TeachMe

STUDY NOTES

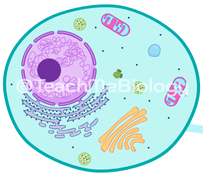
Chapter 2 - Biological Molecules

Proteins

Last update: November 7th 2025

TeachMe

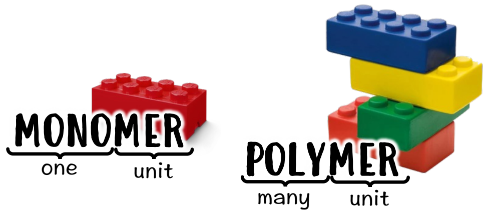
PROTEINS



CARBOHYDRATES | LIPIDS | PROTEIN | NUCLEIC ACIDS (Chapter 6) | WATER

Macromolecules

Macromolecules are large molecules built from smaller, repeating subunits known as **MONOMERS**. By linking many monomers together, you form a **POLYMER**.

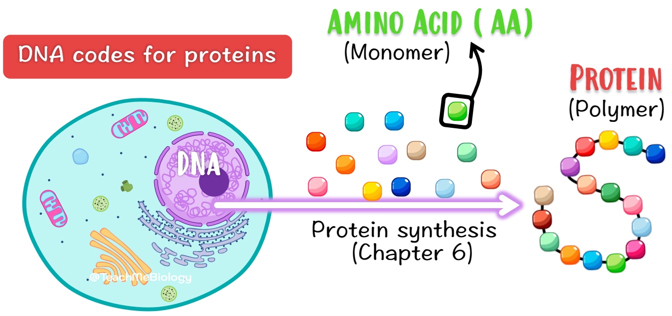


	Monomer		Polymer
Carbohydrates	Monosaccharide	→	Polysaccharide
Protein	Amino acid	→	Polypeptide
Nucleic Acids	Nucleotide	→	Nucleic acid

Big Brain Tip!

You can think of a monomer as a single Lego piece, and when you join multiple together you get a large structure (polymer)

Most macromolecules (except lipids) follow this same principle, but each type uses different monomers. You should by now already be familiar with carbohydrates and lipids — now, let's focus on proteins!



There are **20** different types of amino acids

HUGE variety of proteins exist, differing in:

- Chain Length
- AA sequence

} Influence Folding

Each protein will be able to carry out it own specific function.

Examples of

HEMOGLOBIN
Oxygen-carrying protein found in red blood cells

COLLAGEN
Structural protein that adds strength. Found in bones, tendons, ligaments

MEMBRANE PROTEINS
Many functions; e.g., transport (Chapter 4)

ENZYMES
Catalyze chemical reactions (Chapter 3)

HORMONES
E.g., Insulin & Glucagon. Regulate blood sugar (Chapter 14)

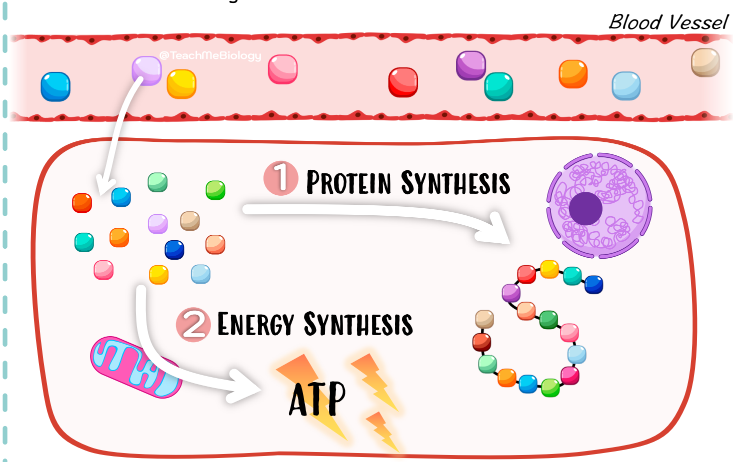
ANTIBODIES
Attack and destroy invading microorganism (Chapter 11)

ACTIN & MYOSIN
Responsible for muscle contraction (Chapter 15)

KERATIN
Hair, nails and surface layers of skin contain it

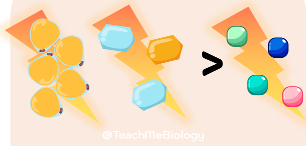
What are Amino Acids used for?

When an animal (you!) eats food which contains protein, it gets digested in the **digestive tract** and absorbed as monomers — amino acids — into the blood stream. These monomers then enter the cells of the body to fulfil two main functions:



1. Amino acids can be used to build larger molecules: proteins. These molecules can then carry out many different functions (see on the right of the page).
2. Amino acids can get used by the mitochondria to generate ATP (energy).

Big Brain Tip!

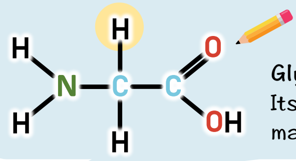


Proteins are used as last resort for cellular energy generation, and do not produce as much energy as lipids and carbohydrates do.

Teach Me

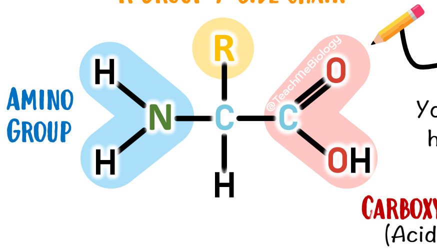
AMINO ACIDS
(Monomer)

Now that we understand proteins are made up of amino acids, we need to understand more about the structure of these amino acids:



BIG BRAIN TIP!
Glycine is the simplest amino acid: Its R group is a hydrogen (H). You may be asked to draw this one!

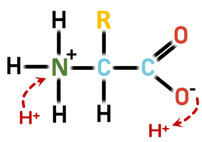
NOTE! The R-group is the ONLY place where the amino acids differ



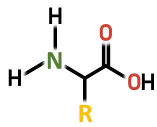
You need to know how to draw it!

AA's can also exist in a different form: Ionized state. This can happen when an AA is in water. Get good at identifying them:

Ionized State



Skeletal Structure

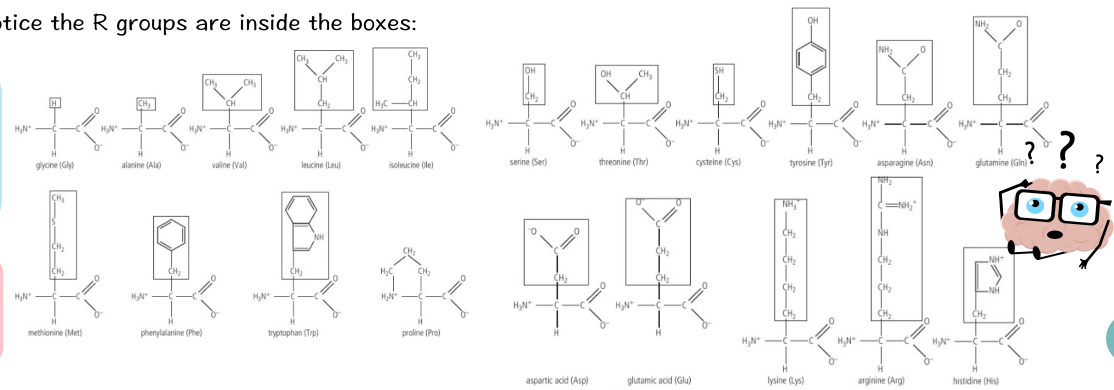


"Does not show carbon, or C-H bonds"

Here are all 20 amino acids, notice the R groups are inside the boxes:

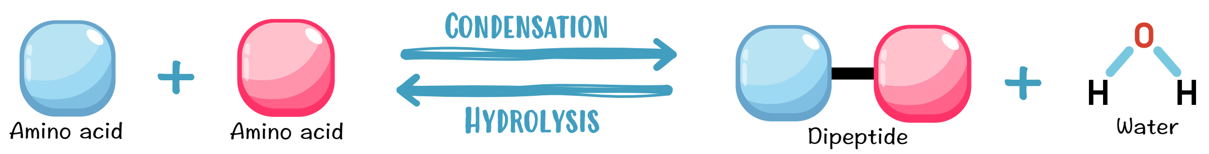
You don't need to know them, this is here just to give you an idea of what we mean when we say each amino acid has a different R group.

These differences in R groups will give different properties to each amino acid.



How do amino acids link together? ... and unlink!

CONDENSATION – "Water formation" Chemical reaction involving the joining together of two molecules by **REMOVAL** of a water molecule.



HYDROLYSIS – "Water Splitting" Chemical reaction by which two molecules are formed through the breaking of a chemical bond by the **ADDITION** of water.

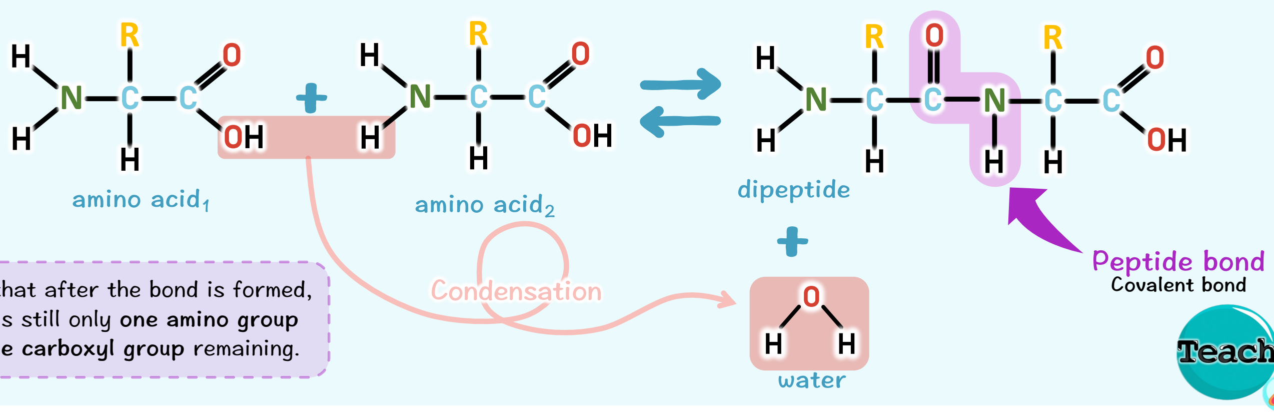
DIPEPTIDE
(Dimer)

The **DIPEPTIDES** are formed by a CONDENSATION REACTION between two amino acids.

Why the name? The bond between the two amino acids is called a "peptide bond", and two (di) amino acids are joining together.

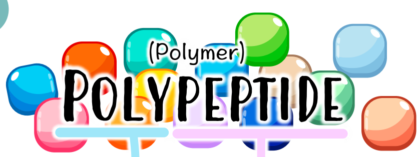
You need to know how to draw it!

amino acid$_1$ + amino acid$_2$ ⇋ dipeptide + water



Notice that after the bond is formed, there is still only **one amino group** and **one carboxyl group** remaining.

Teach Me

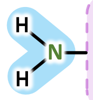


What we call a "PROTEIN"

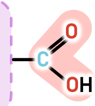
Many

Amino acids linked with peptide bonds

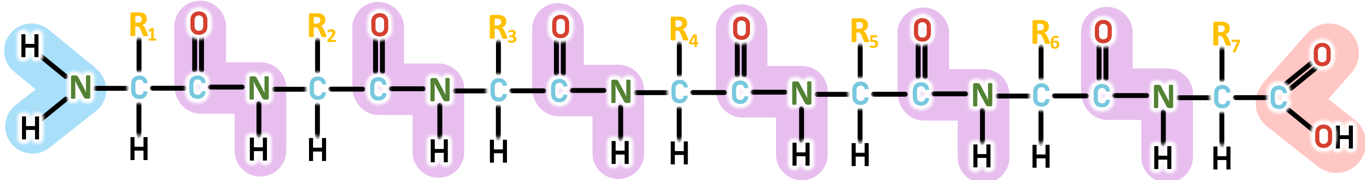
Proteins (polypeptides) are formed by repeated CONDENSATION REACTIONS between amino acids, forming a chain of them linked by peptide bonds.

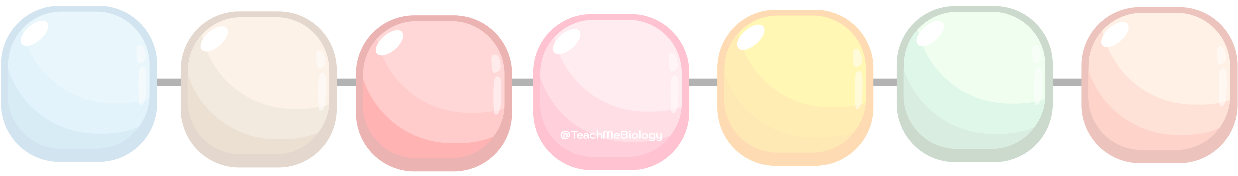


And yet again, after all the peptide bonds are formed, there is still only **one amino group** and **one carboxyl group** remaining.



Example of a protein comprised of seven amino acids:

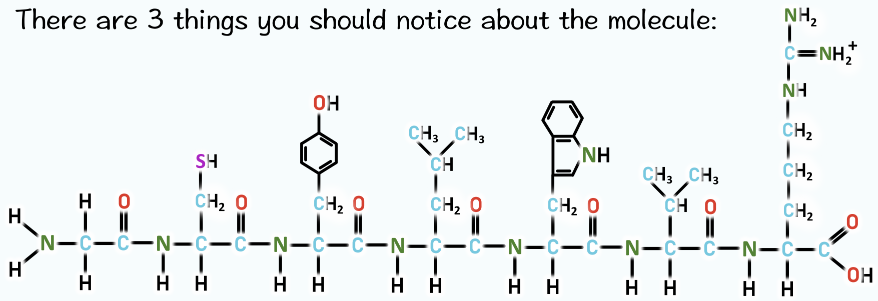




Test Yourself!

Observe the following molecule (crazy right?). How can you know whether it is a protein or not?

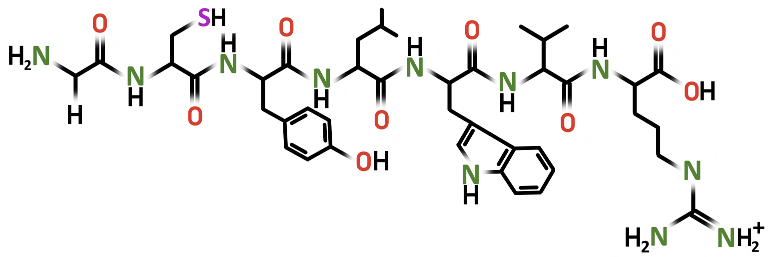
There are 3 things you should notice about the molecule:



1. NCC pattern: proteins always have this NCC sequence as a backbone (the main structure of the amino acid).
2. Presence of an amino group on one end of the molecule.
3. Presence of a carboxyl group on the other end of the molecule.

So YES, this is a protein (and you didn't have to know all the crazy R groups to know so!)

For fun... This structure is the same polypeptide chain shown above, but in its skeletal form — practice by identifying:

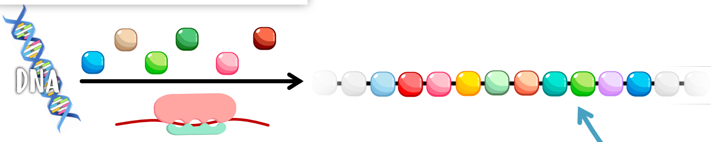


- Peptide bonds
- R groups
- Carboxyl group
- Amino group

Levels Of Protein Structure
an overview

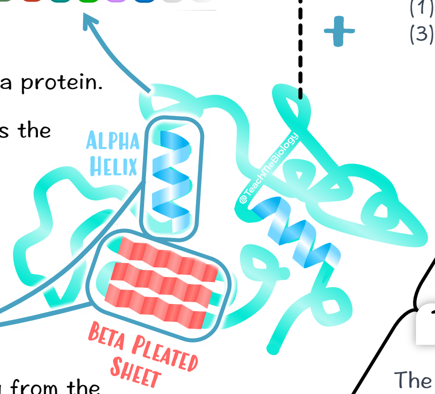
(page 3)

Primary Structure (1°)



The number and sequence of amino acids in a protein.

Determined by your DNA (or gene), it dictates the other levels of protein structure (folding).



(page 4)

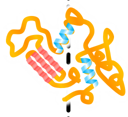
Secondary Structure (2°)

The structure of a protein molecule resulting from the regular coiling or folding of the amino acid chain into alpha helix or beta-pleated sheet.

Caused by hydrogen bonds between the oxygen of the carboxyl group (C=O) of one amino acid and the hydrogen of the amino group (-NH) of another.

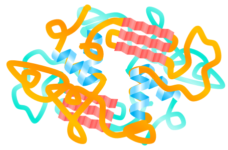
(page 5)

Quaternary Structure (4°)



The structure formed when two or more polypeptide chains bind together.

Due to interactions between R-groups including:
(1) Hydrogen Bonding, (2) Ionic bonding,
(3) Disulphide linkage, (4) Hydrophobic interactions.



(page 5)

Tertiary Structure (3°)

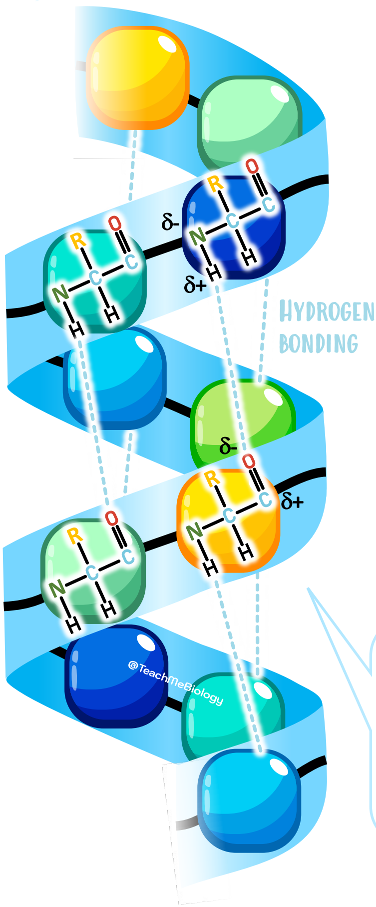
The Complete 3D arrangement of the entire protein molecule.

Due to interactions between R-groups including:
(1) Hydrogen Bonding, (2) Disulphide linkage,
(3) Ionic bonding, (4) Hydrophobic interactions.

Secondary Structure (2°)

[Bonding does NOT involve R-groups]

Alpha Helix (2°)

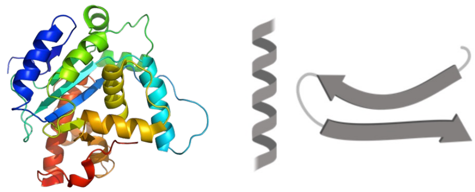


Hydrogen bonding is between non-adjacent amino acids.

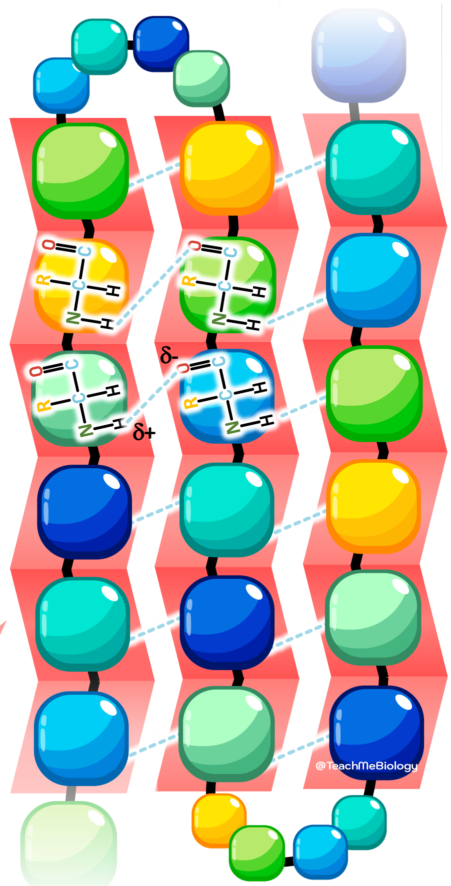
Between the oxygen in the C=O group of one AA and the hydrogen of the —NH group of another

These two shapes maximize the number of hydrogen bonds.

Common ways they are illustrated!



Beta Pleaded Sheet (2°)



Teach Me

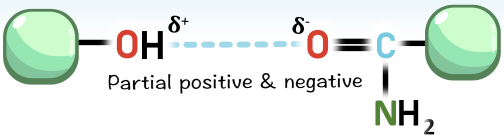
Tertiary Structure (3°)

[Bonding happens between R-groups]

The Complete 3D arrangement of the entire protein molecule. Various types of bonding that occur between R groups will influence the final configuration in which the protein is folded into (which will determine it specific function in our wonderful bodies).

HYDROGEN BOND

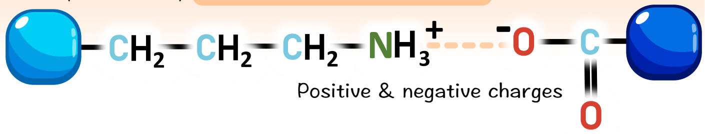
(NOT covalent)



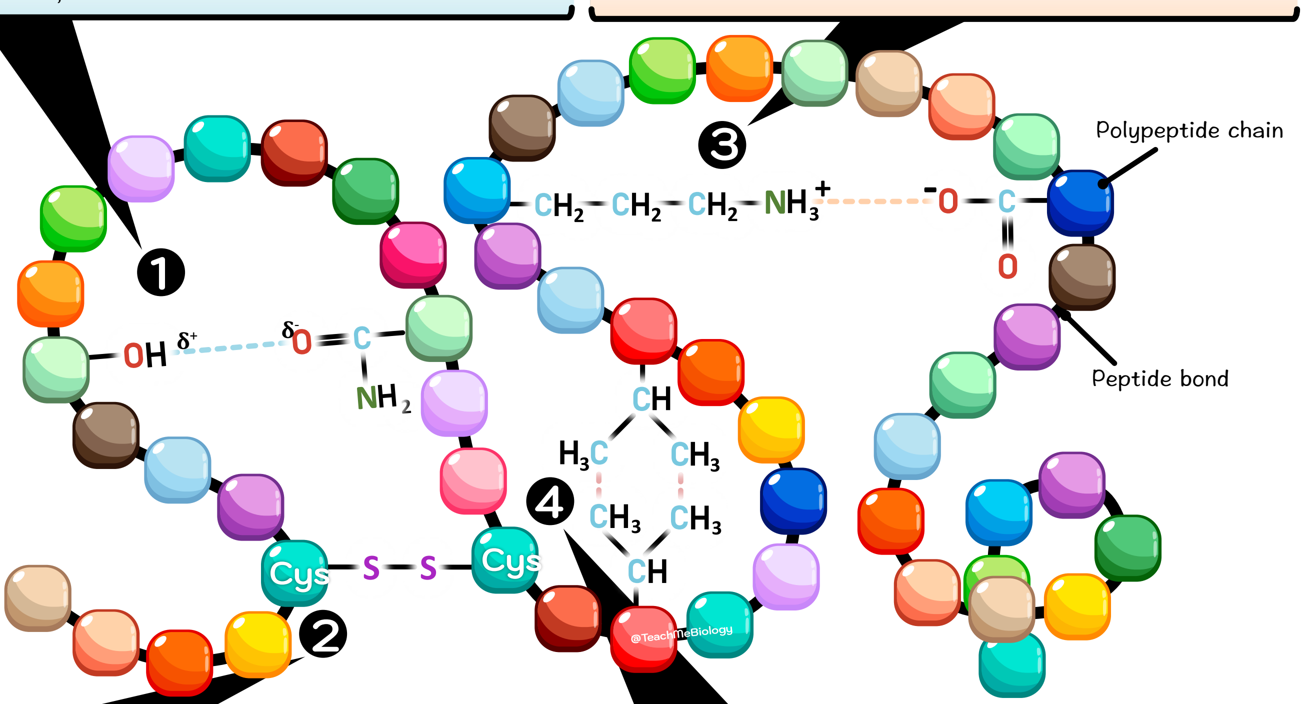
Hydrogen bonds between **polar** amino acid's **R-groups**.
Found mainly near the **exterior of the polypeptide** (hydrophilic).
Relatively **weak**, but **most numerous**.

IONIC BONDING

(NOT covalent)

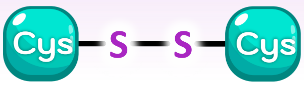


Polar (Ionized) R-groups will align with each to form ionic bonds.
Carboxyl group in R group can lose hydrogen to become negative.
Amino group can gain hydrogen to become positive.
Opposite charges attract (Second strongest bond).



DISULFIDE BOND (LINKAGE)

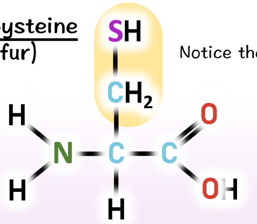
(covalent)



The **strongest** bond that **influences polypeptide shape**.
Between the R-groups of **cysteine (Cys) amino acids**.

Formed by an *oxidation reaction*. Broken by a *reduction reaction*.

<u>Structure of Cysteine</u>
(AA with sulfur)

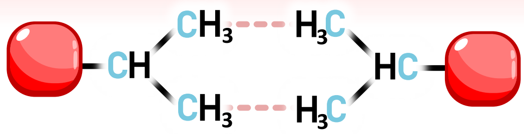


Notice the sulfur in the R group!

HYDROPHOBIC INTERACTIONS

(NOT covalent)

Weakest bond



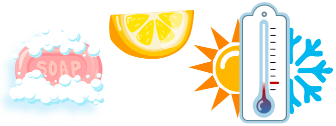
Non-Polar amino acid's R-groups are hydrophobic.

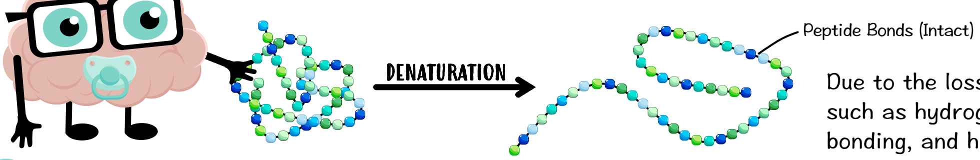
They will fold into an area within the **interior of the polypeptide**, to avoid contact with the polar water molecules.

BIG BRAIN TIP!

We illustrate a bond with a dashed line when it is NOT a covalent bond — and a solid line when it is a covalent bond.

A **DENATURED** protein temporarily loses its function because its 3D structure has been altered by unsuitable temperature or pH (too high or too low).





Due to the loss of non-covalent bonds such as hydrogen bonding, ionic bonding, and hydrophobic interactions.

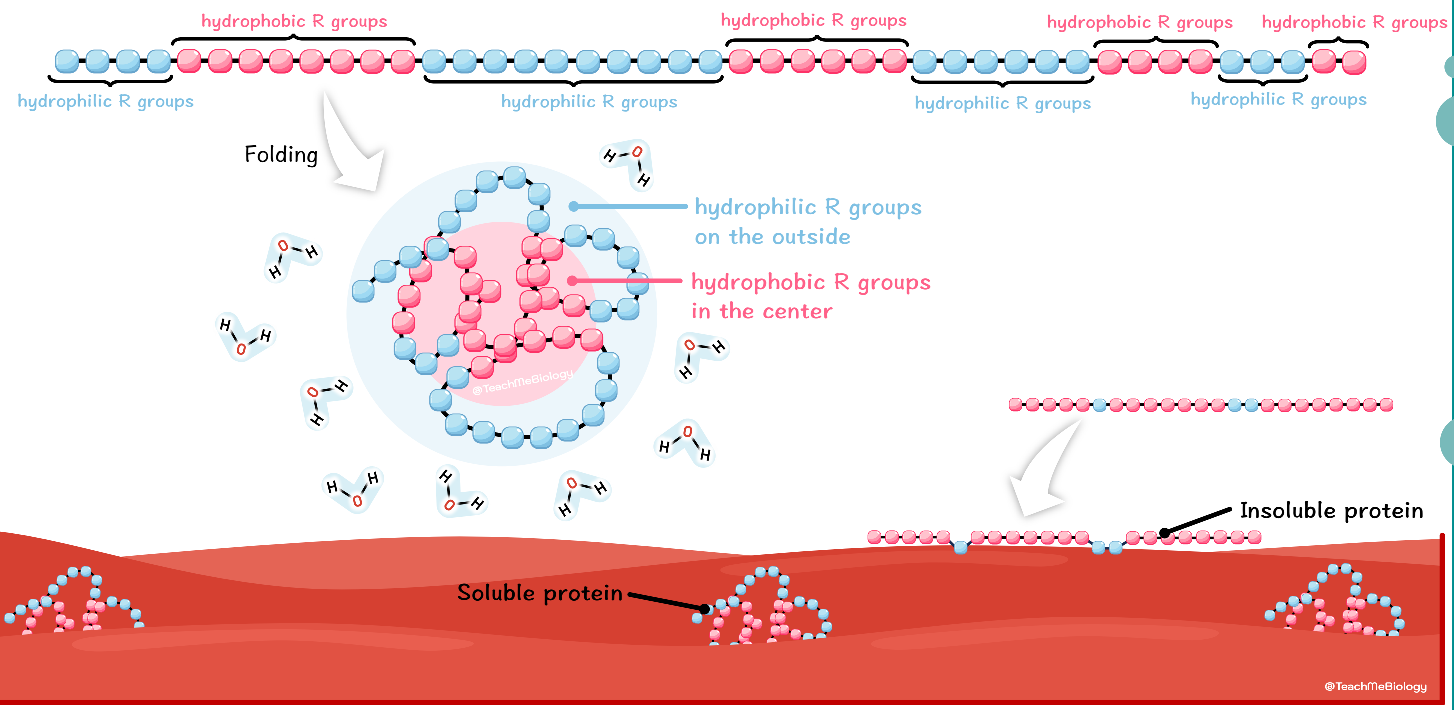
Quaternary Structure (4°)

The structure formed when two or more polypeptide chains bind together. They can broadly be categorized into two categories: **globular proteins** and **fibrous proteins**. We look at two protein examples to illustrate both groups: **Hemoglobin** and **Collagen**.
Page 7 Page 8

Feature	Globular Proteins	Fibrous Proteins
Shape	Roughly spherical	Long strand (linear)
Solubility	(Mostly) Soluble* in water	(Mosty) Insoluble* in water
Purpose	Functional (metabolic reactions)	Structural
Examples	Enzymes, Antibodies, Hormones, Hemoglobin	Collagen, Keratin, Actin/myosin, Fibrin

*Why **are some proteins soluble in water while others are not?**

A protein folds into the shape where each part is most "comfortable." Hydrophobic amino acids hide together in the center, away from water, while hydrophilic ones stay on the outside, happily forming hydrogen bonds with water. This makes many proteins soluble (such as globular proteins). But if a protein has mostly hydrophobic amino acids, it can't make friends with water and stays insoluble (such as fibrous proteins), often clumping together or sitting on membranes instead.

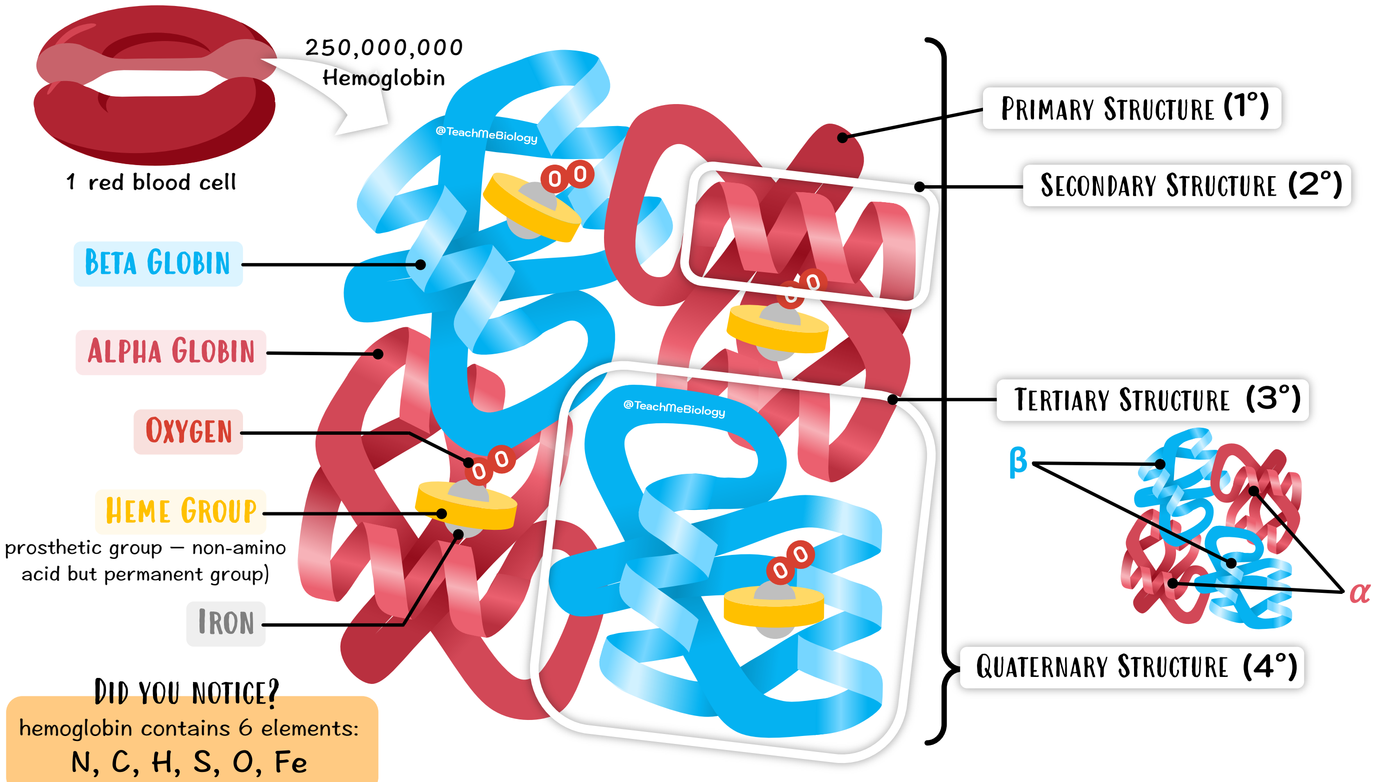


HEMOGLOBIN

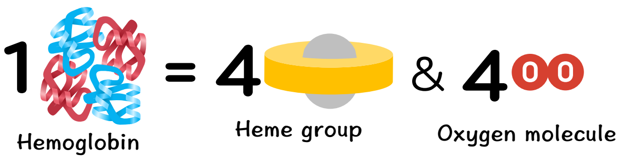
The red pigment found in red blood cells

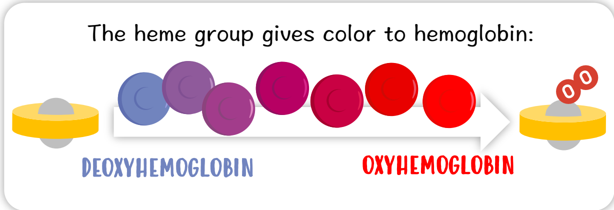
Hemoglobin is a globular protein made up of 4 polypeptides — 2 alpha and 2 beta.

Each polypeptide contains one **HEME GROUP** which has one **IRON ATOM**.
One iron atom can reversibly combine with an **OXYGEN MOLECULE** (two oxygen atoms).



Did you notice?
hemoglobin contains 6 elements:
N, C, H, S, O, Fe





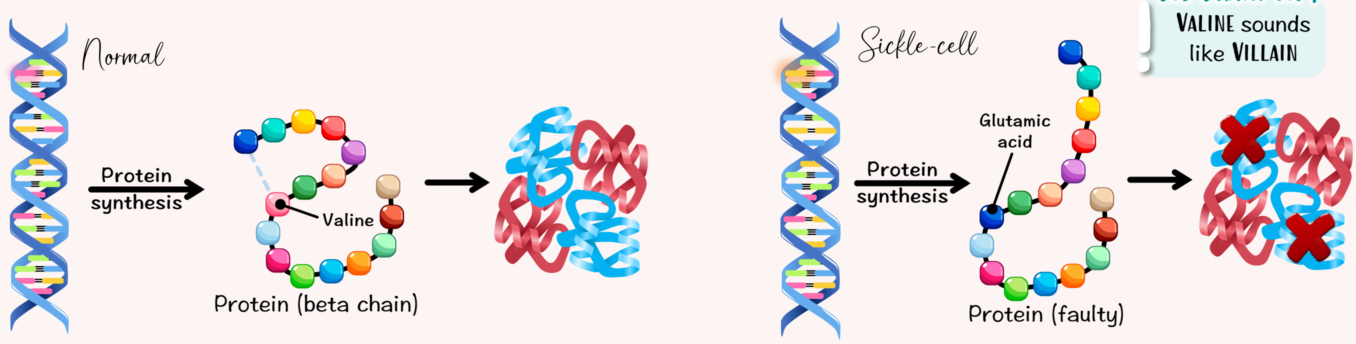
SICKLE CELL ANEMIA

A disease of faulty hemoglobin

SYMPTOMS: Shortness of breath (SOB), weakness, fatigue.

A **MUTATION** in the hemoglobin gene (determining beta chain) causes Valine instead of Glutamic acid to be made — which have different structures and properties. This causes a change in the polypeptide shape and function.

Big Brain Tip! VALINE sounds like VILLAIN



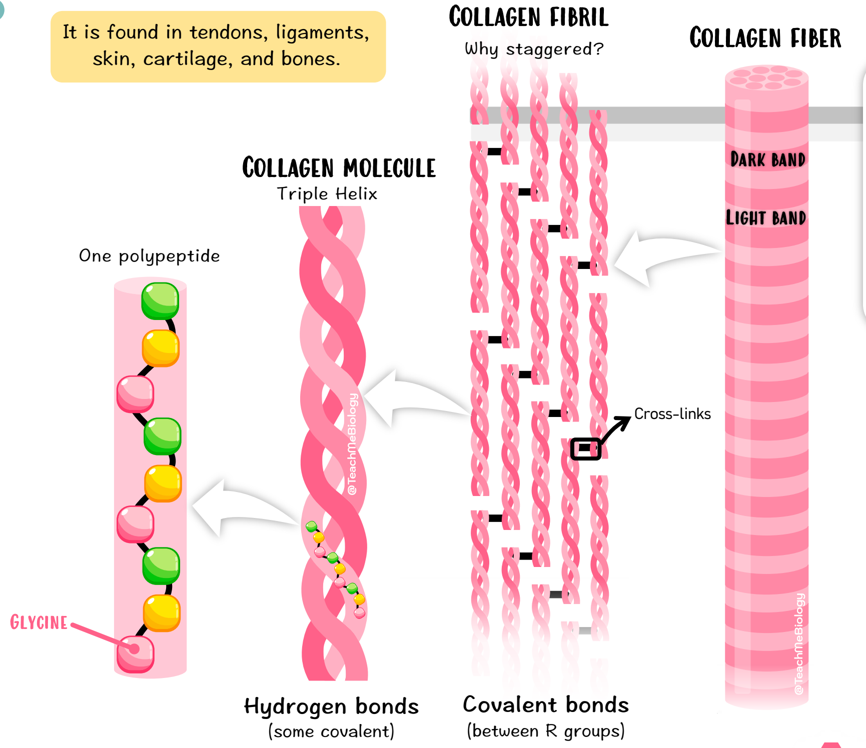
This alters the shape of red blood cells when oxygen levels are low, leading to a sickle-shaped red blood cells. These are not as flexible and therefore can block small vessels.

Collagen

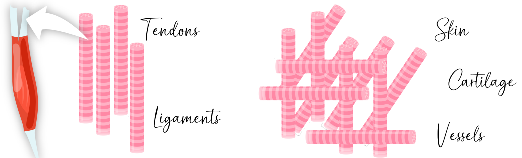
The most common protein (in animals)

Collagen is an **INSOLUBLE, FIBROUS PROTEIN** that plays a **STRUCTURAL ROLE** in the body. It has high tensile strength, allowing tissues to resist stretching forces, while remaining flexible.

It is found in tendons, ligaments, skin, cartilage, and bones.



Dirrectionality varried depending on the tissue:

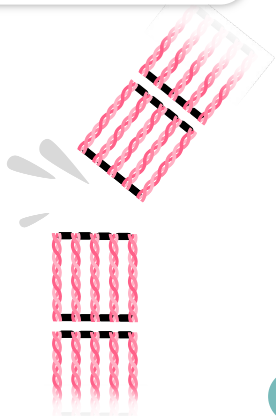


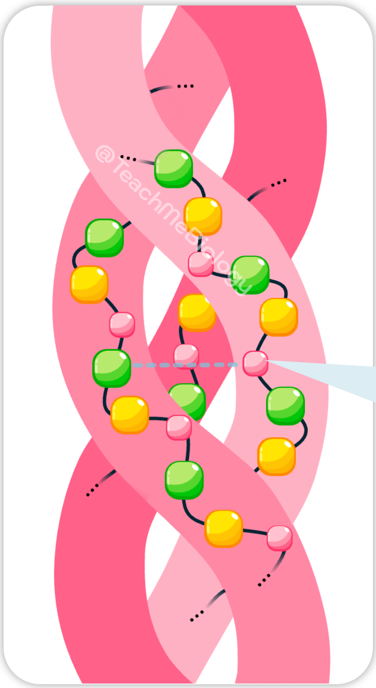
Force is exerted unidirectionally

Force is exerted in different directions

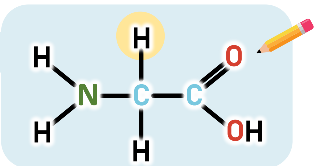
If the collagen fibrils were not arranged in a staggered manner: there would be many weak points, susceptible to breakage.

The staggering give it its **HIGH TENSILE STRENGTH.**

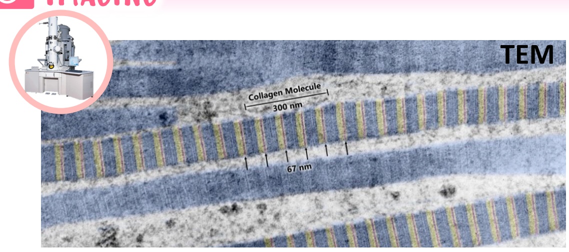


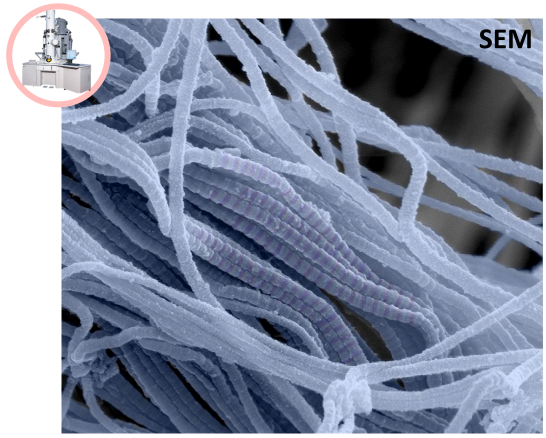


Every third amino acid in the polypeptide structure of collagen includes the amino acid glycine — the smallest amino acid. This allows the helices to coil very tightly with each other (as these tiny amino acids are oriented in the center and cause less crowding).



Imaging





Summary

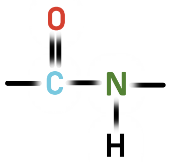
Feature	Collagen	Hemoglobin
Globular OR Fibrous	Fibrous	Globular
Solubility	Insoluble	Soluble
Helical	Entirely	Partly
Helix Type	Triple Helix	Alpha Helix
Prosthetic Group	None	Yes (Heme)
Purpose	Structural	Functional

Teach Me

Testing for the presence of proteins

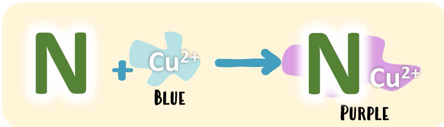
I. The Biuret's test

A test for the presence of peptide bond and thus for the presence of protein.



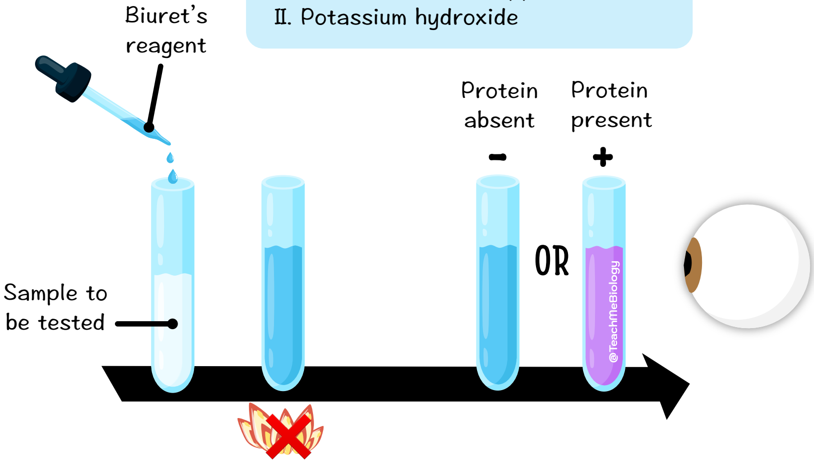
Peptide bond contains Nitrogen

Nitrogen forms a purple complex with copper (II) ions



Biuret's reagent

I. Dilute solution of copper (II) sulfate
II. Potassium hydroxide



When the **Biuret's reagent** is added to a sample to be tested, if proteins are present, the solution changes color from blue to **VIOLET** as the copper(II) ions form a complex with the peptide bonds in the protein.

If no protein is present, the solution remains **BLUE**.

Which foods contain proteins?

[not part of the syllabus, only for your own curiosity]