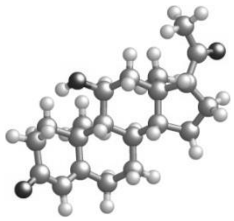


Chem!stry

Name: …………………… (   )

Class: ………………

Date: …… / …… / ……

Biochemistry: Macroconcept – Systems

Natural Monomers and Polymers: Amino Acids, Peptides and Proteins

Question 1: Proteins fulfil a wide range of biologically important functions within the human body. State at least *three* different roles that proteins fulfil within the human body:

(Answer on page 8).

Figure 1 shows a short chain protein or *peptide* composed of eight different amino acids linked together. A total of twenty different amino acids function as the *monomers* from which the polymeric proteins and peptides are produced.

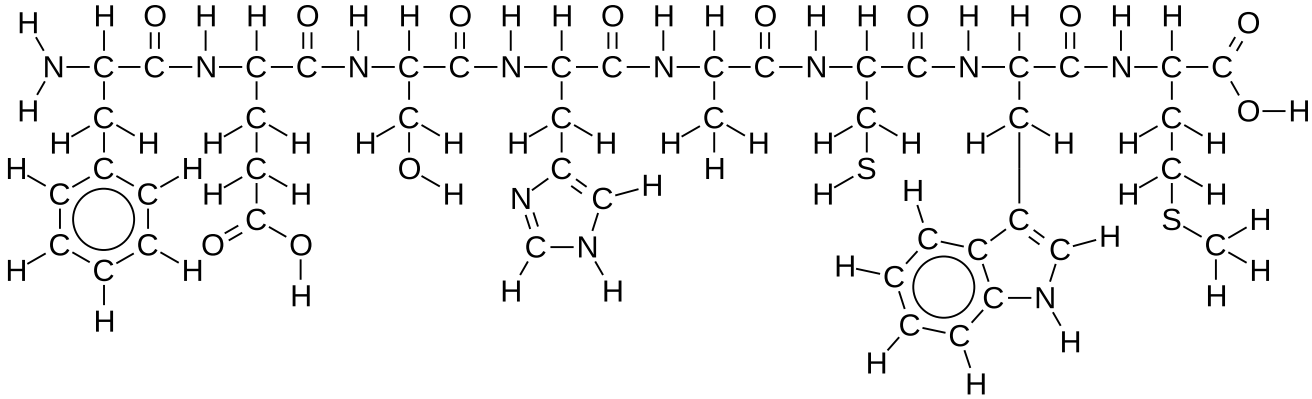


Figure 1. A short chain protein or *peptide*.

Question 2: Proteins are *naturally* occurring polyamides. Give the name and structural formula (showing at least three repeating units) of a *synthetic* polyamide:

Structure:

Name: ……………………………………………………………………

(Answer on page 8).

Figure 2 shows the general structure of an amino acid, the building block for peptide and protein synthesis.

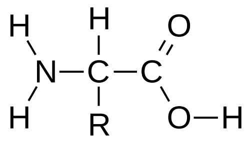


Figure 2. The basic structure of an amino acid. Amino acids contain an amine group (–NH_2) and a carboxylic acid group (–COOH). The 20 naturally occurring amino acids differ from each other by virtue of the R group. For example:

alanine R = –CH_3 *serine* R = –CH_2OH

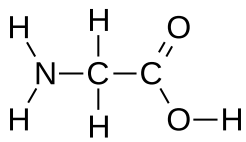


Figure 3. The structural formula of the amino acid *glycine*.

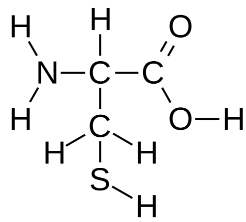


Figure 4. The structural formula of the amino acid *cysteine*.

Question 3: Which one of the two amino acids, either glycine shown in **Figure 3** or cysteine shown in **Figure 4**, exhibits *optical isomerism*? To support your answer, draw the structural formulae of the two optical isomers for the amino acid that you have chosen:

(Answer on page 9).

Question 4: When adjusted to the correct pH, known as the *isoelectric point*, an amino acid will form a *Zwitterion* in which the amine group is protonated and the carboxylic acid group has ionized. The isoelectric point for the amino acid alanine = 6.00. Draw the structural formulae of the amino acid alanine at pH = 4.00, pH = 6.00 and pH = 8.00. For each pH value, state which electrode (anode or cathode) the amino acid alanine will be attracted towards:

pH = 4.00	**pH = 6.00**	**pH = 8.00**
Anode: ☐ Cathode: ☐	Anode: ☐ Cathode: ☐	Anode: ☐ Cathode: ☐

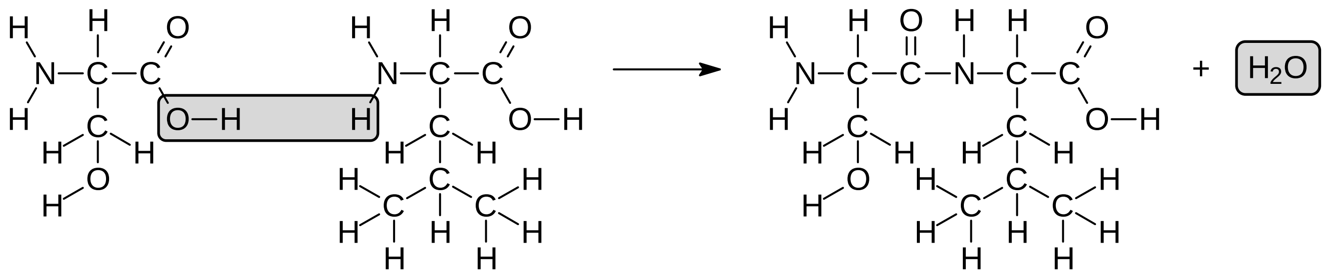
(Answer on page 9).

The carboxylic acid group (–COOH) of one amino acid can react with the amine group (–NH_2) of a second amino acid to form a *peptide bond* and *water*. This process is known as a *condensation reaction* and is catalysed by *enzymes* within the human body. **Note:** while biologists refer to the –CONH– group as a peptide bond, chemists refer to this functional group as an *N–substituted amide*.

amino acid (A) + amino acid (B) → peptide + water

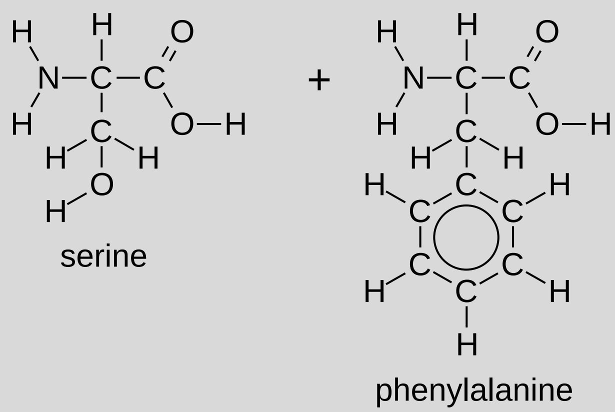
for example:

serine + leucine → peptide + water



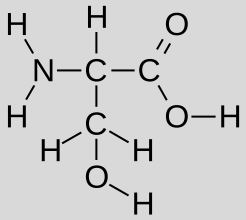
If fewer than 50 amino acids join together in a single chain, the resulting product is described as a *peptide*. If 50 or more amino acids join together in a single chain, then the resulting product is described as a *protein*. **Note:** the numerical value of 50 has been arbitrarily assigned. It is used as a guideline and is therefore not absolute.

Question 5: Give the structural formula of the peptide that is formed when the two amino acids serine and phenylalanine undergo a condensation reaction together:

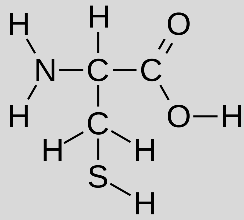


(Answer on page 9).

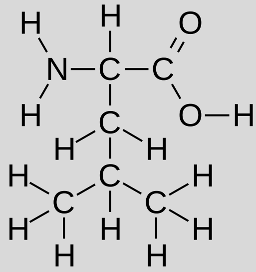
Question 6: Give the structural formula of the peptide that is formed when the three amino acids serine, cysteine and leucine undergo a condensation reaction together:


serine

+

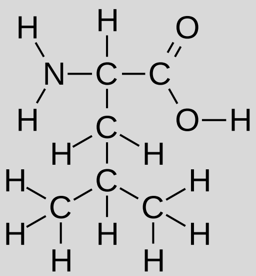

cysteine

+

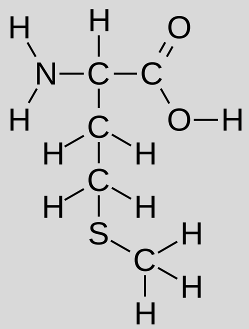

leucine

(Answer on page 9).

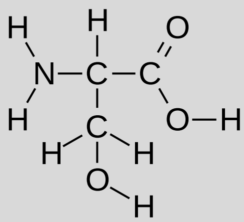
Question 7: Give the structural formula of the peptide that is formed when the four amino acids leucine, methionine, serine and histidine undergo a condensation reaction together:


leucine

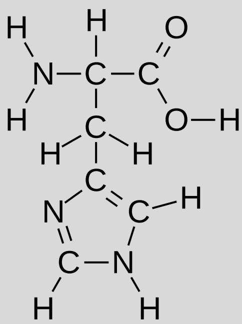
+


methionine

+

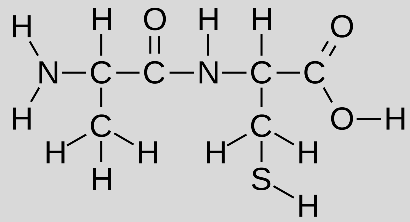

serine

+


histidine

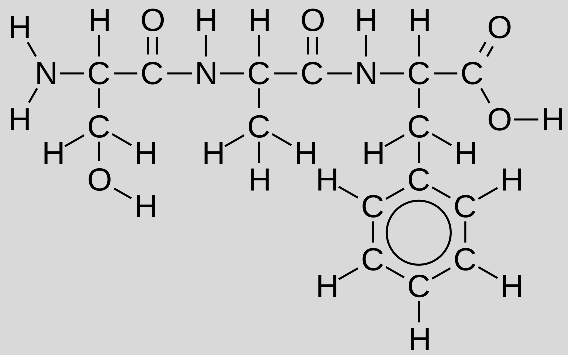
(Answer on page 10).

Question 8: Give the structural formulae and names of the amino acids that are formed when the peptide shown below is hydrolysed, *i.e.* split apart through the addition of water. **Note:** peptides can be hydrolysed by refluxing with either dilute aqueous acids or alkalis.



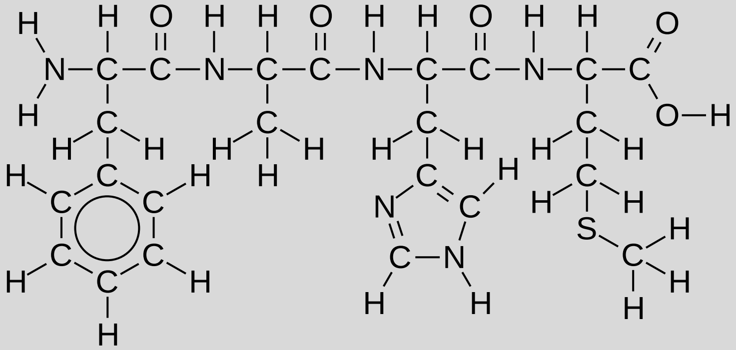
(Answer on page 10).

Question 9: Give the structural formulae and names of the amino acids that are formed when the peptide shown below is hydrolysed, *i.e.* split apart through the addition of water. **Note:** peptides can be hydrolysed by refluxing with either dilute aqueous acids or alkalis.



(Answer on page 10).

Question 10: Give the structural formulae and names of the amino acids that are formed when the peptide shown below is hydrolysed, *i.e.* split apart through the addition of water. **Note:** peptides can be hydrolysed by refluxing with either dilute aqueous acids or alkalis.

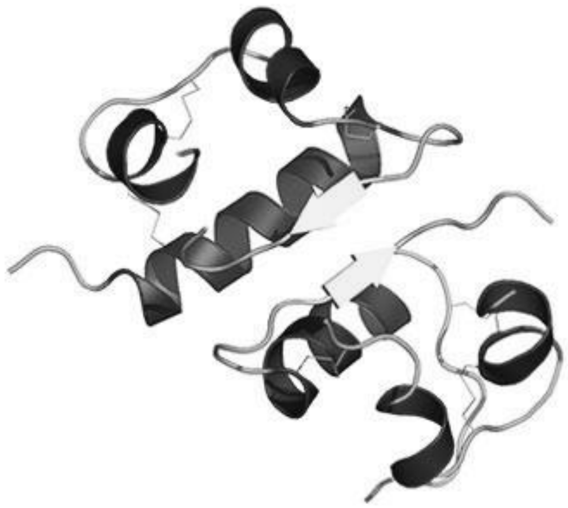


(Answer on page 10).

Figure 5. The figure on the right-hand-side shows the simplified three-dimensional structure of the peptide hormone *insulin*. Insulin takes its name from the Latin word "*insula*" meaning "island" as it is produced by cells within the *Islets of Langerhans* in the pancreas.

One of insulin's most significant roles within the human body is the regulation of carbohydrate metabolism. Individuals suffering from Type I *diabetes mellitus* do not produce sufficient insulin and have to inject samples of the peptide hormone into their bodies.

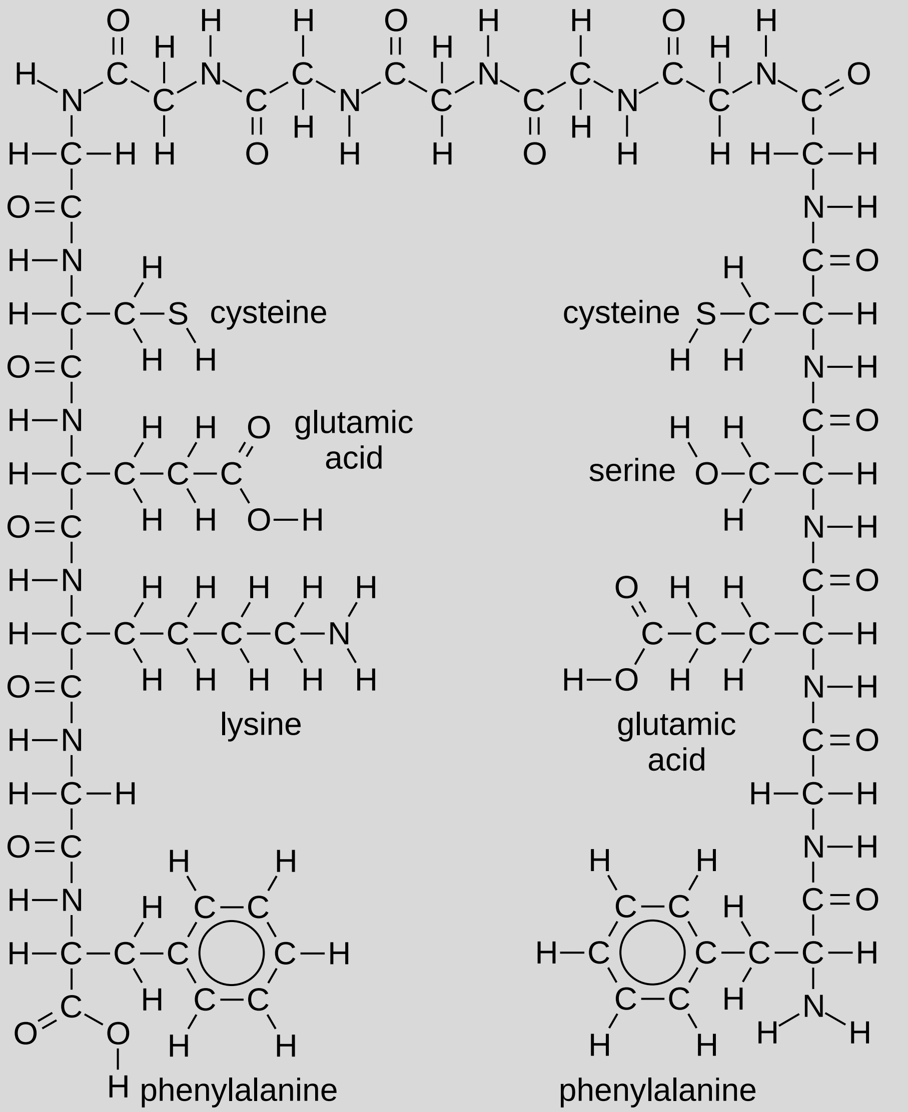
The exact sequence of amino acids comprising the insulin molecule, the so-called *primary structure*, was determined by British molecular biologist Frederick Sanger. It was the first protein for which the primary structure was completely determined. For this he was awarded the Nobel Prize for Chemistry in 1958. In 1967, after decades of work, Dorothy Hodgkin determined the spatial conformation of the molecule by means of X-ray diffraction studies. Dorothy Hodgkin was awarded the Nobel Prize for Chemistry in 1964 "For her determinations by X-ray techniques of the structures of important biochemical substances."



Picture and literature reference:
http://www.3dchem.com/molecules.asp?ID=196
http://nobelprize.org/nobel_prizes/chemistry/laureates/1964/press.html

The *primary structure* of a protein is determined by the sequence of amino acids from which it is composed. The *secondary* and *tertiary structures* of a protein are determined by *intra-molecular bonding*, *i.e.* the different ways in which the functional groups within the protein chain interact with each other.

Question 11: Study the peptide chain shown below and propose possible ways in which the various functional groups may interact with each other, resulting in the formation of intra-molecular bonds that will contribute to the final three-dimensional structure of the molecule.
Electronegativity values (Pauling sale): **H** = 2.1 **C** = 2.5 **N** = 3.0 **O** = 3.5 **S** = 2.5



(Answer on page 11).

Question 12: A protein chain may be described as a *system*.
a) Briefly describe the different ways in which a protein chain can be considered as a *system*.
b) Which different *systems* within the body do proteins form part of?
c) Provide examples of other molecules that can be considered as *systems*, or can be considered to be part of a *system*. For each example, rationalise your choice.

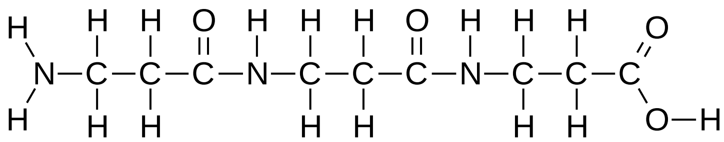
(Answer on page 12).

Answers

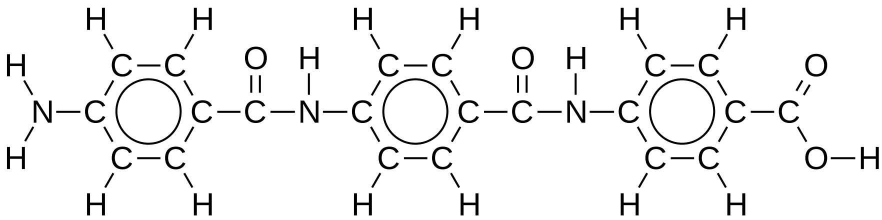
Question 1:

- Transport proteins – *haemoglobin* transports oxygen throughout the body.
- Chemical messengers – the peptide hormone *insulin* regulates the level of glucose in the blood.
- Immune system – various *immunoglobulins* form part of the body's defence against infection.
- Biological catalysts – various *enzymes* increase the rate of chemical reactions within the body.
- Structural proteins – *elastin* and *collagen* are important components of connective tissue.
- Contractile proteins – The relative movement of *actin* and *myosin* fibres results in muscle contraction.
- Protection from the environment – *keratin* (hair) covers the bodies of mammals and helps to protect the body from temperature fluctuations, radiation and physical harm.

Question 2:

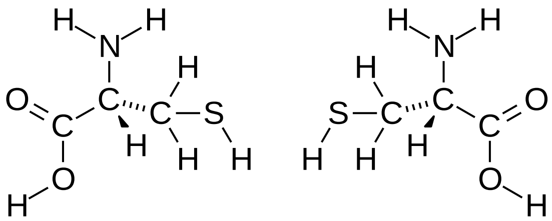


nylon 3,3



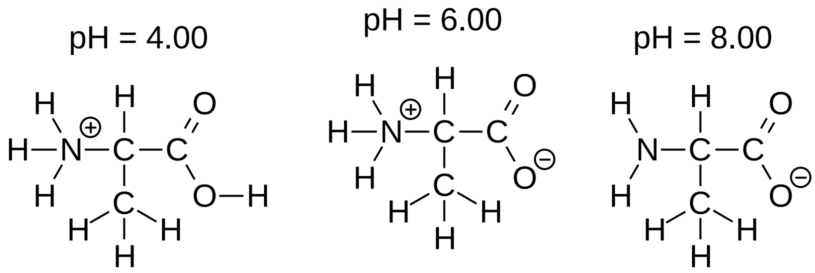
kevlar

Question 3:



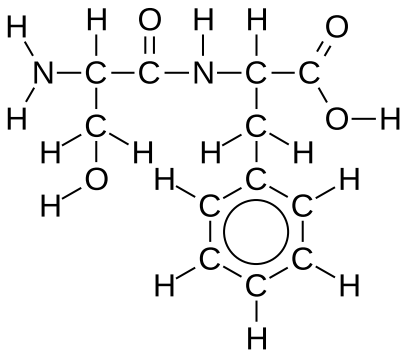
optical isomers of cysteine

Question 4:

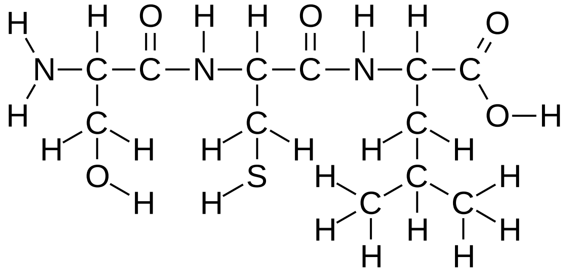


attracted towards the cathode	attracted towards both the anode and the cathode	attracted towards the anode

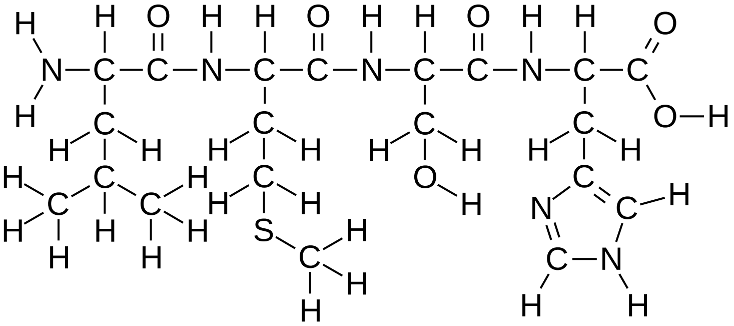
Question 5:



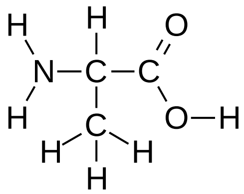
Question 6:



Question 7:

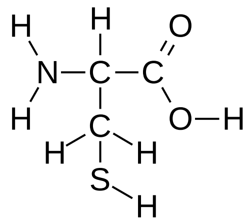


Question 8:



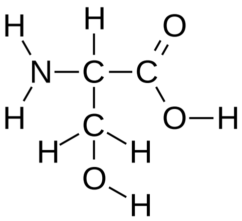
alanine

+



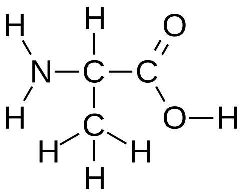
cysteine

Question 9:



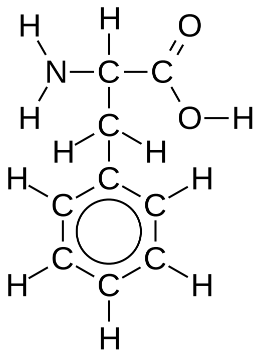
serine

+



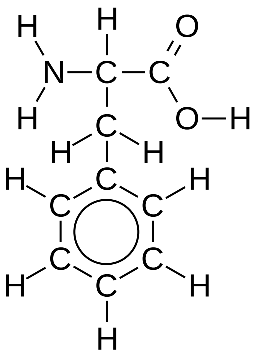
alanine

+



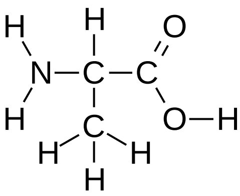
phenylalanine

Question 10:



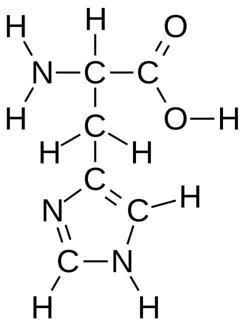
phenylalanine

+



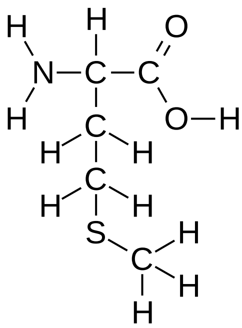
alanine

+



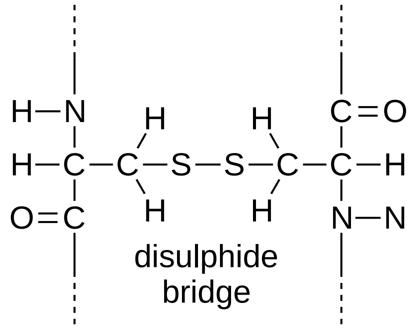
histidine

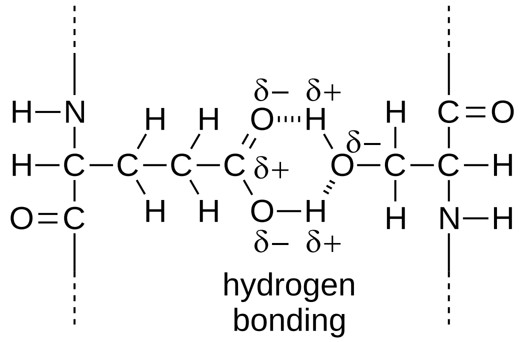
+

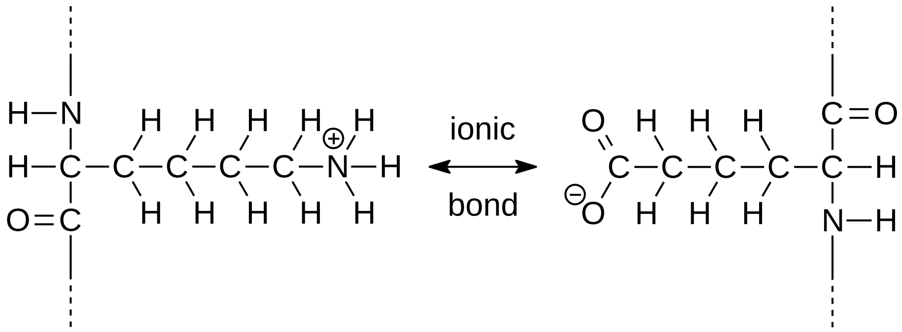


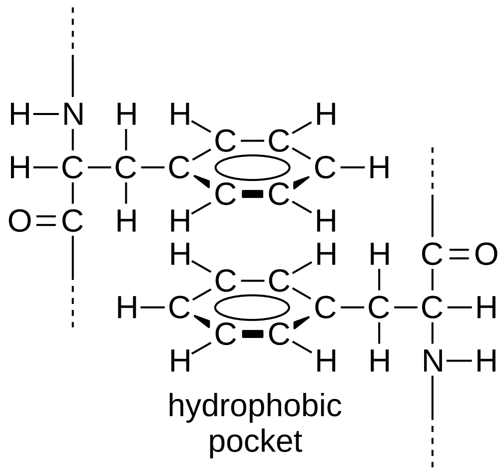
methionine

Question 11:


disulphide bridge


hydrogen bonding


ionic bond


hydrophobic pocket

Question 12:

a) The answer should include references to the generalisations that can be made about a system:

- Systems have elements that interact with each other to perform a function.
- Systems are composed of subsystems.
- Systems may be influenced by other systems.
- Systems interact.
- Systems follow rules.

b) Examples include:

- Transport systems.
- Central nervous systems and hormonal messengers.
- Immune system.
- Catalysts in biochemical pathways.
- Connective tissue.
- Muscle.

c) Both DNA and RNA could be considered as systems. Both molecules are composed of subsystems (adenine, cytosine, guanine, thymine and uracil). Both molecules interact with other systems, for example, enzymes. Both molecules follow "biochemical rules" during replication and protein biosynthesis.
Glucose could be considered to be part of a system as it is converted into carbon dioxide and water during the various stages of cellular respiration. The glucose, and its metabolites, interact with a variety of different enzymes while moving through a precise sequence of biochemical reactions.

Worksheet by Dr. Chris Slatter