (mass of parenchymatous cells), and the **embryo sac** (female gametophyte) inside the nucellus.



Longitudinal section of a typical anatropous ovule. The micropyle is the entry point of the pollen tube; the chalaza is the basal end.

Megasporogenesis

A single cell in the nucellus near the micropylar end, the **megaspore mother cell (MMC)**, enlarges and undergoes meiosis to give four haploid megaspores arranged linearly (a tetrad). In most angiosperms, only **one megaspore** survives — usually the chalazal one — and the other three degenerate. This is the **monosporic** pattern of embryo sac development.

Megagametogenesis: the 8-nucleate, 7-celled embryo sac

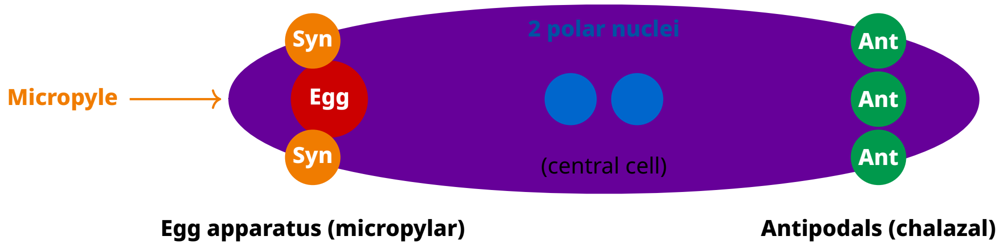
The functional megaspore enlarges and its nucleus undergoes three free-nuclear mitotic divisions to produce eight nuclei ($2 \to 4 \to 8$). Cell walls then organise these into seven cells:

- **3 cells at the micropylar end**: an *egg apparatus* of one **egg cell** flanked by two **synergids**. The synergids carry finger-like cell wall projections called the **filiform apparatus** that direct the pollen tube.
- **3 cells at the chalazal end**: **antipodal cells**.

- **1 large central cell** with two **polar nuclei** (these will give rise to the triploid endosperm after double fertilisation).

Nuclei and cells of the embryo sac

8 nuclei, 7 cells (Polygonum type): 1 egg + 2 synergids + 3 antipodals + 1 central cell with 2 polar nuclei.
The egg + 2 synergids form the *egg apparatus*; only the egg fuses with a male gamete.



Mature embryo sac — Polygonum type — with 8 nuclei in 7 cells.

8-nucleate, 7-celled embryo sac

3 nuclei (egg apparatus) + 3 nuclei (antipodals) + 2 nuclei (one central cell) = 8 nuclei, but only **7 cells** because the two polar nuclei share one central cell.

3 + 3 + 2 rule

For the embryo sac, chant **"3 + 3 + 2"**: 3 at the micropyle (egg apparatus), 3 at the chalaza (antipodals), 2 in the centre (polar nuclei). Total nuclei = 8, total cells = 7.

The 8 ÷ 7 trap

A common slip in MCQs is to write *8 cells* or *7 nuclei*. Always remember: **eight *nuclei*, seven *cells***. The mismatch is because the central cell carries two nuclei.

2.5 Pollination

Pollination is the transfer of pollen grains from an anther to a stigma. It is the bridge between male and female gametophytes.

- **Autogamy**: pollen of a flower lands on the stigma of the same flower. Requires synchrony of anther dehiscence and stigma receptivity.
- **Geitonogamy**: pollen transferred between two flowers of the *same plant*. Functionally cross-pollination (a pollinator is needed) but genetically self-pollination.

- **Xenogamy**: pollen from a different plant of the same species lands on the stigma. This is genetically true cross-pollination — the only type that brings genetic variation.

Three modes of pollination

Autogamy (same flower) $\subset$ **Geitonogamy** (same plant, different flower) $\subset$ **Xenogamy** (different plant).
Only xenogamy delivers *new* genetic material to the embryo sac.

Cleistogamous flowers — guaranteed self-pollination

Some plants (e.g. *Viola*, *Oxalis*, *Commelina*) produce flowers that do not open at all — **cleistogamous flowers**. Anthers dehisce inside the closed bud, releasing pollen onto the stigma of the same flower. The advantage is guaranteed seed-set even when pollinators are absent; the cost is no genetic variation.

Agents of cross-pollination

Agent	Floral features	Examples
Wind (anemophily)	Small, dull, non-scented; light, dry, dusty pollen; large feathery stigma; well-exposed anthers	Maize, grasses, coconut, deodar
Water (hydrophily)	Pollen long, ribbon-like, protected by mucilaginous covering; rare strategy	*Vallisneria*, *Hydrilla*, *Zostera*
Insects (entomophily)	Large, colourful, fragrant, nectar-bearing flowers; sticky pollen	Rose, jasmine, sunflower, salvia
Birds (ornithophily)	Large, bright red/orange, robust, copious nectar	*Bombax* (silk cotton), *Bignonia*
Bats (chiropterophily)	Pale, dull, strong-scented (often unpleasant), night-flowering	*Adansonia* (baobab), *Kigelia*

Spot the agent from the floral cue

Bright + scented = insect. Big + red + lots of nectar = bird. Dull + huge airy stigma = wind. Ribbon-like submerged pollen = water. Night-blooming +

foul odour = bat. NEET routinely asks one such matching question every year.

Pollinator decline matters

Almost 75% of global food crops depend at least partly on animal pollinators — mostly bees. Pesticide overuse and habitat loss are crashing bee populations, with direct consequences for fruit and seed yields. “No bees, no breakfast.”

Solve the NCERT Exercises

Outbreeding devices

Continued self-pollination leads to inbreeding depression. Flowering plants have evolved several devices to encourage cross-pollination:

- **Dichogamy**: anthers and stigma of the same flower mature at different times (*protandry* — anthers first; *protogyny* — stigma first).
- **Herkogamy**: physical separation of anthers and stigma so that pollen of a flower cannot reach its own stigma.
- **Self-incompatibility**: a genetic mechanism that rejects pollen of the same plant, preventing the pollen germinating on the stigma or the pollen tube growing.
- **Production of unisexual flowers**: e.g. in papaya (*dioecious* — different plants), maize (*monoecious* — same plant). Dioecy completely prevents autogamy and geitonogamy.

Three D’s of outbreeding

Different timing (dichogamy), **D**ifferent position (herkogamy), **D**ifferent recognition (self-incompatibility). When in doubt, add a fourth D — **D**ioecy.

Pollen–pistil interaction

After pollination, the pistil “recognises” compatible pollen via species-specific chemical dialogue. Compatible pollen germinates on the stigma; the pollen tube grows down the style, enters the ovule through the micropyle, and discharges its two male gametes into one of the synergids.

Pollen–pistil interaction

The dialogue is mediated by surface proteins on the pollen exine and pistil cells. Knowledge of this dialogue is what allows breeders to overcome self-incompatibility by emasculation, bagging and artificial controlled pollination.

Artificial hybridisation

Plant breeders use these crop-improvement steps to obtain superior hybrids:

1. **Emasculation**: removal of anthers from a bisexual flower bud before they dehisce, using forceps. Skipped if the flower is unisexual.
2. **Bagging**: the emasculated flower is covered with butter-paper or muslin bags to prevent unwanted pollen reaching the stigma.
3. **Controlled pollination**: when the stigma is receptive, mature pollen from the chosen male parent is dusted on, and the flower is re-bagged until fruit develops.

Memorise the order

Emasculation → Bagging → Controlled pollination → Re-bagging. If the question gives you a unisexual female flower, drop step 1 (no anthers to remove).

3 Double Fertilisation

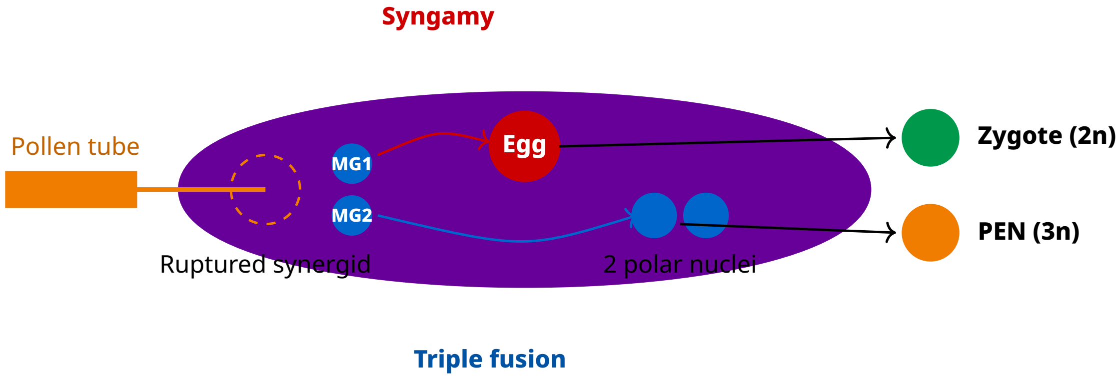
After the pollen tube enters one synergid through the filiform apparatus, it ruptures and releases two male gametes into the cytoplasm of the embryo sac. What follows is unique to flowering plants.

3.1 Syngamy and triple fusion

- **Syngamy**: one male gamete (n) fuses with the egg (n) → **zygote (2n)** → embryo.
- **Triple fusion**: the second male gamete (n) fuses with the two polar nuclei (n + n) of the central cell → **primary endosperm nucleus, PEN (3n)** → endosperm.

Double fertilisation in one line

Syngamy: Male gamete (n) + Egg (n) → Zygote (2n).
Triple fusion: Male gamete (n) + Polar nuclei (n + n) → PEN (3n).
Two fusion events from a single pollen grain → **double fertilisation**.



Two male gametes from one pollen tube fuse with two different female partners — egg (syngamy) and polar nuclei (triple fusion).

Why "double"?

Two fusions happen from the same pollen grain — one diploid product (zygote) and one triploid product (PEN). This is found only in flowering plants and is the defining feature of angiosperm sexual reproduction.

Don't confuse double fertilisation with double pollination

Double fertilisation = two fusions, both inside one embryo sac. It is *not* the same as two pollen grains landing on a stigma. One pollen tube delivers *both* the male gametes that take part in the two fusions.

Ploidy cheat-sheet

Egg (n) + male gamete (n) → Zygote (2n) → Embryo (2n).
Polar nuclei (n + n) + male gamete (n) → PEN (3n) → Endosperm (3n).
Most-asked NEET nuance: nucellus and integuments are 2n (sporophytic tissue); embryo sac is the gametophyte (n).

4 Post-fertilisation: Structures and Events

After fertilisation, the events kick off in this order: zygote → embryo; PEN → endosperm (this is usually faster than embryo development, so the endosperm is laid down *before* the embryo grows); ovule → seed; ovary → fruit. Other floral parts wither away.

4.1 Endosperm

Endosperm development *precedes* embryo development. This sequence is important because the endosperm provides nutrition to the developing embryo. The PEN undergoes repeated free-nuclear divisions to give a multinucleate **free-nuclear endosperm**; this nuclear stage is later cellularised. In coconut, the watery liquid you drink is free-nuclear endosperm and the white kernel is cellular endosperm.

Endosperm = 3n

PEN (3n) → free-nuclear endosperm → cellular endosperm.
Endosperm stores reserve food — starch in cereals, oil in coconut and castor, protein in legumes.

- **Endospermic (albuminous) seeds**: endosperm is retained in the mature seed; embryo absorbs from it during germination. Examples: maize, wheat, rice, coconut, castor.
- **Non-endospermic (exalbuminous) seeds**: endosperm is fully consumed during embryo development; reserves stored in the cotyledons of the embryo. Examples: pea, gram, bean, groundnut.

Why coconut water tastes sweet

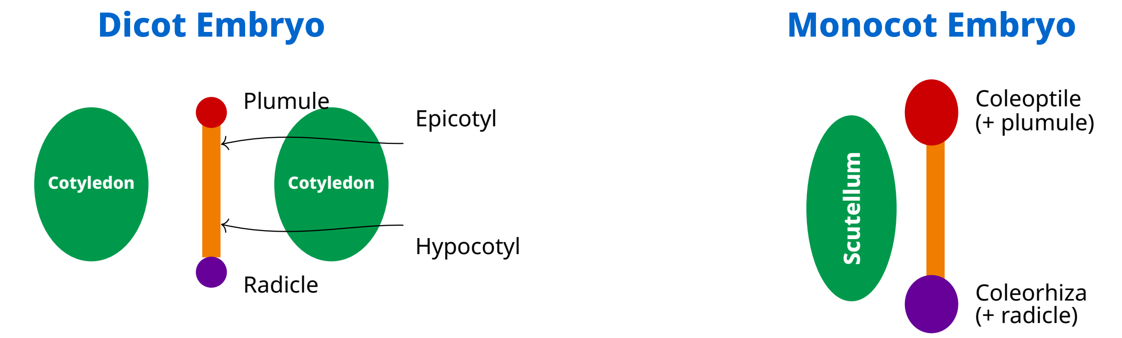
Coconut water is liquid free-nuclear endosperm; the white kernel is the later cellular endosperm. Both nourish the embryo. The clear liquid is a true cytoplasmic suspension of nuclei — packed with sugars, amino acids and growth promoters.

4.2 Embryo

Embryo development starts only after a sizeable amount of endosperm has accumulated. The zygote elongates and undergoes mitotic divisions to give the embryo, which differentiates into root (radicle), shoot (plumule), and cotyledons.

Dicot vs monocot embryo

Dicot embryo	Monocot embryo
Two cotyledons (lateral)	One cotyledon (terminal) called **scutellum**
Embryonal axis between the two cotyledons	Cotyledon on one side, embryonal axis on the other
Above cotyledon attachment → epicotyl + plumule	Plumule enclosed in protective **coleoptile**
Below cotyledon attachment → hypocotyl + radicle	Radicle enclosed in protective **coleorhiza**
Examples: bean, gram, pea	Examples: maize, wheat, rice



Dicot embryo (left) vs monocot embryo (right). Note coleoptile and coleorhiza unique to monocots.

4.3 Seed

The fertilised ovule matures into a seed. A seed has three essentials: **seed coat** (derived from integuments — outer testa, inner tegmen), **cotyledon(s)**, and the **embryonal axis**. Mature seeds usually have a low moisture content of 10–15%; metabolism slows down, and the seed enters **dormancy** until conditions favour germination.

- **Hilum**: scar marking the seed's former attachment to the funicle.
- **Micropyle**: small pore that persists in the seed coat; water enters here during germination.

Seed = baby plant in a box

The seed packs a dormant embryo + reserve food + a protective coat. Even after years (some seeds — lupin, lotus — for over a thousand years), it can germinate when conditions are right.

Why dormant seeds are agriculturally priceless

Dormancy lets farmers store grain across seasons and transport seeds across continents. Without seed dormancy, no human civilisation built on cereal agriculture would have been possible.

4.4 Fruit

The ovary develops into a fruit while other floral parts wither. The wall of the fruit, called the **pericarp**, is the matured ovary wall. A fruit derived only from the ovary is called a **true fruit** (e.g. tomato, mango). When other floral parts (especially the thalamus) also contribute to fruit formation, it is a **false fruit (pseudocarp)** — e.g. apple, strawberry, cashew, where the thalamus is the fleshy edible part.

True vs false fruit

True fruit = developed from ovary only (mango, tomato, banana).
False fruit = ovary + accessory floral parts (mostly thalamus) form the fruit (apple, strawberry, cashew).

Parthenocarpic fruits

Fruits that develop *without* fertilisation are **parthenocarpic**. They are seedless. Banana is the classic example. Artificial parthenocarpy is induced by spraying growth hormones (auxin, GA) on unpollinated flowers — a commercially important technique for seedless grapes and watermelons.

Spot a parthenocarpic fruit

If the question says *seedless* and *no fertilisation*, it is parthenocarpy. If the question says *seedless* but *fertilisation occurred and ovules aborted*, it is *stenospermocarpy* (e.g. Thomson seedless grapes) — a JEE/NEET-favourite distractor.

Why bananas have no seeds

The cultivated banana *Musa* is triploid and largely sterile. It bears fruit by parthenocarpy and is propagated vegetatively. The tiny black flecks inside the fruit are aborted ovules — not viable seeds.

5 Apomixis and Polyembryony

5.1 Apomixis

Some flowering plants produce seeds *without* fertilisation — **apomixis**. It is a form of asexual reproduction that mimics sexual reproduction. The seed contains an embryo that is genetically identical to the maternal parent. Examples: several species of *Asteraceae* and *grasses*, citrus, mango (in some varieties).

Apomixis

Apomixis = asexual seed formation; embryo develops from a diploid cell (e.g. nucellus) without meiosis or fertilisation. The seed is clonal — genetically identical to the mother.

Why hybrid-seed companies dream of apomixis

Hybrid vigour (heterosis) is lost after one or two generations because the F1 progeny segregate. If breeders could engineer apomixis into a hybrid crop, every farmer would replant the saved seed without losing yield — a revolutionary leap for agriculture. Active research is on, but no commercial apomictic cereal exists yet.

5.2 Polyembryony

When an ovule produces *more than one* embryo, the phenomenon is **polyembryony**. The extra embryos may come from the nucellus, the synergids, or from cleavage of the zygote. Citrus and mango show natural polyembryony — sometimes you find two seedlings emerging from a single seed.

Why apomixis and polyembryony are tested together

Both produce seeds with unusual genetic origins (clonal or multi-embryo). NCERT clubs them because both interrupt the standard "one ovule $\rightarrow$ one embryo through fertilisation" rule. NEET likes to ask their differences.

5.3 Significance for plant breeding

- Apomixis preserves the genetic constitution of a hybrid across generations — useful for clonal propagation through seed.
- Polyembryony in citrus is exploited by horticulturists to raise multiple uniform rootstocks from one seed.

6 [JEE/NEET extensions]

The NCERT chapter gives the syllabus floor. Competitive exams routinely test these add-ons:

6.1 Pollen–pistil interaction at the molecular level

The stigma surface is coated with glycoproteins. Compatible pollen carries surface proteins that match — analogous to a key fitting a lock. Self-incompatibility responses are controlled by an *S-locus* with two linked genes: one expressed in the pollen, one in the pistil. When both carry the same S allele, the pistil rejects the pollen.

High-yield NEET fact

Sporophytic self-incompatibility (SSI, e.g. *Brassica*) — pollen rejection determined by the diploid genotype of the male parent (deposited sporopollenin proteins).
Gametophytic self-incompatibility (GSI, e.g. *Solanaceae*) — pollen rejection determined by the haploid genotype of the pollen itself.

6.2 Special types of embryo sacs

The 8-nucleate, 7-celled *Polygonum* type covers most angiosperms (70%). Variants include:

- **Bisporic** (*Allium* type): embryo sac develops from 2 of the 4 megaspores.
- **Tetrasporic** (*Adoxa*, *Fritillaria* types): all 4 megaspore nuclei participate, leading to different ploidies of the endosperm.

In tetrasporic *Fritillaria* type, the endosperm is pentaploid (5n) — a common JEE Advanced trick question.

6.3 Pollen kit and pollination economy

In insect-pollinated species, pollen exine is coated with a sticky, lipid-rich layer called **pollenkitt**. It glues pollen to insect bodies and also acts as an attractant (colour + scent). Wind-pollinated species lack pollenkitt — their pollen is dry and powdery so it travels far.

6.4 Endosperm classification by development

- **Nuclear endosperm**: free-nuclear divisions precede wall formation (most common — coconut water).
- **Cellular endosperm**: walls form after every nuclear division (*Datura*, *Petunia*).
- **Helobial endosperm**: intermediate — one wall formed early, then free-nuclear divisions in each chamber (*Helobiae*).

Endosperm types — NCH

Nuclear, **C**ellular, **H**elobial. "**N**o **C**ell walls until **H**elobial half-way." Nuclear = no walls at first, cellular = walls always, helobial = halfway.

7 Quick Reference Summary

7.1 Ploidy ladder for one ovule

Structure	Ploidy	Origin
Megaspore mother cell (MMC)	2n	Nucellus cell, near micropyle
Megaspore tetrad (4 spores)	n each	Meiosis of MMC
Functional megaspore	n	1 surviving megaspore (chalazal)
Embryo sac nuclei (8)	n each	3 mitoses of functional megaspore
Egg / Synergids / Antipodals / Polar nuclei	n	Cells of embryo sac
Male gamete	n	From pollen generative cell
Zygote	**2n**	Egg (n) + Male gamete (n) — syngamy
Primary Endosperm Nucleus (PEN)	**3n**	2 Polar nuclei (n + n) + Male gamete (n)
Endosperm tissue	3n	Mitoses of PEN
Embryo	2n	Mitoses of zygote
Seed coat	2n	From integuments (sporophytic)
Pericarp (fruit wall)	2n	From ovary wall (sporophytic)

7.2 Key counts to memorise

- Microsporangia per anther: **4**
- Anther wall layers: **4** (Epidermis, Endothecium, Middle, Tapetum)
- Microspores per tetrad: **4**
- Megaspores per tetrad: **4**; functional megaspores: **1**
- Free-nuclear mitoses in embryo sac development: **3** ($1 \to 2 \to 4 \to 8$)
- Embryo sac: **8 nuclei, 7 cells** (3 + 3 + 2)
- Cells in egg apparatus: **3** (egg + 2 synergids)
- Male gametes per pollen tube: **2**
- Fusions per double fertilisation: **2** (syngamy + triple fusion)
- Ploidy of endosperm: **3n**; embryo: **2n**; seed coat: **2n**

7.3 Definitions you must be exam-ready on

- **Sporopollenin**: highly resistant biopolymer of the pollen exine.
- **Tapetum**: innermost nutritive layer of the anther wall.
- **Filiform apparatus**: finger-like wall projections of synergids that guide the pollen tube.
- **Polygonum-type embryo sac**: monosporic, 8-nucleate, 7-celled embryo sac

(most common type).

- **Triple fusion**: fusion of one male gamete with two polar nuclei to form PEN (3n).
- **Apomixis**: seed formation without fertilisation; produces clonal seeds.
- **Polyembryony**: more than one embryo in a single seed.
- **Parthenocarpy**: fruit formation without fertilisation; produces seedless fruit.