



Proteins

Revision notes · IB Biology B1.2: amino acids, peptide bonds, diet and the effect of pH and temperature on protein structure (denaturation).

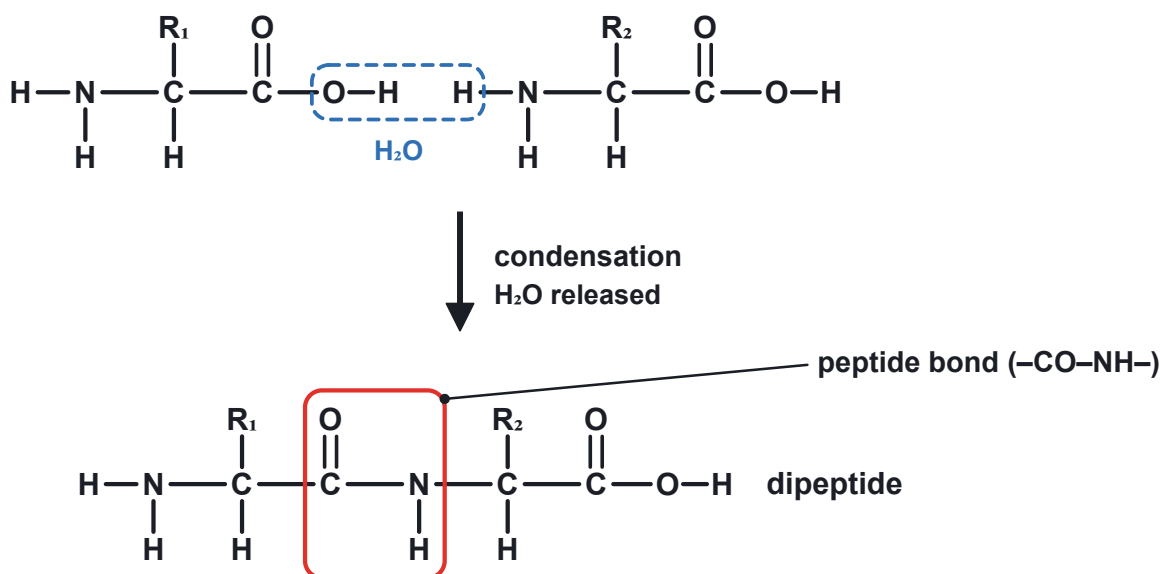
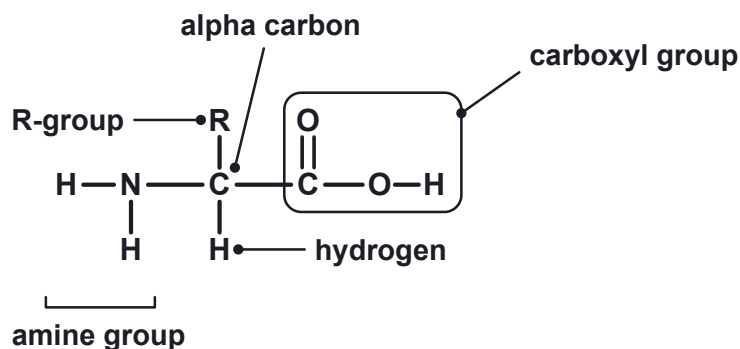
For IB Diploma Biology SL undefined. **HL only** is additional higher level content, for HL students only.

Proteins Spec B1.2

Amino acids and peptide bonds Spec B1.2.1, B1.2.2

Proteins are made of one or more polypeptides, which are chains of amino acids. Every amino acid has the same basic structure, built around a central carbon called the **alpha carbon**.

- an **amine group** (-NH_2)
- a **carboxyl group** (-COOH)
- a hydrogen atom (-H)
- an **R-group**, which differs between the 20 amino acids



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Every amino acid has an **amine group**, a **carboxyl group**, H and an **R-group** on the alpha carbon; condensation joins two by a **peptide bond**.

Exam tip: When drawing an amino acid, show every bond to the alpha carbon and write the groups in full: $\text{H}_2\text{N}-$, $-\text{COOH}$, $-\text{H}$ and R . Marks are lost for a missing hydrogen on the alpha carbon.

Forming dipeptides and polypeptides

The carboxyl group of one amino acid reacts with the amine group of the next in a **condensation reaction**. An $-\text{OH}$ and an $-\text{H}$ are removed as water, and a **peptide bond** ($-\text{CO}-\text{NH}-$) forms between the carbon and the nitrogen.



Further condensation reactions add amino acids one at a time to form a polypeptide. In cells this happens on ribosomes during translation. A polypeptide still has a free amine group at one end and a free carboxyl group at the other.

Practical skill: Build two amino acids with molecular models, remove $-\text{OH}$ and $-\text{H}$ to make water, then join the C and N. Drawing the dipeptide afterwards helps you place the peptide bond correctly.

Dietary amino acids and the variety of peptide chains Spec B1.2.3, B1.2.4

Dietary requirements

Essential amino acids	Amino acids that cannot be synthesised and must be obtained from food.
Non-essential amino acids	Amino acids that can be made from other amino acids.

Proteins in food are hydrolysed into amino acids, which are absorbed and used to build the body's own proteins. If any essential amino acid is missing from the diet, proteins that contain it cannot be made.

Some plant proteins contain only small amounts of certain essential amino acids. **Vegan diets** therefore need attention: eating a variety of plant protein sources, such as legumes together with cereals, ensures that every essential amino acid is consumed.

An infinite variety of peptide chains

- **20 amino acids** are coded for in the genetic code.
- A peptide chain can contain any number of amino acids, from a few to thousands.
- The amino acids can be in any order.

For a chain of n amino acids there are 20^n possible sequences. Even short chains have a vast number of possibilities, so the variety of possible peptide chains is **effectively infinite**. Only a small fraction are actually made by living things.

Counting possible peptide sequences

How many different tripeptides could be made from the 20 amino acids? How many sequences are possible for a chain of 10 amino acids?

1. Each position can be any of 20 amino acids, so the number of sequences is 20^n .
2. Tripeptide: $20^3 = 20 \times 20 \times 20 = 8000$.
3. Ten amino acids: $20^{10} \approx 1.0 \times 10^{13}$.

Answer: 8000 tripeptides; about 1.0×10^{13} sequences of 10 amino acids

Examples of polypeptides

Polypeptide	Size	Function
Insulin	Two chains of 21 and 30 amino acids	Hormone that lowers blood glucose
Beta chain of haemoglobin	146 amino acids	Part of the oxygen-carrying protein in red blood cells
Titin	Up to about 34 000 amino acids, the largest known polypeptide	Gives elasticity to muscle

Effect of pH and temperature on protein structure Spec B1.2.5

A protein's function depends on its precise three-dimensional shape. That shape is held by bonds between parts of the chain, mostly weak ones such as hydrogen bonds and ionic bonds.

Denaturation	A change to the three-dimensional structure (conformation) of a protein so that it can no longer carry out its function. It is usually permanent.
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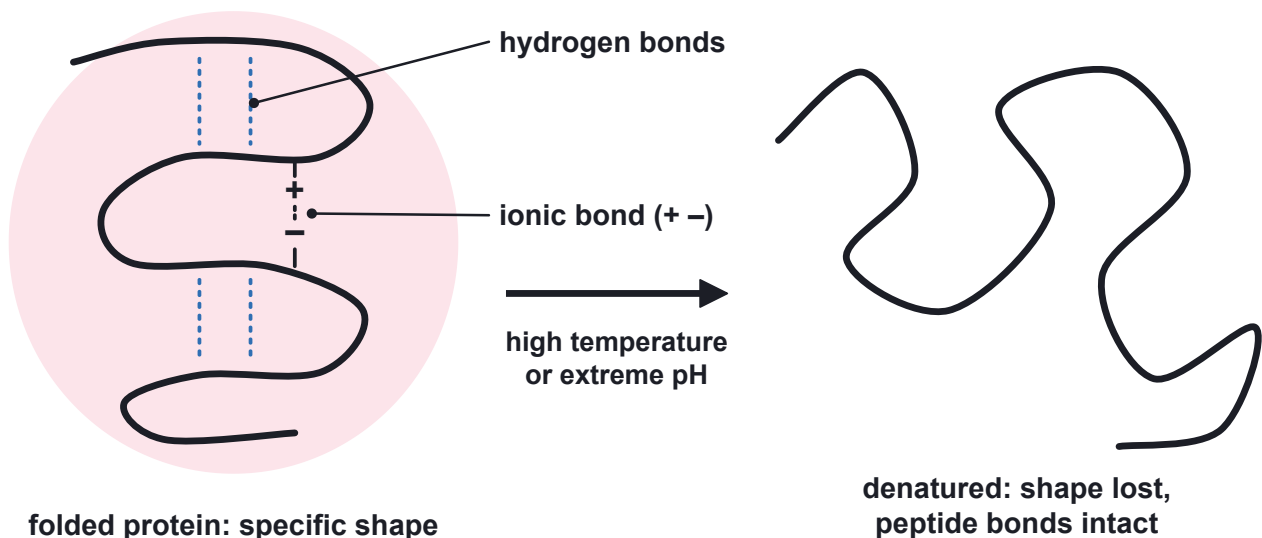
Temperature

Heat makes the atoms in a protein vibrate more. Above a certain temperature, the vibrations break the **hydrogen bonds** and other weak interactions that hold the shape, and the protein unfolds. The temperature at which this happens varies: proteins from organisms living in hot springs stay stable at temperatures that denature most human proteins.

pH

Some R-groups contain amine or carboxyl groups that can gain or lose hydrogen ions. A change in pH changes the **charges on R-groups**, so ionic bonds between them break and new attractions or repulsions form. Each protein is stable over a particular pH range: for example, pepsin works in the acidic stomach while most cytoplasmic proteins need a pH near 7.

- Peptide bonds are not broken, so the amino acid sequence stays the same.
- Soluble proteins often become insoluble when denatured, for example egg white turning solid when heated.
- An enzyme that is denatured loses the shape of its active site, so it can no longer bind its substrate.



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Heat and extreme pH break the **hydrogen and ionic bonds** that hold a protein's shape; the **peptide bonds stay intact**.

Practical skill: When testing the effect of temperature or pH on a protein such as an enzyme, change one independent variable, keep substrate concentration, volume and time constant, and repeat each condition at least three times.

Exam tip: Linking question: how do abiotic factors influence the form of molecules? Temperature and pH are abiotic factors that change protein shape, which limits where organisms can live.

Quick check

1. Which four groups are bonded to the alpha carbon of an amino acid?
2. What is an essential amino acid?
3. What is denaturation?

Quick check answers

Proteins

1. An amine group, a carboxyl group, a hydrogen atom and an R-group.
2. One that cannot be synthesised by the body and must be obtained from food.
3. A usually permanent change in the three-dimensional structure of a protein, so it can no longer carry out its function.