Week 10

AP Biology

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

AP Biology Name: ______________ Score: ______

1. An **enzyme** is a biological…
   - ☐ catalyst that speeds up a reaction
   - ☐ sugar for energy
   - ☐ type of fat
   - ☐ strand of DNA
2. The temperature at which an enzyme works fastest is its…
   - ☐ optimum temperature
   - ☐ freezing point
   - ☐ boiling point
   - ☐ activation energy
3. What is the main job of **ATP** in a cell?
   - ☐ to carry usable energy to where it is needed
   - ☐ to store genetic information
   - ☐ to build the cell wall
   - ☐ to digest food outside the cell
4. What does a plant use as raw materials for **photosynthesis**?
   - ☐ carbon dioxide, water, and light
   - ☐ oxygen and glucose
   - ☐ protein and salt
   - ☐ nitrogen and iron
5. What is the purpose of **cellular respiration**?
   - ☐ to release energy from glucose as ATP
   - ☐ to build glucose from CO_2
   - ☐ to store genetic information
   - ☐ to make the cell wall
6. The green pigment that absorbs light for photosynthesis is ______.

   ____

7. The first stage, splitting glucose in the cytoplasm, is called ______.

____

8. Enzymes speed up reactions by lowering the activation energy.

☐ True ☐ False

9. Each enzyme also has an optimum pH at which it works best.

☐ True ☐ False

10. ADP is recharged back into ATP using energy from respiration.

☐ True ☐ False

AP Biology

1. **catalyst that speeds up a reaction**

   An **enzyme** is a biological **catalyst** — it speeds up a reaction without being used up.

2. **optimum temperature**

   Each enzyme has an **optimum** temperature where it works fastest — often around body temperature.

3. **to carry usable energy to where it is needed**

   ATP is the cell's energy currency — it delivers energy in small, usable packets.

4. **carbon dioxide, water, and light**

   Photosynthesis uses carbon dioxide + water + light energy to make glucose and oxygen.

5. **to release energy from glucose as ATP**

   Cellular respiration breaks down glucose to release energy as ATP.

6. **chlorophyll**

   Chlorophyll in the chloroplasts captures the light energy that drives the whole process.

7. **glycolysis**

   Glycolysis splits glucose into two pyruvate molecules and makes a small amount of ATP.

8. **True**

   By lowering the **activation energy**, an enzyme lets the reaction happen faster and at body temperature.

9. **True**

   The wrong pH also changes the active site's shape, so each enzyme has a best pH too.

10. **True**

    Respiration provides the energy to add a phosphate back to ADP, remaking ATP.

3.1 Enzymes as Biological Catalysts

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS enzyme 酶 • substrate 底物 • active site 活性位点 • activation energy 活化能 • catalyst 催化剂

Objective

Build the skills to answer exam questions on **enzymes as biological catalysts**.

You must be able to:

- explain that an **enzyme** 酶 lowers the **activation energy** 活化能
- describe the **active site** 活性位点 and enzyme-substrate specificity
- explain the induced-fit model

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Enzymes lower activation energy

An **enzyme** is a biological **catalyst** — it speeds up a reaction by **lowering the activation energy**, without being used up. It does not change whether a reaction is favorable, only how fast it goes.

The active site

The **active site** is the part of the enzyme where the **substrate** binds. Its specific shape means each enzyme works on **one** substrate (specificity), like a lock and key.

Induced fit

In the **induced-fit** model, the active site changes shape slightly as the substrate binds, gripping it and straining bonds to help the reaction.

A worked example

Catalase lowers the activation energy for breaking down hydrogen peroxide, so it reacts far faster; catalase is unchanged and reused.

2 Practice

Now apply the methods above.

2.1 What does an enzyme do to the activation energy? [1]

2.2 What is the active site? [1]

2.3 Why is an enzyme specific to one substrate? [1]

3 Exam-style questions

3.1 An enzyme speeds up a reaction by [1]

- **A** raising the activation energy
- **B** lowering the activation energy
- **C** adding energy to the products
- **D** changing ΔG

3.2 An enzyme binds only its specific substrate.

(a) Explain why, in terms of the active site. [2]

(b) Describe the induced-fit model. [2]

3.3 Explain why an enzyme is not used up in the reaction it catalyzes. [2]

Solutions

2.1 Lowers it.

2.2 The region of the enzyme where the substrate binds.

2.3 Its active site has a specific shape that fits only that substrate.

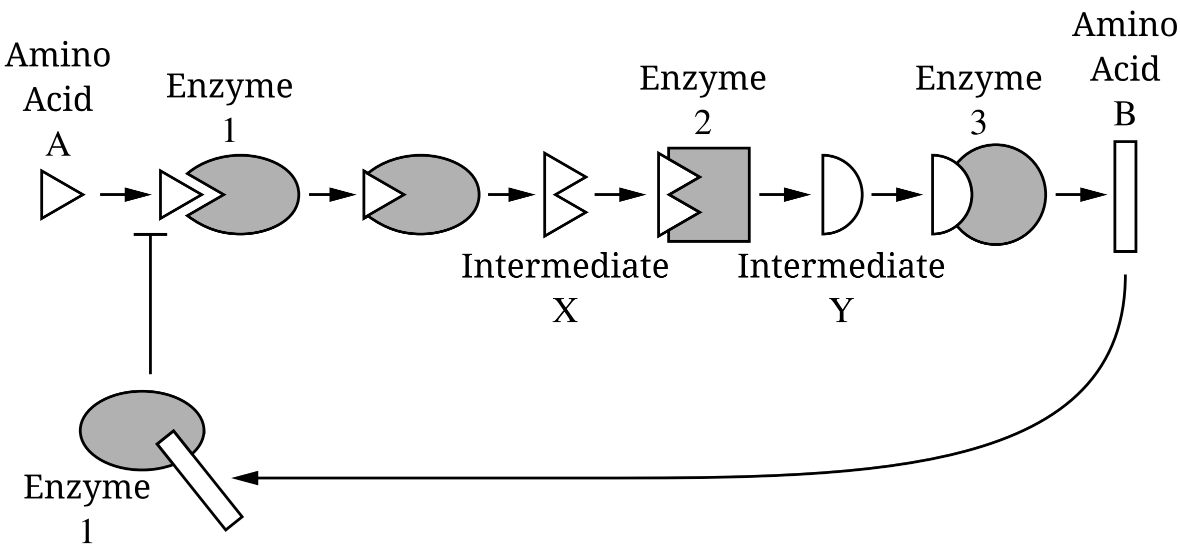
3.1 B — lowering the activation energy.

3.2 (a) The active site has a specific shape that only the matching substrate fits (like lock and key). (b) The active site changes shape slightly as the substrate binds, gripping it and helping the reaction.

3.3 The enzyme is not consumed — it releases the products and returns to its original shape, ready to bind another substrate.

5. Figure 1 shows the reactions of the metabolic pathway used to synthesize amino acid B from amino acid A in cells.

Figure 1. Synthesis of amino acid B from amino acid A



A. Describe a characteristic of an enzyme's active site that allows it to catalyze a specific chemical reaction.

B. Based on Figure 1, **explain** how the binding of amino acid A to enzyme 1 is regulated by amino acid B.

C. Using the information in Figure 1, **identify** the product of the reaction catalyzed by enzyme 2: intermediate X, intermediate Y, or amino acid B.

D. Based on Figure 1, **explain** how a change in pH could affect enzyme 3 in such a way that amino acid B cannot be produced.

3. Fireflies emit light when the enzyme luciferase catalyzes a reaction in which its substrate, D-luciferin, reacts to form oxyluciferin and other products (Figure 1). In order to determine the optimal temperature for this enzyme, scientists added ATP to a solution containing D-luciferin, luciferase, and other substances needed for the reaction. They then measured the amount of light emitted during the first three seconds of the reaction when it was carried out at different temperatures.

$$\text{D-Luciferin} + O_2 + \text{ATP} \xrightarrow{\text{Luciferase}} \text{Oxyluciferin} + CO_2 + \text{AMP} + PP_i + \text{Light}$$

Figure 1. Light is emitted as a result of the reaction catalyzed by luciferase.

(a) **Describe** a characteristic of the luciferase enzyme that allows it to catalyze the reaction.

(b) **Identify** the dependent variable in the experiment.

(c) **State** the null hypothesis for the experiment.

(d) A student claims that, as temperature increases, there will be an increase in the amount of light given off by the reaction in the first three seconds. **Support** the student's claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

		STRAINS		
	MEDIUM	Wild Type	Mutant 1	Mutant 2
Treatment I	All amino acids present	+	+	+
Treatment II	No amino acids present	+	–	–
Treatment III	All amino acids present EXCEPT methionine	+	–	+
Treatment IV	All amino acids present EXCEPT leucine	+	+	–

Table 1. The data show the growth of haploid *Saccharomyces cerevisiae* yeast strains on media that differ in amino acid content. A plus sign (+) indicates that the yeast strains grow, and a minus sign (–) indicates that the strains do not grow.

6. The yeast *Saccharomyces cerevisiae* is a single-celled organism. Amino acid synthesis in yeast cells occurs through metabolic pathways, and enzymes in the synthesis pathways are encoded by different genes. The synthesis of a particular amino acid can be prevented by mutation of a gene encoding an enzyme in the required pathway.

   A researcher conducted an experiment to determine the ability of yeast to grow on media that differ in amino acid content. Yeast can grow as both haploid and diploid cells. The researcher tested two different haploid yeast strains (Mutant 1 and Mutant 2), each of which has a single recessive mutation, and a haploid wild-type strain. The resulting data are shown in Table 1.

   (a) **Identify** the role of treatment I in the experiment.

   (b) **Provide reasoning** to explain how Mutant 1 can grow on treatment I medium but cannot grow on treatment III medium.

   (c) Yeast mate by fusing two haploid cells to make a diploid cell. In a second experiment, the researcher mates the Mutant 1 and Mutant 2 haploid strains to produce diploid cells. Using the table provided, **predict** whether the diploid cells will grow on each of the four media. Use a plus sign (+) to indicate growth and a minus sign (–) to indicate no growth.

		STRAINS			
	MEDIUM	Wild Type (haploid)	Mutant 1 (haploid)	Mutant 2 (haploid)	Diploid Cells Produced by Mating Mutant 1 and Mutant 2
Treatment I	All amino acids present	+	+	+	
Treatment II	No amino acids present	+	−	−	
Treatment III	All amino acids present EXCEPT methionine	+	−	+	
Treatment IV	All amino acids present EXCEPT leucine	+	+	−	

3.2 Environmental Impacts on Enzyme Function

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS denatures 变性 • enzyme 酶 • substrate 底物 • active site 活性位点

Objective

Build the skills to answer exam questions on **environmental impacts on enzyme function**.

You must be able to:

- describe how **temperature** and **pH** affect enzyme rate
- explain **denaturation** 变性 at extremes
- describe the effect of substrate concentration (saturation)

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Temperature

Rate rises with temperature up to an **optimum**, then falls sharply as the enzyme **denatures** (its shape and active site are destroyed). Too cold = slow; too hot = denatured.

■ pH

Each enzyme has an **optimum pH**. Far from it, the active site's shape is disrupted, lowering the rate; extreme pH can denature the enzyme.

■ Substrate concentration

Rate rises with more substrate until all active sites are busy (**saturation**); then adding more substrate does not increase the rate (the plateau).

■ A worked graph reading

An enzyme's rate-vs-temperature curve rises to a peak at ~37°C (human optimum) and then drops steeply — the drop is denaturation, not just slowing.

2 Practice

Now apply the methods above.

2.1 What happens to an enzyme's shape at very high temperature? [1]

2.2 What is meant by an enzyme's optimum pH? [1]

2.3 Why does rate level off at high substrate concentration? [1]

3 Exam-style questions

3.1 Above its optimum temperature, an enzyme's rate falls sharply because the enzyme [1]

- **A** speeds up
- **B** denatures
- **C** gains substrate
- **D** freezes

3.2 An enzyme's activity is measured at pH 2, 7, and 11, with the highest activity at pH 7.

(a) State the optimum pH. [1]

(b) Explain why activity is low at pH 2 and pH 11. [2]

3.3 Describe and explain the shape of a graph of reaction rate against substrate concentration. [3]

Solutions

2.1 It denatures (the active site loses its shape).

2.2 The pH at which the enzyme works fastest.

2.3 All the active sites are occupied (saturated), so more substrate cannot be processed faster.

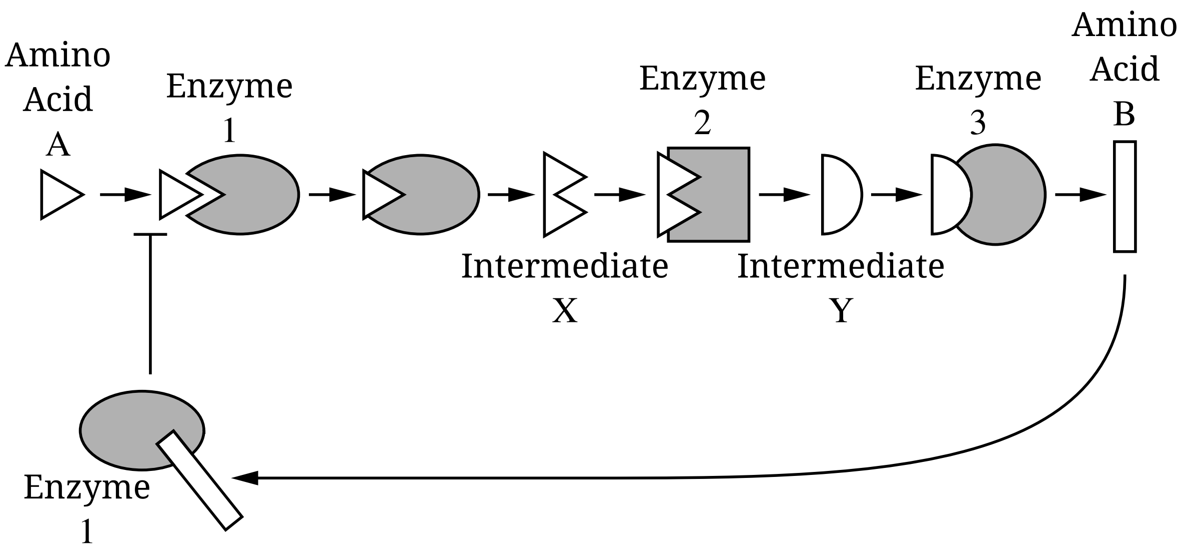
3.1 B — denatures.

3.2 (a) pH 7. (b) At pH 2 and 11 the active site's shape is disrupted (or the enzyme denatures), so the substrate no longer fits and the rate falls.

3.3 Rate rises steeply with substrate at first (more collisions with active sites), then levels off once all active sites are saturated, so adding more substrate has no further effect.

5. Figure 1 shows the reactions of the metabolic pathway used to synthesize amino acid B from amino acid A in cells.

Figure 1. Synthesis of amino acid B from amino acid A



A. Describe a characteristic of an enzyme's active site that allows it to catalyze a specific chemical reaction.

B. Based on Figure 1, **explain** how the binding of amino acid A to enzyme 1 is regulated by amino acid B.

C. Using the information in Figure 1, **identify** the product of the reaction catalyzed by enzyme 2: intermediate X, intermediate Y, or amino acid B.

D. Based on Figure 1, **explain** how a change in pH could affect enzyme 3 in such a way that amino acid B cannot be produced.

3. Fireflies emit light when the enzyme luciferase catalyzes a reaction in which its substrate, D-luciferin, reacts to form oxyluciferin and other products (Figure 1). In order to determine the optimal temperature for this enzyme, scientists added ATP to a solution containing D-luciferin, luciferase, and other substances needed for the reaction. They then measured the amount of light emitted during the first three seconds of the reaction when it was carried out at different temperatures.

$$\text{D-Luciferin} + O_2 + \text{ATP} \xrightarrow{\text{Luciferase}} \text{Oxyluciferin} + CO_2 + \text{AMP} + PP_i + \text{Light}$$

Figure 1. Light is emitted as a result of the reaction catalyzed by luciferase.

(a) **Describe** a characteristic of the luciferase enzyme that allows it to catalyze the reaction.

(b) **Identify** the dependent variable in the experiment.

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(d) A student claims that, as temperature increases, there will be an increase in the amount of light given off by the reaction in the first three seconds. **Support** the student's claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

AP BIOLOGY • EXERCISE SHEET

3.3 Cellular Energy and ATP

Name: ____________ Class: ________ Date: __________ **Total: 10 marks**

KEY WORDS atp 三磷酸腺苷

Objective

Build the skills to answer exam questions on **cellular energy and ATP**.

You must be able to:

- describe **ATP 三磷酸腺苷** as the cell's energy currency
- explain that energy is released when ATP $\rightarrow$ ADP + P_i
- link ATP hydrolysis to powering cell work

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ ATP is the energy currency

ATP (adenosine triphosphate) stores energy in the bonds between its **three phosphate** groups. Cells use ATP to power nearly all their energy-requiring work.

■ Releasing energy

Breaking off the last phosphate by **hydrolysis** releases energy:

$$\text{ATP} \rightarrow \text{ADP} + \text{P}_i + \text{energy}.$$

■ Recharging

The energy from respiration is used to **rebuild** ATP from ADP + P_i. ATP and ADP cycle continuously — used and remade.

■ A worked link

Active transport, muscle contraction, and building molecules all **couple** to ATP hydrolysis — the released energy drives the otherwise-unfavorable work.

2 Practice

Now apply the methods above.

2.1 What does ATP stand for and store? [1]

2.2 Write the reaction when ATP releases energy. [1]

2.3 How is ATP recharged? [1]

3 Exam-style questions

3.1 Energy is released from ATP when it is converted to [1]

- **A** ADP + phosphate
- **B** glucose
- **C** DNA
- **D** a lipid

3.2 A muscle cell uses ATP to contract.

(a) Write the hydrolysis reaction of ATP. [2]

(b) Explain how this powers the contraction (coupling). [2]

3.3 Explain why ATP is described as a “rechargeable” energy currency. [2]

Solutions

2.1 Adenosine triphosphate; it stores energy (in its phosphate bonds).

2.2 ATP $\rightarrow$ ADP + P_i + energy.

2.3 Energy from respiration rebuilds ATP from ADP + P_i.

3.1 **A** — ADP + phosphate.

3.2 (a) ATP $\rightarrow$ ADP+P_i+energy. (b) The energy released is coupled to the contraction, providing the energy the muscle proteins need to move.

3.3 ATP is hydrolyzed to ADP + P_i (used), and respiration re-adds the phosphate to remake ATP (recharged); this cycle repeats continuously.

2. To investigate how increases in environmental temperatures affect the metabolism of certain organisms, researchers incubated liver cells from toads at different temperatures and measured two markers of metabolic activity (Table 1): the rate of oxygen consumption and the rate of ATP synthesis.

(a) **Describe** the role of water in the hydrolysis of ATP.

TABLE 1. RATE OF OXYGEN CONSUMPTION AND ATP SYNTHESIS AT DIFFERENT TEMPERATURES

Metabolic Marker	20°C	25°C	30°C
Rate of Oxygen Consumption (nmol / min / mg of mitochondrial protein $\pm 2\,SE_{\bar{x}}$)	12.8 ± 2.2	16.5 ± 2.0	22.1 ± 0.7
Rate of ATP Synthesis (nmol / min / mg of mitochondrial protein $\pm 2\,SE_{\bar{x}}$)	12.6 ± 1.6	16.8 ± 2.0	21.07 ± 0.8

(b)

(i) Using the template in the space provided for your response, **construct** a bar graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled.

(ii) Based on the data provided, **determine** the temperature in °C at which the rate of oxygen consumption is different from the rate of oxygen consumption at 25°C.

(c)

(i) Based on the data in Table 1, **describe** the effect of temperature on the rate of ATP synthesis in liver cells from toads.

(ii) Based on the data in Table 1, **calculate** the average amount of oxygen consumed, in nmol, for 10 mg of mitochondrial protein after 10 minutes at 25°C.

(d)

(i) Oligomycin is a compound that can block the channel protein function of ATP synthase. **Predict** the effects of using oligomycin on the proton gradient across the inner mitochondrial membrane.

(ii) **Justify** your prediction.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

If there are multiple parts to this question, write the part letter with your response.

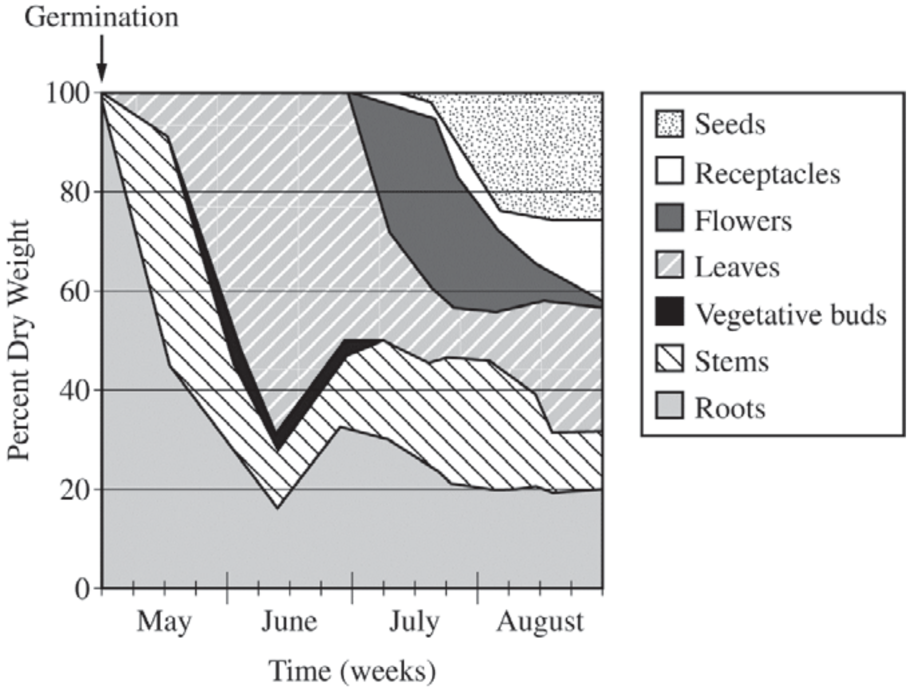

Figure 1. Percent dry weight of different plant structures during the growing season for an annual plant

3. The graph above illustrates the percent dry weight of different parts of a particular annual plant (plants that live less than one year) from early May to late August. The percent dry weight can be used to estimate the amount of energy a plant uses to produce its leaves, vegetative buds, stems, roots, and reproductive parts (seeds, receptacles, and flowers).

   (a) **Identify** the direct source of the energy used for plant growth during the first week of May, and **identify** the part of the plant that grew the most during the same period.

   (b) Based on the data on the graph, **estimate** the percent of the total energy that the plant has allocated to the growth of leaves on the first day of July.

   (c) Compared with perennials (plants that live more than two years), annual plants often allocate a much greater percentage of their total energy to growth of their reproductive parts in any given year. **Propose** ONE evolutionary advantage of the energy allocation strategy in annual plants compared with that in perennial plants.

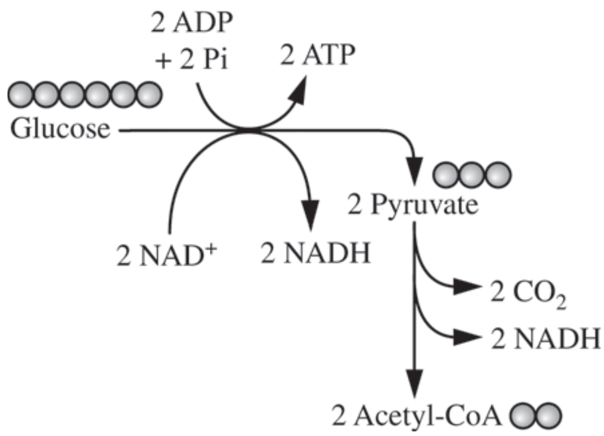

Figure 1. Glycolysis and pyruvate oxidation

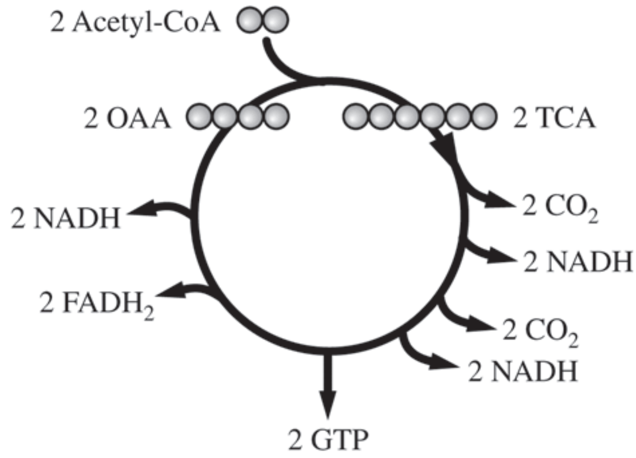

Figure 2. Krebs cycle

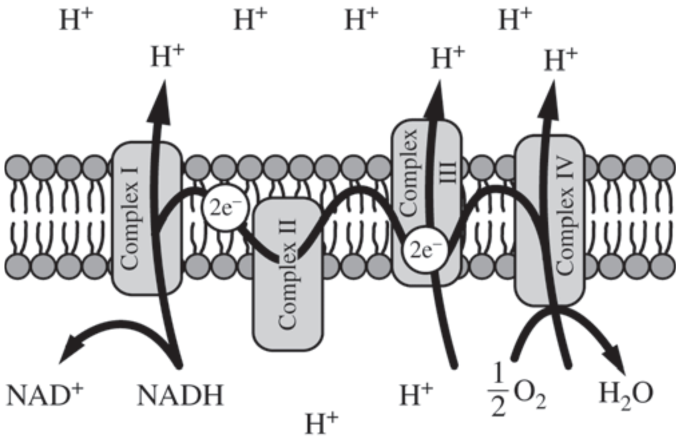

Figure 3. Electron transport chain

2. Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

   (a) Using the information above, **describe** ONE contribution of each of the following in ATP synthesis.

   - Catabolism of glucose in glycolysis and pyruvate oxidation
   - Oxidation of intermediates in the Krebs cycle
   - Formation of a proton gradient by the electron transport chain

   (b) Use each of the following observations to **justify** the claim that glycolysis first occurred in a common ancestor of all living organisms.

   - Nearly all existing organisms perform glycolysis.
   - Glycolysis occurs under anaerobic conditions.
   - Glycolysis occurs only in the cytosol.

(c) A researcher estimates that, in a certain organism, the complete metabolism of glucose produces 30 molecules of ATP for each molecule of glucose. The energy released from the total oxidation of glucose under standard conditions is 686 kcal/mol. The energy released from the hydrolysis of ATP to ADP and inorganic phosphate under standard conditions is 7.3 kcal/mol. **Calculate** the amount of energy available from the hydrolysis of 30 moles of ATP. **Calculate** the efficiency of total ATP production from 1 mole of glucose in the organism. **Describe** what happens to the excess energy that is released from the metabolism of glucose.

(d) The enzymes of the Krebs cycle function in the cytosol of bacteria, but among eukaryotes the enzymes function mostly in the mitochondria. **Pose** a scientific question that connects the subcellular location of the enzymes in the Krebs cycle to the evolution of eukaryotes.

AP BIOLOGY • EXERCISE SHEET

3.4 Photosynthesis

Name: ____________ Class: ________ Date: __________ **Total: 11 marks**

KEY WORDS photosynthesis 光合作用 • light reactions 光反应 • calvin cycle 卡尔文循环

Objective

Build the skills to answer exam questions on **photosynthesis**.

You must be able to:

- write the overall equation and locate the two stages
- describe the **light reactions 光反应** and the **Calvin cycle 卡尔文循环**
- state the inputs and outputs of each stage

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ The overall reaction

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

Plants use light energy to build glucose from CO_2 and water, releasing O_2.

■ The light reactions

In the **thylakoid** membranes, light energy splits water (releasing O_2) and makes **ATP** and **NADPH**. Inputs: light, water. Outputs: O_2, ATP, NADPH.

■ The Calvin cycle

In the **stroma**, the ATP and NADPH power the **Calvin cycle**, which fixes CO_2 into **glucose** (sugar). Inputs: CO_2, ATP, NADPH. Output: sugar.

■ A worked link

The two stages connect: the light reactions supply the ATP and NADPH that the Calvin cycle needs to build sugar from CO_2.

2 Practice

Now apply the methods above.

2.1 Write the overall equation for photosynthesis. [2]

2.2 Where do the light reactions occur? [1]

2.3 What gas is released by the light reactions? [1]

3 Exam-style questions

3.1 The Calvin cycle uses ATP and NADPH to make [1]

- **A** oxygen
- **B** sugar (glucose)
- **C** water
- **D** light

3.2 A plant is photosynthesizing.

(a) State the inputs and outputs of the light reactions. [2]

(b) Explain how the two stages of photosynthesis are connected. [2]

3.3 Explain why the release of oxygen comes from the splitting of water, not from carbon dioxide. [2]

Solutions

2.1 $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (with light).

2.2 In the thylakoid membranes of the chloroplast.

2.3 Oxygen.

3.1 **B** — sugar (glucose).

3.2 (a) Inputs: light and water; outputs: oxygen, ATP, and NADPH. (b) The light reactions produce the ATP and NADPH that power the Calvin cycle to fix CO_2 into sugar.

3.3 The light reactions split water molecules, and the oxygen atoms released come from that water (not from CO_2, whose carbon and oxygen go into sugar).

4. Noncyclic electron flow and cyclic electron flow are two major pathways of the light-dependent reactions of photosynthesis. In noncyclic electron flow, electrons pass through photosystem II, then components of a chloroplast electron transport chain, and then photosystem I before finally reducing $NADP^+$ to NADPH. In cyclic electron flow, electrons cycle through photosystem I and some components of the electron transport chain (Figure 1).

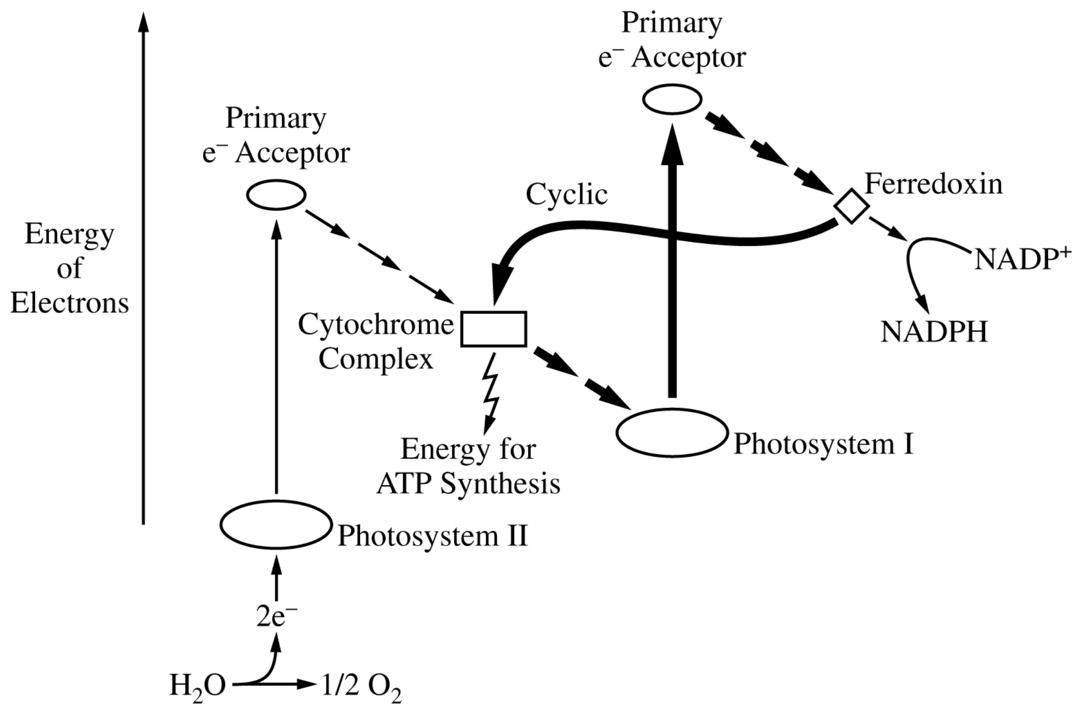

Figure 1. The pathways of noncyclic and cyclic (heavy arrows) electron flow. The cytochrome complex is a component of the electron transport chain between the two photosystems.

(a) **Describe** the role of chlorophyll in the photosystems of plant cells.

(b) Based on Figure 1, **explain** why an increase in the ratio of NADPH to $NADP^+$ will cause an increase in the flow of electrons through the cyclic pathway.

(c) Using rice plants, scientists examined the effect of a mutation that results in the loss of the protein CRR6. CRR6 is a part of the photosystem I complex, and its absence reduces the activity of photosystem I. **Predict** the effect of the mutation on the rate of biomass (dry weight) accumulation.

(d) **Justify** your prediction in part (c).

Write your responses to this question only on the designated pages in the separate Free Response booklet.

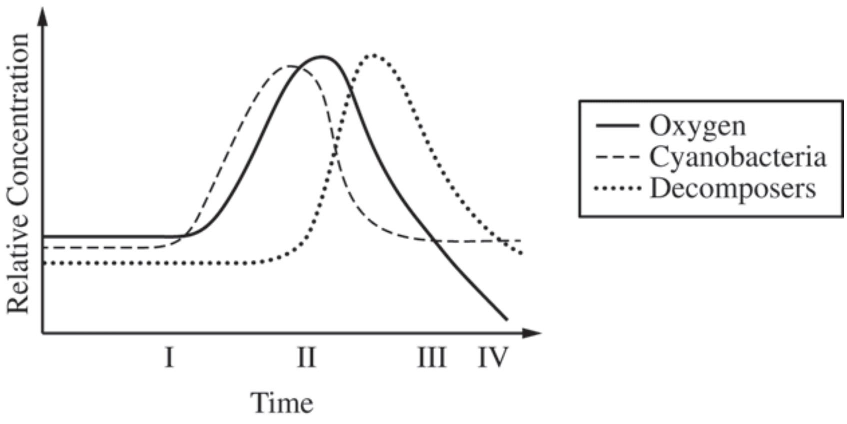

Figure 1. Characteristics of a pond community over time

5. *Microcystis aeruginosis* is a freshwater photosynthetic cyanobacterium. When temperatures increase and nutrients are readily available in its pond habitat, *M. aeruginosis* undergoes rapid cell division and forms an extremely large, visible mass of cells called an algal bloom. *M. aeruginosis* has a short life span and is decomposed by aerobic bacteria and fungi. **Identify** the metabolic pathway <u>and</u> the organism that is primarily responsible for the change in oxygen level in the pond between times I and II AND between times III and IV.

AP BIOLOGY • EXERCISE SHEET

3.5 Cellular Respiration

Name: ____________ Class: ________ Date: __________ **Total: 13 marks**

KEY WORDS electron transport chain 电子传递链 • cellular respiration 细胞呼吸 • glycolysis 糖酵解 • krebs cycle 克雷布斯循环 • fermentation 发酵

Objective

Build the skills to answer exam questions on **cellular respiration**.

You must be able to:

- write the overall equation
- name the three stages (**glycolysis** 糖酵解, **Krebs cycle** 克雷布斯循环, **electron transport chain** 电子传递链)
- state where most ATP is made and the role of oxygen

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ The overall reaction

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

Cells break down glucose with oxygen to release energy as ATP.

■ The three stages

- **Glycolysis** (cytoplasm) — splits glucose into pyruvate, makes a little ATP.
- **Krebs cycle** (mitochondrial matrix) — releases CO_2, makes electron carriers.
- **Electron transport chain** (inner mitochondrial membrane) — makes **most** of the ATP.

■ Oxygen's role

Oxygen is the **final electron acceptor** in the electron transport chain, forming water. Without it, the chain stops and little ATP is made.

■ A worked link

Most ATP comes from the electron transport chain, powered by electrons carried from glycolysis and the Krebs cycle, using a proton gradient across the inner membrane.

2 Practice

Now apply the methods above.

2.1 Write the overall equation for cellular respiration. [2]

2.2 Name the three stages of respiration. [3]

2.3 What is the role of oxygen in respiration? [1]

3 Exam-style questions

3.1 Most of the ATP in cellular respiration is made in the [1]

- **A** glycolysis stage
- **B** Krebs cycle
- **C** electron transport chain
- **D** cytoplasm

3.2 A cell is respiring aerobically.

(a) State where glycolysis occurs and its main product. [2]

(b) Explain what happens to ATP production if oxygen runs out. [2]

3.3 Explain the relationship between photosynthesis and respiration in terms of their reactants and products. [2]

Solutions

2.1 $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (+ ATP).

2.2 Glycolysis, the Krebs cycle, the electron transport chain.

2.3 It is the final electron acceptor in the electron transport chain.

3.1 **C** — the electron transport chain.

3.2 (a) Glycolysis occurs in the cytoplasm; its product is pyruvate. (b) Without oxygen the electron transport chain stops, so most ATP production halts and the cell relies on the small amount from glycolysis (fermentation).

3.3 They are opposites — photosynthesis uses CO_2 and water to make glucose and O_2; respiration uses glucose and O_2 to make CO_2 and water — so the products of one are the reactants of the other.

The following information applies to all parts.

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3. Cyanide is a chemical that affects the enzyme cytochrome *c* oxidase (CCO), a key enzyme in the mitochondrial electron transport chain. At high cyanide concentrations, CCO activity is much lower than when no cyanide is present. At low concentrations of cyanide, CCO activity is slightly higher than when no cyanide is present, as shown in Table 1.

Table 1. Effects of Cyanide on CCO Activity

No Cyanide	Low Cyanide	High Cyanide
Normal CCO activity	Slightly increases CCO activity	Greatly decreases CCO activity

Some strains of bacteria produce cyanide, which they then release into their environment. Other strains of bacteria do not produce cyanide. Researchers grew both types of bacteria in high-concentration nutrient medium and then isolated the medium from the bacteria. One-half of each medium sample was left at a high concentration, while the concentration of the other half was lowered.

To study the effects of cyanide on mammalian cells, researchers then added the four samples of media to the cells growing in culture dishes, as shown in Table 2. They measured ATP and lactic acid production by the mammalian cells in each of the four treatment groups.

Table 2. Experimental Design to Test Effects of Cyanide on Mammalian Cells

Mammalian Cell Treatment Group	Cyanide in Nutrient Medium?	Concentration of Medium
1	Yes	High
2	Yes	Low
3	No	High
4	No	Low

Part A

Describe the advantage to cells of producing ATP from one molecule of glucose by aerobic cellular respiration rather than by glycolysis alone.

Part B

Identify the two treatment groups that served as controls in the researchers' experiment.

Part C

Based on the information provided in both tables, **predict** the treatment group that is likely to have the highest ATP production of all four treatment groups.

Part D

The researchers claim that cells in which CCO activity is inhibited will show an increase in lactic acid production. **Support** the researchers' claim.

2. To investigate how increases in environmental temperatures affect the metabolism of certain organisms, researchers incubated liver cells from toads at different temperatures and measured two markers of metabolic activity (Table 1): the rate of oxygen consumption and the rate of ATP synthesis.

(a) **Describe** the role of water in the hydrolysis of ATP.

TABLE 1. RATE OF OXYGEN CONSUMPTION AND ATP SYNTHESIS AT DIFFERENT TEMPERATURES

Metabolic Marker	20°C	25°C	30°C
Rate of Oxygen Consumption (nmol / min / mg of mitochondrial protein $\pm 2\,SE_{\bar{x}}$)	12.8 ± 2.2	16.5 ± 2.0	22.1 ± 0.7
Rate of ATP Synthesis (nmol / min / mg of mitochondrial protein $\pm 2\,SE_{\bar{x}}$)	12.6 ± 1.6	16.8 ± 2.0	21.07 ± 0.8

(b)

(i) Using the template in the space provided for your response, **construct** a bar graph that represents the data shown in Table 1. Your graph should be appropriately plotted and labeled.

(ii) Based on the data provided, **determine** the temperature in °C at which the rate of oxygen consumption is different from the rate of oxygen consumption at 25°C.

(c)

(i) Based on the data in Table 1, **describe** the effect of temperature on the rate of ATP synthesis in liver cells from toads.

(ii) Based on the data in Table 1, **calculate** the average amount of oxygen consumed, in nmol, for 10 mg of mitochondrial protein after 10 minutes at 25°C.

(d)

(i) Oligomycin is a compound that can block the channel protein function of ATP synthase. **Predict** the effects of using oligomycin on the proton gradient across the inner mitochondrial membrane.

(ii) **Justify** your prediction.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

If there are multiple parts to this question, write the part letter with your response.

2. Elevated levels of CO_2 increase the rate of photosynthesis and growth in plants. Scientists studying the mechanisms involved in these increases examined a variety of species and found that when plants are exposed to elevated levels of CO_2, there is an increase in the number of chloroplasts per cell. To investigate whether the elevated levels of CO_2 have a similar effect on the number of mitochondria in plant cells, the scientists then selected six of these species to quantify the number of mitochondria per cell when the plants were exposed to both normal and elevated levels of CO_2 (Table 1).

TABLE 1. AVERAGE NUMBER OF MITOCHONDRIA IN PLANTS EXPOSED TO NORMAL AND ELEVATED LEVELS OF CO_2

Species	Mitochondria at Normal CO_2 (per 100 μm^2 of cell area) $\pm 2SE_{\bar{x}}$	Mitochondria at Elevated CO_2 (per 100 μm^2 of cell area) $\pm 2SE_{\bar{x}}$
1	1.0 ± 0.10	1.6 ± 0.10
2	0.4 ± 0.05	0.9 ± 0.08
3	0.5 ± 0.07	0.9 ± 0.10
4	0.3 ± 0.03	0.6 ± 0.06
5	0.7 ± 0.06	1.5 ± 0.22
6	1.3 ± 0.15	2.4 ± 0.22

(a) **Describe** the role of the inner mitochondrial membrane in cellular respiration.

(b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data in Table 1. **Determine** which species show(s) a difference in the number of mitochondria between normal and elevated levels of CO_2.

(c) Based on the data in Table 1, **describe** the relationship between the level of CO_2 and the average number of mitochondria per unit area of a cell.

(d) The leaves of a particular plant species are typically green, but scientists notice a plant in which the leaves have white stripes. They determine that the stripes result from a mutation in mitochondrial DNA that interferes with the development of chloroplasts. The scientists crossed plants using pollen from the plant with white-striped leaves and ovules from a plant with green leaves. **Predict** the phenotype(s) of the leaves of offspring produced from this cross. Provide reasoning to **justify** your prediction. **Explain** why plants with the same genotype are able to differ in the structure and/or number of certain organelles in response to changes in atmospheric levels of CO_2.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

3. Researchers hypothesize that the plant compound resveratrol improves mitochondrial function. To test this hypothesis, researchers dissolve resveratrol in dimethyl sulfoxide (DMSO). The solution readily passes through cell membranes. They add the resveratrol solution to mammalian muscle cells growing in a nutrient-rich solution (culture medium) that contains glucose. They measure ATP production at several time points after the addition of the resveratrol solution and find an increase in ATP production by the muscle cells.

(a) **Describe** the primary advantage for a mammalian muscle cell in using aerobic respiration over fermentation.

(b) **Identify** an appropriate negative control for this experiment that would allow the researchers to conclude that ATP is produced in response to the resveratrol treatment.

(c) **Predict** the effect on short-term ATP production when resveratrol-treated mammalian muscle cells are grown in a culture medium that lacks glucose or other sugars.

(d) The researchers find that resveratrol stimulates the production of components of the electron transport chain. The researchers claim that treatment with resveratrol will also increase oxygen consumption by the cells if glucose is not limiting. **Justify** the claim.

Write your responses to this question only on the designated pages in the separate Free Response booklet.

3. The pyruvate dehydrogenase complex (PDC) catalyzes the conversion of pyruvate to acetyl-CoA, a substrate for the Krebs (citric acid) cycle. The rate of pyruvate conversion is greatly reduced in individuals with PDC deficiency, a rare disorder.

   (a) **Identify** the cellular location where PDC is most active.

   (b) **Make a claim** about how PDC deficiency affects the amount of NADH produced by glycolysis AND the amount of NADH produced by the Krebs (citric acid) cycle in a cell. **Provide reasoning** to support your claims based on the position of the PDC-catalyzed reaction in the sequence of the cellular respiration pathway.

   (c) PDC deficiency is caused by mutations in the *PDHA1* gene, which is located on the X chromosome. A male with PDC deficiency and a homozygous female with no family history of PDC deficiency have a male offspring. **Calculate** the probability that the male offspring will have PDC deficiency.

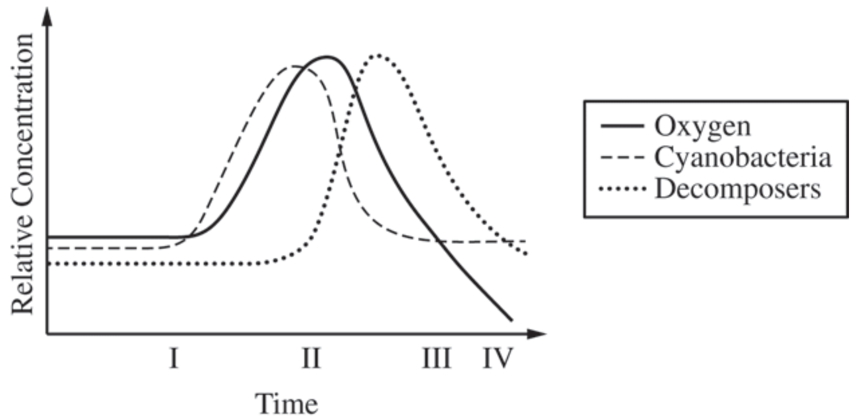

Figure 1. Characteristics of a pond community over time

5. *Microcystis aeruginosis* is a freshwater photosynthetic cyanobacterium. When temperatures increase and nutrients are readily available in its pond habitat, *M. aeruginosis* undergoes rapid cell division and forms an extremely large, visible mass of cells called an algal bloom. *M. aeruginosis* has a short life span and is decomposed by aerobic bacteria and fungi. **Identify** the metabolic pathway <u>and</u> the organism that is primarily responsible for the change in oxygen level in the pond between times I and II AND between times III and IV.

7. Many species of bacteria grow in the mouths of animals and can form biofilms on teeth (plaque). Within plaque, the outer layers contain high levels of oxygen and the layers closest to the tooth contain low levels of oxygen. The surface of the tooth is covered in a hard layer of enamel, which can be dissolved under acidic conditions. When the enamel breaks down, the bacteria in plaque can extract nutrients from the tooth and cause cavities.

   Certain types of bacteria (e.g., *Streptococcus mutans*) thrive in the innermost anaerobic layers of the plaque and are associated with cavities. Other types of bacteria (*Streptococcus sanguinis*) compete with *S. mutans* but are unable to thrive in acidic environments.

   (a) **Identify** the biochemical pathway *S. mutans* uses for metabolizing sugar and **describe** how the pathway contributes to the low pH in the inner layers of plaque.

   (b) Normal tooth brushing effectively removes much of the plaque from the flat surfaces of teeth but cannot reach the surfaces between teeth. Many commercial toothpastes contain alkaline components, which raise the pH of the mouth. **Predict** how the population sizes of *S. mutans* AND *S. sanguinis* in the bacterial community in the plaque between the teeth are likely to change when these toothpastes are used.

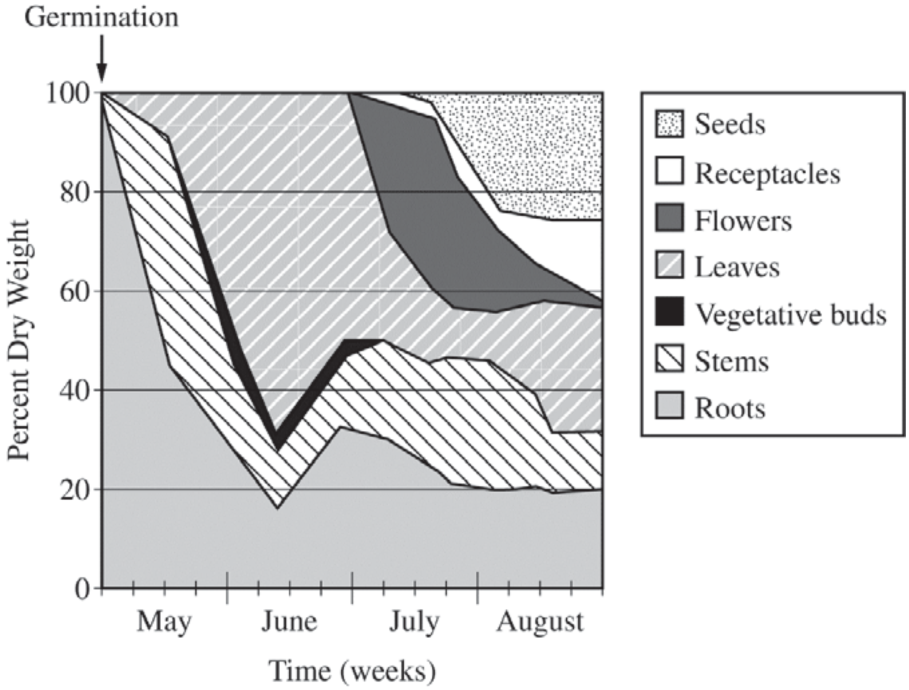

Figure 1. Percent dry weight of different plant structures during the growing season for an annual plant

3. The graph above illustrates the percent dry weight of different parts of a particular annual plant (plants that live less than one year) from early May to late August. The percent dry weight can be used to estimate the amount of energy a plant uses to produce its leaves, vegetative buds, stems, roots, and reproductive parts (seeds, receptacles, and flowers).

   (a) **Identify** the direct source of the energy used for plant growth during the first week of May, and **identify** the part of the plant that grew the most during the same period.

   (b) Based on the data on the graph, **estimate** the percent of the total energy that the plant has allocated to the growth of leaves on the first day of July.

   (c) Compared with perennials (plants that live more than two years), annual plants often allocate a much greater percentage of their total energy to growth of their reproductive parts in any given year. **Propose** ONE evolutionary advantage of the energy allocation strategy in annual plants compared with that in perennial plants.

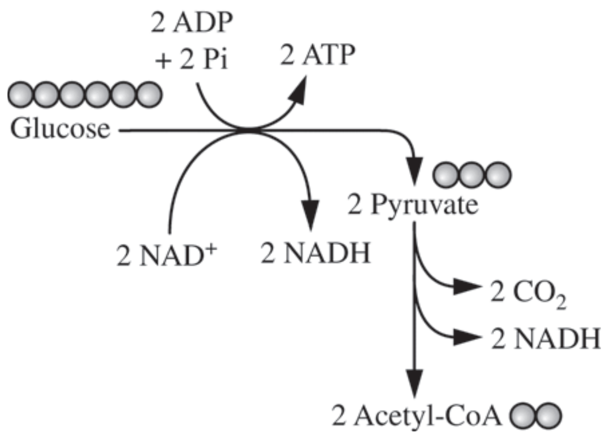

Figure 1. Glycolysis and pyruvate oxidation

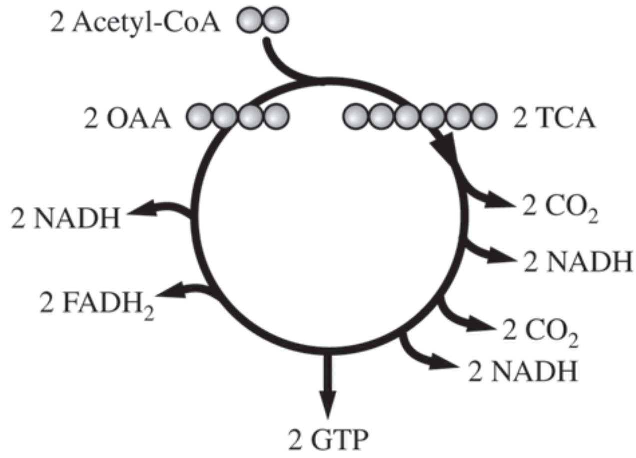

Figure 2. Krebs cycle

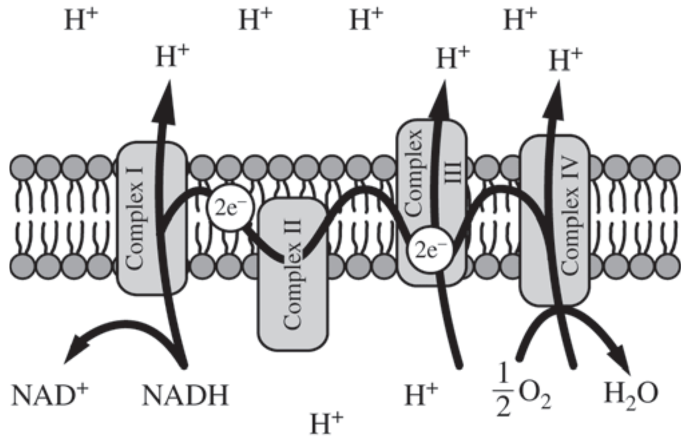

Figure 3. Electron transport chain

2. Cellular respiration includes the metabolic pathways of glycolysis, the Krebs cycle, and the electron transport chain, as represented in the figures. In cellular respiration, carbohydrates and other metabolites are oxidized, and the resulting energy-transfer reactions support the synthesis of ATP.

   (a) Using the information above, **describe** ONE contribution of <u>each</u> of the following in ATP synthesis.

   - Catabolism of glucose in glycolysis and pyruvate oxidation
   - Oxidation of intermediates in the Krebs cycle
   - Formation of a proton gradient by the electron transport chain

   (b) Use each of the following observations to **justify** the claim that glycolysis first occurred in a common ancestor of all living organisms.

   - Nearly all existing organisms perform glycolysis.
   - Glycolysis occurs under anaerobic conditions.
   - Glycolysis occurs only in the cytosol.

(c) A researcher estimates that, in a certain organism, the complete metabolism of glucose produces 30 molecules of ATP for each molecule of glucose. The energy released from the total oxidation of glucose under standard conditions is 686 kcal/mol. The energy released from the hydrolysis of ATP to ADP and inorganic phosphate under standard conditions is 7.3 kcal/mol. **Calculate** the amount of energy available from the hydrolysis of 30 moles of ATP. **Calculate** the efficiency of total ATP production from 1 mole of glucose in the organism. **Describe** what happens to the excess energy that is released from the metabolism of glucose.

(d) The enzymes of the Krebs cycle function in the cytosol of bacteria, but among eukaryotes the enzymes function mostly in the mitochondria. **Pose** a scientific question that connects the subcellular location of the enzymes in the Krebs cycle to the evolution of eukaryotes.