CHAPTER 2

PRACTICAL WORKBOOK

Name: ……

Exercise 2.1 – Taking Notes

Note taking is an essential skill in biology. Instead of copying long passages, your notes should extract only the key information. Read the passage below about carbohydrates carefully, then complete the table to summarize the structure and functions of different polysaccharides.

Passage:

Polysaccharides are polymers of monosaccharides formed by glycosidic bonds. Glucose is the monomer for many polysaccharides. Being highly soluble and reactive, free glucose would alter the osmotic potential of cells and disrupt biochemical reactions. In plants, glucose is stored as starch, which is a mixture of two substances – amylose and amylopectin. In animals, glucose is stored as glycogen. Amylose consists of α-glucose molecules joined by α (1 → 4) glycosidic bonds, resulting in a very compact, helical molecule. Amylopectin, also made of α-glucose, contains many α (1 → 4) glycosidic bonds along the main chain and has side branches connected by α (1 → 6) glycosidic bonds. Glycogen is composed of α-glucose with both α (1 → 4) and α (1 → 6) bonds, producing an even more branched molecule that allows rapid hydrolysis into glucose. In contrast, cellulose is a polymer of β-glucose. In β-glucose the –OH group on carbon 1 is oriented upward, so that every other glucose is rotated 180°. Cellulose molecules are unbranched, forming long straight chains. Sixty to seventy cellulose molecules bind via hydrogen bonds to form microfibrils, which bundle together into fibres that constitute the cell wall. These fibres provide high tensile strength—preventing cells from bursting—while allowing water and water-soluble molecules to pass through.

Complete the Table Below:

Polysaccharide	Name of Monomer	Bonds Joining Monomers	Description	Function
Amylose	α-glucose	α (1 → 4) glycosidic	Long, helical, compact molecule	Energy storage in plants; insoluble, so it does not affect osmotic potential
Amylopectin				
Glycogen				
Cellulose				

Instructions: Use the information in the passage to fill in the missing details for amylopectin, glycogen, and cellulose.

Exercise 2.2 – Calculating the Concentration of Solutions and Making Dilutions

It is essential to be able to accurately prepare solutions of various concentrations. In this exercise you will work with concentrations expressed as percentages (%) and as molarities (mol dm^{-3}). You will also practice unit conversions for mass and volume.

Part A: Unit Conversions

Carry out the following unit conversions:

1. Convert each of the following:
   - (a) 150 mg into grams (g)

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   - (b) 225 mg into kilograms (kg)

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   - (c) 0.005 kg into milligrams (mg)

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   - (d) 100 ng into grams (g)

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   - (e) 100 cm^3 into cubic decimetres (dm^3)

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   - (f) 0.005 cm^3 into cubic millimetres (mm^3)

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   - (g) 150 mm^3 into cubic decimetres (dm^3)

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   - (h) 0.000005 dm^3 into cubic millimetres (mm^3)

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Part B: Making Up a Percentage Solution

When the concentration is given as a percentage, it represents the mass of solute (in grams) dissolved and then made up to a total volume in cm^3.

2. You are to prepare 100 cm^3 of a 5% sucrose solution. Arrange the following steps in the correct order:
   - **A:** Make up to 100 cm^3 by adding distilled water.
   - **B:** Dissolve in a small amount of distilled water.
   - **C:** Place the dissolved sucrose into a 100 cm^3 volumetric flask.
   - **D:** Use a top pan balance to measure out 5 g of sucrose.

Part C: Calculating Percentage Concentrations

The percentage concentration is calculated by:

$$\text{Percentage concentration} = \left(\frac{\text{mass of solute (g)}}{\text{volume of solution (cm}^3\text{)}}\right) \times 100\%$$

3. Calculate the sucrose concentration (as a percentage) for each of the following:
   - (a) 5 g of sucrose made up to 100 cm³.

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   - (b) 10 g of sucrose made up to 500 cm³.

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   - (c) 0.5 g of sucrose made up to 500 cm³.

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   - (d) 37.5 g of sucrose made up to 150 cm³.

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   - (e) 450 g of sucrose made up to 1 dm³.

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   - (f) 0.005 g of sucrose made up to 100 mm³.

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Part D: Calculating the Mass of Sucrose for Solutions

For percentage solutions, the mass of solute required is given by:

$$\text{Mass (g)} = \left(\frac{\text{Percentage}}{100}\right) \times \text{Volume (cm}^3\text{)}$$

4. Calculate the mass of sucrose required to make the following solutions:
   - (a) 100 cm³ of a 0.5% sucrose solution.

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   - (b) 250 cm³ of a 12% sucrose solution.

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   - (c) 500 cm³ of a 25% sucrose solution.

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   - (d) 750 cm³ of a 50% sucrose solution.

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   - (e) 500 mm³ of a 10% sucrose solution.

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   - (f) 1 dm³ of a 45% sucrose solution.

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Part E: Calculating Molarity (mol dm⁻³)

Molarity is defined as:

$$\text{Molarity (mol dm}^{-3}) = \frac{\text{Number of moles of solute}}{\text{Volume of solution in dm}^3}$$

To make a 1 mol dm⁻³ solution, you must dissolve 1 mole of the substance (in grams, equal to its molecular mass) and dilute to 1 dm³.

5. Calculate the masses of solutes required to prepare the following solutions:
   - (a) 1 dm³ of a 1 mol dm⁻³ **glucose** solution.
     Molecular mass of glucose ($C_6H_{12}O_6$) = 180 g/mol.
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   - (b) 1 dm³ of a 1 mol dm⁻³ **maltose** solution.
     Molecular mass of maltose ($C_{12}H_{22}O_{11}$) = 342 g/mol.
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   - (c) 1 dm³ of a 1 mol dm⁻³ **glycine** ($C_2H_5O_2N$) solution.
     Molecular mass of glycine ≈ 75 g/mol.
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   - (d) 100 cm³ of a 2 mol dm⁻³ **glucose** solution.
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   - (e) 100 cm³ of a 2 mol dm⁻³ **sucrose** solution.
     Molecular mass of sucrose ($C_{12}H_{22}O_{11}$) = 342 g/mol.
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Part F: Calculating Molar Concentrations

Sometimes you are given a mass of solute and the volume of the final solution. Use the following steps:

1. Calculate the number of moles (moles = mass / molecular mass).
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2. Divide the number of moles by the volume of solution in dm³.
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3. Calculate the molar concentration for each of the following:
   - (a) 171 g sucrose dissolved in 1 dm³ of distilled water.
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- (b) 150 g glycine ($C_2H_5O_2N$) dissolved in 1 dm^3 of distilled water.

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- (c) 4.5 g glucose dissolved in 100 cm^3 of distilled water.

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- (d) 1.8 g glucose dissolved in 1 dm^3 of distilled water.

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- (e) 342 mg sucrose dissolved in 1 cm^3 of distilled water.

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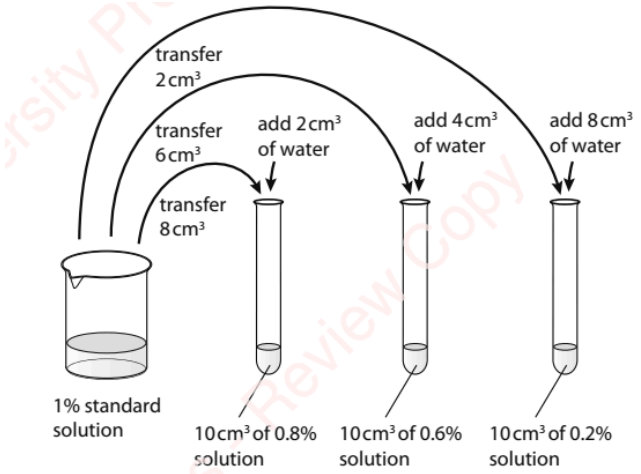
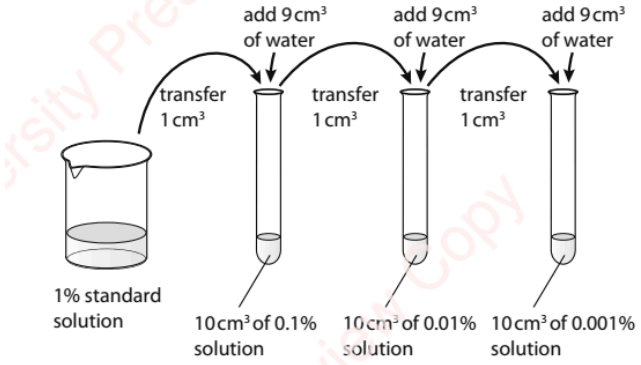
Remember to convert all units appropriately (e.g. cm^3 to dm^3, mg to g) before performing calculations.

Exercise 2.3 – Graph Plotting and Using Calibration Curves

Benedict's test is used to detect reducing sugars. Benedict's reagent is initially blue because of copper(II) sulfate. When heated with a reducing sugar, the copper(II) is reduced to insoluble red copper(I) oxide; the higher the concentration of reducing sugar, the less blue the solution remains. A colorimeter is used to quantify the percentage of red light absorbed by the solution. To determine the concentration of reducing sugar in an unknown sample, you first prepare a range of known concentrations (by diluting a 1% standard solution) and then plot a calibration curve.





Part A: Making Dilutions

Dilution Table

Copy and complete the table below showing how to prepare a range of sucrose concentrations when given a 1% standard solution. Assume you are preparing 10 cm³ of each diluted solution. (The first two rows are provided as examples.)

Concentration of sucrose (%)	Volume of 1% solution (cm³)	Volume of added water (cm³)
0.9	9	1
0.8	8	2
0.7	7	3
0.6	6	4
0.5	5	5
0.4	4	6
0.3	3	7
0.2	2	8
0.1	1	9

Hint: Use the formula

Volume of stock solution =

$$V = \left(\frac{0.02}{1}\right) \times 10 = 0.2\,\text{cm}^3$$

then add water to reach a total volume of 10 cm³.

Part B: Preparing Low Concentration Solutions

Making Up Glucose Solutions

For each of the following, describe one method for preparing the desired glucose concentration from a 1% standard solution. (There are several acceptable methods.)

a) **0.02% Glucose:**
Example Answer:
To prepare 10 cm³ of a 0.02% solution directly, calculate:

$$V = \left(\frac{0.02}{1}\right) \times 10 = 0.2\,\text{cm}^3$$

Because 0.2 cm³ is difficult to measure accurately, you could first prepare a 0.1% solution by mixing 1 cm³ of the 1% solution with 9 cm³ of water. Then take 2 cm³ of this 0.1% solution and dilute it with 8 cm³ of water to obtain 10 cm³ of a 0.02% solution.

b) **0.003% Glucose:**
Example Answer:
Direct calculation gives:

$$V = \left(\frac{0.003}{1}\right) \times 10 = 0.03\,\text{cm}^3.$$

Since 0.03 cm³ is impractical, perform a serial dilution. For example, dilute the 1% solution 1:10 to get a 0.1% solution (1 cm³ stock + 9 cm³ water). Then, take 0.3 cm³ of the 0.1% solution and add 9.7 cm³ water to yield 10 cm³ of a 0.003% solution.

c) **0.0005% Glucose:**
Example Answer:
Direct calculation yields:

$$V = \left(\frac{0.0005}{1}\right) \times 10 = 0.005\,\text{cm}^3,$$

which is too small to measure accurately. Instead, perform serial dilutions: first, prepare a 0.01% solution by diluting 1 cm³ of the 1% solution in 99 cm³ of water. Then take 1 cm³ of the 0.01% solution and dilute it 1:20 (by adding 19 cm³ water) to obtain a 0.0005% solution.

Part C: Plotting the Calibration Curve

A calibration curve is created by plotting known concentrations against their percentage absorption of red light (as measured by a colorimeter). Use the data in the table below.

Concentration of glucose (%)	Absorption of light (%)
1.0	5
0.8	35
0.6	45
0.4	64

0.2	85
0.1	92
0	96

Graph Plotting Instructions:

- **Step 1:** Label the x-axis “Concentration of glucose (%)” (independent variable).
- **Step 2:** Label the y-axis “Absorption of light (%)” (dependent variable).
- **Step 3:** Choose appropriate linear scales on both axes so that all points are clearly displayed. (You may not need to start at 0 if that does not suit the data, but ensure you use at least half the axis range.)
- **Step 4:** Plot each data point accurately using a sharp pencil.
- **Step 5:** Draw a smooth curve or line of best fit through the points.

Part D: Using the Calibration Curve

A mystery glucose sample is tested with Benedict’s test. The colorimeter gives an absorption reading of 74%.

a) Using a ruler, draw a horizontal line from 74% on the y-axis until it meets the calibration curve. Then, drop a vertical line down to the x-axis. Record the corresponding glucose concentration.

b) Repeat the procedure for an absorption reading of 53%.

Note: Report the approximate concentrations obtained by interpolation from your graph.

Part E: Controlling Experimental Variables

When comparing different glucose solutions using this method, list three factors that must be kept constant to ensure valid comparisons.

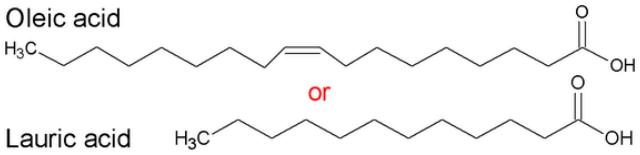
Exercise 2.4 – Processing and Analysing Data

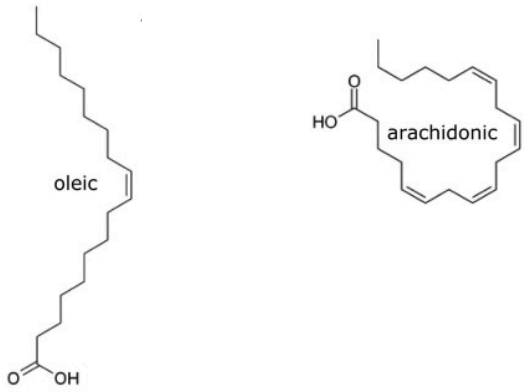
You will need to apply your factual knowledge to interpret unfamiliar data. Read the information carefully, then answer the questions that follow.

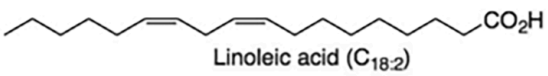
Part 1: Fatty Acid Structures and Melting Points

Figure A shows the structures of four different fatty acids:

- Lauric acid
- Oleic acid
- Linoleic acid
- Arachidonic acid







1a. Classifying Fatty Acids

Copy out and complete the table below by identifying for each fatty acid whether it is saturated, monounsaturated, or polyunsaturated.

Fatty Acid	Type of Fatty Acid	Melting Point (°C)
Lauric acid		
Oleic acid		
Linoleic acid		
Arachidonic acid		

1b. Matching Melting Points

The melting points of these fatty acids are: 45 °C, 13 °C, –49 °C, –11 °C. Match each fatty acid with its corresponding melting point (remember that the presence of double bonds lowers the melting point).

Part 2: Explaining Differences in Melting Points

2. **Explain why the melting points of these fatty acids are different.**
   (Hint: Consider the effects of saturation and the presence of double bonds.)

Part 3: Comparing Fatty Acid Composition in Lipid Extracts

The table below shows the masses (in grams) of saturated, monounsaturated, and polyunsaturated fatty acids extracted from the total lipid of different organisms. Note that the starting masses of total lipid differ between samples. To compare fairly, you must convert each value into grams per 100 g of total lipid.

Given Data

Organism	Total Lipid (g)	Saturated (g)	Monounsaturated (g)	Polyunsaturated (g)
Sheep (animal)	100	40.8	43.8	9.6
Cow (butter) (animal)	100	54.0	19.8	2.6
Duck (animal)	50	16.7	24.5	6.8
Mackerel (animal)	10	2.4	3.2	2.3
Olive oil (plant)	200	28.0	139.4	22.4
Corn oil (plant)	100	12.7	24.7	57.8
Sunflower oil (plant)	100	11.9	20.2	63.0
Hemp oil (plant)	75	7.5	10.0	50.0
Coconut oil (plant)	150	127.8	9.9	2.5

3a. Converting to g per 100 g of Lipid

Copy out and complete the table below by converting each value to grams per 100 g of total lipid. (For example, in duck fat, 16.7 g saturated fat in 50 g of lipid becomes (16.7 ÷ 50) × 100 = 33.4 g per 100 g.)

Organism	Saturated (g/100 g)	Monounsaturated (g/100 g)	Polyunsaturated (g/100 g)
Sheep (animal)			
Cow (butter) (animal)			
Duck (animal)			
Mackerel (animal)			
Olive oil (plant)			
Corn oil (plant)			

Sunflower oil (plant)			
Hemp oil (plant)			
Coconut oil (plant)			

Part 4: Evaluating the Data

4. **Analyzing Patterns and Anomalies**

a) Identify any patterns you can see in the data once all values are expressed as grams per 100 g of total lipid.

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b) Are there any results that do not seem to fit with these patterns?

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c) Suggest any explanations for the observed patterns, using your knowledge about fatty acids.

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(Consider points such as: the higher the level of saturation, the higher the melting point and energy content; more unsaturation means lower melting points; and homeothermic animals often maintain a consistent internal temperature.)

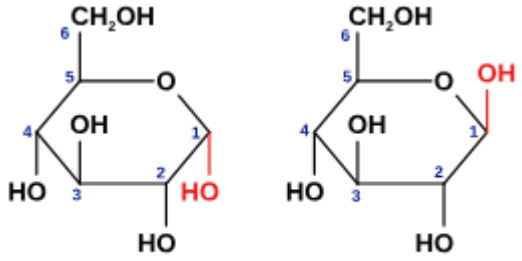
Exercise 2.5 – Drawing Molecular Structures

Most biochemical reactions are best represented by drawing them out. Accuracy when drawing molecular structures is very important, as small mistakes can cost valuable exam marks.

Part 1: Drawing Bond Formation

1a. Formation of Glycosidic Bonds in Disaccharides

Using Figure A as a guide (which shows two α-glucose molecules), complete the following steps:



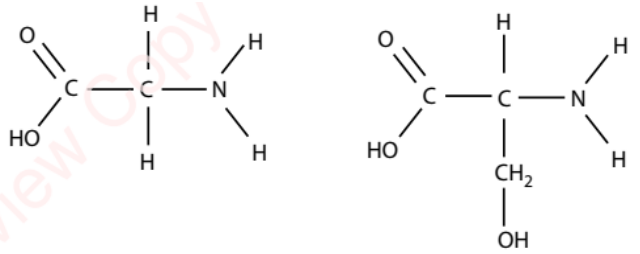
Alpha-(α) Glucose Beta-(β) Glucose

1. **Draw the two α-glucose molecules:**
    - Draw the two cyclic (Haworth) structures of α-glucose. (Refer to your notes for the correct orientation of –OH groups, especially on carbon 1.)
2. **Identify the groups involved in bond formation:**
    - **Step 1:** On the α-glucose on the left, circle (or draw a ring around) the –OH group on carbon 1.
    - **Step 2:** On the α-glucose on the right, circle the –OH group on carbon 4.
3. **Draw the reaction arrow(s):**
    - **Step 3:** Draw reversible arrows (⇌) between the reactants and the product.
4. **Form the disaccharide (maltose):**
    - **Step 4:** Draw the resulting disaccharide maltose below the arrows. Make sure to clearly show the glycosidic bond between carbon 1 of the left glucose and carbon 4 of the right glucose. Label this bond (e.g. “α(1→4) glycosidic bond”).

5. **Indicate the water involvement:**
    - **Step 5:** On the arrow(s), indicate (by writing "– H_2O" on the condensation side and "+ H_2O" on the hydrolysis side) where water is removed or added.
6. **Name the reactions:**
    - **Step 6:** Next to the arrows, write "condensation" for the formation of the bond (which releases water) and "hydrolysis" for the reverse reaction (where water is added to break the bond).

1b. Formation of a Peptide Bond

Using Figure B (which shows the amino acids glycine on the left and serine on the right), repeat a similar procedure to show peptide bond formation:



1. **Draw the structures of glycine and serine:**
    - Draw the structural formula for glycine (simplest amino acid, $NH_2–CH_2–COOH$) and serine ($NH_2–CH(CH_2OH)–COOH$) with clear indication of the $–NH_2$ and –COOH groups.
2. **Show the bond formation:**
    - Illustrate that the –OH from the carboxyl group (–COOH) of one amino acid and an –H from the amino group ($–NH_2$) of the other are removed to form water.
    - Draw a bond (an amide linkage) connecting the carbonyl carbon of one amino acid to the nitrogen of the other. Label this bond as "peptide bond."
3. **Draw the reaction arrow(s) and indicate water:**
    - Draw reversible arrows (⇌) between the reactants and the dipeptide.
    - Indicate on the arrow(s) "– H_2O" (for condensation) and "+ H_2O" (for hydrolysis).

4. **Name the reactions:**

    - Next to the arrows, write “condensation” (for peptide bond formation) and “hydrolysis” (for its reversal).

Part 2: Evaluating a Student’s Answer – Triglyceride Formation

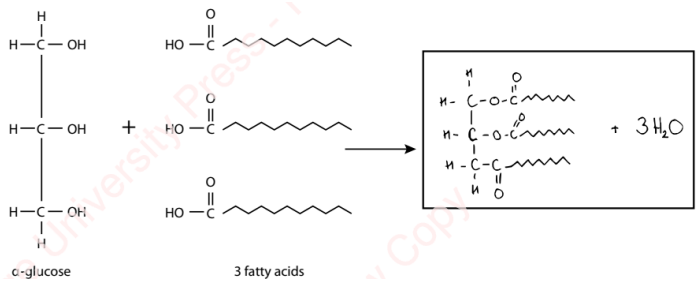
Below is an example exam question and a student’s answer. First, use the provided mark scheme to identify the correct elements and any mistakes in the student’s work. Then, write your own, corrected answer.

2i. Diagram of Triglyceride Formation

Task:

Complete the diagram below showing the formation of a triglyceride from a glycerol molecule and three fatty acids. (You must show the formation of three ester bonds and indicate that three water molecules are produced on the right side of the arrow.)

Diagram (simplified sketch):



Glycerol + 3 Fatty acids → Triglyceride + 3 H_2O

(The student’s answer should show a glycerol molecule ($CH_2OH–CHOH–CH_2OH$) linked via ester bonds to three fatty acid chains. Water molecules should be drawn on the right-hand side of the reaction arrow.)

2ii. Naming the Reaction

Task:

Name the type of reaction that occurs during triglyceride formation.

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Exercise 2.6 – Planning Experiments That Generate Reliable Results

When planning experiments, you must design your investigation so that you generate data that are both reliable (repeatable) and valid (accurately reflecting what you want to measure). This means you should include appropriate repeats, change only one variable at a time, and control all other factors.

The Following Experiment Was Proposed by a Student:

Title: An Experiment to Determine the Temperature at Which Egg White Protein (Albumin) Denatures

Apparatus:

- 4 test tubes
- Test tube rack
- Measuring cylinder
- 4 eggs
- Thermometers
- Glass marker pen
- Bunsen burner
- Stop clock

Method:

1. Place the test tubes into the test-tube rack.
2. In each test tube, pour the clear egg white from one egg.
3. Insert a thermometer into the egg white in each tube.
4. Heat each test tube using a Bunsen burner for 5 minutes at different temperatures (20 °C, 25 °C, 50 °C, and 55 °C).
5. Observe the test tubes and record in which ones the albumin turns white.
6. The lowest temperature at which the albumin turns white is taken as the denaturation temperature.

Answer the following questions:

a) State the independent variable in this experiment.

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b) State the dependent variable in this experiment.

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c) Will this experiment generate valid data? Explain your answer.

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d) Write an improved method that would produce more reliable and valid data. In your method, consider and describe:

i) How you will change and monitor the independent variable (the temperature), including the range and increments.

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ii) How you will measure the dependent variable (the extent of protein denaturation) more accurately and reliably.

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iii) What other variables you will control, and how you will control them.

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iv) How you will make the results more reliable (e.g. repeats, consistent measurement conditions).

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Exercise 2.7 – Extended Writing Skills

Writing well-organised, factually accurate essays is essential for higher level biology. A high-quality essay must include detailed scientific content that is directly relevant to the question. In this exercise, you are required to write an essay (maximum 500 words) on the biological importance of water. Before writing, plan your essay to include the following topics:

- **Water as a solvent:** Explain how water's polarity and hydrogen bonding allow it to dissolve many substances. Provide biological examples (e.g., nutrient transport in blood, plant sap).
- **Water as a transport medium:** Describe how water facilitates the movement of molecules in biological systems (e.g., circulation in animals, xylem and phloem in plants).
- **High specific heat capacity:** Explain how water's ability to absorb or release large amounts of heat with minimal temperature change helps stabilize environments and body temperatures in organisms.
- **High latent heat of vaporisation:** Discuss how water's high latent heat of vaporisation plays a role in cooling mechanisms (e.g., sweating in animals, transpiration in plants).
- **Density and freezing properties:** Describe how water's density behavior (ice being less dense than liquid water) is vital for aquatic life, and how freezing properties affect organisms in cold environments.
- **High surface tension and cohesion:** Explain how these properties contribute to phenomena such as capillary action, which is crucial for water transport in plants and for maintaining cell integrity.
- **Water as a reagent:** Detail how water participates in chemical reactions (e.g., hydrolysis) in both animal and plant cells.

Instructions:

1. **Plan Your Essay:**
    - Outline your introduction, main body (with one paragraph or section for each property listed above), and conclusion.
    - Include bullet points of key explanations and examples (for both plants and animals) for each property.
2. **Write Your Essay:**
    - Compose a coherent, well-structured essay (maximum 500 words) covering the topics above.
    - Make sure your essay flows logically from one topic to the next and that all points are clearly explained.

3. **Self-Evaluation:**
    - After writing your essay, use the provided mark scheme (in the Answer Key) to assess your essay.
    - Critically review your work to determine how many marks you would gain and identify any areas for improvement.

Exercise 2.7 – Extended Writing Skills

Any higher-level study of biology requires you to write well-organised, factually accurate essays. A high-quality essay is planned so that it flows logically and covers all relevant topics. The number of words is a guide (maximum 500 words), but quality and scientific detail are paramount.

Task:

Write an essay on the biological importance of water. Your essay should cover the following topics, explaining both how water's unique properties arise and giving biological examples (from both plants and animals) for each:

- Water as a solvent
- Water as a transport medium
- High specific heat capacity
- High latent heat of vaporisation
- Density and freezing properties
- High surface tension and cohesion
- Water as a reagent

Instructions:

1. **Plan Your Essay:**
    - Create a brief outline that includes an introduction, body paragraphs (one for each property), and a conclusion.
    - Under each property, note key points:

Water as a solvent: Explain water's polarity and hydrogen bonding; examples include nutrient transport in blood and dissolving minerals in plant cell sap.

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Transport medium: Describe how water facilitates the movement of substances (e.g. blood circulation in animals, xylem/phloem in plants).

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High specific heat capacity: Explain how water buffers temperature changes; examples include stabilizing body temperature and moderating environmental climates.

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High latent heat of vaporisation: Discuss how water's energy requirement for evaporation underpins cooling mechanisms (sweating in animals, transpiration in plants).

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Density and freezing properties: Explain how water expands on freezing (ice is less dense than water), which insulates aquatic life; include examples such as frozen lakes.

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High surface tension and cohesion: Explain capillary action and the maintenance of cell structure; examples include water transport in plants and droplet formation.

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Water as a reagent: Describe water's participation in hydrolysis and other biochemical reactions.

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2. **Write Your Essay:**
    - Compose a coherent essay (up to 500 words) that integrates all these topics.
    - Ensure that each paragraph clearly explains one property with examples and that your essay flows logically.
3. **Self-Evaluation:**
    - After writing, use the provided mark scheme in the Answer Key to assess your essay.
    - Critically evaluate your work, noting strengths and areas for improvement.

When you have finished, use the mark scheme below to decide how many marks you might gain and identify any aspects that could be improved.

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TEACHER COMMENTS