Topic 2 Molecular Biology

Topic 2.4 Proteins

Essential idea: Proteins have a very wide range of functions in living organisms.

Understandings:

- 2.4.U1 Amino acids are linked together by condensation to form polypeptides.
- 2.4.U2 There are 20 different amino acids in polypeptides synthesized on ribosomes.
- 2.4.U3 Amino acids can be linked together in any sequence giving a huge range of possible polypeptides.
- 2.4.U4 The amino acid sequence of polypeptides is coded for by genes.
- 2.4.U5 A protein may consist of a single polypeptide or more than one polypeptide linked together.
- 2.4.U6 The amino acid sequence determines the three-dimensional conformation of a protein.
- 2.4.U7 Living organisms synthesize many different proteins with a wide range of functions.
- 2.4.U8 Every individual has a unique proteome.

Applications:

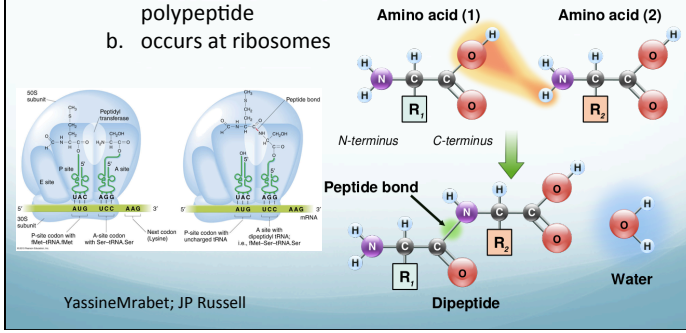
- 2.4.A1 Rubisco, insulin, immunoglobulins, rhodopsin, collagen and spider silk as examples of the range of protein functions.
- 2.4.A2 Denaturation of proteins by heat or by deviation of pH from the optimum.

Skills

- 2.4.S1 Drawing molecular diagrams to show the formation of a peptide bond.

I. Amino Acids and Polypeptides

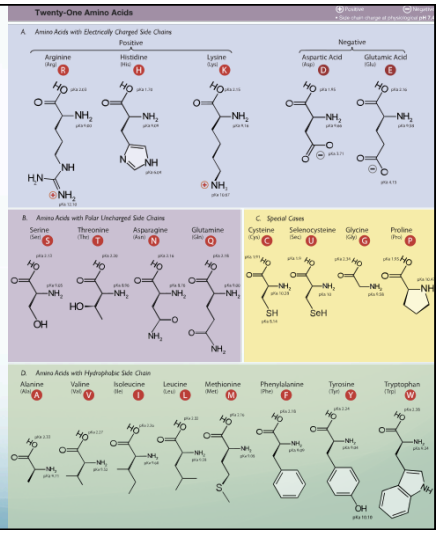
A. Amino acids are linked together by condensation to form polypeptides.
   1. Amino acids are linked by condensation
      a. results in a peptide bond forming a dipeptide or polypeptide
      b. occurs at ribosomes



YassineMrabet; JP Russell

II. Diversity of Amino acids

A. There are 20 different amino acids in polypeptides synthesized on ribosomes.
   1. Each amino acid has a different R group that determines it properties and properties of the protein it makes up.



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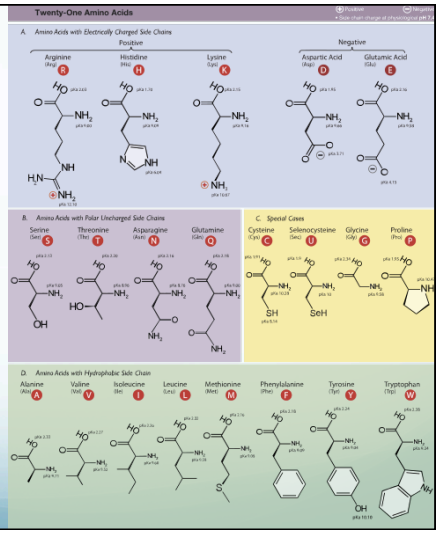
II. Diversity of Amino acids

2. Some R groups are positively or negatively charged (hydrophilic), hydrophobic, polar, acidic or basic, or contain sulfur.

You don't need to memorize all 20 amino acids, but given a description you should be able to predict how the amino acid can affect the shape of a protein or it's interaction in an environment.



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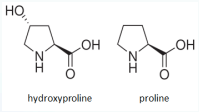
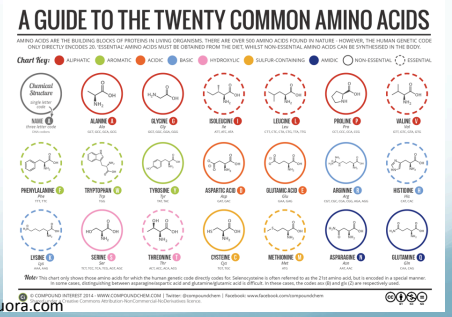
II. Diversity of Amino Acids

3. 9 of the 20 amino acids are essential (required in our diet).
4. Other amino acids do exist, but are modified forms of the base amino acid i.e. hydroxyproline from proline.



Hydroxyproline is an important component of collagen used to provide tensile strength in tendons, ligaments, skin and blood vessel walls.



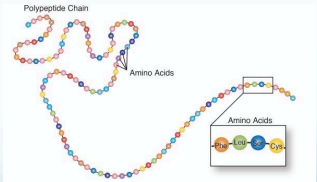
compoundchem.com; quora.com

III. Polypeptide Diversity

A. Amino acids can be linked together in any sequence giving a huge range of possible polypeptides.
   1. Polypeptides can be any length
   2. There are 20 amino acids
   3. There can be any combination of 20 amino acids in any order

Just for a dipeptide there a 20^2 or 400 different possible combinations!

Given that polypeptides can contain up to 30,000 amino acids (e.g. Titin) the different possible combinations of polypeptides are effectively infinite.



Amino Acids

Ala: Alanine	Gln: Glutamine	Leu: Leucine	Ser: Serine
Arg: Arginine	Glu: Glutamic acid	Lys: Lysine	Thr: Threonine
Asn: Asparagine	Gly: Glycine	Met: Methionine	Trp: Tryptophane
Asp: Aspartic acid	His: Histidine	Phe: Phenylalanine	Tyr: Tyrosisne
Cys:Cysteine	Ile: Isoleucine	Pro: Proline	Val: Valine

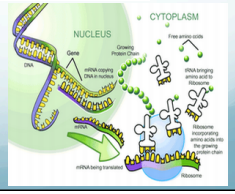
quantum-mind.co.uk

IV. Genes and Polypeptides

A. The amino acid sequence of polypeptides is coded for by genes
   1. The central dogma of biology is that genes (DNA) are simply codes for making polypeptides.
      a. Genome – all the genes present in an organism.
      b. Proteome – all the protein produced by an organism.

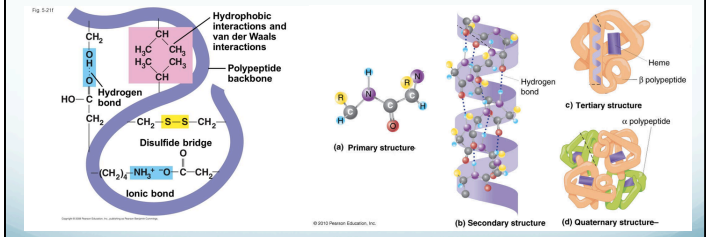
- *DNA is stored in the nucleus*
- *mRNA (messenger RNA) is a copy of DNA that carries the instructions on how to assemble the polypeptide to the ribosome in the cytoplasm*
- *Ribosome uses the sequences of bases on mRNA to link corresponding amino acids together into a polypeptide.*

bioknowledgy.net; proteinsynthesis.org



V. Proteins, Polypeptides and Conformation

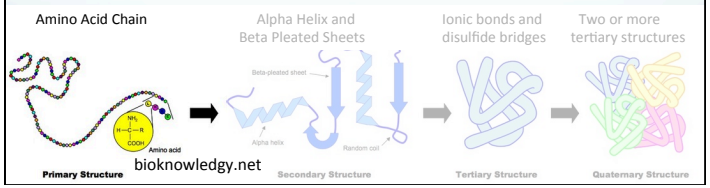
A. A protein may consist of a single polypeptide or more than one polypeptide linked together.
B. The amino acid sequence determines the three-dimensional conformation of a protein.



Pearson Education

VI. The Four Levels of Protein Structure

A. The sequence and number of amino acids in the polypeptide is the primary structure.
   1. The order / sequence of the amino acids of which the protein is composed
   2. Formed by covalent peptide bonds between adjacent amino acids
   3. Controls all subsequent levels of structure



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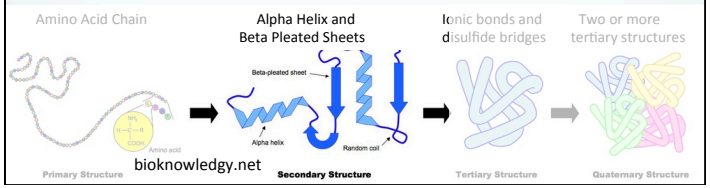
VI. The Four Levels of Protein Structure

B. The secondary structure is the formation of alpha helices and beta pleated sheets stabilized by hydrogen
   1. The chains of amino acids fold or turn upon themselves
   2. Held together by hydrogen bonds between (non-adjacent) amine (N-H) and carboxylic (C-O) groups
   3. H-bonds provide a level of structural stability
   4. Fibrous proteins have secondary structure



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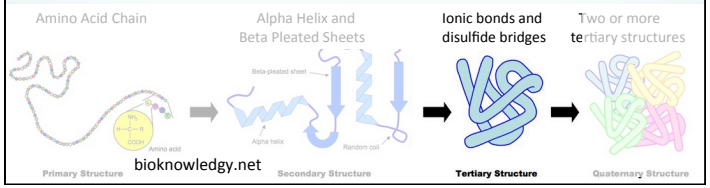
VI. The Four Levels of Protein Structure

C. The tertiary structure is the further folding of the polypeptide stabilized by interactions between R groups.
   1. The polypeptide folds and coils to form a complex 3 dimensional shape
   2. Caused by interactions between R groups (H-bonds, disulfide bridges, ionic bonds and hydrophilic / hydrophobic interactions)
   3. Tertiary structure may be important for the function (e.g. specificity of active site in enzymes)
   4. Globular proteins have tertiary structure



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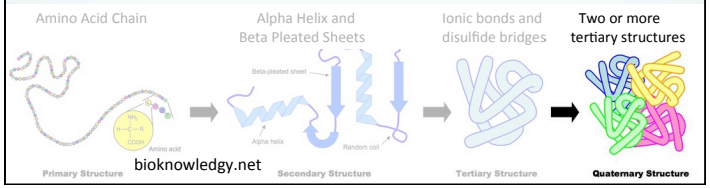
VI. The Four Levels of Protein Structure

D. The quaternary structure exists in proteins with more than one polypeptide chain.
   1. The interaction between multiple polypeptides or prosthetic groups
   2. A prosthetic group is an inorganic compound involved in a protein (e.g. the heme group in hemoglobin)
   3. Quaternary structures have combinations of fibrous and globular proteins



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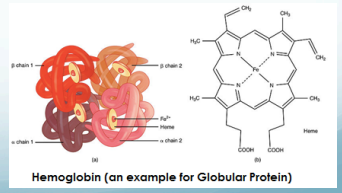
VII. Proteins are commonly described as either being fibrous or globular in nature.

Fibrous proteins have structural roles whereas globular proteins are functional (active in a cell's metabolism).

Properties	Fibrous Protein	Globular Protein
Shape	Long and narrow	Rounded / spherical
Role	Structural (strength and support)	Functional (catalytic, transport, etc.)
Solubility	(Generally) insoluble in water	(Generally) soluble in water
Sequence	Repetitive amino acid sequence	Irregular amino acid sequence
Stability	Less sensitive to changes in heat, pH, etc.	More sensitive to changes in heat, pH, etc.
Examples	Collagen, myosin, fibrin, actin, keratin, elastin	Catalase, haemoglobin, insulin, immunoglobulin

In globular proteins the hydrophobic R groups are folded into the core of the molecule, away from the surrounding water molecules, this makes them soluble.
In fibrous proteins the hydrophobic R groups are exposed and therefore the molecule is insoluble.



bioninja.au; Anatomy and Physiology

VIII. Protein Functions

Nothing can compare with the versatility of proteins. Their functionality and usage in organisms is unrivalled.

Function	Description	Key examples
Catalysis	An enzyme vital for the fixation of carbon dioxide during photosynthesis; There are thousands of different enzymes to catalyze specific chemical reactions within the cell or outside it.	**rubisco**
Muscle contraction	Actin and myosin together cause the muscle contractions used in locomotion and transport around the body.	actin, myosin
Cytoskeleton	Tubulin is the subunit of microtubules that give animals cells their shape and pull on chromosomes during mitosis.	tubulin
Tensile strengthening	Fibrous proteins give tensile strength needed in skin, tendons, ligaments and blood vessel walls.	**collagen**
Blood clotting	Plasma proteins act as clotting factors that cause blood to turn from a liquid to a gel in wounds.	fibrinogen
Transport of nutrients and gases	Proteins in blood help transport oxygen, carbon dioxide, iron and lipids.	hemoglobin

VIII. Protein Functions

Function	Description	Key examples
Cell adhesion	Membrane proteins cause adjacent animal cells to stick to each other within tissues.	integrins
Membrane transport	Membrane proteins are used for facilitated diffusion and active transport, and also for electron transport during cell respiration and photosynthesis.	sodium/potassium pumps
Hormones	Vital to the control of blood sugar; Hormones regulate processes within in the body	**insulin**
Receptors	Binding sites in membranes and cytoplasm for hormones, neurotransmitters, tastes and smells, and also receptors for light in the eye and in plants.	**rhodopsin**
Packing of DNA	Histones are associated with DNA in eukaryotes and help chromosomes to condense during mitosis.	histones
Immunity	This is the most diverse group of proteins, as cells can make huge numbers of different antibodies.	**Immunoglobulins**
Catching prey	A strong, fine, slightly elastic fiber produced by web-building spiders	**spider silk**