Biology Study Guide

Properties of Water

- Polar (+ and − ends)
- High cohesion & adhesion ⇒ high surface tension
- High specific heat capacity
- Ice less dense than water (floats)
- Universal solvent
- Amphoteric (acid & base)
- Always contains some ions

Basic Chemistry

- Main elements of life: O, C, H, N
- **Covalent bonds:** share valence electrons
- **Ionic bonds:** electron stripped away; attraction between ions; (+) = cation, (−) = anion
- **H-bonds:** e^- pulled from H ⇒ partial + charge ⇒ attracted to electronegative atoms

Other Chemistry Notes

- Carbon's 4 valence e^- = huge molecular variety
- Isomers: same atoms, different shape
- Key groups: −OH (hydroxyl), >C=O (carbonyl), −COOH (carboxyl), $-NH_2$ (amino), −SH (sulfhydryl), $-OPO_3{}^{2-}$ (phosphate), $-CH_3$ (methyl)
- Dehydration synthesis: form bonds by removing H_2O
- Hydrolysis: break bonds by adding H_2O
- Protein denaturing: wrong shape ⇒ nonfunctional

Macromolecules

Carbohydrates

- Monomer: monosaccharide | Polymer: polysaccharide
- Ex: glucose (M), cellulose (P)
- Shape: carbon chain or ring
- Function: energy storage & structure

Lipids

- Not true polymers; components = fatty acids + glycerol
- Saturated fats: no double bonds; unsaturated: have double bonds
- Shape: glycerol head + fatty acid tails; steroids = 4 fused C rings
- Function: energy storage, cell membrane, signaling

Proteins

- Monomer: amino acid | Polymer: polypeptide
- Ex: glycine (M), insulin (P)
- AA shape: central C + H + carboxyl + side chain + amino
- Chain folds into 3D shape
- Function: enzymes, structure, transport

Level	Description
Primary (1°)	Sequence of amino acids
Secondary (2°)	Folding/bending of chain
Tertiary (3°)	Overall 3D shape
Quaternary (4°)	Multiple chains together

Nucleic Acids

- Monomer: nucleotide | Polymer: nucleic acid
- Ex: adenine (M), DNA (P)
- Nucleotide = N-base + pentose + phosphate
- DNA: deoxyribose, no uracil; double helix
- Function: instructions for making proteins

DNA	RNA
Double stranded	Single strand
Deoxyribose	Ribose
A, T, C, G	A, U, C, G
Stores genes	Protein production
A pairs w/ T	A pairs w/ U
Double helix	Single strand

Cells & Organelles

Organelle	In	Function
Ribosomes	Both	Protein synthesis
Rough ER	Euk.	Protein synth. & folding
Smooth ER	Euk.	Lipid synth. & detox
Golgi	Euk.	Modify/sort/transport
Mitochondria	Euk.	Cellular respiration
Chloroplast	Plants	Photosynthesis
Lysosome	Animals	Digestion/autophagy
Vacuole	Euk.	Storage / plant struct.

Other Cell Structures

- Nucleus: double membrane w/ pores
- Nucleolus: makes ribosomes
- Chromatin: DNA + protein strands
- Centrosome: makes microtubules
- Cytoskeleton (small→big): microfilaments → intermediate → microtubules

Endosymbiotic Theory

Big prokaryote engulfed smaller ones → eukaryotes.

- Mito. & chloroplasts have own DNA
- Reproduce independently
- Have double membrane

Cell Membrane

- Phospholipids: lipid bilayer
- Cholesterol: maintains fluidity
- Peripheral proteins: signaling; no passage
- Integral proteins: span bilayer; move molecules
- Glycoproteins/glycolipids: extend carbs for signaling

Selective Permeability

- Small nonpolar → freely diffuse
- Small uncharged polar → slower diffusion
- Large/ions → need membrane proteins

Active & Passive Transport

- Passive: no ATP; with concentration gradient
- Active: ATP; against concentration gradient
- Passive structures: simple diffusion (membrane), facilitated diffusion (carrier/channel proteins)
- Active structure: carrier proteins powered by ATP
- Ex: Na^+/K^+ pump (active), aquaporin (passive)

Osmosis & Diffusion

- Diffusion: high → low concentration (entropy)
- Osmosis: water moves across membrane from low solute → high solute
- Hypotonic: low exterior solute; Hypertonic: high exterior; Isotonic: equal

Water Potential: $\Psi = -(\text{ion val.})(\text{mol. conc.})(0.0831)(273 + C) + P$

Enzymatic Reactions

- Substrate binds active site (exact fit or induced fit); enzyme lowers activation energy
- Allosteric regulation: molecule binds elsewhere → shape change; pH extremes & high temp → denaturation

Photosynthesis

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

Light Reactions

- PSII splits $H_2O \rightarrow \frac{1}{2}\,O_2 + 2H^+$; electrons excited (P680)
- ETC pumps 4 H^+ per H_2O through membrane
- PSI excites e^- again → 12 NADPH
- ATP synthase makes 18 ATP (4 H^+/ATP)

Calvin Cycle

- 2 cycles per glucose; uses 18 ATP + 12 NADPH
- Output: 2 G3P, 12 $NADP^+$, 18 ADP, 6 H_2O
- Fixation: Rubisco binds CO_2 to RuBP
- Reduction: 6 CO_2 → 6 G3P
- Regeneration: 5 G3P → 3 RuBP

Cellular Respiration

Equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$

- **Glycolysis:** glucose → 2 pyruvate; net 2 ATP + 2 NADH
- **Krebs:** pyruvate → AcCoA → oxaloacetate; yields 6CO_2, 8 NADH, 2 $FADH_2$, 2 ATP
- **Ox. Phosphorylation:** $NADH/FADH_2$ → proton gradient → 26–28 ATP
- **Fermentation:** no O_2 → 2 ATP only; pyruvate → ethanol/lactate; recycles NAD^+

Key Terms: Reduction = gain e^-; Oxidation = lose e^-; $-\Delta G$ = spontaneous; exergonic = releases energy; endergonic = uses energy; catabolic = break; anabolic = build

Cell Communication

Type	Signal	Example
Autocrine	Growth factors	Cancer growth
Paracrine	Neurotransmitters	Synaptic signaling
Endocrine	Insulin/glucagon	Blood sugar
Juxtacrine	Membrane ligands	T-cell activation

- **Neg. feedback:** corrects to set point (homeostasis, blood sugar)
- **Pos. feedback:** amplifies deviation (clotting, ripening)
- Secondary messengers amplify signals; phosphorylation cascade
- Apoptosis: programmed cell death; tumor suppressors stop cycle/repair DNA

The Cell Cycle

Interphase

G1: growth/metabolism → S: DNA replication → G2: prep for division

Mitosis Phases

Prophase: chromatin condenses, spindle forms → Prometaphase: envelope breaks, spindle attaches → Metaphase: align at plate → Anaphase: chromatids to poles → Telophase: nuclei reform → Cytokinesis: 2 daughter cells Cyclins accumulate → activate CDKs → pass checkpoints; failed checkpoint → repair or apoptosis

Mitosis vs. Meiosis

Mitosis	Meiosis
Growth/healing	Sex cell production
2 identical diploid	4 different haploid
Somatic cells	Germ cells
1 division	2 divisions
Regular chromosomes	Tetrads

- **Crossing over:** Prophase I; arms swap alleles with non-sister chromatid → variation
- **Independent assortment:** random chromosome distribution to daughter cells
- **Random fertilization:** any sperm + any egg

Genetics & Punnett Squares

- Monohybrid (Aa×Aa): 25% AA, 50% Aa, 25% aa → 3:1 dominant:recessive
- Dihybrid (AaBb×AaBb): 9:3:3:1 ratio
- **Gene linkage:** recom. freq. <50% → genes on same chromosome; RF% = map units
- Probability: independent events → multiply; mutually exclusive → add

Mutations

Point Mutations

- Types: substitution, insertion, deletion
- Silent: no change; Missense: diff. AA; Nonsense: stop codon; Frameshift: shifts all downstream codons

Chromosome Mutations

Deletion, Duplication, Inversion, Translocation

DNA Replication (5' → 3')

Leading strand: continuous; Lagging strand: fragmented (Okazaki fragments)

Enzyme	Function
Topoisomerase	Relieves tension
Helicase	Splits strands
SSB proteins	Keep strands apart
DNA Primase	Creates RNA primer
DNA Pol III	Synthesizes most DNA
DNA Pol I	Replaces RNA primer
DNA Ligase	Joins Okazaki fragments

Transcription & Translation

- **Transcription:** RNA pol binds promoter; reads template → mRNA; pre-mRNA: introns spliced, poly-A tail (3'), 5' cap added
- **Translation:** mRNA → ribosome; tRNA matches codon → delivers AA; A → P → E site
- Gene regulation: transcription factors & operons = on/off switches for transcription

Evolution & Natural Selection

Natural Selection requires:: Variation in species · Overproduction · Heritable traits · Selection pressure

- **5 Evolutionary forces:** mutation, gene flow, sexual selection, genetic drift, natural selection
- Disruptive: extremes favored; Stabilizing: middle favored; Directional: one extreme favored
- Adaptive radiation: one species → many niches; Convergent evolution: unrelated species develop similar traits

Population Genetics

- Bottleneck: event ↓ population → shifts allele freq.
- Founder effect: founders' alleles dominate new population

Hardy-Weinberg Equilibrium

Requires: no mutation, no gene flow, random mating, large pop., no selection

Equations: $p + q = 1 \quad p^2 + 2pq + q^2 = 1$
p^2=hom. dom. $2pq$=het. q^2=hom. rec.

Reproductive Isolation

Pre-zygotic: geographic, ecological, temporal, behavioral, mechanical, gametic isolation
Post-zygotic: reduced viability, reduced fertility, hybrid breakdown

Biotechnology

- CRISPR: Cas9 cuts & replaces genes; viruses inject DNA
- Gel electrophoresis: sorts DNA by size via electric current through polymer
- PCR: heat → separate strands; DNA polymerase duplicates
- Transformation: plasmids introduced to bacteria

Human Effects on Biodiversity

Artificial selection (reduce variety) · Habitat destruction · Direct species pressure