GENERAL BIOLOGY · STUDY GUIDE

Exam 6 Study Guide

This guide covers chapters 11 and 12. First you follow plants from algae to flowers, then look inside them to see how they are built, how they move water and sugar without a heart, how they reproduce and how they sense the world. Then you map the animal kingdom, from sponges to our own species. Work one chapter at a time. Read the "what to know" paragraphs, copy the tables out by hand, then try each worked case with the steps covered. Finish each chapter with its ten self-test items. The cram sheet at the end holds every group, number and rule.

WHAT THIS GUIDE COVERS

- Chapter 11 · land plant innovations, alternation of generations, bryophytes to angiosperms, cell types and tissue systems, meristems and secondary growth, monocots versus eudicots, water potential, cohesion tension, stomata, pressure flow, essential elements, flowers, double fertilization, seeds and fruits, hormones, phytochrome and photoperiodism.
- Chapter 12 · animal traits and development, symmetry, germ layers and body cavities, protostomes and deuterostomes, the animal tree, sponges to arthropods, echinoderms, the four chordate traits, vertebrate innovations, fishes to birds, the amniotic egg, mammals, primates and hominin evolution.

CHAPTER 11

Plants: Diversity, Structure, Transport and Reproduction

Read it in full: **Chapter 11 in the textbook**. See it in motion: **Plant Diversity Lab** and **Plant Structure Lab** and **Plant Transport Lab** and **Plant Reproduction and Responses Lab**.

What to know

Land plants descend from **charophyte** green algae and share chlorophylls a and b, starch and cellulose walls with green algae. Five traits are unique to land plants: alternation of generations, dependent embryos, walled spores in sporangia (sporopollenin), multicellular gametangia

(archegonia and antheridia) and apical meristems. Plants moved onto land about 470 to 500 million years ago.

In **alternation of generations**, the diploid **sporophyte** makes haploid spores by meiosis. A spore grows into a haploid **gametophyte**, which makes gametes by mitosis. Fertilization makes a zygote that grows into the next sporophyte. In bryophytes the green plant is the gametophyte; in ferns and seed plants the sporophyte dominates and the gametophyte shrinks.

Bryophytes (liverworts, mosses, hornworts) lack lignified vascular tissue, stay short and need water for swimming sperm. **Seedless vascular plants** add xylem with lignin and phloem: lycophytes have microphylls; monilophytes (ferns, horsetails) have megaphylls. **Seed plants** add reduced gametophytes, heterospory, ovules and pollen, freeing fertilization from water. **Gymnosperms** have naked seeds on cones. **Angiosperms** (about 300,000 species, about 90 percent of plants) add flowers, fruit, vessel elements and double fertilization.

A plant has roots, stems and leaves, each built of three tissue systems: dermal (epidermis, later periderm), vascular (xylem and phloem) and ground (pith and cortex). Cell types: parenchyma (living, thin walls), collenchyma (flexible support), sclerenchyma (fibers and sclereids, dead and lignified), tracheids and vessel elements (dead water pipes), and sieve-tube elements (alive but without a nucleus) served by companion cells.

Apical meristems make primary growth (length). Root tips show the root cap and zones of division, elongation and differentiation. **Lateral meristems** make secondary growth (girth): the vascular cambium makes secondary xylem (wood) inward and secondary phloem outward; the cork cambium makes periderm. Bark is everything outside the vascular cambium, so girdling starves the roots. Monocots have one cotyledon, parallel veins, scattered bundles, fibrous roots and parts in threes; eudicots have two cotyledons, net veins, a ring of bundles, taproots and parts in fours or fives.

Water moves from higher to lower **water potential**, $\Psi = \Psi_S + \Psi_P$, in megapascals. Pure water is 0. Solutes make Ψ_S negative; turgor makes Ψ_P positive and xylem tension makes it negative. Water enters roots by apoplastic, symplastic and transmembrane routes. The **Casparian strip** of suberin in the endodermis forces water and ions through a membrane, a checkpoint like tight junctions.

Xylem sap rises by **cohesion tension**: transpiration from leaves creates tension, cohesion holds the water column together, adhesion holds it to the walls, and the plant spends no ATP. More than 90 percent of water taken up is lost by transpiration. **Guard cells** open stomata by taking up K^+ (water follows) and close when K^+ leaves; abscisic acid closes them in drought.

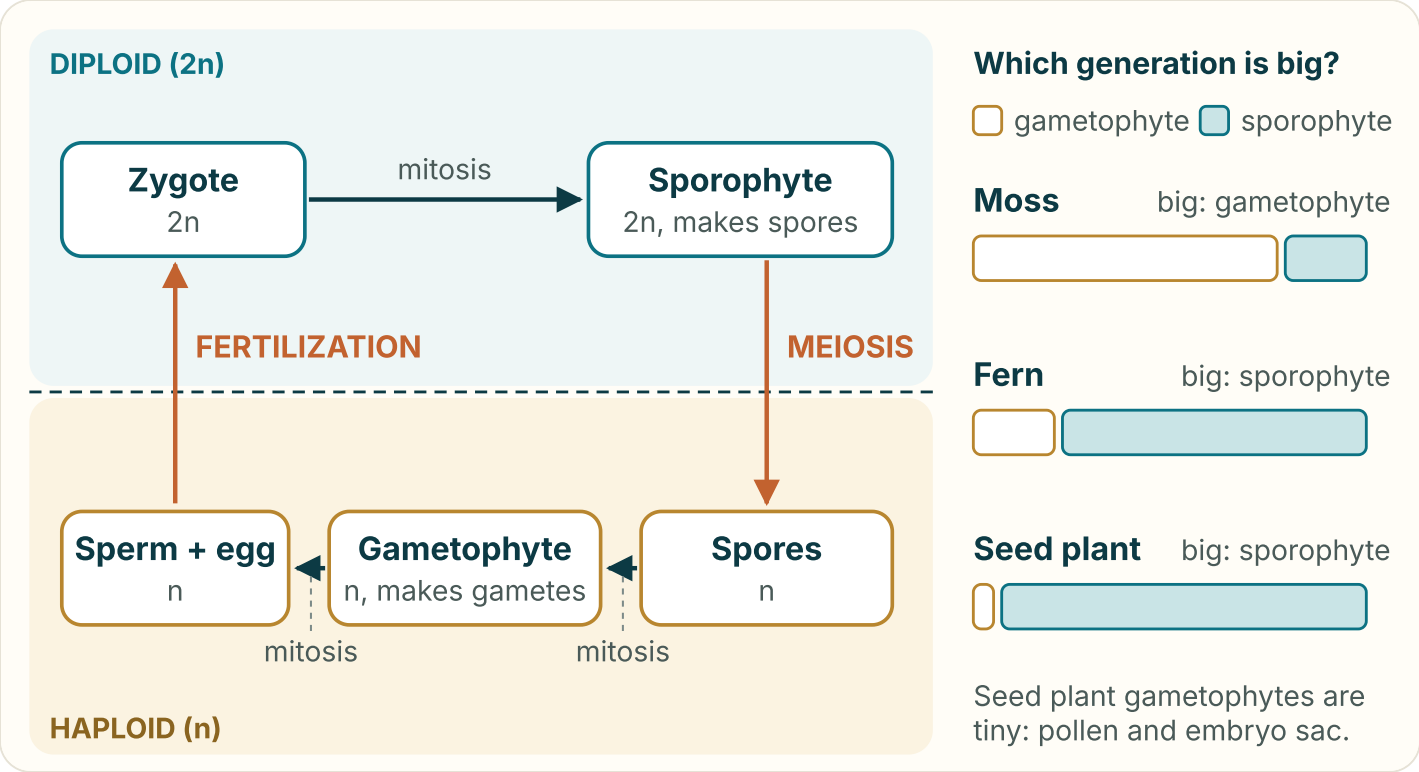
Phloem moves sugar by **pressure flow** from **source** to **sink**. Sucrose is loaded at the source (often by H^+/sucrose cotransport), water follows and pressure rises; at the sink sucrose is unloaded, water leaves and pressure falls. About 96 percent of plant dry mass is C, O and H from air and water. Seventeen elements are essential. Mobile nutrients (N, P, K, Mg) show deficiency in older leaves first; immobile ones (Ca, Fe) in young leaves first. Rhizobium in legume nodules fixes N_2 (leghemoglobin keeps O_2 low), and mycorrhizae help about 90 percent of plants take up phosphate.

A flower has four whorls: sepals, petals, stamens (filament and anther) and carpels (stigma, style, ovary). An anther makes pollen, a two-cell male gametophyte (tube cell and generative cell). An ovule makes the **embryo sac**: seven cells and eight nuclei, including the egg, two synergids, three antipodals and a central cell with two polar nuclei. Many plants avoid selfing with S-gene self-incompatibility. In **double fertilization**, one sperm plus the egg makes the 2n zygote and the other sperm plus the polar nuclei make the 3n **endosperm**. Ovules become seeds and ovaries become fruits (simple, aggregate, multiple, accessory).

Hormones: **auxin** (elongation, tropisms, apical dominance; acid growth), **cytokinins** (division, release of axillary buds), **gibberellins** (stem growth, germination via amylase), **abscisic acid** (drought, dormancy), **ethylene** (ripening by positive feedback, abscission, triple response), plus brassinosteroids, jasmonates and strigolactones. 2,4-D is a synthetic auxin that kills broadleaf weeds.

Phytochrome switches between Pr (absorbs red, about 660 nm) and active Pfr (absorbs far-red, about 730 nm); the last flash wins. Shade is rich in far-red, which triggers shade avoidance. **Photoperiodism** depends on night length: short-day plants need a long night; long-day plants need a short night; a red flash mid-night breaks a long night. The flowering signal FT travels through phloem. Statoliths sense gravity; roots and shoots bend opposite ways because roots are

more sensitive to auxin. Plants defend with PAMP-triggered immunity, R genes, the hypersensitive response and salicylic acid signaling.



Alternation of generations. Meiosis makes spores, not gametes, in plants. Gametes come from the haploid gametophyte by mitosis.

LOCK THESE IN

- Sporophytes make spores by meiosis; gametophytes make gametes by mitosis.
- Bryophyte green plant = gametophyte. Fern and seed plant = sporophyte dominant.
- Xylem dead; phloem alive. Bark contains phloem.
- Water moves toward the lower (more negative) Ψ. $\Psi = \Psi_S + \Psi_P$.
- Cohesion tension pulls water up with no ATP; pressure flow pushes sugar from source to sink.
- Mobile nutrients: old leaves first. Immobile: young leaves first.
- Double fertilization: zygote 2n, endosperm 3n.
- Phytochrome: red makes Pfr, far-red makes Pr; plants measure night length.

Key terms and comparisons: plant groups

Group	Vascular tissue	Dominant generation	Sperm need water?	Dispersal
Bryophytes	No	Gametophyte	Yes	Spore
Lycophytes	Yes; microphylls	Sporophyte	Yes	Spore
Monilophytes	Yes; megaphylls	Sporophyte	Yes	Spore
Gymnosperms	Yes; tracheids	Sporophyte	No (pollen)	Naked seed
Angiosperms	Yes; vessels too	Sporophyte	No (pollen)	Seed in fruit

Formulas and values

Item	Value	Note
Water potential	$\Psi = \Psi_S + \Psi_P$	Pure water 0 MPa
0.1 M sucrose	Ψ_S about −0.23 MPa	More solute, more negative
Soil to air	About −0.3 (soil) to about −100 MPa (dry air)	Largest drop leaf to air
Embryo sac	7 cells, 8 nuclei	Egg, 2 synergids, 3 antipodals, central cell
Ploidy in seed	Embryo 2n; endosperm 3n; seed coat 2n maternal	Pericarp 2n maternal
Phytochrome	Pr absorbs about 660 nm; Pfr about 730 nm	Last flash wins
Nitrogenase	About 16 ATP per N_2	Leghemoglobin keeps O_2 low

Key terms and comparisons: hormones

Hormone	Main effects
Auxin	Elongation, tropisms, apical dominance, rooting
Cytokinins	Division; release axillary buds; delay aging
Gibberellins	Stem growth; germination; fruit size
Abscisic acid	Closes stomata; seed dormancy
Ethylene	Ripening; abscission; triple response
Jasmonates	Defense against herbivores
Strigolactones	Suppress branching; attract mycorrhizae

Worked cases

WORKED CASE 1 · WHICH WAY WILL WATER MOVE?

Cell A has $\Psi_S = -0.8$ MPa and $\Psi_P = 0$ and sits in a solution of $\Psi = -0.5$ MPa. Cell B has $\Psi_S = -0.7$ MPa and $\Psi_P = +0.5$ MPa and sits in pure water.

STEP 1 · CELL A

$\Psi = -0.8 + 0 = -0.8$ MPa. The solution is higher (−0.5), so water moves **into** the cell.

STEP 2 · WHEN A STOPS

Flow stops when the cell reaches −0.5. With Ψ_S still −0.8, that needs Ψ_P = **+0.3 MPa** of turgor.

STEP 3 · CELL B

$\Psi = -0.7 + 0.5 = -0.2$ MPa. Pure water is 0, so water moves **in** until turgor rises to +0.7.

THE RULE

Always toward the more negative number.

WORKED CASE 2 · PLOIDY INSIDE A SEED

A eudicot has 2n = 20. Give the chromosome number in a pollen sperm, the egg, the embryo, the endosperm and the seed coat.

STEP 1 · GAMETES

Sperm and egg are haploid: **10** each.

STEP 2 · EMBRYO

Egg plus sperm: 10 + 10 = **20** (2n).

STEP 3 · ENDOSPERM

Two polar nuclei plus a sperm: 10 + 10 + 10 = **30** (3n).

STEP 4 · SEED COAT

It comes from the integuments, maternal tissue: **20**, with no paternal genes.

WORKED CASE 3 · PHOTOPERIOD WITH A FLASH

A short-day plant has a critical night of 12 hours. A long-day plant has a critical night of 10 hours. Both get 14 hours of darkness, once without and once with a red flash at the midpoint.

STEP 1 · SHORT-DAY, NO FLASH

14 hours is longer than 12: **flowers**.

STEP 2 · SHORT-DAY, RED FLASH

Red makes Pfr and splits the night into two 7 hour nights: **no flowering**.

STEP 3 · LONG-DAY, NO FLASH

14 hours is longer than 10: **no flowering**.

STEP 4 · LONG-DAY, RED FLASH

Two 7 hour nights are shorter than 10: **flowers**.

FAR-RED AFTER RED

A far-red flash right after the red cancels it; the night counts as unbroken.

WORKED CASE 4 · DIAGNOSING A DEFICIENCY

Plant 1 shows yellowing in its oldest leaves. Plant 2 shows yellowing between the veins of its youngest leaves. Suggest a likely nutrient for each.

STEP 1 · PLANT 1

Older leaves first means a mobile nutrient moved out to new growth. General yellowing of old leaves fits **nitrogen**.

STEP 2 · PLANT 2

Young leaves first means an immobile nutrient. Yellowing between veins of young leaves fits **iron**.

FERTILIZER

The N-P-K numbers on a bag list nitrogen, phosphorus and potassium, the nutrients most often short.

TRAPS PEOPLE FALL INTO

- **Expecting plant gametes from meiosis.** Meiosis makes spores; gametes come by mitosis.
- **Calling the leafy moss a sporophyte.** In bryophytes the green plant is the gametophyte.
- **Calling a palm trunk wood.** Monocots lack a vascular cambium, so no rings of secondary xylem.
- **Thinking water moves away from negative Ψ.** It moves toward the lower, more negative value.
- **Saying plants spend ATP to lift water.** Sun and dry air drive transpiration; ATP is spent loading phloem.
- **Calling a tomato a vegetable in botany.** Any mature ovary is a fruit.
- **Thinking plants measure day length.** They measure uninterrupted darkness.
- **Giving the seed coat paternal genes.** Seed coat and pericarp are maternal; only embryo and endosperm carry paternal genes.

Chapter 11 self-test · ten items

1. In a fern, what kind of division makes the sperm?

A. Meiosis in the diploid sporophyte
B. Meiosis in the haploid gametophyte
C. Mitosis in the diploid sporophyte
D. Mitosis in the haploid gametophyte

D. Mitosis in the haploid gametophyte The gametophyte is already haploid, so it makes gametes by mitosis.

2. Which innovation first freed plant fertilization from water?

A. Lignified xylem
B. Apical meristems
C. Pollen grains
D. Megaphyll leaves

C. Pollen grains Pollen carries the male gametophyte by wind or animals, so sperm no longer swim.

3. Which cells conduct sugar while alive but lack a nucleus?

A. Sclerenchyma fibers
B. Sieve-tube elements
C. Xylem tracheids
D. Vessel elements

B. Sieve-tube elements Sieve-tube elements are living but rely on companion cells for nuclear functions.

4. A cut stump shows 60 rings. What kind of plant was it?

A. A eudicot or a gymnosperm
B. A lycophyte such as club moss
C. A monocot such as a palm
D. A bryophyte such as a moss

A. A eudicot or a gymnosperm Rings are secondary xylem from a vascular cambium, which monocots lack.

5. A cell has $\Psi_S = -0.6$ MPa and $\Psi_P = +0.2$ MPa in a solution of −0.3 MPa. What happens?

A. Water moves out of the cell
B. Water moves into the cell
C. The cell bursts at once
D. No net water movement

B. Water moves into the cell The cell is at −0.4 MPa, lower than −0.3, so water enters.

6. What does the Casparian strip force water and ions to do?

A. Pass through the cell walls
B. Leave through the stomata
C. Cross a plasma membrane
D. Enter the phloem directly

C. Cross a plasma membrane Suberin blocks the wall route, so solutes must pass through an endodermal membrane, where transporters screen them.

7. Removing a ring of bark kills a tree slowly. Why?

A. Sugar can no longer reach the roots
B. Water can no longer reach the leaves
C. Stomata can no longer close at night
D. The leaves stop making chlorophyll

A. Sugar can no longer reach the roots Bark contains phloem. The wood keeps carrying water for a while, but the roots starve.

8. What is the ploidy of angiosperm endosperm?

A. Diploid (2n)
B. Haploid (n)
C. Tetraploid (4n)
D. Triploid (3n)

D. Triploid (3n) One sperm fuses with the two polar nuclei of the central cell.

9. Which hormone closes stomata during drought?

A. Gibberellin
B. Abscisic acid
C. Auxin (IAA)
D. Cytokinin

B. Abscisic acid ABA makes guard cells lose K^+ and water, closing the pore.

10. A seedling grows under a leafy canopy. What does phytochrome detect?

A. Pure blue light, so high Pr
B. Light rich in red, so high Pfr
C. No light, so only Pfr remains
D. Light rich in far-red, so low Pfr

D. Light rich in far-red, so low Pfr Leaves absorb red, so shade is enriched in far-red, lowering Pfr and triggering shade avoidance.

CHAPTER 12

Animal Diversity

Read it in full: **Chapter 12 in the textbook**. See it in motion: **Animal Diversity Lab**.

What to know

Animals are multicellular heterotrophs that ingest food. They have no cell walls; collagen in the extracellular matrix holds them together, and nervous and muscle tissue are unique to them. Development runs cleavage, blastula and **gastrulation**, which forms the gut (archenteron) and its opening, the blastopore. Hox genes set the head to tail axis. Choanoflagellates are the closest living relatives. Animals arose perhaps 770 to 800 million years ago, and most phyla appear in the Cambrian explosion about 535 to 525 million years ago.

Body plans are sorted by tissues (sponges have none), **symmetry** (radial in cnidarians; bilateral with cephalization in most others), **germ layers** (diploblastic: ectoderm and endoderm; triploblastic: plus mesoderm) and **body cavity**. A coelom is fully lined by mesoderm; a pseudocoelom is lined by mesoderm outside and endoderm inside; an acoelomate (flatworm) has none. Cavity type changed more than once, so it is not a reliable guide to relationships.

Protostomes usually have spiral, determinate cleavage, a coelom from splitting mesoderm, and the blastopore becomes the mouth. **Deuterostomes** have radial, indeterminate cleavage (the basis of identical twins), a coelom budded from the archenteron, and the blastopore becomes the anus. On the tree, sponges and comb jellies branch first, cnidarians are sister to bilaterians, and bilaterians split into **Lophotrochozoa** (flatworms, rotifers, molluscs, annelids), **Ecdysozoa** (nematodes, arthropods; they molt) and **Deuterostomia** (echinoderms, hemichordates, chordates).

Sponges filter water with flagellated choanocytes; it leaves by the osculum; amoebocytes build spicules or spongin. **Cnidarians** are radial and diploblastic, with a gastrovascular cavity of one opening, polyp and medusa forms, cnidocytes with nematocysts and a nerve net. Hydrozoans alternate forms, scyphozoans are mostly medusae, cubozoans are box jellies, and anthozoans (corals, anemones) are only polyps; heat-stressed corals bleach.

Flatworms are acoelomates that get oxygen by diffusion and use flame cells; flukes and tapeworms are parasites. **Molluscs** have a foot, visceral mass and mantle, and many use a radula. Gastropods undergo torsion; bivalves filter feed; cephalopods have a closed circulation, camera eyes and the largest invertebrate brains. **Annelids** are segmented coelomates; earthworms have

five pairs of hearts and metanephridia. **Nematodes** are pseudocoelomates with a cuticle and only longitudinal muscles; C. elegans has 959 somatic cells.

Arthropods (over a million species) have tagmata, a chitin exoskeleton they must molt (ecdysone), jointed appendages and an open circulation of hemolymph. Chelicerates (spiders, ticks, scorpions) have 8 legs and no antennae; myriapods have many segments; crustaceans have two pairs of antennae; insects have three body regions, 6 legs, one pair of antennae and usually wings, with incomplete or complete metamorphosis.

Echinoderms are deuterostomes with pentaradial adults but bilateral larvae, an endoskeleton of ossicles and a **water vascular system** (madreporite, ring and radial canals, tube feet). A sea star everts its stomach into a clam. **Chordates** have four traits at some stage: a **notochord**, a **dorsal hollow nerve cord**, **pharyngeal slits** and a **muscular post-anal tail**, plus an endostyle that becomes the thyroid. Lancelets and tunicates are invertebrate chordates; tunicates are the closest living relatives of vertebrates.

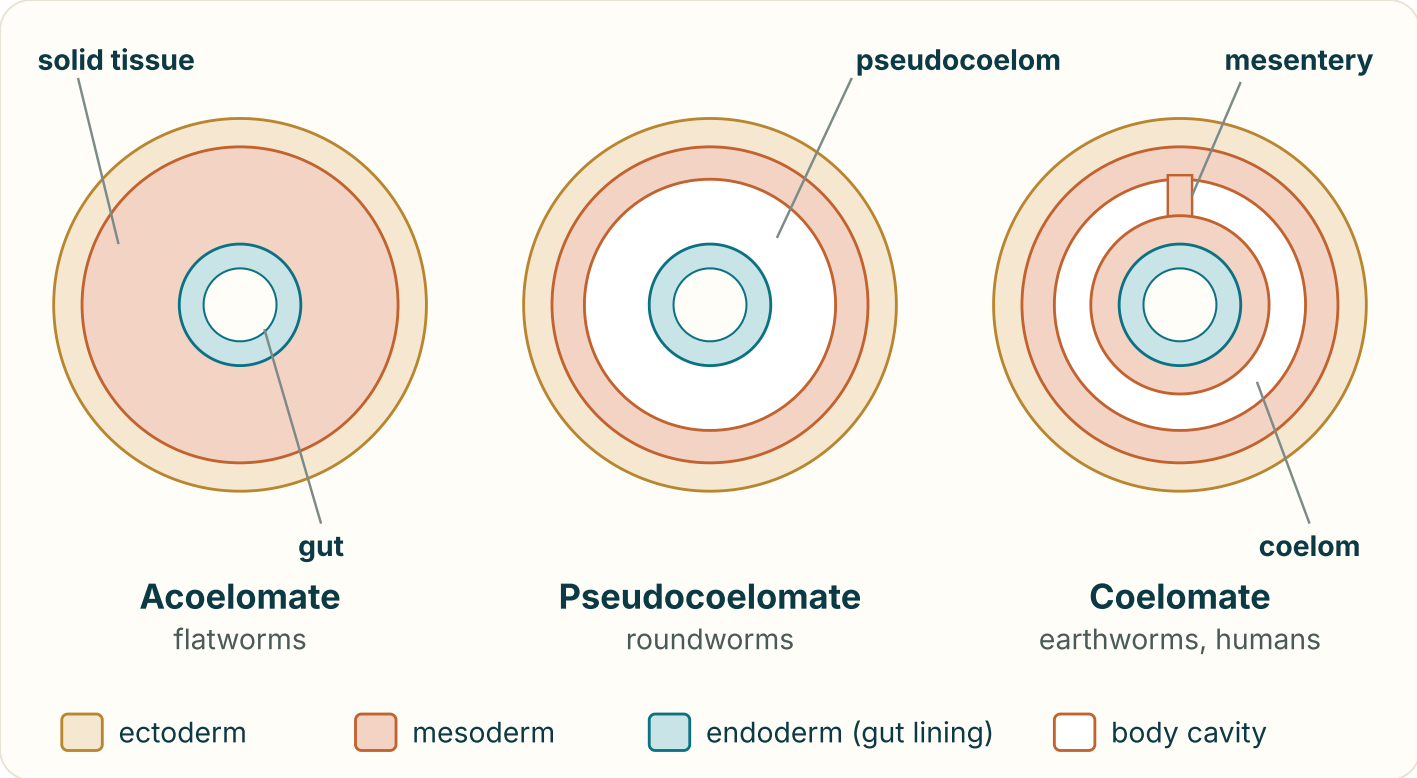
Craniates add a skull and the **neural crest**. Vertebrates add a backbone (hagfishes and lampreys are jawless). **Gnathostomes** have hinged jaws from pharyngeal arches, paired fins and a lateral line. Cartilaginous fishes (sharks) lack a swim bladder and have electroreceptors. Bony fishes have an operculum and usually a swim bladder; ray-finned fishes (over 30,000 species) dominate, and lobe-finned fishes (coelacanths, lungfishes) gave rise to tetrapods. Tiktaalik, about 375 million years old, mixes fish and tetrapod traits.

Amphibians (about 8,000 species: salamanders, frogs, caecilians) have shell-less eggs, moist skin used for gas exchange and often metamorphosis; many are declining, partly from chytrid fungus. **Amniotes** have the **amniotic egg** with amnion, chorion, yolk sac and allantois. Reptiles have keratin scales and are mostly ectotherms. **Birds** are feathered theropod dinosaurs with hollow bones, a keeled sternum, endothermy, a four-chambered heart and one-way airflow through air sacs; crocodilians are their closest living relatives, so birds are reptiles in a clade sense.

Mammals descend from synapsids and have milk, hair, a four-chambered heart, a diaphragm, a single-bone lower jaw (dentary), three middle ear bones and differentiated teeth. Monotremes lay eggs, marsupials finish development in a pouch, and eutherians have a complex placenta.

Primates have grasping hands, nails, forward-facing eyes and large brains. Humans share about 98.8 percent of DNA sequence with chimpanzees and bonobos and share an ancestor 6 to 7 million years ago.

Hominins became bipedal (foramen magnum underneath, S-shaped spine, bowl-shaped pelvis, inward knees, in-line big toe) millions of years before brains grew. Sahelanthropus (7 to 6 million years ago), Ardipithecus, Australopithecus afarensis ("Lucy," 3.2 million; brain 400 to 500 cm^3; Laetoli footprints 3.6 million), Homo habilis (2.4 million; about 600 cm^3), Homo erectus (1.9 million; about 900 to 1,000 cm^3; left Africa) and Neanderthals (400,000 to 40,000 years ago). Homo sapiens arose in Africa about 300,000 years ago, spread out mainly 60,000 to 70,000 years ago, and interbred with Neanderthals (1 to 2 percent of non-African DNA) and Denisovans.



Where the mesoderm sits. Count the sides of the cavity lined by mesoderm: none, one or both.

LOCK THESE IN

- Protostome: blastopore becomes mouth; spiral, determinate. Deuterostome: anus; radial, indeterminate.
- Coelom fully lined by mesoderm; pseudocoelom half; acoelomate none.
- Lophotrochozoa, Ecdysozoa (molting), Deuterostomia.
- Mollusc = foot, visceral mass, mantle. Arthropod = chitin, jointed legs, molting, open circulation.
- Spider: 8 legs, 0 antennae, 2 regions. Insect: 6 legs, 2 antennae, 3 regions.
- Chordate traits: notochord, dorsal hollow nerve cord, pharyngeal slits, post-anal tail.
- Amniotic egg: amnion, chorion, yolk sac, allantois.
- Bipedalism came first; big brains came later.

Key terms and comparisons: invertebrate phyla

Phylum	Symmetry	Germ layers	Cavity	Signature
Porifera	None	No true tissues	None	Choanocytes, spicules
Cnidaria	Radial	Two	None; one-opening gut	Cnidocytes; polyp and medusa
Platyhelminthes	Bilateral	Three	Acoelomate	Flat; flame cells
Mollusca	Bilateral	Three	Coelom (reduced)	Foot, visceral mass, mantle, radula
Annelida	Bilateral	Three	Coelom	Segments
Nematoda	Bilateral	Three	Pseudocoelom	Cuticle; longitudinal muscle only
Arthropoda	Bilateral	Three	Hemocoel	Chitin exoskeleton; jointed legs
Echinodermata	Pentaradial adult	Three	Coelom	Water vascular system

Key terms and comparisons: vertebrate groups

Group	Covering	Breathing	Heart	Eggs and temperature
Cartilaginous fishes	Placoid scales	Gills	2 chambers	Internal fertilization; ectotherm
Ray-finned fishes	Bony scales	Gills, operculum	2 chambers	Mostly external fertilization; ectotherm
Amphibians	Moist skin	Lungs, skin, larval gills	3 chambers	Shell-less eggs in water; ectotherm
Nonavian reptiles	Keratin scales	Lungs	3 (4 in crocodilians)	Amniotic shelled eggs; ectotherm
Birds	Feathers	Lungs with air sacs	4 chambers	Hard-shelled eggs; endotherm
Mammals	Hair	Lungs, diaphragm	4 chambers	Mostly live birth, milk; endotherm

Hominin numbers

Hominin	Age (million years ago)	Brain (cm^3)
Ardipithecus ramidus	4.4	About 300 to 350
Australopithecus afarensis	3.9 to 2.9	About 400 to 500
Homo habilis	2.4 to 1.4	About 600
Homo erectus	1.9 to about 0.1	About 900 to 1,000
Homo neanderthalensis	0.4 to 0.04	About 1,450
Homo sapiens	0.3 to present	About 1,350

Worked cases

WORKED CASE 1 · KEYING OUT AN ANIMAL

An animal has bilateral symmetry, three germ layers, a cavity lined by mesoderm on the outside and endoderm on the inside, a cuticle it molts, and only longitudinal muscles. Place it.

STEP 1 · THREE LAYERS, BILATERAL

It is a bilaterian, triploblastic animal.

STEP 2 · THE CAVITY

Mesoderm outside and endoderm inside is a **pseudocoelom**.

STEP 3 · MOLTING

Shedding a cuticle places it in **Ecdysozoa**.

STEP 4 · RESULT

A **nematode** (roundworm). Thrashing movement comes from longitudinal muscles alone.

WORKED CASE 2 · COUNTING LEGS AND ANTENNAE

Classify: (a) 8 legs, no antennae, 2 body regions; (b) 6 legs, 2 antennae, 3 regions, wings; (c) 4 antennae, many appendages, gills; (d) 2 pairs of legs per segment.

STEP 1 · (A)

Chelicerate (arachnid): spider, tick, mite or scorpion.

STEP 2 · (B)

Insect (hexapod).

STEP 3 · (C)

Crustacean: two pairs of antennae.

STEP 4 · (D)

Millipede (myriapod); centipedes have one pair per segment.

WORKED CASE 3 · BRAINS AND TIME

Compare brain sizes: A. afarensis about 450 cm^3, H. habilis about 600, H. erectus about 900 and H. sapiens about 1,350. How many times larger is each Homo brain than the australopith brain? How long after Lucy did H. erectus appear?

STEP 1 · HABILIS

600 ÷ 450 = about **1.3 times**.

STEP 2 · ERECTUS

900 ÷ 450 = **2 times**.

STEP 3 · SAPIENS

1,350 ÷ 450 = **3 times**.

STEP 4 · TIME

Lucy is about 3.2 million years old and H. erectus about 1.9 million: 3.2 − 1.9 = **1.3 million years**.

MOSAIC EVOLUTION

Lucy already walked upright with an ape-sized brain, so bipedalism came first.

TRAPS PEOPLE FALL INTO

- **Calling deuterostomes "more advanced."** Protostomes and deuterostomes are sister lineages; insects far outnumber us.
- **Treating "invertebrate" as a clade.** It is paraphyletic, defined by lacking a backbone.
- **Calling ticks insects.** Ticks have 8 legs and no antennae; they are arachnids.
- **Treating chordate and vertebrate as the same.** Lancelets and tunicates are chordates without backbones.
- **Calling shark cartilage primitive.** Their ancestors had bone; cartilage is derived.
- **Saying birds are not reptiles.** Crocodilians are closer to birds than to lizards, so a clade must include birds.
- **Saying humans evolved from chimpanzees or Neanderthals.** They are cousins sharing common ancestors.
- **Thinking big brains came before upright walking.** Bipedalism came millions of years first.

Chapter 12 self-test · ten items

1. A four-cell embryo is split and each cell forms a whole larva. What does this suggest?

A. No cleavage at all in this animal

B. Spiral cleavage like a snail

C. Determinate, protostome cleavage

D. Indeterminate, deuterostome cleavage

D. Indeterminate, deuterostome cleavage Indeterminate cleavage, where each early cell keeps full potential, is typical of deuterostomes.

2. Which tissue layer forms muscle and most organs?

A. Endoderm
B. Mesoderm
C. Mesoglea
D. Ectoderm

B. Mesoderm Mesoderm forms muscle, most organs and the circulatory system. Ectoderm forms skin and nerves.

3. Which group grows by molting a cuticle?

A. Deuterostomia
B. Porifera
C. Ecdysozoa
D. Lophotrochozoa

C. Ecdysozoa Ecdysozoans, including nematodes and arthropods, shed their cuticle to grow.

4. What drives the water current through a sponge?

A. Flagella of choanocytes
B. Cilia on the osculum
C. Contraction of muscle cells
D. Tube feet along the body

A. Flagella of choanocytes Choanocytes beat their flagella and trap food in their collars.

5. A planarian has no lungs or blood vessels. How do its cells get oxygen?

A. Through gills under a mantle
B. From hemolymph in an open system
C. By diffusion across a thin body
D. Through a tracheal tube system

C. By diffusion across a thin body Its flat body keeps every cell close to the surface or the gut.

6. Which feature belongs to cephalopods?

A. A hinged two-part shell
B. A closed circulatory system
C. A one-opening gastrovascular gut
D. An open hemocoel and molting

B. A closed circulatory system Squids and octopuses have closed circulation, camera eyes and large brains.

7. An animal has eight legs, no antennae and two body regions. What is it?

A. A crustacean such as a crab
B. A myriapod such as a centipede
C. An insect such as a beetle
D. A chelicerate such as a spider

D. A chelicerate such as a spider Chelicerates have chelicerae, four pairs of legs and no antennae.

8. Adult sea squirts lack a notochord. Why are they still chordates?

A. Their larvae have all four traits
B. Their adults have a backbone
C. They grow by molting a cuticle
D. They have a water vascular system

A. Their larvae have all four traits Classification counts traits at any stage of development.

9. Which structure of the amniotic egg stores nitrogenous waste?

A. The amnion
B. The chorion
C. The allantois
D. The yolk sac

C. The allantois The allantois stores uric acid and, with the chorion, exchanges gases.

10. Which skull feature points to bipedal walking in a fossil hominin?

A. A foramen magnum right underneath
B. A grasping big toe on each foot
C. A brain larger than 1,000 cm^3
D. A foramen magnum set at the back

A. A foramen magnum right underneath An opening under the skull balances the head on an upright spine.

Cram sheet

Everything from chapters 11 and 12 in one place. Cover the right column and see if you can rebuild each row.

Numbers to know

Item	Value	Note
Plants on land	About 470 to 500 million years ago	From charophytes
Angiosperms	About 300,000 species, about 90% of plants	Monocots plus eudicots about 97%
Water potential	$\Psi = \Psi_S + \Psi_P$	Pure water 0 MPa
Transpiration	Over 90% of water taken up	Corn: over 200 L per season
Essential elements	17	C, H, O about 96% of dry mass
Mycorrhizae	About 90% of plant species	Phosphate for sugar
Embryo sac	7 cells, 8 nuclei	Endosperm 3n
Phytochrome	660 nm red; 730 nm far-red	Last flash wins
Arthropods	Over a million species	Insects outnumber all others
C. elegans	959 somatic cells	Nematode model
Ray-finned fishes	Over 30,000 species	Largest vertebrate group
Amphibians	About 8,000 species	Chytrid declines
Human and chimp	About 98.8% shared sequence; split 6 to 7 million years ago	Cousins
Homo sapiens	About 300,000 years ago in Africa	1 to 2% Neanderthal DNA outside Africa

Key terms and comparisons

Pair	How to tell them apart
Sporophyte vs gametophyte	2n, spores by meiosis; n, gametes by mitosis.
Monocot vs eudicot	One cotyledon, parallel veins, scattered bundles; two, net veins, ring.
Xylem vs phloem	Dead pipes, water up by tension; living cells, sugar by pressure flow.
Apoplast vs symplast	Walls and spaces; cytoplasm through plasmodesmata.
Short-day vs long-day	Needs a long night; needs a short night.
Protostome vs deuterostome	Mouth first; anus first.
Coelom vs pseudocoelom	Fully mesoderm lined; mesoderm and endoderm.
Open vs closed circulation	Hemolymph bathes organs; blood stays in vessels.
Ectotherm vs endotherm	Heat from surroundings; heat from metabolism.
Marsupial vs eutherian	Pouch, simple placenta; complex placenta, long pregnancy.

Rules that win points

Topic	The rule
Plant life cycle	Spores by meiosis; gametes by mitosis.
Water problems	Add the components; water goes to the more negative side.
Seeds	Embryo 2n, endosperm 3n, coats maternal.
Arthropods	Count legs, antennae and body regions.
Chordates	Look for the four traits at any stage.
Trees	Read by shared ancestry, not a ladder.

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