Amino Acids, Proteins, and Enzymes

Functions of Proteins

Proteins perform many different functions in the body.

Tal fication of Some Proteins and their Functions

Class of Protein	Function in the Body	Examples
Structural	Provide structural components	*Collagen* is in tendons and cartilage. *Keratin* is in hair, skin, wool, and nails.
Contractile	Movement of muscles	*Myosin* and *actin* contract muscle fibers.
Transport	Carry essential substances throughout the body	*Hemoglobin* transports oxygen. *Lipoproteins* transport lipids.
Storage	Store nutrients	*Casein* stores protein in milk. *Ferritin* stores iron in the spleen and liver.
Hormone	Regulate body metabolism and nervous system	*Insulin* regulates blood glucose level. *Growth hormone* regulates body growth.
Enzyme	Catalyze biochemical reactions in the cells	*Sucrase* catalyzes the hydrolysis of sucrose. *Trypsin* catalyzes the hydrolysis of proteins.
Protection	Recognize and destroy foreign substances	*Immunoglobulins* stimulate immune responses.

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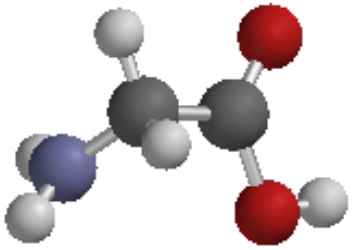
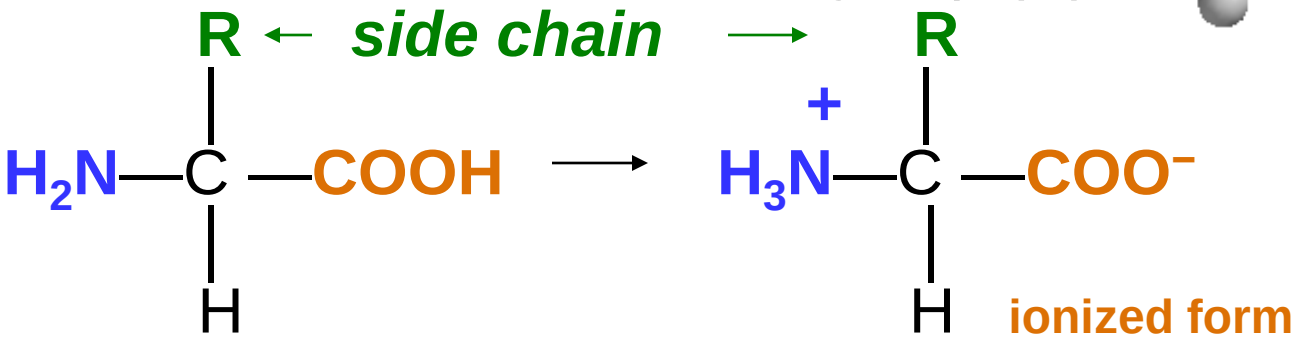
Ligand -receptor

Amino Acids

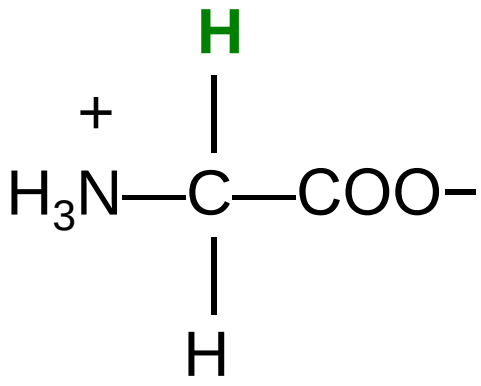
Amino acids

- are the building blocks of proteins.
- contain a carboxylic acid group and an amino group on the alpha (α) carbon.
- are ionized in solution.
- each contain a different side group (R).

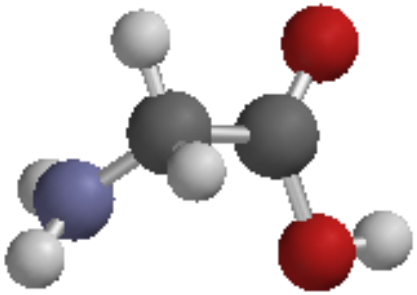


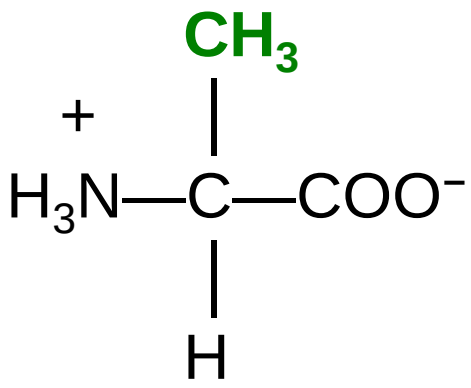


Examples of Amino Acids

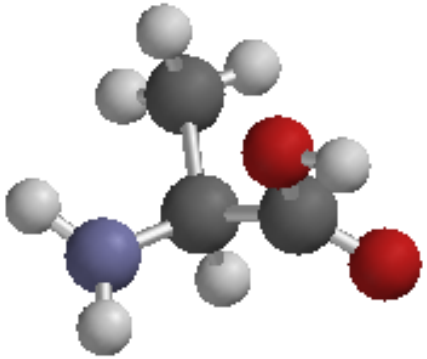


glycine





alanine

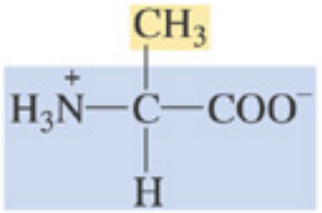


Types of Amino Acids

Amino acids are classified as

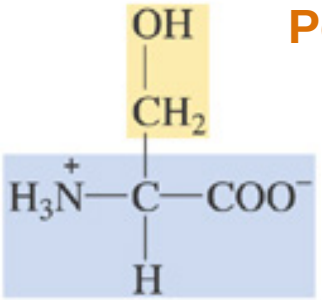
- **nonpolar** (hydrophobic) with hydrocarbon side chains.
- **polar** (hydrophilic) with polar or ionic side chains.
- **acidic** (hydrophilic) with acidic side chains.
- **basic** (hydrophilic) with $-NH_2$ side chains.

Nonpolar



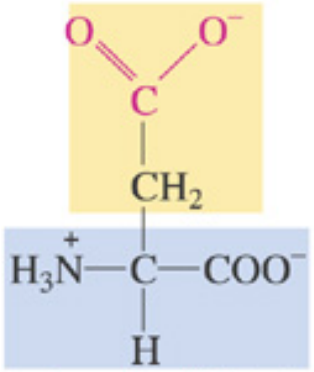
Alanine (Ala)

Polar



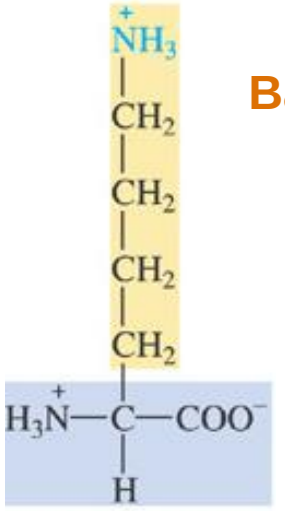
Serine (Ser)

Acidic



Aspartic acid (Asp)

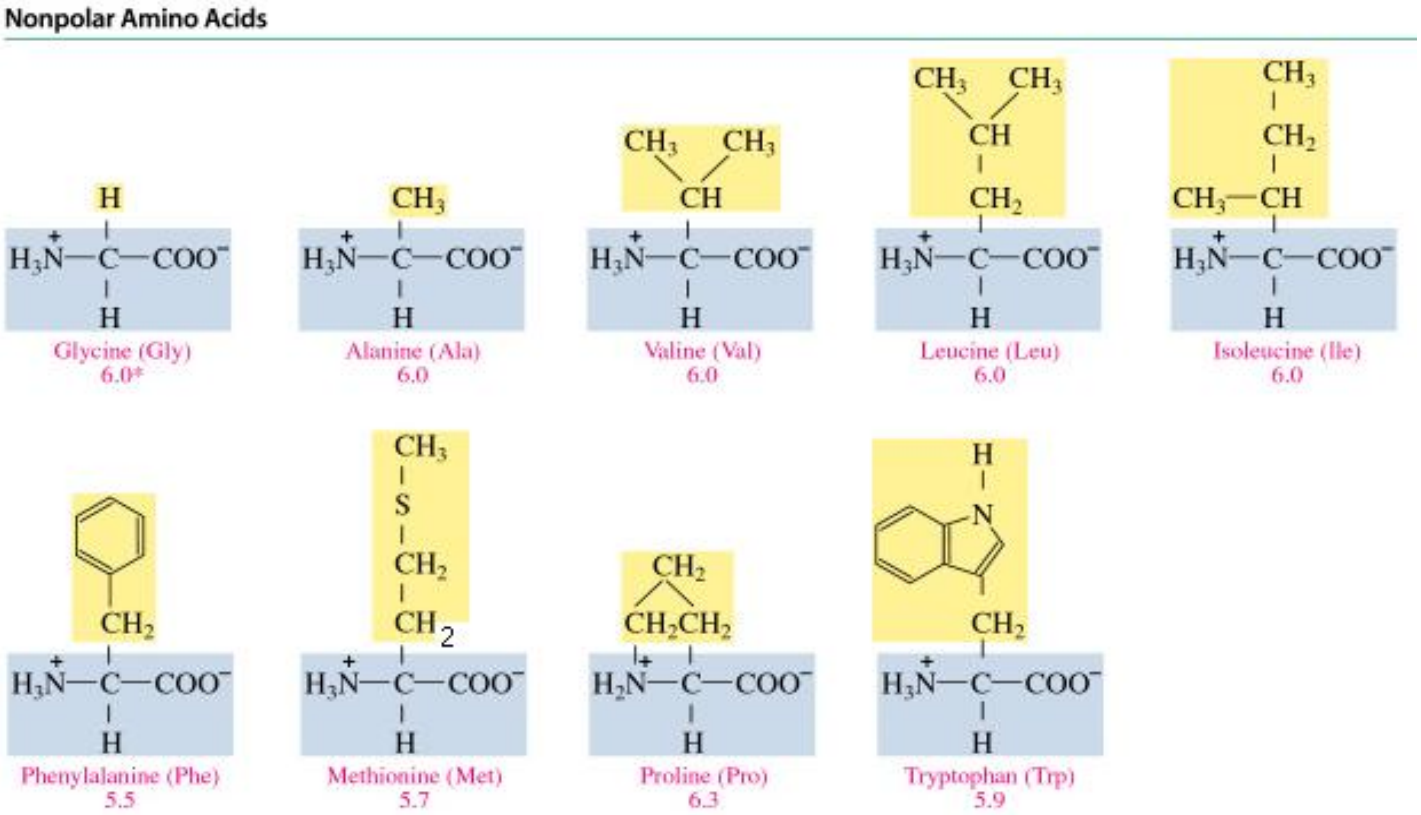
Basic



Lysine (Lys)

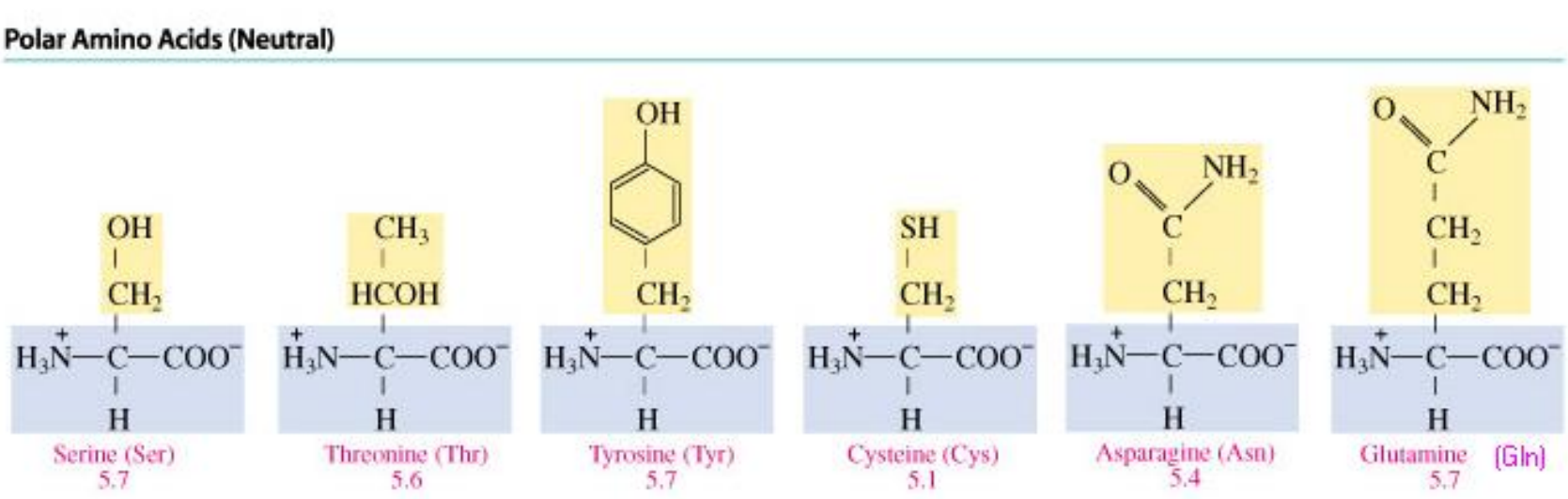
Nonpolar Amino Acids

An amino acid is nonpolar when the R group is H, alkyl, or aromatic.



Polar Amino Acids

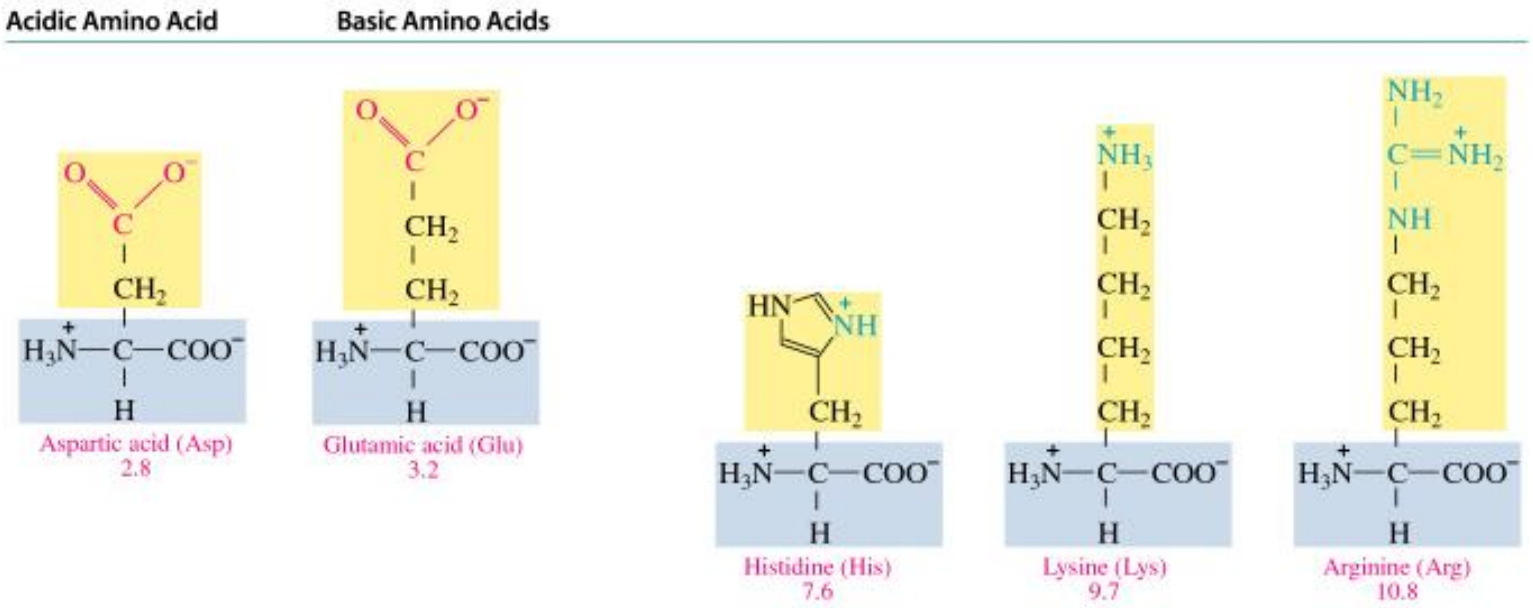
An amino acid is polar when the R group is an alcohol, thiol, or amide.



Acidic and Basic Amino Acids

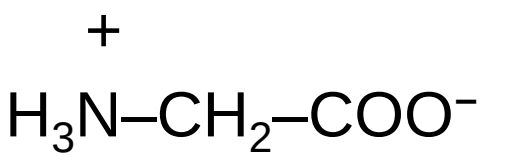
An amino acid is

- acidic when the R group is a carboxylic acid.
- basic when the R group is an amine.

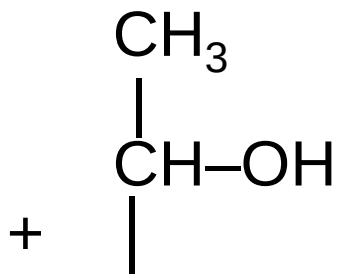


Learning Check

Identify each as (1) polar or (2) nonpolar.

A. 

(Glycine)

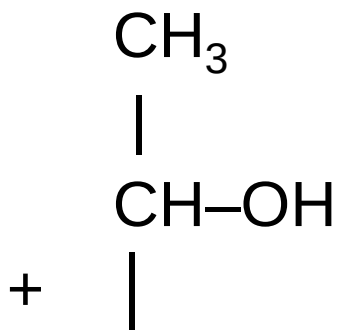
B. 

(Threonine)

Solution

Identify each as (1) polar or (2) nonpolar.

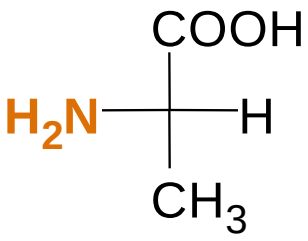
A. $H_3N^+–CH_2–COO^-$ (Glycine) **(2) nonpolar**

B.  (Threonine) **(1) polar**

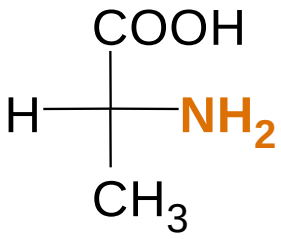
Fischer Projections of Amino Acids

Amino acids

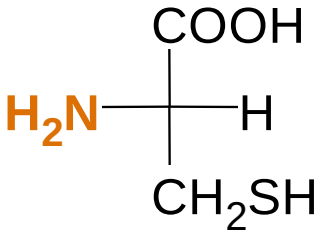
- are chiral except glycine.
- have Fischer projections that are stereoisomers.
- that are L are the only amino acids used in proteins.



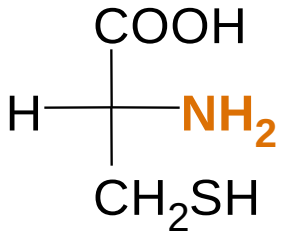
L-Alanine



D-Alanine



L-Cysteine

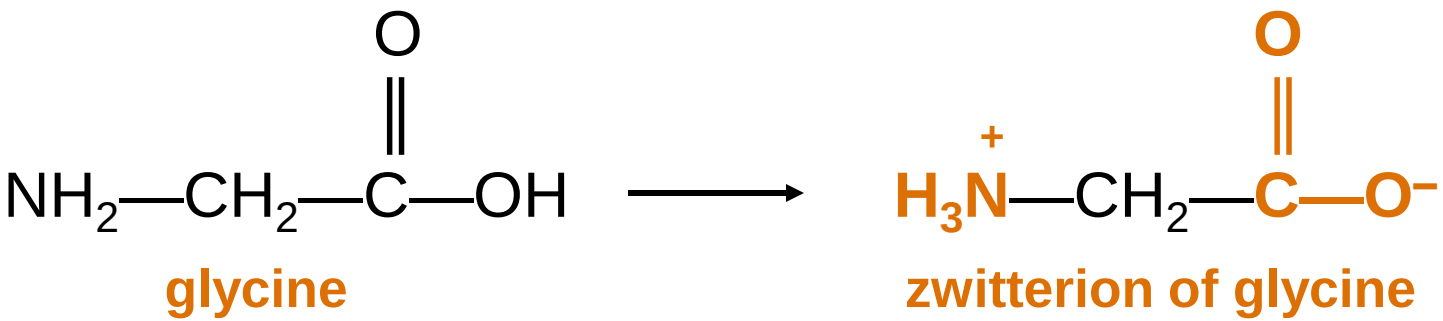


D-Cysteine

Zwitterions

A **zwitterion**

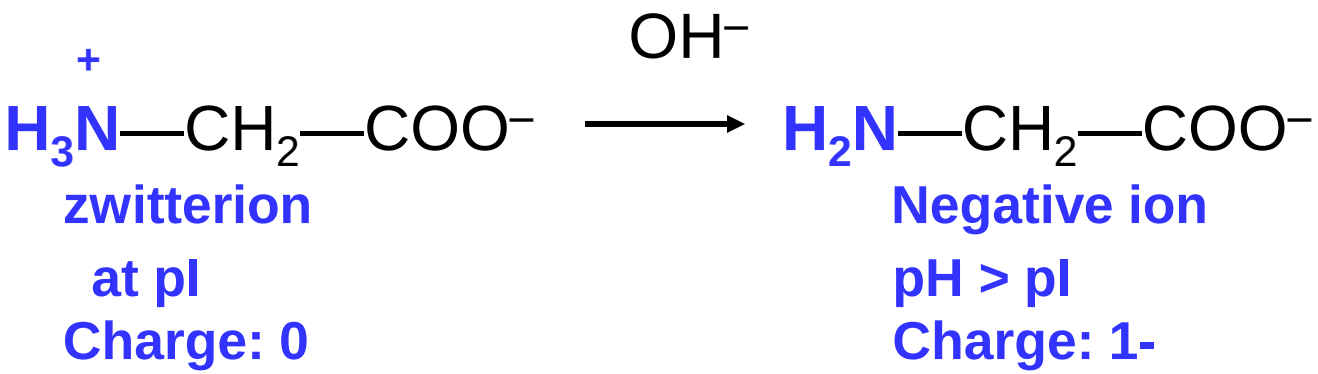
- has charged $-NH_3^+$ and COO^- groups.
- forms when both the $-NH_2$ and the –COOH groups in an amino acid ionize in water.
- has equal + and – charges at the isoelectric point (pI).



Amino Acids as Acids

In solutions more basic than the pI,

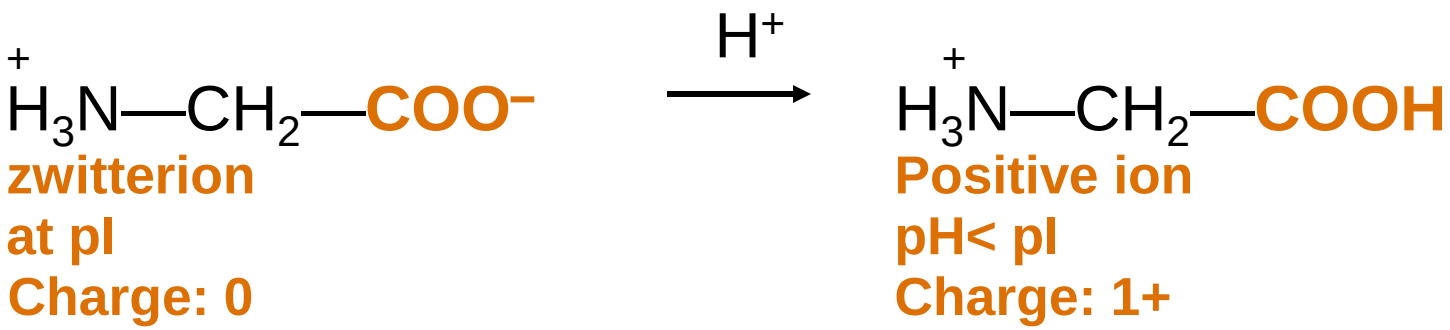
- the —NH_3^+ in the amino acid donates a proton.



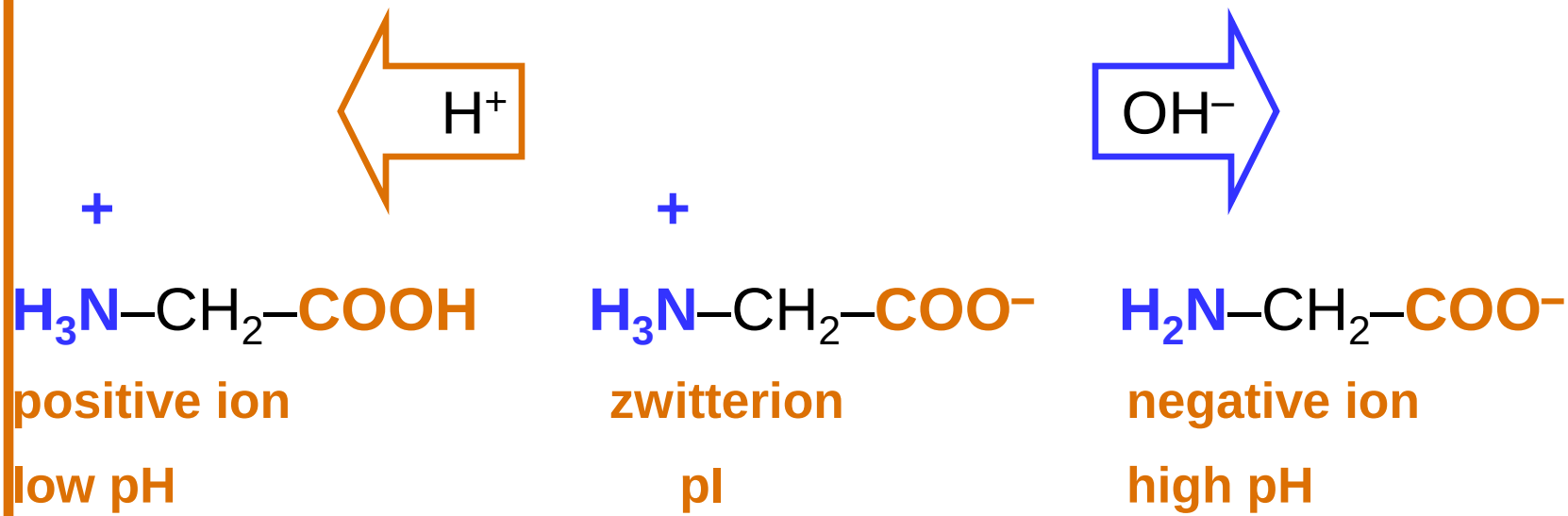
Amino Acids as Bases

In solution more acidic than the pI,

- the COO^- in the amino acid accepts a proton.



pH and ionization



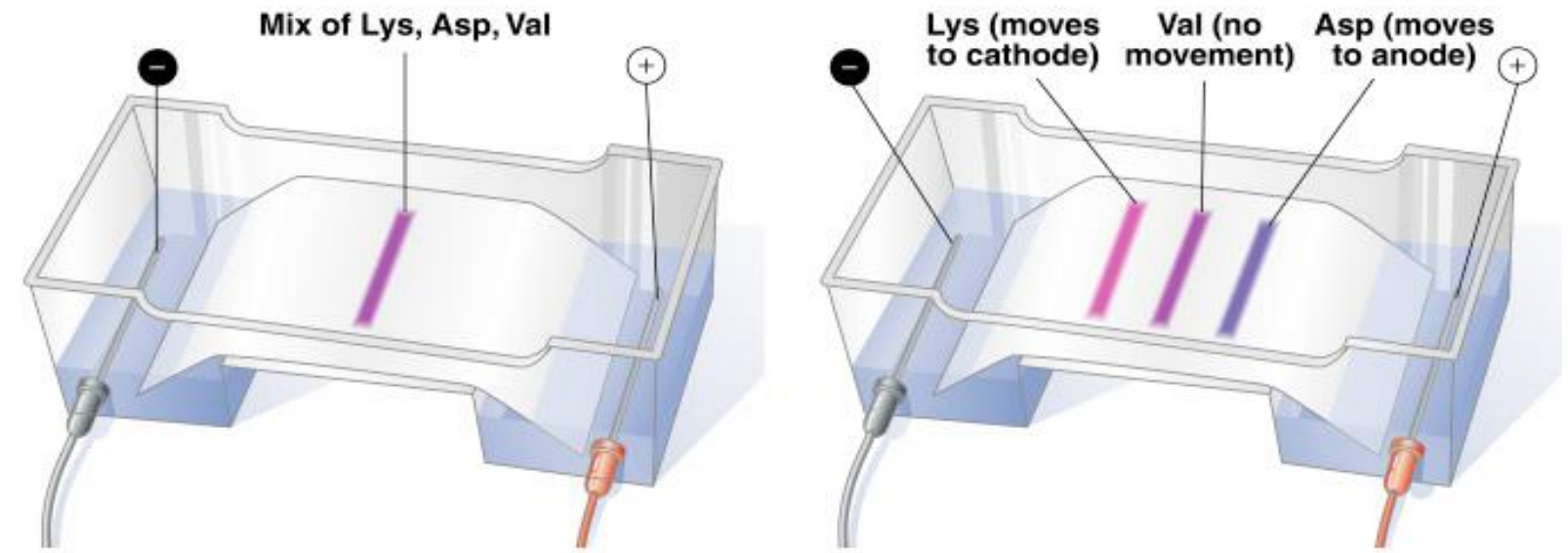
Separation of Amino Acids

When an electric current is used to separate a mixture of amino acids

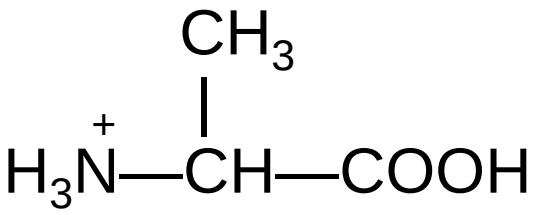
- the positively charged amino acids move towards the negative electrode.
- the negatively charged amino acids move toward the positive electrode.
- an amino acid at its pI does not migrate.
- the amino acids are identified as separate bands on the filter paper or thin layer plate.

Separation of Amino Acids

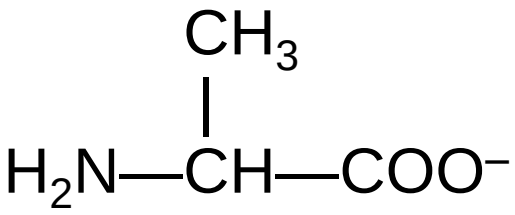
With an electric current, a mixture of lysine, aspartate, and valine are separated.



Learning Check



(1)



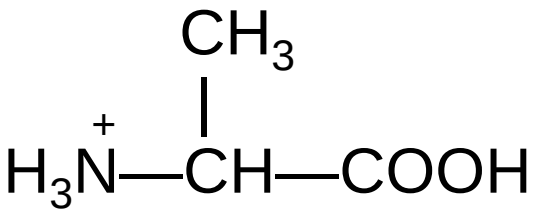
(2)

Which structure represents:

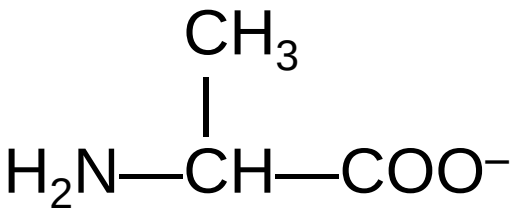
A. Alanine at a pH above its pI?

B. Alanine at a pH below its pI?

Solution



(1)



(2)

Which structure represents:

A. Alanine at a pH above its pI? **(2)**

B. Alanine at a pH below its pI? **(1)**

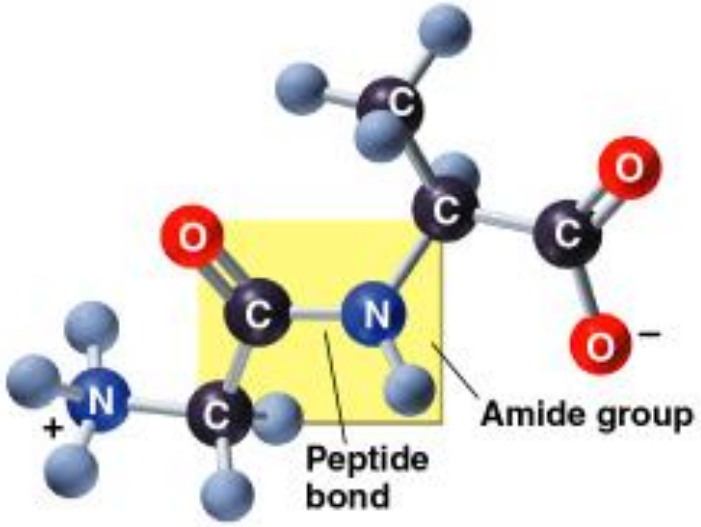
Essential Amino Acids

Essential amino acids

- must be obtained from the diet.
- are ten amino acids not synthesized by the body.
- are in meat and diary products.
- are missing (one or more) in grains and vegetables.

Essential Amino Acids	
Arginine (Arg)	Methionine (Met)
Histidine (His)	Phenylalanine (Phe)
Isoleucine (Ile)	Threonine (Thr)
Leucine (Leu)	Tryptophan (Trp)
Lysine (Lys)	Valine (Val)

16.4
Formation of Peptides

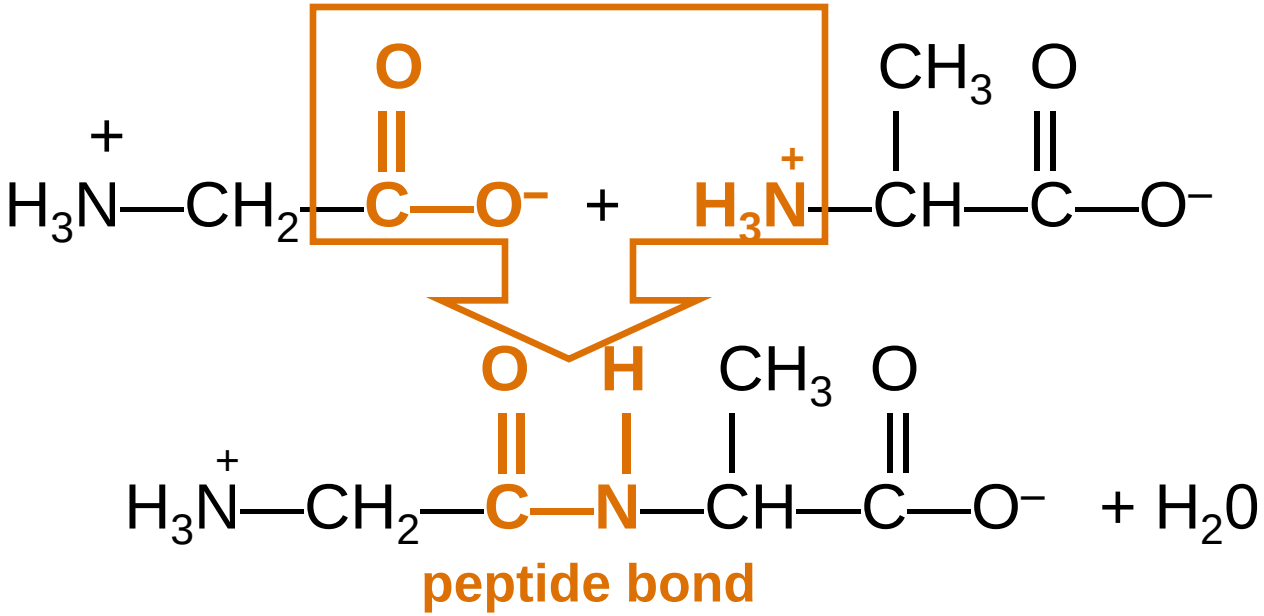


Glycylalanine (Gly-Ala)

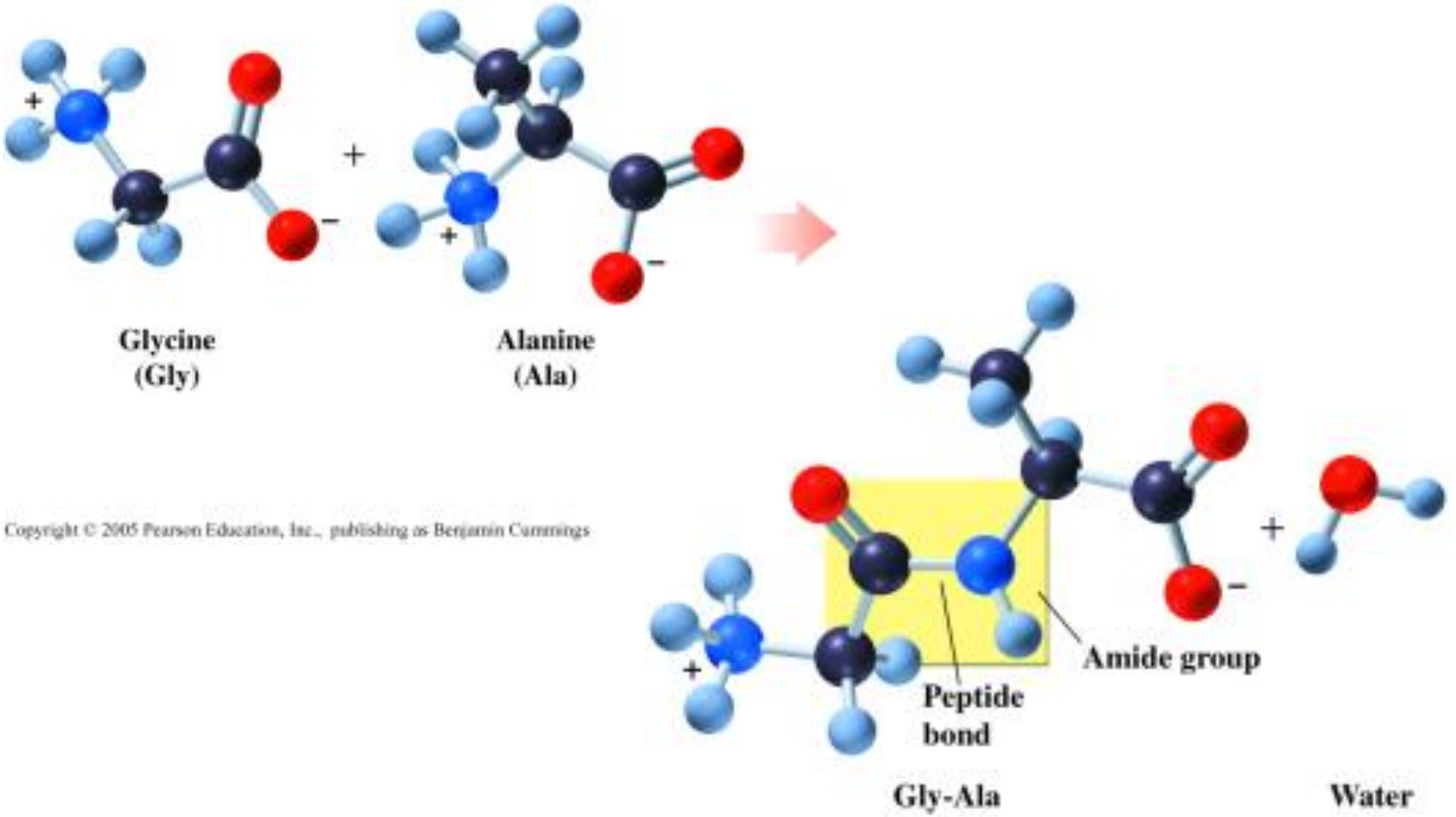
The Peptide Bond

A **peptide bond**

- is an amide bond.
- forms between the carboxyl group of one amino acid and the amino group of the next amino acid.

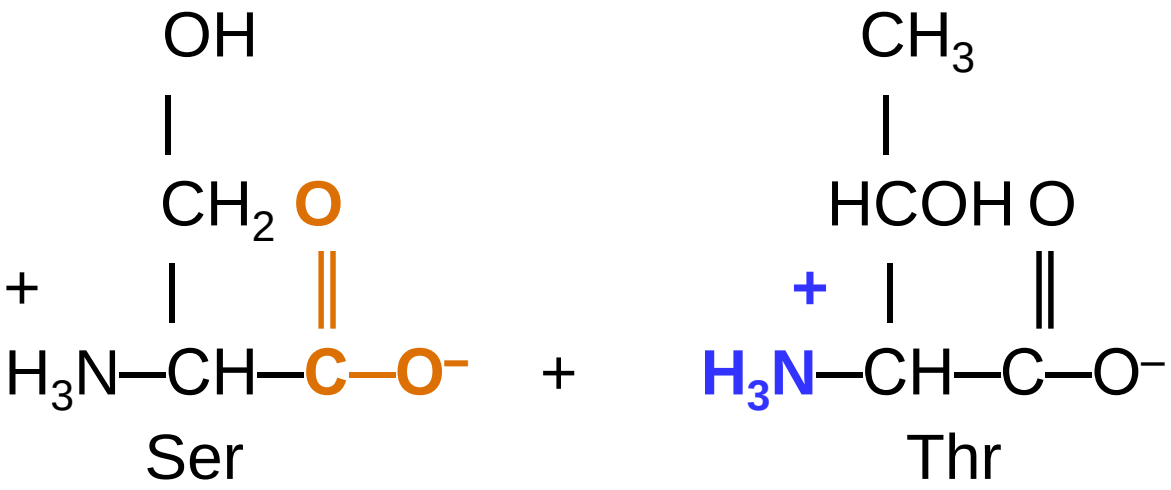


Formation of a Dipeptide



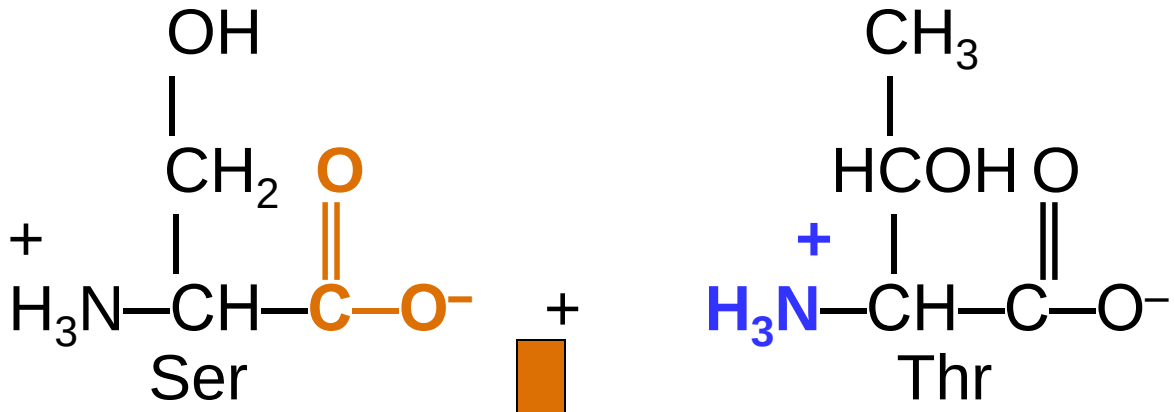
Learning Check

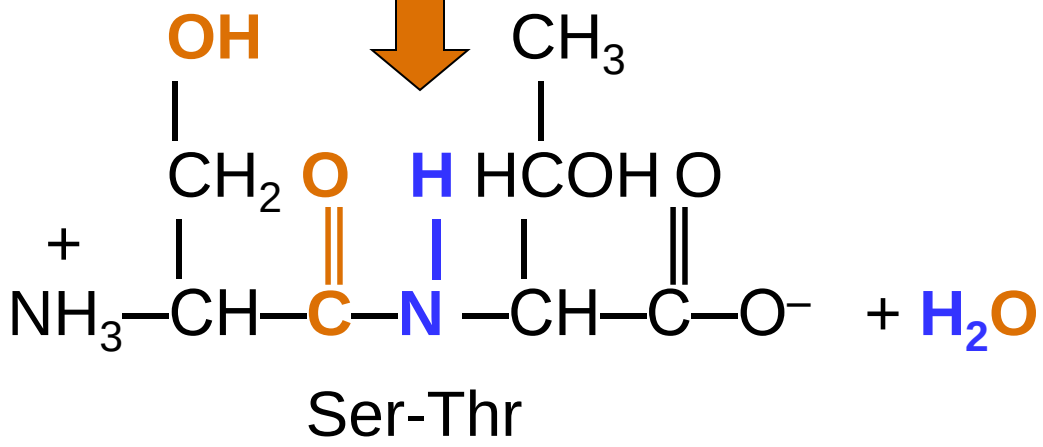
Write the dipeptide Ser-Thr.



Solution

Write the dipeptide Ser-Thr.





Ser-Thr

Learning Check

What are the possible tripeptides formed from one each of leucine, glycine, and alanine?

Solution

Tripeptides possible from one each of leucine, glycine, and alanine:

Leu-Gly-Ala

Leu-Ala-Gly

Ala-Leu-Gly

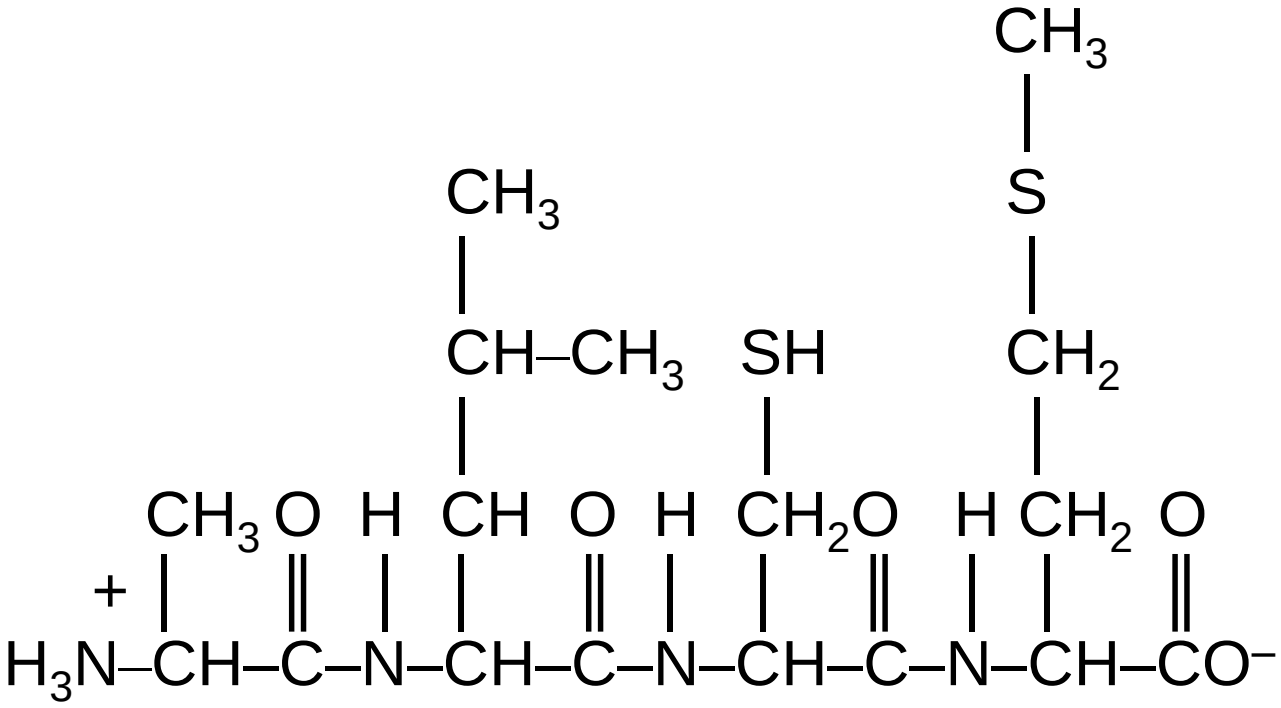
Ala-Gly-Leu

Gly-Ala-Leu

Gly-Leu-Ala

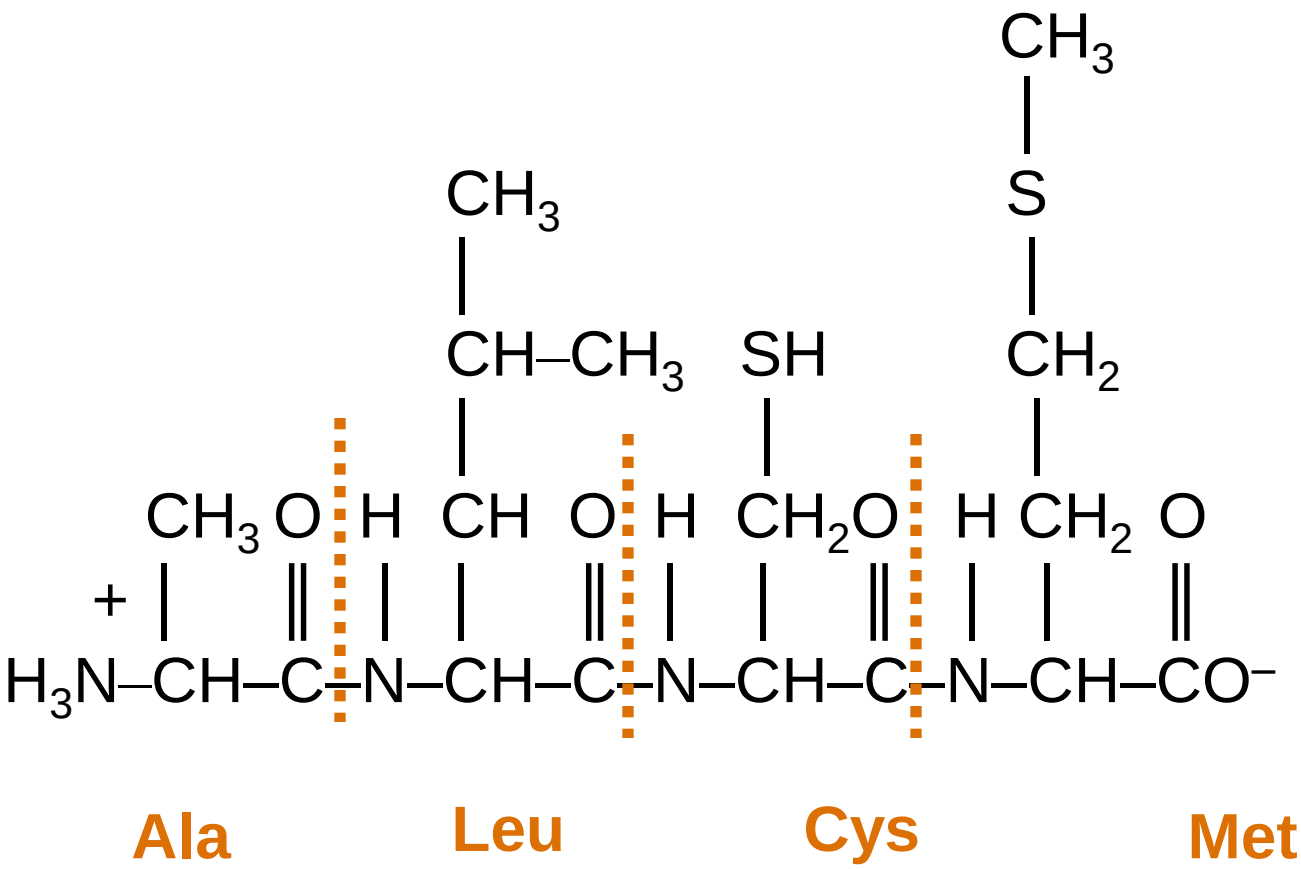
Learning Check

Write the three-letter abbreviation and name for the following tetrapeptide.

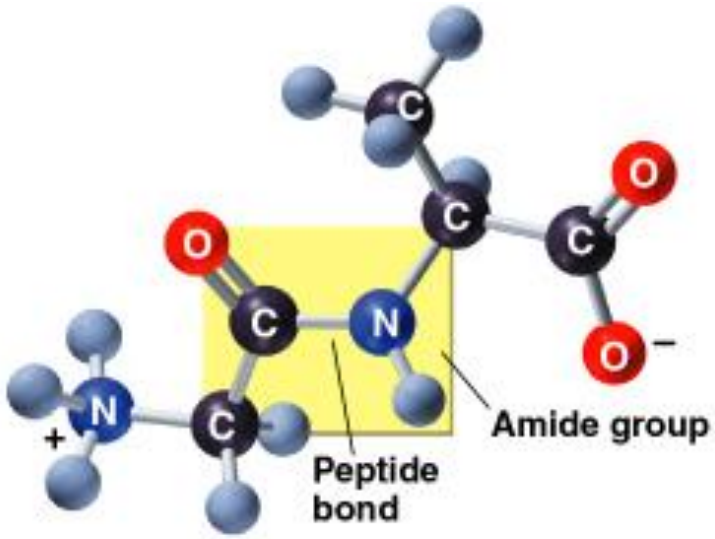


Solution

Ala-Leu-Cys-Met **Alanylleucylcysteinylmethionine**



16.5
Levels of Proteins Structure

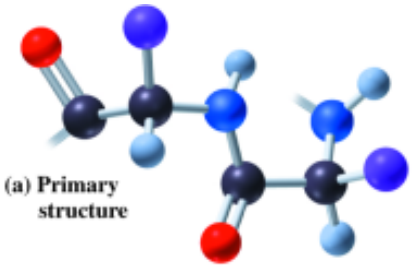


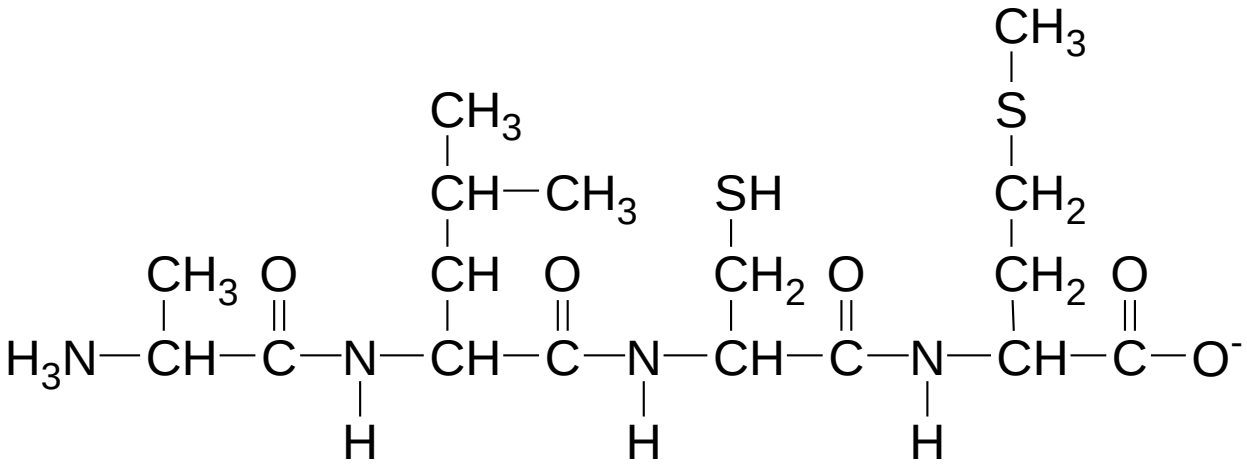
Glycylalanine (Gly-Ala)

Primary Structure of Proteins

The **primary structure** of a protein is

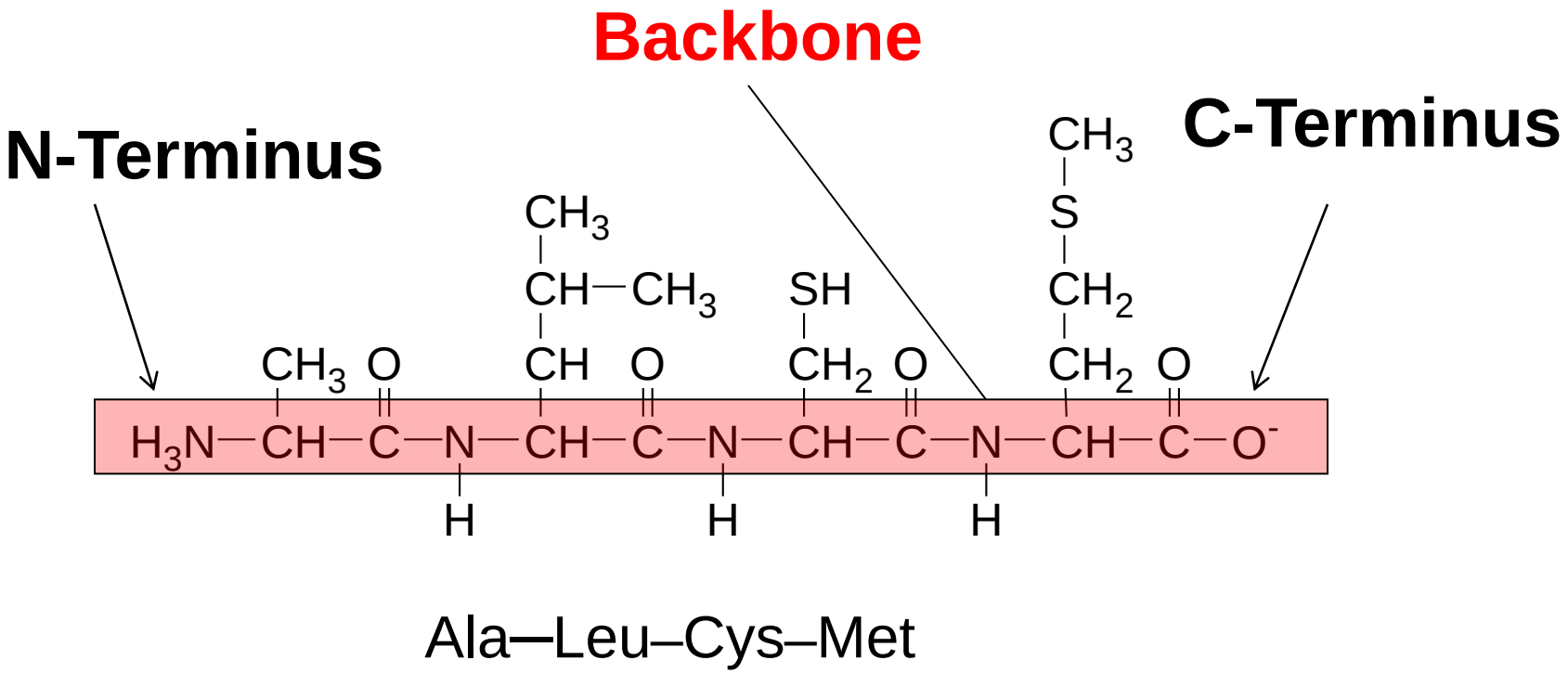
- the particular sequence of amino acids.
- the backbone of a peptide chain or protein.





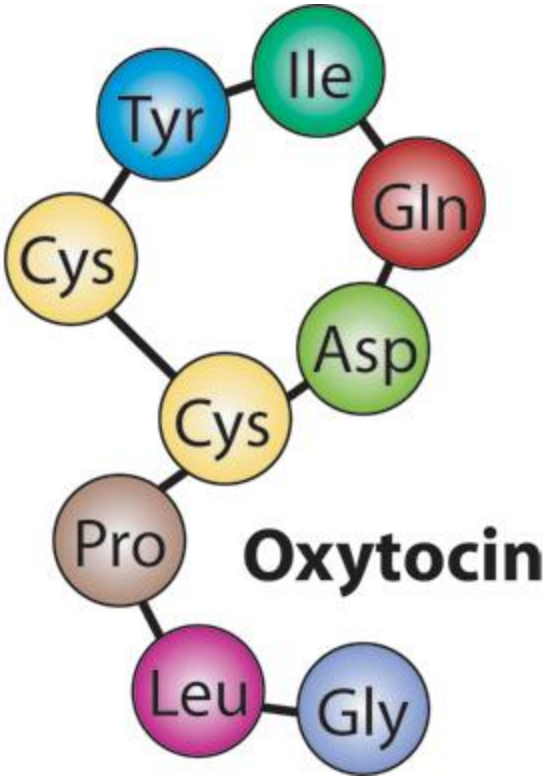
Ala–Leu–Cys–Met

Primary Structure of Proteins



Primary Structures

- The first peptide to be sequenced and synthesized biochemically is the nonapeptide oxitocyn.



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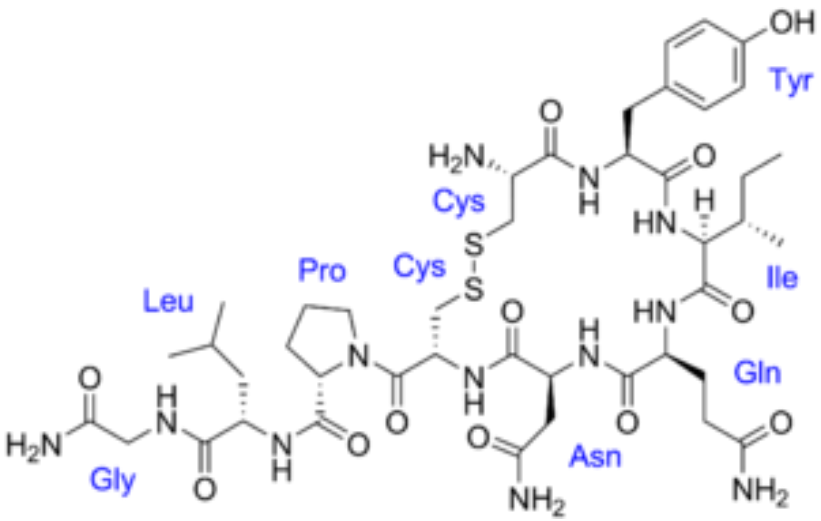
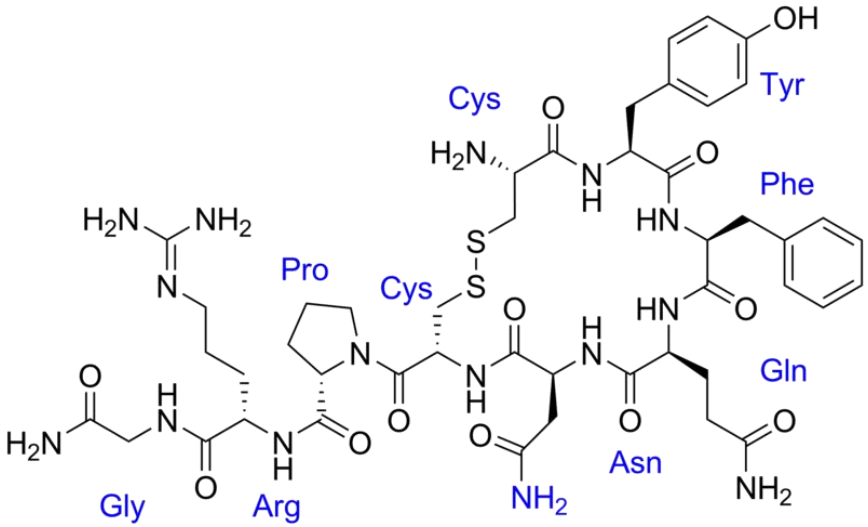
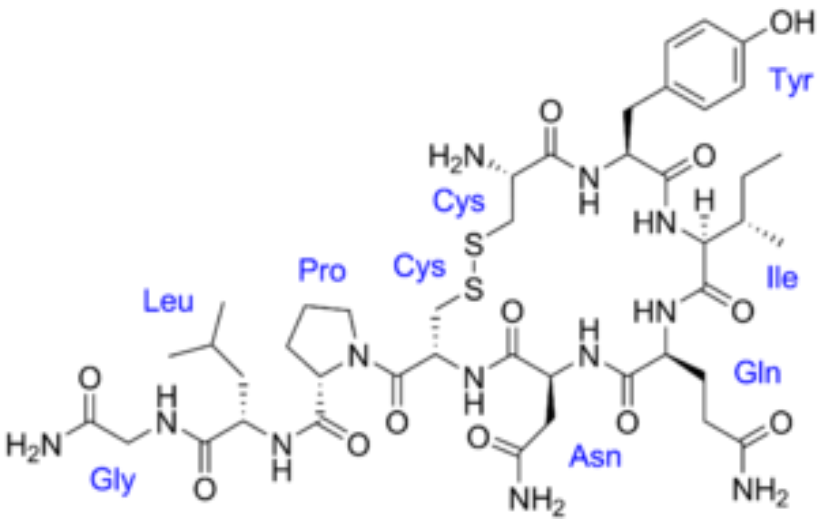
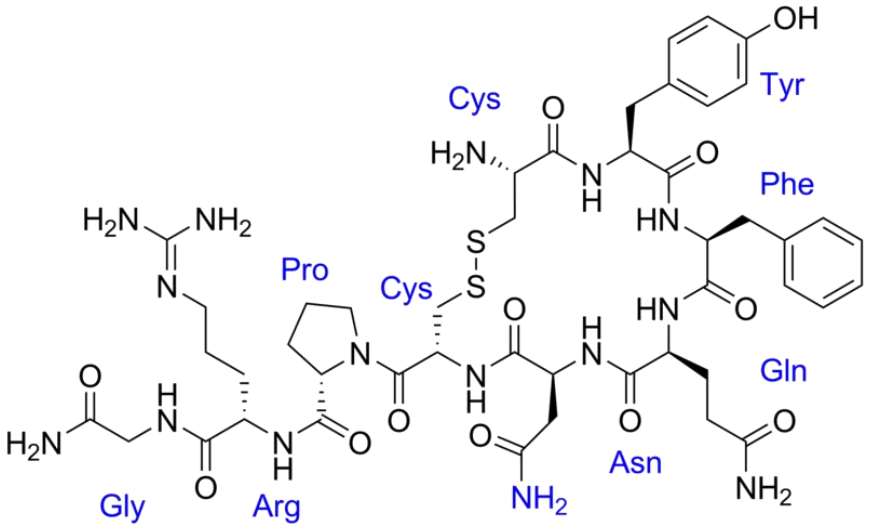




SCOPRI LE DIFFERENZE,



ossitocina



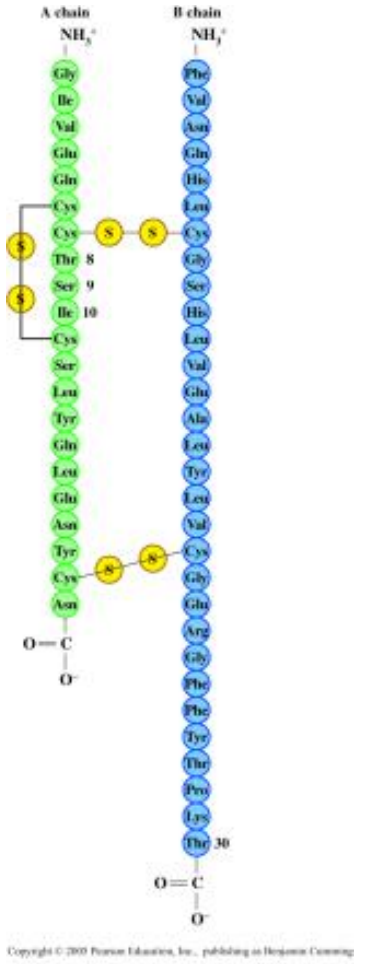
vasopressina

Nonostante le straordinarie somiglianze, questi due ormoni hanno ruoli molto diversi

Primary Structure of Insulin

Insulin

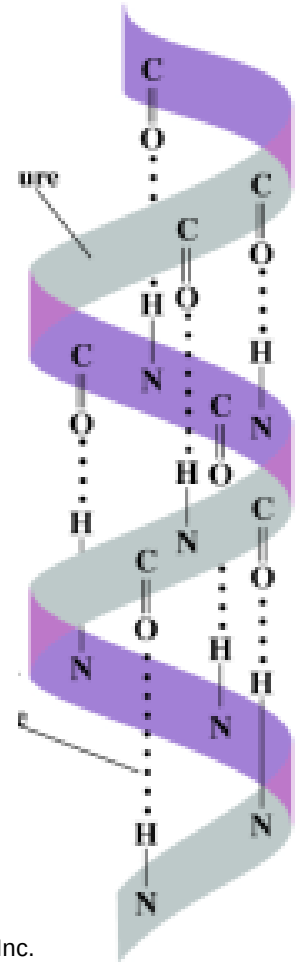
- was the first protein to have its primary structure determined.
- has a primary structure of two polypeptide chains linked by disulfide bonds.
- has a chain A with 21 amino acids and a chain B with 30 amino acids.



Secondary Structure – Alpha Helix

The **secondary structure of an alpha helix** is

- a three-dimensional spatial arrangement of amino acids in a polypeptide chain.
- held by H bonds between the H of –N-H group and the O of C=O of the fourth amino acid down the chain.
- a corkscrew shape that looks like a coiled “telephone cord”.



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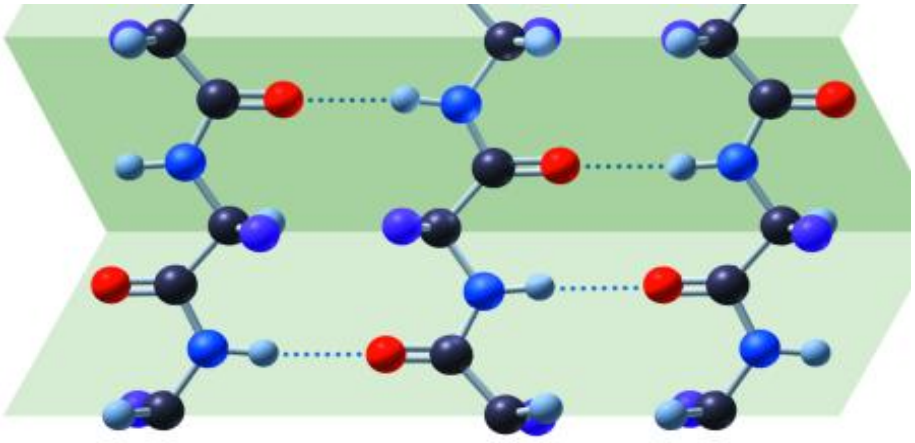
Secondary Structure – Beta Pleated Sheet

The **secondary structure of a beta pleated sheet**

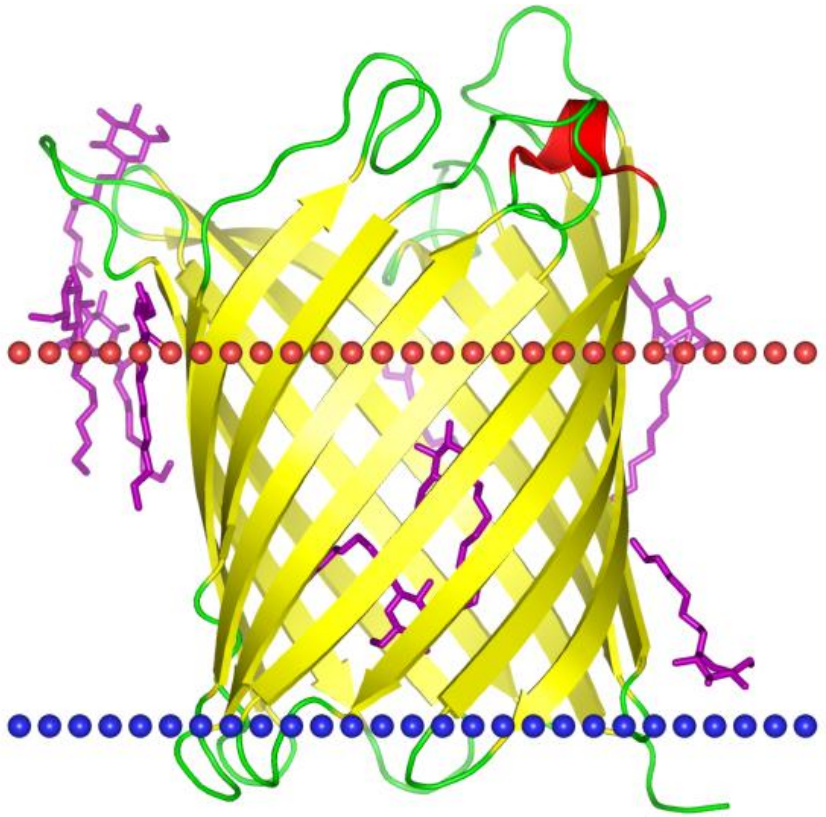
- consists of polypeptide chains arranged side by side.
- has hydrogen bonds between chains.
- has R groups above and below the sheet.
- is typical of fibrous proteins such as silk.



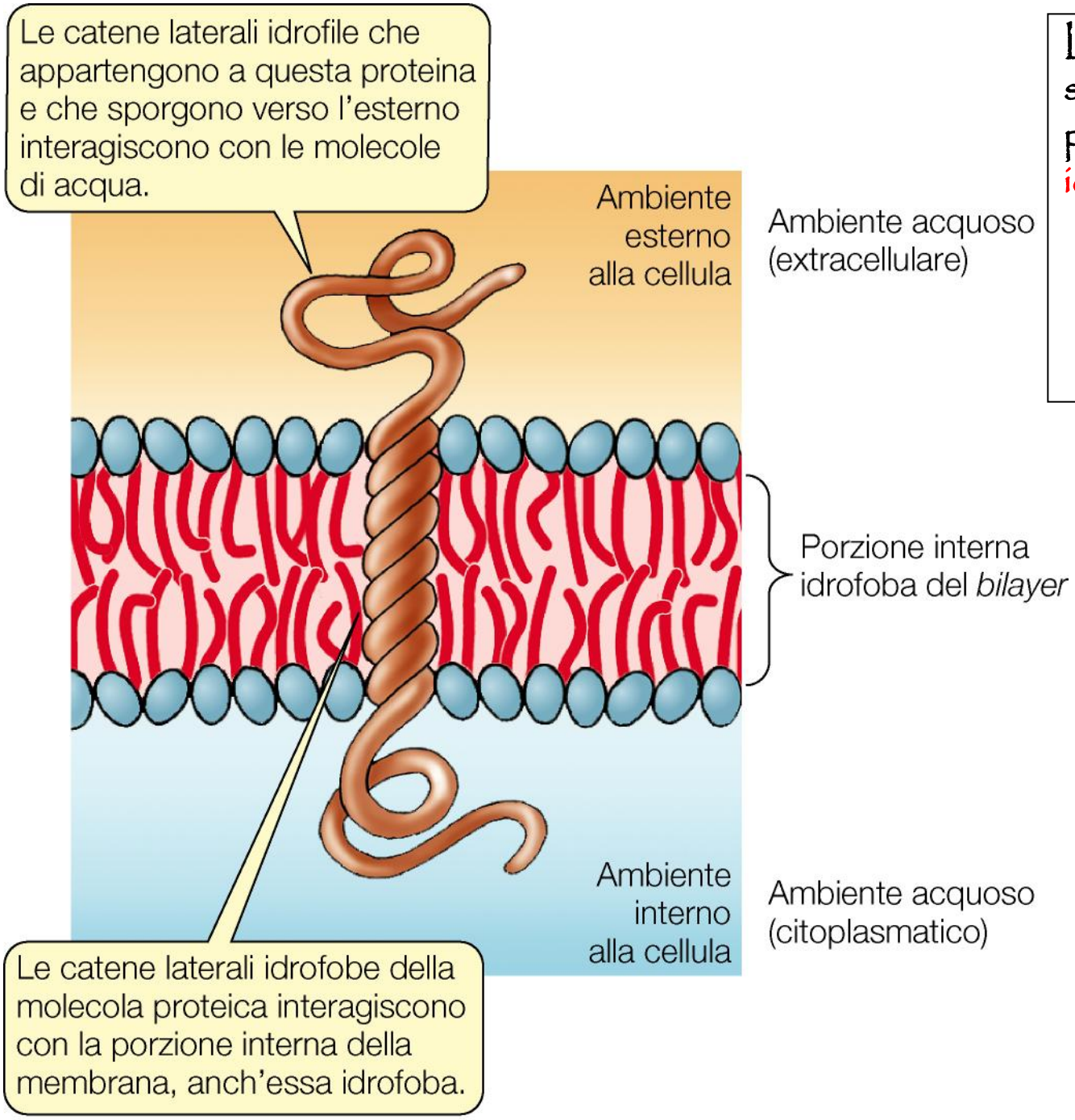
Beta Barrel

- Beta Barrel

- Es. una
- Porina di E. Coli



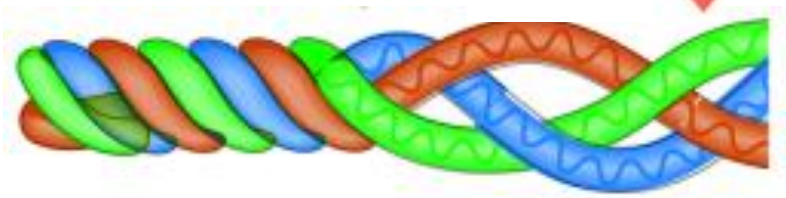
Le proteine di membrana sono formate da una parte idrofila ed una idrofoba



Secondary Structure – Triple Helix

The **secondary structure of a triple helix** is

- three polypeptide chains woven together.
- typical of collagen, connective tissue, skin, tendons, and cartilage.



Triple helix — 3 α-Helix peptide chains

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Learning Check

Indicate the type of protein structure.

1) primary
2) alpha helix
3) beta pleated sheet
4) triple helix

A. polypeptide chains held side by side by H bonds
B. sequence of amino acids in a polypeptide chain
C. corkscrew shape with H bonds between amino acids
D. three peptide chains woven like a rope

Solution

Indicate the type of protein structure.

1) primary 2) alpha helix

3) beta pleated sheet 4) triple helix

A. 3 polypeptide chains held side by side by H bonds

B. 1 sequence of amino acids in a polypeptide chain

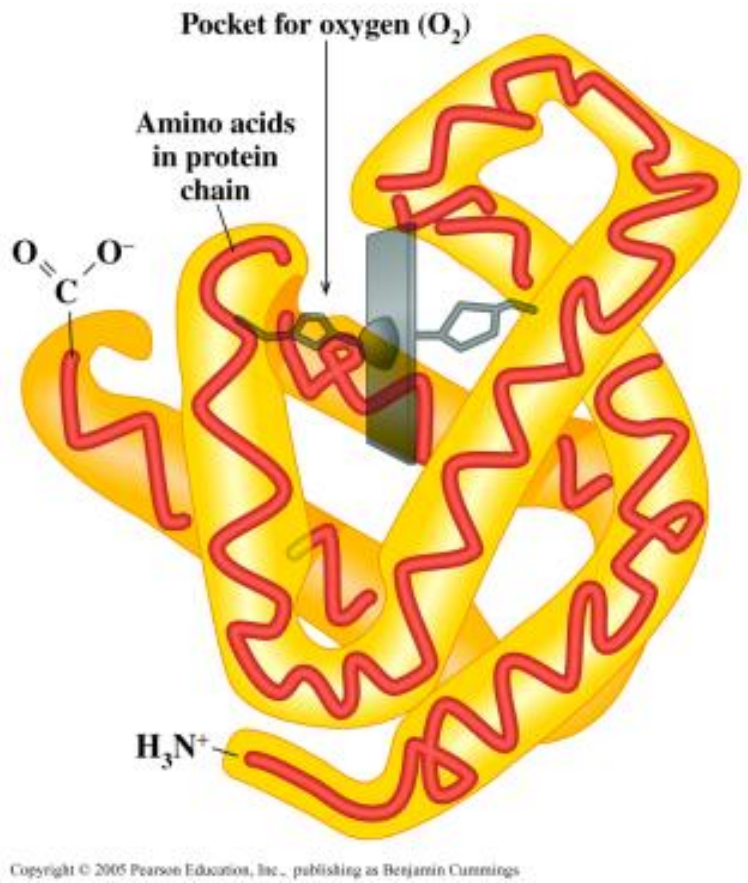
C. 2 corkscrew shape with H bonds between amino acids

D. 4 three peptide chains woven like a rope

Tertiary Structure

The **tertiary structure** of a protein

- is the overall three-dimensional shape.
- is determined by attractions and repulsions between the side chains of the amino acids in a peptide chain.



Crosslinks in Tertiary Structures

Crosslinks in tertiary structures involve attractions and repulsions between the side chains of the amino acids in the polypeptide chain.

Some Cross-Links in Tertiary Structures

	Nature of Bonding
Hydrophobic interactions	Attractions between nonpolar groups
Hydrophilic interactions	Attractions between polar groups and water
Salt bridges	Ionic interactions between acidic and basic amino acids
Hydrogen bonds	Occur between H and O or N
Disulfide bonds	Strong covalent links between sulfur atoms of two cysteine amino acids

Learning check

Select the type of tertiary interaction.

1) disulfide
2) ionic
3) H bonds
4) hydrophobic

A. leucine and valine
B. two cysteines
C. aspartic acid and lysine
D. serine and threonine

Solution

Select the type of tertiary interaction.

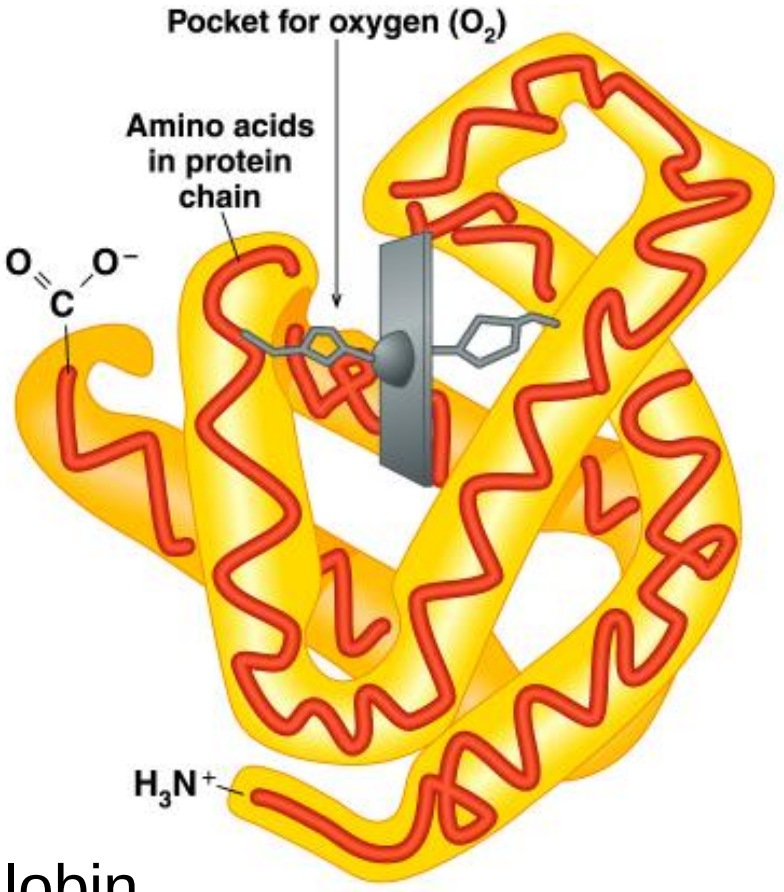
1) disulfide
2) ionic
3) H bonds
4) hydrophobic

A. 4 leucine and valine
B. 1 two cysteines
C. 2 aspartic acid and lysine
D. 3 serine and threonine

Globular Proteins

Globular proteins

- have compact, spherical shapes.
- carry out synthesis, transport, and metabolism in the cells.
- such as myoglobin store and transport oxygen in muscle.



Myoglobin

Fibrous Proteins

Fibrous proteins

- consist of long, fiber-like shapes.
- such as alpha keratins make up hair, wool, skin, and nails.
- such as feathers contain beta keratins with large amounts of beta-pleated sheet structures.

Alpha keratin

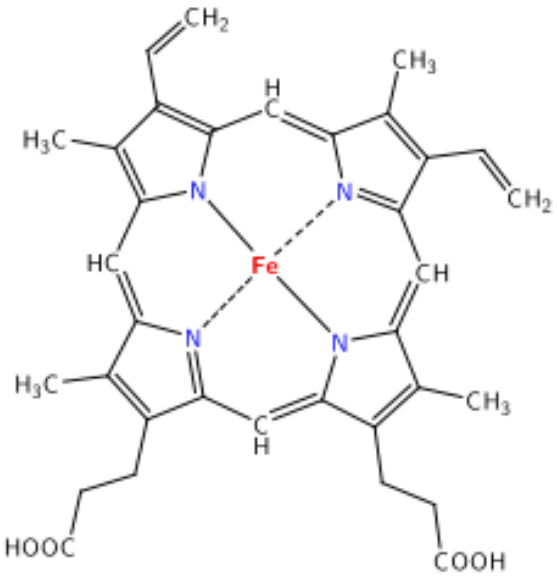
Quaternary Structure

The **quaternary structure**

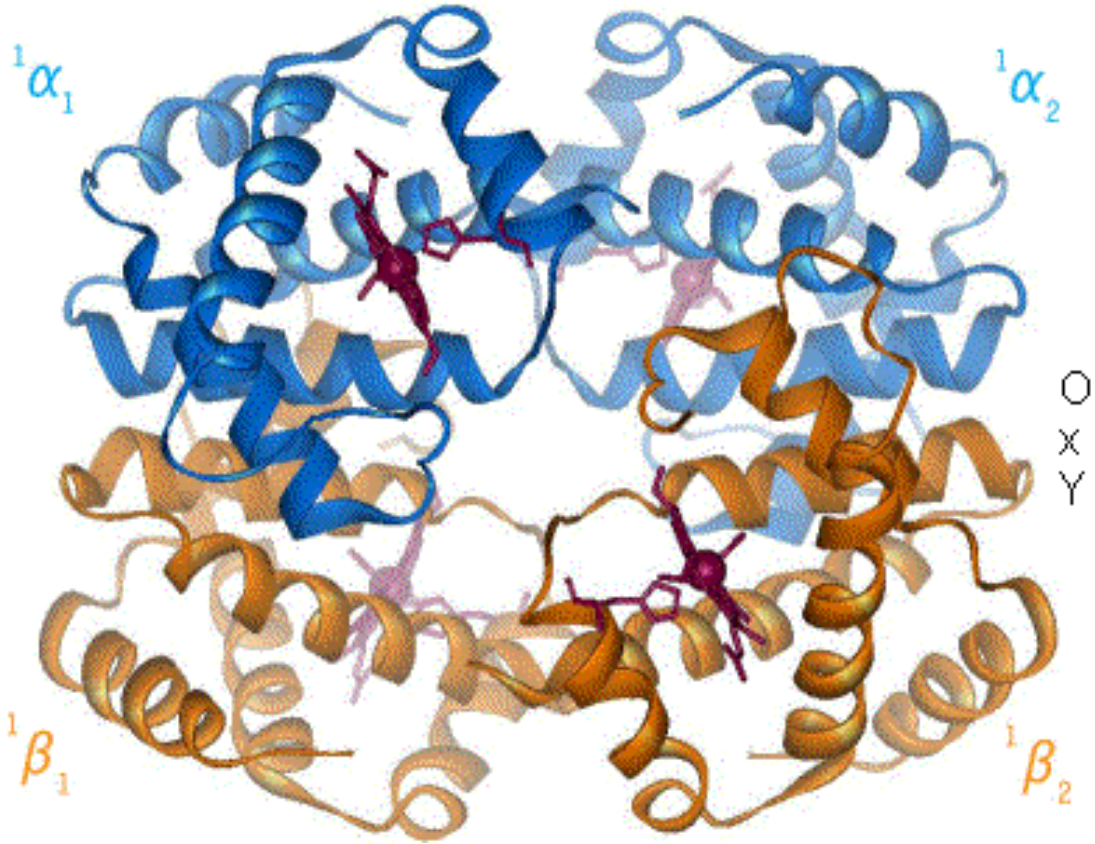
- is the combination of two or more protein units.
- of hemoglobin consists of four polypeptide chains as subunits.
- is stabilized by the same interactions found in tertiary structures.

EMOGLOBINA

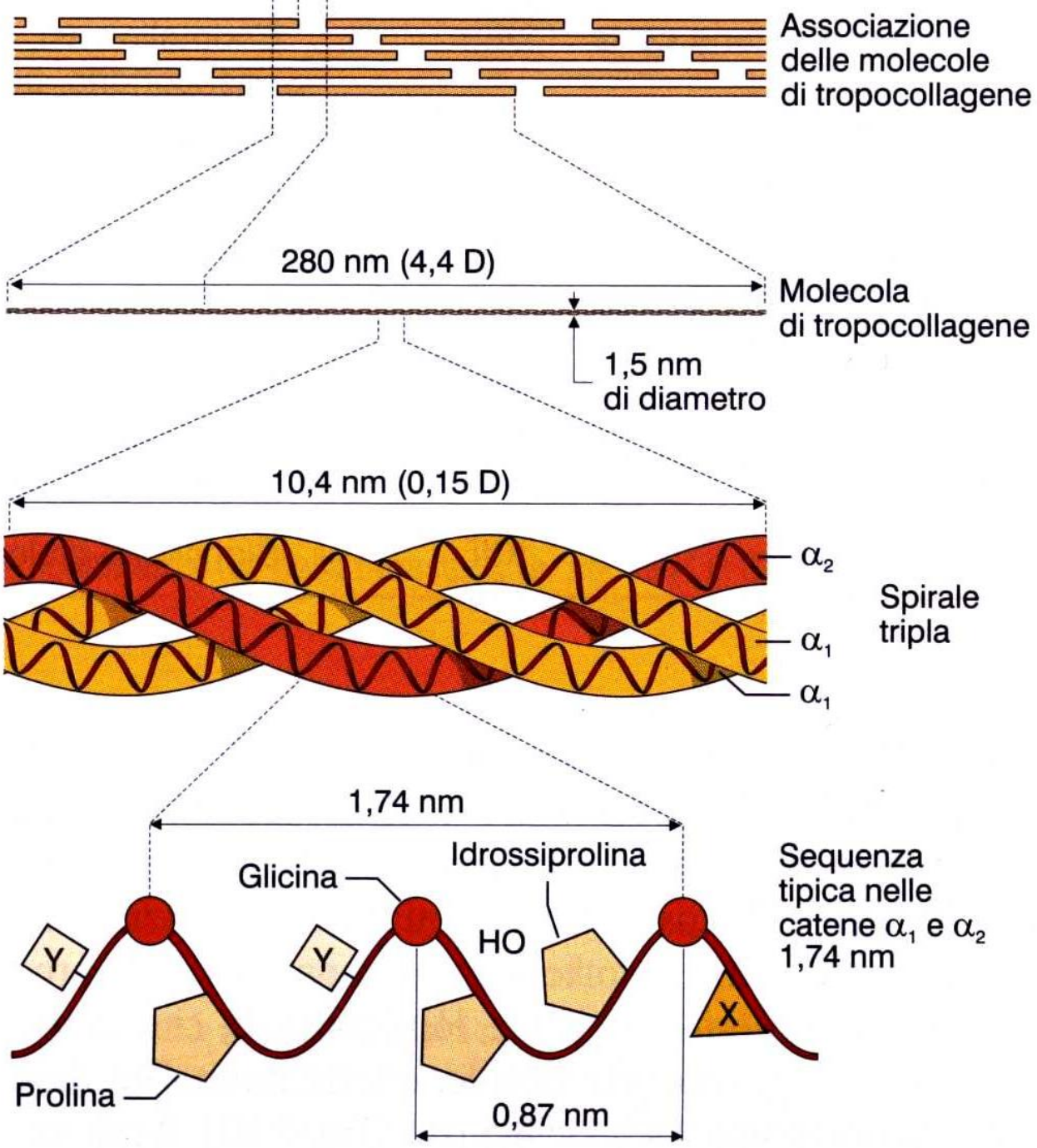
Grossa proteina tetramerica, composta da 4 catene polipeptidiche legate covalentemente ad un gruppo Eme.

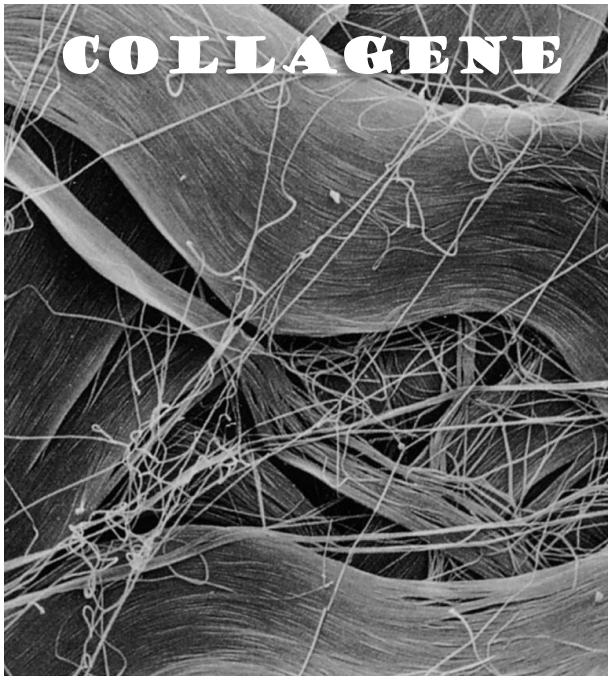


Ogni catena contiene un atomo di ferro nel suo gruppo eme.



Esistono due stati conformazionali: Emoglobina Ossigenata/Deossigenata

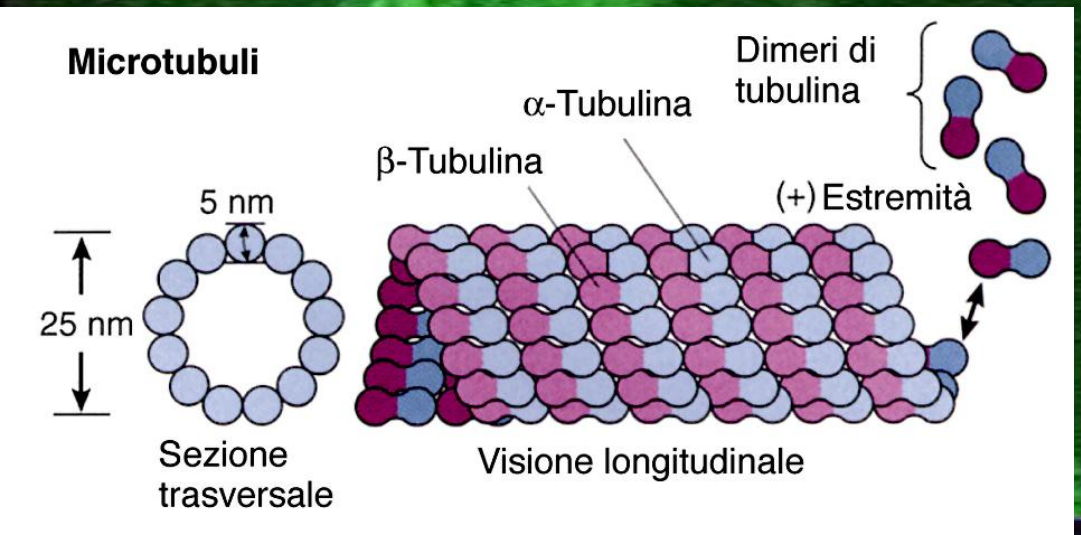




Il tropocollagene è formato da tre catene α

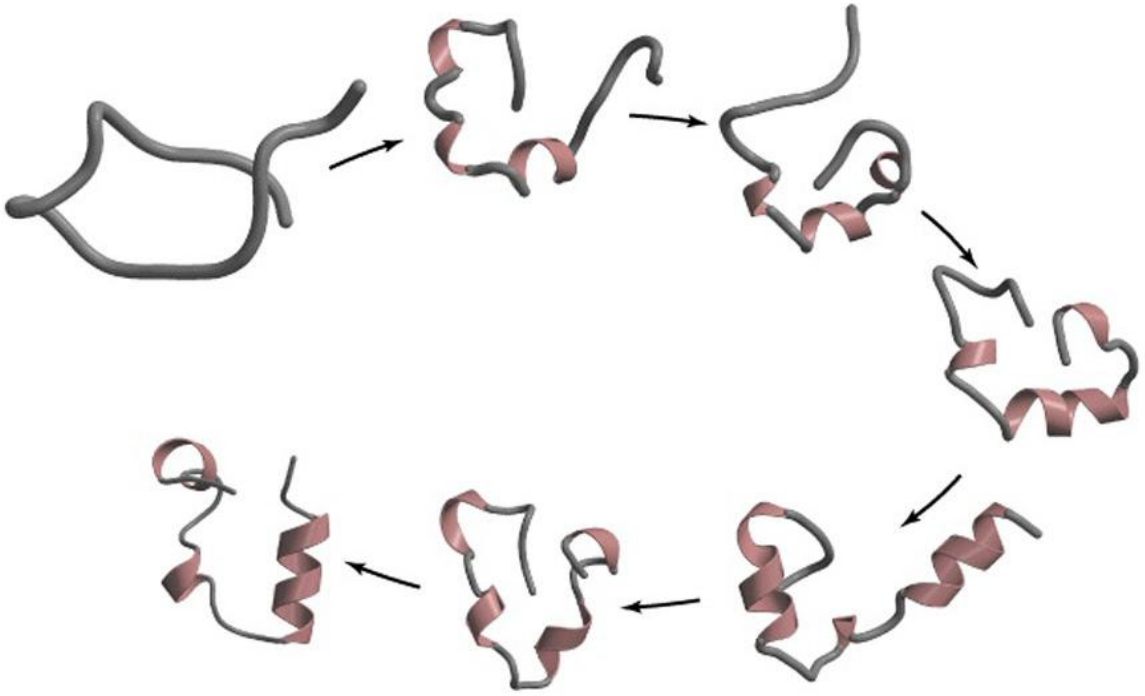
In queste catene, un residuo ogni tre è una glicina,
spesso ci sono anche prolina e idrossiprolina

Tubulin


Microtubuli
Dimeri di tubulina
α-Tubulina
β-Tubulina
(+) Estremità
5 nm
25 nm
Sezione trasversale
Visione longitudinale

PROTEIN FOLDING

Depends on the interaction between the protein and the environement



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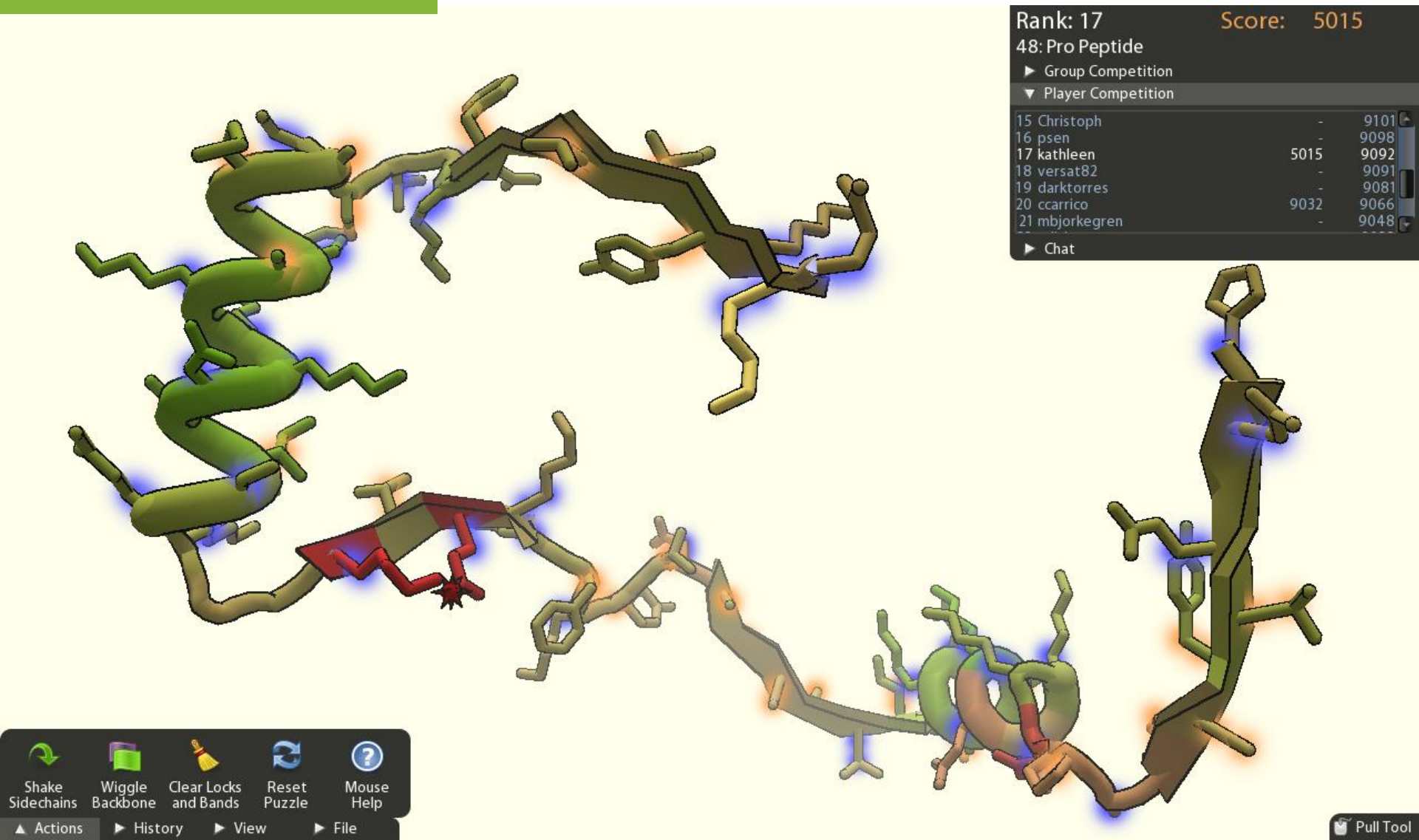
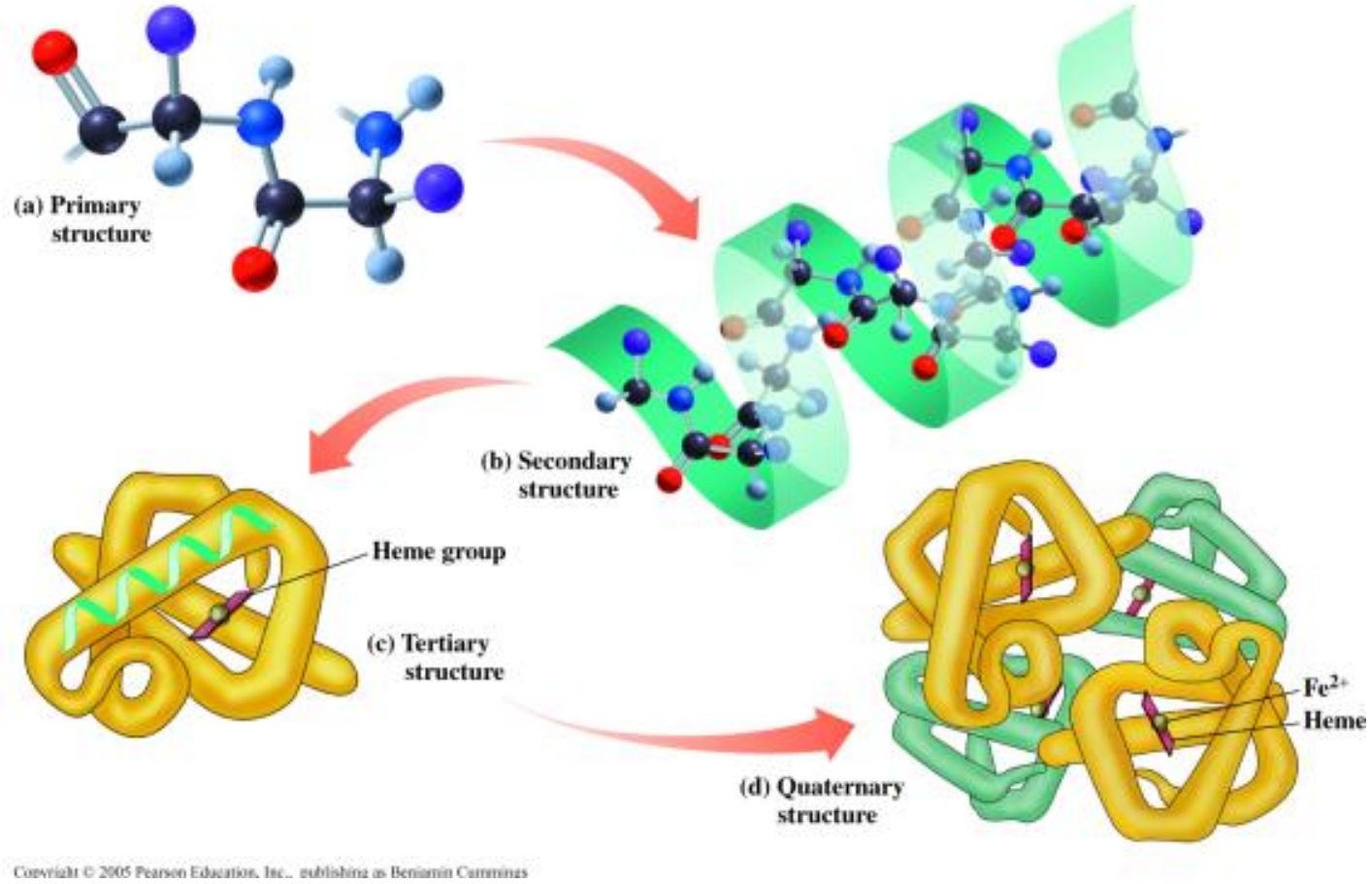


Summary of Protein Structure

Structural Level	Characteristics
Primary	The sequence of amino acids
Secondary	The coiled α-helix, β-pleated sheet, or a triple helix formed by hydrogen bonding between peptide bonds along the chain
Tertiary	A folding of the protein into a compact, three-dimensional shape stabilized by interactions between side R groups of amino acids
Quaternary	A combination of two or more protein subunits to form a larger, biologically active protein

Summary of Protein Structure



Learning Check

Identify the level of protein structure.

1) Primary
2) Secondary
3) Tertiary
4) Quaternary

A. beta pleated sheet
B. order of amino acids in a protein
C. a protein with two or more peptide chains
D. the shape of a globular protein
E. disulfide bonds between R groups

Solution

Identify the level of protein structure.

1) Primary
2) Secondary
3) Tertiary
4) Quaternary

A. 2 beta pleated sheet
B. 1 order of amino acids in a protein
C. 4 a protein with two or more peptide chains
D. 3 the shape of a globular protein
E. 3 disulfide bonds between R groups

Denaturation

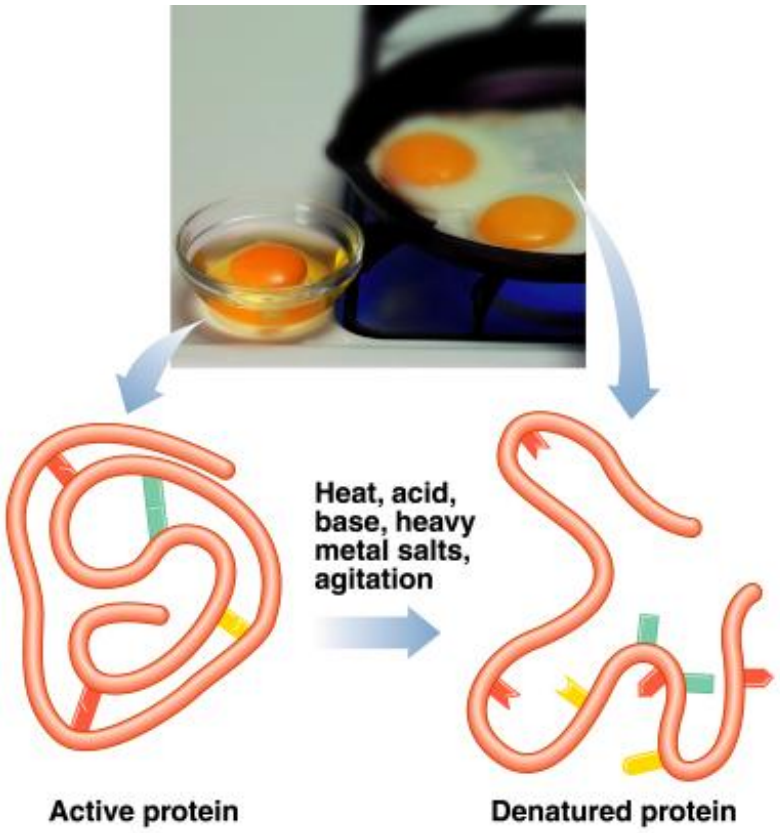
Denaturation involves

- the disruption of bonds in the secondary, tertiary and quaternary protein structures.
- **heat and organic compounds** that break apart H bonds and disrupt hydrophobic interactions.
- **acids and bases** that break H bonds between polar R groups and disrupt ionic bonds.
- **heavy metal ions** that react with S-S bonds to form solids.
- **agitation** such as whipping that stretches peptide chains until bonds break.

Applications of Denaturation

Denaturation of protein occurs when

- an egg is cooked.
- the skin is wiped with alcohol.
- heat is used to cauterize blood vessels.
- instruments are sterilized in autoclaves.



Learning check

Tannic acid is used to form a scab on a burn. An egg is hard boiled by placing it in boiling water. What is similar about these two events?

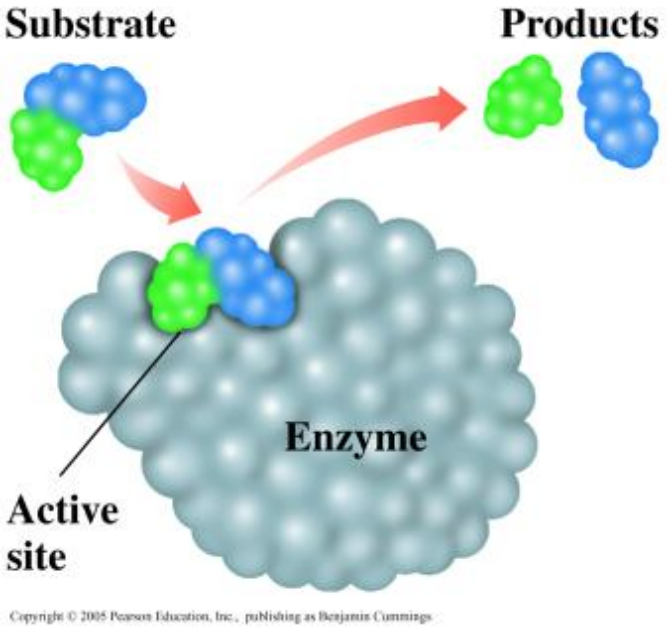
Solution

Acid and heat cause the denaturation of protein. They both break bonds in the secondary and tertiary structures of proteins.

Chapter 16 Amino Acids, Proteins, and Enzymes

16.6 Enzymes

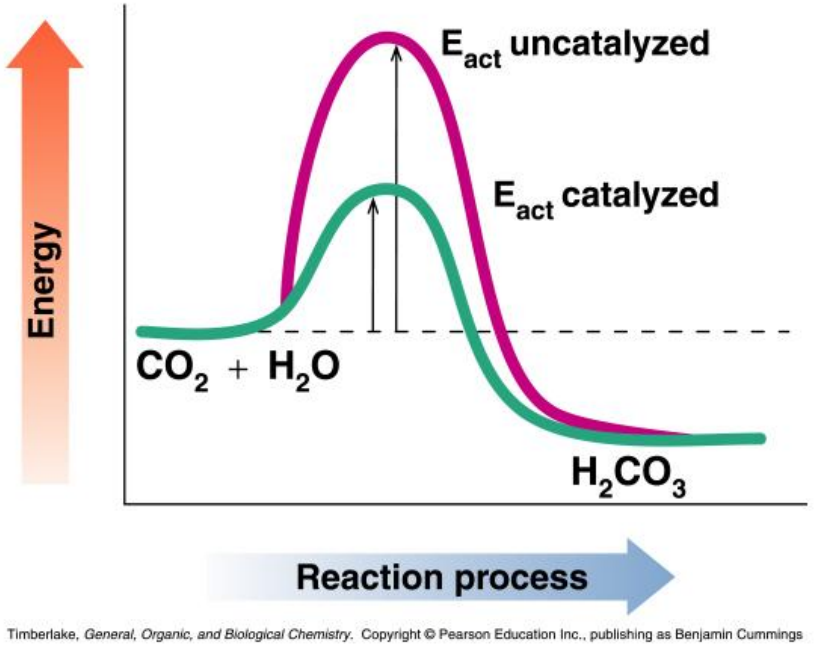
16.7 Enzyme Action



Enzymes are Biological Catalysts

Enzymes are proteins that

- Catalyze nearly all the chemical reactions taking place in the cells of the body.
- Increase the rate of reaction by lowering the energy of activation.



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Names of Enzymes

The name of an enzyme

- usually ends in –**ase**.
- identifies the reacting substance. For example, *sucrase* catalyzes the reaction of sucrose.
- describes the function of the enzyme. For example, *oxidases* catalyze oxidation.
- could be a common name, particularly for the digestion enzymes such as *pepsin* and *trypsin*.

Classification of Enzymes

Enzymes are classified by the reaction they catalyze.

Class	Type of Reactions catalyzed
Oxidoreductases	Oxidation-reduction
Transferases	Transfer groups of atoms
Hydrolases	Hydrolysis
Lyases	Add atoms/remove atoms to or from a double bond
Isomerases	Rearrange atoms
Ligases	Use ATP to combine small molecules

Learning Check

Match the type of reaction with an enzyme.

1) aminase 2) dehydrogenase

3) isomerase 4) synthetase

A. Converts a *cis*-fatty acid to a *trans*-fatty acid.

B. Removes 2 H atoms to form double bond.

C. Combines two molecules to make a new compound.

D. Adds NH_3.

Solution

Match the type of reaction with an enzyme

1) aminase 2) dehydrogenase

3) isomerase 4) synthetase

A. 3 Converts a *cis*-fatty acid to a *trans*-fatty acid.

B. 2 Removes 2 H atoms to form double bond.

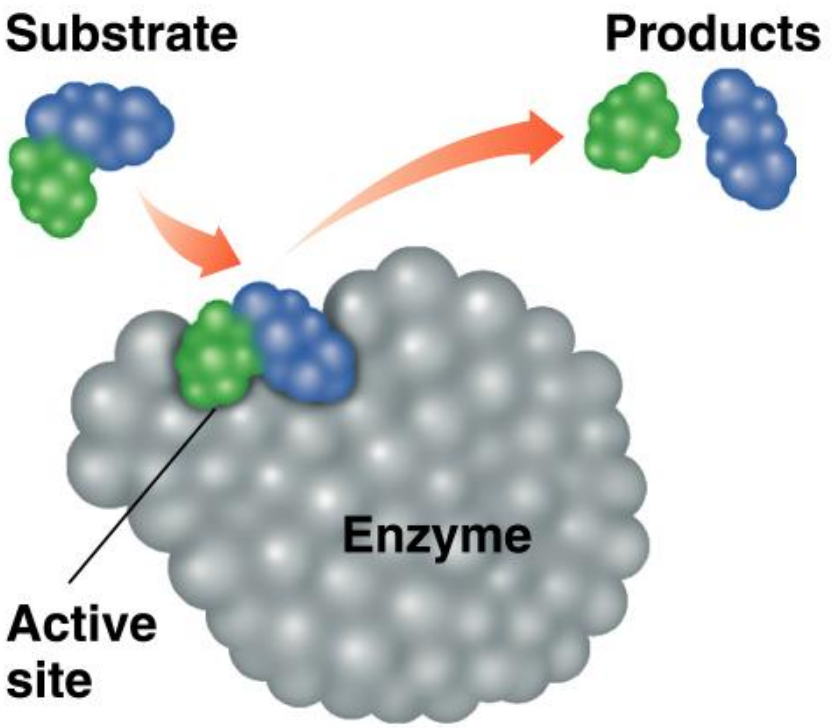
C. 4 Combines two molecules to make a new compound.

D. 1 Adds NH_3.

Active Site

The **active site**

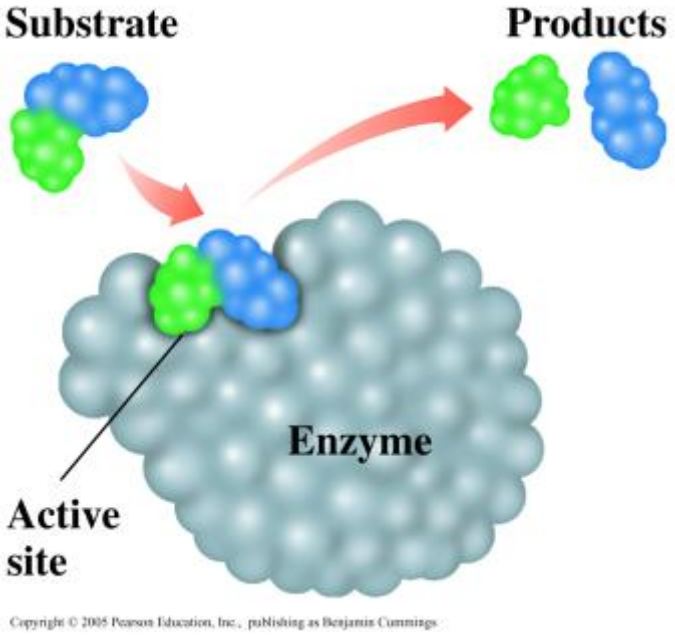
- is a region within an enzyme that fits the shape of the reacting molecule called a **substrate**.
- contains amino acid R groups that bind the substrate.
- releases products when the reaction is complete.



Enzyme Catalyzed Reaction

In an **enzyme-catalyzed reaction**

- a substrate attaches to the active site.
- an enzyme-substrate (ES) complex forms.
- reaction occurs and products are released.
- an enzyme is used over and over.



$$E + S \rightleftharpoons ES \longrightarrow E + P$$