

**Chapter 6: Metabolism: Energy and Enzymes**

1. Describe the first and second law of thermodynamics.
2. Compare the energy associated with endergonic and exergonic reactions.
3. Explain how energy is stored in a molecule of ATP. Describe the structure of ATP.
4. Explain the purpose of a metabolic pathway and how enzymes help to regulate it.
5. Explain how enzymes increase the rate of a reaction.
6. Distinguish between conditions and factors that affect an enzyme's rate of reaction.
7. Compare and contrast the different types of inhibitors that can stop an enzyme from working.
8. Describe the currently accepted model of enzymes and substrates.
9. Evaluate the usefulness of cofactors in enzyme regulation.
10. Compare the role of carbon dioxide in photosynthesis and cellular respiration.
11. Distinguish how energy from electrons is used to establish an electrochemical gradient in chloroplasts and mitochondria.

**Chapter 7: Photosynthesis**

1. Describe three major groups of photosynthetic organisms. Explain how photosynthesis represents a redox reaction. Understand where oxidation and reduction of compounds occurs during the process.
2. Describe the components of a chloroplast. Explain where the light reaction and the Calvin cycle occur.
3. Compare energy input and output of the light reaction. Compare carbon input and output of the Calvin cycle reaction.
4. Describe the role of enzymes during photosynthesis.
5. Describe the relationship between wavelength and energy in the electromagnetic spectrum.
6. Explain the role of photosynthetic pigments in harvesting solar energy.
7. Explain how ATP and NADPH are produced from redox reactions and membrane gradients.
8. Describe the three phases of the Calvin cycle and when ATP and/or NADPH are needed.

**Chapter 8: Cellular Respiration**

1. Describe the overall reaction for glucose breakdown and show that it is a redox reaction.
2. Describe the four phases of complete glucose breakdown, including which release  $\text{CO}_2$  and which produce  $\text{H}_2\text{O}$ .
3. Explain the role of NADH and  $\text{FADH}_2$  in cellular respiration.
4. Identify the locations of each of the four phases of cellular respiration.
5. Explain how ATP is produced during glycolysis.
6. Explain how ATP can be produced in the absence of oxygen. Describe the role of NADH in fermentation.
7. Compare the benefits and drawbacks of fermentation.
8. Contrast substrate-level phosphorylation and chemiosmosis as methods of ATP synthesis.
9. Describe the process of oxidative phosphorylation in cellular respiration. Identify the molecule that accepts the electrons at the end of the line.
10. Identify which processes during cellular respiration produce the most ATP.
11. Evaluate how catabolism and anabolism are balanced within a cell.
12. Compare the structure and function of chloroplasts and mitochondria.

## Past AP Exam Essay Questions

### 1999 Question 1

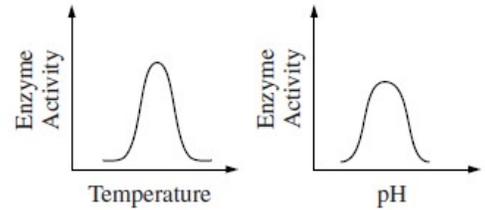
The rate of photosynthesis may vary with changes that occur in environmental temperature, wavelength of light, and light intensity. Using a photosynthetic organism of your choice, choose only ONE of the three variables (temperature, wavelength of light, or light intensity) and for this variable

- Design a scientific experiment to determine the effect of the variable on the organism's rate of photosynthesis
- Explain how you would measure the rate of photosynthesis in your experiment
- Describe the results you would expect. Explain why you would expect these results.

### 2000 Question 1

The effects of pH and temperature were studied for an enzyme-catalyzed reaction. The following results were obtained.

- How do (1) temperature and (2) pH affect the activity of this enzyme? In your answer, include a discussion of the relationship between the structure and the function of this enzyme, as well as a discussion of how structure and function of enzymes are affected by temperature and pH.
- Describe a controlled experiment that could have produced the data shown for either temperature or pH. Be sure to state the hypothesis that was tested.



### 2004 Question 3

A controlled experiment was conducted to analyze the effects of darkness and boiling on the photosynthetic rate of incubated chloroplast suspensions. The dye reduction technique was used. Each chloroplast suspension was mixed with DPIP, an electron acceptor that changes from blue to clear when it is reduced. Each sample was placed individually in a spectrophotometer and the percent transmittance was recorded. The three samples used were prepared as follows.

- Sample 1: chloroplast suspension + DPIP
- Sample 2: chloroplast suspension surrounded by foil wrap to provide a dark environment + DPIP
- Sample 3: chloroplast suspension that has been boiled + DPIP

Time (min)	Light, Unboiled % Transmittance/ Sample 1	Dark, Unboiled % Transmittance/ Sample 2	Light, Boiled % Transmittance/ Sample 3
0	28.8	29.2	28.8
5	48.7	30.1	29.2
10	57.8	31.2	29.4
15	62.5	32.4	28.7
20	66.7	31.8	28.5

- On the axes provided, construct and label a graph showing the results for the three samples.
- Identify and explain the control or controls for this experiment.
- The differences in the curves of the graphed data indicate that there were differences in the number of electrons produced in the three samples during the experiment. Discuss how electrons are generated in photosynthesis and why the three samples gave different transmittance results.

### 2005 Question 1

Yeast cells are placed in an apparatus with a solution of sugar (a major nutrient for yeast metabolism). The apparatus detects bubbles of gas released by yeast cells. The rate of respiration varies with the surrounding temperatures as indicated

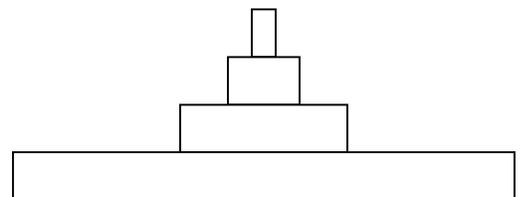
Temperature (C°)	0	10	20	30	40	50	60	70
# of bubbles of gas produced per min	0	3	7	12	7	4	1	0

- Graph the results on the axes provided. Determine the optimum temperature for respiration in the yeast.
- Respiration is a series of enzyme-catalyzed reactions. Using your knowledge of enzymes and the data above, analyze and explain the results of this experiment.
- Design an experiment to test the effect of varying the pH of the sugar solution on the rate of respiration. Include a prediction of the expected results.

### 2009 Question 2

ATP and GTP are primary sources of energy for biochemical reactions.

- Describe the structure of the ATP or GTP molecule.
- Explain how chemiosmosis produces ATP.
- Describe two specific cell processes that require ATP and explain how ATP is used in each process.
- An energy pyramid for a marine ecosystem is shown below. Label each trophic level of the pyramid and provide an example of a marine organism found at each level of this pyramid. Explain why the energy available at the top layer of the pyramid is a small percentage of the energy present at the bottom of the pyramid.



### 2010 Question 2

An experiment was conducted to measure the reaction rate of the human salivary enzyme  $\alpha$ -amylase. Ten mL of a concentrated starch solution and 1.0 mL of  $\alpha$ -amylase solution were placed in a test tube. The test tube was inverted several times to mix the solution and then incubated at 25°C. The amount of product (maltose) present was measured every 10 minutes for an hour. The results are given in the table below.

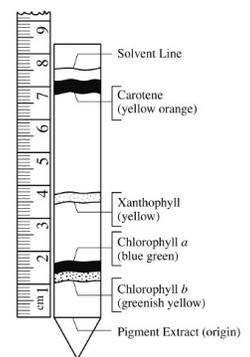
Time (minutes)	Maltose Concentration ( $\mu\text{M}$ )
0	0
10	5.1
20	8.6
30	10.4
40	11.1
50	11.2
60	11.5

- Graph the data on the axes provided and calculate the rate of the reaction for the time period 0 to 30 minutes.
- Explain why a change in the reaction rate was observed after 30 minutes.
- Draw and label another line on the graph to predict the results if the concentration of  $\alpha$ -amylase was doubled. Explain your predicted results.
- Identify two environmental factors that can change the rate of an enzyme-mediated reaction. Discuss how each of those two factors would affect the reaction rate of an enzyme.

### 2010 Form B Question 1

Biological molecules can be separated by using chromatographic techniques. The diagram below shows the separation of several spinach leaf pigments by paper chromatography. Using the diagram below

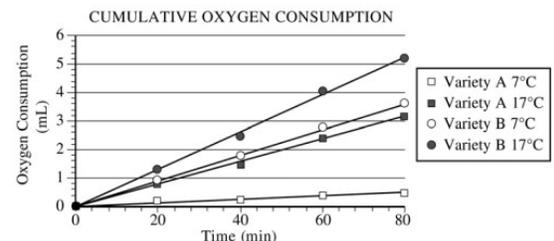
- Explain how paper chromatography can be used to separate pigments based on chemical and physical properties.
- Discuss the role of pigments in capturing light energy and in converting it to chemical energy of ATP + NADPH.
- Use the ruler shown below to determine the  $R_f$  value of xanthophyll. Show your calculations.



### 2012 Question 2

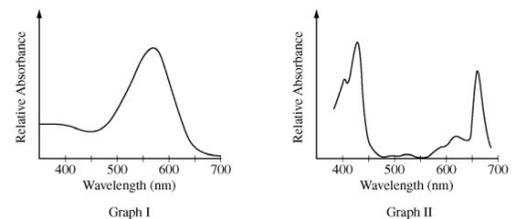
An agricultural biologist was evaluating two newly developed varieties of wheat as potential crops. In an experiment, seedlings were germinated on moist paper towels at 20°C for 48 hours. Oxygen consumption of the two-day-old seedlings was measured at different temperatures. The data are shown in the graph below.

- Calculate the rates of oxygen consumption in mL/min for each variety of wheat at 7°C and at 17°C. Show your work (including setup and calculation).
- Explain the relationship between metabolism and oxygen consumption. Discuss the effect of temperature on metabolism for each variety of seedlings.
- In a second experiment, variety A seedlings at both temperatures were treated with a chemical that prevents NADH from being oxidized to NAD<sup>+</sup>. Predict the most likely effect of the chemical on metabolism and oxygen consumption of the treated seedlings. Explain your prediction.



### 2013 Question 2

An absorption spectrum indicates the relative amount of light absorbed across a range of wavelengths. The graphs represent the absorption spectra of individual pigments isolated from two different organisms. One of the pigments is chlorophyll *a*, commonly found in green plants. The other pigment is bacteriorhodopsin, commonly found in purple photosynthetic bacteria. The table shows the approximate ranges of wavelengths of different colors in the visible light spectrum.



- Identify** the pigment (chlorophyll *a* or bacteriorhodopsin) used to generate the absorption spectrum in each of the graphs. **Explain and justify** your answer.
- In an experiment, identical organisms containing the pigment from graph II as the predominant light-capturing pigment are separated into three groups. The organisms in each group are illuminated with light of a single wavelength (650 nm for the first group, 550 nm for the second equal intensity, and all organisms are illuminated for equal lengths of time. **Predict** the relative rate of photosynthesis in each of the three groups. **Justify** your predictions.

Color	Wavelength (nm)
Violet	380–450
Blue	450–475
Cyan	475–495
Green	495–570
Yellow	570–590
Orange	590–620
Red	620–750

- c. Bacteriorhodopsin has been found in aquatic organisms whose ancestors existed before the ancestors of plants evolved in the same environment. **Propose** a possible evolutionary history of plants that could have resulted in a predominant photosynthetic system that uses only some of the colors of the visible light spectrum.

### 2015 Question 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.

- 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
- Use each observation 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.
- 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.
- 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.

### 2017 Question 5

*Microcystis aeruginosa* is a freshwater photosynthetic cyanobacterium. When temperatures increase and nutrients are readily available in its pond habitat, *M. aeruginosa* undergoes rapid cell division and forms an extremely large, visible mass of cells called an algal bloom. *M. aeruginosa* has a short life span and is decomposed by aerobic bacteria and fungi. **Identify** the metabolic pathway AND the organism that is primarily responsible for the oxygen levels in the pond for the following times:

- between I and II
- between III and IV

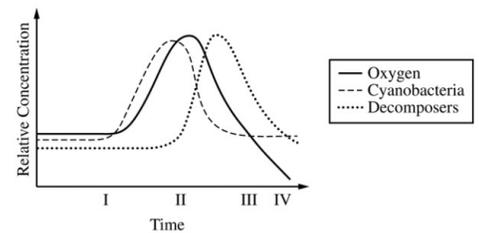


Figure 1. Characteristics of a pond community over time

### 2017 Question 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.

- 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.
- 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 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.