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BIOLOGY 12 - ENZYMES & METABOLISM

- **Part A: Definitions**: Define the following terms, **IN YOUR OWN WORDS, IN AS FEW WORDS AS CLARITY AND COMPLETENESS ALLOW**.

i.	metabolism	all the chemical reactions that take place in living systems to maintain homeostasis
ii.	substrate	the substances that enter a specific reaction
iii.	enzyme	proteins that serve as catalysts (they speed up reactions)
iv.	active site	the place on an enzyme where substrate(s) bind
v.	apoenzyme	the protein part of an enzyme, gives the enzyme its specificity
vi.	coenzyme	non-protein organic molecules (e.g. NAD+) that help enzymes to catalyze reactions or carry electrons, hydrogen, or functional groups stripped from substrates. Often complete the active site.
vii.	metabolic pathway	a stepwise sequence of reactions in cells, with specific enzymes catalyzing each step.
viii.	activation energy	the minimum amount of energy that colliding reactants must have in order for a chemical reaction to occur.

Part B: Short Answers

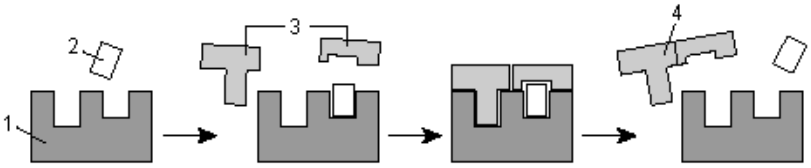
1. The equation ADP + $P_i \rightarrow$ ATP is energy (*requiring or releasing*) **requiring**.
2. In the pathway below, the letters stand for **substrates** and the numbers stand for **enzymes**. Each and every reaction in a cell requires a specific **enzyme**.

3. If an enzymatic reaction is heated *gently*, it will **speed up**.
4. Enzymes **LOWER** the amount of activation energy necessary for a reaction to take place by putting its substrates on a precise "collision course."
5. When NAD accepts hydrogens from a substrate, it is **reduced**, while the substrate is **oxidized**.
6. In the equation S + E $\rightarrow$ SE $\rightarrow$ P + E, what do the letters stand for?
   S: **substrate** P: **product**
   SE: **substrate-enzyme complex** E: **enzyme**
7. Name two environmental factors that can change the shape of an enzyme.
   i. **temperature** ii. **pH**
8. Name two factors that can speed up enzymatic reactions
   i. **increase temp** ii. **increase [] of substrate or enzyme**
9. Enzymes have helpers called **coenzymes**. A common example of the latter is NAD. What is the function of NAD in cells? **Carries H atoms in oxidation reduction reactions**.
10. Give the overall equation for aerobic cellular respiration. Indicate energy on the correct side.

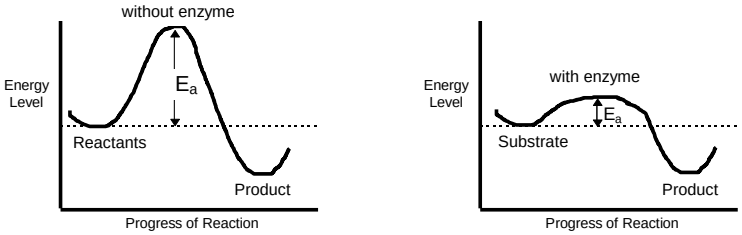
$C_6H_{12}O_6$	+	$6O_2$	-------->	$6CO_2$	+	$6H_2O$	+	38 ATP
Food (Glucose)	+	oxygen		carbon dioxide	+	Water	+	Energy

11. In a metabolic pathway, a) the product of one reaction becomes the substrate of the next reaction b) the same enzyme is used for all reactions c) the end product is always pyruvic acid d) ATP is used up all the time e) all of these **correct answer = a**
12. Label the parts on the diagram to the right.

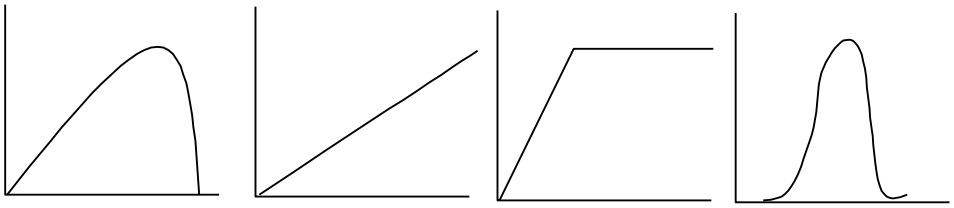
1	**ENZYME**
2	**COENZYME**
3	**SUBSTRATE**
4	**PRODUCT**



13. Label all missing parts on the graphs to the right. **Highlight the energy of activation** on both graphs.



14. Which graph below best represents a graph of the Enzyme activity vs pH? **D**



Part C: Thinking Questions - Answer on separate sheets of paper, in your OWN WORDS.

1. What **advantages** can you see in having **complex metabolic pathways** within body cells to produce various substances, such as amino acids and ATP?
- *more control over reactions (can be halted/modified/sped up/slowed down at any step).*
- *more sophisticated reactions possible, so more complex molecules can be made*
- *intermediate products can be used in other pathways*
- *cyclic pathways/feedback mechanisms possible*

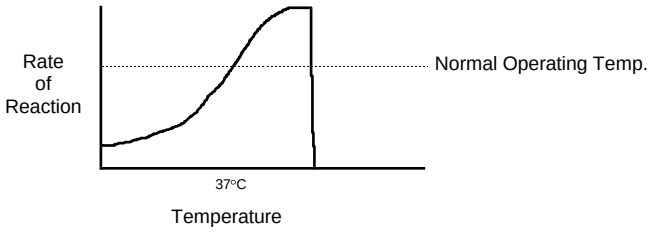
2. What gland produces the hormone thyroxin? What is the function of thyroxin in metabolism?
Thyroid gland. Thyroxin increases cellular metabolism (increases oxygen uptake, protein synthesis etc.)

3. Explain, using a good example, how a metabolic pathway can be **self-regulating** (that is, how it can shut itself on and off).
- *The amino acid aspartate becomes the amino acid threonine by a sequence of 5 enzymatic reactions. When threonine, the end product of this pathway, is present in excess, it binds to an allosteric site on enzyme 1, and then the active site is no longer able to bind aspartate.*

4. How does the "**Lock and Key**" theory of enzyme action differ from the "Induced Fit" theory? Use diagrams to help your explanation.
In Induced Fit model, once the substrate binds the enzyme, the enzyme changes shape to more tightly bind the substrate. In Lock & Key model, E and S fit each other perfectly before they bind. See notes for diagrams

5. Why do you think each enzyme has its own preferred pH at which it operates?
- *Changes in pH cause conformation changes (denaturing) in proteins (because they disrupt bonds holding the enzyme in its precise shape). Changes in E shape at active site will impair or destroy its substrate-binding ability.*

6. What is the effect of lowering the temperature on enzyme activity. How about raising the temperature? Draw a graph to show these relationships.
Lowering temperature lowers the rate of activity (but does not usually denature the enzyme). Raising the temperature moderately (e.g. from 37 degrees to 40 degrees) raises the rate of reaction. Raising the temperature a large amount (e.g. from 37 degrees to 50 degrees) will denature the enzyme.



7. Describe three factors that can lead to the **denaturing of enzymes**. How would denaturing an enzyme affect its activity?
- *Factors:*
  1) pH 2) high temperature 3) heavy metals 4) specific chemicals (e.g. HCN)
- *The bonds that hold enzyme together become disrupted, causing the Enzyme to lose its precise 3D tertiary structure/quaternary structure.*

8. What happens to the **rate of product formation** if you continue to add to an enzyme-catalyzed reaction the following:
a) **substrate** b) **enzyme** c) **an inhibitor** d) **Lead**, **mercury**, or **cadmium** e) **H^+ ions** f) **$OH^=$ ions**
- *a) Increase until enzymes saturated b) increase as long as substrate present c) decrease d) decrease and can cause denaturing e) decrease and can cause denaturing f) decrease and can cause denaturing*

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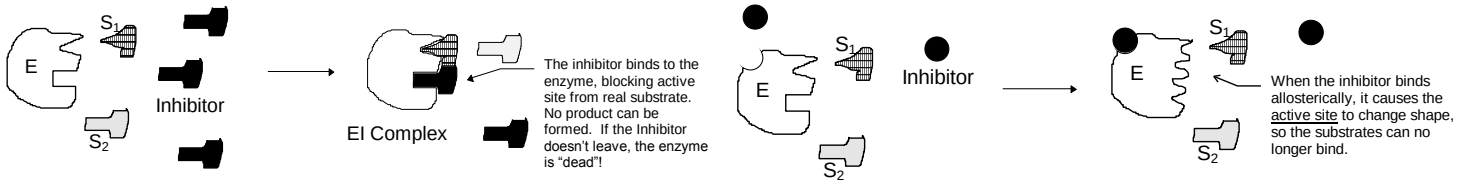
9. Explain, using diagrams, how **competitive inhibitors** differ from **non-competitive** inhibitors in the way they act on enzymes.



Competitive is on the left, non-competitive is on the right. Both slow the rate of reaction.

10. Discuss, using examples, the effects of **reversible** and **non-reversible** inhibitors on enzyme activity.

- *Reversible inhibitors will slow down enzyme action. The more inhibitor that is added, the more the activity slows. e.g. threonine. Non-reversible inhibitors will slow down enzyme action. Each inhibitor will destroy an enzyme. If enough I added, E activity will eventually cease. e.g. HCN, Pb++, Hg++, penicillin*

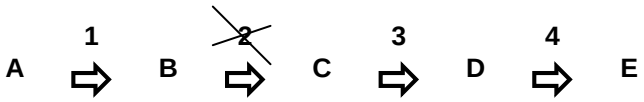
11. Explain the role of vitamins in metabolic reactions. List at least 2 examples.

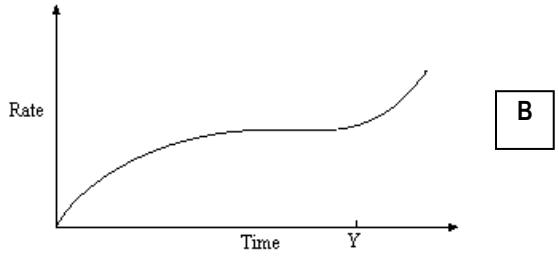
- *Many vitamins are integral (i.e. structural) parts of coenzymes and therefore are necessary for enzyme function. Vitamins are relatively small organic molecules that our bodies can't synthesize, and so must be ingested in trace amounts in our diets. For example*

Vitamin	Coenzyme
Niacin	$NAD^{=}$
B_2 (riboflavin)	FAD
B_1 (Pantothenic acid)	Coenzyme A (CoA)
B_{12} (cobalamin)	B_{12} coenzymes

12. Explain why a genetic defect that affects only one enzyme in a metabolic pathway can have serious consequences.

- *A genetic effect in an enzyme in a metabolic pathway means that the enzyme may no longer function. If it no longer functions, this means that the pathway will stop at that point, and all the other steps "downstream" will also be affected or stop. This could cause disastrous effects on homeostasis. For example, if enzyme 2 in the pathway below is non-functional due to a genetic defect, C, D, and E will not be produced, and any pathways requiring C, D, and E will also be affected.*



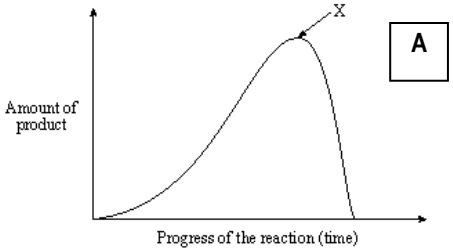


B

The graph above shows the rate of an enzyme-catalyzed reaction in the stomach. What was done at time **Y**?

A. Lead ions were added.
B. More enzyme was added.
C. Temperature was increased by 50°C.
D. Substrate concentration was decreased.

The graph below shows the rate of product formation in an enzyme-catalyzed reaction.



A

The change observed at **X** could result from the addition of

A. lead.
B. a coenzyme.
C. more enzyme.
D. more substrate.