Unit 14 · Animal Tissues

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Animal Tissue (Unit 14): 5 of 75 marks; 1 MCQ (understanding) and 1 short question (4 marks: knowledge 1, understanding 2, application 1)
- **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: haemopoiesis (where blood cells are made); a short question on animal tissue
- **MCQ (1 mark)**
  - Bichat; tissue = cells of similar origin; parenchyma is a plant tissue
  - epithelium from all three germ layers; has a free border, basement membrane
  - visceral epithelium = mesothelium; intestine simple columnar; skin stratified squamous; vagina non-keratinized; plastic = urothelium
  - connective tissue: most abundant, all three components; histiocytes; adipose; sutures white fibrous
  - tendon collagen; ligament bone to bone, mainly collagen; cartilage avascular; Haversian system in mammals
  - RBC biconcave, carry O_2; monocytes, neutrophils phagocytes; leukemia
  - skeletal syncytial; epimysium; tongue striated; arrector pili unstriped; intercalated discs; cardiac striped, involuntary
  - neuroglia; neurons don't divide; microglia; Nissl in cyton; bipolar in retina; gray matter; ependymal cells; longest cells nervous
- **Short (in parts)**
  - levels of organization; simple epithelia with diagrams; simple vs compound
  - tessellated vs cuboidal, columnar; rare types; plastic epithelium
  - modified epithelia; glands and their types
  - connective tissue types, functions; areolar tissue; cartilage vs bone; Haversian system
  - formed elements; voluntary muscle; a multipolar neuron, labelled

Key terms

Tissue (Bichat; French *tissu*, cloth): cells of **common origin** with their matrix, working at one function.

Histology (Mayer, 1819): study of tissues; Malpighi, founder.

Matrix (ECM): ground substance + fibers round the cells.

Basement membrane: protein–sugar mat under an epithelium (collagen, laminin).

Avascular: without blood vessels (epithelium, cartilage).

Endothelium: simple squamous lining heart, vessels; **mesothelium**: lining body cavities (both mesoderm).

Gland: cell or cells specialized to secrete.

Fibroblast: makes fibers and matrix.

Osteon (Haversian system): canal + concentric lamellae, compact bone.

Hematopoiesis: making blood cells (red bone marrow).

Diapedesis: white cells squeezing out of capillaries.

Syncytium: one mass of cytoplasm, many nuclei.

Sarcomere: Z line to Z line; unit of contraction.

Intercalated disc: joint between cardiac cells (desmosomes, gap junctions).

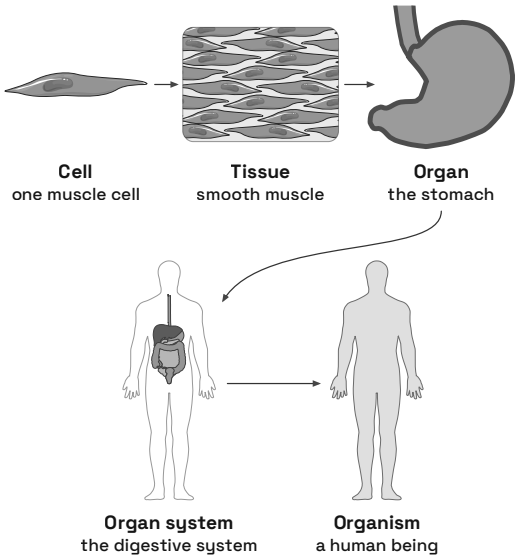
Neuroglia: non-conducting cells of nervous tissue; divide.

Saltatory conduction: impulse jumps node to node.

Animal tissue

Tissue	Job	Origin
epithelial	covers, lines, secretes	all three germ layers
connective	binds, supports, transports	mesoderm
muscular	contracts	mesoderm
nervous	conducts, controls	ectoderm

- **connective**: cells + **much matrix** + **fibers**; others mostly cells, little matrix
- levels: cell → tissue → organ → organ system → organism
- Porifera: cellular grade; **Coelenterata**: tissue grade (first true tissues); Platyhelminthes: organs, mesoderm



Levels of organization.

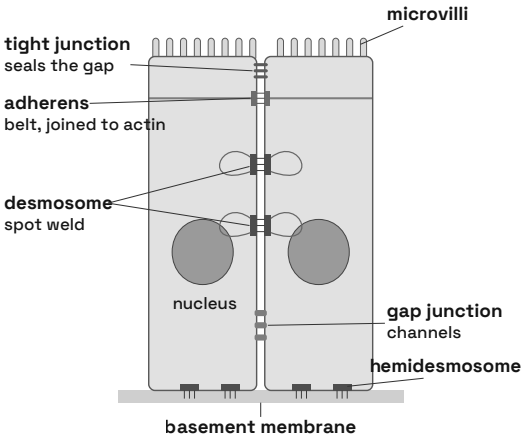
Epithelial tissue

- **covers**, **lines**, **forms glands**, **secretes**
- cells packed close; little matrix, **no fibers**
- **free surface + basement membrane**
- **avascular**: fed by diffusion → thin
- **cell junctions**; renews fast; from **all three germ layers**

Cell junctions

1. **tight** (*zonula occludens*): nothing leaks between cells (gut, bladder)
2. **adherens** (*zonula adherens*): belt, actin
3. **desmosome** (*macula adherens*): spot welds, keratin threads (skin, heart)
4. **gap junction**: channels; ions pass cell to cell (heart)

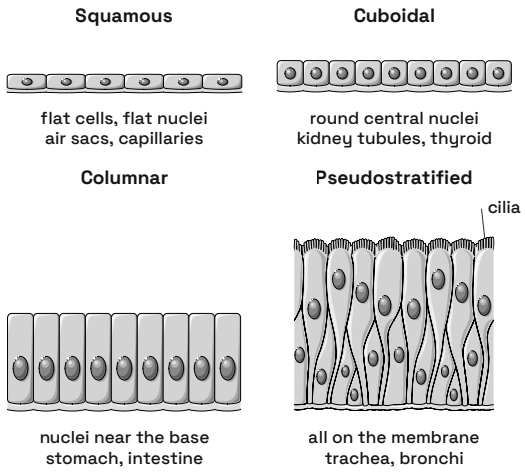
- **hemidesmosomes** fix cells to the basement membrane; septate junctions **seal** (insects)



Cell junctions.

Functions: protection; movement by cilia; absorption, excretion; gas exchange, filtration; sensation

Simple epithelium (one layer)



Simple epithelia.

Squamous (pavement, tessellated, mosaic): thin flat polygonal cells, flat nucleus

- **alveoli**, **Bowman's capsule**, descending limb of Henle, **capillaries**
- **endothelium**: heart (endocardium), vessels, lymph vessels
- **mesothelium**: parietal, **visceral (splanchnic)**, mesenteries; peritoneum, pleura, pericardium
- endothelium is **mesoderm**, not endoderm (*endo* = inside)

Cuboidal: as tall as wide, **round central nucleus**

- non-ciliated: **kidney tubules**, **thyroid follicles**, small ducts (salivary, pancreas), iris back, lens front, ovary surface
- ciliated: smallest bronchioles
- brush-bordered: **PCT** (reabsorption)
- ovary's "germinal epithelium": old name, doesn't make eggs

Columnar: tall, **oval basal nucleus**; secretes, absorbs

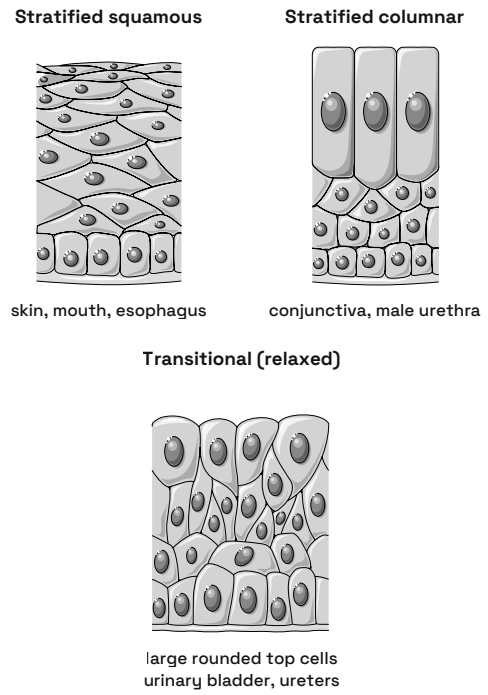
- non-ciliated: **stomach**, **intestine**, gall bladder; **goblet cells**
- ciliated: **oviducts**, small bronchi, brain ventricles, **central canal** (CSF)
- brush-bordered: **small intestine** (~3,000 microvilli a cell)

Pseudostratified: cells of **different heights**, **all on the basement membrane**; only tall ones reach the surface; nuclei at different levels

- ciliated, with goblet cells: **nasal cavity**, **trachea**, **bronchi**; mucus carpet swept up

Compound epithelium (many layers)

- only bottom layer on the basement membrane; bottom cells divide, push up; **protection**



Compound epithelia.

Stratified squamous (commonest): top layers flat

- **non-keratinized**: moist; **mouth**, pharynx, **esophagus**, anal canal, **vagina**, cornea
- **keratinized**: top cells dead, keratin; **epidermis**; waterproof
- keratin (vertebrates only): reptile scales, scutes; feathers, beaks, claws; hair, horns, hoofs, nails; fish scales are **bone**

Stratified cuboidal (rare): 2–3 layers; ducts of **sweat, salivary, mammary** glands
Stratified columnar (uncommon): **conjunctiva**, part of male urethra, large gland ducts

Transitional (urothelium, **plastic**): kidney pelvis, **ureters**, **bladder**, upper urethra

- 5–6 layers; empty: top cells **dome-shaped**; full: 2–3 layers, top cells **flat**; tight junctions stop urine leaking

	Simple	Compound
layers	one	two or more
on basement membrane	every cell	bottom layer only
free surface	every cell	top layer only
job	absorb, secrete, filter, exchange	protect
renewal	cells replaced among each other	from the bottom layer
examples	alveoli, kidney tubules, intestine	skin, mouth, bladder

- similar: both cells packed, little matrix, avascular, on a basement membrane

Modified epithelium

1. **ciliated**: **kinocilia** (9 + 2, beat: mucus, egg, CSF); **stereocilia** (long microvilli, actin, no microtubules, don't beat: **epididymis**, inner ear)
2. **brush-bordered**: microvilli; PCT, small intestine
3. **neurosensory**: sense cells with hairs + nerve fibers; olfactory, taste buds, inner ear
4. **pigmented**: melanin; **retinal pigment epithelium**
5. **germinal**: **seminiferous tubules** → sperms
6. **glandular**: secretes

Glands

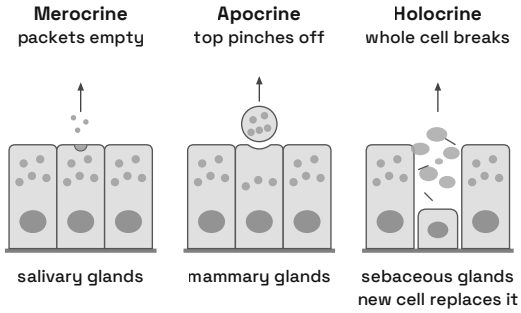
By ducts

- **exocrine** (ducted): sweat, salivary, gastric, intestinal
- **endocrine** (ductless): pituitary, pineal, thyroid, adrenal
- **heterocrine**: **pancreas** (juice by duct + insulin, glucagon from islets); testes, ovaries

By secretion: **serous** (watery: sweat, tear, parotid); **mucous** (goblet cells); **mixed** (submandibular, sublingual)

By release

- **merocrine**: exocytosis, cell loses **nothing** (salivary, pancreas, sweat)
- **apocrine**: **top of cell** pinched off (mammary fat, armpit scent)
- **holocrine**: **whole cell** bursts (**sebaceous**)

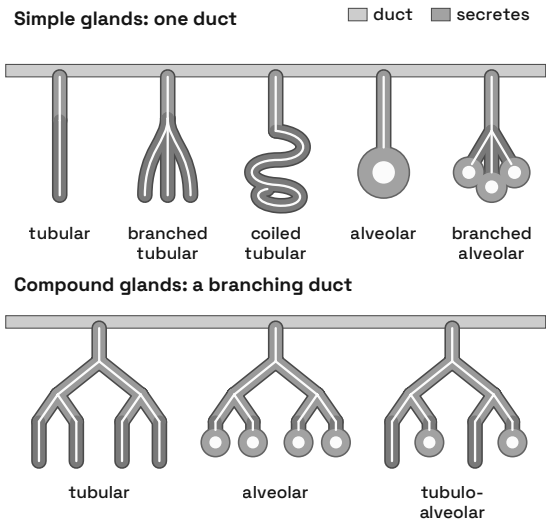


Merocrine, apocrine, holocrine.

By cells: **unicellular** (goblet cells); **multicellular** (sweat, liver, thyroid)

By shape: duct unbranched = **simple**, branched = **compound**; secretory part **tubular** or **alveolar (acinar)**

Kind	Example
simple tubular	intestinal glands (crypts of Lieberkühn)
simple branched tubular	gastric, uterine glands
simple coiled tubular	sweat glands
simple alveolar	frog's skin mucous glands
simple branched alveolar	sebaceous glands
compound tubular	Brunner's glands, bulbourethral; liver
compound alveolar	salivary, mammary
compound tubulo-alveolar	pancreas, mammary



Shapes of exocrine glands.

Connective tissue

- binds, supports, transports; **most abundant**; **mesoderm**
- few cells, **much matrix**, **fibers**; made by the cells
- three types: **proper**, **supportive**, **fluid**

Cells of proper connective tissue

1. **fibroblasts**: make fibers, matrix (resting: fibrocytes)
2. **mast cells**: **heparin** (anticoagulant), **histamine** (dilates, leaky: inflammation, allergy), **serotonin**
3. **macrophages (histiocytes)**: from monocytes; **phagocytic**
4. **lymphocytes**
5. **plasma cells**: from B cells; **antibodies**; cartwheel nucleus

Matrix: glycoproteins, proteoglycans, **hyaluronic acid**, water; jelly or gel

Fiber	Protein	Color	Nature	Job
collagen	collagen	white	thick, wavy, unbranched, bundles; don't stretch	resist pulling
elastic	elastin	yellow	thin, branched, network; stretch 1.5×	recoil
reticular	reticulin	colorless	very thin, branched net	**stroma** of liver, spleen, lymph nodes, marrow

Proper connective tissue

Loose

- **areolar** (commonest): collagen + elastic fibers all ways, **all five cell types**; under skin, between organs, round vessels, nerves, **submucosa**; **packing tissue**; fights infection
- **adipose**: fat cells; **white** (one droplet, signet ring: under skin, round kidneys, camel's hump, blubber, frog's fat bodies); **brown** (many droplets, mitochondria → **heat**: newborns, hibernators)
- fat: **food store**, **insulator**, **cushion** (kidneys, eyeballs, soles)
- red marrow fills with fat → **yellow marrow**; can turn red again

Dense

- **white fibrous**: collagen bundles; **periosteum**, **perichondrium**, sclera, organ capsules, dermis, **sutures**
- **tendon**: parallel collagen; **muscle to bone**
- **ligament**: collagen + some elastic; **bone to bone**; mostly white fibers (*ligamenta flava* elastic)
- **elastic (yellow fibrous)**: **large arteries**, lungs, between tracheal rings, vocal cords
- **reticular**: stroma of liver, spleen, lymph nodes, marrow

Cartilage

- **chondrin** matrix; **chondroblasts** → **chondrocytes** in **lacunae**, in groups of 2–4
- **perichondrium** (not at joints); **avascular** → heals slowly; shock absorber

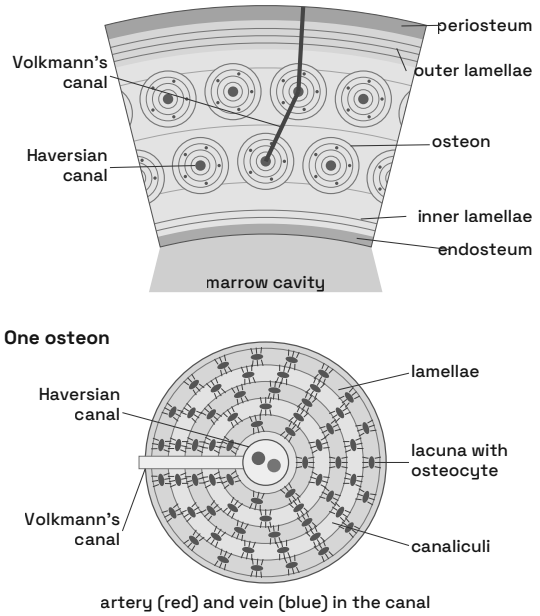
Type	Matrix	Where
hyaline (gristle, commonest)	fine invisible collagen; glassy	ends of long bones, costal, nose (tip too), larynx, tracheal **C-rings**, sharks, embryo skeleton
calcified	calcium salts	frog's **suprascapula**, **pubis**
fibrocartilage (toughest)	thick collagen bundles; no perichondrium	**intervertebral discs**, **pubic symphysis**, knee **menisci**
elastic (yellow)	elastic fibers	**pinna**, **epiglottis**, Eustachian tube

Bone

- hardest connective tissue; **vascular**
- matrix: **organic** 25–30% (collagen, **ossein**: tough); **inorganic** 60–70% (**calcium phosphate**: hard); water ~10%
- **osteoblasts** (build); **osteocytes** (singly in lacunae, **canaliculi**); **osteoclasts** (dissolve, many nuclei)
- **periosteum**; support, protection, levers, Ca and P store, marrow
- acid → bends (collagen left); burnt → brittle (minerals left)
- **cartilage bones**: limbs, vertebrae, **ribs**, scapula, skull base; **membrane bones**: skull roof, face, jaw, **clavicle**; **sesamoid**: **patella**
- by shape: flat (skull roof, sternum, ribs, scapula), irregular (vertebrae, ossicles), short (carpals, tarsals), long (limbs)
- long bone: **epiphysis** (spongy bone, trabeculae, **red marrow**: hematopoiesis); **diaphysis** (compact bone, **yellow marrow**); **growth plate** in children

Compact bone (T.S.)

- frog: periosteum, osteoblasts, ring lamellae, **no osteons**, endosteum, marrow
- mammal: periosteum → outer circumferential lamellae → **osteons** + interstitial lamellae → inner circumferential lamellae → endosteum → marrow



Compact bone and an osteon.

Haversian system (Havers, 1691), ~0.2 mm across

- **Haversian canal**: artery, vein, lymph vessel, nerve
- **concentric lamellae** (4–20), fibers spiral differently in each
- **lacunae** with osteocytes, linked by **canaliculi**
- **Volkmann's canals** join Haversian canals, at right angles
- mammals (large birds, reptiles); **not amphibians**

	Cartilage	Bone
matrix	chondrin, flexible	ossein + calcium salts, hard
cells	chondrocytes, in groups	osteocytes, singly
canaliculi	none	present
blood vessels	none	present
sheath	perichondrium	periosteum
growth	from within and surface	surface only
marrow	none	present
healing	slow	faster

- similar: both supportive connective tissue, cells in lacunae, mesoderm, a fibrous sheath

Fluid connective tissue

- liquid matrix, **no fibers**; carries; temperature, water, pH; defence

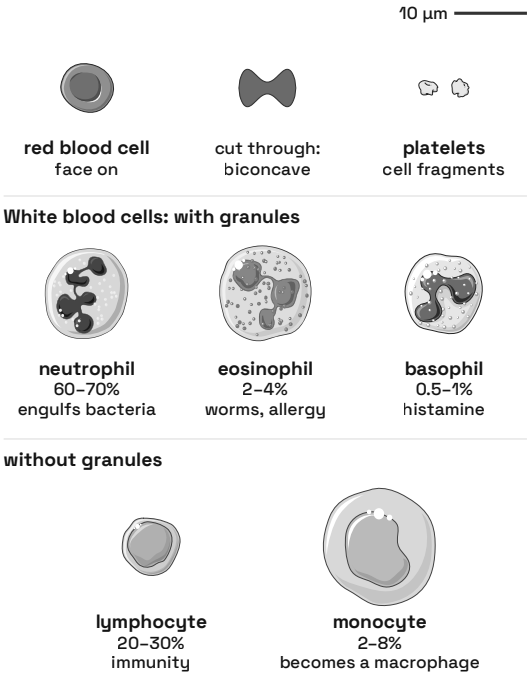
Blood: 7–8% of body weight (5–5.5 L in a 70 kg man); salty; **pH 7.4** (bicarbonate : carbonic acid ≈ 20 : 1)

Plasma (55%): 90–92% water, ~7% proteins

- **albumins** (osmotic pressure), **globulins** (carriers; gamma = **antibodies**), **fibrinogen** (clotting); serum = plasma without fibrinogen
- carries food, gases, wastes (urea), hormones, salts, vitamins

Formed elements (45%)

- made in **yolk sac** → **liver, spleen** (fetus) → **red bone marrow** (myeloid tissue); lymphocytes mature in lymphoid tissue: **hematopoiesis**



Blood cells.

RBCs (erythrocytes)

- mammals: round **biconcave**, **no nucleus**, no mitochondria (anaerobic); others: oval, biconvex, **nucleated**
- 7.5 µm; amphibians largest, mammals smallest; camels oval, no nucleus; musk deer tiny
- O_2 as **oxyhemoglobin**; some CO_2 as carbaminohemoglobin
- **5 million/mm³** (man), 4.5 million (woman); life **120 days**, broken in **spleen**, liver
- **erythropoiesis**; Hb 13–17 g/100 mL (men), 12–15 (women); below → **anemia** (Nepal 2022: 34% women, 43% young children)

WBCs (leukocytes): nucleated, no Hb; **defence**; amoeboid; **diapedesis**

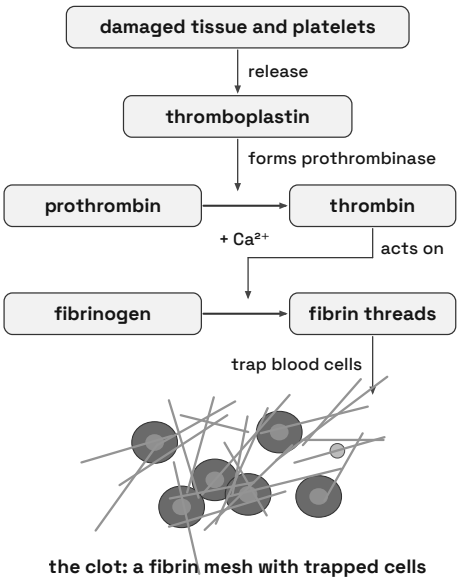
- **4,000–11,000/mm³** (TC); DC = shares; **leukopoiesis**
- **leukopenia** (too few), **leukocytosis** (too many), **leukemia** (cancer)

Cell	Granules	Nucleus	Share	Job
neutrophil	fine, lilac	3–5 lobes	**60–70%**	first **phagocytes**; pus
eosinophil	red-orange (eosin)	2 lobes	2–4%	**worms**, **allergy**
basophil	dark blue	2–3 lobes, S	0.5–1%	**histamine**, **heparin**
lymphocyte	none	large round	**20–30%**	**immunity**: B (antibodies), T (thymus; CD4 helpers, HIV)
monocyte	none	kidney-shaped	2–8%, largest	phagocyte → **macrophage**

Platelets (thrombocytes): fragments of **megakaryocytes**, no nucleus, 2–3 μm; **150,000–400,000/mm^3**; life 7–10 days; plug, start clotting; nucleated thrombocytes in other vertebrates

Clotting

1. **thromboplastin** + factors + **Ca^{2+}** → **prothrombinase**
2. **prothrombin** (liver, **vitamin K**) → **thrombin**
3. **fibrinogen** → **fibrin** mesh → clot; shrinks → **serum**



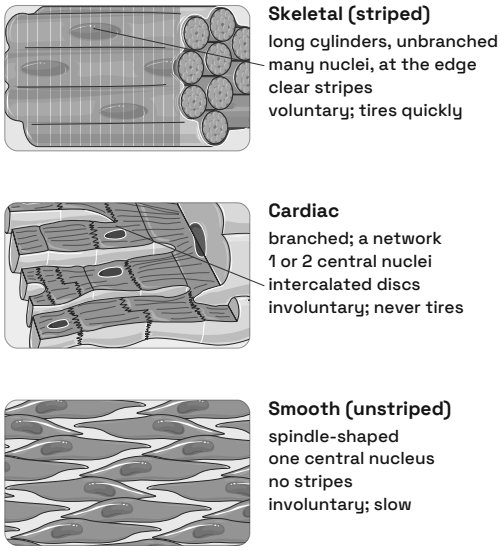
Blood clotting.

Lymph: tissue fluid in **lymph capillaries**; through **lymph nodes** (filter, lymphocytes) → **thoracic** and **right lymphatic ducts** → **subclavian veins**

- less protein, **lymphocytes**, **no RBCs**, no platelets; **lacteals** carry fats
- returns fluid and proteins, carries fats, fights infection

Muscular tissue

- **contracts**; **muscle fibers** (myocytes), little matrix; **actin** (thin) + **myosin** (thick)
- **sarcolemma**, **sarcoplasm**; mesoderm; locomotion, movement, heat



Three kinds of muscle.

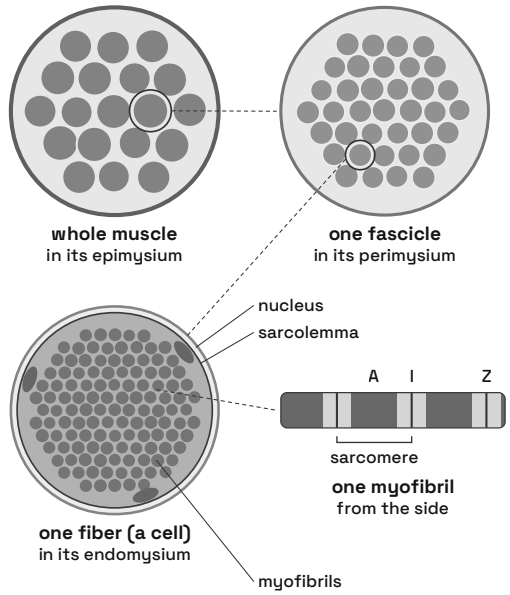
Skeletal muscle

- **cylindrical, unbranched, striped**; **many peripheral nuclei** (**syncytium**: myoblasts fuse)
- myofibrils with bands:
- **A band** (dark): **myosin** length
- **I band** (light): **actin** only
- **Z line** (Krause's membrane): actin fixed
- **H zone**: myosin only; **M line** in its middle
- **sarcomere**: Z to Z, ~2.5 μm

Sliding filament theory (H. Huxley, Hanson; A. Huxley, Niedergerke, 1954)

- myosin heads pull actin to the middle; **ATP**, **Ca^{2+}**; filaments don't shorten
- **Z lines closer**, sarcomere, **I band** and **H zone shorten**; **A band unchanged**

Fiber to muscle: myofibril → fiber (**endomysium**) → **fascicle** (**perimysium**) → muscle (**epimysium**, into the tendon)



From muscle to myofibril.

- ~75% water, 20% protein, 5% other
- **red (slow)**: thin, many mitochondria, **myoglobin**; endurance (posture, marathon, long flights: duck)
- **white (fast)**: thick, glycogen; fast, strong, tire (sprints; chicken breast)
- on bones (tendons), tongue, upper esophagus, eye muscles, diaphragm; **voluntary**; fast, tires

Smooth muscle

- **spindle-shaped**, **one central nucleus**, **no stripes**; filaments criss-cross; sheets
- **single-unit** (gap junctions, contract together, waves): gut, bladder, uterus
- **multi-unit** (each cell its own nerve): **arrector pili**, **iris**, large vessels, airways
- hollow organs (peristalsis); **involuntary**; slow, long without tiring

Cardiac muscle

- **heart only**; **cylindrical, branched**, network; **faint stripes**
- separate cells, **1 (2) central nuclei**; **intercalated discs** (desmosomes + gap junctions)
- structure like skeletal (striped), function like smooth (involuntary); **never tires**
- self-starting (**SA node**); ~70 a minute

	Skeletal	Smooth	Cardiac
fiber	cylindrical, unbranched	spindle	cylindrical, branched
nuclei	many, peripheral	one, central	one or two, central
stripes	clear	none	faint
intercalated discs	absent	absent	present
control	voluntary	involuntary	involuntary, self-beating
fatigue	tires quickly	slow, long	never tires
where	bones, tongue	gut, vessels, bladder, uterus, iris	heart only

Nervous tissue

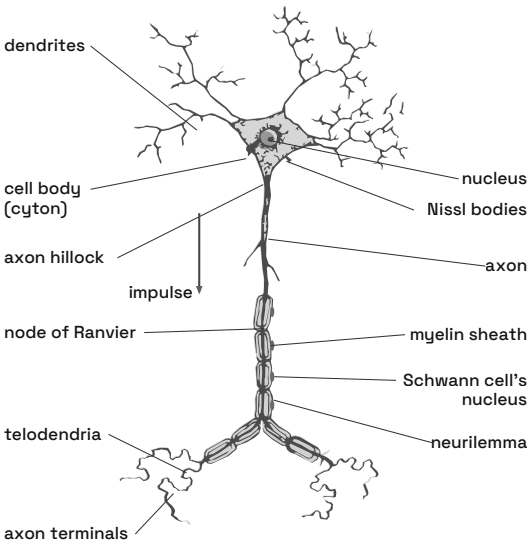
- **controls, coordinates**; **neurons**: excitable, conductive; little matrix; **ectoderm**
- brain, spinal cord, nerves

Neuroglia (glue; don't conduct; **divide**; ~as many as neurons)

- CNS: **astrocytes** (star; **blood–brain barrier**, scars); **oligodendrocytes** (CNS **myelin**, many axons); **microglia** (**macrophages**, mesoderm); **ependymal cells** (line ventricles, central canal; cilia; **choroid plexus** → **CSF**)
- PNS: **satellite cells** (round ganglion cell bodies); **Schwann cells** (PNS myelin, one stretch of one axon; help regrowth)

Neuron: structural, functional unit; **longest cells** (~1 m)

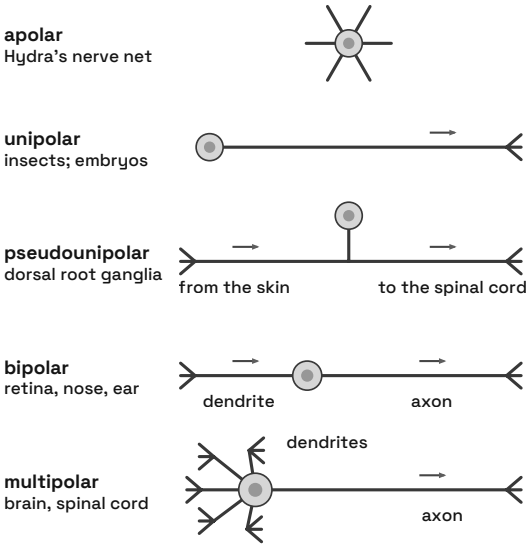
- **cell body** (cyton, soma, perikaryon): nucleus, nucleolus, **Nissl (tigroid) bodies** (rough ER, ribosomes); gray; in ganglia
- **dendrites**: many, short, branched, with Nissl; **towards** the cell body (afferent)
- **axon**: one, long; from the **axon hillock** (no Nissl); **axolemma**, **axoplasm**; collaterals; **telodendria** → **axon terminals**; **away** (efferent)
- **myelin sheath**: Schwann cell's membrane wrapped round, lipid, white; **neurilemma** outside it; **nodes of Ranvier** between Schwann cells; CNS fibers no neurilemma
- **saltatory conduction**: up to ~120 m/s myelinated, ~1 m/s non-myelinated
- **synapse** (neurotransmitters); **neuromuscular junction**, **motor end plate**
- cut peripheral fibers regrow ~1 mm a day; CNS fibers hardly



A multipolar neuron.

Types

- by job: **sensory** (receptor → CNS), **motor** (CNS → effector), **interneurons** (in CNS)
- by myelin: **myelinated** (white, fast), **non-myelinated** (gray, slow)
- by processes: **apolar** (*Hydra* nerve net); **unipolar** (invertebrates, embryo); **pseudounipolar** (T-shaped; **dorsal root ganglia**); **bipolar** (**retina**, olfactory, inner ear); **multipolar** (commonest; motor neurons, interneurons)



Neurons by their processes.

- **gray matter**: cell bodies; brain **cortex**, spinal cord's **H core**
- **white matter**: myelinated axons; brain inside, spinal cord outside
- nerve: **endoneurium** (fiber), **perineurium** (fascicle), **epineurium** (nerve)

	Epithelial	Connective	Muscular	Nervous
cells	very many, packed	few, scattered	many, long	many, long
matrix	very little	abundant	very little	very little
fibers	absent	abundant	absent	absent
blood vessels	none	present (not cartilage)	present	present
basement membrane	present	absent	external lamina	absent
cells divide	readily	yes	little	neurons no, glia yes

COMMON MISTAKES

✗ Endothelium comes from endoderm
✓ from **mesoderm**.

✗ Pseudostratified has many layers
✓ **one layer**, all cells on the basement membrane.

✗ Septate junctions are gap junctions
✓ they **seal**, like tight junctions.

✗ Fish scales are keratin
✓ **bone**, in the dermis.

✗ Merocrine cells lose a little of themselves
✓ they lose **nothing**; apocrine the top, holocrine the whole cell.

✗ Ligaments are yellow elastic fibers
✓ mainly **white collagen**.

✗ Nose tip is elastic cartilage
✓ **hyaline**; elastic in pinna, epiglottis.

✗ Bone has no fibers
✓ full of **collagen** (ossein).

✗ Ribs, scapula are membrane bones
✓ **cartilage** bones; clavicle membrane.

✗ Camel RBCs have a nucleus
✓ oval, but **no nucleus**.

✗ The A band shortens
✓ **A band unchanged**; I band, H zone shorten.

✗ Myelin is secreted by the neurilemma
✓ wrapped Schwann membrane, **inside** the neurilemma.

✗ Dorsal root ganglion neurons are unipolar
✓ **pseudounipolar**.

✗ Stellate cells round ganglia
✓ **satellite** cells.