Amino Acids

A Level
C C C

Part A General structure

An amino acid is an organic molecule, containing a central [ ] atom bound to a hydrogen atom and to three other chemical groups: [ ] group ($\mathrm{NH_2}$), [ ] group (COOH), and [ ] group/side-chain - which is the part that differs in structure among different amino acids.

There are [ ] standard amino acids that are coded for by the universal genetic code. Of these standard amino acids, humans can only synthesise 11, and so we have to get the other 9 from our diet. These 9 amino acids are sometimes called [ ] amino acids.

Items:

20 | an amino | an alcohol | oxygen | a carboxyl | essential | carbon | an R | dispensable | 100 | a nitrate

Part B Amino acid or not?

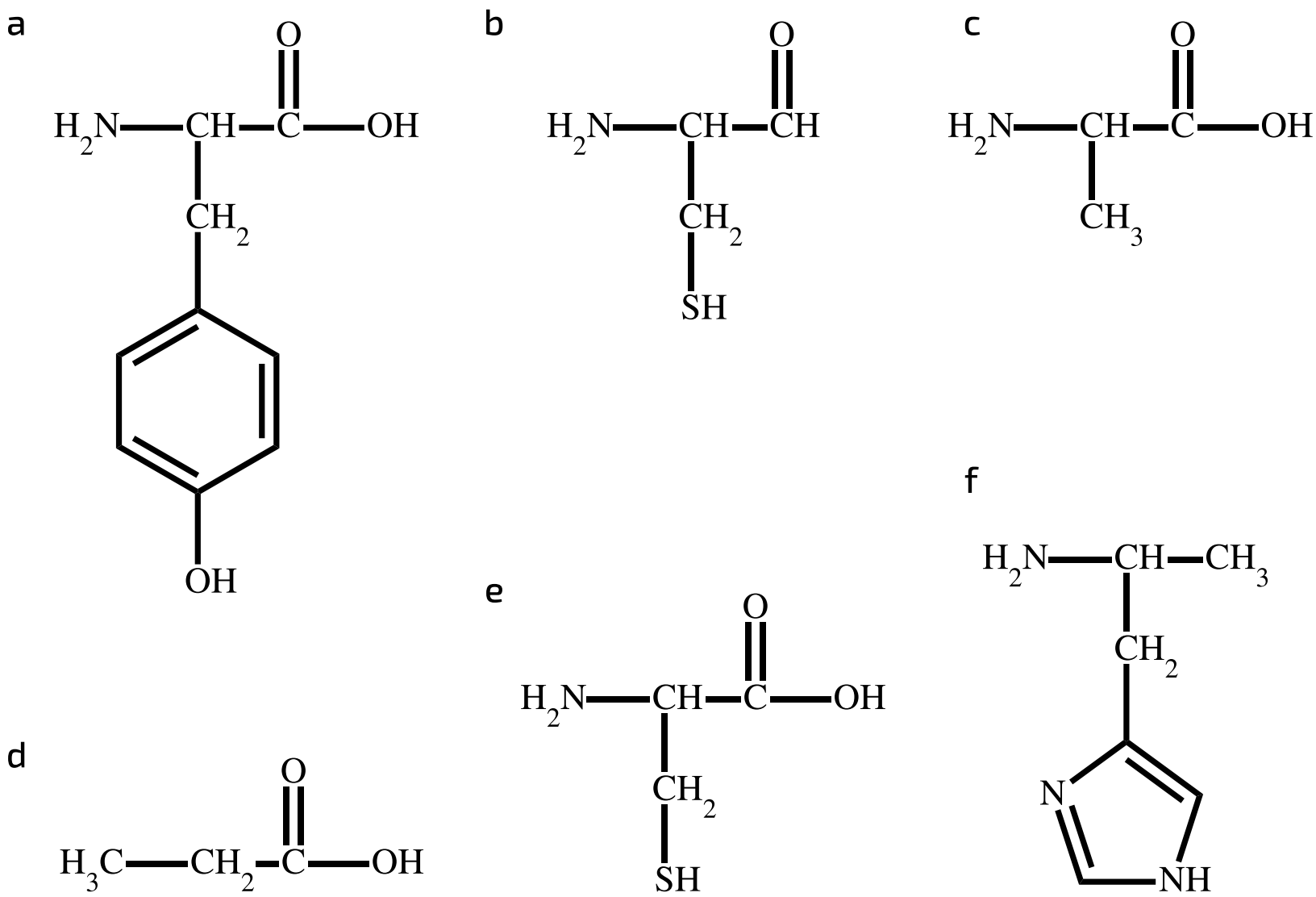


Figure 1: The molecular structures of six organic molecules (a-f).

Which of the organic molecules in Figure 1 are amino acids? Select all that apply.

- [ ] a
- [ ] b
- [ ] c
- [ ] d
- [ ] e
- [ ] f
- [ ] none of them

Part C Dipeptide identification

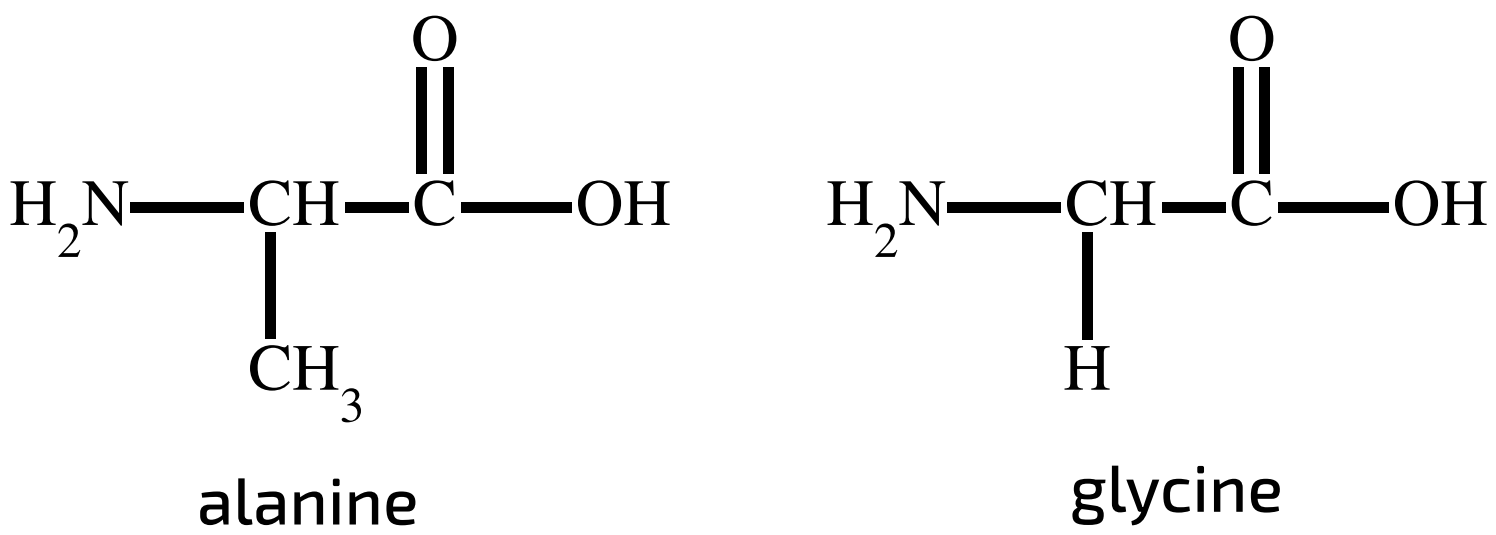
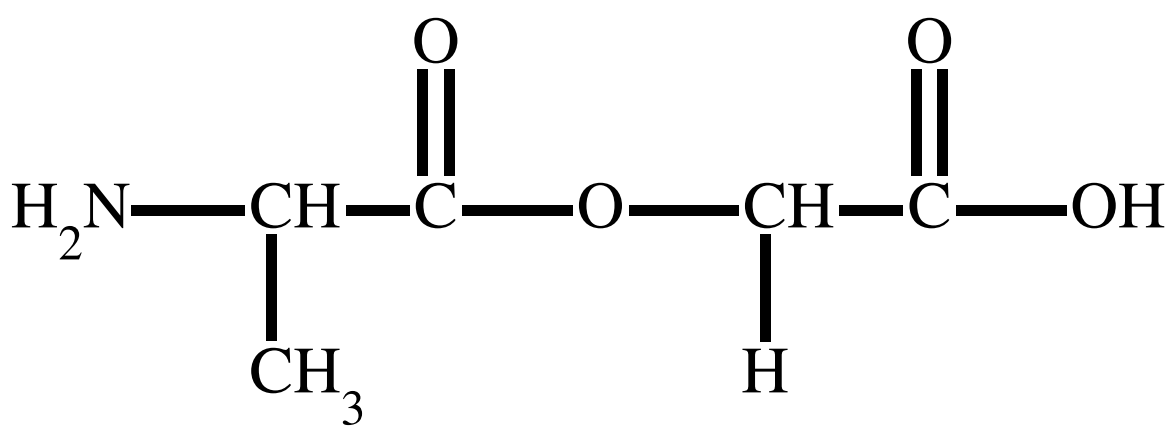
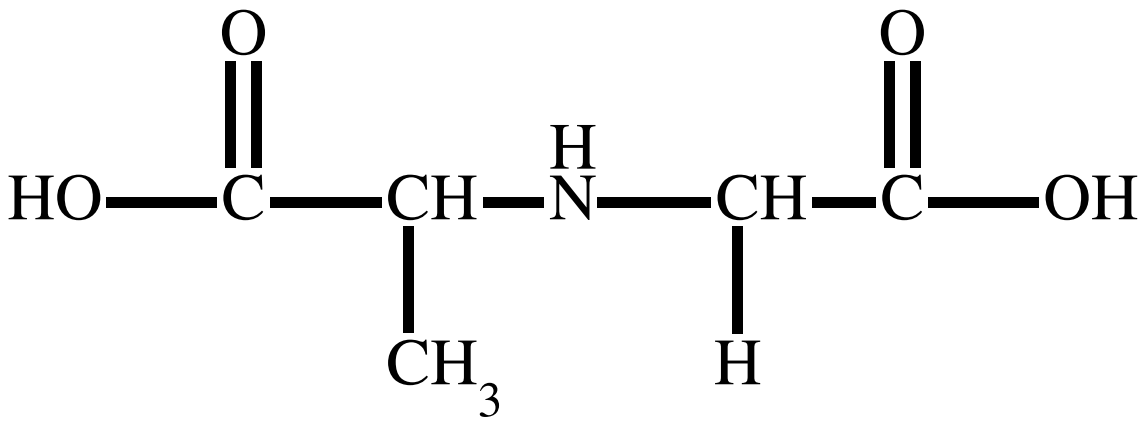


Figure 2: The molecular structures of two amino acids: alanine and glycine.

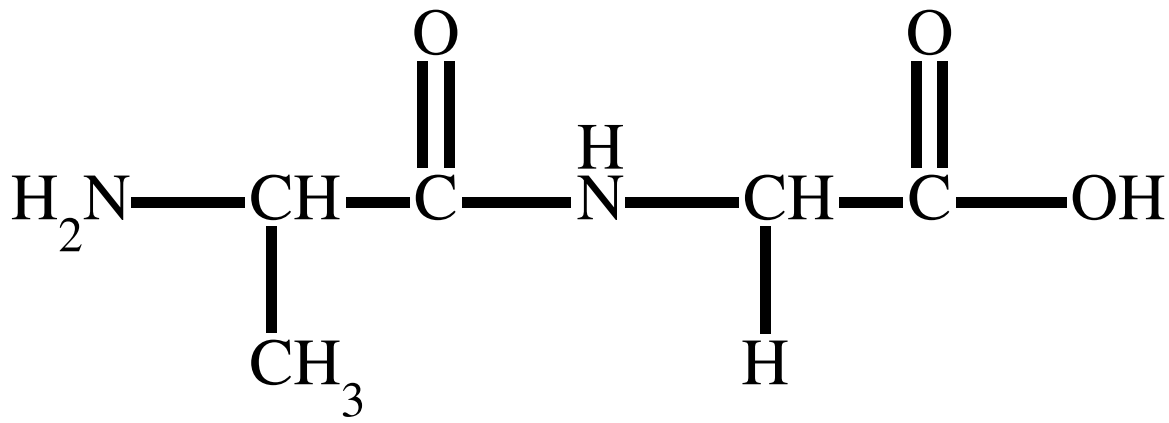
Figure 2 shows the molecular structures of two amino acids: alanine and glycine. Which molecule below represents the dipeptide that would be formed from these amino acids?



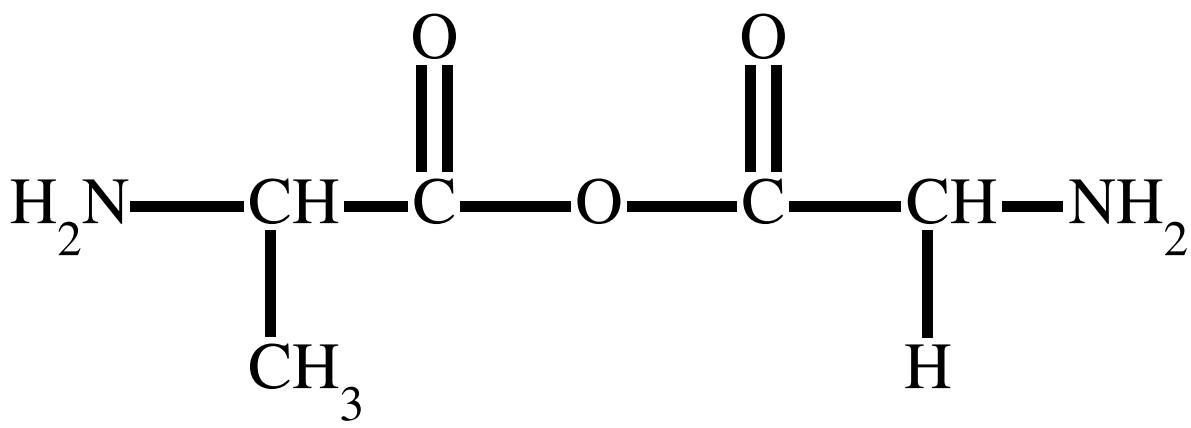
Molecule A



Molecule B



Molecule C



Molecule D

- A
- B
- C
- D

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Protein Primary Structure

A Level

C C C

Part A The building blocks

Proteins are polymers made up of [ ] called [ ]. Proteins range in size from just a few amino acids to tens of thousands of amino acids, but most are between 50 and $2\,000$ amino acids.

A chain of two amino acids is called a [ ]. A chain of many amino acids is called a [ ].

The sequence of amino acids is called the [ ] of the protein.

Items:

secondary structure **quaternary structure** **amino acids** **monomers** **polypeptide** **diamide** **glucose** **dipeptide** **primary structure** **monosaccharides** **tertiary structure** **polyamine**

Part B Formation and breakdown

Amino acids join together by the process of [ ]. During this process, the [ ] group ($\mathrm{NH_2}$) of one amino acid reacts with the [ ] group (COOH) of another amino acid to form a [ ] bond and [ ].

Proteins are broken down into amino acids by the process of [ ]. During this process, [ ] is used to break apart the [ ] bond.

Items:

peptide **ester** **carboxyl** **condensation** $\mathrm{CO_2}$ **nitrate** **hydrolysis** $\mathrm{H_2O}$ **amino**

Part C Polypeptide possibilities

There are 20 different standard amino acids that are used to build proteins. How many primary structures could be produced for a protein that is 50 amino acids long? Give your answer to 2 significant figures.

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STEM SMART Biology Week 3 - Proteins

Levels of Protein Structure

A Level

Part A Levels overview

Match the terms to the definitions.

[ ]: the association of several polypeptides with each other and (in some cases) with non-protein groups e.g. haemoglobin is made of four polypeptides and four haem groups (iron-containing organic molecules). Not all proteins have this level of structure, as some are only made of one polypeptide.

[ ]: the folding of the polypeptide due to hydrogen bonds between the H of one amino acid's NH group (within the peptide bond) and the O of another amino acid's CO group (within the peptide bond). Depending on the amino acid sequence, these hydrogen bonds can cause the polypeptide chain to form a tight coil (α-helix) or a long, snaking chain (β-sheet).

[ ]: the sequence of amino acids in the polypeptide (e.g. methionine-alanine-glycine-tyrosine).

[ ]: the folding of the polypeptide due to interactions between R side-chains of different amino acids (which are able to interact due to coiling/zig-zagging caused by hydrogen bonds). These interactions include ionic bonds (between carboxyl and amino groups within the R side-chains), disulfide bridges (between the S of one amino acid and the S of another), and hydrophilic/hydrophobic interactions (i.e. the polypeptide will fold such that hydrophilic R side-chains are on the outside, and hydrophobic R side-chains are on the inside).

Items:

Primary structure **Secondary structure** **Tertiary structure** **Quaternary structure**

Part B Primary structure

Which of these describes the primary structure of a protein? Select all that apply.

- [ ] the 3D folding of a polypeptide chain due to hydrogen bonds, disulfide bridges, ionic bonds, and hydrophobic/hydrophilic interactions
- [ ] the association between multiple protein-subunits and non-protein groups to form a single, large protein
- [ ] the coiling of a polypeptide chain to form an α-helix
- [ ] the sequence of amino acids in a polypeptide chain e.g. methionine-glycine-alanine-glycine-lysine-alanine-leucine
- [ ] the snaking of a polypeptide chain to form a β-sheet

Part C Secondary structure

Which of these describes the secondary structure of a protein? Select all that apply.

- [ ] the coiling of a polypeptide chain to form an α-helix
- [ ] the snaking of a polypeptide chain to form a β-sheet
- [ ] the association between multiple protein-subunits and non-protein groups to form a single, large protein
- [ ] the sequence of amino acids in a polypeptide chain e.g. methionine-glycine-alanine-glycine-lysine-alanine-leucine
- [ ] the 3D folding of a polypeptide chain due to hydrogen bonds, disulfide bridges, ionic bonds, and hydrophobic/hydrophilic interactions

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Part D Tertiary structure

Which of these describes the tertiary structure of a protein? Select all that apply.

- [ ] the coiling of a polypeptide chain to form an α-helix
- [ ] the association between multiple protein-subunits and non-protein groups to form a single, large protein
- [ ] the snaking of a polypeptide chain to form a β-sheet
- [ ] the 3D folding of a polypeptide chain due to hydrogen bonds, disulfide bridges, ionic bonds, and hydrophobic/hydrophilic interactions
- [ ] the sequence of amino acids in a polypeptide chain e.g. methionine-glycine-alanine-glycine-lysine-alanine-leucine

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Part E Quaternary structure

Which of these describes the quaternary structure of a protein? Select all that apply.

- [ ] the association between multiple protein-subunits and non-protein groups to form a single, large protein
- [ ] the 3D folding of a polypeptide chain due to hydrogen bonds, disulfide bridges, ionic bonds, and hydrophobic/hydrophilic interactions
- [ ] the snaking of a polypeptide chain to form a β-sheet
- [ ] the sequence of amino acids in a polypeptide chain e.g. methionine-glycine-alanine-glycine-lysine-alanine-leucine
- [ ] the coiling of a polypeptide chain to form an α-helix

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Tertiary Structure Interactions 1

A Level

C C C

Within a polypeptide, the R groups/side-chains of amino acids interact with each other, and with the surrounding water, to produce the tertiary structure of the protein.

Figure 1 shows a selection of eight amino acids.

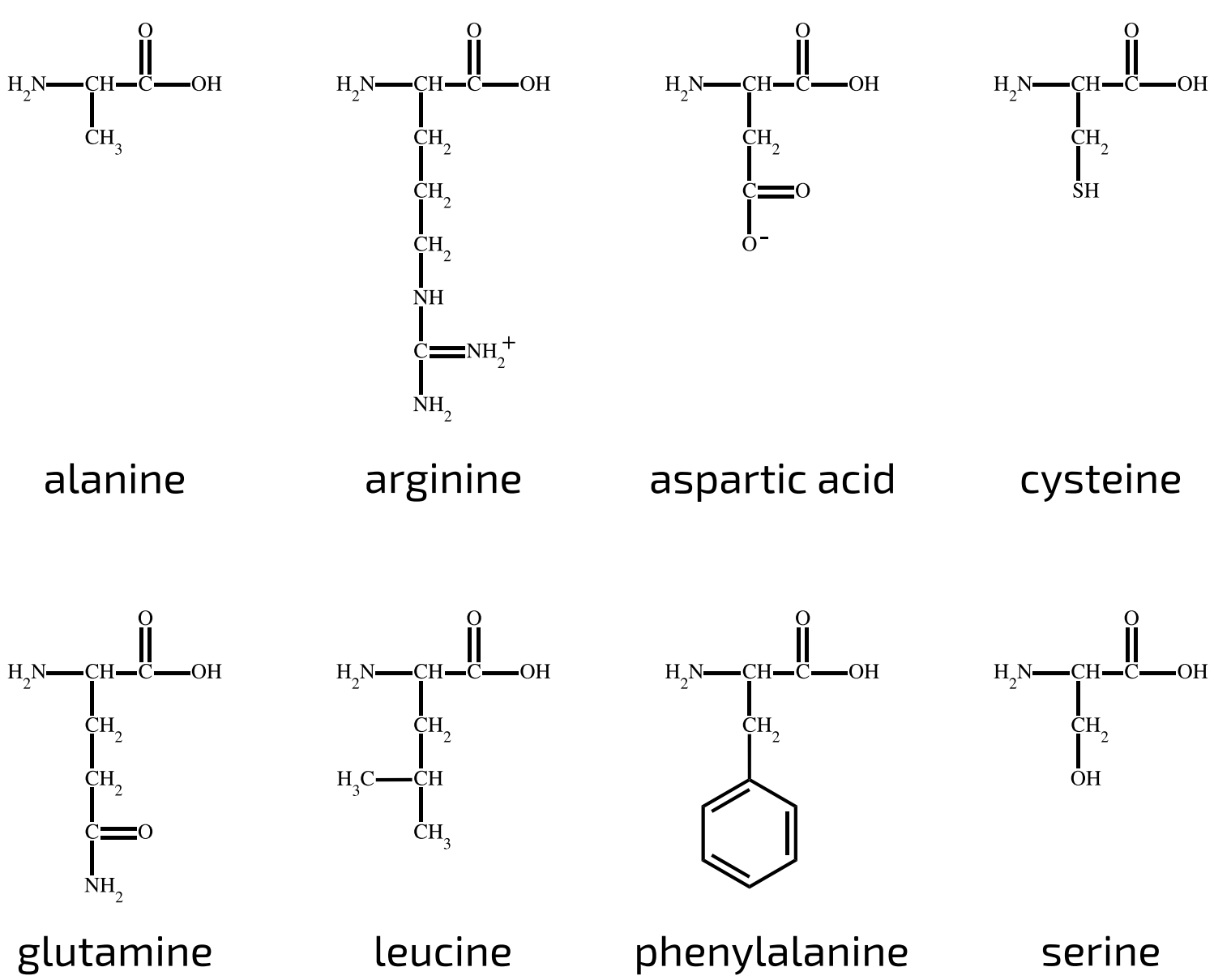

Figure 1: The chemical structures of eight amino acids.

In each part below, identify the amino acids whose R groups could form the given bond type with other amino acids within the same polypeptide.

Part A Ionic bonds

Which amino acids could form **ionic bonds** with other amino acids within the same polypeptide?

- [ ] alanine
- [ ] arginine
- [ ] aspartic acid
- [ ] cysteine
- [ ] glutamine
- [ ] leucine
- [ ] phenylalanine
- [ ] serine
- [ ] none of the above

Part B Hydrogen bonds

Which amino acids could form strong **hydrogen bonds** with other amino acids within the same polypeptide?

- [ ] alanine
- [ ] arginine
- [ ] aspartic acid
- [ ] cysteine
- [ ] glutamine
- [ ] leucine
- [ ] phenylalanine
- [ ] serine
- [ ] none of the above

Part C Disulfide bridges

Which amino acids could form **disulfide bridges** with other amino acids within the same polypeptide?

- [ ] alanine
- [ ] arginine
- [ ] aspartic acid
- [ ] cysteine
- [ ] glutamine
- [ ] leucine
- [ ] phenylalanine
- [ ] serine
- [ ] none of the above

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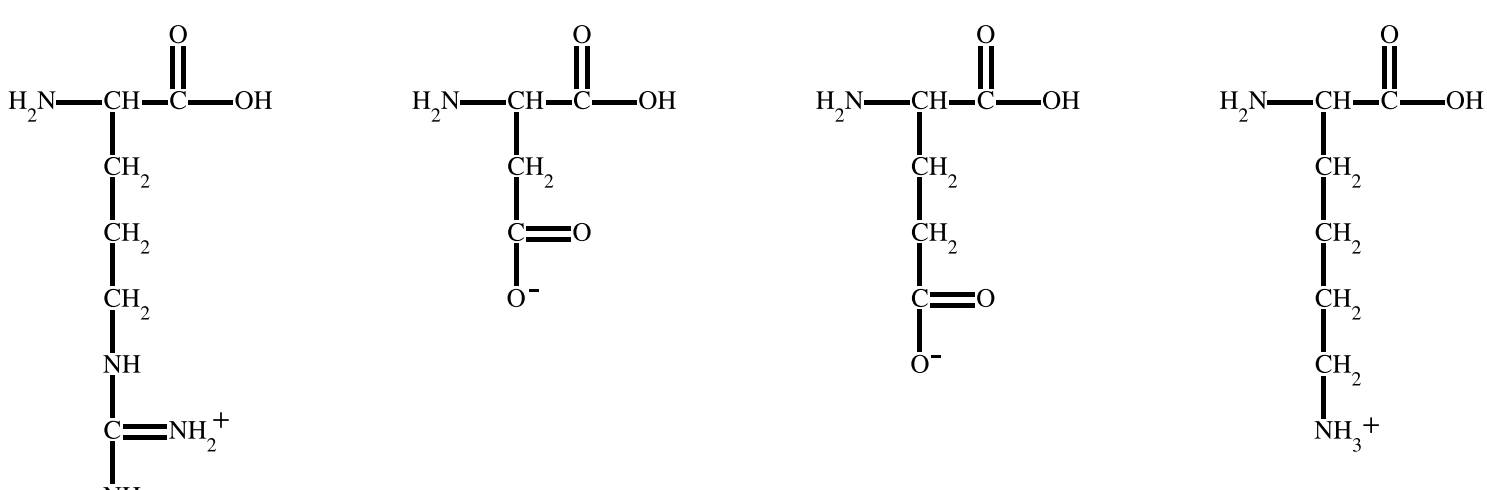
Tertiary Structure Interactions 2

A Level

C C C

Within a polypeptide, the R groups/side-chains of amino acids interact with each other, and with the surrounding water, to produce the tertiary structure of the protein.

Figure 1 shows a selection of eight amino acids.



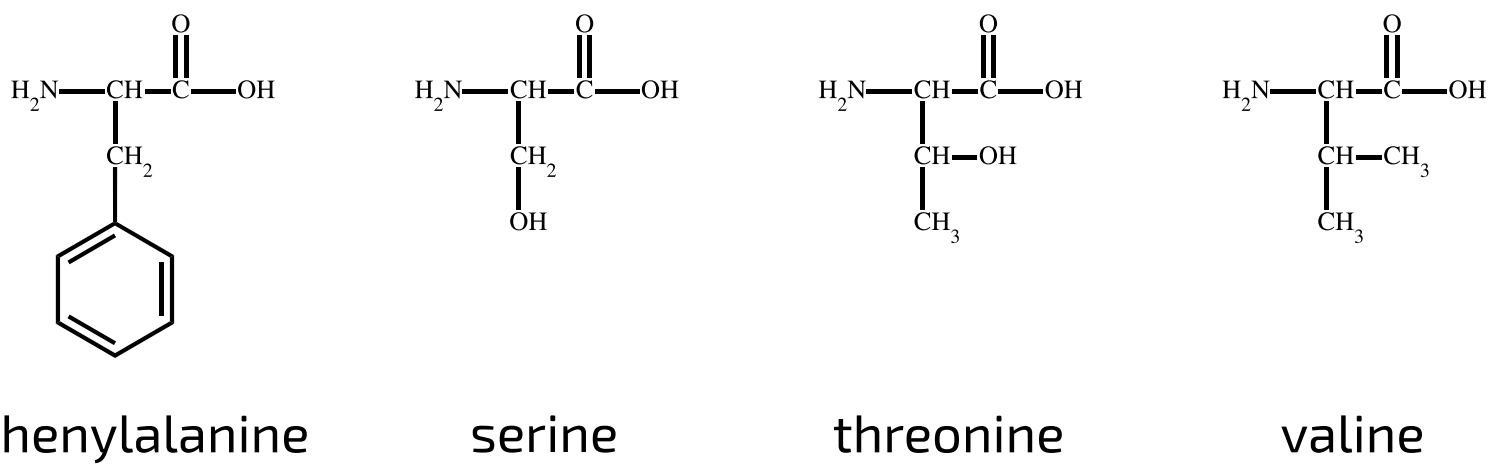


Figure 1: The chemical structures of eight amino acids.

Part A Hydrophilic interactions

Which amino acids would be involved in **hydrophilic** interactions?

- [ ] arginine
- [ ] aspartic acid
- [ ] glutamic acid
- [ ] lysine
- [ ] phenylalanine
- [ ] serine
- [ ] threonine
- [ ] valine
- [ ] none of the above

Part B Hydrophobic interactions

Which amino acids would be involved in **hydrophobic** interactions?

- [ ] arginine
- [ ] aspartic acid
- [ ] glutamic acid
- [ ] lysine
- [ ] phenylalanine
- [ ] serine
- [ ] threonine
- [ ] valine
- [ ] none of the above

Part C Tertiary structure

Which of the following statements explain how hydrophilic and hydrophobic interactions affect the tertiary structure of a protein? Select all that apply.

- [ ] **hydrophilic** R groups cluster together on the **inside** of the protein
- [ ] **hydrophilic** R groups are found on the **outside** of the protein
- [ ] **hydrophobic** R groups cluster together on the **inside** of the protein
- [ ] **hydrophobic** R groups are found on the **outside** of the protein
- [ ] **hydrophilic** R groups cause the formation of α-helices and **hydrophobic** R groups cause the formation of β-sheets
- [ ] **hydrophobic** R groups cause the formation of α-helices and **hydrophilic** R groups cause the formation of β-sheets

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Types of Proteins

A Level

Part A Definitions

Most proteins can be categorized as either fibrous or globular, based on their structures.

Fill in the table below, comparing fibrous and globular proteins.

	Fibrous	Globular
Primary structure		
Tertiary/quaternary structure		
Solubility in water		
Function(s)		

Items:

structural **soluble** **chemical interactions** **repetitive sequence** **insoluble** **complex: highly folded** **non-repetitive sequence** **simple: long & linear**

Part B Fibrous proteins

Which of the following are examples of fibrous proteins? Select all that apply.

- [ ] α-amylase (the enzyme that breaks down starch into disaccharides and trisaccharides)
- [ ] collagen (a major component of tendons, ligaments, bones, and skin)
- [ ] elastin (the protein that gives elasticity to blood vessel walls)
- [ ] haemoglobin (the protein that transports oxygen through the bloodstream)
- [ ] insulin (the hormone that causes cells to increase their uptake of glucose and convert it to glycogen and/or triglycerides)
- [ ] keratin (a type of protein found in hair, nails, and skin)

Part C Globular proteins

Which of the following are examples of globular proteins? Select all that apply.

- [ ] α-amylase (the enzyme that breaks down starch into disaccharides and trisaccharides)
- [ ] collagen (a major component of tendons, ligaments, bones, and skin)
- [ ] elastin (the protein that gives elasticity to blood vessel walls)
- [ ] haemoglobin (the protein that transports oxygen through the bloodstream)
- [ ] insulin (the hormone that causes cells to increase their uptake of glucose and convert it to glycogen and/or triglycerides)
- [ ] keratin (a type of protein found in hair, nails, and skin)

Part D Conjugated proteins

Conjugated proteins are [ ] proteins that have a non-protein component, which is called a [ ].

[ ] is a conjugated protein, as it is made of four polypeptides - each bound to a haem group (an organic molecule containing [ ]).

Examples of other non-protein components include carbohydrates and lipids.

Items:

prosthetic group | **an Fe^{2+} ion** | **Haemoglobin** | **Insulin** | **fibrous** | **globular** | **a Ca^{2+} ion** | **Collagen**

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Protein Practicals

A Level

C C C

Part A Testing for proteins

What is the name of the test used to determine if proteins are present in a solution?

Fill in the blanks to explain how this test works.

The protein solution is added to [ ] (e.g. sodium hydroxide solution), and dilute copper(II) sulfate solution is added to this. The solution will change colour from [ ] to [ ], due to a reaction between the copper(II) ions and the [ ].

Items:

peptide bonds **carboxyl groups** **an alkaline solution** **blue** **red** **purple** **an acidic solution** **R side-chains**

Part B Thin-layer chromatography

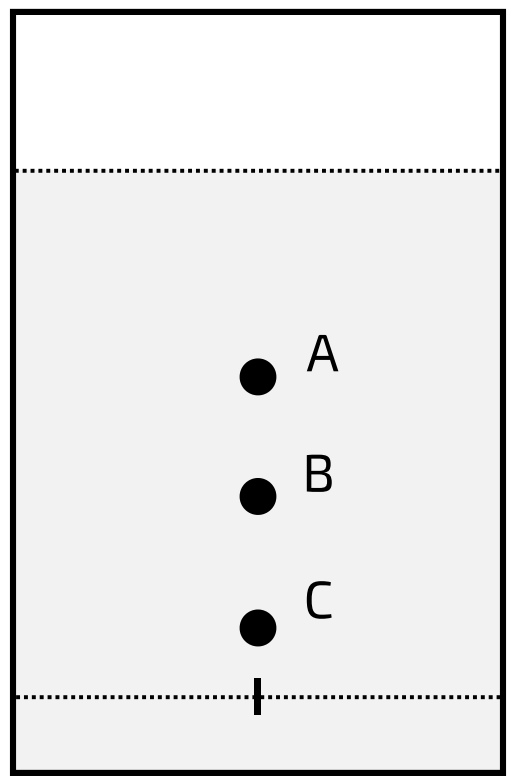

Figure 1: A thin-layer chromatography (TLC) plate was prepared for one solution ("Solution X"), which contained three amino acids. After 10 minutes, the plate was removed and sprayed with ninhydrin spray to visualise the amino acids (labelled A-C).

In Figure 1, the solvent front (top dotted line) had moved a distance of $18\,\text{cm}$ above the baseline (bottom dotted line). "A" moved $11.0\,\text{cm}$. "B" moved $6.8\,\text{cm}$. "C" moved $2.3\,\text{cm}$. The retention factor (R_f) values for some amino acids are given in the table below.

Amino acid	R_f value
alanine	0.38
arginine	0.20
cysteine	0.40
glutamine	0.13
methionine	0.55
phenylalanine	0.68
serine	0.27
threonine	0.35
valine	0.61

Which amino acids are present in solution X?

- [ ] alanine
- [ ] arginine
- [ ] cysteine

- [ ] glutamine
- [ ] methionine
- [ ] phenylalanine
- [ ] serine
- [ ] threonine
- [ ] valine

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