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VCE Biology ¾
Proteins, Protein Export & Enzymes [1.4]
Workbook

Outline:

Study Design: Proteins and Enzymes

Amino acids as the monomers of a polypeptide chain and the resultant hierarchical levels of structure that give rise to a functional protein.

Proteins as a diverse group of molecules that collectively make an organism's proteome, including enzymes as catalysts.

The general factors that impact enzyme function, including temperature, pH, and competitive and non-competitive inhibitors.

Learning Objectives:

- ☐ **BI34 [1.4.1] -** Define and compare primary, secondary, tertiary, and quaternary structures of proteins.
- ☐ **BI34 [1.4.2]** - Identify and describe the roles of ribosomes, rough endoplasmic reticulum, and Golgi apparatus in the transport and export of proteins from a cell.
- ☐ **BI34 [1.4.3]** - Explain the lock-and-key model, the induced fit model, and why enzymes are specific and only catalyse one reaction.
- ☐ **BI34 [1.4.4]** - Explain how enzymes change/denature at different pHs and at different temperatures.
- ☐ **BI34 [1.4.5]** – Explain the function of competitive and non-competitive enzyme inhibitors and how they affect the rate of reaction and how they may/may not be overcome.

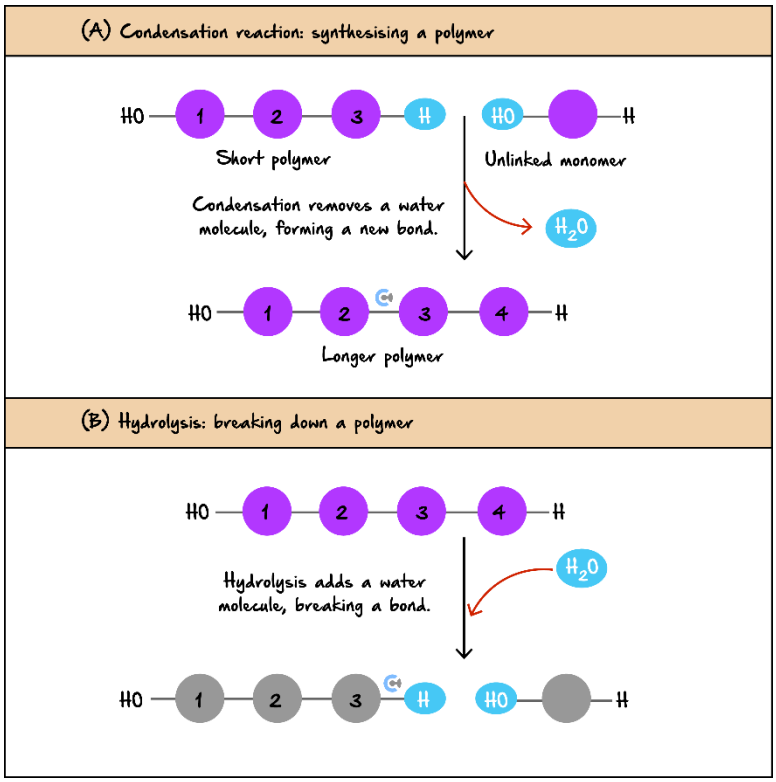
Section A: Proteins (6 Marks)

Sub-Section: Introducing Proteins

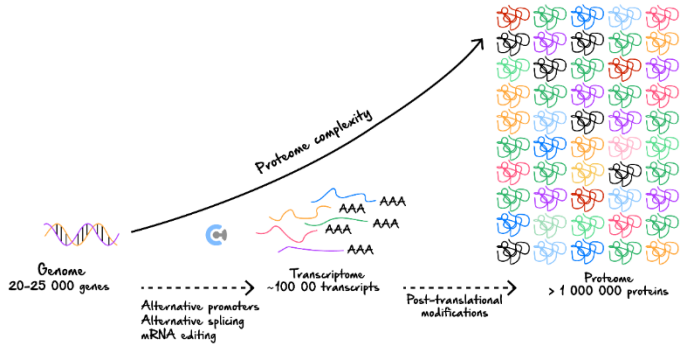
How can we define proteins?

Introduction to Proteins

- Proteins are of the 4 major classes of biomolecules, responsible for most, if not all, of the _____ of an organism.
  - They are large polymers consisting of _____ monomers, joined together via _____.

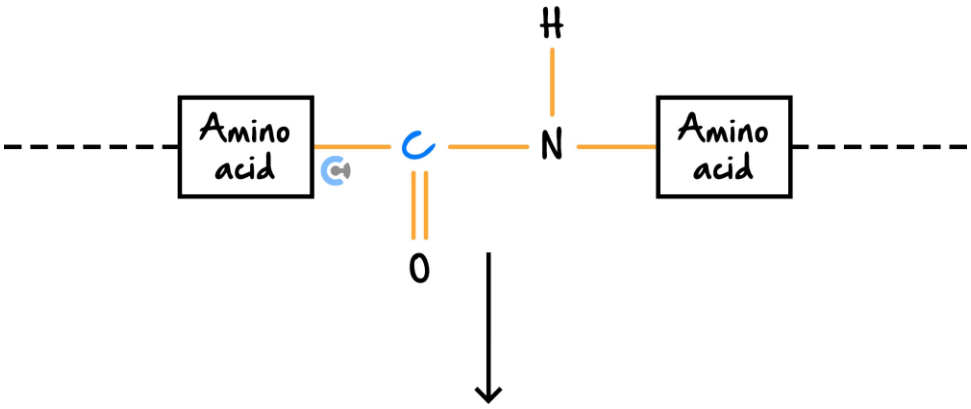


- Immense functional diversity – informed by their _____– especially of interest as they act together to form complex biochemical pathways.
- The proteome refers to the entire set of proteins expressed by a cell, tissue, and organism at a given time.



Question 1 (2 marks)

The diagram below represents two amino acids joined together in part of a protein chain.



a. Explain what happens to the bond between the amino acids if it is hydrolysed. (1 mark)

_____

_____

_____

_____

b. Explain why the joining together of amino acids into a protein chain is called condensation polymerisation. (1 mark)

_____

_____

_____

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Sub-Section: Protein Functions

Function	Example
S_____	
H_____	
I_____	
T_____	
S_____	
M_____	
E_____	

= SHITSME

Discussion: What might contribute to proteins being so diverse?

- Think about this in terms of what leads to protein function in the first place!
- Their _____.
- What contributes to that?
- Also, how can we get more proteins than we can genes? (2 marks)

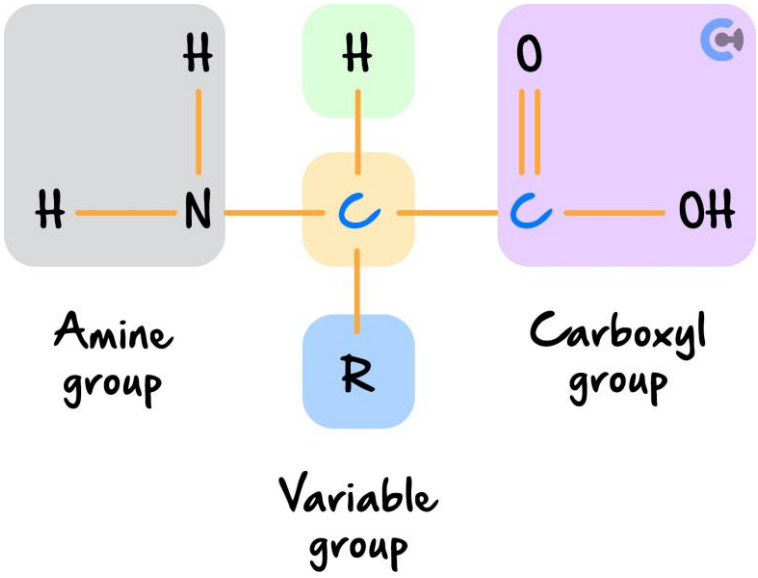
Space for Personal Notes

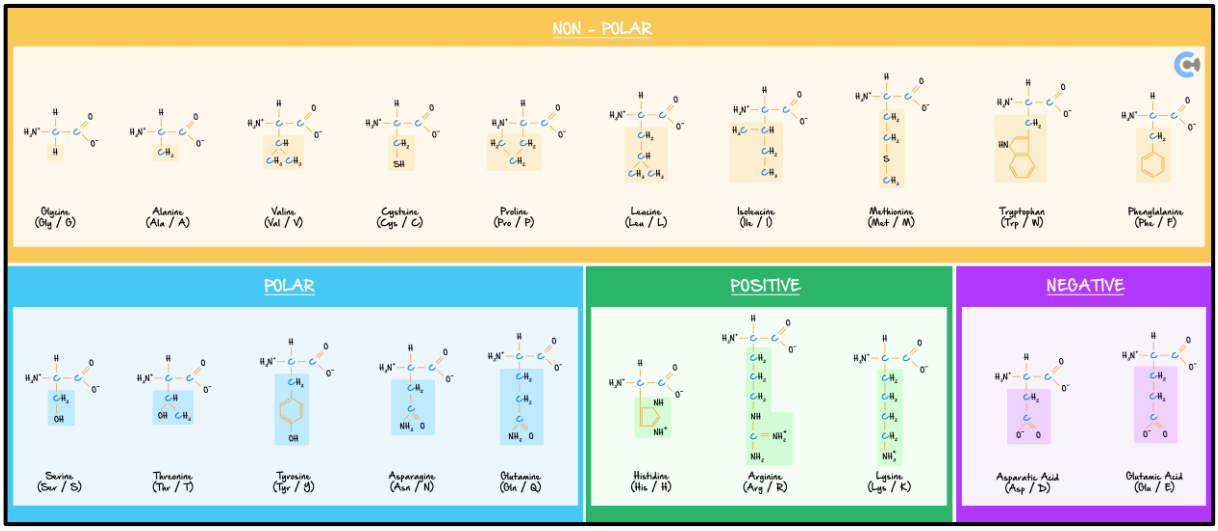
Sub-Section: Amino Acids

What are proteins made up of?

Amino Acids

- Proteins are polymers composed of monomers called amino acids.
  - There are _____ universal amino acids that are used to make proteins.
- They have an amine group, a carboxyl group, and a variable R group.

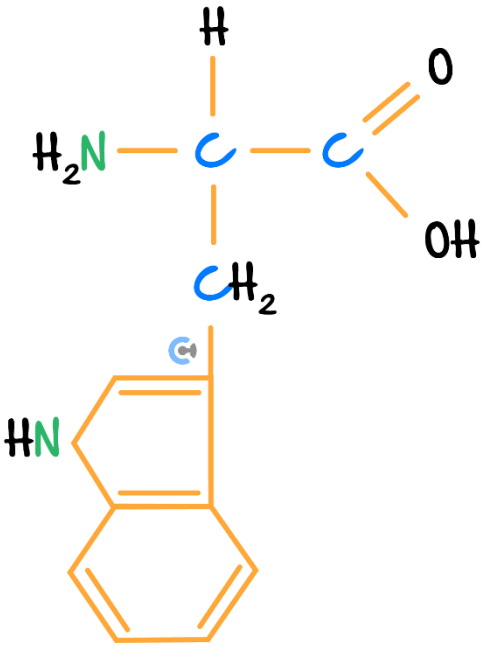




Exploration: What part of the amino acid do you think is most critical in determining a protein's properties?

Question 2 (2 marks)

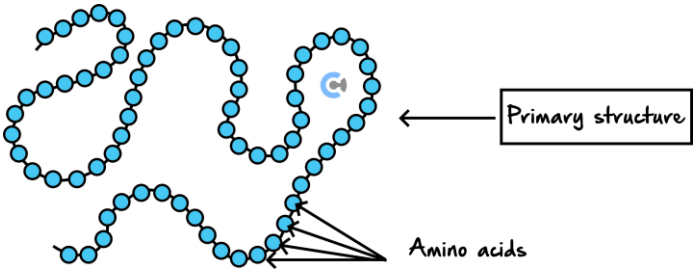
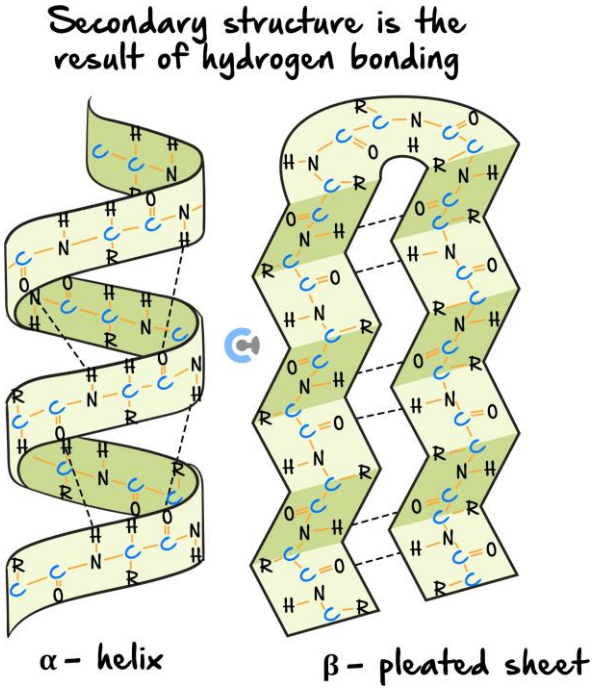
The diagram below shows the structure of tryptophan.

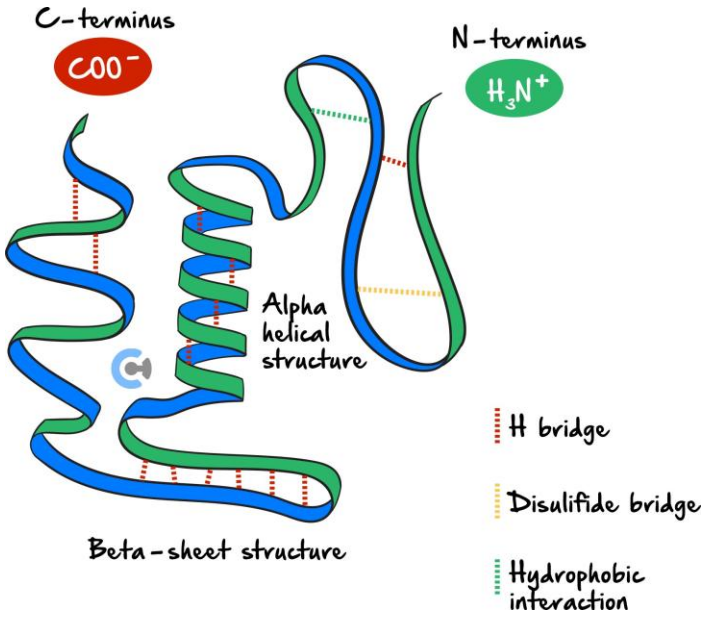
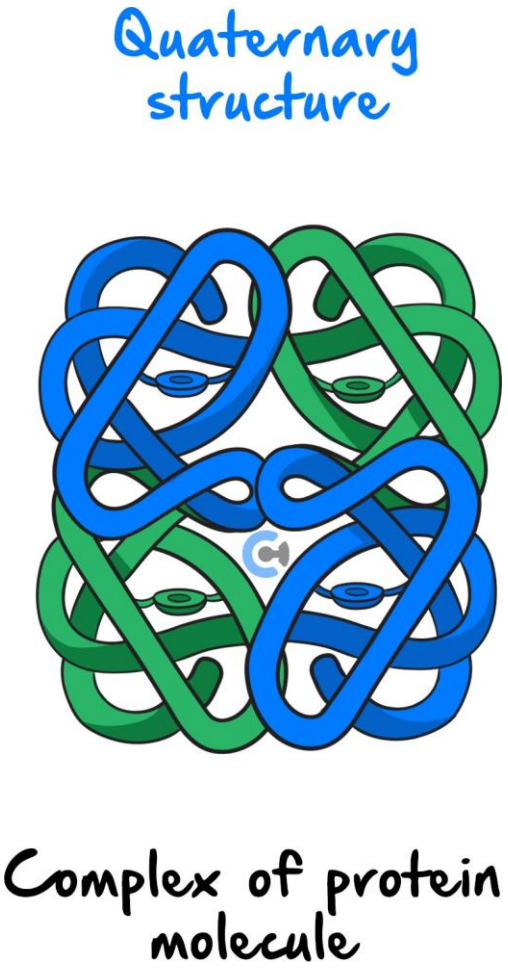


To what group of biological monomers does typtophan belong? Use the information in the diagram to justify your response.

Sub-Section: Levels of Protein Structure

Levels of Protein Structure

Level	Explanation	Diagram
Primary	The linear sequence, number, and type of amino acids are joined together to form a polypeptide. The most basic stage; all proteins have it. Because it determines the order of R groups, it sets the stage for the other structures.	
Secondary	The secondary structure is the way a polypeptide folds in a *repeating arrangement* to **form α-helices** and **β-pleated sheets.** Folding is a result of *hydrogen bonding* between the amine and carboxyl groups of *non-adjacent* amino acids. The α-helices increase the tensile strength of the polypeptide, while β-pleated sheets increase the mechanical stability of the polypeptide. Sequences that do not form either an alpha helix or a beta-pleated sheet will exist as a random coil.	

Tertiary	The complex three-dimensional shape is formed when the polypeptide turns and folds at the secondary level. It is caused by *interactions between R groups.* Relative amino acid positions are important (e.g., non-polar amino acids usually avoid exposure to aqueous solutions). Tertiary structure is often the determining factor of the actual function of a protein.	
Quaternary	Certain proteins may possess a fourth level of structural organisation called a *quaternary structure.* Quaternary structures are found in proteins that consist of **more than one** polypeptide chain linked together. Not all proteins will have a quaternary structure – many proteins will only consist of a single polypeptide chain.	

Exploration: Sickle Cell Anaemia

	Primary Structure	Secondary and Tertiary Structures	Quaternary Structure	Function	Red Blood Cell Shape
Normal hemoglobin	1 Val 2 His 3 Leu 4 Thr 5 Pro 6 Glu 7 Glu	Normal β subunit	Normal hemoglobin β α β α	Normal hemoglobin proteins do not associate with one another, each carries oxygen.	Normal red blood cells are full of individual hemoglobin proteins. 5 µm
Sickle-cell hemoglobin	1 Val 2 His 3 Leu 4 Thr 5 Pro 6 Val 7 Glu	Sickle-cell β subunit	Sickle-cell hemoglobin β α β α	Hydrophobic interactions between sickle-cell hemoglobin proteins lead to their aggregation into a fiber; capacity to carry oxygen is greatly reduced.	Fibers of abnormal hemoglobin deform red blood cell into sickle shape. 5 µm

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Question 3 (2 marks)

Look carefully at the diagrams in boxes **A., B., C., and D.** and then at the text in boxes **W., X., Y., and Z.** below. Place the letter for each into the table so that they correspond to the correct level of protein structure.

A.	**B.**	**C.**	**D.**
			
W.	**X.**	**Y.**	**Z.**
Polypeptide chain folds on itself to form a 3D structure.	Amino acids become joined by peptide bonds to form a polypeptide.	Polypeptide chain folds on itself into two or more polypeptide chains that become entwined and chemically bonded together into a 3D structure.	Polypeptide chain becomes coiled or pleated.

Level of structure	**Diagram (A-D)**	**Diagram (W-Z)**
Primary		
Secondary		
Tertiary		
Quaternary		

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Key Takeaways

- ☑ Proteins are made of amino acids joined by condensation polymerisation.
- ☑ Proteins have diverse functions determined by their structure.
- ☑ The proteome is the full set of proteins expressed by a cell, tissue, or organism.
- ☑ Amino acids have an amine group, a carboxyl group, and an R group.
- ☑ The R group determines the chemical properties of the amino acid (non-polar, polar, positive, or negative).

Key Takeaways

- ☑ **Primary structure**: The sequence of amino acids in a polypeptide chain, determining the order of R groups and the foundation for higher levels of structure.
- ☑ **Secondary structure**: The folding of the polypeptide chain into alpha-helices or beta-pleated sheets, stabilised by hydrogen bonds between non-adjacent amino acids. These structures increase stability and provide mechanical strength.
- ☑ **Tertiary structure**: The overall $3D$ shape of a polypeptide, formed by interactions between R groups, including hydrophobic interactions, hydrogen bonds, ionic bonds, and disulphide bridges. This structure often determines the protein's specific function.
- ☑ **Quaternary structure**: The combination of multiple polypeptide chains into a single functional protein complex. Not all proteins have a quaternary structure.

Key Takeaways

- ☑ Proteins can be structural (collagen), hormones (insulin), immunity (antibodies), transport (haemoglobin), sensation (rhodopsin), movement (actin/myosin), or enzymes (rubisco).
- ☑ Protein diversity comes from their shape and post-translational modifications.
- ☑ More proteins exist than genes due to alternative splicing and modifications.

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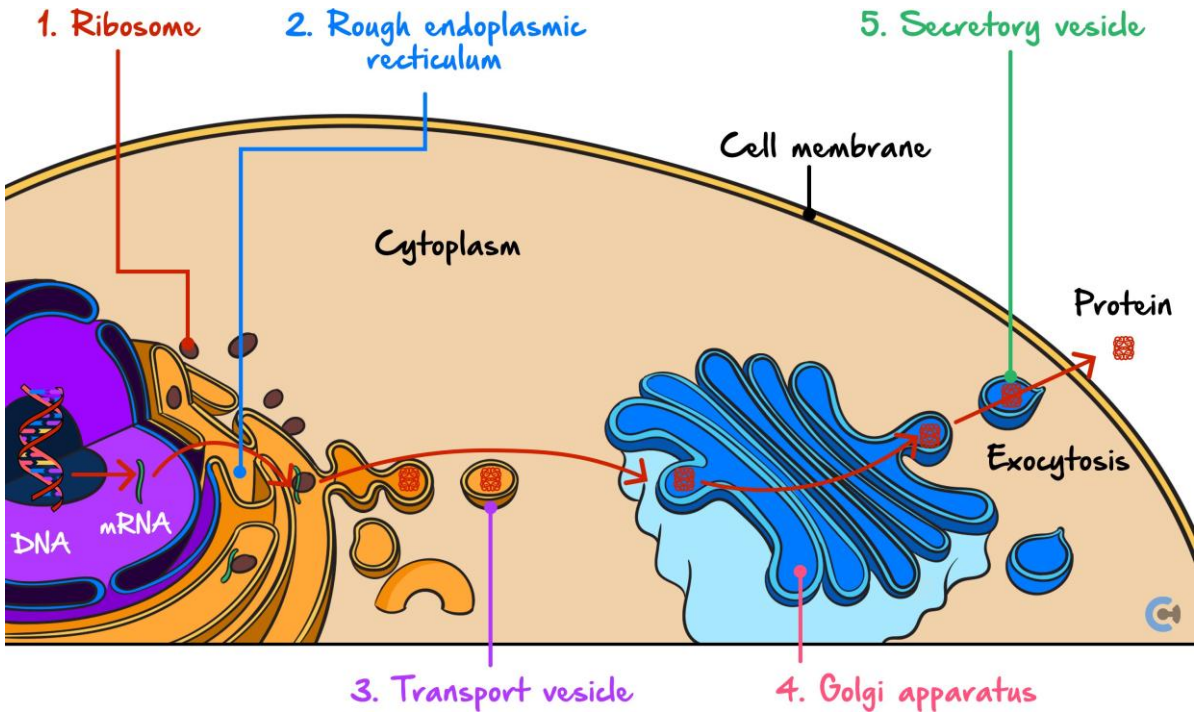
Section B: Protein Export Pathway

Export

- Often a protein will have an extracellular destination where it will perform its function – to get it out of the cell we must "export" it.
  - Translation occurs at the _____ in the _____.
  - Then it moves into the lumen of the RER for some modifications and initial folding.
  - Then it is shifted to the Golgi apparatus, where it is folded and packaged further until it is released.
  - Exported via exocytosis.



NOTE: Do not abbreviate Endoplasmic Reticulum as ER in your SACs or Exams.

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Key Takeaways

- ☑ Ribosome - site of protein synthesis (amino acids joined together from a polypeptide chain).
- ☑ Rough ER – site of the initial folding of the polypeptide chain, packaged into transport vesicles for delivery to the Golgi apparatus.
- ☑ Golgi - its function is to modify and package the protein into a vesicle for transport to various locations within the cell, including to the cell membrane for secretion.
- ☑ Transport vesicles take proteins or polypeptides from the rough endoplasmic reticulum to the Golgi apparatus, and secretory vesicles take the finished product for exocytosis at the membrane.

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Section C: Enzymes (4 Marks)

Sub-Section: Introducing Enzyme Function

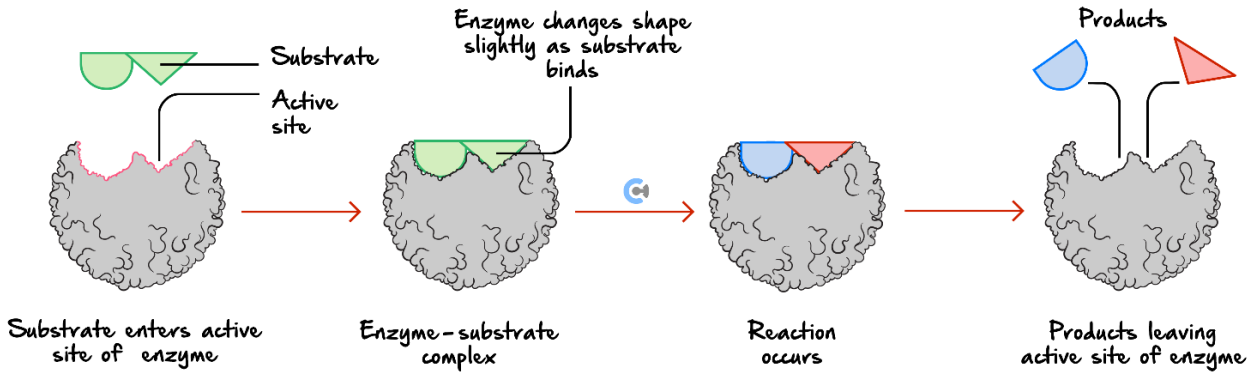
Overview

- Enzymes are organic catalysts – _____.

  _____

  - They are proteins with a 3D shape (active site) complementary to their substrate (a molecule undergoing an enzyme-based reaction).

- Coenzymes are molecules that can _____, by changing the shape of the active site or providing electrons and protons for reactions.



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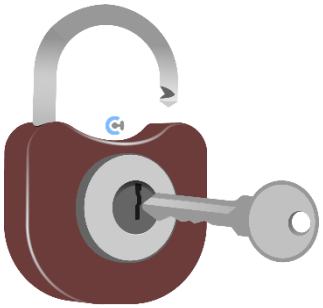
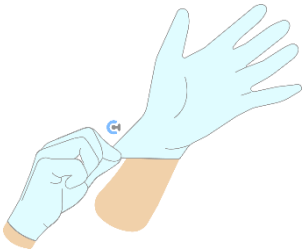
Are there different models of function for enzymes?

Exploration: Describing enzyme function

Lock and Key



Induced Fit



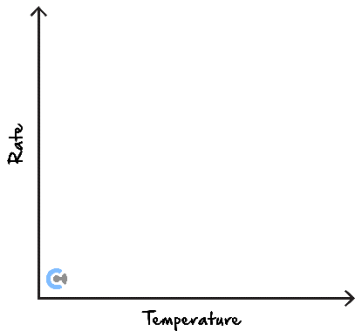
Key Takeaways

- ☑ Reusable - the enzyme is unchanged at the end of the reaction.
- ☑ Specific – they are particular to only 1 substrate; there are some exceptions to this.
- ☑ Reversible – capable of not only breaking apart molecules but building up new molecules from smaller ones.
- ☑ Are proteins.
- ☑ They have an active site that is complementary to a substrate.
- ☑ Speed up reactions – don't create.
- ☑ Usually put above the arrow in a written chemical reaction.
- ☑ Can be denatured in certain conditions.

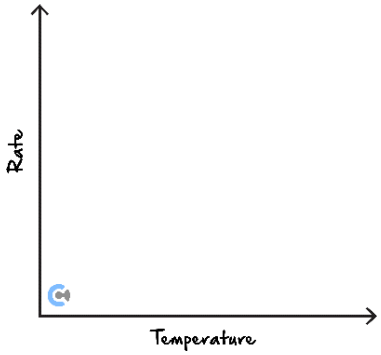
Sub-Section: Factors Affecting Enzyme Function

Factors that impact Enzyme Function

- Temperature



- pH



- Inhibitors
  - Competitive inhibitors block the active site.
  - Non-competitive inhibitors change the active site while binding to an allosteric site.
- Enzymes can lose function when they are denatured; this is when their 3D structure is changed to the extent to which the substrate can no longer bind to the active site.

Sample Response: For all the factors that affect enzyme function!

1. Temperature: As the temperature increases, the rate of enzyme function will INCREASE (as there is an increase in the frequency of successful collisions), until the optimal temperature is reached; after this,

2. pH: As the pH increases or decreases towards the optimal functioning pH range of an enzyme, the rate of enzyme function will increase (as this allows for the greatest frequency of successful collisions). When the pH is outside of this optimal functioning pH range of an enzyme, the rate of enzyme function will decrease (as the active site of the enzyme will be denatured, allowing for less successful collisions).

3. Competitive Inhibitor: A competitive inhibitor will reduce the activity of an enzyme, as it will compete with the substrate for the active site. This can be overcome by increasing substrate concentration.

4. Non-competitive inhibitor binds to the allosteric site of an enzyme, causing a conformational shape change of the active site, preventing the substrate from binding and reducing the activity.

TIP: Make sure to reference the SPECIFIC enzyme that is being asked about in the question!

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Question 4 (2 marks)

Explain how enzymes work using the lock and key model. A diagram may assist your explanation.

_____

_____

_____

_____

Question 5 (2 marks)

Explain why refrigerating foods helps them last longer.

_____

_____

_____

_____

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Key Takeaways

- ☑ Enzymes act as organic catalysts, speeding up chemical reactions that would take much longer to occur naturally.
- ☑ They are proteins with a 3D active site that is complementary to the shape of their specific substrate.
- ☑ Coenzymes assist enzymes by altering the shape of the active site or by providing necessary electrons and protons for the reaction.

Process of enzyme function

1. The substrate binds to the enzyme's active site.
2. The enzyme changes its shape slightly to fit the substrate better (induced fit).
3. The reaction occurs, transforming the substrate into products.
4. The products are released, and the enzyme is ready for another reaction.
5. **Lock and Key Model:** The enzyme's active site and substrate fit together perfectly, like a key fitting into a lock.

   Induced Fit Model: The enzyme's active site moulds itself to fit the substrate upon binding, like a glove fitting a hand.

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Factors Affecting Enzyme Function

1. Temperature: As the temperature increases, the rate of enzyme function will INCREASE (as there is an increase in the frequency of successful collisions), until the optimal temperature is reached; after this,

2. pH – As the pH increases or decreases towards the optimal functioning pH range of an enzyme, the rate of enzyme function will increase (as this allows for the greatest frequency of successful collisions). When the pH is outside of this optimal functioning pH range of an enzyme, the rate of enzyme function will decrease (as the active site of the enzyme will be denatured, allowing for less successful collisions).

3. Competitive Inhibitor: A competitive inhibitor will reduce the activity of an enzyme, as it will compete with the substrate for the active site. This can be overcome by increasing substrate concentration.

4. Non-competitive inhibitor binds to the allosteric site of an enzyme, causing a conformational shape change of the active site, preventing the substrate from binding and reducing the activity.

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Contour Check

Learning Objective: [1.4.1] - Define and compare primary, secondary, tertiary, and quaternary structures of proteins.

Study Design

Amino acids as the monomers of a polypeptide chain and the resultant hierarchical levels of structure that give rise to a functional protein.

Key Takeaways

- ☐ Proteins are made of amino acids joined by _____.
- ☐ Proteins have diverse functions determined by their structure.
- ☐ The proteome is the full set of proteins expressed by a cell, tissue, or organism.
- ☐ Amino acids have an _____ group, _____ group, and an _____ .
- ☐ The _____ determines the chemical properties of the amino acid (non-polar, polar, positive, or negative).
- ☐ **Primary structure**:

  _____

  _____

- ☐ **Secondary structure**:

  _____

  _____

  _____

- ☐ **Tertiary structure**:

  _____

  _____

  _____

- **Quaternary structure**:

_____

_____

- Protein diversity comes from their shape and post-transcriptional modifications.
- More proteins exist than genes due to _____ and modifications.

Learning Objective: [1.4.2] – Identify and describe the roles of ribosomes, rough endoplasmic reticulum and Golgi apparatus in the transport and export of proteins from a cell

Study Design

The role of rough endoplasmic reticulum, Golgi apparatus, and associated vesicles in the export of proteins from a cell via the protein secretory pathway.

Key Takeaways

- Ribosome - _____
- Rough ER –

_____

_____

- Golgi –

_____

_____

- Transport vesicles take proteins/polypeptides from the _____ to the _____, and secretory vesicles take the finished product for exocytosis at the membrane.

Learning Objective: [1.4.3] – Explain the lock-and-key model, the induced fit model, and why enzymes are specific and only catalyse one reaction.

Study Design

The general factors that impact enzyme function, including temperature, pH, and competitive and non-competitive inhibitors.

Key Takeaways

- ☐ Enzymes act as organic catalysts, speeding up chemical reactions that would take much longer to occur naturally.
- ☐ They are proteins with a 3D active site that is complementary to the shape of their specific substrate.
- ☐ Coenzymes assist enzymes by altering the shape of the active site or by providing necessary electrons and protons for the reaction.
- ☐ **Process of enzyme function:**

1. _____
2. _____
3. _____
4. _____
5. **Lock and Key Model:** The enzyme's active site and substrate fit together perfectly, like a key fitting into a lock.

   Induced Fit Model: The enzyme's active site moulds itself to fit the substrate upon binding, like a glove fitting a hand.

Learning Objective: [1.4.4] - Explain how enzymes change/denature in different pH and at different temperatures

Study Design

The general factors that impact enzyme function, including temperature, pH, and competitive and non-competitive inhibitors.

Key Takeaways

- **Factors Affecting Enzyme Function**
- Temperature: As the temperature increases, the _____ (as there is an increase in the frequency of successful collisions), until the _____ is reached; after this.
- pH - If the pH is within the optimal pH range of an enzyme, the rate of enzyme function will be maximal (as this allows for the greatest frequency of successful collisions). When the pH is outside of this optimal functioning pH range of an enzyme, the rate of enzyme function will decrease (_____)

Learning Objective: [1.4.5] – Explain the function of competitive and non-competitive enzyme inhibitors and how they affect the rate of reaction and how they may/may not be overcome.

Study Design

The general factors that impact enzyme function including temperature, pH, and competitive and non-competitive inhibitors.

Key Takeaways

- ☐ Competitive Inhibitor –

_____

_____

- ☐ Non-competitive Inhibitor –

_____

_____

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