BIOLOGY · UNIT 10 · QUICK REFERENCE

Anatomy & Physiology

Grades 10–12+ · 8 pages

Anatomical language, homeostasis and normal values; cells and tissues; the skin, skeleton and muscles; neurons, brain, cranial nerves and special senses; hormones; heart, blood and vessels; lymphatic and immune defense; breathing, digestion, kidneys and acid–base; reproduction and development.

1 Anatomical terms · 2 Homeostasis & values · 3 Cells & tissues · 4 Integumentary · 5 Skeletal · 6 Muscular · 7 Neurons · 8 Brain & nerves · 9 Special senses · 10 Endocrine · 11 Heart · 12 Blood & immunity · 13 Respiratory · 14 Digestive · 15 Urinary & acid–base · 16 Reproduction & development

1 ANATOMICAL LANGUAGE

Anatomical position

- Upright, facing forward, arms at the sides, **palms forward**.
- Directions are the **patient's**: "left" means the patient's left.

Directional terms

Term	Means	Opposite
Superior (cranial)	toward the head	inferior (caudal)
Anterior (ventral)	toward the front	posterior (dorsal)
Medial	toward the midline	lateral
Proximal	nearer a limb's attachment	distal
Superficial	toward the surface	deep

EX: the wrist is proximal to the fingers; skin is superficial to muscle.

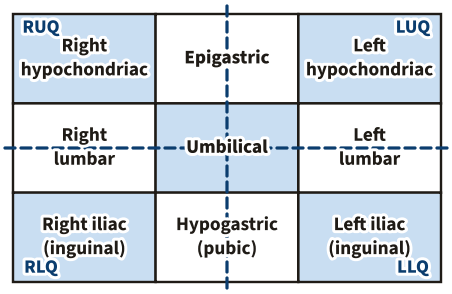
Body planes

Plane	Divides into
Sagittal (median = midsagittal)	right and left
Frontal (coronal)	front and back
Transverse (axial)	upper and lower

Body cavities

Cavity	Holds
Cranial; vertebral canal	brain; spinal cord
Thoracic: pleural ×2	lungs
Thoracic: mediastinum	heart (pericardial cavity), trachea, esophagus, great vessels
Abdominal	stomach, intestines, liver, spleen, pancreas
Pelvic	bladder, rectum, internal reproductive organs

The **diaphragm** divides thoracic from abdominopelvic.



Nine abdominopelvic regions (solid) and four quadrants (dashed), facing the patient.

What lies where

Quadrant	Main organs
RUQ	liver, gallbladder, duodenum, pancreas head
LUQ	stomach, spleen, pancreas tail
RLQ	cecum, appendix, right ovary
LLQ	sigmoid colon, left ovary

Appendicitis pain often starts at the navel, then settles in the RLQ.

2 ORGANIZATION, HOMEOSTASIS & NORMAL VALUES

Levels of organization

- **Chemical → cell → tissue → organ → organ system → organism**. Eleven systems: integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, reproductive.

"I will praise thee; for I am fearfully and wonderfully made: marvellous are thy works; and that my soul knoweth right well" (Psalm 139:14, KJV).

Homeostasis

- A stable internal state. **Stimulus → receptor → control center → effector → response**.
- **Negative feedback** (most) reverses a change: temperature, glucose, blood pressure.
- **Positive feedback** amplifies until an end event: labor (oxytocin), platelet plug, LH surge.

MEMORY TRICK

Negative keeps you normal

Negative feedback **n**udges back to **n**ormal; positive feedback pushes on until something ends it (a birth, a clot).

Resting vitals, chemistry and gases

Measure	Typical adult
Temperature	36.5–37.3 °C (97.7–99.1 °F)
Heart rate	60–100/min
Breathing rate	12–18/min
Blood pressure	< 120/80 mm Hg
O_2 saturation	95–100 %
Sodium	136–144 mEq/L
Potassium	3.5–5.0 mEq/L
Bicarbonate	22–28 mEq/L
Calcium (total)	8.5–10.2 mg/dL
Glucose (fasting)	70–99 mg/dL
Creatinine	0.8–1.2 mg/dL
Arterial pH	7.35–7.45
$PaCO_2$; PaO_2	35–45; 80–100 mm Hg

Blood counts

CBC	Male	Female
Hemoglobin (g/dL)	13–18	12–16
Hematocrit (%)	40–55	36–48
WBC (per µL)	4,500–11,000	same
Platelets (per µL)	150,000–400,000	same

Typical values (MedlinePlus, Merck Manual); each lab sets its own range.

Body fluids

Fluid	Share	70 kg
Total body water	≈ 60 % of mass (men)	42 L
Intracellular	⅔ of water	28 L
Extracellular	⅓: ¾ interstitial, ¼ plasma	14 L

Plasma osmolality ≈ 2 Na^+ + glucose ÷ 18 + BUN ÷ 2.8 = 2(140) + 90 ÷ 18 + 14 ÷ 2.8 = **290** mOsm/kg (normal ≈ 275–295).

3 CELLS & TISSUES

Cell parts

Cell part	Job	Cell part	Job
Plasma membrane	phospholipid bilayer with proteins; controls entry	Golgi apparatus	modifies, packages and ships proteins
Nucleus; nucleolus	holds DNA; builds ribosomes	Mitochondria	make most ATP (aerobic respiration)
Ribosomes; rough ER	make proteins	Lysosomes	digest worn parts and microbes
Smooth ER	lipids; detoxification; Ca^{2+} store (muscle)	Cilia; flagellum	move fluid (airway); move a sperm

Crossing the membrane

Process	ATP?	Example
Diffusion; osmosis	no	O_2 into blood; water toward more solute
Facilitated diffusion	no	glucose by carriers
Active transport	yes	Na^+/K^+ pump: 3 Na^+ out, 2 K^+ in
Exocytosis	yes	releasing neurotransmitter

Red cells: isotonic (0.9 % NaCl) no change; hypotonic swell and burst; hypertonic shrink.

Connective tissues

Connective tissue	Where
Areolar; adipose	under epithelia; hypodermis
Dense regular	tendons, ligaments
Dense irregular	dermis, joint capsules
Hyaline cartilage	joint surfaces, trachea, costal cartilage
Elastic cartilage	external ear, epiglottis
Fibrocartilage	intervertebral discs, menisci

The four tissue types

Tissue	Features	Examples
Epithelial	cell sheets on a basement membrane; no vessels; covers, lines, forms glands	epidermis, gut lining
Connective	cells in matrix of fibers and ground substance	tendon, bone, fat, blood
Muscle	contracts	skeletal, cardiac, smooth
Nervous	neurons signal; glia support	brain, nerves

Junctions and glands

- **Tight junctions** seal; **desmosomes** anchor; **gap junctions** pass ions cell to cell (heart, smooth muscle).
- **Exocrine** glands use ducts (sweat, saliva); **endocrine** glands release hormones into the blood.

Epithelia

Epithelium	Where
Simple squamous	alveoli, capillary endothelium
Simple cuboidal	kidney tubules, gland ducts
Simple columnar	stomach, intestine
Pseudostratified ciliated	trachea, bronchi
Stratified squamous	epidermis, mouth, esophagus
Transitional	bladder, ureters (stretch)

Muscle tissue

	Skeletal	Cardiac	Smooth
Striated	yes	yes	no
Control	voluntary	involuntary	involuntary
Nuclei	many, peripheral	1–2, central	1, central
Special	long cylinders	branched; intercalated discs	spindle-shaped

4 INTEGUMENTARY SYSTEM

Jobs of the skin

- Barrier to water loss, microbes and UV; temperature control; makes **vitamin D_3** with UVB; senses touch, pain and temperature.

Layers

Layer	Made of; notes
Epidermis	keratinized stratified squamous epithelium; no vessels; renews ≈ every 4 weeks
Dermis	papillary (areolar; fingerprints) over reticular (dense irregular; glands, follicles)
Hypodermis	fat and areolar tissue; not part of the skin

Glands and hair

- **Eccrine** sweat glands cool the body; **apocrine** (armpit, groin) start at puberty; **sebaceous** glands oil hair and skin.
- **Melanin** from melanocytes shields DNA from UV.

Epidermis

Stratum (deep → surface)	Notes
Basale	stem cells divide; melanocytes, tactile (Merkel) cells
Spinosum	desmosomes; dendritic (Langerhans) immune cells
Granulosum	keratin fills cells; they die
Lucidum	thick skin only (palms, soles)
Corneum	dead, flat keratin cells that flake off

MEMORY TRICK

Come, Let's Get Sun Burned

Corneum, Lucidum, Granulosum, Spinosum, Basale: surface to deep. (Traditional.)

Skin cancer warning signs

- **ABCDE** of a mole (Traditional): **A**symmetry, **B**order irregular, **C**olor varied, **D**iameter > 6 mm, **E**volving. Basal cell carcinoma is most common; melanoma is most deadly.

Burns

Burn depth	Damage; look
Superficial (1st degree)	epidermis; red, painful
Partial thickness (2nd)	into dermis; blisters, very painful
Full thickness (3rd)	whole dermis; white or leathery, little pain

Rule of nines (Traditional)

Adult area	%
Head and neck	9
Each arm	9
Front of trunk	18
Back of trunk	18
Each leg	18
Perineum	1

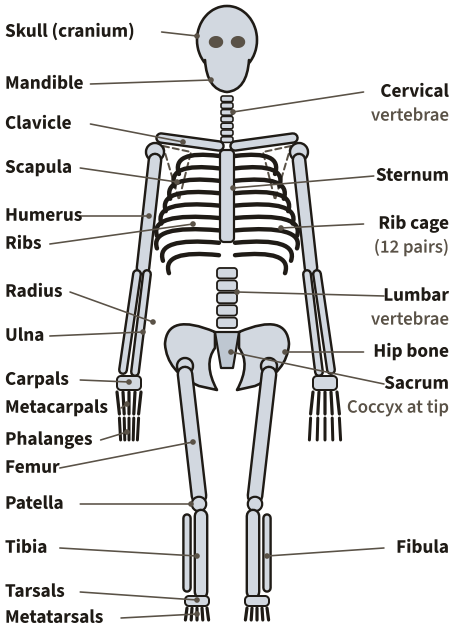
The patient's palm with fingers ≈ 1 %. Children need a separate chart.

Estimate a burn WORKED

whole right arm + front of trunk: 9 + 18 = **27 %**

partial and full thickness only

5 SKELETAL SYSTEM



Adult skeleton. Bones support, protect, store 99 % of body calcium and make blood cells. Vesalius drew it from his own dissections (Fabrica, 1543).

The 206 adult bones

Division	Bones	Count
Axial: 80	skull (8 cranial + 14 facial)	22
	ossicles 6, hyoid 1	7
	vertebrae	26
	24 ribs + sternum	25
Appendicular: 126	pectoral girdles (clavicle, scapula ×2)	4
	upper limbs	60
	hip bones	2
	lower limbs	60

Arm (30): humerus, radius, ulna, 8 carpals, 5 metacarpals, 14 phalanges. Leg (30): femur, patella, tibia, fibula, 7 tarsals, 5 metatarsals, 14 phalanges.

MEMORY TRICK

Sally Left The Party To Take Cathy Home

Carpals, lateral to medial: scaphoid, lunate, triquetrum, pisiform; trapezium, trapezoid, capitate, hamate. (Traditional.)

Vertebrae (26) and ribs

- Cervical 7 (C1 atlas nods; C2 axis turns), thoracic 12, lumbar 5, sacrum, coccyx. Breakfast at 7, lunch at 12, dinner at 5. (Traditional.) Ribs 1–7 true; 8–12 false (11–12 floating).

Bone tissue

- **Diaphysis** (shaft): compact bone, yellow marrow. **Epiphysis** (end): spongy bone, red marrow. Growth plate between.
- Osteo**b**lasts **b**uild; osteo**c**lasts **c**arve; osteocytes maintain. (Traditional.)

Synovial joints (move freely)

Synovial joint	Examples
Hinge	elbow, fingers; knee (modified)
Pivot	atlas on axis; radius on ulna
Saddle	thumb base
Ball-and-socket	shoulder, hip

Fibrous: sutures. Cartilaginous: pubic symphysis, discs.

6 MUSCULAR SYSTEM

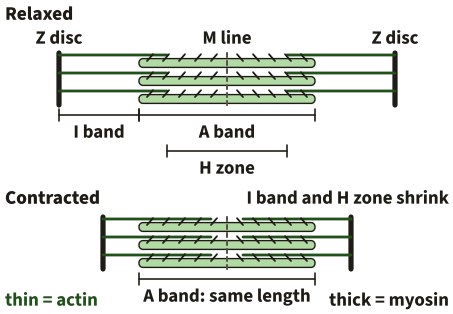
Major muscles

Muscle	Action	Muscle	Action
Sternocleidomastoid	flexes, turns neck	Rectus abdominis	flexes trunk
Trapezius	moves scapula	Iliopsoas	flexes hip
Deltoid	abducts arm	Gluteus maximus	extends hip
Pectoralis major	flexes, adducts arm	Gluteus medius	abducts hip
Latissimus dorsi	extends, adducts arm	Quadriceps	extends knee
Biceps brachii	flexes elbow, supinates	Hamstrings	flex knee
Triceps brachii	extends elbow	Gastrocnemius	plantar flexes
Diaphragm	inspiration	Tibialis anterior	dorsiflexes

"C3, 4, 5 keeps the diaphragm alive": the phrenic nerve's roots. (Traditional.)

Terms

- **Origin** fixed, **insertion** moves. **Agonist** acts, **antagonist** opposes, **synergist** helps.
- Muscle → fascicle → fiber → myofibril → **sarcomere**.



Filaments slide; none changes length.

Sliding filament steps

- Motor neuron releases **acetylcholine** at the neuromuscular junction.
- Action potential runs along the sarcolemma and **T tubules**.
- Sarcoplasmic reticulum releases **Ca^{2+}**; Ca^{2+} binds **troponin**, moving **tropomyosin** off actin.
- Myosin binds actin and pulls (**power stroke**); **ATP** releases and re-cocks it.
- Relax: ACh broken down; Ca^{2+} pumped back.

Proposed in 1954 by H. E. Huxley and J. Hanson and by A. F. Huxley and R. Niedergerke.

MEMORY TRICK

Calcium unlocks, ATP lets go

Ca^{2+} uncovers actin; ATP releases the grip. No ATP after death: **rigor mortis**.

MEMORY TRICK **SITS**

Rotator cuff: **S**upraspinatus, **I**nfraspinatus, **T**eres minor, **S**ubscapularis. (Traditional.)

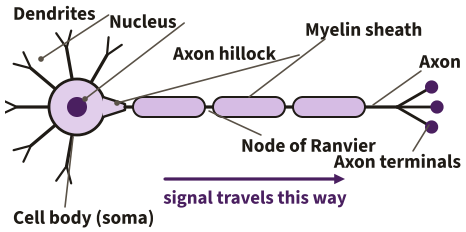
Movements and energy

- Flexion/extension close/open a joint; abduction/adduction move from/to the midline; pronation/supination turn the palm back/forward.
- ATP: creatine phosphate (≈ 10–15 s), anaerobic glycolysis, aerobic respiration (hours).

7 NEURONS & NERVE SIGNALS

Organization

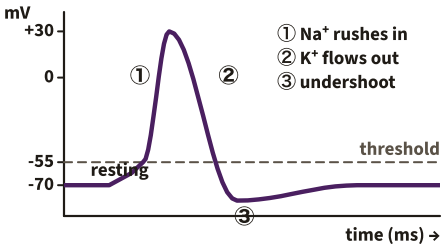
- **CNS**: brain, spinal cord. **PNS**: 12 cranial and 31 spinal nerve pairs.
- **Afferent** (sensory) fibers carry signals in; **efferent** (motor) carry them out: **somatic** to skeletal muscle, **autonomic** to heart, smooth muscle, glands.



Myelin: the signal jumps node to node (saltatory).

Neuroglia

- CNS: astrocytes, **oligodendrocytes** (myelin), microglia, ependymal cells. PNS: **Schwann cells** (myelin).



One action potential lasts ≈ 1–2 ms.

The action potential

- **Resting** ≈ −70 mV; the Na^+/K^+ pump keeps Na^+ out, K^+ in.
- **Threshold** ≈ −55 mV: Na^+ channels open → **depolarization** to ≈ +30 mV.
- K^+ channels open → **repolarization**, brief **hyperpolarization**.
- **All-or-none**; the **refractory period** keeps it one-way.

Hodgkin and Huxley measured these currents in squid axons (1952).

Synapse

- Ca^{2+} enters terminal → transmitter released → binds receptors → cleared.
- ACh (muscle, parasympathetic); norepinephrine (sympathetic); dopamine (movement); GABA inhibits; glutamate excites.

Tendon reflexes

Reflex	Level
Biceps	C5–C6
Triceps	C7–C8
Patellar (knee)	L3–L4
Calcaneal (ankle)	S1–S2

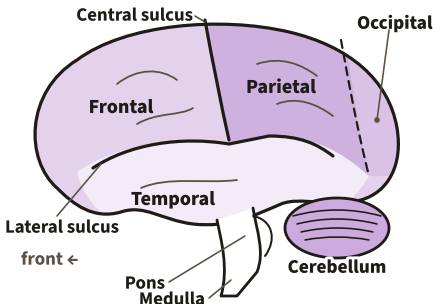
Arc: receptor → sensory neuron → cord → motor neuron → effector.

MEMORY TRICK **Buckle my shoe**
"S1, 2, buckle my shoe; L3, 4, kick the door; C5, 6, pick up sticks; C7, 8, lay them straight." (Traditional.)

8 BRAIN, CRANIAL NERVES & AUTONOMIC SYSTEM

Cranial nerves (S sensory, M motor, B both)

#	Nerve		Main job	#	Nerve		Main job
I	Olfactory	S	smell	VII	Facial	B	facial expression; taste, front ⅔; tears, saliva
II	Optic	S	vision	VIII	Vestibulocochlear	S	hearing, balance
III	Oculomotor	M	most eye movements, eyelid, pupil constriction	IX	Glossopharyngeal	B	taste, back ⅓; swallowing; parotid; carotid sinus
IV	Trochlear	M	superior oblique	X	Vagus	B	throat, voice; parasympathetic to heart, lungs, gut
V	Trigeminal	B	face sensation; chewing	XI	Accessory	M	sternocleidomastoid, trapezius
VI	Abducens	M	lateral rectus	XII	Hypoglossal	M	tongue



Left hemisphere, cerebellum and brainstem.

Protection

- Meninges, brain outward: **P**ia, **A**rachnoid, **D**ura ("PAD," Traditional). **CSF** (≈ 150 mL; ≈ 500 mL/day from choroid plexus) fills the subarachnoid space.
- Spinal cord ends near **L1–L2**.

Brain regions

Region	Main jobs
Frontal	planning; motor cortex; Broca area (speech, usually left)
Parietal	body sensation (postcentral gyrus)
Temporal	hearing; Wernicke area (language); memory
Occipital	vision
Thalamus	sensory relay to cortex
Hypothalamus	temperature, thirst, hunger; runs the pituitary
Brainstem	midbrain, pons, medulla: breathing, heart rate
Cerebellum	balance, coordination

MEMORY TRICK
Oh Oh Oh To Touch And Feel Very Good Velvet, AH
Cranial nerves I to XII. (Traditional.)

MEMORY TRICK
Some Say Marry Money, But My Brother Says Big Brains Matter More
Sensory, motor or both, I to XII. (Traditional.)

Autonomic nervous system

	Sympathetic	Parasympathetic
Called	fight or flight	rest and digest
Leaves CNS	T1–L2	CN III, VII, IX, X; S2–S4
Final transmitter	norepinephrine	acetylcholine
Pupils; heart	dilate; faster	constrict; slower
Airways; gut	dilate; slows	constrict; speeds

Sympathetic also triggers adrenal epinephrine; sweat glands use ACh. The vagus carries ≈ 75 % of parasympathetic fibers.

9 SPECIAL SENSES

The eye

Eye layer	Parts
Fibrous	**sclera**; **cornea** (most focusing)
Vascular (uvea)	**choroid**, **ciliary body** (shapes lens), **iris**
Neural	**retina**: rods, cones

Light: cornea → aqueous humor → pupil → lens → vitreous humor → retina → optic nerve → thalamus → occipital cortex.

Receptors

Retina	Notes
Rods (≈ 120 million)	dim light; gray scale
Cones (≈ 6 million)	color, detail
Fovea centralis	cones only; sharpest
Optic disc	no receptors: blind spot

Pupil and pathway

- Near focus: ciliary muscle contracts, lens rounds, pupil constricts (parasympathetic, CN III). Dim light or alarm: pupil dilates (sympathetic).
- At the **optic chiasm** the nasal half of each retina crosses, so each side of the brain sees the opposite visual field.

MEMORY TRICK **Cones for color**

Cones see **c**olor and detail; **r**ods work in dim **r**ooms.

Focus problems

- **Myopia**: image in front of retina; concave lens. **Hyperopia**: behind; convex lens.
- **Presbyopia**: stiff lens with age. **Cataract**: cloudy lens. **Glaucoma**: optic-nerve damage, often high eye pressure.

The ear

Ear	Structures	Job
Outer	auricle, canal, eardrum	collect sound
Middle	malleus, incus, stapes; auditory tube	amplify; equalize pressure
Inner	cochlea (spiral organ)	hearing
	vestibule; semicircular canals	tilt and straight motion; rotation

Sound: eardrum → ossicles → oval window → cochlear fluid → hair cells → CN VIII → temporal lobe. Hearing ≈ 20–20,000 Hz.

Smell and taste

- Smell: CN I; the one sense that reaches cortex without passing the thalamus first.
- Taste: sweet, sour, salty, bitter, umami; CN VII, IX, X.

10 ENDOCRINE SYSTEM

Glands and hormones

Gland	Hormones → main effect
Hypothalamus	releasing hormones (TRH, CRH, GnRH, GHRH) for the pituitary; makes ADH, oxytocin
Anterior pituitary	GH → growth; TSH → thyroid; ACTH → adrenal cortex; FSH, LH → gonads; prolactin → milk
Posterior pituitary	releases ADH (kidneys keep water) and oxytocin (labor, milk let-down)
Thyroid	T_4, T_3 (iodine) → metabolic rate; calcitonin → lowers Ca^{2+}
Parathyroids	PTH → raises Ca^{2+} (bone, kidney, vitamin D)
Adrenal cortex	aldosterone → keep Na^+, lose K^+; cortisol → stress, glucose; androgens
Adrenal medulla	epinephrine, norepinephrine → fight or flight
Pancreatic islets	insulin (β) lowers glucose; glucagon (α) raises it
Pineal; thymus	melatonin (sleep); thymosins (T cells)
Gonads	testosterone; estrogen and progesterone
Kidney; heart	EPO (red cells); ANP (lose Na^+ and water)

Two kinds of hormones

- **Steroids** (cortisol, aldosterone, sex hormones) and thyroid hormone enter cells and change gene expression.
- **Peptides and amines** (insulin, ADH, epinephrine) bind membrane receptors; second messengers such as cAMP.

MEMORY TRICK **FLAT PiG**

Anterior pituitary: **F**SH, **L**H, **A**CTH, **T**SH, **P**rolactin, (**i**), **G**H. (Traditional.)

Feedback axis

- Low T_4 → **TRH** → **TSH** → thyroid makes T_4; rising T_4 shuts off TRH and TSH.
- Same pattern: CRH → ACTH → cortisol; GnRH → FSH/LH → sex hormones.

MEMORY TRICK

Salt, sugar, sex hormones

Adrenal cortex, outer to inner: aldosterone, cortisol, androgens. (Traditional.)

Glucose criteria

Fasting glucose	A1C	ADA category
70–99 mg/dL	< 5.7 %	normal
100–125	5.7–6.4 %	prediabetes
≥ 126	≥ 6.5 %	diabetes (repeat to confirm)

MEMORY TRICK

Glucagon when glucose is gone

Gluca**gon** answers glucose **gone**; insulin puts glucose **in**. (Traditional.)

Blood glucose

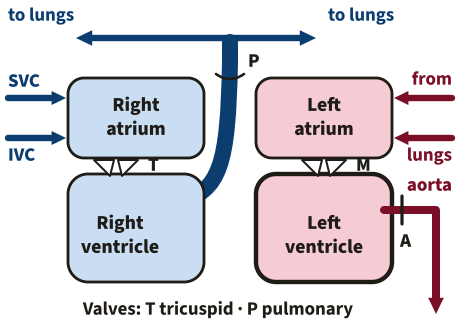
- High → **insulin** → cells take up glucose; liver stores glycogen.
- Low → **glucagon** → liver releases glucose.
- **Type 1**: autoimmune loss of β cells. **Type 2**: insulin resistance (most common).

Banting and Best isolated insulin in Toronto (1921).

Too much, too little

- Thyroid: **hyper** (Graves): fast pulse, heat intolerance, weight loss; **hypo** (Hashimoto): fatigue, cold intolerance, weight gain.
- Cortisol: excess = **Cushing** syndrome; adrenal failure = **Addison** disease. GH excess: gigantism in children, acromegaly in adults.

11 THE HEART



Valves: T tricuspid · P pulmonary M mitral (bicuspid) · A aortic

Front view: patient's right on your left

Blue: oxygen-poor (right heart). Red: oxygen-rich (left heart).

Path of blood

- Venae cavae → RA → tricuspid → RV → pulmonary valve → **lungs** (pulmonary circuit) → pulmonary veins → LA → mitral → LV (thickest wall) → aortic valve → **aorta** → body (systemic circuit).

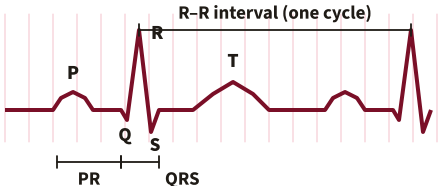
Harvey showed the blood circulates (De Motu Cordis, 1628).

MEMORY TRICK **Tri before you bi**

Blood passes the **tri**cuspid before the **bi**cuspid (mitral). (Traditional.)

Conduction system

Conduction	Own rate
SA node (pacemaker)	60–100/min
AV node (delay lets ventricles fill)	40–60/min
AV bundle → bundle branches → **Purkinje fibers**	20–40/min



P: atria depolarize. QRS: ventricles depolarize. T: ventricles repolarize.

Resting adult WORKED

EDV 120, ESV 50 mL: SV = **70 mL**; EF = **58 %**

normal ≈ 50–70 %

CO = 70/min × 70 mL = **4.9 L/min**

Coronary arteries

Coronary artery	Supplies
LAD	front of left ventricle; front ⅔ of septum
Circumflex	side and back of left ventricle
Right coronary	right ventricle; usually SA and AV nodes

Reading the ECG WORKED

PR 0.12–0.20 s; QRS < 0.12 s; big box 0.20 s *at 25 mm/s*

R to R = 4 big boxes = 0.80 s → 60 ÷ 0.80 = **75/min**

or 300 ÷ 4

Output

Frank–Starling: more filling → stronger beat.

S1: AV valves close; **S2**: semilunar valves close.

$$CO = HR \times SV$$

$$SV = EDV - ESV$$

$$EF = SV \div EDV$$

12 BLOOD, VESSELS & IMMUNITY

Blood (≈ 5 L)

Part	Facts
Plasma ≈ 55 %	≈ 92 % water; albumin, globulins, fibrinogen
Red cells ≈ 45 %	the hematocrit; no nucleus; live ≈ 120 days; kidney EPO drives production
White cells, platelets < 1 %	platelets: cell fragments; 7–10 days

"For the life of the flesh is in the blood" (Leviticus 17:11, KJV).

White cells, most to fewest

White cell	%	Job
Neutrophils	40–60	first responders; bacteria
Lymphocytes	20–40	B, T and NK cells
Monocytes	2–8	become macrophages
Eosinophils	1–4	parasites, allergy
Basophils	0.5–1	histamine

Order: Never Let Monkeys Eat Bananas. (Traditional.)

Hemostasis

- Spasm → platelet plug → **coagulation**: thrombin turns fibrinogen into **fibrin** (needs Ca^{2+}, vitamin K).

ABO types (Landsteiner, 1901)

Type	Antigens	Antibodies	Receives
A	A	anti-B	A, O
B	B	anti-A	B, O
AB	A, B	none	all
O	none	anti-A, B	O

Rh^+ = D antigen. O^-: universal donor; AB^+: universal recipient.

Adult blood pressure (mm Hg)

2025 AHA/ACC	Systolic		Diastolic
Normal	< 120	and	< 80
Elevated	120–129	and	< 80
Stage 1	130–139	or	80–89
Stage 2	≥ 140	or	≥ 90

Arteries carry blood away from the heart; veins hold ≈ 60–70 % of it.

Mean arterial pressure WORKED

120/80: 80 + ⅓(120 − 80) = **93 mm Hg**

MAP ≈ D + ⅓(S − D)

Lymphatic system

- Returns ≈ 3 L/day of tissue fluid (**lymph**); absorbs fat (lacteals). Organs: red marrow, **thymus** (T cells mature), lymph nodes, **spleen** (filters blood). **Thoracic duct** → left subclavian vein; **right lymphatic duct** drains the upper right quarter.

Lines of defense

Defense	Examples
Innate: barriers	skin, mucus, cilia, stomach acid
Innate: inside	phagocytes, NK cells, inflammation, fever, complement
Adaptive	specific, with memory: B cells (antibodies), T cells

Inflammation: redness, heat, swelling, pain (rubor, calor, tumor, dolor).

Lymphocytes

- **Helper T** (CD4) directs; **cytotoxic T** (CD8) kills infected cells; **plasma cells** (from B cells) make antibodies; memory cells speed a second response.

MEMORY TRICK **GAMED**

Antibodies: Ig**G** (most; crosses placenta), Ig**A** (tears, milk), Ig**M** (first made), Ig**E** (allergy, parasites), Ig**D** (B-cell receptor). (Traditional.)

Acquired immunity

Immunity	Natural	Artificial
Active (lasting)	having the disease	vaccination
Passive (weeks)	via placenta, milk	antibody shot

Jenner vaccinated against smallpox with cowpox (1796).

13 RESPIRATORY SYSTEM

Airway

- Nasal cavity → pharynx → larynx (epiglottis, vocal folds) → trachea → main bronchi → bronchioles → **alveoli** (≈ 300–500 million, ≈ 70 m^2).
- Type I alveolar cells: gas exchange. Type II: **surfactant**.

Lungs

- Right: 3 lobes; left: 2 (cardiac notch).
- Right main bronchus is wider and more vertical: inhaled objects usually go right.

Lung volumes

Volume	Typical (male)
Tidal (TV)	500 mL
Inspiratory reserve	3100 mL
Expiratory reserve	1200 mL
Residual (RV)	1200 mL
Vital capacity = TV + IRV + ERV	4800 mL
Total = VC + RV	6000 mL

Women's are ≈ 20–25 % smaller.

Breathing (Boyle's law)

- Inhale: diaphragm contracts and flattens, external intercostals lift ribs → volume up, pressure down → air in.
- Quiet exhale is passive recoil.

Ventilation WORKED

500 mL × 12/min = **6.0 L/min** *minute*

(500 − 150 dead space) × 12 = **4.2 L/min** *alveolar*

Partial pressures (mm Hg)

Site	PO_2	PCO_2
Air at sea level	0.21 × 760 ≈ 160	≈ 0.3
Alveoli	≈ 104	40
Arterial	80–100	35–45
Venous	≈ 40	≈ 46

Control

- Rhythm from the **medulla** (with the pons).
- Main drive: **CO_2** sensed centrally (CSF H^+). Carotid and aortic bodies add a low-O_2 drive (PaO_2 below ≈ 60).

Transport

- O_2: ≈ 98.5 % on hemoglobin. CO_2: ≈ 70 % as HCO_3^-, ≈ 23 % on hemoglobin, ≈ 7 % dissolved.
- More O_2 unloads when CO_2, H^+ or temperature rise (**Bohr effect**).

Oxygen content WORKED

$CaO_2 = 1.34 \times Hb \times SaO_2 + 0.003 \times PaO_2$

1.34(15)(0.98) + 0.003(100) = **20.0 mL/dL**

Common lung problems

Problem	What goes wrong
Asthma	reversible airway narrowing; wheeze
COPD	emphysema (alveoli destroyed), chronic bronchitis; mostly smoking
Pneumonia	infected alveoli fill with fluid
Pneumothorax	air in the pleural space; lung collapses
Pulmonary embolism	clot (usually from leg veins) blocks a pulmonary artery

14 DIGESTIVE SYSTEM

The GI tract

- Mouth → pharynx → esophagus → stomach → **duodenum**, **jejunum**, **ileum** → cecum (appendix) → ascending, transverse, descending, sigmoid colon → rectum → anus.
- Accessory: salivary glands, **liver**, **gallbladder**, **pancreas**.

Teeth and swallowing

- Adult **32**: in each quarter 2 incisors, 1 canine, 2 premolars, 3 molars. Children **20**: 2 incisors, 1 canine, 2 molars per quarter.
- Swallowing: the epiglottis covers the larynx; **peristalsis** moves food; the lower esophageal and pyloric sphincters guard the stomach.

Gastric glands

Stomach cell	Secretes
Parietal	HCl (pH ≈ 1.5–3.5); **intrinsic factor** (for B_{12})
Chief	pepsinogen
G cell	gastrin
D cell	somatostatin (brakes acid)

Enzymes

Enzyme	Source	Breaks
Salivary amylase	mouth	starch
Pepsin	stomach	protein
Pancreatic amylase	pancreas	starch
Trypsin, chymotrypsin	pancreas	protein
Lipase	pancreas	fat → monoglycerides, fatty acids
Lactase, sucrase, peptidases	brush border	disaccharides, peptides

Bile salts (liver, stored in the gallbladder) emulsify fat; bile has no enzymes.

GI hormones

Hormone	Trigger → effect
Gastrin	food in stomach → acid
Secretin	acid in duodenum → pancreatic bicarbonate
CCK	fat in duodenum → gallbladder contracts, enzymes

MEMORY TRICK **Secretin sends soda**

Secretin **s**ends bicarbonate (baking **s**oda); **C**CK **c**alls bile and enzymes for fat.

Absorption

Where	Absorbed
Duodenum	iron, calcium
Jejunum	most nutrients
Terminal ileum	B_{12}, bile salts
Colon	water, salts; bacteria make vitamin K

Fats enter **lacteals** as chylomicrons; the rest goes to the liver by the hepatic portal vein.

Common digestive problems

Problem	Cause; sign
GERD	acid backs up past the lower esophageal sphincter; heartburn
Peptic ulcer	mostly H. pylori infection or NSAIDs
Gallstones	pain after fatty meals (CCK)
Lactose intolerance	low lactase; gas, diarrhea after milk
Celiac disease	gluten damages small-intestine villi

Liver (≈ 1.5 kg)

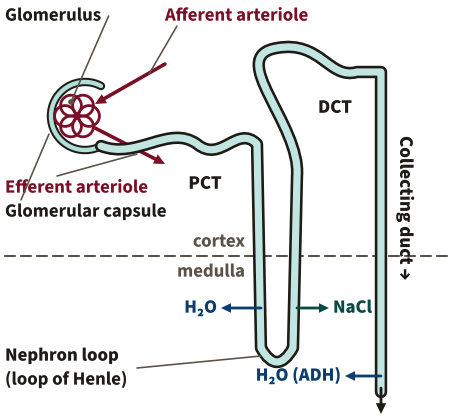
- Makes bile (bilirubin from old red cells), albumin and clotting factors; stores glycogen, iron, vitamins; turns ammonia into **urea**; detoxifies drugs.

Beaumont studied digestion through Alexis St. Martin's stomach opening (1822–1833).

15 URINARY SYSTEM & ACID–BASE

Organs and jobs

- Kidneys (retroperitoneal, ≈ T12–L3) → ureters → bladder → urethra. Kidneys filter blood, balance water, ions and pH, and make renin, EPO and active vitamin D.



About 1 million nephrons per kidney.

Along the nephron

Part	What happens
Glomerulus, capsule	**filtration** of water and small solutes
PCT	≈ 65 % of Na^+, water back; all glucose
Descending limb	water out
Ascending limb	NaCl out; water stays
DCT	aldosterone: Na^+ in, K^+ out
Collecting duct	**ADH** inserts aquaporins: water back

How much is reabsorbed? WORKED

GFR 125 mL/min × 1440 = **180 L/day**

urine 1.5 L/day: 1.5 ÷ 180 ≈ 0.8 % → ≈ **99 %** reabsorbed

RAAS

- Low pressure → **renin** → angiotensin I → **ACE** (lungs) → **angiotensin II**: vasoconstriction, aldosterone, ADH, thirst. **ANP** (heart) opposes it.

Acid–base

Normal: 24 ÷ (0.03 × 40) = 20; 6.1 + log 20 = **7.40**. Lungs fix CO_2 in minutes; kidneys fix HCO_3^- over days.

$$\mathbf{pH = 6.1 + \log [HCO_3^- \div (0.03 \times PaCO_2)]}$$

Acid–base disorders

Disorder	pH	Primary	Example
Resp. acidosis	↓	CO_2 ↑	slow breathing
Resp. alkalosis	↑	CO_2 ↓	fast breathing
Metab. acidosis	↓	HCO_3^- ↓	ketoacidosis, diarrhea
Metab. alkalosis	↑	HCO_3^- ↑	vomiting

MEMORY TRICK **ROME**
Respiratory **O**pposite (pH vs CO_2); **M**etabolic **E**qual (pH with HCO_3^-). (Traditional.)

16 REPRODUCTION & DEVELOPMENT

Sex is set at fertilization

- The sperm carries X or Y: **XX** female, **XY** male.
- The **SRY** gene on the Y starts testis development (≈ week 7); testosterone shapes male anatomy.

Male system

Male	Job
Testes (≈ 2–3 °C below core)	tubules make sperm (FSH); Leydig cells make testosterone (LH)
Epididymis	sperm mature, are stored
Ductus (vas) deferens	carries sperm
Seminal vesicles	≈ 60–70 % of semen; fructose
Prostate	≈ 25–30 %; PSA
Bulbourethral glands	neutralizing mucus

MEMORY TRICK **SEVEN UP**
Sperm path: **S**eminiferous tubules, **E**pididymis, **V**as deferens, **E**jaculatory duct, (**N**othing), **U**rethra, **P**enis. (Traditional.)

Making gametes (meiosis)

- Sperm: from puberty on; 4 per cell; ≈ 64–74 days. Eggs: begun before birth, paused in prophase I; 1 ovum + polar bodies; meiosis II ends at fertilization.

Female system

Female	Job
Ovaries	oocytes; estrogen, progesterone
Uterine tubes	fertilization, usually in the **ampulla**
Uterus	endometrium (lining), myometrium (muscle); cervix
Vagina; vulva	birth canal; external genitalia

A 28-day cycle

Day	Ovary	Uterus
1–5	follicles start (FSH)	**menstrual**: lining sheds
6–13	**follicular**: estrogen rises	**proliferative**
≈ 14	**ovulation** after the **LH surge**	
15–28	**luteal**: corpus luteum, progesterone	**secretory**

Rising estrogen triggers the LH surge (positive feedback); 21–35-day cycles are normal. hCG, which pregnancy tests detect, keeps the corpus luteum.

First two weeks

- **Fertilization**: a new human organism, the **zygote**, with 46 chromosomes and its own DNA. Morula (day 3–4) → **blastocyst** (inner cell mass → embryo; trophoblast → placenta) → **implantation** begins ≈ day 6–7.

"For thou hast possessed my reins: thou hast covered me in my mother's womb" (Psalm 139:13, KJV).

Gastrulation (week 3)

Germ layer	Becomes
Ectoderm	epidermis; brain, spinal cord, nerves
Mesoderm	muscle, bone, heart, blood, kidneys, gonads
Endoderm	gut and airway linings, liver, pancreas, thyroid

Timeline

From fertilization	Milestone
Day ≈ 22	heart beats
Week 4	neural tube closes (folic acid helps)
Weeks 3–8	**embryo**: organs form
Week 9 on	**fetus**: growth
≈ 38 weeks	birth (≈ 40 weeks from LMP)

Due date (Naegele, Traditional) WORKED

LMP + 1 yr − 3 mo + 7 days ≈ LMP + 280 days

LMP March 1, 2026 → **December 8, 2026** by the rule (about 280 days)

Fetal circulation

Fetal shunt	Route	Becomes
Ductus venosus	skips liver	ligamentum venosum
Foramen ovale	RA → LA	fossa ovalis
Ductus arteriosus	pulmonary trunk → aorta	ligamentum arteriosum

Umbilical vein (1) brings O_2-rich blood; 2 arteries return it. Maternal and fetal blood do not mix.