BIOLOGY · UNITS 1–10 · QUICK REFERENCE

General Biology

Grades 9–12+ | 8 pages

Life and the scientific method, the chemistry of life, cells and transport, energy, cell division, heredity, DNA and biotechnology, variation and origins, classification, microbes, plants and animals, the human body and ecology.

1 Study of life | 2 Chemistry of life | 3 Cells | 4 Transport | 5 Energy | 6 Cell division | 7 Mendel | 8 Beyond Mendel | 9 DNA | 10 Gene expression | 11 Biotech | 12 Origins | 13 Classification & microbes | 14 Plants & animals | 15 Human body | 16 Ecology

1 THE STUDY OF LIFE

Seven marks of living things

- Made of one or more **cells**.
- Uses energy (**metabolism**).
- **Grows** and develops.
- **Responds** to stimuli.
- **Reproduces**.
- Keeps a stable inside (**homeostasis**).
- Carries inherited instructions in **DNA**.

Viruses reproduce only inside a living cell.

Independent variable	the one factor you change (x-axis)
Dependent variable	what you measure (y-axis)
Control group	gets no treatment; the baseline for comparison
Theory	a broad, well-tested explanation; strong or weak, always open to testing

MEMORY TRICK

Cells Make Great Reasons, Really Hard to Deny

Cells, **M**etabolism, **G**rowth, **R**esponse, **R**eproduction, **H**omeostasis, **D**NA.

Levels of organization

- molecule → cell → tissue → organ → organ system → organism
- population → community → ecosystem → biosphere

Scientific method

- **Observe** and ask a testable question.
- Form a **hypothesis** (an if–then prediction).
- **Experiment**: change one variable, keep the rest **constant**, repeat trials.
- **Analyze** data (tables, graphs, averages).
- **Conclude** and share; others repeat the test.

Name the variables WORKED

Does fertilizer change bean height?

IV **fertilizer**; DV **height**; control **none added**

light, water, soil constant

Microscope

Field of view shrinks by the same factor the power rises.

total magnification = ocular × objective

Estimate a cell size WORKED

10× ocular, 40× objective → **400×**

FOV at 40× is 4.5 mm, so at 400× it is 0.45 mm = 450 µm

10× more power

9 cells span it → $\frac{450\ \mu m}{9}$ = **50 µm** each

2 THE CHEMISTRY OF LIFE

The four macromolecules

Molecule	Monomer	Job	Examples	Test
Carbohydrate	monosaccharide	quick energy, structure	glucose, starch, cellulose, glycogen	Benedict's (sugar), iodine (starch)
Lipid	glycerol + fatty acids	stored energy, membranes	fats, oils, phospholipids, steroids	grease spot on brown paper
Protein	amino acid (20 kinds)	enzymes, structure, transport	hemoglobin, keratin, insulin	biuret (turns violet)
Nucleic acid	nucleotide	genetic information	DNA, RNA (ATP is a nucleotide)	—

Elements: carbs and lipids C, H, O; proteins add N (S); nucleic acids add N, P. **Saturated** fats (no C=C) are solid; **unsaturated** oils are liquid.

Water: why life depends on it

- **Polar**: O slightly −, H slightly +.
- **Hydrogen bonds** give **cohesion** (surface tension) and **adhesion** (climbing xylem).
- **High specific heat** steadies temperatures.
- **Ice floats** (less dense), so lakes freeze from the top.
- **Solvent**: dissolves ions and polar molecules.

pH scale

0–14; below 7 acidic, 7 neutral, above 7 basic. Each step is a **10×** change.

$pH = -\log[H^+]$

EX pH 3 is 10^{5-3} = **100×** more acidic than pH 5. **Buffers** resist change (blood stays near 7.4).

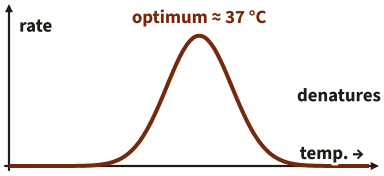
Building and breaking

- **Dehydration synthesis** links monomers and releases water (one H_2O per bond).
- **Hydrolysis** adds water to split them.

EX $C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$ (glucose + glucose → maltose)

Enzymes

- Protein catalysts: speed reactions by **lowering activation energy**; not used up.
- The **substrate** fits the **active site** (lock and key; the site flexes to fit, **induced fit**).
- Each has a best **temperature** and **pH**; heat or wrong pH **denatures** it (shape lost, job lost).
- Lactase splits lactose.



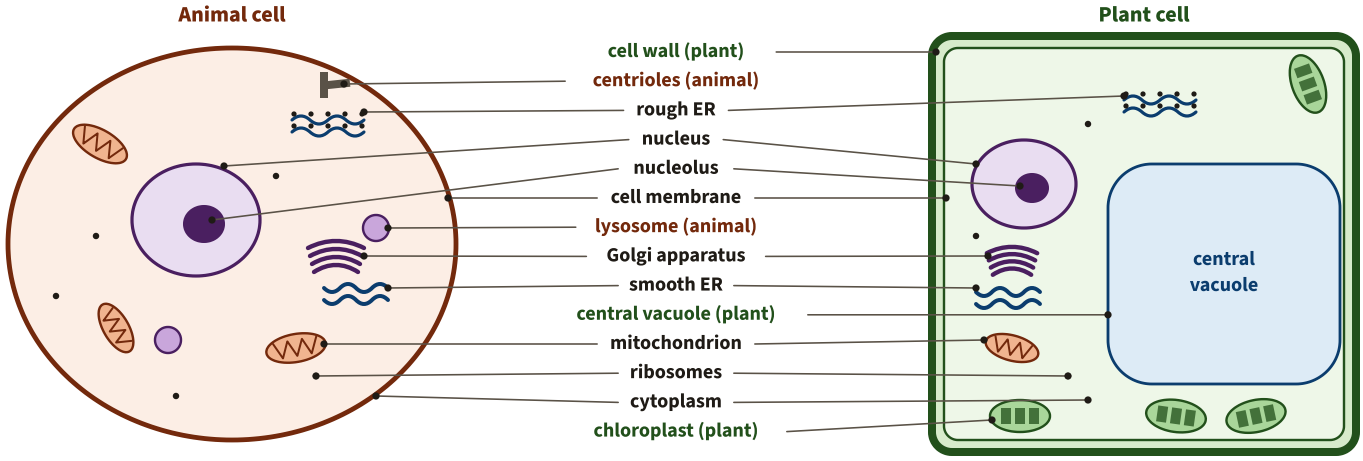
A human enzyme works fastest near body temperature; above it the shape breaks down.

MEMORY TRICK

Enzymes end in -ase and never go to waste

Look for **-ase**, and remember an enzyme comes out of the reaction **unchanged**, ready to work again.

3 CELLS



Animal and plant cells (not to scale). Labels in the middle point to the part in each cell; color tags mark parts found in only one.

Cell theory

- All living things are made of **cells**.
- The cell is the basic unit of **structure and function**.
- All cells come from **existing cells** (Virchow, 1855).

Hooke (1665), Schleiden, Schwann.

MEMORY TRICK **Pro = no**

Prokaryotes have **no** nucleus; **eu**karyotes have a true one. (Traditional.)

Why cells stay small WORKED

surface area ÷ volume falls as a cell grows

1 cm cube: SA = 6 cm^2, V = 1 cm^3 → **6 : 1**

2 cm cube: SA = 24 cm^2, V = 8 cm^3 → **3 : 1**

half the ratio

Organelles at work

Part	Job
Nucleus	holds DNA; control center
Nucleolus	makes ribosome parts
Ribosome	builds proteins
Rough ER	ribosome-studded; makes and ships proteins
Smooth ER	makes lipids; detoxifies
Golgi apparatus	modifies, sorts and packages
Mitochondrion	cellular respiration: makes ATP
Lysosome	digests waste and worn parts
Vacuole	stores water and materials
Chloroplast	photosynthesis (plants, algae)
Cell membrane	controls what enters and leaves
Cell wall	rigid support (plants: cellulose)
Cytoskeleton	protein fibers: shape, movement

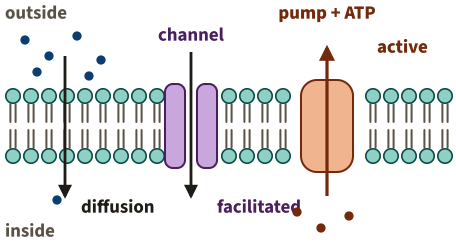
Two cell types

	Prokaryote	Eukaryote
Nucleus	no (DNA loop in cytoplasm)	yes
Membrane organelles	none	many
Size	1–5 µm	10–100 µm
Ribosomes	yes (small)	yes
Examples	bacteria, archaea	protists, fungi, plants, animals

MEMORY TRICK **The factory**

Nucleus = **front office**, ribosomes = **workers**, ER = **assembly line**, Golgi = **shipping dock**, mitochondria = **power plant**, lysosomes = **cleanup crew**. (Traditional comparison.)

4 MEMBRANES & TRANSPORT



Passive transport runs down the concentration gradient; active transport pumps against it and uses ATP.

Fluid mosaic — a phospholipid bilayer (water-loving heads out, water-fearing tails in) with proteins drifting in it

Selectively permeable — lets only some substances through

Osmosis and tonicity

Outside solution	Water moves	Animal cell	Plant cell
Hypotonic (less solute)	in	swells, may burst	firm (turgid): best
Isotonic (equal)	in = out	normal	limp (flaccid)
Hypertonic (more solute)	out	shrivels	plasmolysis: membrane pulls from wall

MEMORY TRICK **Water chases salt**

Water moves toward **more dissolved stuff**: hyper outside, water leaves; hypo, water enters. (After the traditional "water follows salt.")

Ways across the membrane

Kind	Energy?	How
Diffusion	no	high → low (O_2, CO_2)
Facilitated diffusion	no	high → low via a channel or carrier (glucose)
Osmosis	no	water moves toward more solute
Active transport	ATP	low → high by a pump (Na^+/K^+)
Endo- / exocytosis	ATP	membrane folds in / vesicles fuse out

Potato in salt water WORKED

mass 5.00 g → 4.60 g after 1 h

$$\% \text{ change} = \frac{4.60 - 5.00}{5.00} \times 100 = \mathbf{-8.0\ \%}$$

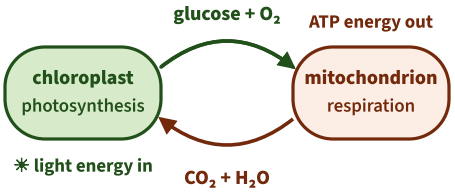
lost water: solution was hypertonic

5 ENERGY: PHOTOSYNTHESIS & RESPIRATION

ATP adenosine triphosphate; the cell's energy "cash"; ATP → ADP + P releases energy

Autotroph makes its own food (plants, algae)

Heterotroph eats other organisms (animals, fungi)



The two processes run in opposite directions: the products of one are the reactants of the other.

Photosynthesis

In chloroplasts. Chlorophyll absorbs red and blue light and reflects green.

$$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$$

Photosynthesis in two stages

Stage	Where	In	Out
Light reactions	thylakoid membranes	light, H_2O	O_2, ATP, NADPH
Calvin cycle	stroma	CO_2, ATP, NADPH	sugar (G3P → glucose)

Rate goes up with…

- more **light**, more **CO_2**, warmer **temperature**, until something else runs short (a limiting factor) or heat damages enzymes.

Cellular respiration

Aerobic (needs oxygen); mostly in mitochondria.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

MEMORY TRICK **Go Keep Eating**

Glycolysis → **K**rebs → **E**lectron transport: the order the cell "eats" glucose.

Respiration in three stages

Stage	Where	Net ATP
Glycolysis	cytoplasm	2
Krebs (citric acid) cycle	mitochondrial matrix	2
Electron transport chain	inner membrane	≈ 26–34

Total: about **30–38 ATP** per glucose. Oxygen is the final electron acceptor and becomes water.

Mass is conserved WORKED

180.2 g glucose + 192.0 g O_2 *1 mol + 6 mol*

→ 264.1 g CO_2 + 108.1 g H_2O: **372.2 g** each side

Fermentation (no oxygen)

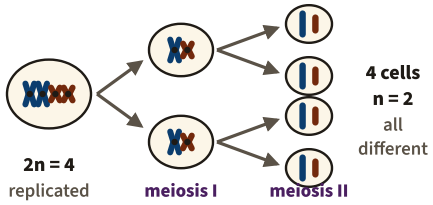
	Lactic acid	Alcoholic
Who	muscles, some bacteria (yogurt)	yeast (bread, brewing)
Products	lactic acid	ethanol + CO_2
ATP per glucose	2	2

6 CELL CYCLE, MITOSIS & MEIOSIS

The cell cycle

- **G1**: cell grows, does its job.
- **S**: DNA is copied (synthesis).
- **G2**: prepares to divide.
- **M**: mitosis (nucleus divides), then **cytokinesis** (cytoplasm divides).

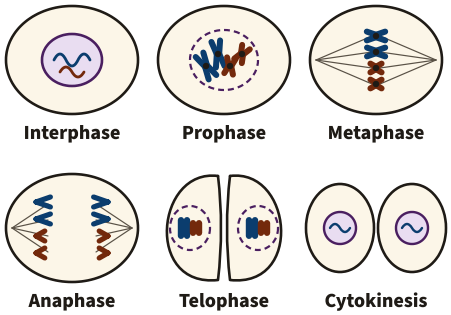
G1 + S + G2 = **interphase** (about 90 % of the cycle). Checkpoints stop a damaged cell; when they fail, cells divide out of control (**cancer**).



Meiosis I separates homologous pairs; meiosis II separates sister chromatids.

Mitosis vs meiosis

	Mitosis	Meiosis
Purpose	growth, repair	eggs and sperm
Divisions	1	2
Cells made	2 identical	4 different
Chromosomes	2n → 2n	2n → n
Crossing over	no	yes (prophase I)



Mitosis in a cell with 2n = 4 (blue = long pair, rust = short pair).

Mitosis step by step

Phase	What happens
Prophase	chromosomes condense; nuclear envelope breaks down; spindle forms
Metaphase	chromosomes line up at the middle
Anaphase	sister chromatids pulled to opposite poles
Telophase	two nuclei form; chromosomes unwind
Cytokinesis	animal: cell pinches (furrow); plant: cell plate forms

MEMORY TRICK

PMAT: Please Make Another Twin

Prophase, **M**etaphase, **A**naphase, **T**elophase (PMAT is traditional; the sentence is new). Metaphase = **M**iddle; Anaphase = **A**part.

Chromatid one of two identical copies joined at the centromere

Homologous pair one chromosome from each parent, same genes

Diploid (2n) two sets; human body cells 46

Haploid (n) one set; human egg or sperm 23

Sources of variety in meiosis

- **Crossing over**: homologs swap segments.
- **Independent assortment**: pairs line up at random.
- **Random fertilization**: any egg with any sperm.

Nondisjunction: chromosomes fail to separate (Down syndrome: three copies of chromosome 21).

Combinations WORKED

human: n = 23 pairs, each lines up 2 ways

2^{23} = **8,388,608** kinds of gametes

before crossing over

7 MENDELIAN GENETICS

Gene	a stretch of DNA that codes for a trait
Allele	one version of a gene (B or b)
Dominant	shows with one copy (capital: B)
Recessive	shows only with two copies (bb)
Homozygous	two alike (BB, bb)
Heterozygous	two different (Bb), a hybrid
Genotype	the alleles (Bb)
Phenotype	the trait you see (black fur)

	B	b
B	BB	Bb
b	Bb	bb

Bb × Bb

	b	b
B	Bb	Bb
b	bb	bb

test cross: any bb pup means the parent was Bb

Mendel's numbers WORKED

F_2 seeds: 5474 round, 1850 wrinkled

$\frac{5474}{1850} = \mathbf{2.96 : 1} \approx 3 : 1$

what a Bb × Bb cross predicts

	BR	Br	bR	br
BR	BBRR	BBRr	BbRR	BbRr
Br	BBRr	BBrr	BbRr	Bbrr
bR	BbRR	BbRr	bbRR	bbRr
br	BbRr	Bbrr	bbRr	bbrr

Dihybrid BbRr × BbRr: gametes BR, Br, bR, br; 9 : 3 : 3 : 1 (shaded: both dominant).

Probability rules

Multiply for independent events together; add for exclusive outcomes.

and: P(A) × P(B)

or: P(A) + P(B)

Mendel's laws (1865)

- **Segregation**: each parent passes on one of its two alleles.
- **Independent assortment**: genes on different chromosomes sort separately.
- **Dominance**: one allele can mask another.

Mendel, an Augustinian friar, counted about 28,000 pea plants.

Use the rules WORKED

BbRr × BbRr: P(bbrr) = $\frac{1}{4} \times \frac{1}{4} = \mathbf{\frac{1}{16}}$

Bb × Bb: P(shows dominant) = $\frac{1}{4} + \frac{1}{2} = \mathbf{\frac{3}{4}}$

BB or Bb

four children of Bb × Bb, all bb: $(\frac{1}{4})^4 = \mathbf{\frac{1}{256}}$

each child is independent

MEMORY TRICK

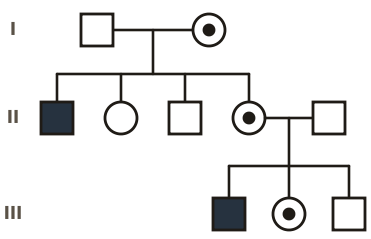
Each child is a new coin toss

Earlier children never change the odds for the next one: three girls in a row still leave $\mathbf{\frac{1}{2}}$ for a boy.

8 BEYOND MENDEL: SEX LINKAGE & PEDIGREES

Non-Mendelian patterns

Pattern	What happens	Example
Incomplete dominance	blend in hybrids	red × white snapdragons → pink; F_2 1 : 2 : 1
Codominance	both show fully	roan cattle (red and white hairs); AB blood
Multiple alleles	more than two alleles	ABO blood: I^A, I^B, i
Polygenic	many genes, a smooth range	height, skin color, eye color
Environment	conditions affect the trait	hydrangea color and soil pH



X-linked recessive pedigree: □ male, ○ female, shaded affected, dot carrier; rows are generations.

ABO blood types

Blood type	Genotypes	Antigen on red cells
A	I^AI^A, I^Ai	A
B	I^BI^B, I^Bi	B
AB	I^AI^B	A and B
O	ii	none

Blood type cross WORKED

$I^Ai \times I^Bi$

¼ AB, ¼ A, ¼ B, ¼ O *all four from two parents*

Sex chromosomes

- 22 pairs of **autosomes** + 1 pair of **sex chromosomes**.
- Female **XX**; male **XY**. Every egg carries X; a sperm carries X or Y, so P(boy) = P(girl) = ½.

Reading a pedigree

Clue in the chart	Points to
Affected child, unaffected parents	recessive
Every affected child has an affected parent	dominant
Mostly males, via carrier mothers	X-linked recessive

Sex-linked (X-linked) trait gene on the X chromosome; Y has no matching allele

Carrier a female with one recessive allele (X^HX^h): unaffected but can pass it on

	X^H	Y
X^H	X^HX^H	X^HY
X^h	X^HX^h	X^hY

Carrier mother × normal father (shaded: affected).

Reading the square

- Daughters: **½ carriers**, none affected. Sons: **½ affected**. Overall ¼.

Examples: red-green color blindness, hemophilia, Duchenne muscular dystrophy.

MEMORY TRICK

Sons get their X from Mom

A boy's only X comes from his **mother**, so X-linked recessive traits show mostly in **males** and skip through carrier daughters.

9 DNA & REPLICATION

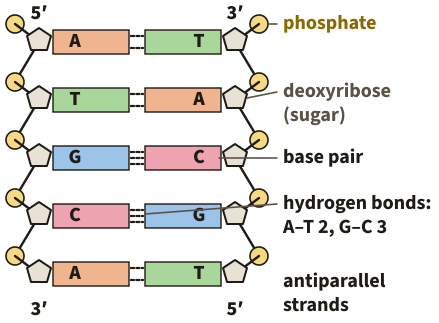
Finding the genetic material

Year	Who	Found
1928	Griffith	a "transforming principle" turned harmless bacteria deadly
1944	Avery, MacLeod, McCarty	the principle is DNA
1952	Hershey & Chase	virus DNA, not protein, enters cells
1952	Franklin (Photo 51)	X-ray pattern of a helix
1953	Watson & Crick	double-helix model

Replication

- **Helicase** unzips the helix at the origin.
- **Primase** lays a short RNA primer.
- **DNA polymerase** adds matching nucleotides 5′→3′ and proofreads.
- Leading strand: continuous; **lagging** strand: in Okazaki fragments joined by **ligase**.

Semiconservative: each new helix keeps one old strand and one new one.



A DNA ladder (untwisted). The rungs are base pairs; the rails are sugar and phosphate.

MEMORY TRICK

Apple in the Tree, Car in the Garage

A pairs with **T**, **C** pairs with **G**. (Traditional.)

Chargaff's rule WORKED

A sample is 30 % A

T = **30 %**; G + C = 40 %, so G = **20 %**, C = **20 %**

A = T, G = C

Nucleotide phosphate + sugar (deoxyribose) + base

Purines A, G (two rings)

Pyrimidines C, T, U (one ring)

Antiparallel one strand runs 5′→3′, its partner 3′→5′

Write the partner strand WORKED

5′ ATG CCT AGA 3′

3′ **TAC GGA TCT** 5′ *A–T, G–C*

DNA vs RNA

	DNA	RNA
Sugar	deoxyribose	ribose
Strands	2 (double helix)	1
Bases	A, T, G, C	A, U, G, C
Where	nucleus	nucleus and cytoplasm
Job	stores the code	carries it out (mRNA, tRNA, rRNA)

10 GENE EXPRESSION & MUTATIONS

first base	second base U	second base C	second base A	second base G	third base
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA **Stop**	UGA **Stop**	A
	UUG Leu	UCG Ser	UAG **Stop**	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG **Met (start)**	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

The genetic code (mRNA codons). Find the first base at left, the second at top, the third at right.

DNA to protein WORKED

template DNA: 3′ TAC CGA AGT ATT 5′

mRNA: 5′ **AUG GCU UCA UAA** 3′ *pair A→U, T→A, G→C, C→G*

protein: **Met – Ala – Ser – stop** *read the table*

Kinds of mutations

Mutation	Change	Effect
Silent	base swap, same amino acid	none
Missense	base swap, new amino acid	sickle cell: GAG → GUG, Glu → Val
Nonsense	base swap makes a stop	short, broken protein
Frameshift	insert or delete 1–2 bases	every later codon changes (THE CAT → TEC AT…)
Chromosomal	deletion, duplication, inversion, translocation	many genes affected

The central dogma

Transcription (DNA → mRNA, in the nucleus), then **translation** (mRNA → protein, at a ribosome).

DNA → RNA → protein

Transcription

- **RNA polymerase** binds a **promoter** and copies the template strand.
- In eukaryotes the pre-mRNA is edited: **introns** cut out, **exons** joined, cap and tail added.

Translation

- The ribosome reads mRNA three bases at a time (a **codon**).
- Each **tRNA** has an **anticodon** that matches a codon (GCU ↔ CGA) and carries one amino acid.
- Starts at **AUG** (Met); ends at a stop codon (UAA, UAG, UGA).

MEMORY TRICK **Copy, then Cook**

Transcription = **t**ranscribe a copy of the recipe;
Translation = **t**urn it into the meal (protein).

Mutagen raises the mutation rate: UV, X-rays, some chemicals

Repair enzymes fix most errors; most mutations are neutral or damaging

11 BIOTECHNOLOGY

Biotech tools

Tool	What it does	Used for
PCR (1983)	copies one DNA segment over and over	testing, forensics
Gel electrophoresis	sorts DNA fragments by size; small ones travel farthest	DNA fingerprints
Restriction enzyme	cuts DNA at a set sequence (EcoRI: GAATTC)	cutting and pasting genes
Recombinant DNA	a gene inserted into another organism	human insulin made by bacteria (since 1982)
CRISPR (2012)	guided enzyme edits a chosen DNA site	research, gene therapy
Sequencing	reads the order of bases	Human Genome Project (2003)

PCR doubling

Heat to separate strands (≈ 95 °C), cool so primers bind, let a heat-proof polymerase build (≈ 72 °C); repeat.

$$\text{copies} = 2^n$$

EX 30 cycles: 2^{30} = **1,073,741,824** ≈ a billion copies

Reading a gel

- DNA is negative, so it moves toward the **+** end.
- Shorter fragments move **farther**.
- Matching band patterns = matching DNA.

Bioethics

- Every human life has worth at every stage, so treating a sick patient is a mercy, while making or destroying embryos for research treats persons as products.
- Ask of any technique: what is it for, who bears the risk, and does it respect human life?

12 VARIATION, ADAPTATION & ORIGINS

Natural selection: the observable steps

- Individuals **vary**.
- Much variation is **inherited**.
- More offspring are born than **survive**.
- Those with helpful traits survive and **reproduce more**, so those traits become more common.

Selection **sorts existing variation**; it does not create new traits.

Adaptation — an inherited trait that helps survival and reproduction in an environment

Artificial selection — humans choose which animals or plants breed

Microevolution — small changes within a population, such as allele frequencies

Macroevolution — large-scale change, such as new body plans, proposed over long ages

Kind — in creation biology, an originally created group whose members can vary and sometimes interbreed (often near the family level)

Selection in numbers WORKED

beetles 80 % green, 20 % brown; birds eat ½ of green, $\frac{1}{10}$ of brown

left: 40 green, 18 brown per 100 → $\frac{40}{58}$ ≈ **69 % green, 31 % brown**

brown rises

Observation vs. interpretation

- **Observed**: variation, heredity, selection within populations, fossils in rock layers, similar bones and DNA.
- **Inferred** about the unobserved past: who descended from whom, and when.
- Darwin (Beagle, 1831–36) observed island variation; universal common descent was his inference.

The case for universal common descent, as each side presents it

Evidence offered for common descent	Open questions critics raise
fossil sequences (Tiktaalik, whale series)	Cambrian explosion: body plans appear suddenly
homology (arm, wing, flipper)	similarity can also reflect common design
molecular similarity; shared "broken" genes	"junk" DNA and vestigial claims often revised
biogeography; vestigial structures	origin of new genetic information; origin of life; timescales

Weigh it fairly

- All agree variation and natural selection are real.
- They differ on the age of the earth, the reach of natural processes, the origin of new kinds and of humans, and how to read Genesis.
- State each view so its holders would agree: "He that is first in his own cause seemeth just; but his neighbour cometh and searcheth him" (Proverbs 18:17, KJV).

Observed by everyone

Example	What was observed
Galápagos finches (Grants, 1973–)	1977 drought: deeper beaks survived; average depth rose about 4 %. After 1983 rains smaller beaks were favored.
Peppered moths	dark moths common on sooty trees; light moths returned after clean-air laws
Antibiotic resistance	resistant bacteria survive a drug and multiply; finish every prescription

Views of origins, stated fairly

View	Its holders say
Young-earth creation	Genesis is history: six ordinary days thousands of years ago; created kinds vary within limits; a global Flood laid down most fossil-bearing rock
Old-earth creation	the earth is billions of years old, but God created distinct kinds by special acts
Intelligent design	some features (irreducible complexity, information in DNA) are best explained by an intelligent cause
Darwinian theory	all life descends from a common ancestor by natural processes, chiefly mutation and selection; theistic evolutionists see this as God's method

MEMORY TRICK **See it, then say it**

What you can **see** (variation, selection) is observation; what you **say** happened long ago is interpretation. Label which is which.

13 CLASSIFICATION & MICROBES

Three domains, six kingdoms

Domain	Kingdom	Cells	Wall	Food	Examples
Bacteria	Bacteria	prokaryote	peptidoglycan	auto / hetero	E. coli, Streptococcus
Archaea	Archaea	prokaryote	no peptidoglycan	auto / hetero	hot-spring, salt-lake microbes
Eukarya	Protista	eukaryote, mostly 1 cell	some	auto / hetero	amoeba, algae
Eukarya	Fungi	eukaryote, most many	chitin	hetero (absorb)	mushrooms, yeast, molds
Eukarya	Plantae	eukaryote, many	cellulose	auto	mosses, ferns, pines, flowers
Eukarya	Animalia	eukaryote, many	none	hetero (ingest)	sponges, insects, fish, people

Naming

- **Linnaeus** (1735) sorted life into nested groups.
- Binomial name: **Genus species**, italic, genus capitalized: *Canis lupus*, *Homo sapiens*.

MEMORY TRICK

Daring Kids Pack Crisp Oranges For Great Snacks

Ranks from broad to narrow: **D**omain, **K**ingdom, **P**hylum, **C**lass, **O**rder, **F**amily, **G**enus, **S**pecies.

Species organisms that can interbreed and produce fertile offspring

Dichotomous key two choices at each step lead to a name (needles in bundles → pine)

Bacteria vs viruses

	Bacteria	Viruses
Living cell?	yes	no; genes in a protein coat
Size	1–5 µm	20–300 nm
Reproduce	binary fission	only inside a host cell
Treated by	antibiotics	not antibiotics; vaccines prevent some
Helpful roles	decomposers, nitrogen fixers	research tools

Shapes cocci (spheres), bacilli (rods), spirilla (spirals)

Lytic / lysogenic virus bursts the cell now / hides in host DNA, activating later

Vaccine a harmless form or part of a germ trains the immune system (Jenner, 1796)

Bacterial growth WORKED

1 cell, doubling every 20 min, for 3 h

3 h = 9 doublings → 2^9 = **512 cells**

Protozoa animal-like protists: amoeba, paramecium, Plasmodium (malaria)

Algae plant-like: diatoms, kelp, Euglena

Molds fungus-like: slime molds, potato blight

Fungi

- Bodies of threadlike **hyphae** forming a **mycelium**; walls of **chitin**.
- Absorb food: **decomposers** that recycle nutrients.
- Reproduce by **spores**; yeast by budding.
- Uses: bread and cheese, antibiotics (Fleming found **penicillin** in a mold, 1928); harms: athlete's foot, crop rusts.

14 PLANTS & ANIMALS

Plant groups

Group	Vessels?	Seeds?	Examples
Nonvascular	no	no (spores)	mosses, liverworts
Seedless vascular	yes	no (spores)	ferns, horsetails
Gymnosperms	yes	naked, in cones	pines, firs, cycads
Angiosperms	yes	in fruit; flowers	grasses, oaks, roses

Xylem carries water and minerals up from roots

Phloem carries sugar from leaves to the rest of the plant

Stomata leaf pores run by guard cells: CO_2 in, water vapor out

Transpiration water loss from leaves; pulls water up

MEMORY TRICK

Xylem goes up, phloem flows food

Xylem lifts water **up** like a ladder; **ph**loem moves **f**ood (sugar) wherever it is needed.

Two kinds of flowering plants

	Monocot	Dicot
Seed leaves	1	2
Leaf veins	parallel	net
Flower parts	threes	fours or fives
Examples	corn, lilies	beans, oaks

Flower parts

- Male **stamen** = anther (pollen) + filament.
- Female **pistil** = stigma + style + ovary (ovules).
- Petals attract pollinators.

After fertilization the ovule becomes a **seed**, the ovary a **fruit**.

Vertebrate classes

Class	Traits
Fish	gills, fins, scales; ectotherm
Amphibians	moist skin; young in water
Reptiles	dry scales; shelled eggs on land
Birds	feathers, hollow bones, endotherm
Mammals	hair, milk, endotherm; most bear live young

Major animal phyla

Phylum	Key traits	Examples
Sponges	pores; no tissues	bath sponge
Cnidarians	stinging cells; radial	jellyfish, coral
Flatworms	flat; one gut opening	planaria
Roundworms	round; two-opening gut	hookworm
Mollusks	mantle; often a shell	snail, octopus
Annelids	segmented worms	earthworm
Arthropods	jointed legs; exoskeleton	insects, crabs
Echinoderms	spiny skin; tube feet	sea star
Chordates	notochord; nerve cord	fish to mammals

Every phylum but the chordates is **invertebrate** (no backbone). Symmetry: radial, bilateral or none.

MEMORY TRICK **Arthropod body count**

Insects **6** legs (3 body parts), spiders **8** (2 parts), crustaceans **10+**.

15 THE HUMAN BODY

11 organ systems

System	Main organs	Job
Skeletal	bones, joints	support, protect, make blood cells
Muscular	skeletal, smooth, heart muscle	movement, heat
Circulatory	heart, blood vessels, blood	carry O_2, food, wastes
Respiratory	nose, trachea, lungs (alveoli)	gas exchange
Digestive	mouth, stomach, intestines, liver	break down and absorb food
Excretory	kidneys, bladder, skin	remove wastes, balance water
Nervous	brain, spinal cord, nerves	sense, control, think
Endocrine	glands (pituitary, thyroid, pancreas)	hormone signals
Immune	white blood cells, lymph nodes	fight disease
Integumentary	skin, hair, nails	barrier, temperature
Reproductive	ovaries, testes	make eggs or sperm; continue the family

Homeostasis by negative feedback

- A change triggers a response that **reverses** it.
- Too hot → sweat; too cold → shiver.
- Blood sugar high → pancreas releases **insulin**; low → **glucagon**.

Path of blood

- body → right atrium → right ventricle → **lungs** → left atrium → left ventricle → aorta → body

Arteries carry blood **away** from the heart; veins return it; capillaries trade with cells.

MEMORY TRICK **A for Away**

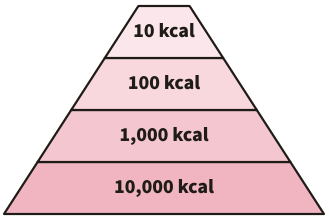
Arteries carry blood **a**way from the heart; veins bring it back in. (Traditional.)

16 ECOLOGY & STEWARDSHIP

Biotic / abiotic living parts / nonliving parts (water, light, soil)

Ecosystem a community of species plus its nonliving setting

Niche an organism's role; habitat is where it lives



About 10 % of the energy at one level becomes the next level's body; the rest is used for living or lost as heat.

The 10 % rule WORKED

producers capture 50,000 kcal

herbivores 5,000 → carnivores 500 → top carnivores **50 kcal**

× 0.1 at each step

MEMORY TRICK

Ten percent, the rest is spent

About a **tenth** moves up each step, so chains seldom pass five links. Energy flows one way; matter cycles.

Dominion and care

- Stewardship: measure and manage living resources wisely.
- Bison fell to about a thousand by the late 1880s and recovered under protection and ranching; Duck Stamp sales (since 1934) fund wetland refuges.

Species interactions (+ helped, – harmed, 0 neither)

Relationship	Effect	Example
Mutualism	+ / +	bee and flower
Commensalism	+ / 0	barnacles on a whale
Parasitism	+ / –	tick on a dog
Predation	+ / –	owl and mouse
Competition	– / –	two plants for light

Water cycle

- evaporation → condensation (clouds) → precipitation → runoff and groundwater → back to the sea; plants add **transpiration**.

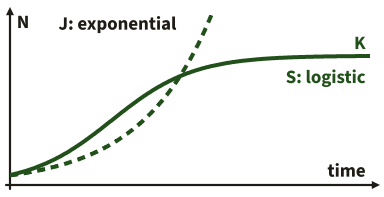
"All the rivers run into the sea; yet the sea is not full" (Ecclesiastes 1:7, KJV).

Carbon cycle

- Photosynthesis pulls CO_2 into sugar; respiration, decay and burning return it. Stores: oceans, rock, soil, fossil fuels.

Nitrogen cycle

- Air is 78 % N_2, unusable by most organisms.
- **Fixation**: soil and root-nodule bacteria (and lightning) make ammonia and nitrates.
- Plants absorb nitrates; animals eat plants; decomposers return ammonia; **denitrifying** bacteria release N_2.



Unlimited resources give a J curve; limits bend it into an S that levels off at the carrying capacity K.

Trophic levels

Level	Gets energy from	Examples
Producer	sunlight (photosynthesis)	grass, algae, trees
Primary consumer	producers (herbivore)	rabbit, grasshopper, deer
Secondary consumer	herbivores	frog, snake, fox
Tertiary consumer	other carnivores	hawk, wolf
Decomposer	dead matter of every level	bacteria, fungi

Carrying capacity (K) the largest population the environment can support

Density-dependent limits that grow with crowding: food, disease, predators

Density-independent fire, flood, freeze

Succession community change: primary (bare rock, lichens first) or secondary (soil remains)

Density and growth WORKED

density = number ÷ area: 240 deer on 12 km² → **20 per km²**

start 500; +120 born, −70 died → $\frac{50}{500}$ = **10 %** growth

add immigrants, subtract emigrants

Mark and recapture WORKED

mark 50 fish; later catch 40, of which 8 are marked

$N = \frac{50 \times 40}{8}$ = **250 fish** *marked fraction matches*