Chapter 2 Outline

Thursday, September 12, 2019 11:18 AM

Molecular Biology

1. Molecular biology explains living processes in terms of the chemical substances involved.
2. Molecules vary in complexity (simple molecules like water and more complex ones like nucleic acids and proteins)

Synthesis of Urea

- Produced by living organisms but can also be artificially synthesized
- Urea is formed when there are too many amino acids in the body

Urea and falsification of vitalism

1. Vitalism
    a. The theory that the origin and phenomena of life are due to a vital principle, which is different from purely chemical or physical forces
2. Friedrich Wohler
    a. Synthesized urea in 1828, a major step in disproving vitalism.

Carbon Compounds

1. Carbon atoms can form four bonds allowing a diversity of compounds to exist.
2. Carbon is very common in life
    a. Carbon can form covalent bonds (share electrons)
    b. Carbon can form 4 bonds, allowing for complex structures
        i. Can form rings and stuff

Classifying carbon compounds

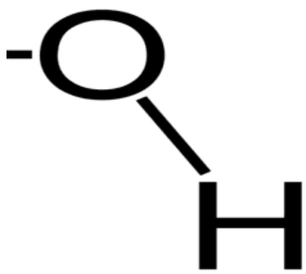
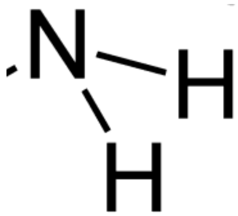
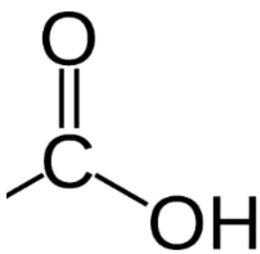
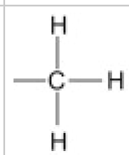
1. Carbohydrates
    a. Composed of carbon, hydrogen, and oxygen
    b. In the ratio of 2H:1O

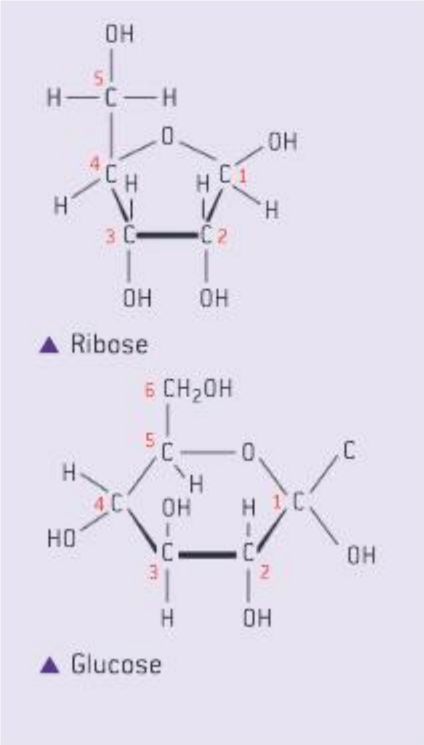
2. Lipids
    a. Broad class of molecules that are insoluble in water
    b. Includes steroids, waxes, fatty acids, triglycerides

3. Proteins
    a. Chains of amino acids

4. Nucleic acids
    a. Made of nucleotides,
    b. RNA and DNA

Structures

Hydroxyl	
Amine	
carboxyl	
Methyl	



Identifying molecules

1. Proteins contain C, H, O, and N. Carbohydrates and lipids contain just C, H, and O.
2. Many proteins have sulfur, but carbs and lipids do not
3. Lipids have less oxygen than carbohydrates

Metabolism

1. Metabolism- the sum of all chemical reactions that occur in an organism
    a. Web of all the enzyme catalyzed reactions in an organism

Anabolism

1. Anabolism is the synthesis of complex molecules from simpler molecules including the formation of macromolecules form monomers by condensation reactions
    a. Ex: protein synthesis or DNA synthesis

Catabolism

1. Catabolism is the breakdown of complex molecules into simpler molecules including the hydrolysis of macromolecules into monomers
    a. Ex: digestion or cell respiration

2.2 Water

Hydrogen bonding in Water

1. Water molecules are dipolar, causing hydrogen bonds to form between them
    a. This is caused by the unequal sharing of electrons in the H2O molecules
        i. Hydrogen has a positive charge and oxygen has a negative charge
    b. Hydrogen bonding is called an Intermolecular Force

Hydrogen bonds and the properties of water

1. We cannot prove hydrogen bonds exist because they are impossible to observe

Properties of water

- Hydrogen bonding and dipolarity explain the properties of water

1. Cohesive properties
    a. Binding of two water molecules together
    b. Helps water transport in plants (water gets pulled up the xylem of trees if there is a continuous stream of water molecules)
    c. Causes surface tension
2. Adhesive properties
    a. Water can form bonds with other polar molecules because water is polar.
    b. In leaves, water can adhere to cellulose molecules in cell walls
3. Thermal Properties
    a. High specific heat capacity
        i. Hydrogen bonds restrict the motion of water molecules
        ii. This causes more energy to be absorbed when increasing the temperature of water.
        iii. Creates thermally stable environments
    b. High latent heat of vaporization
        i. Latent heat- energy for evaporation
        ii. A lot of energy is needed to evaporate water. This is useful for water being a coolant, such as in the case of sweating
    c. High boiling point
        i. The temperature range of liquid water is 0 to 100 degrees Celsius. This makes water suitable for most habitats on Earth.
4. Solvent properties
    a. Water is polar, so it forms shells around polar molecules, preventing the polar molecules from clustering together.

Hydrophilic and hydrophobic

1. Hydrophilic substances are "water loving"
    a. These dissolve in water to form a solution
2. Hydrophobic substances are "water fearing"
    a. These substances tend to clump together in water. This is because the nonpolar molecules attract each other.
        i. This is called "hydrophobic interactions"

Comparing water and methane

1. Methane is a waste product of anaerobic respiration
2. Methane (CH_4) is nonpolar, so it has many different properties.
    a. For example, the thermal properties (much lower melting/boiling point because of the weaker intermolecular forces)

Cooling the body with sweat

1. Use of water as a coolant in sweat
    a. Sweat is secreted by glands in the skin. Sweat is carried along narrow ducts to the surface of the skin, where it spreads out.
    b. Heat from the body is used to help evaporate the sweat, which reduces the temperature of the body.
2. Sweat control
    a. Sweat secretion is controlled by the hypothalamus
        i. This is an example of a negative feedback loop!

Transport in blood plasma

1. Sodium chloride (ions)
    a. Dissolves into Na+ and Cl- ions in water, which can be carried in blood
2. Amino acids
    a. Are polar, so are soluble in water (however, this depends on the functional (R) group (if it is hydrophobic))
    b. Carried in plasma
3. Glucose
    a. Polar, carried in blood plasma
4. Oxygen
    a. Nonpolar and very very small. SOME of it can dissolve in water, but not a lot
    b. However, the concentration in blood is not high enough for cellular respiration, so we use Hemoglobin (protein with binding spots for oxygen)
5. Fat molecules
    a. Nonpolar and large
    b. Carried with lipoprotein complexes
        i. These complexes are like a vesicle, but they have a single layer of phospholipids with fats on the inside. There are also a few proteins in the monolayer.
        ii. The phospholipid heads are polar, so this structure can move through water
6. Cholesterol
    a. Mostly hydrophobic with a small polar ending.
    b. Its mostly nonpolar so it has to be transported with fats in lipoprotein complexes (same complex to transport fats)
    c. Cholesterol can fit into the phospholipid monolayer.

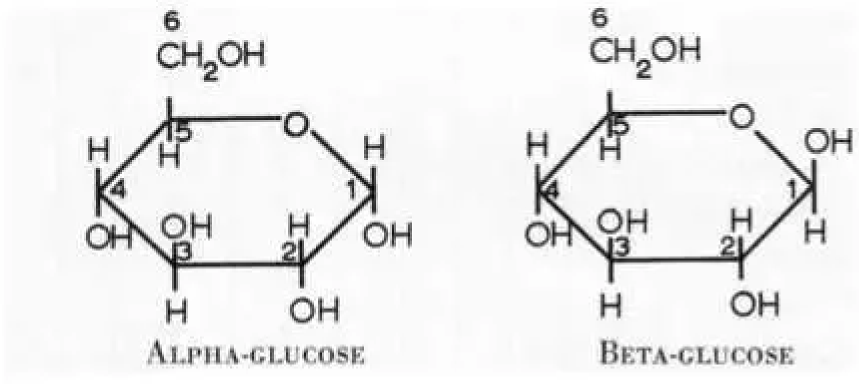
2.3

Carbohydrates
1. Monosaccharides (glucose, fructose, ribose) are single sugar units
2. Disaccharides consist of two monosaccharides linked together.
    a. Maltose is made out of 2 glucose linked together
    b. Sucrose is made out of 1 glucose and 1 fructose
3. Polysaccharides consist of many monosaccharides linked together (starch, glycogen, cellulose)

The combination of monosaccharides is called condensation.
- Caused by loss of -OH group and -H group
- ATP supplies energy for this process

Imaging carbohydrate molecules
1. Jmol :)))))))

Polysaccharides
1. Starch, glycogen, and cellulose are made of glucose molecules, but they still have vastly different functions and structures
2. Alpha glucose
    a. -OH group on the first carbon atom points down
3. Beta glucose
    a. -OH group on the first carbon atom points up



1. Cellulose
    a. Made out of beta glucose.
    b. Each Beta glucose is positioned 180 degrees in respect to the previous one, causing cellulose to form a straight chain
    c. Cellulose is unbranched, allowing for a lot of hydrogen bonds
        i. These hydrogen bonds form "bundles" which are called **microfibrils**
        ii. This makes cellulose pretty strong with a lot of tensile strength, ideal for cell walls
2. Starch
    a. Made out of alpha glucose molecules
    b. All glucose molecules are rotated the same way, forming a curved chain
    c. Made from plant cells
    d. Stores energy
3. Glycogen
    a. Similar to starch, but there is more branching, causing glycogen to be more compact
    b. Energy storage in humans (found in liver and muscles)
4. Starch and glycogen are found where large stores of glucose would cause osmotic problems

Lipids

1. Most common is triglycerides
    a. Made out of three fatty acids and one glycerol
    b. Bonds formed with condensation reactions
    c. Ester bond
        i. Linkage formed between fatty acid and glycerol
        ii. Reaction happens between -COOH of fatty acid and -OH on glycerol
    d. Used for energy storage or heat insulators

Energy storage

1. Lipids and carbohydrates are all used for energy storage, BUT lipids are generally for long term energy storage.
2. Adipose tissue
    a. Specialized groups of fat cells
    b. Located beneath skin and around some organs like the kidneys
3. Lipids as long term storage:
    a. Releases more energy in cell respiration (2 times more than carbohydrates)
    b. Lipids are used as heat insulators and used as shock absorbent, so it has other uses as well
4. Glycogen as short term storage:
    a. Glycogen can be broken down to glucose rapidly and transported easily by blood to where it is needed.
    b. Lipids take a longer time to be broken down into glucose so it is less ideal for short term storage/

Body mass index

1. Formula:
    a. BMI = (mass in kilos) / (height in meters)^2
2. Accumulating too much fat = leads to coronary heart disease and type 2 diabetes

Fatty acids

1. Structure: chain of carbon atoms with H atoms linked to them with covalent bonds (hydrocarbon chain)
    a. At the end there is a carboxyl group (-COOH). This is polar, but the entire fatty acid still is considered non-polar
2. Length of hydrocarbon chain- 14-20 carbon atoms
3. Saturated fatty acid
    a. Fatty acids with single bonds between all of its carbon atoms
        i. Contains as much hydrogens as possible. Each carbon is bonded to 2 hydrogens
4. Unsaturated fatty acids
    a. Have one or more double bonds
    b. Monounsaturated
        i. Just one double bond
    c. Polyunsaturated
        i. More than one double bond

Unsaturated fatty acids

1. Unsaturated fatty acids can be Cis or Trans isomers
    a. Cis- fatty acids
        i. When hydrogen atoms are on the same side of the two carbon atoms that are double bonded
    b. Trans-fatty acids
        i. When hydrogen atoms are on the opposite side of the two carbon atoms that are double bonded
2. Cis- causes a bend at the double bonded area
    a. These are less "packed" because of the bend, so they are generally liquid at room temp
3. Trans- do not have a bend anywhere
    a. Higher melting point.
    b. Created by partial hydrogenation of vegetable or fish oils
    c. Produces solid fats

Health risk of fats

1. Coronary heart disease
    a. Coronary arteries become partially blocked by fatty acids, leading to blood clots and heart attacks
2. There is a general positive correlation between saturated fatty acid intake and rates of CHD.

2.4 proteins

1. Amino acids and polypeptides
    a. Polypeptides are chains of amino acids that are made by linking together amino acids by condensation reactions
    b. These polypeptides then make up proteins
    c. Condensation occurs between the amine group and the carboxyl group

2. Oligopeptides
    a. Chains of fewer than 20 amino acids

Drawing peptide bonds

Dipeptide- two amino acids linked by condensation reaction

Recognizing peptides:

Chain of atoms linked with covalent bonds with a repeating sequence of –N-C-C-
Each hydrogen atom is linked with a single bond to each nitrogen atom. Each oxygen atom is linked by a double bond to one of the two carbon atoms
R groups project out from the backbone.

The diversity of amino acids

- There are twenty different amino acids in polypeptides synthesized on ribosomes
- There are 20 different functional groups (R Groups)

Amino Acids and Origins

- Most organisms make proteins using the same 20 amino acids
- Hypothesis about the origin of amino acids:
    - The 20 amino acids were created by chemical processes before the origin of life
    - These are the 20 amino acids that are the most ideal, so no other amino acids exist because of natural selection
    - All life evolved from a single species that used these 20 amino acids..

Polypeptide diversity

- There can be a lot of proteins made.
    - For a chain of peptides "n" long, there are 20^n different combinations

Genes and polypeptides

1. Amino acid sequences for polypeptides is coded for by genes.
2. Open reading frame
    a. The base sequence on DNA that actually codes for a polypeptide
    b. This is because there are always extra DNA sequences at both ends and at certain points in the middle

Proteins and polypeptides

1. Proteins may consist of a single polypeptide or more than one polypeptide linked together

Protein conformations

1. The amino acid sequence determines the 3D conformation of a protein
   - Different interactions between the functional groups

Denaturation of proteins

1. Bonds between amino acids are generally pretty weak, so its pretty easy to deform them (denature)
2. Denatured proteins do not normally return to its former structure
3. Heat
   a. Cause denaturation because it causes vibrations within the molecule that break intermolecular bonds or interactions.
4. PH
   a. Extremes of pH can change charges on R groups, breaking ionic bonds or causing new ionic bonds to be formed.

Protein functions

1. Catalysis
   a. Thousands of different enzymes to catalyze specific chemical reactions in the cell
2. Muscle contraction
   a. Acting and myosin together cause the muscle contractions used to move the body
3. Cytoskeletons
   a. Tubulin is a subunit of microtubules that gives animal cells their shape
4. Tensile strengthening
   a. Fibrous proteins give tensile strength in skin, tendons, ligaments, and blood vessel walls
5. Blood clotting
   a. Plasma proteins act as clotting factors that cause blood to turn from a liquid to a gel in wounds
6. Transport of nutrients and gases
   a. Proteins in blood help transport oxygen, carbon dioxide, iron, and lipids
7. Cell adhesion
   a. Membrane proteins cause adjacent animal cells to stick to each other within tissues
8. Membrane transport
   a. Membrane proteins are used for facilitated diffusion and active transport
9. Hormones
   a. Insulin, FSH, LH
10. Receptors
    a. Binding sites in membranes and cytoplasm for hormones, neurotransmitters
11. Packing of DNA
    a. Histones used to help chromosomes condense during mitosis
12. Immunity
    a. Antibodies

Proteomes

1. Proteome- all of the proteins produced by a cell, tissue, or an organism
2. Genome- all the genes of a cell, tissue, or organism
3. Gel electrophoresis- can identify the proteins being produced by a cell
4. Every individual has a unique proteosomes because of different DNA and different DNA tags.

Examples of proteins??

2.5 enzymes

1. Active sites and enzymes
    a. Enzymes- globular proteins that work as catalysts (speeding up chemical reactions)
    b. Substrate
        i. Substances enzymes convert into products
    c. Enzyme-substrate specificity
        i. Unique enzyme for each chemical reaction
    d. Active site
        i. Only allows substrate to bind to this part
2. Enzyme activity
    a. Steps:
        i. First, a substrate binds to the active site
        ii. Substrates change into products
        iii. Products leave active site
3. Factors affecting enzyme activity
    a. Temperature
        i. Higher temperatures
            1. Substrate and enzyme molecules move around faster and a higher chance of colliding correctly
        ii. Very high temperatures
            1. Substrate denatures because vibrations disrupt bonding in enzyme
    b. PH
        i. Different pH can denature the protein
        ii. Each enzyme has a particular pH that it works best in
    c. Substrate concentration
        i. If there are more substrates, there is a higher chance that the substrate and enzyme collide correctly.'
        ii. However, because each reaction takes some amount of time, there is a limited ability that substrate concentration can affect reaction speed

4. Denatured
    a. Enzymes are proteins so they can be denatured

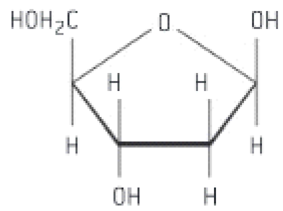
5. immobilized enzymes
    a. Immobilized enzymes are attached to another material so the movement of the enzyme is restricted.
    b. Advantages
        i. The enzyme can be easily separated from the products of the reaction, preventing contamination
        ii. The enzymes can be recycled (saving $$)
        iii. Increases the stability of enzymes to changes in temperature and pH, so they do not get degraded
        iv. Substrate can be exposed to higher enzyme concentrations, increasing reaction speeds

6. Lactose-free milk
    a. Lactose is a sugar in ilk
    b. By using lactase, we can remove lactose from milk

c. This can help lactose intolerant people

Structure of DNA and RNA 2.6

1. Nucleic acids
    a. Nucleotides create nucleic acids. The structure of nucleotides:
        i. Sugar- 5 carbons, a pentose
        ii. Phosphate- acidic, negatively charged
        iii. Base- contains nitrogen and has 1-2 rings
2. Differences between DNA and RNA
    a. The sugar in DNA is deoxyribose and the sugar in RNA is ribose
    b. There are generally two polymers of nucleotides in DNA but only one in RNA
        i. Polymers are referred to as "strands", so DNA is double stranded and RNA is single stranded
    c. RNA has Uracil instead of Thymine



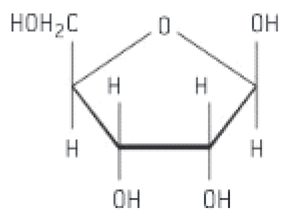
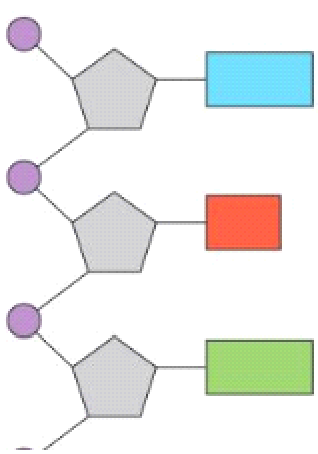
3. 

Figure 3 The sugar within DNA is deoxyribose (top) and the sugar in RNA is ribose (bottom)

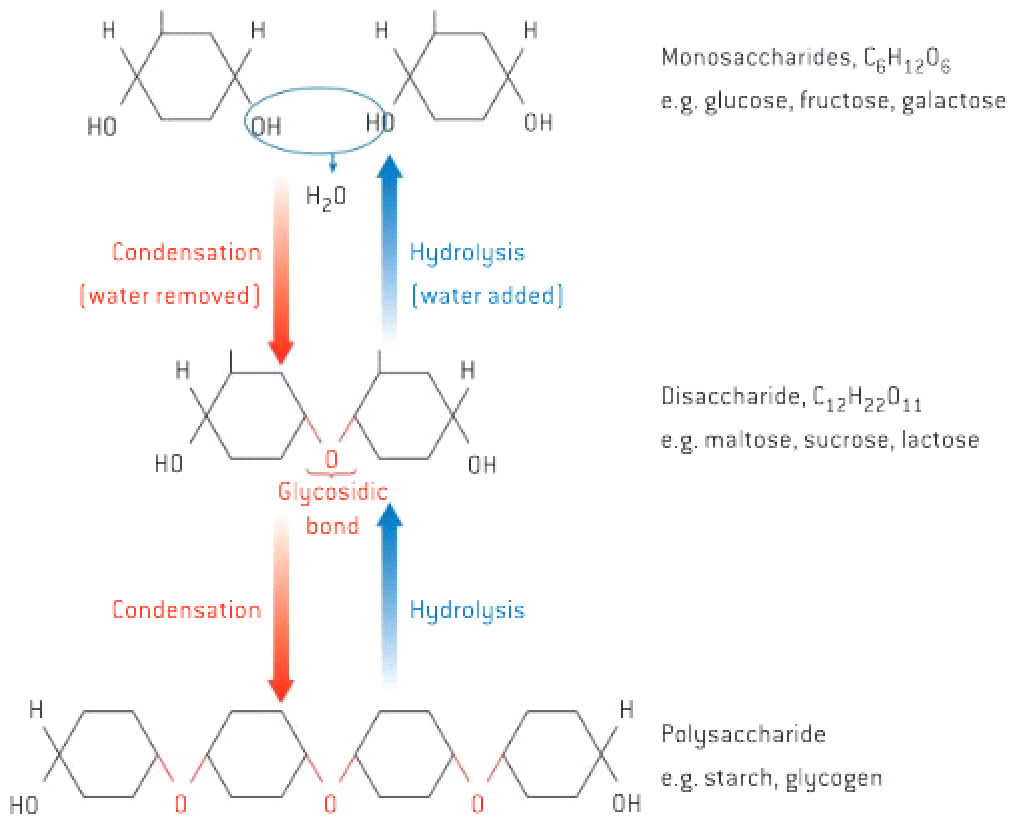
4. Drawing DNA and RNA
    a. Draw circles for phosphates
    b. Pentagons for pentose sugar
    c. Rectangles for bases



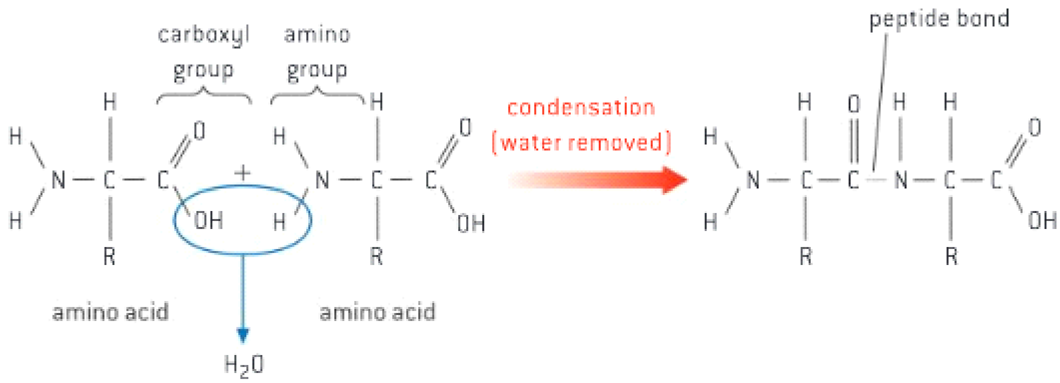
a. Remember that adenine only pairs with thymine and cytosine only pairs with guanine
b. 3' vs 5'
    i. The 3' end means there is a phosphate attached to the third carbon on the pentose
    ii. The 5' end means there is a phosphate attached to the fifth carbon of the pentose

4. Structure of DNA
    a. Each strand contains a chain of nucleotides linked with covalent bonds
    b. Antiparallel
        i. The strands run in opposite directions (one from 3' to 5' and the other 5' to 3')
    c. Double helix
        i. Two strands of DNA wound together in a bent up structure
    d. Complementary base pairing
        i. A and T pair
        ii. G and C pair
5. Crick and Watson's model of DNA structure
    a. These two guys relied on 3d models to make their "discoveries"

Other important information



▲ Figure 1 Condensation and hydrolysis reactions between monosaccharides and disaccharides



Number of polypeptides	Example	Background
1	lysozyme	Enzyme in secretions such as nasal mucus and tears; it kills some bacteria by digesting the peptidoglycan in their cell walls.
2	integrin	Membrane protein used to make connections between structures inside and outside a cell.
3	collagen	Structural protein in tendons, ligaments, skin and blood vessel walls; it provides high tensile strength, with limited stretching.
4	hemoglobin	Transport protein in red blood cells; it binds oxygen in the lungs and releases it in tissues with a reduced oxygen concentration.

▲ Table 3 Example of proteins with different numbers of polypeptides