Proteins

Importance

Proteins are naturally occurring **polypeptides**. They:

- contribute to the mechanical structure of animals, including humans, e.g. keratin in hair and fingernails, and fibrous proteins such as collagen in tendons
- enable animals to move, e.g. myosin in muscle
- facilitate transport of smaller molecules around animals' bodies, e.g. haemoglobin
- control the types and rates of chemical reactions in living things; then they are called **enzymes**, e.g. amylase
- are important components of the human immune system, e.g. immunoglobins

> See the topic about Enzymes

Proteins make up about 15% of our body mass. They are the most abundant 'solid' substances in our bodies.

Each protein has its own precise function under the direction of its own gene. The shapes of proteins are of key importance. These are determined by the sequence of amino acids that make them up.

Amino acids

Amino acids are the building blocks (monomers) of proteins. Twenty different amino acids are used to make the body's proteins. Of these nine are called **essential** (meaning they can only be obtained from the food we eat) and eleven are **non-essential** (they may be synthesised in the body though they are usually obtained from food).

Amino acids have the general structural molecular formula $-NH_2CHRCOOH$. They have two important functional groups (a functional group means a group of atoms in a molecule that have characteristic chemical reactions regardless of the rest of the molecule):

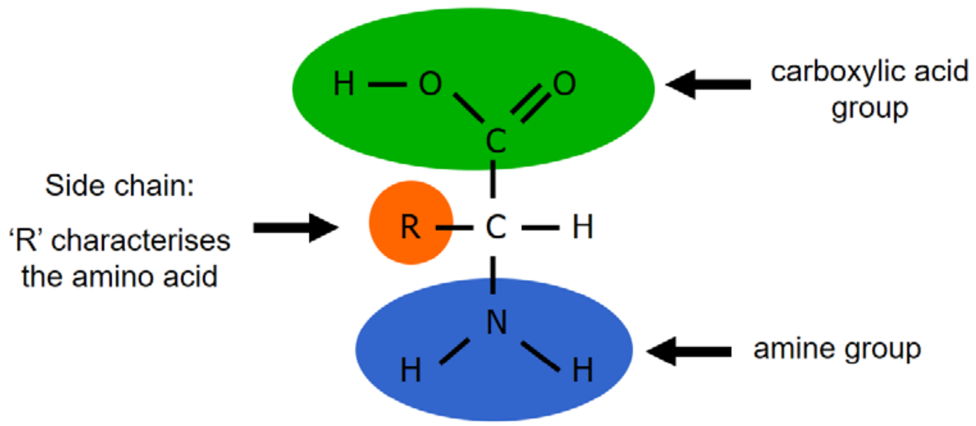
carboxylic acid group	$-COOH$
amine group	$-NH_2$

Amino acids

The general molecular formula of an amino acid is **$RCH(NH_2)COOH$**

However, it's easier to 'see' the bonds that are present

by writing its structural formula:



The R group determines the amino acid. For example,

R group	amino acid	Side chain
- H	glycine	non-polar
- CH_3	alanine	non-polar
- CH_2OH	serine	uncharged polar
- CH_2SH	cysteine	uncharged polar
- CH_2COOH	aspartic acid	acidic
- $CH_2CH_2CH_2CH_2NH_2$	lysine	basic

When amino acids dissolve in water they ionise. At a particular pH each amino acid exists in solution as a **zwitterion**. In effect a proton transfers from the carboxylic group to the amine group. The pH at which this happens is the **isoelectric point** for the amino acid.

Zwitterions

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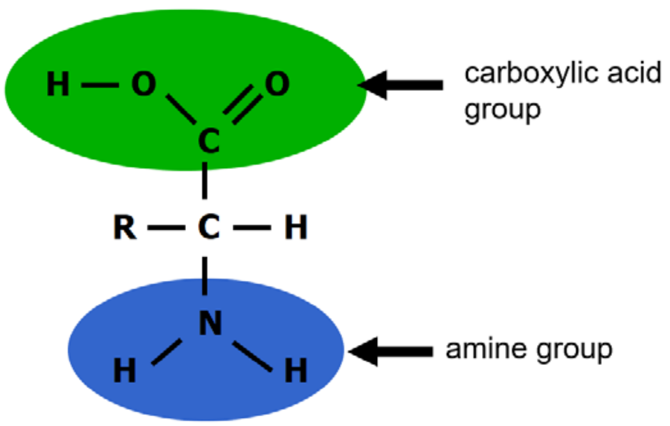
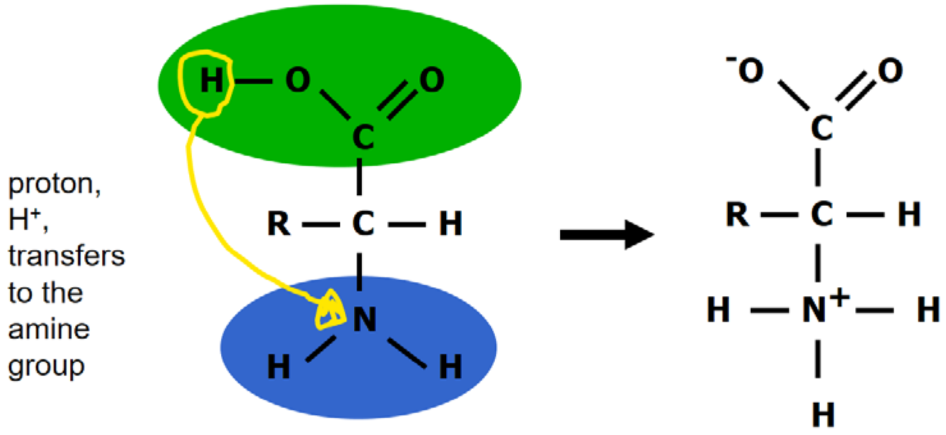


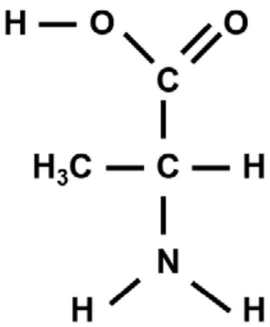
A zwitterion is formed when a **proton** (a hydrogen nucleus) moves from the **carboxylic acid** group to the **amine** group



The zwitterion ion forms when an amino acid is dissolved in water – and this is how they are usually found in nature

Alanine

Alanine is an amino acid. Its molecular formula is $C_3H_7O_2N$

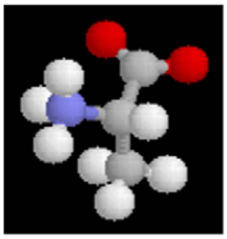


Make a molecular model of alanine and use it to:

1. investigate the shape of the molecule and explain why can it exist in two forms
2. show how its zwitterion is formed.

Look at the picture of the zwitterion:

1. where is the – NH_3^+ group?
2. where is the – COO^- group?



Solutions of amino acids are **buffers**. This means they resist changes in pH when an acid or an alkali is added to an amino acid in solution.

When an acid is added, the $-NH_2$ group combines with H^+ ions from the acid to form $-NH_3^+$

$$NH_2CHRCOOH\ (aq) + H^+\ (aq) \rightarrow NH_3^+CHRCOOH\ (aq)$$

(H^+ is frequently used as shorthand for H_3O^+)

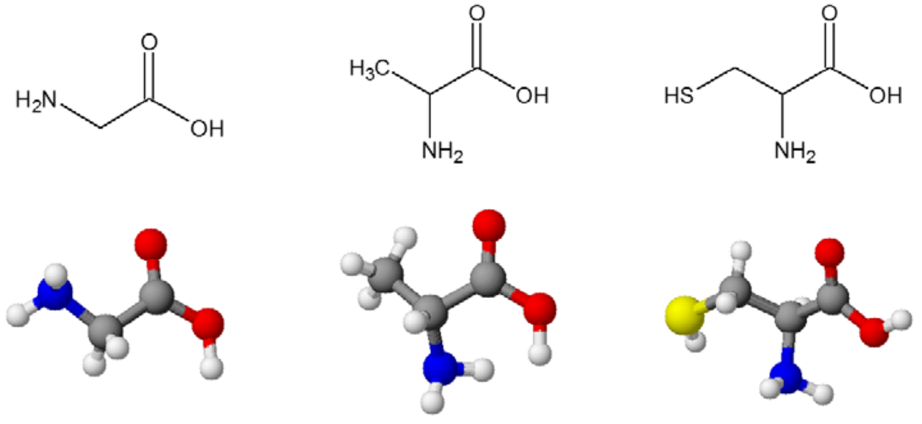
When an alkali is added, the -COOH group combines with OH^- ions from the alkali by loss of H^+ to form $-COO^-$

$$NH_2CHRCOOH\ (aq) + OH^-\ (aq) \rightarrow NH_2CHRCOO^-\ (aq) + H_2O$$

In both cases, the concentration of H^+ ions in solution does not change greatly and so the pH remains about the same.

The shape of the amino acid molecule is also important.

The shapes of some amino acid molecules



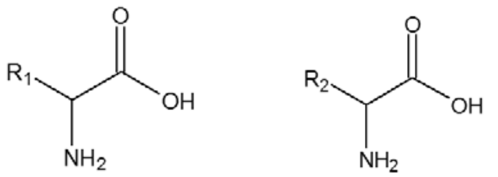
glycine | alaninine | cysteine

Peptide bond formation

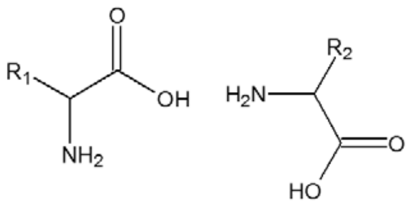
Two amino acids can undergo a condensation reaction to form a **dipeptide**. Further condensation reactions result in a polypeptide. The amino acid units are linked by **peptide bonds** (sometimes called **peptide links**).

$R_1\text{-}COOH + R_2\text{-}NH_2 \rightarrow R_1\text{-}CO\text{-}NH\text{-}R_2 + H_2O$

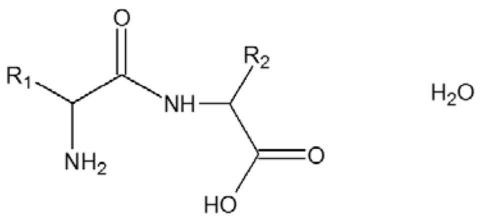
Formation of the peptide bond



Two amino acid molecules; the nature of the R group (R_1 and R_2) determines the amino acid



The molecules must be orientated so that the carboxylic acid group of one can react with the amine group of the other



The peptide bond forms with the elimination of a water molecule; it is another example of a condensation reaction

Rotation about the carbon-nitrogen bond in the peptide link is restricted. This has a huge influence on the shape and structure of proteins, which in turn determine how they behave.

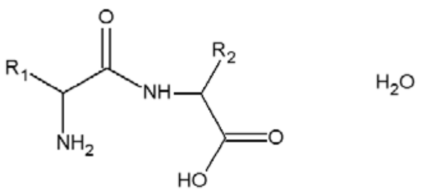
Peptide bonds can be broken down by **hydrolysis**.

R_1-CO-NH-R_2+ H_2O → R_1-COOH +R_2-NH_2

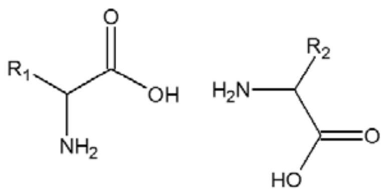
Hydrolysis of the peptide bond

The peptide bond holds two amino acid 'residues' together. It is a flat, rigid group

A water molecule reacts with this group



The two amino acids form or, if the peptide bond is somewhere in a long peptide chain, two smaller peptide molecules are formed

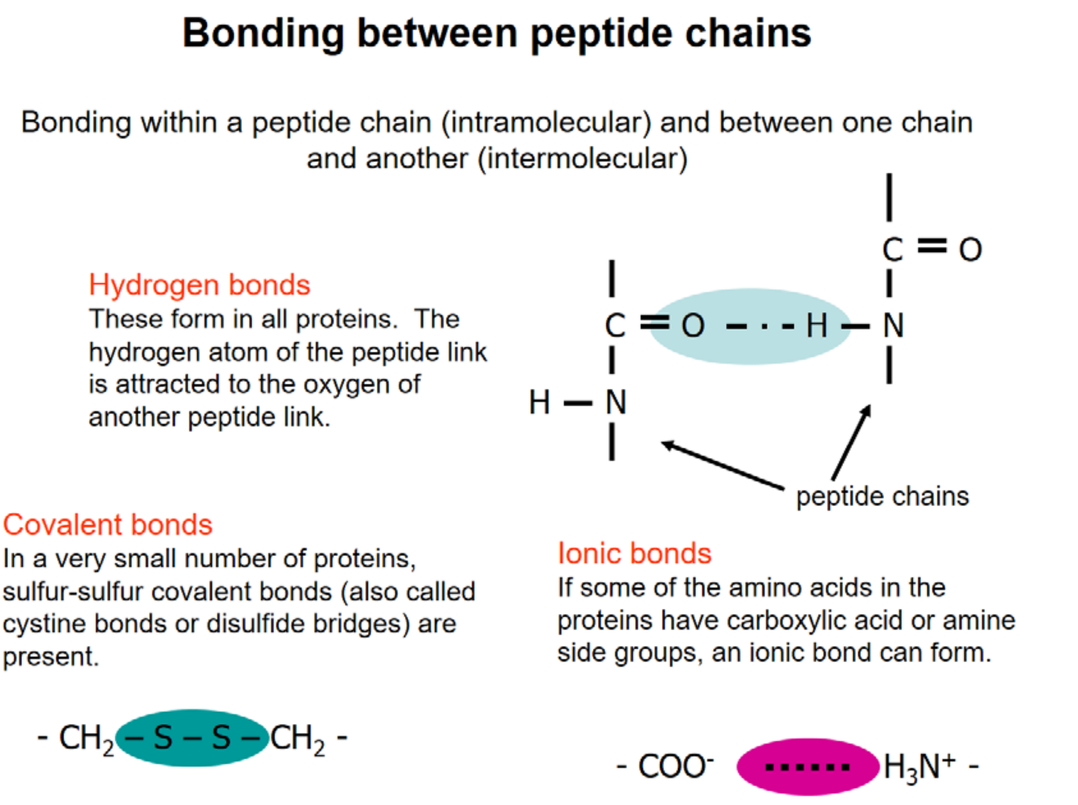


Protein structures

The sequence of amino acids in a protein is called its **primary structure**. Within a chain the atoms are held together by covalent bonds. Each protein has its own characteristic sequence of amino acids.

Three types of bonding can happen within a protein molecule (**intramolecular bonding**) and between protein molecules (**intermolecular bonding**):

- Hydrogen bonds
- Covalent bonds
- Ionic bonds



Protein chains arrange themselves to maximise the intra- and intermolecular bonding. The structure when protein chains are held in place is called the **secondary structure**. This may be:

- helical, e.g. keratin (the protein found in hair), or
- pleated sheet, e.g. fibroin (the protein found in silk)

These structures are held in place by hydrogen bonds.

Protein chains may fold into a globular shape. This is the **tertiary structure** of a protein. These globular proteins include enzymes and immunoglobins. The structures are held in place by hydrogen bonds, disulfide bridges and ionic bonds.

The precise structure of a globular protein is the key to specificity of enzymes. Similarly proteins that act as receptor sites on the cell surface can recognise specific molecules because of their shapes.

Finally some proteins have a **quaternary structure**. These contain more than one protein chain. Examples are insulin and haemoglobin.

Try this website for a good description of formation of peptides and their primary, secondary, tertiary and quaternary structures: www.johnkyrk.com/aminoacid.html

Test your knowledge

Take quiz on *Proteins*