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BIOLOGY
SECTION II
Time—90 minutes
4 Questions

Directions: Answer all questions. Write your answers on the pages following the questions in the pink booklet.

Answers must be in essay form. Outline form is NOT acceptable. Labeled diagrams may be used to supplement discussion, but in no case will a diagram alone suffice. It is important that you read each question completely before you begin to write.

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

![Graphs showing enzyme activity vs. temperature and pH]

a) 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.

b) 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 here.

As the results from the experiment show, the enzyme has both an optimal temperature and an optimal pH. Deviation from this optimum results in a decrease in enzyme activity and efficiency. Enzymes are proteins whose unique structure allow them to catalyze chemical reactions. They have primary structure, the sequence of amino acids, presence or absence of alpha helices and beta...
pleated Sheets, the types of bonds (ionic, covalent, disulfide, etc.) and the aggregation with another enzyme all affect an enzyme's ability to perform. This unique structure results in an active site, an area that is conducive to the reactants of a particular reaction. Each enzyme is very specific and can catalyze only one reaction. Its active site is only open to one substrate (reactant). This is known as the lock and key theory of enzyme specificity. By temporarily hydrogen bonding to the substrate, the enzyme puts the reactants in positions which enhance the probability of a reaction occurring. When heat is applied to an enzyme, the movement of substrate increases and the substrates are more likely to come in contact with the enzyme's active site. This increases enzyme activity. However, if too much heat is applied, the enzyme will denature, its shape will change, and the substrate will no longer be able to fit in the active site, decreasing enzyme activity. The same is true for pH. If the pH is too acidic, the influx of \( H^+ \) may affect the bonds of the enzyme, as may an influx of \( OH^- \) if the pH is too basic. This will
also affect the shape of the enzyme's active site and adversely influence its ability to catalyse a reaction.

(b) A controlled experiment could have been produced to show the effects of temperature on enzyme activity. The hypothesis would be that enzymes work best at a warmer temperature, but if the temperature is too hot, the enzyme will denature and its activity rate will decrease. In order to do this an enzyme and substrate must be chosen. A good enzyme would be catalase, which increases the rate at which hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) breaks down into water (H<sub>2</sub>O) and oxygen (O<sub>2</sub>). For the control, the enzyme and substrate would be placed in room temperature. Numerous beakers of enzyme and substrate would be allowed to sit for different time intervals. The reactions could be stopped by the addition of a strong acid to the beakers. This would denature the enzymes and stop the conversion of H<sub>2</sub>O<sub>2</sub> into H<sub>2</sub>O and O<sub>2</sub>. A graph could then be plotted of energy in order to determine how active the enzyme was; a titration could be used. A titration is the introduction of an indicator chemical.
that allows one to visualize the endpoint of a reaction. The amount of H2O2 remaining could be determined and plotted on a graph. To check the affects of temperature on enzyme activity, the experiment could be run several times more, but each time with a different temperature, some colder and some warmer. By comparing these various graphs to the graph of the control, it would be possible to determine the affects of heat on enzyme activity.
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The graphs shown indicate a normal shaped distribution meaning that as temperature or pH levels increase, the enzyme activity will also increase. This is reversed once a peak, maximum potential is reached. Then the further increase of temperature or pH level will hinder enzymatic activity. An enzyme is produced to fit the needs of one function. Each enzyme can only bond with its respective substrate. This model, often called the lock and key model, allows for only slight variations in order

The two match up at the binding site only with each other.

GO ON TO THE NEXT PAGE
to allow the enzyme to fit properly with the substrate. Enzymes have natural habitats within an organism which include an ideal temperature and pH level. At lower or higher temperatures the enzyme loses its ability to bind to its substrate, thus as the temperature decreases or increases outside of the enzyme's ideal range, more and more enzymes become inactive. pH levels have similar effects, enzymes can only tolerate specific (often small) ranges of pH, this once the range of effective pH levels is left the enzyme becomes denatured. The denatured enzyme loses its ability to bind with substrate and alter the shape of the enzyme into an effective shape. 

It is possible to restore the shape but only if the alteration of the enzyme is minimal (thus the ideal range). So in order for an enzyme to begin a reaction in an organism, it is ideal for the organism to be able to maintain proper pH levels and body temperature.

The hypothesis of the experiment is that temperature does have an effect on the activities of the enzyme. In order to reveal the data curve for temperature effects on enzyme activity an experiment can be conducted. Using several beakers possibly four. An experimenter would place an equal amount of substrate into the beakers. Then it would be necessary to heat or cool each beaker to a specific OC perhaps 10°C, 20°C, 30°C, 40°C. Then the experimenter can place an equal amount of enzyme (the same corresponding to the chosen substrate) and pour them into their beakers. Allowing for the reaction to occur after a set amount of time (maybe 2 minutes) an acid should be added in order to cease all reactions via denaturation. The experimenter can then measure the products of the reaction to
determine the amount of enzymatic activity in each respective temperature.
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Enzymes are proteins that catalyze biological reactions. Although they are unable to make a reaction occur that would not normally occur in nature, they substantially lower the necessary activation energy for the reaction. This greatly increases the reaction rate. Enzymes are also usually highly specific, which means that each enzyme catalyzes one or maybe a few chemical reactions.

There are two different theories as to how an enzyme functions. The first is known as the lock-and-key model,
as shown below. Note that the structure of the enzyme remains essentially unchanged.

**Lock-and-Key Model**

enzyme $\xrightarrow{\text{bonding sites}}$ enzyme-substrate complex

Another theory is based on the **induced-fit model**. This is currently thought to be the most likely model of an enzyme, as shown below. Note that the conformation of the protein changes slightly in the presence of the proper reactants.

**Induced-Fit Model**

enzyme $\xrightarrow{\text{reactants}}$ enzyme-substrate complex $\xrightarrow{\text{product}}$

Enzymes are affected by a variety of factors, including temperature and pH. Most enzymes work most effectively at between 20-30°C and 6-8 pH. When enzymes are exposed to temperature or pH extremes, it affects their tertiary bonding structure and may even permanently denature the enzyme. However, some enzymes such as pepsin function at pH or temperature extremes. Pepsin is most effective at low (acidic) pH’s as are found in the stomach.
b) The hypothesis is that enzymes are most effective at temperatures between 20° and 30°C. In order to test this, an experiment could be designed in which potatoes and the enzyme amylase are mixed together combined in solutions at varying temperatures ranging from 0°C to 50°C. Thus, there would be setups for 0°, 10°, 20°, 30°, 40°, and 50°. Potatoes contain starch, and amylase is an enzyme that breaks this down. After a specified time period, content for all temperatures the amount of product could be measured, and the data processed to obtain a curve and graphed. This experiment should serve to reinforce the aforementioned hypothesis and produce the following curve:
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\[ \text{[A1] It seems to me that the enzyme is affected well by temperature. There is a rise as the enzyme catalysis reaches its optimum temperature and then a fall as temperatures get so hot that they actually inhibit catalysis.} \]

\[ \text{[A2] As for pH it also has an optimum pH but it seems to be lower than the optimum temperature. The optimum pH is in the middle so it might be an} \]
enzyme whose optimum pH is around 7 (not acid or basic but neutral). As the pH scale rises, its enzyme activity increases but only until it reaches the middle because when it does it starts going down again as the environment gets too basic.

My experiment would consist on testing for the optimum temperature for the enzyme lactase on the catalyst lactase found in ordinary cows milk.

I would keep the milk in different beakers. Exactly 5 beakers each filled with 500 mL of milk. Beaker #1 would be at 40°F. Beaker #2 would be at 55°F. Beaker #3 would be at room temperature ≈ 70°F. Beaker #4 @ 85°F. Beaker #5 @ 100°F. I would grind up 16one) Lactaid® Lactase caplet into each beaker. Then I'd test for glucose content in each in 5 min. The one with the highest content would be the optimum temp.