Enzymes

Learning Outcome B11

Learning Outcome B11

- Analyse the roles of enzymes in biochemical reactions.

Student Achievement Indicators

- Explain the following terms: metabolism, enzyme, substrate, coenzyme and activation energy
- Use graphs to identify the role of enzymes in lowering the activation energy of a biochemical reaction
- Explain models of enzymatic action (e.g., induced fit)
- Differentiate between the roles of enzymes and coenzymes in biochemical reactions
- Identify the role of vitamins as coenzymes
- Apply knowledge of proteins to explain the effects on enzyme activity of pH, temperature, substrate concentration, enzyme concentration, competitive inhibitors, and non-competitive
- inhibitors including heavy metals
- Devise an experiment using the scientific
- Identify the thyroid as the source gland for thyroxin, and relate the function of thyroxin to metabolism

Metabolic Pathways

- A series of linked reactions made up of many steps.
- Begin with a particular reactant and end with the specific product
- One reaction leads to the next which leads to the next.
- Reactions have many specific steps with are organized in a highly structured manner.
- An enzyme is a protein that speeds up a chemical reaction
- Acts like a catalyst

Metabolic Pathways

- Participates in the reaction but is not used up in the reaction.
- Enzymes do not determine whether a chemical reaction moves forward or not that is determined by the activation energy
- Reactants are also known as substrates.

Example - Substrate

$$A \xrightarrow{E_1} B \xrightarrow{E_2} C$$

- ✓ B – product and second substrate
- ✓ E_1 – enzyme #1
- ✓ E_2 – enzyme #2
- ✓ Energy of Activation (E_A)

Metabolic Pathways

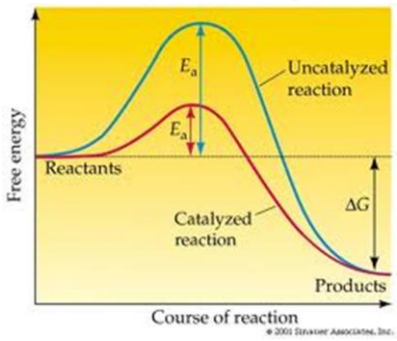
E_A – is the energy that must be added to cause the molecules to react with one another

- The E_A must be achieved in order for a reaction to occur
- E_A is the minimum energy required
- Enzymes lower the E_A, which means a lower amount of energy is required in order for activation to occur.
- Without enzymes reaction rates would be very slow, therefore enzymes lower the activation energy and increase the rate of the reaction.

$$S + E \rightarrow ES \rightarrow E + P$$

- ✓ S – substrate
- ✓ E – enzyme
- ✓ ES – Enzyme –Substrate complex
- ✓ P - product

Graph showing E_A



Metabolic Pathways

- The active site forms a complex with the substrate and the enzyme and substrate fit together.
- Active site undergoes a small conformational change in order to accommodate the substrate known as induced-fit model.
- Change in shape facilitates the reaction.
- After the reaction occurs a product is released and the active site returns to its original state.
- Only a small amount of enzyme is needed because it is not used up in the reaction.
- Some enzymes do more than just bind to the active site, they participate in the reaction.

Metabolic Pathways

- Example –trypsin digests protein by breaking peptide bonds between amino acids.
- The active site for trypsin contains three amino acids with R-groups that actually interact with parts of the peptide bond
- Sometimes a particular reactant(s) may produce more than one type of product.
- The presence or absence of an enzyme determines which reaction takes place.

Metabolic Pathways

- So if the substrate can react to form more than one product, than the enzyme that is present and active determines which product is produced.
- Every reaction in a cell requires that its specific enzyme can be present, because enzymes only compete with their substrate.
- They are often named after their substrate.
- Example: lipid – lipase
  urea – urease
  ribonucleic acid – ribonuclease

Factors Affecting Reaction Rates

- Enzymatic reactions may proceed at different rates.
- Need enough substrate to fill most active sites.

Factors Affecting Reaction Rates

Substrate Concentration

- ✓ Enzymatic activity increase as substrate concentration increases because there are more collisions between substrate molecules and the enzymes.
- ✓ As more substrate fills active sites, more products result.
- ✓ When an enzymes active site is filled continuously with substrate the enzymes rate of activity cannot increase anymore
- ✓ This means the maximum rate of the reaction has been achieved.

Factors Affecting Reaction Rates

Temperature and pH

- ✓ As temperature increase enzyme activity increase allowing more collisions between enzymes and substrates.
- ✓ However if the temperature is too high the enzyme will denature (change shape).
- ✓ If an enzyme changes shape it can no longer bind with an active site.
- ✓ Each enzyme has a preferred pH, for optimal reaction rate
- ✓ A change in pH can alter the ionization of R-groups and disrupt normal interaction
- ✓ Extreme pH conditions can cause proteins to denature.
- ✓ When an enzymes shape is altered it cannot bind to the substrate

Factors Affecting Reaction Rates

Enzyme Activation

- ✓ Genes can increase or decrease the concentration of an enzyme present
- ✓ Enzyme are activated in many different ways
- ✓ *Example* – addition or removal of a phosphate group to a molecule
- ✓ *Example* – removing part of a protein or cofactor

Factors Affecting Reaction Rates

Enzyme Inhibition

- ✓ Occurs when substrate is unable to bind to active sites on an enzyme
- ✓ Regulated by feedback inhibition
- ✓ Plenty of products, all binding to the active site on the enzyme
- ✓ As a product is used up inhibition is reduced and more substrate can bind to the enzymes active sites.
- ✓ Most metabolic pathways are regulated this way
- ✓ Also known as competitive inhibition
- ✓ Non-competitive inhibition is when a product bind to another sites besides the active site of the enzyme.
- ✓ This causes a conformational change of the active site.
- ✓ The active site is where the substrate is trying to bind so the substrate cannot bind and no more products can be made.

Factors Affecting Reaction Rates

Enzyme Cofactors

- ✓ Most enzymes require an inorganic or organic non-protein helper to function normally.
- ✓ Example of ions that act as cofactors are Cu, Zn or Fe (inorganic cofactors)
- ✓ Organic non-protein molecules are called coenzymes.
- ✓ Coenzymes assist enzymes and may even accept or contribute atoms to the reaction.
- ✓ Vitamins are often components of coenzymes
- ✓ Vitamins are small organic molecules that are required in trace amounts in our diet for synthesis of coenzymes
- ✓ Vitamins become a part of a coenzyme's molecular structure.
- ✓ Vitamin deficiencies result when there is a lack of coenzyme which cause a decrease in enzymatic reactions.

Factors Affecting Reaction Rates

Examples of vitamin deficiency symptoms

- Niacin deficiency cause a skin disease known as pellagra
- Riboflavin deficiency causes cracks in the corner of the mouth.