Chapter 5 (continued)

The Structure and Function of Proteins

Lectures modified by Garrett Dancik
Concept 5.4: Proteins include a diversity of structures, resulting in a wide range of functions

- Proteins account for more than 50% of the dry mass of most cells
- Protein functions include structural support, storage, transport, cellular communications, movement, and defense against foreign substances
Enzymatic proteins

Function: Selective acceleration of chemical reactions
Example: Digestive enzymes catalyze the hydrolysis of bonds in food molecules.

- **Enzymes** are a type of protein that acts as a **catalyst** to speed up chemical reactions
- Enzymes can perform their functions repeatedly, functioning as workhorses that carry out the processes of life
- [http://www.biotopics.co.uk/other/morinf.html](http://www.biotopics.co.uk/other/morinf.html)
Storage proteins

Function: Storage of amino acids

Examples: Casein, the protein of milk, is the major source of amino acids for baby mammals. Plants have storage proteins in their seeds. Ovalbumin is the protein of egg white, used as an amino acid source for the developing embryo.
Hormonal proteins

Function: Coordination of an organism’s activities

Example: Insulin, a hormone secreted by the pancreas, causes other tissues to take up glucose, thus regulating blood sugar concentration

Insulin protein entry:
Insulin and Glucose transport

(a) In the absence of insulin, glucose cannot enter the cell.

(b) Insulin signals the cell to insert GLUT 4 transporters into the membrane, allowing glucose to enter the cell.
Contractile and motor proteins

Function: Movement

Examples: Motor proteins are responsible for the undulations of cilia and flagella. Actin and myosin proteins are responsible for the contraction of muscles.
Defensive proteins

Function: Protection against disease

Example: Antibodies inactivate and help destroy viruses and bacteria.
Transport proteins

Function: Transport of substances
Examples: Hemoglobin, the iron-containing protein of vertebrate blood, transports oxygen from the lungs to other parts of the body. Other proteins transport molecules across cell membranes.
Receptor proteins

Function: Response of cell to chemical stimuli

Example: Receptors built into the membrane of a nerve cell detect signaling molecules released by other nerve cells.
Structural proteins

Function: Support

Examples: Keratin is the protein of hair, horns, feathers, and other skin appendages. Insects and spiders use silk fibers to make their cocoons and webs, respectively. Collagen and elastin proteins provide a fibrous framework in animal connective tissues.
Stress signals such as DNA damage

activation of p53

The activated p53 protein binds to a specific DNA sequence... composed of RRRCWGWGY (spacer of 0–21 nucleotides) RRRCWGWGY, where R is a purine, W is A or T, and Y is a pyrimidine.

https://www.nature.com/articles/1208615
Proteins

- **Amino acids** are the building blocks (monomers) of proteins
  - Amino acids are organic molecules with carboxyl and amino groups
  - Amino acids differ in their properties due to differing side chains, called R groups (see next slide)
- **Polypeptides** are unbranched polymers built from the same set of 20 amino acids
- A **protein** is a biologically functional molecule that consists of one or more polypeptides
Figure 5.UN01

Side chain (R group)

Amino group

Carboxyl group

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Figure 5.16

Nonpolar side chains; hydrophobic

- Glycine (Gly or G)
- Alanine (Ala or A)
- Valine (Val or V)
- Leucine (Leu or L)
- Isoleucine (Ile or I)

Polar side chains; hydrophilic

- Serine (Ser or S)
- Threonine (Thr or T)
- Cysteine (Cys or C)
- Tyrosine (Tyr or Y)
- Asparagine (Asn or N)
- Glutamine (Gln or Q)

Electrically charged side chains; hydrophilic

Acidic (negatively charged)
- Aspartic acid (Asp or D)
- Glutamic acid (Glu or E)

Basic (positively charged)
- Lysine (Lys or K)
- Arginine (Arg or R)
- Histidine (His or H)
Amino Acid Polymers

- Amino acids are linked by **peptide bonds**
- A polypeptide is a polymer of amino acids
- Polypeptides range in length from a few to more than a thousand monomers (amino acids)
- Each polypeptide has a unique linear sequence of amino acids, with a carboxyl end (C-terminus) and an amino end (N-terminus)
How are peptide bonds formed?

Methionine (M) Tyrosine (Y)

Cysteine (C)

Peptide bond

New peptide bond forming

H₂O

Amino end (N-terminus)
Peptide bond
Carboxyl end (C-terminus)
• A functional protein consists of one or more polypeptides precisely twisted, folded, and coiled into a unique shape
• The sequence of amino acids determines a protein’s three-dimensional structure
• A protein’s structure determines its function
• Bioinformatics uses computer programs to predict protein structure and function from amino acid sequences
Four Levels of Protein Structure

• The primary structure of a protein is its unique sequence of amino acids
• Secondary structure, found in most proteins, consists of coils and folds in the polypeptide chain
• Tertiary structure is determined by interactions among various side chains (R groups)
• Quaternary structure results when a protein consists of multiple polypeptide chains
- **Transthyretin polypeptide**
  - Transports thyroid hormones
  - Transports retinol (Vitamin A)

- **Primary structure**
  - The sequence of amino acids in a protein
  - Determined by inherited genetic information
Secondary structure results from hydrogen bonds between parts of the polypeptide backbone.

- Includes the α helix and β pleated sheet.

β strand, shown as a flat arrow pointing toward the carboxyl end.

α helix
• **Tertiary structure** is the shape of a polypeptide in three dimensions

• **Quaternary structure** results when two or more polypeptide chains form one macromolecule (not all proteins have a quaternary structure)
  
  – Transthyretin is composed of 4 identical polypeptides
Putting it all together…
(but primary structure is not shown)

Secondary structure

Tertiary structure

Quaternary structure

α helix

β pleated sheet

β strand

Hydrogen bond

Hydrogen bond

Transthyretin polypeptide

Transthyretin protein
(composed of 4 identical polypeptides)
Sickle-Cell Disease: A Change in Primary Structure

- A slight change in primary structure can affect a protein’s structure and ability to function
  - How does the primary structure change?
- **Sickle-cell disease**, an inherited blood disorder, results from a single amino acid substitution in the protein hemoglobin
- Genpept:
Hemoglobin is a protein made up of 4 polypeptide chains: two $\alpha$ and two $\beta$ subunits.
<table>
<thead>
<tr>
<th>Primary Structure</th>
<th>Secondary and Tertiary Structures</th>
<th>Quaternary Structure</th>
<th>Function</th>
<th>Red Blood Cell Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hemoglobin</td>
<td><img src="image" alt="Normal hemoglobin" /></td>
<td>Normal hemoglobin</td>
<td>Molecules do not associate with one another; each carries oxygen.</td>
<td><img src="image" alt="Normal hemoglobin" /></td>
</tr>
<tr>
<td>Sickle-cell hemoglobin</td>
<td><img src="image" alt="Sickle-cell hemoglobin" /></td>
<td>Sickle-cell hemoglobin</td>
<td>Molecules crystallize into a fiber; capacity to carry oxygen is reduced.</td>
<td><img src="image" alt="Sickle-cell hemoglobin" /></td>
</tr>
</tbody>
</table>