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Biology

Chapter 5

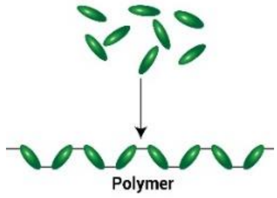
The structure and function of large biological molecules

Med learn

❖ Introduction

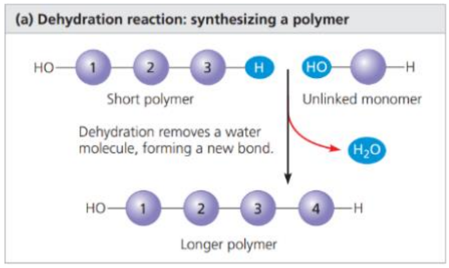
- All organisms are composed of four types of biological molecules (carbohydrates, lipids, proteins & nucleic acids)
  - ➢ **Macro**-molecules = **large** molecules such as large carbohydrates, proteins & nucleic acids

❖ 5.1: [Macromolecules are polymers, built from monomers]



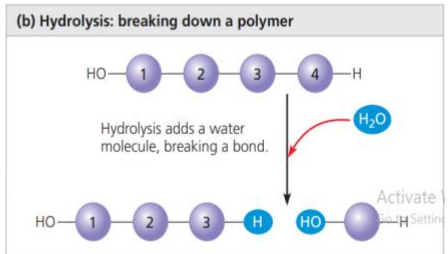
- **Polymer: (Poly = Many)** It is a long molecule consisting of <u>many similar or identical building blocks</u> linked by **covalent bonds**
  - ➢ <u>**Only**</u> carbohydrates, proteins & nucleic acids are considered as polymers
- **Monomers:** The repeating units that serve as the **building blocks of the polymer**

- **The Synthesis of Polymers:**
  - ➢ It is called **polymerization** or **<u>de</u>hydration** reaction
  - ➢ It is the reaction that <u>connects</u> monomers (2 molecules) to each other **via a covalent bond** → and it involves the <u>**loss** of a water molecule</u>



  - ➢ During dehydration reaction, each monomer contributes in a part of the water molecule that is released (lost) during the reaction
    - o One monomer provides a **hydroxyl group (OH^-)**
    - o The other one provides a **hydrogen ion (H^+)**

- **The Break-down of Polymers:**
  - ➢ It is called **hydrolysis** reaction
  - ➢ It is the reaction that <u>disassembles</u> polymers into monomers by **breaking covalent bond** between monomers by the <u>**addition** of a water molecule</u>

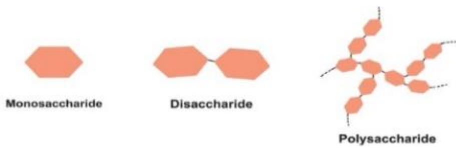


- An example of hydrolysis within our bodies is <u>**digestion**</u> process of organic materials in our food which present in the form of polymers that are too large to enter our cells
  - ➢ Within our bodies various **enzymes** attack the polymers **speeding up** hydrolysis → Releasing the monomers which are absorbed into the bloodstream and distributed to all body cells

- Dehydration & hydrolysis reactions <u>can also be involved</u> in the formation and breakdown of molecules that are <u>**not polymers**</u>, such as <u>lipids</u>

- **The Diversity of Polymers:**
  - o Each cell has thousands of different macromolecules
  - o Macromolecules vary among cells of an organism, vary more between different individuals from the same species, and vary even more between different species
  - o A huge variety of polymers can be built from a small set of monomers

❖ 5.2: [Carbohydrates serve as fuel and building material]



- **Carbohydrates** are <u>sugars</u> and the polymers of sugars
- Carbohydrate divided into 3 classes:
  - **Mono-saccharides ➔** The <u>simplest</u> class of carbohydrates → they represent the <u>monomers</u> from which more complex carbohydrates are built ➔ consist of <u>1 sugar only</u>
  - **Di-saccharides ➔ Double sugars ➔** consist of <u>two monosaccharides</u>
  - **Poly-saccharides ➔ Many sugars ➔** consist of <u>3 or more monosaccharides</u> forming carbohydrate macromolecules

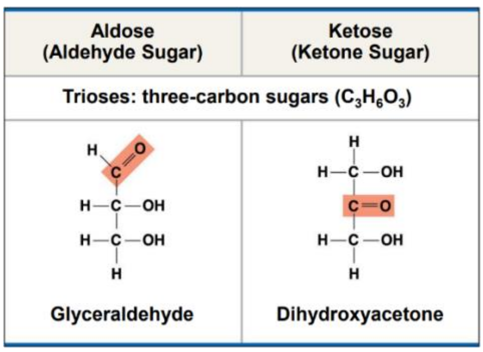
☐ Monosaccharides

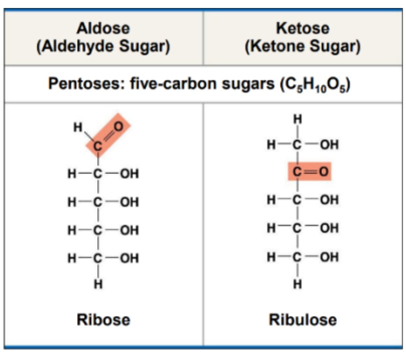
- Each monosaccharide has a <u>carbonyl group C=O</u>, and <u>multiple hydroxyl groups OH^-</u>
- Their molecular formulas are usually multiples of **<u>CH_2O</u>**
- They serve as a ***<u>major fuel for cells</u>*** and as ***<u>raw material for building molecules</u>***
- The most common monosaccharide is **Glucose ($C_6H_{12}O_6$)**
  - ➢ It is the major nutrient for cells which is used in the process of **cellular respiration**

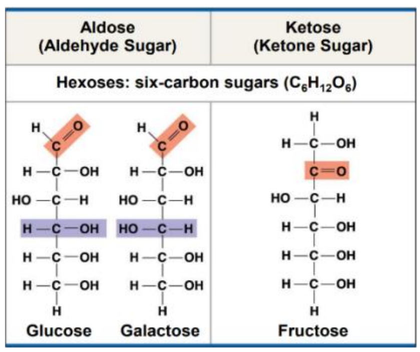
- Monosaccharides can be classified according to:

  1) <u>The location of carbonyl group:</u>
  - ✓ **<u>Aldose</u>** → <u>Terminal</u> carbonyl group → aldehyde sugar (such as <u>Glucose, Galactose, Ribose & Glyceraldehyde</u>)
  - ✓ **<u>Ketose</u>** → The carbonyl group is in the <u>middle</u> → ketone sugar (Such as <u>Fructose, Ribulose & Dihydroxyacetone</u>)

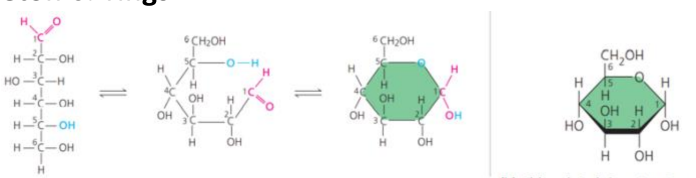
  2) <u>The number of carbons:</u>
  - ✓ **<u>Triose</u>** → consists of <u>3</u> carbons (such as <u>Glyceraldehyde & Dihydroxyacetone</u>) → the smallest
  - ✓ **<u>Tetrose</u>** → consists of <u>4</u> carbons
  - ✓ **<u>Pentose</u>** → consists of <u>5</u> carbons (such as <u>Ribose & Ribulose</u>)
  - ✓ **<u>Hexose</u>** → consists of <u>6</u> carbons (such as <u>Glucose, Galactose & Fructose</u>)







- Monosaccharides can be in the form of **linear skeleton** or **rings**
  - ➢ Often they form <u>rings</u> in aqueous solutions

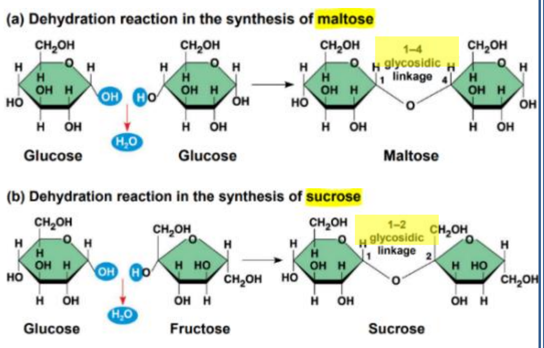


(a) Linear and ring forms.

(b) Abbreviated ring structure.

☐ Disaccharides

- They are formed when a **dehydration** reaction joins **two** monosaccharides, by a covalent bond called glycosidic linkage
- Examples of disaccharide:
  - Maltose (malt sugar) ➔ **Glucose + Glucose**
  - Sucrose (table sugar) ➔ **Glucose + Fructose**
  - Lactose (milk sugar) ➔ **Glucose + Galactose**
- Disaccharides must be broken down into monosaccharides to be used for energy by organisms

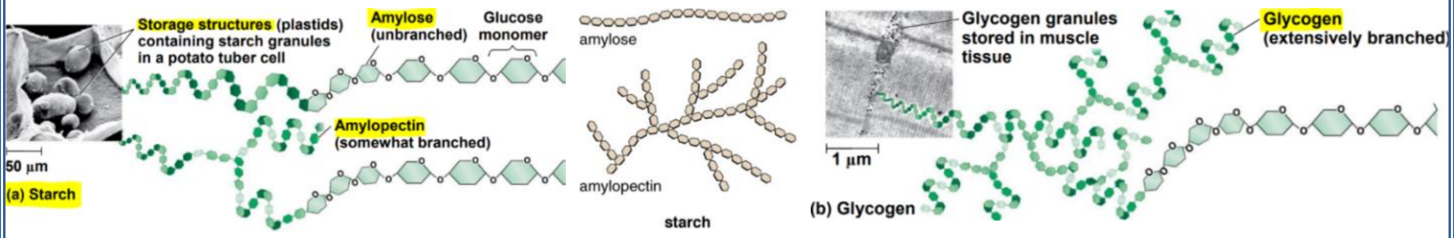


- **Lactase** is the enzyme that breaks down (hydrolyze) lactose
  - ➢ people who lack this enzyme suffer from **lactose intolerance, so:**
    - Lactose is broken down by intestinal bacteria instead of lactase → causing the formation of **gas** and subsequent **cramping**
    - The problem may be avoided by → uptaking lactase in dairy products

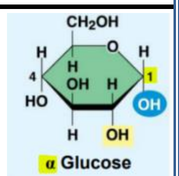
☐ Polysaccharides

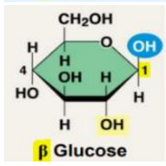
- They are polymers with a few hundred to a few thousand monosaccharides (**more than 2**) joined by glycosidic linkages
- The architecture and function of a polysaccharide are determined by its sugar monomers and the positions of its glycosidic linkages
- **Polysaccharides** classified according their roles:
  - ➢ **Storage Polysaccharides**
    - ✓ They **store** sugars and energy until needed
    - ✓ Such as starch in plants & glycogen in animals
  - ➢ **Structural Polysaccharides**
    - ✓ They are **structurally support** cells and organisms
    - ✓ Such as cellulose in plants & chitin in animals

Storage Polysaccharides	Starch	Glycogen
	Present in **plants** as granules within plastids (such as chloroplast)	Present in **animals** (mainly in **liver** & **muscle** cells of vertebrates)
	Composed of many **α-glucose** monomers linked by α (1–4) glycosidic linkage	Composed of many **α-glucose** monomers linked by α (1–4), (1–6) glycosidic linkages
	• We have enzymes that can hydrolyze (Break down) starch • The major sources for starch are potato tubers and grains, the fruits of wheat, maize (corn), rice and other grasses • **There are 2 forms (types) of starch:** 1. **Amylose:** Simple and unbranched 2. **Amylopectin:** complex and branched with α (1–6) linkages at the branch points	• It is a **highly branched** polysaccharide and it is much more extensively branched than amylopectin ➔ that fits its function providing more free ends for hydrolysis when the demand for sugar increases • Glycogen stores cannot sustain for a long time, they deplete in about a day unless they are **replenished by eating**, which can result in weakness and fatigue



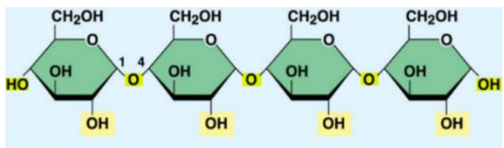
Structural Polysaccharides	Cellulose	Chitin
	Present in the <u>cell walls</u> of **plant cells**	Present in **animals** especially in the **<u>exoskeleton of arthropods</u>** (insects, spiders, crustaceans …) It also presents in the **cell wall of fungi**
	Composed of many **β-glucose** monomers linked by β (1–4) glycosidic linkage	Composed of many **β-glucose** monomers **<u>BUT</u>** the monomers of chitin have a **nitrogen-containing** attachment
	• Globally, plants produce almost 10^{14} kg (100 billion tons) of cellulose per year; **it is the most abundant organic compound on Earth** • Cellulose is the major constituent of **paper** and the **only component of cotton** • **Few** organisms possess enzymes that can digest (hydrolyze) cellulose. Almost all animals (including humans) **<u>do not</u>** possess these enzymes	• The exoskeleton of arthropods is made up from **chitin embedded in a layer of proteins** (which is leathery and flexible) but it is **<u>hardened</u>** when the proteins are chemically <u>linked to each other</u> (as in insects) or <u>encrusted with calcium carbonate</u> (as in crabs) • Exoskeleton forms a hard case (cover) that surrounds the soft part of these animals





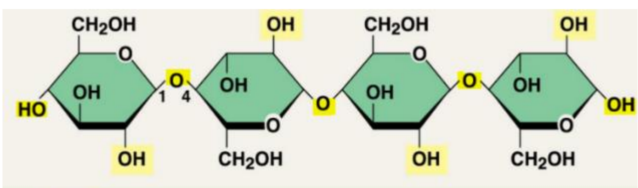
- The difference between **α-glucose and β-glucose** is based on the <u>orientation of Hydroxyl group (OH) attached on the carbon number 1</u> of each type of glucose ring
  - ➢ **Alpha (α)** → the **hydroxyl group** is positioned **<u>below</u>** number **1** carbon
  - ➢ **Beta (β)** → the **hydroxyl group** is positioned **<u>above</u>** number **1** carbon

- The **different glycosidic linkages** (α & β) in starch and cellulose give the two molecules **distinct three-dimensional shapes:**
  - ➢ **Starch** molecules (**α**) are **largely helical** increasing the efficiency for the function of glucose storage

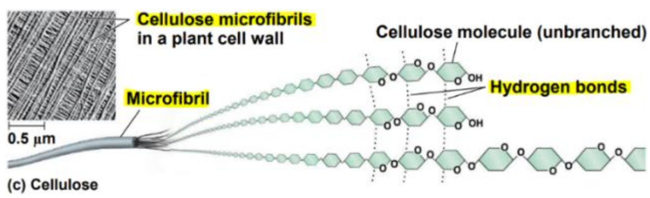


Starch: 1–4 linkage of α glucose monomers

  - ➢ **Cellulose** molecules (**β**) are **straight** & **never branched** and some <u>hydroxyl groups</u> on its glucose monomers are free to <u>hydrogen-bond</u> with the <u>hydroxyls</u> of other cellulose → make them **<u>parallel</u>** <u>to each other and</u> they are grouped into units called **<u>microfibrils</u>** → increasing the efficiency for the function of structural support (cellulose as a strong building material for plants)



Cellulose: 1–4 linkage of β glucose monomers



- Most fruits, vegetables and whole grains are rich in cellulose
- As we said, we don't have the enzymes that hydrolyze cellulose → so when we eat cellulose in our food it passes through the digestive tract → and is **eliminated with the feces (not digested)**
    - **Insoluble fiber** → refers mainly to **cellulose**
- As cellulose is passing through the digestive system it **stimulates the lining epithelium to secrete mucus** → which aids in the smooth passage of food through the tract
- Some microorganisms can digest cellulose, such as:
    - **prokaryotes** and **protists** in cow gut & a termite
    - **Some fungi** can also digest cellulose in soil and elsewhere, thereby helping recycle chemical elements within Earth's ecosystems

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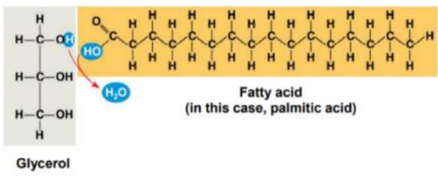
❖ 5.3: [Lipids are a diverse group of hydrophobic molecules]

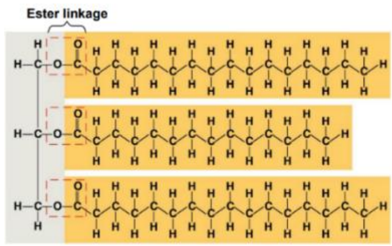
- Lipids are large biological molecules and they are generally not big enough to be considered macromolecules also they do not include true polymers
- The unifying feature of lipids is that → they mix poorly with water → **Hydrophobic** → **non-polar**
    - The hydrophobic behavior of lipids is based on their molecular structure → lipids consist mostly of hydrocarbon regions
- Lipids vary in form and function
    - They include **waxes** and **certain pigments**, but the most important biologically: **fats**, **phospholipids**, and **steroids**

☐ Fats



(a) One of three dehydration reactions in the synthesis of a fat

- Fats are **not polymers**; they are large molecules assembled from smaller molecules by **dehydration**
- A fat is constructed from two kinds of smaller molecules: glycerol and fatty acids
    - Glycerol → is a **three-carbon alcohol** with **a hydroxyl group** attached to each carbon
    - Fatty acid → consists of a **carboxyl group** attached to a long **hydrocarbon skeleton** (usually **16** or **18** carbon)

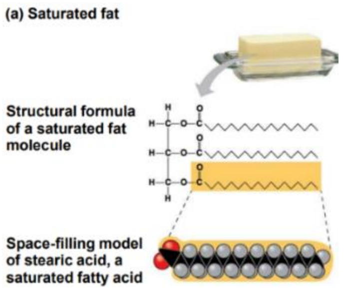


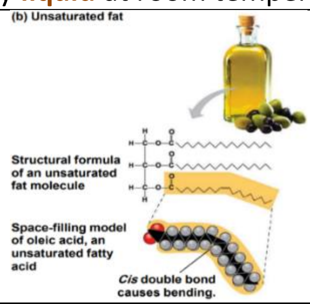
(b) Fat molecule (triacylglycerol)

- In a fat, **3 fatty** acids are joined to **glycerol** by an **ester linkage** creating a **triacylglycerol**, or **triglyceride**
- The fatty acids in a fat can be all the same or of two or three different kinds
- Fatty acids are called acids due to the presence of carboxyl group
- Fatty acids are hydrophobic due to the relatively **non-polar (C-H) bonds** in the hydrocarbon chains
- Fats are **separated** from water because the water molecules **hydrogen-bond** to one another and exclude the fats → so, vegetable oil (a liquid fat) is separated from the aqueous vinegar

- Fatty acids vary in length (number of carbons) and in the number and locations of double bonds
  - ➢ We can classify fatty acids according to the presence of double bonds into <u>saturated</u> or <u>unsaturated</u>

<u>Saturated fatty acids</u>	<u>Unsaturated fatty acids</u>
There are **no double bonds** between carbon atoms composing a chain	There is **<u>one or more</u> double bonds** between carbon atoms composing a chain
The **maximum** number of hydrogen atoms	The **fewer** number of hydrogen atoms
They are flexible allowing fat molecules to **pack together tightly**	Double bonds create **kinks** in the hydrocarbon chain which **prevent** the tight packing of molecules
Ex: Saturated **animal fat** such as lard and butter	**Ex**: The fats (oils) of **plants** and **fishes** such as (olive oil and cod liver oil)
Solid at room temperature	Usually **liquid** at room temperature





- Unsaturated fatty acids are divided into 2 types:
  - ➢ **Cis:** Appears **naturally** → contain kinks preventing tight packing → prevent solidifying → liquid
  - ➢ **Trans:** Appears by **hydrogenation** → no kinks → solidify at room temperature
- **Hydrogenation:** It is the process of <u>converting unsaturated fats</u> to <u>saturated fats</u> by <u>**adding hydrogen**</u>
  - o Hydrogenation produce trans fats
  - o Examples on hydrogenated products: **Peanut butter, margarine**

- A diet rich in **saturated fats** may contribute to → **cardiovascular disease** through plaque deposits
  - o Trans fats may <u>**contribute more**</u> than saturated fats to cardiovascular disease
  - o Trans fats are especially common in baked goods and processed foods
  - o **fats** can also contribute to **coronary heart disease**

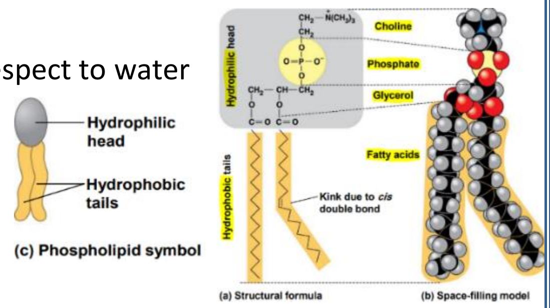
- The major function of fats is → **energy storage**
  - ➢ A gram of fat stores <u>more than twice</u> as much energy as a gram of a polysaccharide (starch)
  - ➢ Humans and other mammals store their **long-term food** reserves as <u>fat in adipose cells</u>
- Adipose tissue also **cushions vital organs** and **insulates the body**

☐ Phospholipids

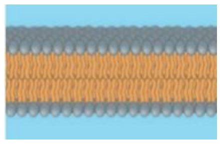
- They are similar to fat but they have **only** <u>2</u> fatty acids attached to glycerol rather than three
  - ➢ <u>Two</u> hydroxyl group of glycerol are attached to <u>2 fatty acids</u> and the <u>third</u> hydroxyl group is joined to <u>a phosphate group</u>, which has a **negative** electrical charge in the cell
  - ➢ A small charged or polar molecule is also linked to the phosphate group such as **Choline**

- **Phospholipids** are **major** constituents of <u>cell membranes</u>

- The two ends of phospholipids show different behaviors with respect to water
  - The **two fatty acid** tails are → **hydrophobic**
  - The **phosphate group** + the attached **polar group** form a **hydrophilic head**
  - So, they are called **amphipathic** (has polar and non-polar)

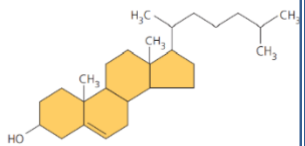


- When phospholipids are added to water, they self-assemble into a **double-layered sheet** called bilayer that **shields their hydrophobic** fatty acid tails from water
- Phospholipids in the cell membrane at the surface of a cell also form a bilayer:
  - The **hydrophilic heads** of the molecules are **exposed outside** the bilayer in **contact with the aqueous solutions** inside and outside of the cell
  - The **hydrophobic tails** point toward the **interior of the bilayer away from water**



- This phospholipid bilayer Forms a boundary between the cell and its external environment

☐ Steroids



- They are lipids characterized by a carbon skeleton consisting of **four fused rings**
- Cholesterol is a type of steroid:
  - It is a common component of **animal** cell membranes
  - It is the precursor from which other steroids are synthesized
  - The vertebrate sex hormones are synthesized from cholesterol
  - Cholesterol is **synthesized in the liver** or **obtained from diet**
  - High levels of cholesterol in the blood may contribute to cardiovascular disease and atherosclerosis

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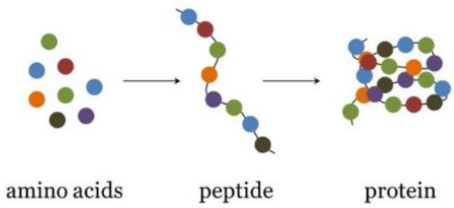
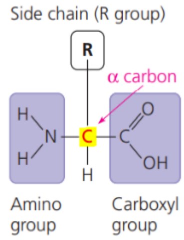
❖ 5.4: [Proteins include a diversity of structures, resulting in a wide range of functions]

- Proteins account for more than 50% of the dry mass of most cells
- **Structure of protein:**
  - Proteins are composed of **unbranched polymers of amino** acids called **Polypeptides**
  - The monomers are amino acids which they are organic molecules with amino and carboxyl groups
  - Proteins are all constructed from the same set of 20 amino acids
  - The bond between amino acids is called → **peptide bond**
- Each type of protein having a **unique three-dimensional (3D) shape** and **specific function**
  - A protein is made up of 1 or more polypeptides, each folded and coiled into a specific 3D structure



☐ Amino Acids (The Monomers)

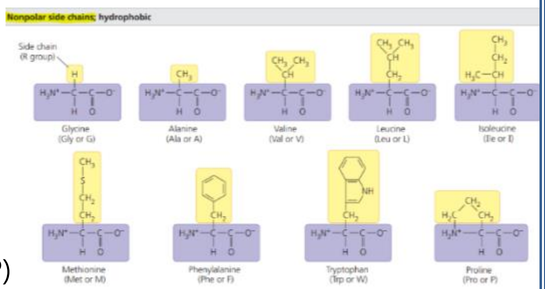


- All amino acids share a common structure ➔ they are composed from:
  - At the center there is an **asymmetric carbon** atom called the alpha **(α) carbon**
  - α carbon is linked to <u>four different</u> partners (amino group, carboxyl group, hydrogen atom, and a variable group symbolized by R)

- Amino acids differ in their properties due to the <u>difference in the side chain (R group)</u>
  - ➢ The side chain (R group) may be as simple as a **hydrogen atom** (as in the amino acid **glycine**) or it may be a carbon skeleton with various functional groups attached (as in glutamine)
  - ➢ The physical and chemical properties of the side chain (R group) determine the unique characteristics of a particular amino acid, thus affecting its functional role in a polypeptide

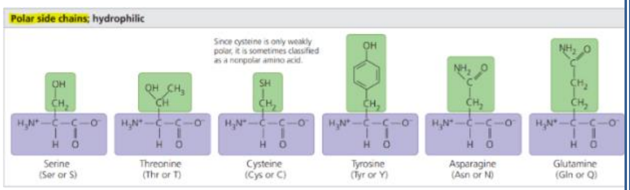
- **<u>The amino acids are grouped according to the properties of their side chains:</u>**

1) Nonpolar Amino Acids



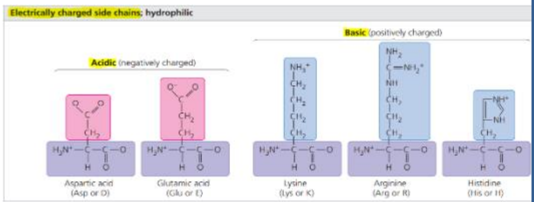
- ➢ They are **<u>hydrophobic</u>**
- ➢ They **don't contain** OH/NH_2/ SH in the side chain
- ➢ **Examples:** **Glycine** (Gly, G), **Methionine** (Met, M), **Leucine** (Leu, L), **Isoleucine** (Ile, I), **Alanine** (Ala, A), **Valine** (Val, V), **Phenylalanine** (Phe, F), **Tryptophan** (Trp, W), **Proline** (Pro, P)

2) Polar amino acids



- ➢ They are **<u>hydrophilic</u>**
- ➢ They **contain** <u>OH / NH_2 / SH</u> in the side chain
- ➢ **Examples:** **Serine** (Ser, S), **Threonine** (Thr, T), **Cysteine** (Cys, C), **Tyrosine** (Tyr, Y), **Asparagine** (Asn, N), **Glutamine** (Gln, Q)

3) Electrically charged amino acids

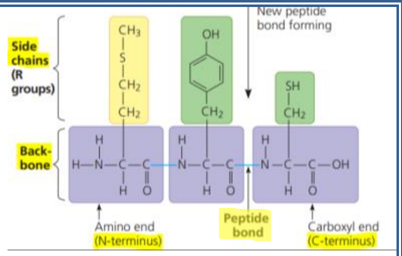


- ➢ They are **<u>hydrophilic</u>**
- ➢ They can be either **acidic (-)** and **basic (+)**
- ➢ **Examples:**
  - ✓ Acidic → **Aspartic acid** (Asp, D), **Glutamic acids** (Glu, E)
  - ✓ Basic → **Lysine** (Lys, K), **Arginine** (Arg, R), **Histidine** (His, H)

☐ Polypeptides (Amino Acid Polymers)

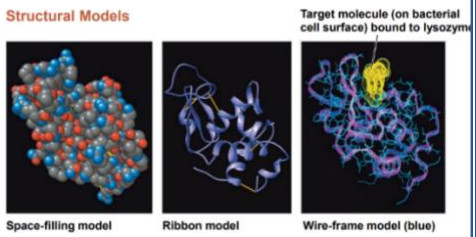
- **Dehydration reaction** between 2 adjacent amino acids (between the <u>amino group of the first one</u> and the <u>carboxyl group of the other</u>) → results in the formation of a <u>covalent</u> bond called **Peptide bond**
- The polypeptide is divided into 2 parts:
  - ➢ **<u>The backbone</u>** ➔ the **repeated** unit of all amino acids (<u>α-Carbon +Carboxyl + Amino + H</u>)
  - ➢ **<u>Side chain</u>** ➔ The **different** region for each amino acid (<u>R group</u>), it extends from the backbone

- Polypeptides range in length from a few amino acids to 1,000 or more
- **Ends of the polypeptides:**
  - **N-terminus:** has a free **amino group**
  - **C-terminus:** has a free **carboxyl group**



☐ Protein Structure and Function

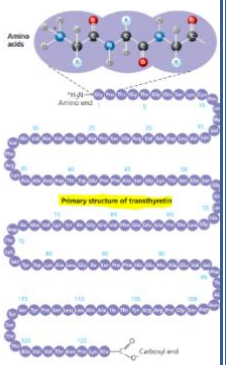
- The term polypeptide **is not** synonymous with the term protein (**Polypeptide ≠ Protein**)
  - ➢ A functional **protein** is not just a polypeptide chain, but one or more polypeptides precisely twisted, folded, and coiled into a molecule of unique shape, **intricate 3D structure** & **Function**
  - ➢ The amino **acid sequence** of each polypeptide that contributes in **determining the 3D structure of the protein** under normal cellular conditions
  - ➢ The structure of a protein is visualized & represented by:
- Structural models such as Space-filling, Ribbon & Wire-frame model
- Simplified diagrams



Four Levels of Protein Structure:

1. primary structure

- It is the unique **sequence of amino acids** of the protein like the order of letters in a long word
- What determine the primary structure of a protein is the inherited genetic information
- The primary structure in turn dictates secondary and tertiary structure, due to the chemical nature of the backbone and the side chains (R groups) of the amino acids along the polypeptide
- **Example:**
  - **Transthyretin** is made up of **four identical polypeptide chains**, each composed of **127 amino acids**
    - Transthyretin a globular blood protein that **transports vitamin A** and one of the **thyroid hormones** throughout the body

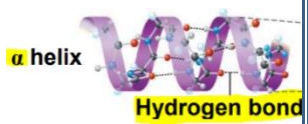


2. Secondary structure

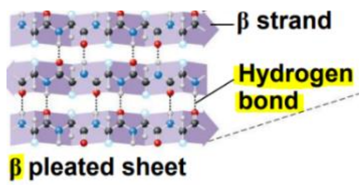
- It consists of **coils and folds in the polypeptide chain,** due to hydrogen bonds between the repeating constituents of the polypeptide **backbone** (not side chains)
  - ➢ hydrogen bonds are formed between the oxygen atoms (partially negative) and the hydrogen atoms attached to the nitrogen (partial positive charge)
  - ➢ Although H-bonds are weak, they can support protein structure because they're **repeated many times**
- The secondary structure is divided mainly into 2 shapes (**α-helix** & **β-pleated sheet**)

A. α-helix:

- ➢ A delicate **helical coil** held together by hydrogen bonding between every fourth amino acid
- ➢ **Examples:**
  - ✓ Each transthyretin polypeptide has only one α helix region
  - ✓ Other globular proteins (such as hemoglobin) have multiple stretches of α-helix separated by non-helical regions
  - ✓ Some fibrous proteins (such as α-keratin) the structural protein of hair, have the α-helix formation over most of their length

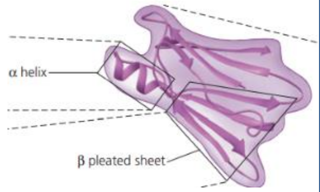


B. β-pleated sheet



- Two or more segments of the polypeptide chain lying <u>side by side</u> (β-strands) are connected by <u>hydrogen bonds</u> between parts of the <u>two parallel segments</u> of polypeptide backbone
- <u>**Examples:**</u>
  - ✓ β pleated sheets make up the <u>core of many globular proteins</u>, such as transthyretin
  - ✓ <u>Dominating</u> some fibrous proteins, such as the <u>silk protein</u> of a spider's web

3. Tertiary Structure



- It is the **overall shape** of a polypeptide resulting from <u>interactions</u> between the **side chains (R groups)** of the various amino acids
- <u>**Types of interactions that contribute in the tertiary structure**</u>:

a) **Hydrogen bonds** between **polar** side chains → help **stabilizing** tertiary structure

b) **ionic bonds** between **positively & negatively** charged side chains → help **stabilizing** tertiary structure

c) **Hydrophobic interactions** occur between the side chains of **hydrophobic** (<u>non-polar</u>) amino acids clustering them in the <u>**core**</u> of the protein <u>**away**</u> (out of contact) from aqueous solution (water)

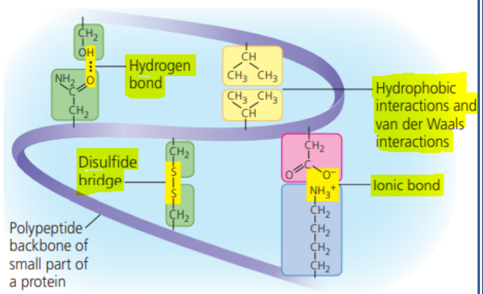
d) **Van der Waals interactions** which keep amino acids close to each other and **stabilize** the structure

e) **Disulfide bridges** which are **covalent bonds** between **2 cysteine** monomers

- They **reinforce** the shape of the protein due to their strength
- Cystine has a **sulfhydryl group (SH)** which can form disulfide bond with another Cystine

✓ **Note:**

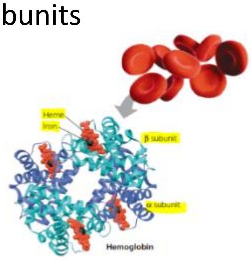
- All the previous interactions are <u>weak non-covalent</u> interactions except <u>disulfide</u> bonds which are <u>strong covalent</u> bonds



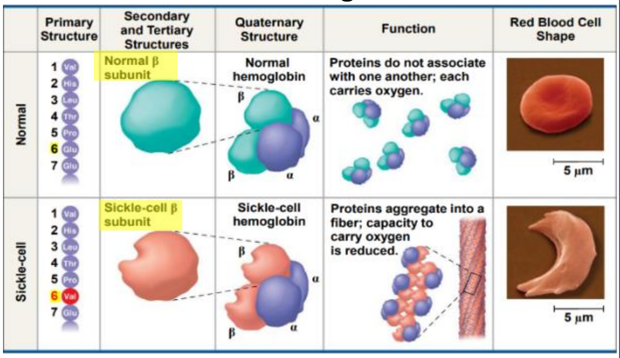
4. Quaternary structure

- It is the **overall protein structure** that results from the aggregation of <u>**polypeptide subunits**</u>
- It occurs <u>**only**</u> in proteins that consist of more than 1 polypeptide chain, such as:
  - **Transthyretin** is made up of <u>**4 identical polypeptides**</u>
  - **Collagen** is a fibrous protein that has <u>**3 identical helical polypeptides**</u> intertwined into a larger triple helix, this protein is the <u>girders of connective tissue</u> in skin, bone, tendons, ligaments & other parts
    - ✓ Collagen accounts for **40%** of the proteins in a human body

  - **Hemoglobin** a globular protein consists of <u>**4 polypeptide subunits**</u>**:** 2 α and 2 β subunits
    - ✓ Both **α** and **β** subunits consist primarily of **α-helical secondary structure**
    - ✓ Each subunit has a non-polypeptide component → **heme** with an **iron** atom that binds oxygen
    - ✓ Hemoglobin is the <u>oxygen-binding protein</u> of red blood cells

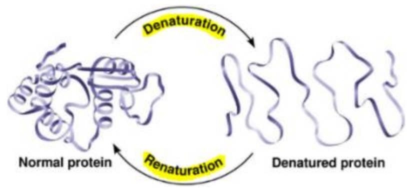


- **Sickle-Cell Disease: A Change in Primary Structure**
  - A slight change in **primary structure** → can affect a protein's **shape** and ability to **function**
  - **Sickle-cell disease**, an inherited blood disorder is caused by → the substitution of **valine** for the normal amino acid **glutamic acid** at the position of **the sixth amino acid** in hemoglobin **beta** chain
  - **Normal red blood cells** → are disk-shaped → high capacity to carry oxygen
  - **sickle-cell disease** → red blood cells **aggregate into chains** and to deform into a sickle shape → low capacity to carry oxygen
  - In sickle-cell disease, the angular cells clog tiny blood vessels cause **impeding** blood flow



- A polypeptide chain of a given amino acid sequence can be **arranged into a three-dimensional shape (native shape)** determined by the interactions responsible for secondary and tertiary structure
- protein structure also depends on the physical and chemical conditions of the protein's environment
- **Denaturation:** A change or loss of the protein shape (misshapen) caused by **destroying** chemical bonds and interactions within a protein due to the exposure of the protein to physical or chemical conditions such as **pH**, **salt concentration**, **temperature**, or other aspects of its environment
- The **denatured protein** is biologically **inactive** because it is misshapen
- **Examples of denaturation agents and causes:**
  - Most proteins become denatured if they are transferred from an aqueous environment to a **nonpolar solvent**, such as **ether** or **chloroform** → because the polypeptide chain **refolds** so that its hydrophobic regions face outward toward the solvent
  - Some chemicals that **disrupt** the hydrogen bonds, ionic bonds, and disulfide
  - **Excessive heat** agitates the polypeptide chain enough to **overpower** the weak interactions that stabilize the structure

- The white of an egg becomes opaque during cooking because **the denatured proteins are insoluble and solidify**
- The excessively high fevers can be fatal because **proteins** in the blood tend to **denature** at very high body temperatures
- When a protein has been denatured by heat or chemicals, it can **sometimes return** to its functional shape when the denaturing agent is removed → a process called **renaturation**



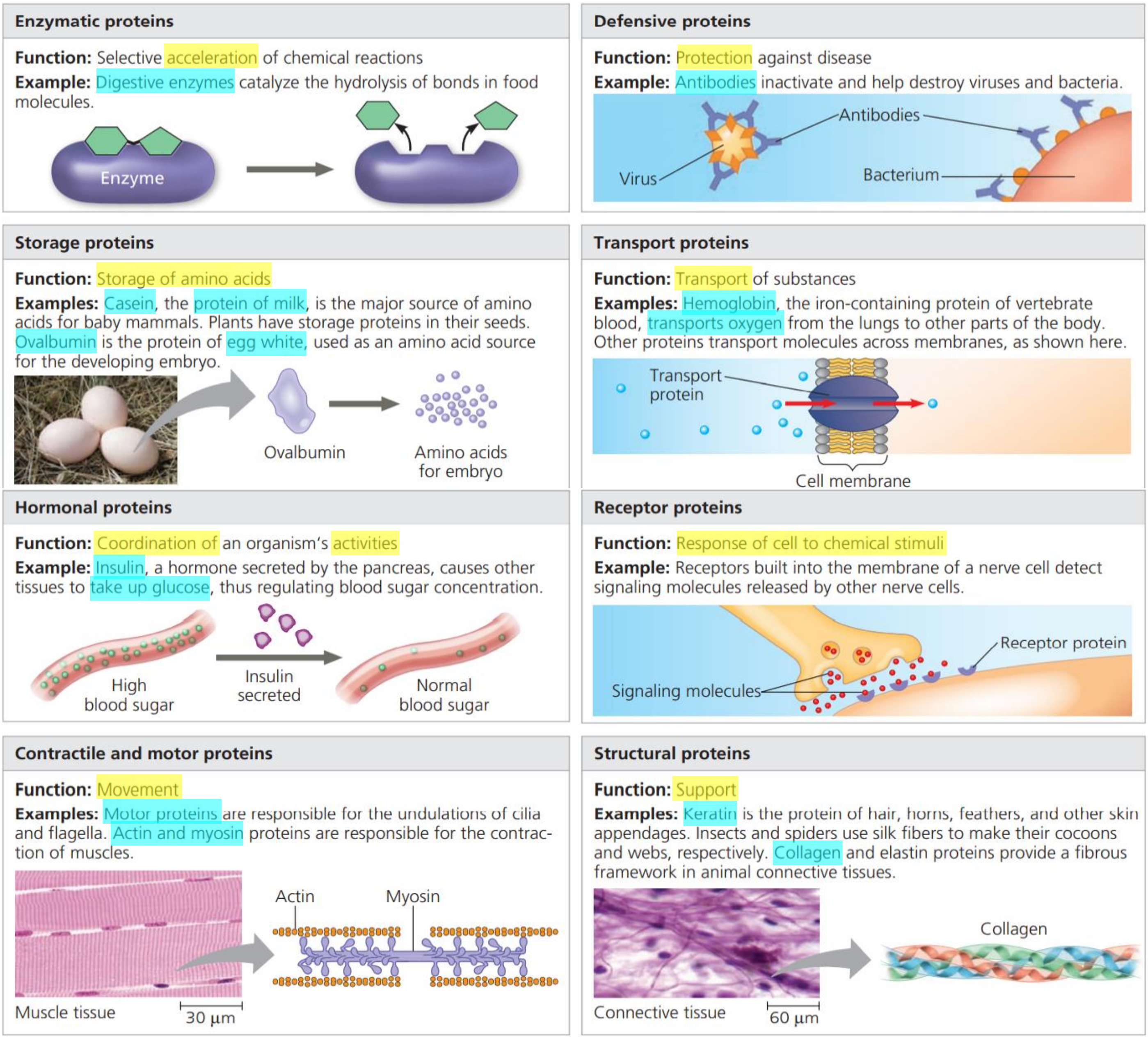
- The information for **building specific shape** is intrinsic to the protein's **primary structure**
  - The sequence of amino acids determines the protein's shape (where an α helix can form, where β pleated sheets can exist, where disulfide bridges are located, where ionic bonds can form …)

☐ Protein folding in the cell

- Misfolding of polypeptides in cells is a serious problem causing many diseases**,** (such as: **cystic fibrosis, Alzheimer's, Parkinson's, mad cow disease & senile**) which are associated with an **accumulation of misfolded proteins**

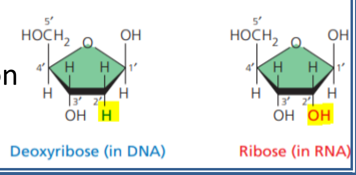
- Scientists use many methods to determine the structure (folding) of a protein, such as:
  - **X-ray crystallography**
  - **Nuclear Magnetic Resonance (NMR) spectroscopy**
- **Bioinformatics** is an approach to predict protein structure from amino acid sequences

☐ Protein's functions:

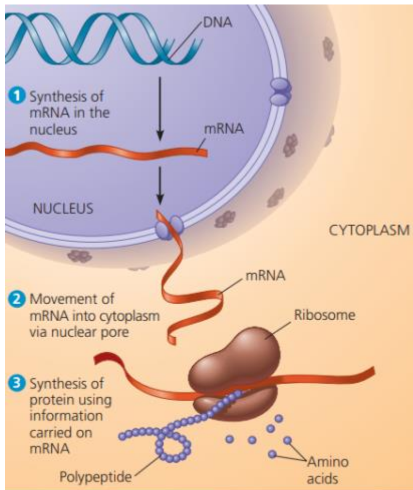


❖ 5.4: [Nucleic acids store, transmit, and help express hereditary information]

- The amino acid sequence of a polypeptide is programmed by **a unit of inheritance** called a <u>**gene**</u>
  - **Genes** consist of **DNA**
- **Nucleic acids** are <u>polymers</u> made of **monomers** called <u>nucleotides</u>
- There are **two** types of nucleic acids:
  - **Deoxyribonucleic acid** (**DNA**) → lacks an oxygen atom on the second carbon
  - **Ribonucleic acid** (**RNA**)



- **Roles of DNA:**
  - DNA provides **directions for its own replication** (replicates itself)
  - DNA directs **synthesis of messenger RNA** (mRNA) ➔ which controls protein synthesis and this process is called **gene expression**

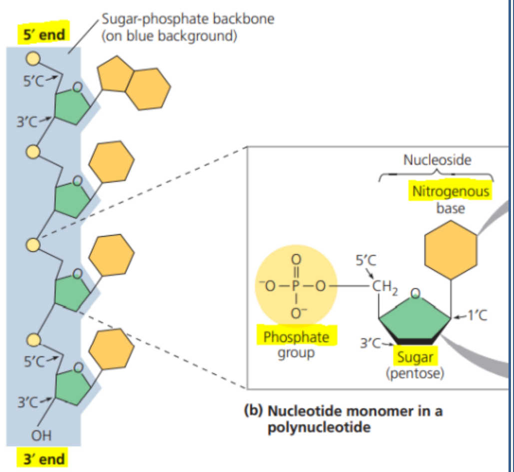


- Each gene along a DNA molecule directs synthesis of a messenger RNA (mRNA) → The **mRNA** molecule interacts with **ribosomes** to direct **production of a polypeptide**
  - ➢ The flow of **genetic information** can be summarized as

    DNA → RNA → protein
  - ➢ **Ribosomes:** The sites of protein synthesis
- DNA is the genetic material that organisms inherit from their parents
  - ➢ Each chromosome contains one long DNA molecule, usually carrying several hundred or more genes
  - ➢ When a cell reproduces itself by dividing**,** its DNA molecules are **copied** and **passed** along from one generation of cells to the next

- In a **eukaryotic cell** DNA → resides in the **nucleus,** and ribosomes reside in the cytosol
- In **prokaryotic cells** lack nuclei, so its genetic material resides in **nucleoid**

☐ The Components of Nucleic Acids

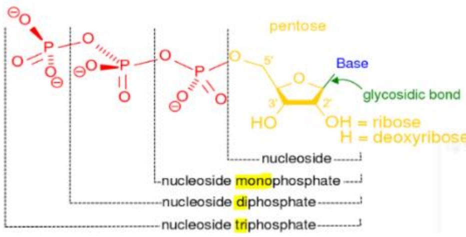


(b) Nucleotide monomer in a polynucleotide

(a) Polynucleotide, or nucleic acid

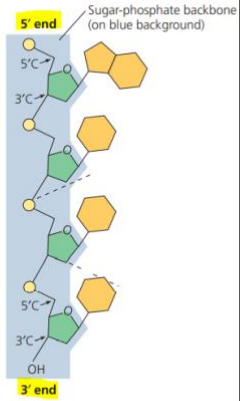
- Nucleic acids are **macromolecules** that exist as **polymers** called → **polynucleotides**
- Each polynucleotide consists of **monomers** called → **nucleotides**
- A nucleotide, in general, is composed of **three parts:**
  - A **five**-carbon sugar → **pentose**
  - A nitrogen-containing **(nitrogenous) base** → **(A/T/C/G)**
  - One to three **phosphate groups**
- The **beginning (1st) monomer** used to build a polynucleotide has **three** phosphate groups
- **But,** each nucleotide **within** the polymer has **only 1 phosphate** group (2 phosphate groups are lost during the polymerization process)

- **Nucleoside:** The portion of a nucleotide without any phosphate groups
  - Nucleoside = nitrogenous base + sugar
  - Nucleotide = nucleoside + phosphate groups (1-3 groups)
  - **Backbone** = phosphate + sugar
  - **Side chain** = Nitrogenous bases



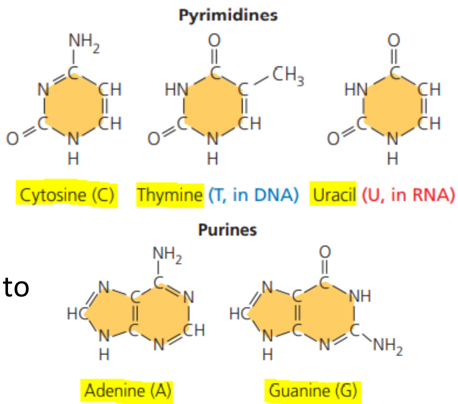
- Phosphate groups are attached to the **5' carbon** of sugar
- If the sugar is attached to:
  - ➢ 1 phosphate → it is called **nucleoside monophosphate** or **a nucleotide**
  - ➢ 2 phosphates → it is called **nucleoside diphosphate** or **a nucleotide**
  - ➢ 3 phosphates→ this is a **nucleoside triphosphate** or **a nucleotide**

- In **DNA** the sugar is **deoxyribose** → which lacks an oxygen atom on the second carbon (2′ carbon)
- In **RNA** the sugar is **ribose**



- **Nucleotides** are linked together by **phosphodiester linkage**
  - ➢ Phosphodiester linkage consists of **a phosphate group** that links the sugars of <u>two nucleotides</u>
- The two free ends of the polymer are distinctly different from each other:
  - One end has **a phosphate** attached to a **5′ carbon** of the pentose
  - The other end has **a hydroxyl group** on a **3′ carbon** of the pentose
- **Prime (')** is used to indicate the number of the carbon in the **sugar**
- The sequence of nucleotides (base pairs) is **read from 5′ → 3′** ends

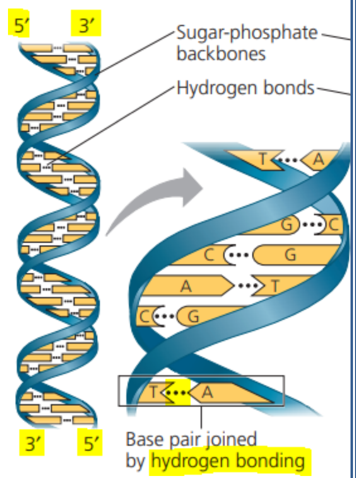
- **The nitrogenous bases:**
- They are <u>bases</u> because the nitrogen atoms **tend to take up H+** from solution thus acting as bases
- There are **two** families of nitrogenous bases:
  - ➢ Pyrimidine:
    - ✓ Has **<u>one</u>** six-membered ring of carbon and nitrogen atoms
    - ✓ **cytosine (C), thymine (T) and uracil (U)**
  - ➢ Purines:
    - ✓ They are larger, with **<u>two rings</u>** a six-membered ring fused to a five-membered ring
    - ✓ **adenine (A) and guanine (G)**



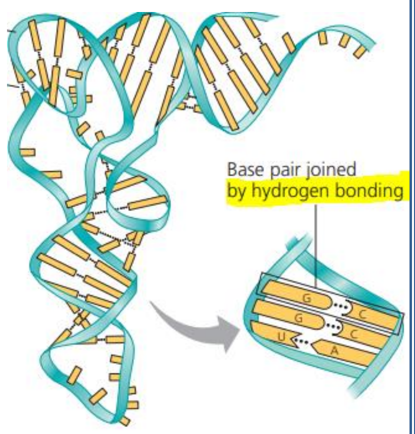
- **Adenine A**, **guanine G**, and **cytosine C** → are found **in both DNA and RNA**
- **Thymine T** → is found only in **DNA**
- **Uracil U** → only in **RNA**

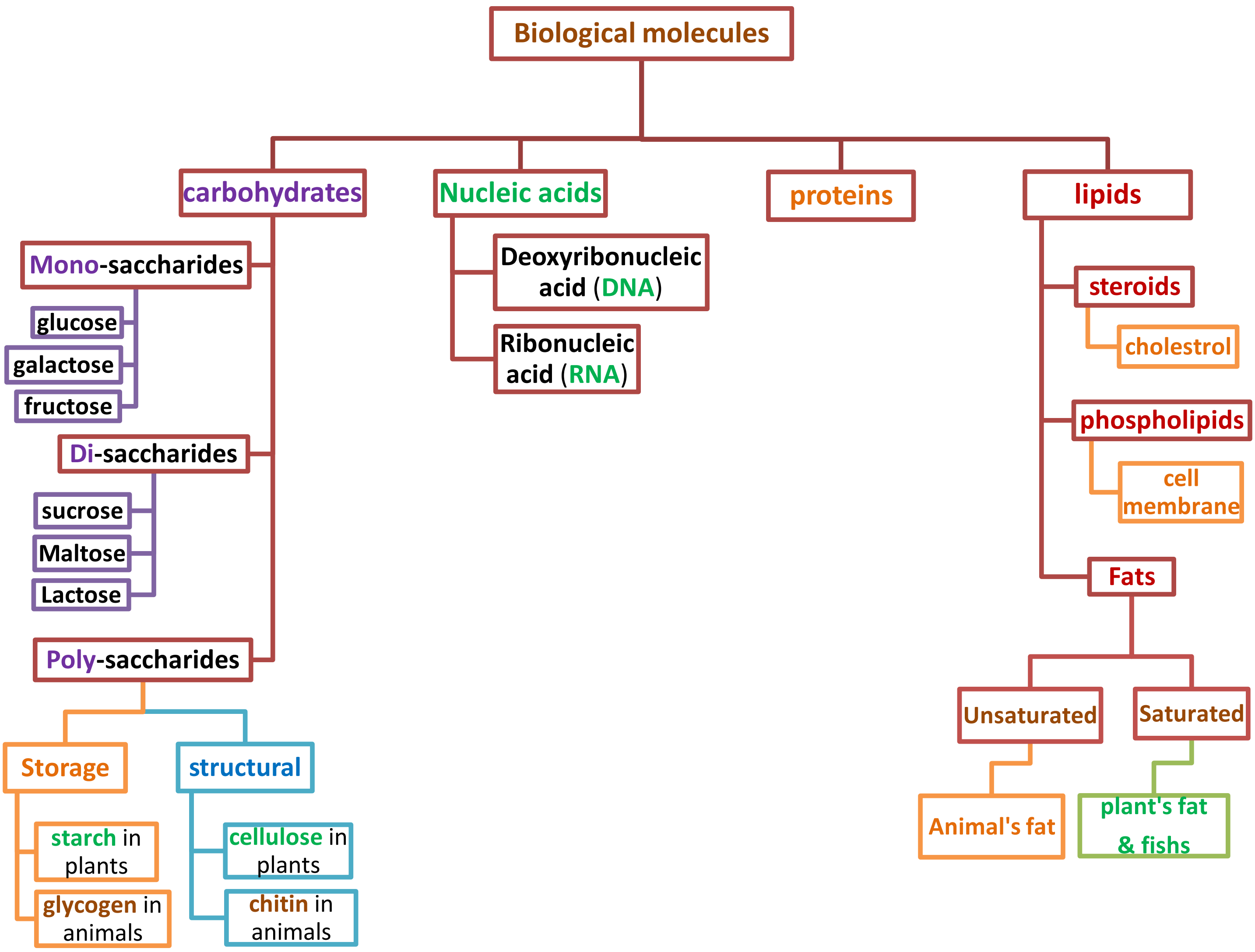
☐ <u>The Structures of DNA and RNA Molecules</u>

- DNA has 2 polynucleotide strands spiraling around an imaginary axis forming **a double helix**
- The two strands are **antiparallel** → run in opposite 5′→ 3′ directions from each other
- The two strands are held together by **hydrogen bonds** between the paired bases (This is called complementary base pairing):
  - **adenine (A)** always with **thymine (T) by 2 H-bonds**
  - **guanine (G)** always with **cytosine (C) by 3 H-bonds**
- The **two strands of the double helix are complementary** → If a stretch of one strand has the base sequence **5′-AGGTCCG-3′,** then the other strand must have the sequence **3′-TCCAGGC-5′**
  - ➢ DNA **can generate two identical copies of itself** in a **cell division** because the property of having 2 complementary strands



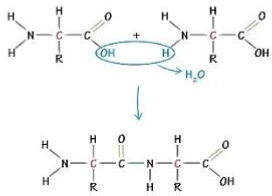
- RNA molecules exist as **single strands**
- Complementary pairing can also occur between two RNA molecules or between parts of the same molecule allows it to take on the particular three-dimensional shape necessary for its function
- In **RNA**, **thymine** is replaced by **uracil (U)**, so **A** and **U** pair.
- **DNA** almost always exists as a **double helix**, whereas **RNA** molecules are **more variable in shape**
- One type of RNA is called → **transfer RNA (tRNA)**, which **brings amino acids to the ribosome** during the synthesis of a polypeptide
    - tRNA molecule is about 80 nucleotides in length
    - Its functional shape results from base pairing between nucleotides where **complementary stretches of the molecule can run antiparallel to each other**





Past peppers

1) What is formed in the reaction shown & the type of reaction?



A. Ester bond /dehydration reaction
B. Peptide bond /dehydration reaction
C. hydrogen bond / hydrolysis reaction
D. ionic bond / hydrolysis reaction

Answer: B

2) Sulfur can be found in:

A. Proteins
B. Starch
C. DNA
D. Cholesterols
E. Fats

Answer: A

3) All of the following considered as lipids except of:

A. Fats
B. Phospholipids
C. Some waxes
D. Cholesterols
E. All of them are lipids

Answer: E

4) The sugar that have nitrogen containing appendage in their monomer

A. Cellulose
B. Starch
C. Glycogen
D. Chitin

Answer: D

5) Insoluble fibers is

A. Carbs
B. Cellulose
C. Starch
D. Glycogen
E. A + B

Answer: B

6) Disulfide bridge can stabilize __________ structure of protein

A. Primary
B. Secondary
C. Tertiary
D. Quaternary
E. All of the above

Answer: C

7) Which of the following doesn't contain amino acids

A. Hemoglobin
B. Collagens
C. Enzymes
D. RNA
E. Insulin

Answer: D

8) Large organic molecules are usually assembled by polymerization of few kinds of simple subunits Which of the following is exception to this statement?

A. Steroid
B. Cellulose
C. DNA
D. An enzyme
E. Contractile protein

Answer: A

9) Lipids are a group of molecules that ________

A. Contain peptide bonds
B. Mix poorly with water
C. Contain polar parts
D. All of the above
E. A + B

Answer: B

10) How many molecules of water are needed to completely hydrolyze a polymer that is 11 monomers long ?

A. 12
B. 11
C. 10
D. 9
E. 8

Answer: C

11) Secondary structure of protein form by hydrogen bonding between_________

A. Backbone
B. Side chain
C. R group
D. Amino groups
E. None of the above

Answer: A

12) Which of the following is "Storage carbs in plant

A. Starch
B. Cellulose
C. Glycogen
D. Chitin
E. Insulin

Answer: A

13) Enzymes are usually _________

A. Carbs
B. Fats
C. Nucleic acid
D. Monosaccharides
E. Protein

Answer: E

14) Animals store glucose in the form of which macromolecule

A. Amylose
B. Glycogen
C. Glycerol
D. Cellulose

Answer: B

15) Which of the following is true about globular proteins

A. It's hydrophilic amino acids can be found at the surface
B. It's hydrophilic amino acids can be found in the core
C. It's hydrophobic amino acid can be found at the surface
D. It's hydrophobic amino acid can be found in the core
E. A + D

Answer: E

16) Which of the following is mismatched

A. Polypeptide =peptide bond
B. Fats= ester bond
C. Carbs= glycosidic linkage
D. All of them are correct

Answer: D

17) Which of the following is true about DNA

A. It's 5 end contains OH
B. It's 3 end contains phosphate group
C. It contains ribose sugar in its nucleotide
D. It is found as a double helix molecule

Answer: D

18) The minimum number of carbons in monosaccharide is

A. 4
B. 5
C. 3
D. 2
E. 1

Answer: C

19) In the formation of macromolecule what type of reaction would join two subunits together

A. Hydrophobic reaction
B. Hydrolysis reaction
C. Dehydration reaction
D. Denaturation reaction

Answer: C

20) Assuming that all of the below given compound had the same number of carbon atoms, which of the following has the most C-H bonds

A. Unsaturated fat
B. Poly saturated fat
C. Polysaccharides
D. Saturated fats

Answer: D

21) Aldose sugars and ketose sugars differ in

A. Position of carbonyl group
B. Number of carbonyl groups
C. Position of carboxyl group
D. Number of carboxyl groups

Answer: A

22) Which of the following is hydrophobic

A. Cellulose
B. Starch
C. Animal fats
D. Oils
E. C + D

Answer: E

23) Oils are liquid at room temperature because they

A. Are small molecules
B. Are nonpolar
C. Are hydrophobic
D. Contains unsaturated fatty acid
E. Contains saturated fatty acid

Answer: D

24) Which of the following is true:

A. Amylose is branched molecule
B. Amylopectin is unbranched molecule
C. Starch contains alpha glucose in its monomer
D. Human can digest starch
E. Both C and D are correct

Answer: E

25) Misfolded protein involved in:

A. Mad cow disease
B. Parkinson’s disease
C. Cystic fibrosis
D. Alzheimer’s
E. All of the above

Answer: E

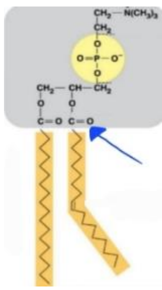
26) Which of the following is false about cellulose?

A. It made of B-glucose
B. It is the main component of plant cell wall
C. Can form hydrogen bond with other parallel cellulose molecules
D. It cannot be digested by human enzymes
E. All of them are true

Answer: E

27) The bond is described as ________ bond

A. Glycosidic
B. Ester
C. Peptide
D. Ionic



Answer: B

28) What type of macromolecule carries out catalysis in biological systems

A. Protein called enzymes
B. Carbs called starches
C. Lipids called steroids

Answer: A

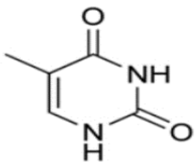
29) In a sucrose molecule, the linkage between glucose and fructose is :

A. 1-4 glycosidic
B. 1-2 glycosidic
C. 1-6 glycosidic
D. Peptide
E. Ester

Answer: B

30) The figure represents

A. Purine
B. Pyrimidine
C. Sugar
D. Fat



Answer: B

31) Molecule with which functional group may form polymers via dehydration reactions ?

A. hydroxyl group
B. carbonyl group
C. Carboxyl group
D. Either carbonyl or carboxyl group
E. Either carboxyl or hydroxyl group

Answer: E

32) Which of these molecules is not formed by dehydration reaction ?

A. Fatty acid
B. Disaccharide
C. DNA
D. Protein
E. Amylose

Answer: A

33) Which of the following is true about sickle cell anemia?

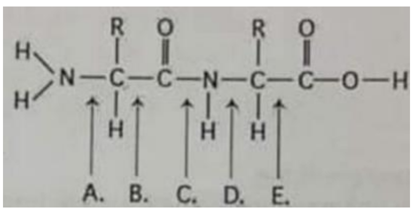
A. It is caused by point mutation that lead to substitution of one amino acid
B. It is involved abnormal alpha subunit
C. Hemoglobin molecules aggregate in a long fiber
D. Reduced capacity for oxygen transport
E. All of them are true except of (B)

Answer: E

34) According to the figure:

Which bond is peptide bond?

A. A
B. B
C. C
D. D
E. E



Answer: C

Which bond is closest to the amino terminus of the molecule?

A. A
B. B
C. C
D. D
E. E

Answer: A

At which bond water needed to be added to achieve hydrolysis of the peptide

A. A
B. B
C. C
D. D
E. E

Answer: C

35) Human sex hormone can be classified as

A. Protein
B. Lipid
C. Steroids
D. B+C
E. A+ B

Answer: D

36) The simplest amino acid is

A. Glycine
B. Serine
C. Valine
D. Lysine

Answer: A

37) when protein lose its native shape it called:

A. Denatured
B. Renatured
C. Destructed
D. Deformated
E. None of the above

Answer: A

38) Phospholipids contain:

A. Glycerol
B. 2 hydrocarbon tails
C. Phosphate group
D. Amino group
E. All of them except of (D)

Answer: E

39) There are 20 different amino acids, what makes one amino acid different from another

A. Different side chain (R group) attached to COOH group
B. Different side chain (R group) attached to amino groups
C. Different side chain (R group) attached to α-carbon
D. Different asymmetric carbons

Answer: C

40) If a DNA sample were composed of 10% thymine, what would be the percentage of guanine

A. 10
B. 20
C. 40
D. 80

Answer: C

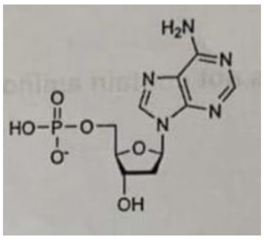
41) The molecular formula for glucose is $C_6H_{12}O_6$. What would be the molecular formula for a polymer made by linking 10 glucose by dehydration reaction (C : H : O)

A. (60 120 60)
B. (6 12 6)
C. (60 102 51)
D. (60 100 50)

Answer: C

42) The figure represents :

A. Nucleotide
B. Nucleoside mono phosphate
C. Nucleoside diphosphate
D. A+ B



Answer: D

43) Which of the following pairs of base form normal double helix of DNA

A. 5'-AGCT-3' with 5'-TCGA-3'
B. 5'-GCGC-3' with 5'-TATA-3'
C. 5'-ATGC-3' with 5'-GCAT-3'
D. All of the above are correct

Answer: C

44) The molecular formula for a polymer of 10 ribose molecules (C : H : O)

A. 6 : 12 : 6
B. 5 : 10 : 5
C. 60 : 120 : 60
D. 60 : 102 : 51
E. 50 : 82 : 41

Answer: E

45) A saturated fatty acid contains more ______ atoms than unsaturated fatty acid

A. Carbon
B. Oxygen
C. Nitrogen
D. Phosphate
E. Hydrogen

Answer: E

46) Which of the following molecules is a not a polysaccharide?

A. Amylose
B. Glycogen
C. Cellulose
D. Chitin
E. Collagen

Answer: E

47) In a double-stranded DNA molecule, phosphodiester linkage consists of a phosphate group that links

A. cytosine to guanine
B. the sugars of two nucleotides
C. thymine to adenine
D. ribose to a nitrogenous base
E. deoxyribose to a nitrogenous base

Answer: B

48) Which characteristic could be shared by the primary and tertiary structures of protein?

A. Both could have hydrogen bonds between the repeating constituents of the polypeptide backbone
B. Both have peptide bond between the amino acids
C. Both are functional proteins
D. Both could have disulfide bridge
E. Both must contain glycerol molecule

Answer: B

49) Changing one amino acid in a protein could change

A. its ability to function
B. its shape
C. its primary structure
D. its tertiary structure
E. all are correct

Answer: E

50) Which of the following is amphipathic?

A. Phospholipids
B. Cholesterol
C. Cellulose
D. Collagen
E. Glycogen

Answer: A

51) Which of these classes of biological molecules consist of both small molecules and macromolecular polymers (both polymer & monomer) ?

A. lipids
B. carbohydrates
C. proteins
D. nucleic acids

Answer: B

52) The enzyme amylase can break glycosidic linkages between glucose monomers only if the monomers are the α form. Which of the following could amylase break down?

A. glycogen
B. cellulose
C. chitin
D. glycogen and chitin only
E. glycogen, cellulose, and chitin

Answer: A

53) One of the following is an example of ketose?

A. glyceraldehyde
B. ribose
C. ribulose
D. glucose

Answer: C

54) Humans can digest starch but not cellulose because:

A. the monomer of starch is glucose, while the monomer of cellulose is galactose
B. humans have enzymes that can hydrolyze the β glycosidic linkages of starch but not the α Glycosidic linkages of cellulose
C. humans have enzymes that can hydrolyze the α glycosidic linkages of starch but not the β Glycosidic linkages of cellulose
D. humans harbor starch-digesting bacteria in the digestive tract.

Answer: C

55) Which of the following is an example of hydrolysis?

A. the reaction of two monosaccharides, forming a disaccharide with the release of water
B. the synthesis of two amino acids, forming a peptide with the release of water
C. the reaction of a fat, forming glycerol and fatty acids with the release of water
D. the reaction of a fat, forming glycerol and fatty acids with the consumption of water

Answer: D

56) The four main categories of macromolecules in a cell are:

A. Proteins, nucleic acids, carbohydrates, and lipids
B. Nucleic acids, carbohydrates, monosaccharides, and proteins
C. Proteins, DNA, RNA, and steroids
D. Monosaccharides, lipids, polysaccharides, and proteins
E. RNA, DNA, proteins, and carbohydrates

Answer: A

57) Denaturation causes changes in the protein's confirmation by disrupting:

A. Hydrogen bonds
B. ionic bonds
C. Hydrophobic interactions
D. All of the options are correct
E. Disulfide bonds

Answer: D

58) Dehydration and hydrolysis reactions involve removing or adding of – to macromolecule subunits Select one:

A. OH and H
B. COOH and H
C. C and O
D. H and C
E. CH and NH2

Answer: A

59) Sickle-cell hemoglobin differs from normal hemoglobin by replacement of glutamic acid the sixth amino acid in the Alpha-chain, by valine. Select one:

A. True
B. False

Answer: B

60) Nucleotides contain ________ sugars, Select one:

A. six-carbon
B. three-carbon
C. five-carbon
D. seven-carbon
E. four-carbon

Answer: C

61) Steroid hormones such as testosterone and estrogen are derived from:

A. None of the options is correct
B. Triacylglycerol
C. Cholesterol
D. Saturated fatty acids
E. Glycolipids

Answer: C

62) For a protein to have a quaternary structure it must have four polypeptide subunits:

A. False
B. True

Answer: A

63) The unfolding of protein induces by heat or treatment with certain chemicals is referred to:

A. Denaturation
B. Renaturation
C. Digestion
D. Polymerization
E. Activation

Answer: A

64) What makes a fatty acid an acid?

A. its carboxyl group
B. Its insolubility in water
C. Its hydrocarbon skeleton
D. Being a polymer
E. its ability to form an ester bond

Answer: A

65) Which of the following is true regarding saturated fatty acids:

A. Are the principal molecules in butter
B. have double bonds between their carbon atoms
C. Are liquid at room temperature
D. All of the options are true
E. Are the predominant fatty acids in corn oil

Answer: A

66) Both DNA and RNA have the same pentose

A. False
B. True

Answer: A

67) Bacterial cells are prokaryotic; in comparison to a typical eukaryotic cell they:

A. Their organelles are small and packed together
B. have fewer internal membranous compartments
C. lack a plasma membrane
D. have a smaller nucleus
E. lack a nucleus

Answer: E

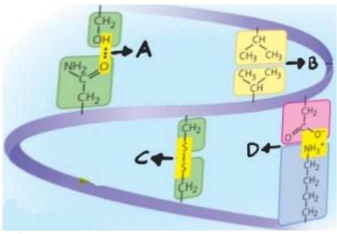
68) Triglycerides are synthesized from:

A. A Cholesterol and glycerol
B. fatty acids and glycerol
C. Cholesterol and starch
D. glycerol and amino acids
E. Collagen and fatty acids

Answer: B

69) Van-der-waal interactions are represented in the shown figure by the letter:

A. A
B. B
C. C
D. D



Answer: B

70) Chromosomes are a complex of DNA, RNA and proteins, Select one:

A. False
B. True

Answer: A

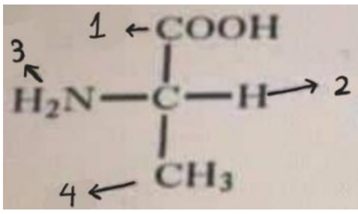
71) The structural level of a protein least affected by a disruption in hydrogen bonding is the?

A. All are equally affected
B. Tertiary
C. Quaternary
D. Primary
E. Secondary

Answer: D

72) The diagram represents the structure of an amino acid. In this diagram, the R group is represented by number:

A. 1
B. 2
C. 3
D. 4



Answer: D

73) Which of the following are pyrimidine?

A. Cytosine and Uracil
B. Guanine and Cytosine
C. Adenine and Thymine
D. Thymine and Guanine
E. Guanine and Adenine

Answer: A

74) Which class of biological polymers has the greatest functional variety?

A. RNA
B. DNA
C. Both DNA and RNA
D. Polysaccharides
E. Proteins

Answer: E

75) Which of the following molecules possesses glycosidic bonds?

A. Glycogen
B. All are correct
C. Cellulose
D. Amylose
E. Chitin

Answer: B

76) Which of the following is made of 1-4 linkage of beta glucose monomers:

A. Glycogen
B. Cellulose
C. Starch
D. Sucrose
E. Maltose

Answer: B

77) Which of the following is a branched polysaccharide?

A. Cellulose
B. Amylose
C. Glycogen
D. Chitin
E. None is correct

Answer: C

78) DNAase is an enzyme that breaks the covalent bonds between nucleotides. Which bonds are broken?

A. A CH group on carbon 2 of the ribose
B. The phosphodiester bond
C. The glycosidic linkage
D. All bases will be separated from the deoxyribose sugar

Answer: B