Cambridge AS & A Level · Biology 9700

Biology 9700 formulas and definitions

All 158 formulas, facts and definitions to learn, by syllabus topic. Formulas the exam gives you are left out.

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AS Level

1 Cell structure

$\text{magnification} = \dfrac{\text{image size}}{\text{actual size}}$, with both sizes in the same unit

$\text{actual size} = \dfrac{\text{image size}}{\text{magnification}}$ and $\text{image size} = \text{actual size} \times \text{magnification}$

$1\ \text{mm} = 1000\ \mu\text{m}$ and $1\ \mu\text{m} = 1000\ \text{nm}$

Scale bar: $\text{magnification} = \dfrac{\text{measured length of bar}}{\text{length the bar represents}}$

Calibration: $1\ \text{graticule unit} = \dfrac{\text{length on stage micrometer}}{\text{number of graticule units that match it}}$

$\text{actual length} = \text{number of graticule units} \times \text{value of one unit}$

Light microscope: $\text{total magnification} = \text{eyepiece} \times \text{objective}$

Resolution: light microscope about 200 nm; electron microscope about 0.5 nm

2 Biological molecules

Monosaccharides: $(CH_2O)_n$; hexoses such as glucose and fructose: $C_6H_{12}O_6$

$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$ (maltose or sucrose)

Glucose polymer of n units: $(C_6H_{10}O_5)_n$ (plus one H_2O for the chain ends)

A chain of n monomers has $n - 1$ bonds; making it releases $n - 1$ water molecules, and hydrolysing it uses $n - 1$

Glycerol + 3 fatty acids → triglyceride + 3 H_2O (three ester bonds)

Saturated fatty acid: $C_nH_{2n}O_2$; each C=C in the tail means 2 fewer H

Amino acid: $H_2N{-}CHR{-}COOH$; glycine has R = H

Mass of a product of condensation = total mass of the parts − 18 for each water removed (relative masses: H = 1, C = 12, O = 16)

Haemoglobin: 2 α + 2 β chains, 4 haem groups, 4 Fe^{2+}, up to 4 O_2

3 Enzymes

$\text{rate} = \dfrac{1}{\text{time}}$ (for "time taken" results; unit s^{-1})

$\text{rate} = \dfrac{\text{change in amount of product (or substrate)}}{\text{time taken}}$

Initial rate = gradient of the tangent to the progress curve at $t = 0$

K_m = substrate concentration at which rate $= \frac{1}{2}V_{max}$ (units of concentration)

Low K_m = high affinity; high K_m = low affinity

Competitive inhibitor: V_{max} unchanged, K_m increases

Non-competitive inhibitor: V_{max} decreases, K_m unchanged

Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$

$2\text{H}_2\text{O}_2 \xrightarrow{\text{catalase}} 2\text{H}_2\text{O} + \text{O}_2$

Starch $\xrightarrow{\text{amylase}}$ maltose; iodine: orange-brown → blue-black with starch

4 Cell membranes and transport

Cube of side L: surface area $= 6L^2$, volume $= L^3$

Cuboid $a \times b \times c$: surface area $= 2(ab + ac + bc)$, volume $= abc$

Cylinder of radius r, length h: surface area $= 2\pi r^2 + 2\pi rh$, volume $= \pi r^2 h$

SA:V $= \dfrac{\text{surface area}}{\text{volume}}$, written as $n : 1$

Percentage change $= \dfrac{\text{final} - \text{initial}}{\text{initial}} \times 100$

Rate of diffusion $\propto \dfrac{\text{surface area} \times \text{concentration difference}}{\text{thickness}}$

Pure water has $\psi = 0$ kPa; solutions have negative ψ; water moves from higher (less negative) to lower (more negative) ψ

Membrane thickness about 7–10 nm

5 The mitotic cell cycle

Mitotic index $= \dfrac{\text{number of cells in mitosis}}{\text{total number of cells}} \times 100$

Percentage in a stage $= \dfrac{\text{cells in that stage}}{\text{total cells}} \times 100$

Number of cells after d divisions $= \text{starting number} \times 2^d$

Actual size $= \dfrac{\text{image size}}{\text{magnification}}$, magnification $= \dfrac{\text{image size}}{\text{actual size}}$

$1\ \text{mm} = 1000\ \mu\text{m} = 1\,000\,000\ \text{nm}$

6 Nucleic acids and protein synthesis

Base pairing in DNA: A–T (**2** hydrogen bonds), C–G (**3** hydrogen bonds)

Base pairing with RNA: A–U (2), T–A (2), C–G (3)

Double-stranded DNA: $\%A = \%T$, $\%C = \%G$, $\%A + \%G = 50\%$, so $\%C = \dfrac{100 - 2 \times \%A}{2}$

Hydrogen bonds $= 2 \times (\text{A–T pairs}) + 3 \times (\text{C–G pairs})$

Phosphodiester bonds: one strand of n nucleotides has $n - 1$; linear double-stranded DNA of n base pairs has $2(n - 1)$; circular DNA of n base pairs has $2n$

Triplet code: $4^3 = 64$ triplets for 20 amino acids; start codon AUG (methionine); 3 stop codons (UAA, UAG, UGA); 61 codons for amino acids

Number of amino acids $= \dfrac{\text{coding nucleotides in mRNA}}{3} - 1$ (the last codon is a stop); nucleotides for the amino acids alone $= 3\times$ amino acids

Replication forks $= \dfrac{\text{base pairs}}{\text{bp per second per fork} \times \text{time in seconds}}$

Number of amino acids $\approx \dfrac{\text{mass of polypeptide}}{\text{mean mass of an amino acid}}$

Meselson–Stahl: after g generations of ^{15}N DNA in ^{14}N, fraction hybrid $= \dfrac{2}{2^g}$, the rest light, none heavy

7 Transport in plants

Volume of water taken up $= \pi r^2 \times$ distance moved by the bubble (r = radius of the capillary)

Rate $= \dfrac{\text{distance or volume}}{\text{time}}$; rate per unit leaf area $= \dfrac{\text{rate}}{\text{leaf area}}$

Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$

Magnification $= \dfrac{\text{image size}}{\text{actual size}}$ (for drawings and scale bars)

Water moves from higher (less negative) to lower (more negative) water potential

Transpiration: ψ of mesophyll cell $>$ air spaces $>$ atmosphere

Loading at a source: sieve tube ψ falls, water enters, volume and pressure rise

Unloading at a sink: sieve tube ψ rises, water leaves, volume and pressure fall

Pressure in the xylem of a transpiring plant is negative (tension), lowest at the top

8 Transport in mammals

$\mathrm{CO_2 + H_2O \rightleftharpoons H_2CO_3}$ (catalysed by carbonic anhydrase, in red blood cells)

$\mathrm{H_2CO_3 \rightleftharpoons H^+ + HCO_3^-}$

$\mathrm{HbO_8 + H^+ \rightarrow HHb + 4\,O_2}$ (haemoglobinic acid)

$\mathrm{Hb} + \mathrm{CO_2} \rightarrow \mathrm{HbCO_2}$ (carbaminohaemoglobin)

$\mathrm{Hb} + 4\,\mathrm{O_2} \rightleftharpoons \mathrm{HbO_8}$: 4 O_2 per haemoglobin, one per haem (Fe^{2+})

Chloride shift: $\mathrm{HCO_3^-}$ out of the red cell, $\mathrm{Cl^-}$ in

A valve opens when the pressure behind it is higher than the pressure in front

Heart rate (beats per minute) $= \dfrac{60}{\text{length of one cardiac cycle in s}}$

Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$

Net pressure out of a capillary = (hydrostatic pressure in blood − hydrostatic pressure in tissue fluid) − the inward pull caused by the plasma proteins

Magnification $= \dfrac{\text{image size}}{\text{actual size}}$ (1 mm $= 1000$ µm)

Curve to the left: higher affinity for O_2; curve to the right: lower affinity (Bohr shift)

9 Gas exchange

Magnification $= \dfrac{\text{image size}}{\text{actual size}}$, so actual size $= \dfrac{\text{image size}}{\text{magnification}}$

1 mm $= 1000$ µm and 1 µm $= 1000$ nm

Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$

Oxygen, alveolus to haemoglobin: $2 + 2 + 1 = 5$ membranes $= 10$ phospholipid layers

Carbon dioxide, plasma to alveolus: $2 + 2 = 4$ membranes $= 8$ phospholipid layers

Faster diffusion: larger surface area, shorter distance, steeper gradient

Oxygen: air → blood; carbon dioxide: blood → air (down their partial pressure gradients)

Cartilage: trachea and bronchi only. Squamous epithelium: alveoli only

10 Infectious diseases

Percentage change $= \dfrac{\text{new} - \text{old}}{\text{old}} \times 100$ (negative means a decrease)

Case-fatality rate $= \dfrac{\text{number of deaths}}{\text{number of cases}} \times 100$

Rate per 100 000 $= \dfrac{\text{number of cases}}{\text{population}} \times 100\,000$

Cholera: *Vibrio cholerae*, bacterium, faecal-oral (water and food)

Malaria: *Plasmodium* (four species), protoctist, female *Anopheles* mosquito vector

TB: *Mycobacterium tuberculosis* and *M. bovis*, bacteria, airborne droplets (and unpasteurised milk for *M. bovis*)

HIV/AIDS: human immunodeficiency virus, body fluids (sex, needles, blood, mother to baby)

Penicillin inhibits transpeptidases, so no cross-links in a growing peptidoglycan wall, then osmotic lysis

11 Immunity

How many times higher $= \dfrac{\text{larger value}}{\text{smaller value}}$ (for example peak antibody concentrations)

Percentage $= \dfrac{\text{part}}{\text{whole}} \times 100$ (for example vaccination coverage, correct test results)

Phagocytosis: receptors bind → endocytosis → phagocytic vacuole → lysosomes fuse → hydrolytic enzymes digest → (macrophage) presents antigens

Primary response: antigen presentation → clonal selection → clonal expansion (mitosis) → cytokines → plasma cells (antibodies), T-killer cells, memory cells

Secondary response: memory cells → plasma cells → faster, more, longer-lasting antibody

Antibody: 2 heavy + 2 light chains, disulfide bonds, 2 identical antigen-binding sites (variable regions), hinge, constant region

Hybridoma: B-lymphocyte (plasma cell) + myeloma cell

Vaccine = artificial active; injected antibodies = artificial passive; placenta and breast milk = natural passive; infection = natural active

Transfusion is safe if the recipient has no antibodies against the donor's antigens

A Level

12 Energy and respiration

$\mathrm{ATP} + \mathrm{H_2O} \rightarrow \mathrm{ADP} + \mathrm{P_i}$, releasing 30.5 kJ mol^{-1}

$\mathrm{RQ} = \dfrac{\mathrm{CO_2\ given\ out}}{\mathrm{O_2\ taken\ in}}$

RQ: carbohydrate 1.0, protein about 0.8, lipid 0.7; above 1.0 means some anaerobic respiration

Energy values: carbohydrate and protein about 17 kJ g^{-1}, lipid about 37–39 kJ g^{-1}

Respirometer: volume $= \pi r^2 \times$ distance; $\mathrm{RQ} = \dfrac{x - y}{x}$

Redox indicator: rate $= \dfrac{1}{\text{time}}$

Efficiency $= \dfrac{\text{energy captured in ATP}}{\text{energy released by the substrate}} \times 100$

Glycolysis per glucose: 2 ATP used, 4 made (net 2), 2 reduced NAD, 2 pyruvate

Link reaction per pyruvate: 1 CO_2, 1 reduced NAD, 1 acetyl CoA

Krebs cycle per turn (two per glucose): 2 CO_2, 3 reduced NAD, 1 reduced FAD, 1 ATP

Without oxygen: net 2 ATP per glucose (glycolysis only)

13 Photosynthesis

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

Photolysis: $2\,H_2O \rightarrow O_2 + 4\,H^+ + 4\,e^-$ (in PS II, by the oxygen-evolving complex)

$\text{RuBP (5C)} + CO_2 \xrightarrow{\text{rubisco}} \text{unstable 6C} \rightarrow 2\,\text{GP (3C)}$

$\text{GP} \xrightarrow{\text{ATP, reduced NADP}} \text{TP}$; $\text{TP} \xrightarrow{\text{ATP}} \text{RuBP}$

Per 3 CO_2: 3 RuBP → 6 GP → 6 TP; 5 TP → 3 RuBP; 1 TP leaves

$$R_f = \frac{\text{distance moved by pigment from origin}}{\text{distance moved by solvent from origin}}$$

Gross rate of photosynthesis = net rate + rate of respiration

Light intensity $\propto \frac{1}{d^2}$ (d = distance from lamp)

Rate $= \frac{\text{amount}}{\text{time}}$; redox indicator rate $= \frac{1}{t}$

Percentage change $= \frac{\text{new} - \text{original}}{\text{original}} \times 100$

Mean increase per unit $= \frac{\text{change in rate}}{\text{change in } x}$

14 Homeostasis

Percentage change $= \frac{\text{new} - \text{original}}{\text{original}} \times 100$ (a fall gives a negative value: state it as a decrease)

Percentage reabsorbed $= \frac{\text{volume filtered} - \text{volume in urine}}{\text{volume filtered}} \times 100$

Rate of change $= \frac{\text{change in quantity}}{\text{time taken}}$, with units such as pmol dm^{-3} min^{-1}

"How many times" $= \frac{\text{later value}}{\text{earlier value}}$ (no units)

$cm^3\ min^{-1}$ to dm^3 per day: $\times 60 \times 24 \div 1000$

$\text{glucose} + O_2 \xrightarrow{\text{glucose oxidase}} \text{gluconic acid} + H_2O_2$

$H_2O_2 + \text{chromogen} \xrightarrow{\text{peroxidase}} \text{coloured oxidised chromogen} + H_2O$

$\text{ATP} \xrightarrow{\text{adenylyl cyclase}} \text{cAMP}$ (the second messenger)

Useful values: GFR about 125 $cm^3\ min^{-1}$ (180 dm^3 a day); filter cut-off about 68 000–70 000 relative molecular mass; blood glucose about 4–6 mmol dm^{-3}; core temperature about 37 °C

15 Control and coordination

Resting potential about -70 mV; inside negative

Na^+/K^+ pump: 3 Na^+ out, 2 K^+ in, uses ATP
Depolarisation: Na^+ in; repolarisation: K^+ out (voltage-gated channels, no ATP)
Speed $= \dfrac{\text{distance}}{\text{time}}$, so time $= \dfrac{\text{distance}}{\text{speed}}$
Maximum impulse frequency $= \dfrac{1}{\text{refractory period}}$
Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$
Sarcomere = A band + I band; H zone = sarcomere $- 2\times$ actin filament length
On contraction: A band same; I band, H zone and sarcomere shorter
Ca^{2+} roles: vesicle release at synapses; binding troponin in muscle
ATP roles in muscle: detach myosin head, recock it, pump Ca^{2+} into the SR

16 Inheritance

Degrees of freedom = number of classes -1
Expected number = total $\times$ that class's fraction of the ratio
χ^2 below the critical value: difference not significant, due to chance
Haploid $= n$, diploid $= 2n$; chromatids at the start of meiosis $= 2 \times 2n$
Combinations of chromosomes from random orientation $= 2^n$
$Aa \times Aa$: genotypes $1:2:1$; phenotypes $3:1$ (dominance) or $1:2:1$ (codominance)
$Aa \times aa$ (test cross): $1:1$
$AaBb \times AaBb$, unlinked: $9:3:3:1$; test cross $AaBb \times aabb$: $1:1:1:1$
$X^HX^h \times X^HY$: all daughters unaffected, half of sons affected

17 Selection and evolution

Degrees of freedom for the t-test $= n_1 + n_2 - 2$
$t >$ critical value at $p = 0.05$: significant difference
$q = \sqrt{\text{frequency of the recessive phenotype}}$, then $p = 1 - q$
Number of heterozygotes $= 2pq\times$ population size

18 Classification, biodiversity and conservation

D near 1: high diversity; near 0: low diversity
Correlation value (ignoring sign) $>$ critical value at $p = 0.05$: significant, reject the null hypothesis

Mean rate of change $= \dfrac{\text{change in value}}{\text{time taken}}$
Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$

19 Genetic technology

Copies after PCR $= N_0 \times 2^n$, for N_0 starting copies and n cycles
Reaching the same amount k cycles later means 2^k times less DNA at the start
Part of a total $= \text{total} \times \dfrac{\text{percentage}}{100}$
Percentage change $= \dfrac{\text{new} - \text{original}}{\text{original}} \times 100$