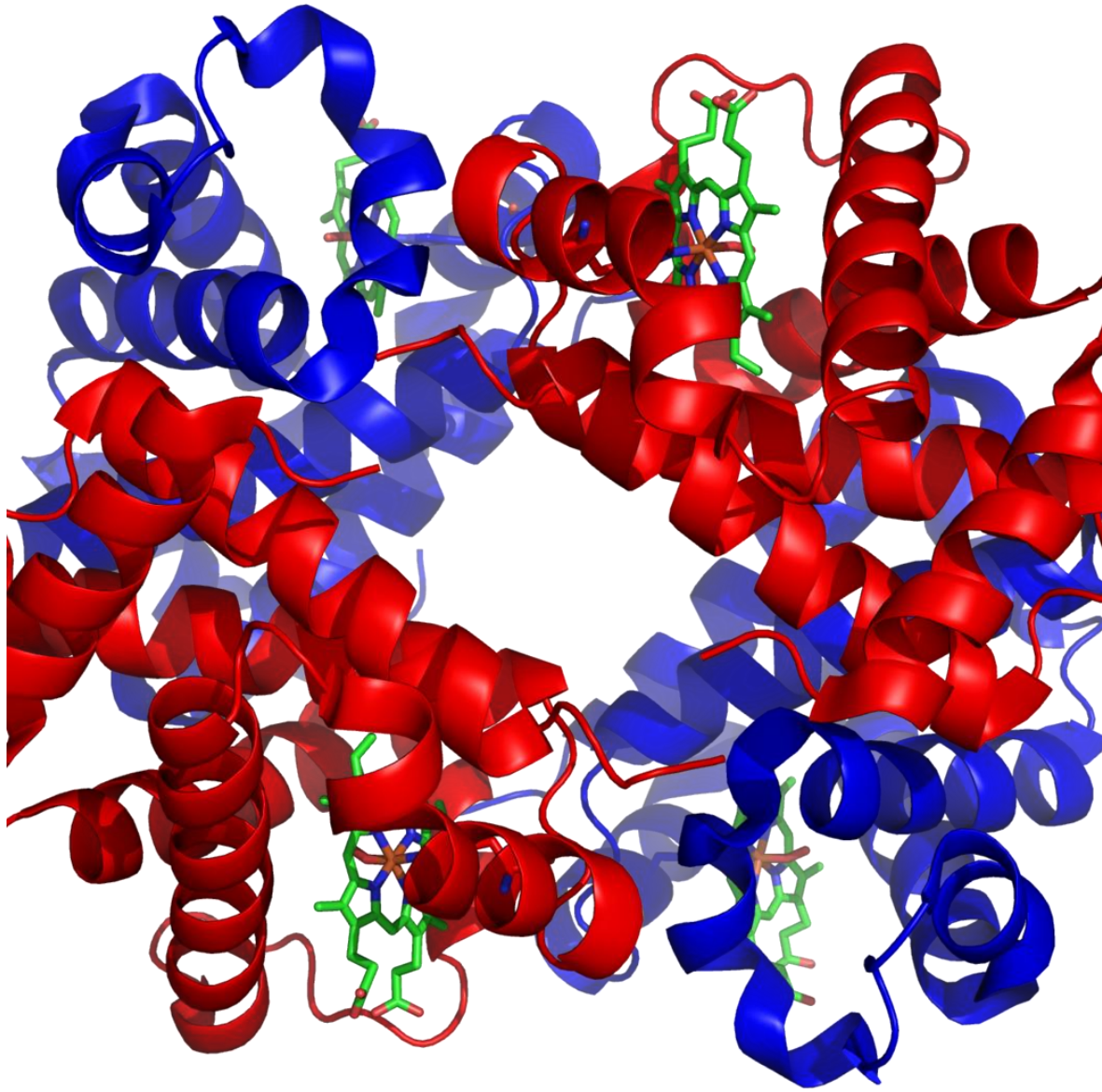
DP Biology – B1.2 (HL extension)

Protein structure

- How does the order of amino acids produce such a variety of protein forms and functions?
- How do chemical and physical conditions affect protein molecules?



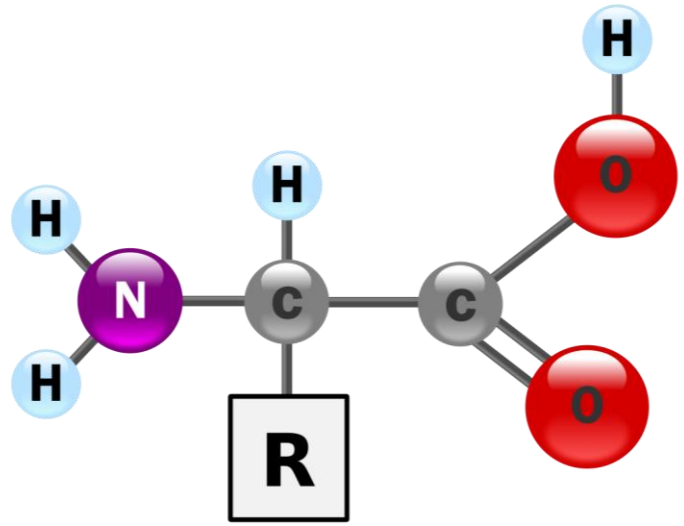
HL statements B1.2.6–12. Textbook pp. 210–222.
Image: haemoglobin, four chains with haem groups (green). Richard Wheeler, CC BY-SA 3.0.

Objectives for each class

Class	Statements	By the end of the class, you can...
1	B1.2.6–8	Explain how R-groups give proteins their properties, and how primary structure leads to secondary structure
2	B1.2.9–10	Explain the bonds that hold tertiary structure, and where hydrophobic and hydrophilic amino acids end up
3	B1.2.11–12	Compare quaternary structure in insulin, collagen and haemoglobin, and relate the form of globular and fibrous proteins to their function

R-groups make the difference

B1.2.6



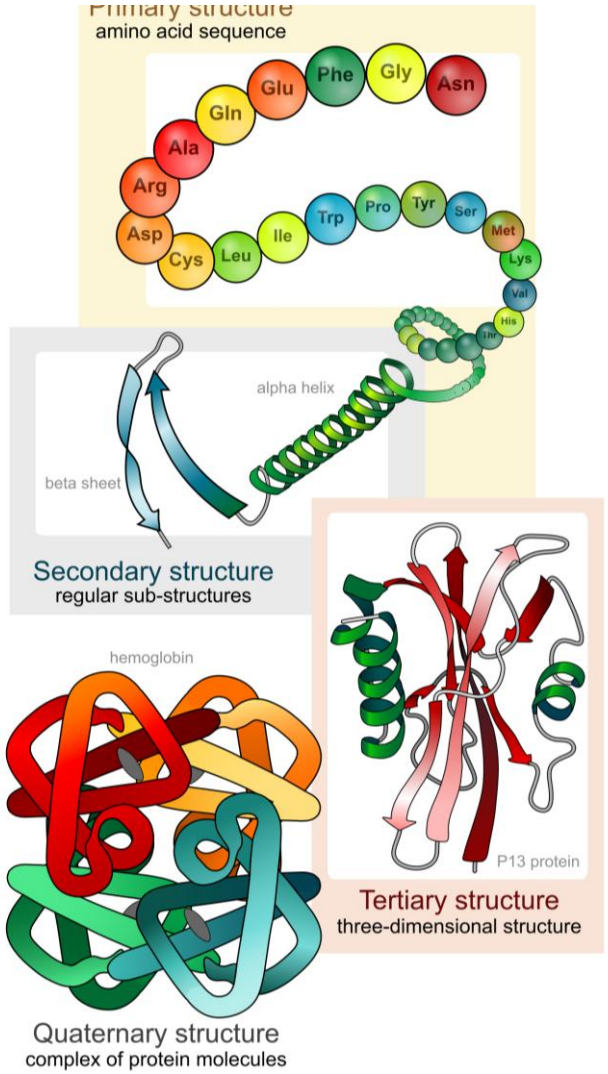
General structure of an amino acid. Public domain.

Type of R-group	Properties
Non-polar	Hydrophobic; avoids water
Polar, uncharged	Hydrophilic; forms hydrogen bonds
Acidic	Extra -COOH; loses H+ to become negative
Basic	Extra -NH2; gains H+ to become positive

Key idea

Twenty different R-groups, combined in any order, give an almost unlimited number of sequences. The R-groups decide how a chain folds and what it can bind, so they explain the huge diversity of protein form and function.

Sequence decides shape



Levels of protein structure. LadyofHats, public domain.

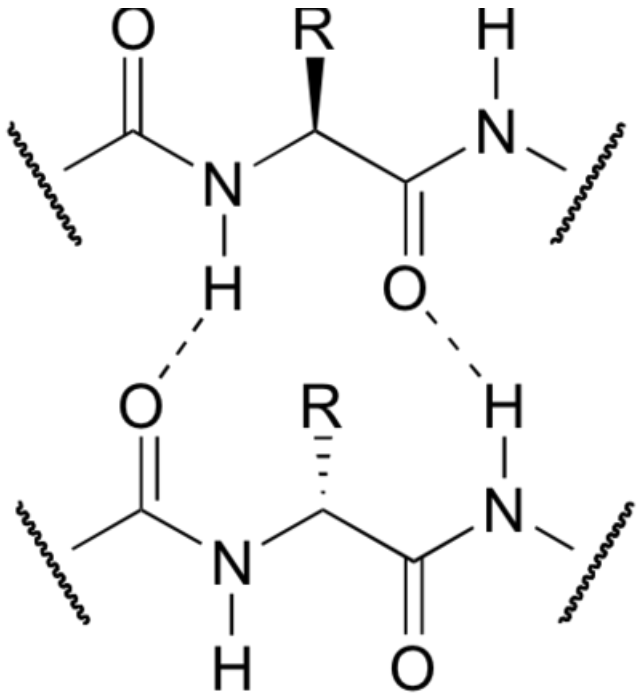
- **Primary structure**: the sequence of amino acids, set by the gene
- The sequence fixes where each R-group sits, so it determines how the chain folds
- So every copy of a protein has the same precise, predictable shape
- Small proteins that are unfolded can refold correctly on their own: the information is in the sequence
- Changing one amino acid can change the shape, as in sickle-cell haemoglobin

Think about it

Why can a computer now predict a protein's shape from its sequence, but not from a list of its amino acids?

Secondary structure: coils and pleats

B1.2.8



hydrogen bonding in a β-strand

Hydrogen bonds between C=O and N-H in the backbone. CC BY-SA

	Alpha helix	Beta-pleated sheet
Shape	Right-handed coil	Strands side by side, pleated
Hydrogen bonds	Between C=O and N-H four residues along the same chain	Between C=O and N-H of neighbouring strands
Regularity	Bonds at regular positions	Bonds at regular positions

Common mistake

Secondary structure is held by hydrogen bonds between backbone atoms, not between R-groups. R-group bonds belong to tertiary structure.

Bonds that hold tertiary structure

B1.2.9

Bond	Between	Strength and sensitivity
Hydrogen bonds	Polar R-groups	Weak; broken by heat
Ionic bonds	Positively charged (-NH3+) and negatively charged (-COO-) R-groups	Moderate; broken by changes in pH
Disulfide bonds	The -SH groups of two cysteines	Strong covalent bond
Hydrophobic interactions	Non-polar R-groups, clustered away from water	Weak individually, strong together

Charge depends on pH

Amine groups gain H+ and carboxyl groups lose H+, so whether ionic bonds form depends on the pH. This is why pH can denature proteins.

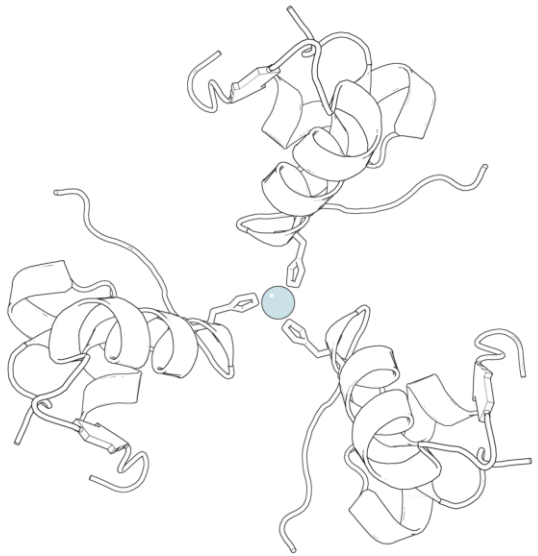
Inside or outside?

Protein type	Where amino acids go
Soluble globular protein	Non-polar in the core; polar on the surface, in contact with water
Integral membrane protein	Non-polar where it crosses the lipid bilayer; polar where it meets water on either side
Channel protein	Polar amino acids also line the pore, letting ions through

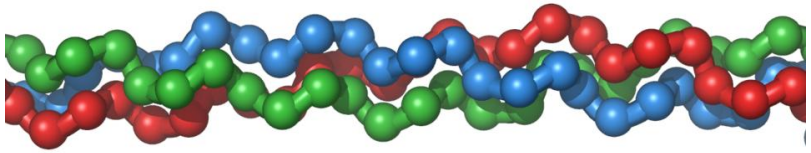
Activity

A protein has a stretch of about 20 amino acids that are all non-polar. Predict where in the cell this stretch is likely to be, and explain. Then predict what would happen to the protein if a polar amino acid replaced one in the middle.

Quaternary structure



Insulin, stored as six molecules (hexamer). Public domain.



Collagen triple helix. CC BY-SA 3.0.

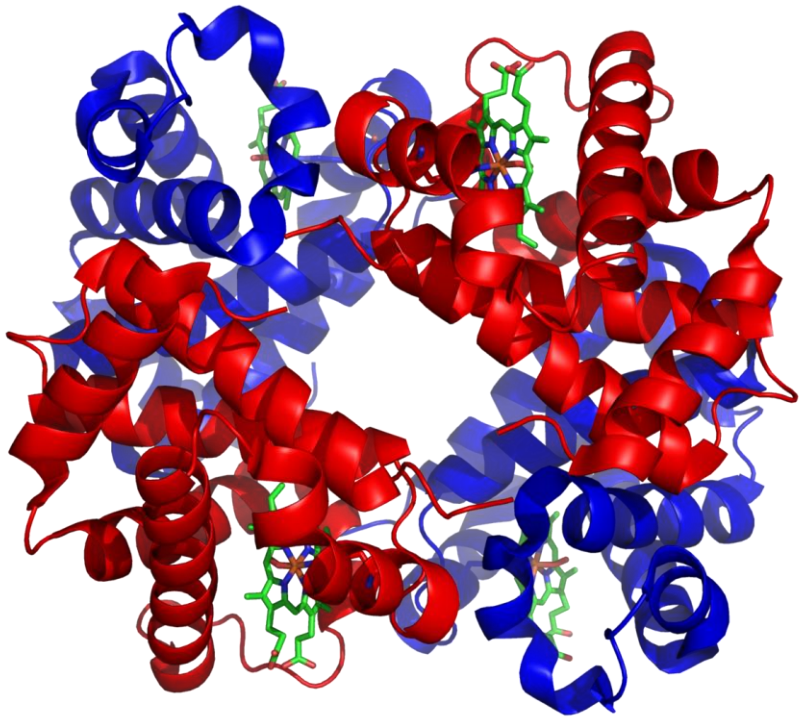
Protein	Polypeptides	Conjugated?
Insulin	Two chains (A and B) joined by disulfide bonds	No
Collagen	Three chains wound into a triple helix	No
Haemoglobin	Four chains, each with a haem group	Yes: haem is a prosthetic group

Definitions

Quaternary structure: two or more polypeptides joined. A conjugated protein also has a non-polypeptide part (prosthetic group), such as haem with its iron.

Haemoglobin: a conjugated protein

B1.2.11



Haemoglobin: alpha chains red, beta chains blue, haem green. CC BY-SA 3.0.

- Two alpha and two beta globin chains
- Each chain holds one **haem group**, with an iron ion at its centre
- Each iron ion binds one oxygen molecule, so one haemoglobin carries up to four
- The chains fit together so that binding of one oxygen makes the next bind more easily

Form and function: globular and fibrous

B1.2.12

	Insulin (globular)	Collagen (fibrous)
Shape	Compact and roughly spherical	Long, rope-like triple helix
Solubility	Soluble, carried in blood plasma	Insoluble
Sequence	Varied; folds into a precise shape	Repeating; every third amino acid is glycine
Function	Hormone: binds a specific receptor on target cells	Strength in skin, tendons and bone
Link	Exact shape fits the receptor	Glycine lets chains pack tightly; cross-links add tensile strength

Protein detective

B1.2.6–12

1. Open a protein structure in a 3D viewer (for example insulin or collagen on PDB-101). Colour it by hydrophobicity. Where are the hydrophobic amino acids?
2. Find two cysteines joined by a disulfide bond in insulin.
3. **Explain** why boiling denatures insulin but does not break its disulfide bonds.

Link

Denaturation, and why an enzyme's shape matters, is covered in B1.2 (SL) and C1.1.

Check that you can explain

1. Four kinds of R-group and how they affect a protein
2. Why the amino acid sequence determines the shape
3. How hydrogen bonds stabilize alpha helices and beta sheets
4. Four kinds of bond in tertiary structure
5. Where hydrophobic and hydrophilic amino acids sit in soluble and membrane proteins
6. Quaternary structure in insulin, collagen and haemoglobin
7. How the shapes of globular and fibrous proteins suit their functions

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Name the type of bond that stabilizes an alpha helix, and the atoms it joins.
2. State where non-polar amino acids are found in a soluble globular protein.
3. Explain why haemoglobin is called a conjugated protein.

Image credits

1GZX Haemoglobin.png – Zephyris at English Wikipedia – CC BY-SA 3.0

AminoAcidball.svg – GYassineMrabet – Public domain

Main protein structure levels en.svg – LadyofHats – Public domain

Both helix and the beta-sheet structures are held by specific hydrogen-bonding interactions.png – Unknown author – CC BY-SA 4.0

Insulin hexamer 4INS.png – Fvasconcellos (talk · contribs) – Public domain

Collagentriplehelix.png – Author not stated – CC BY-SA 3.0

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