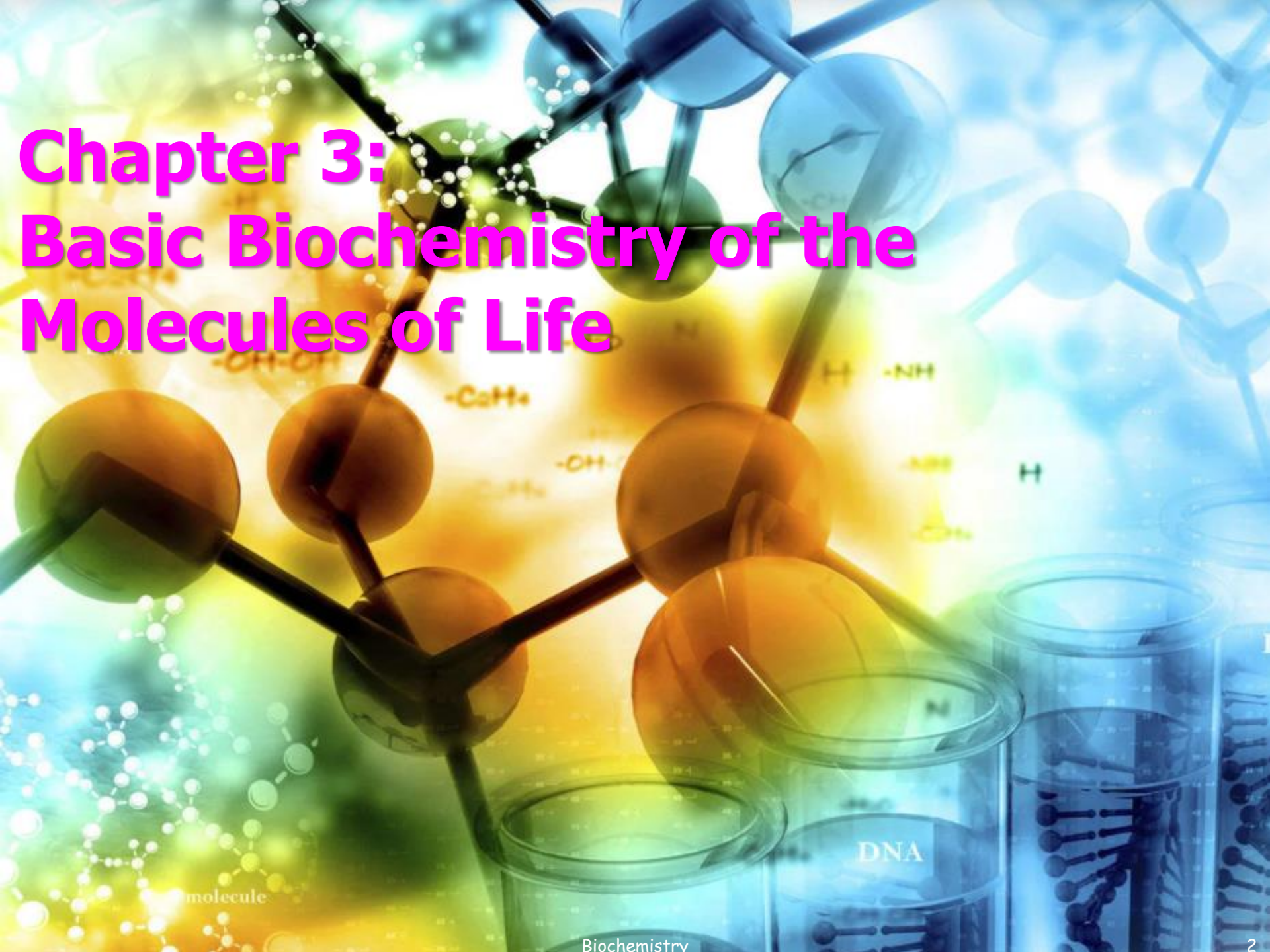
Go to the "Slide Show" shade above

Click on "Play from Beginning"



Chapter 3: Basic Biochemistry of the Molecules of Life

Chemistry of LIfe

WARM-UP

A(n) _____ is a pure substance that cannot be broken down into a simpler form

The FOUR most abundant elements in nature: _____.

_____ are the simplest chemical unit. Atomic number is the # of _____ in the nucleus of an atom. Atomic ____ includes protons and neutrons in the nucleus. A charged atom is called a(n) ____.

Water is a _____ molecule that exhibits _____ bonds, causing solid ice to be _____ dense than liquid water. Water has high _____ (sticks to other things) and _____ (sticks to itself) and resists _____ in temperature.

Water is the universal _____ that determines acids (___ ions) & bases (___ ions). pH below __ is acidic. _____ resist pH changes.

Chemistry of LIfe

A(n) element is a pure substance that cannot be broken down into a simpler form

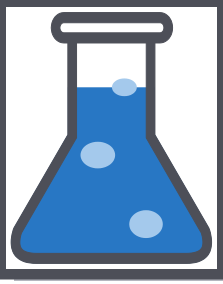
The FOUR most abundant elements in nature: CHON.

Atoms are the simplest chemical unit. Atomic number is the # of protons in the nucleus of an atom. Atomic mass includes protons and neutrons in the nucleus. A charged atom is called a(n) ion.

Water is a polar molecule that exhibits hydrogen bonds, causing solid ice to be less dense than liquid water. Water has high adhesion (sticks to other things) and cohesion (sticks to itself) and resists changes in temperature.

Water is the universal solvent that determines acids (H+ ions) and bases (OH- ions). pH below 7 is acidic. Buffers resist pH changes.

Lesson Objectives

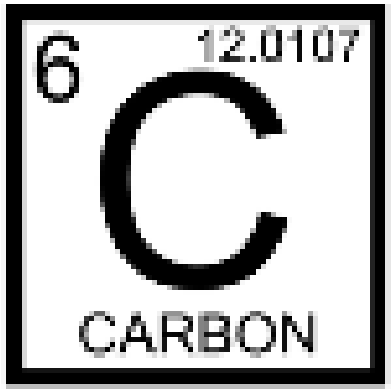


By the end of this lesson, you should be able to:

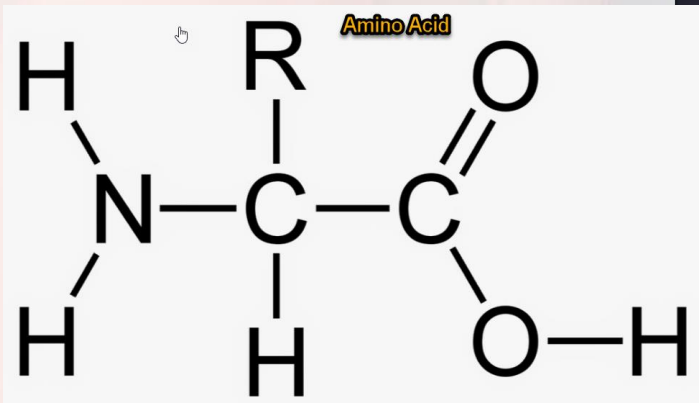
- Describe the structures and functions of each of the four groups of Macromolecules of Life: Carbohydrates, Lipids, Proteins, and Nucleic Acids.
- Investigate how the four groups of Macromolecules of Life are metabolized by cells.

Science Practice: Biomolecules Lab

Organic Molecules

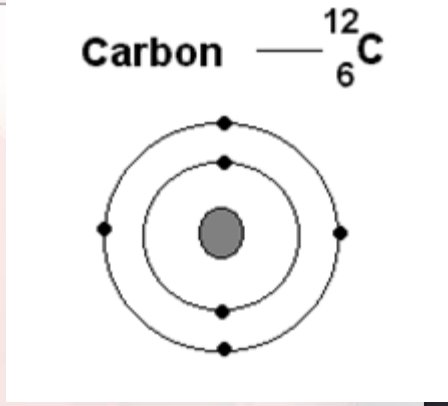


- Life's molecular diversity is based on the properties of the **CARBON** atom.
- Almost all the molecules a cell makes are composed of **carbon** bonded to
  - other carbons
  - Hydrogen, oxygen, & nitrogen



Carbon-based molecules (when combined with hydrogen or possessing a long carbon chain including oxygen or nitrogen) are called ORGANIC MOLECULES.

Carbon Atom

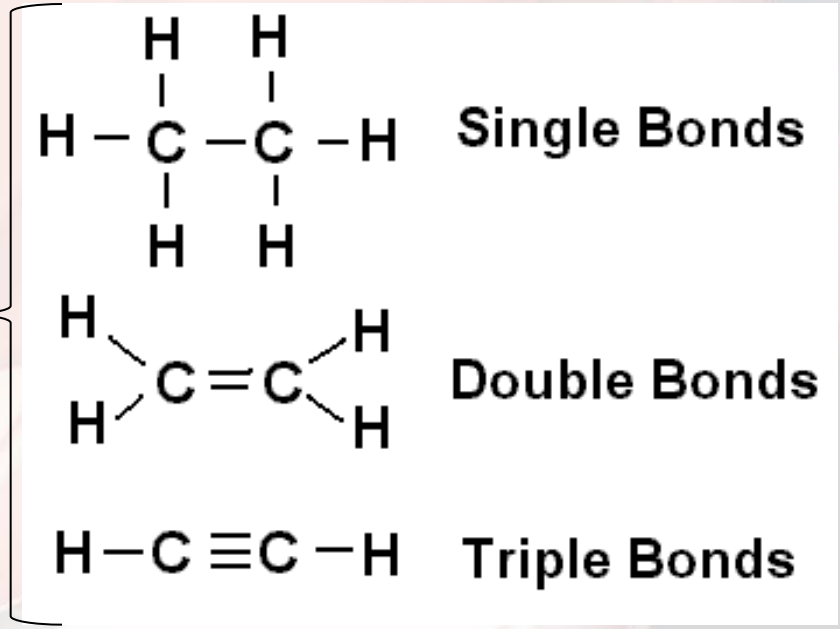


CARBON is essential for life

"the backbone of life"

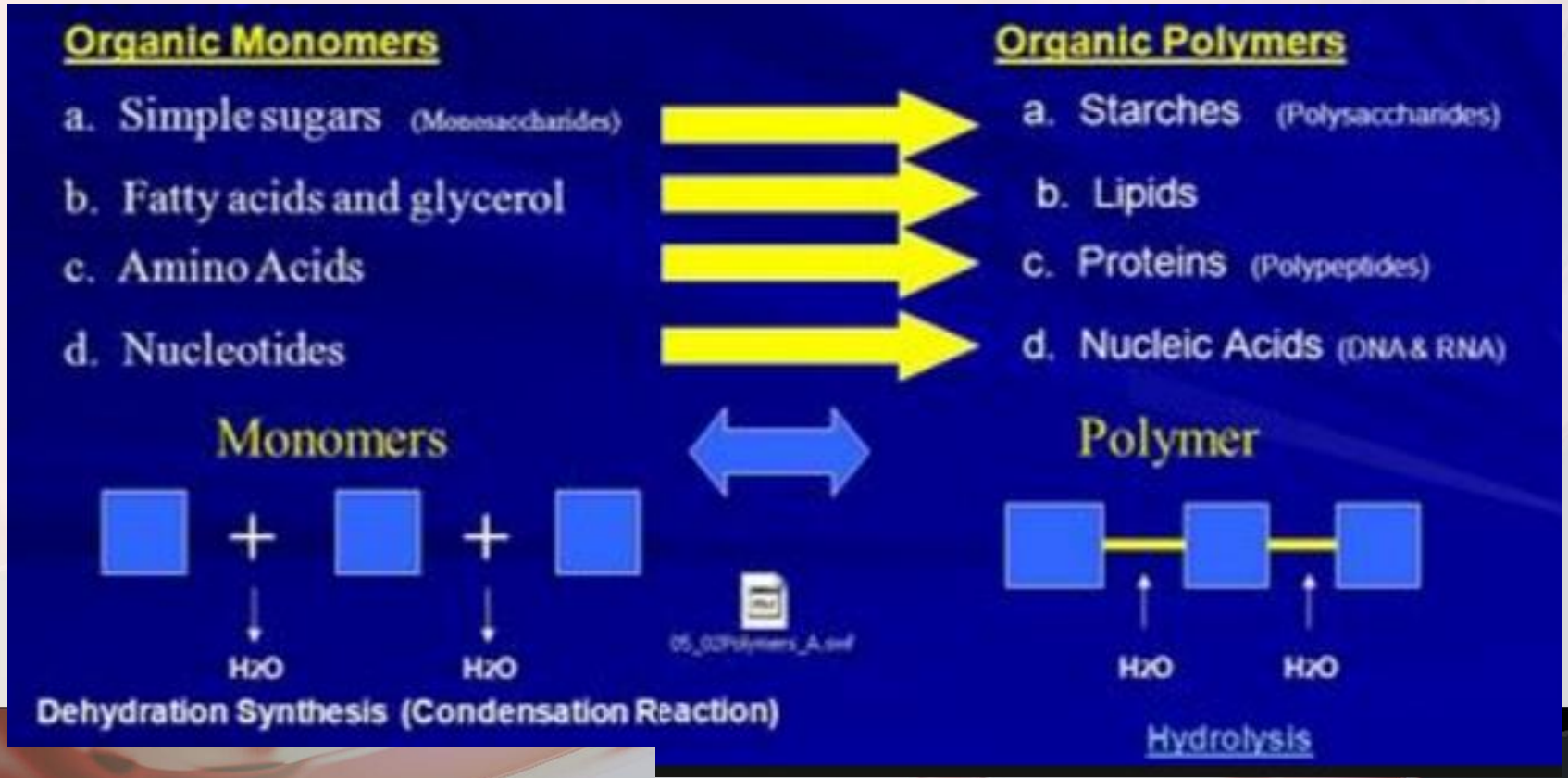
"*carbon-based life forms*"

- Contains 4 electrons in its outer shell (*for bonding*).
- Each carbon atom creates 4 bonds: single, double, or triple bonds.
- "**Swiss Army Knife of Chemistry**"



Macromolecules or Polymers

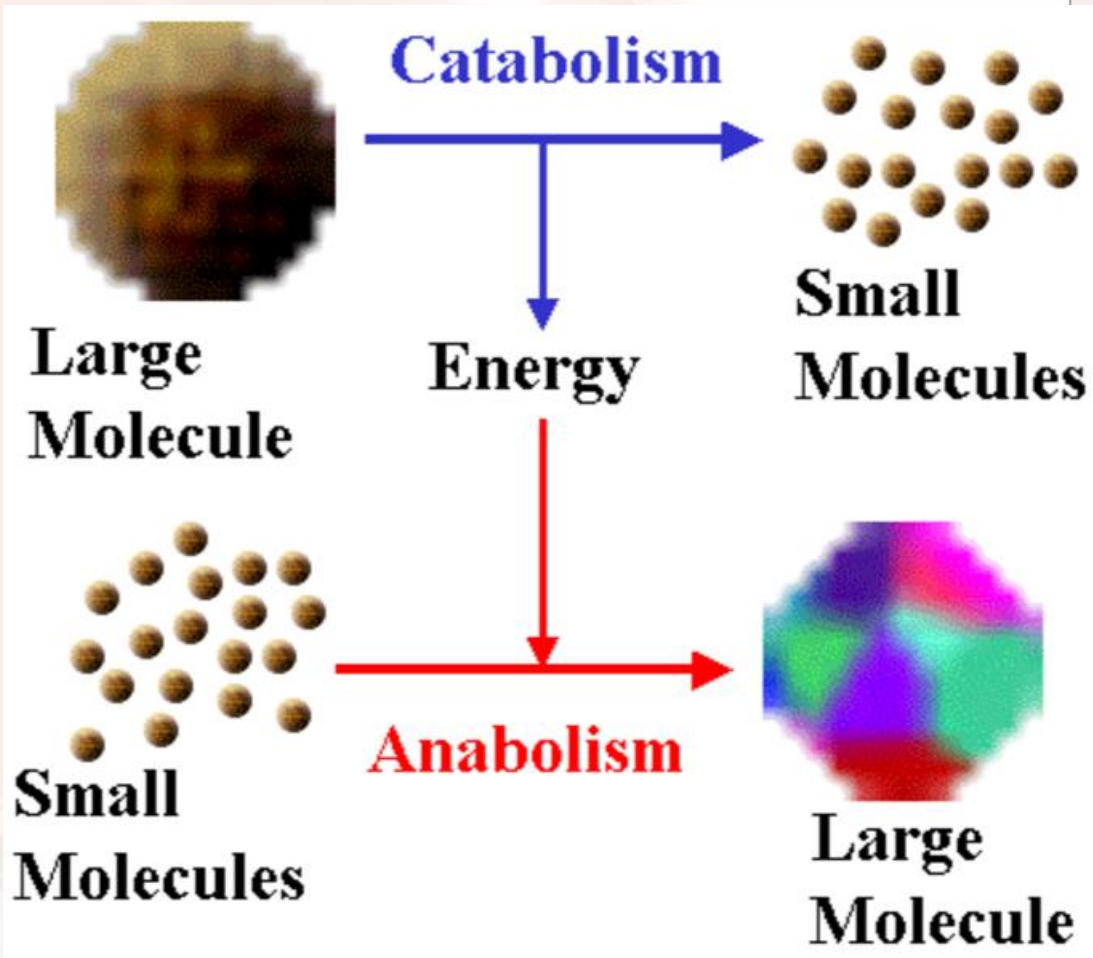
- Macromolecules (*larger*) are built from smaller molecules called MONOMERS ("one unit").



Organic Reactions

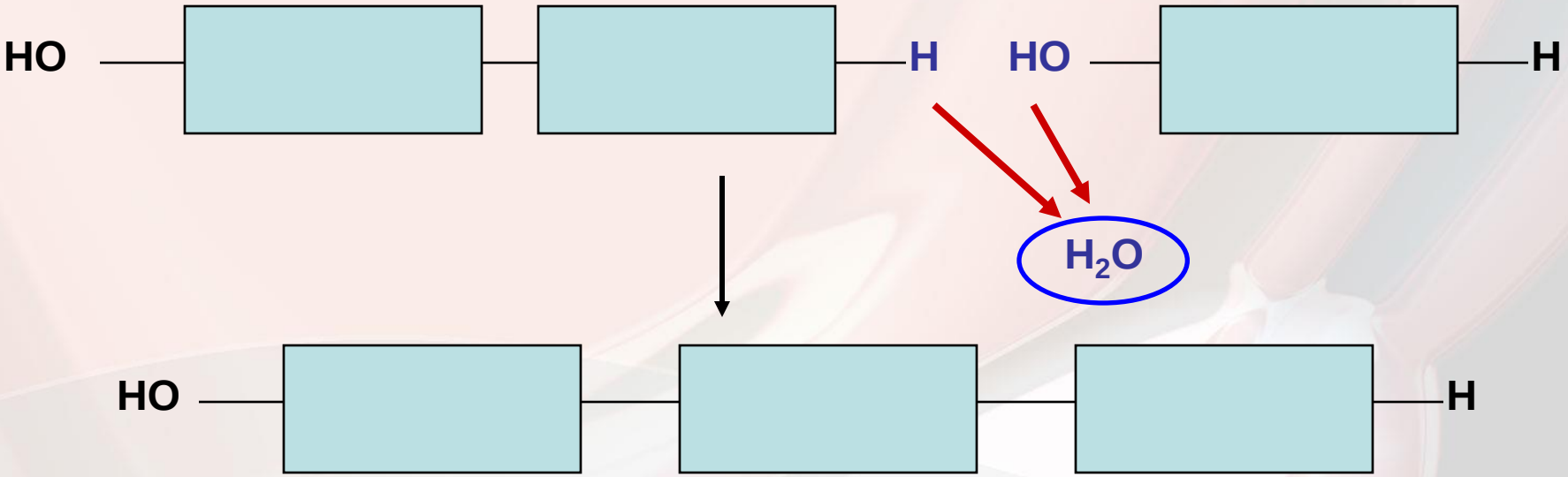
Anabolic Reactions: BUILD macromolecules from monomers.

Catabolic Reactions: BREAK macromolecules into its components (monomers).



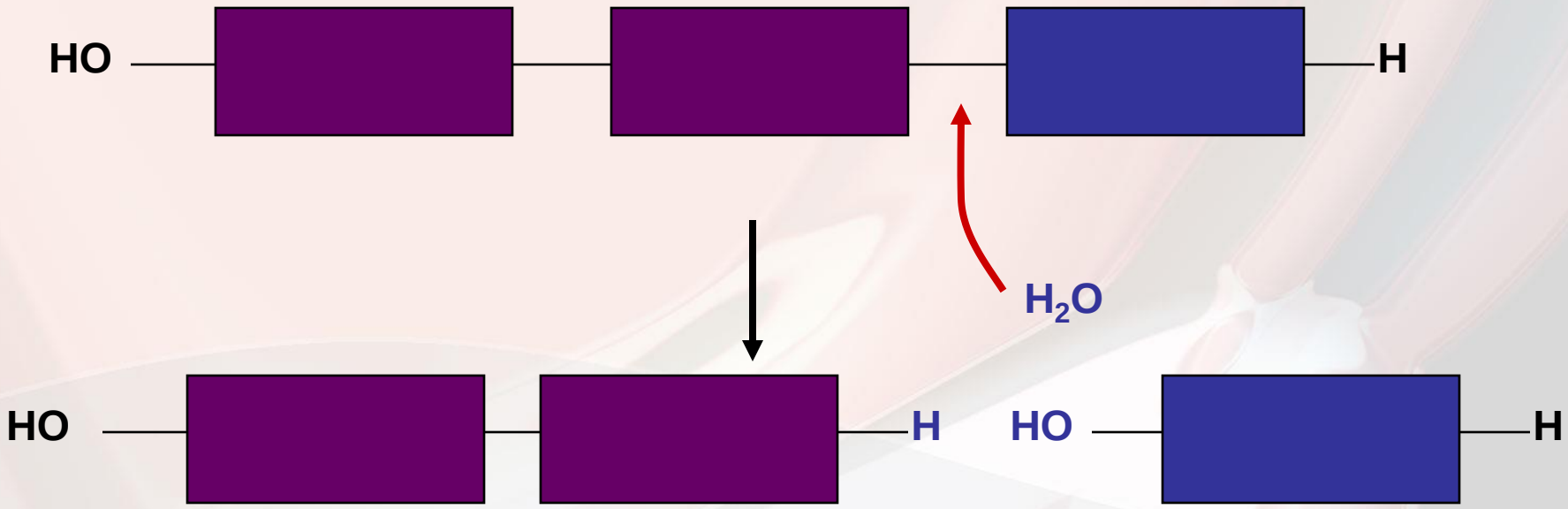
Dehydration Synthesis

- Also called a "condensation reaction"
- **Anabolic** Reactions which form macromolecules by combining monomers by **"removing water".**



Hydrolysis

- **Catabolic** Reactions which break down macromolecules by removing monomers one at a time *[opposite of condensation reaction]*.
- Separates monomers by **"adding water".**

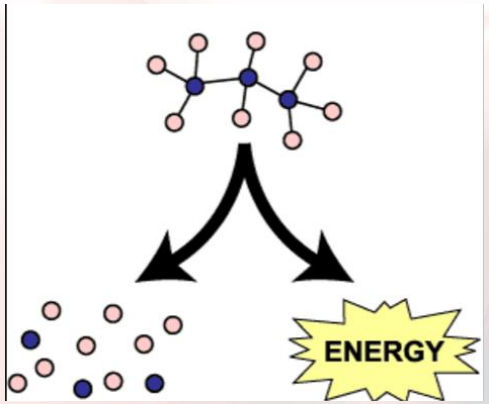


Review

QUICK CHECK

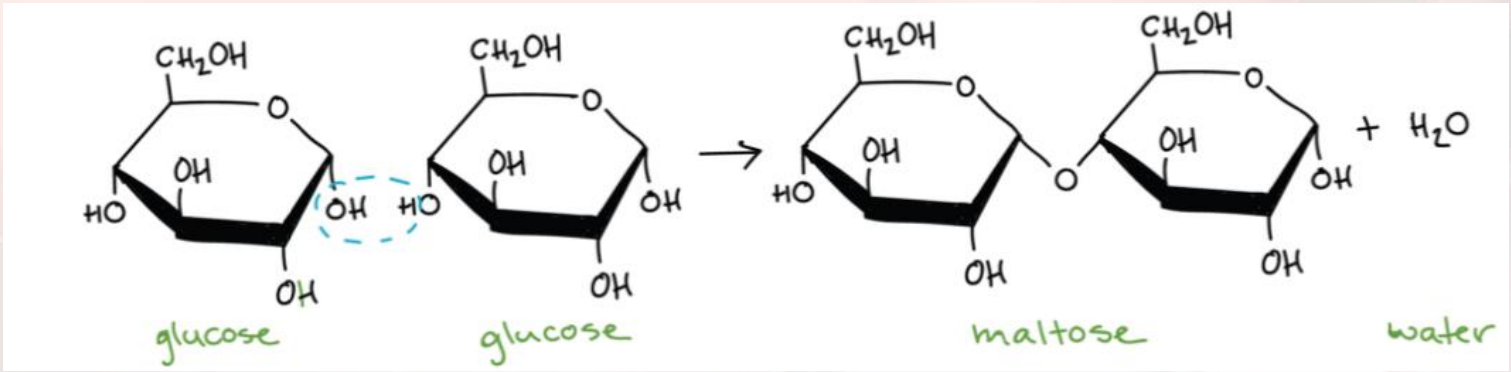
What does "organic" mean in Biology?

What organic reaction took place? →



What organic reaction took place ↓

(Distinguish monomer, polymer, macromolecule)



Review

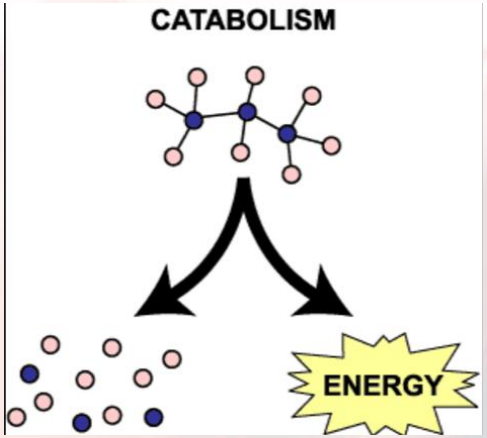
QUICK CHECK

What does "organic" mean in Biology?

Contains carbon (& hydrogen, oxygen, nitrogen)

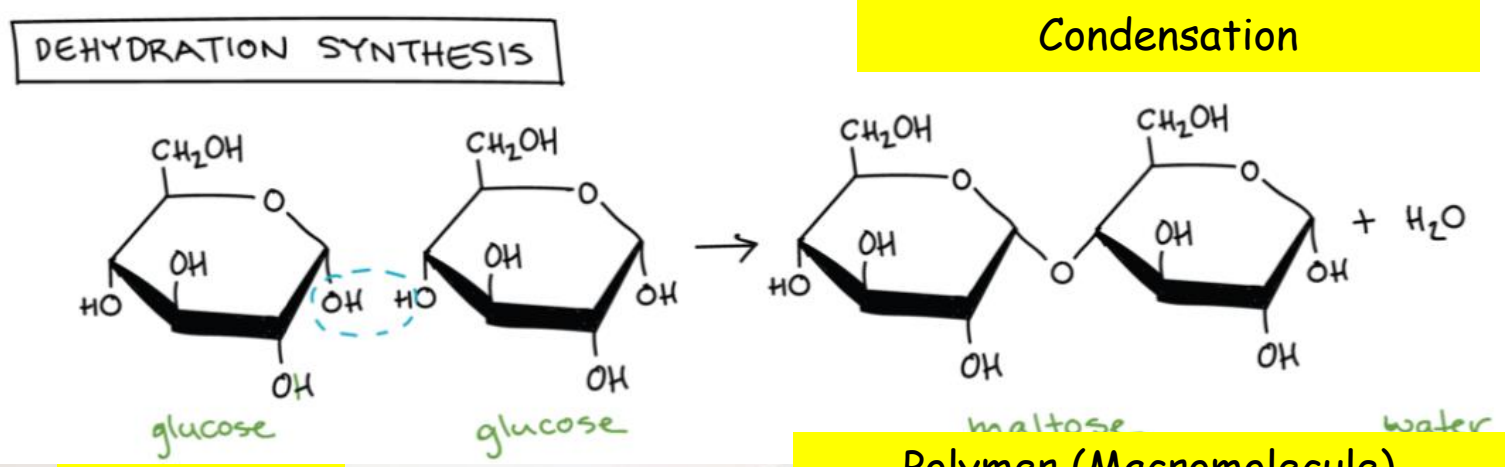
What organic reaction took place? →

Catabolism, hydrolysis



What organic reaction took place ↓

(Distinguish monomer, polymer, macromolecule)



Biochemical Molecules

ORGANIC MOLECULES

Category	Monomer	Polymer
Carbohydrates		
Proteins		
Lipids		
Nucleic Acids		

Biochemical Molecules

ORGANIC MOLECULES

Category	Monomer	Polymer
Carbohydrates	monosaccharide	polysaccharide
Proteins	amino acids	polypeptide
Lipids	Fatty acid, Glycerol	Lipid
Nucleic Acids	Nucleotide	Nucleic acid

Carbohydrates

Energy from the Sun is taken up by the plants, which absorb that energy in their chloroplasts.

Energy

Oxygen

O_2

CO_2

Plants can reuse these products with the input of energy from the Sun.

CO_2

H_2O

Energy used in chloroplasts to created ordered, energy -rich sugar molecules.

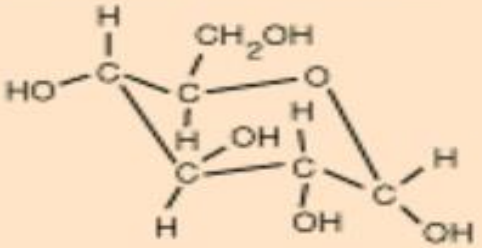
H_2O

Water

In the process , they convert the highly ordered sugars into carbon dioxide and water, a disorganized form.

Sugars

O_2



Glucose

Sugars available to plants to use for their own purposes.

Sugars also available to the animals for food.

Animals use the sugars to produce their own "energy currency" through the mitochondria

ATP

The energy source for animal life processes.

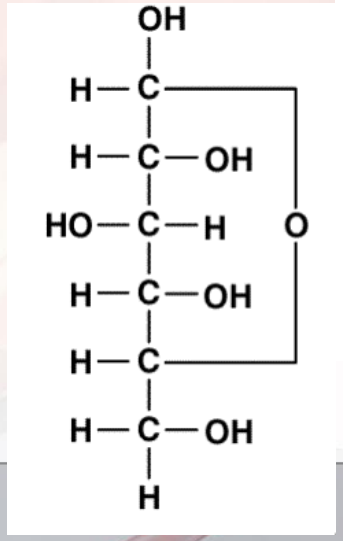
Carbohydrates

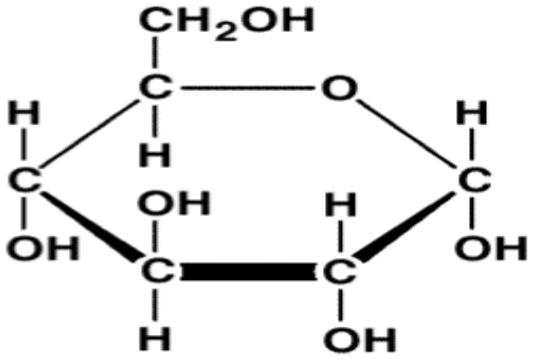
- **Important Source of Energy** for all life forms (e.g. glucose).
- Made of only **Carbon**, **Hydrogen**, and **Oxygen** (1:2:1) – CH_2O **[C + water]**
- Includes simple sugars and starches (complex sugars).
- Classified according to the number of sugar molecules they contain.
- Monomer: **Monosaccharides**

Monosaccharides

- Called "**Simple Sugars**"
- **MONOMERS** or **Building Blocks of Carbohydrates**
- **Glucose:** Universal Fuel of Cells - $C_6H_{12}O_6$
- Fructose (fruit sugar) and Galactose (milk sugar)
- Exist in the following forms:
  - **Cyclic** (aqueous in cells)
  - **Straight** Chain

Straight

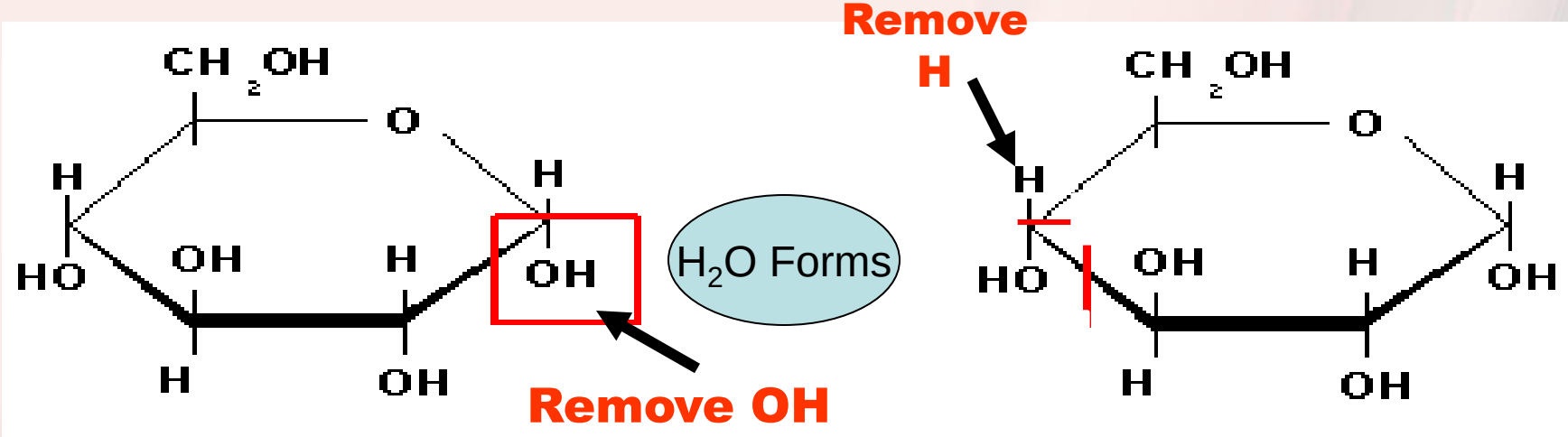




Cyclic

Carbohydrate Synthesis

- Cells link monosaccharides together by **Dehydration Synthesis** to form more complex sugars and polysaccharides.

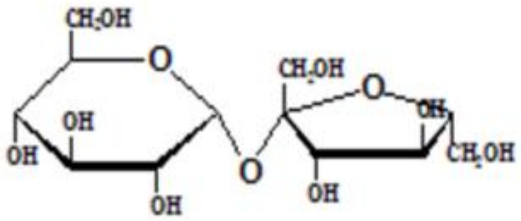


Disaccharides

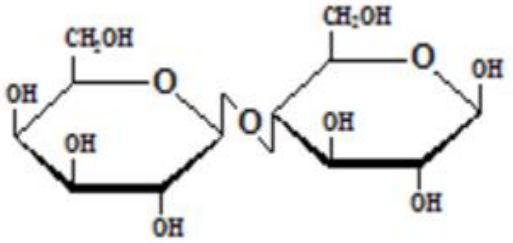
- "Double sugar"
- Formed by joining two monosaccharides by Dehydration Synthesis.
- Sucrose (table sugar)
- Lactose (milk sugar)
- Maltose (grain sugar)
- Form a bond called a **GLYCOSIDIC bond.**

Most simple sugars in nature are disaccharides

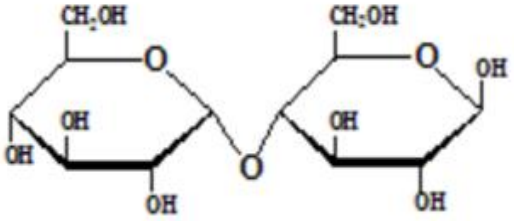
Sucrose
(Glucose-fructose)



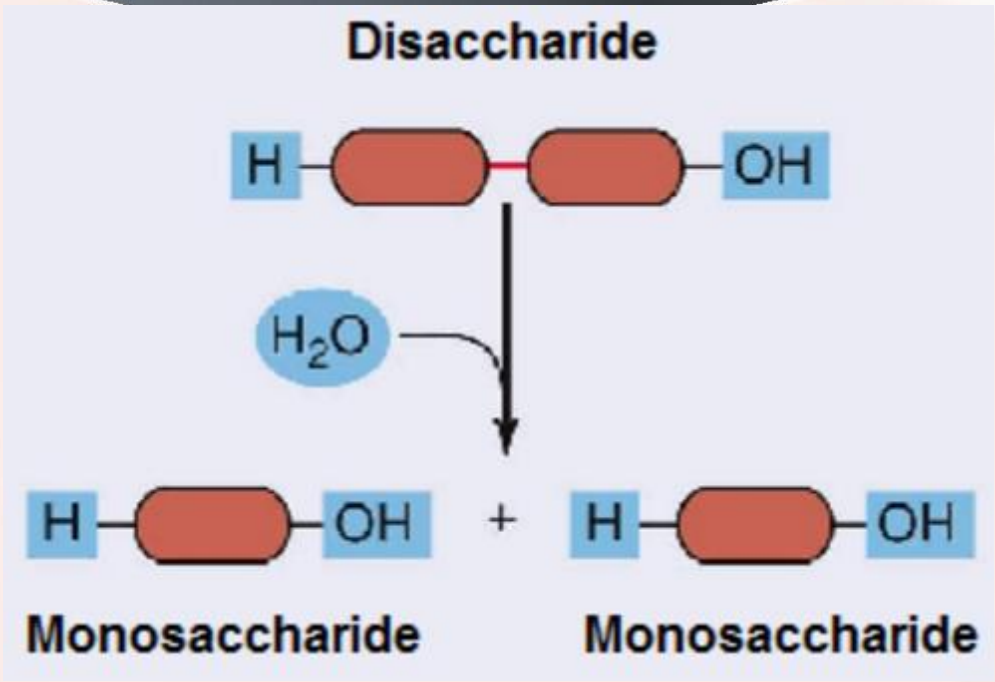
Lactose
(Galactose-glucose)

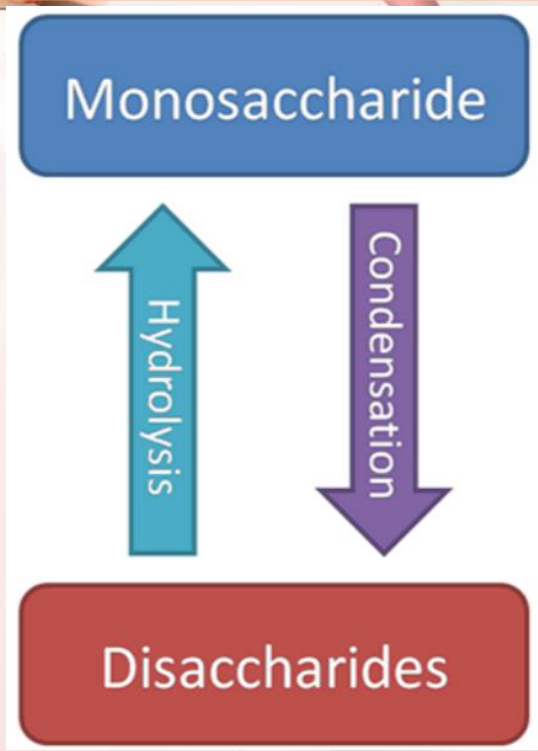


Maltose
(Glucose-glucose)



Hydrolysis of Disaccharides





$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[\text{or Invertase}]{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$
Sucrose — Glucose — Fructose

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[\text{or Maltase}]{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$
Maltose — Glucose — Glucose

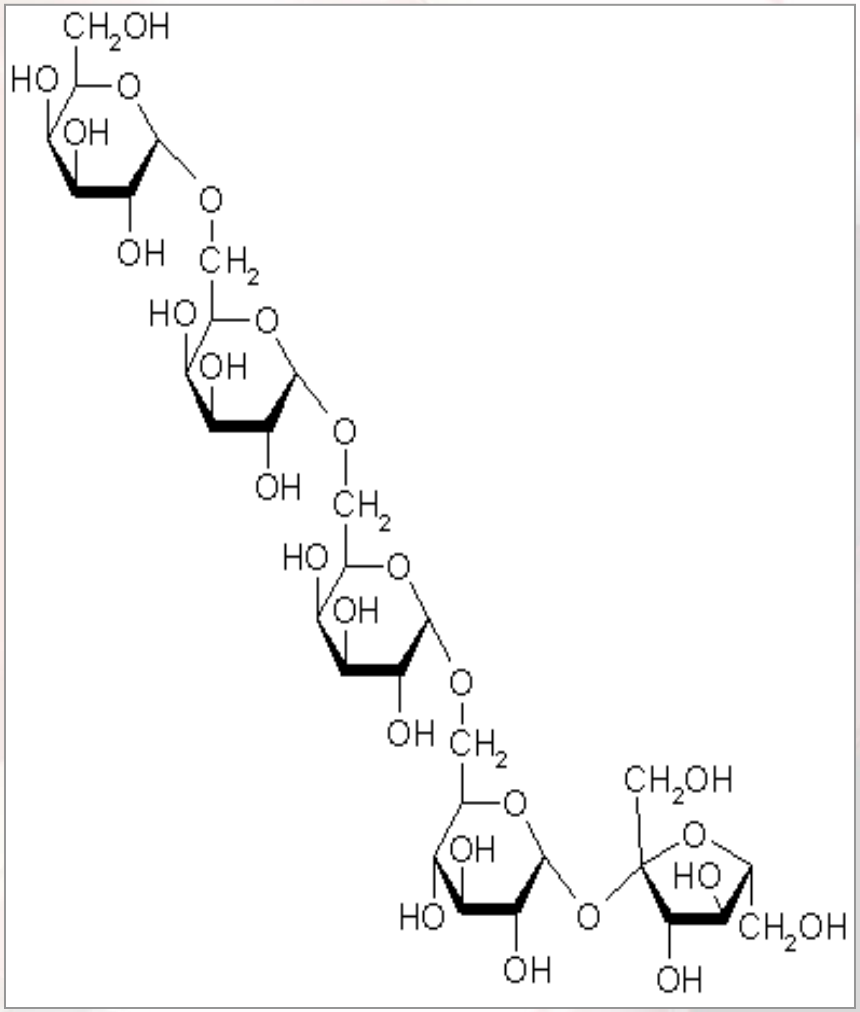
$$C_{12}H_{22}O_{11} + H_2O \xrightarrow[\text{or Lactase}]{H^+} C_6H_{12}O_6 + C_6H_{12}O_6$$
Lactose — Glucose — Galactose

Polysaccharides

"Many Sugars"

- Chains of thousands of Monosaccharides.
- Also called "Complex Carbohydrates".
- Functions:
  - **Energy Storage Molecules**
  - **Structural Molecules**

Too large to leave the cell.

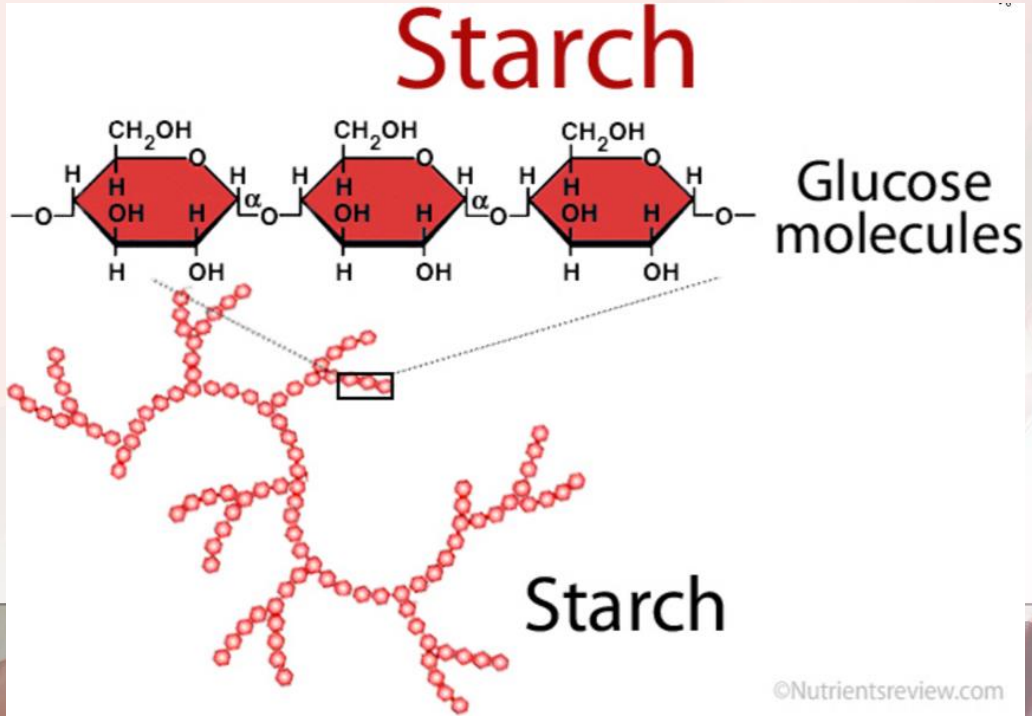


Polysaccharides

Energy Storage Molecules:

Starch

- Chain of molecules of Glucose formed by Plants.
- This is the way plants store excess glucose.
- We consume it in products like potatoes and carrots.

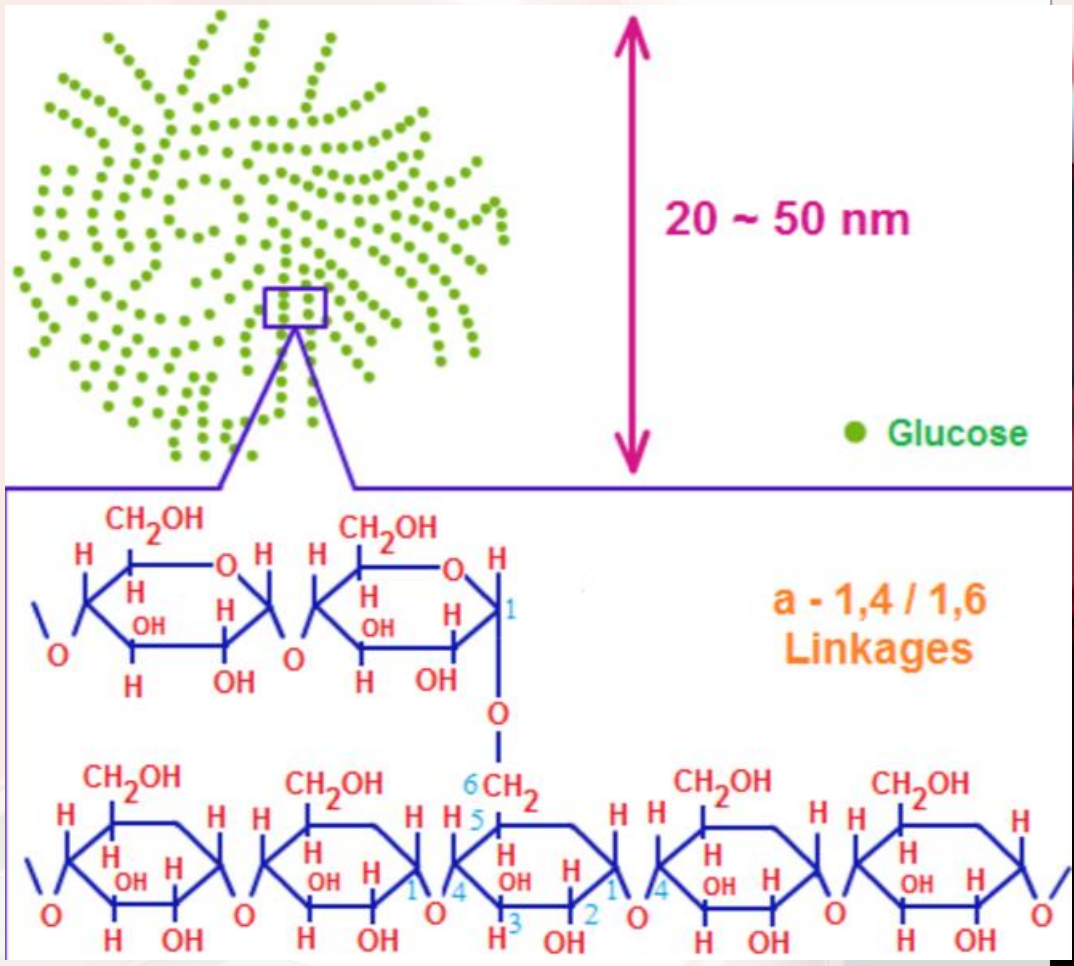


Polysaccharides

Energy Storage Molecules:

Glycogen

- Chain of molecules of Glucose formed by Animals.
- This is the way animals store excess glucose.
- Stored in liver and muscles.

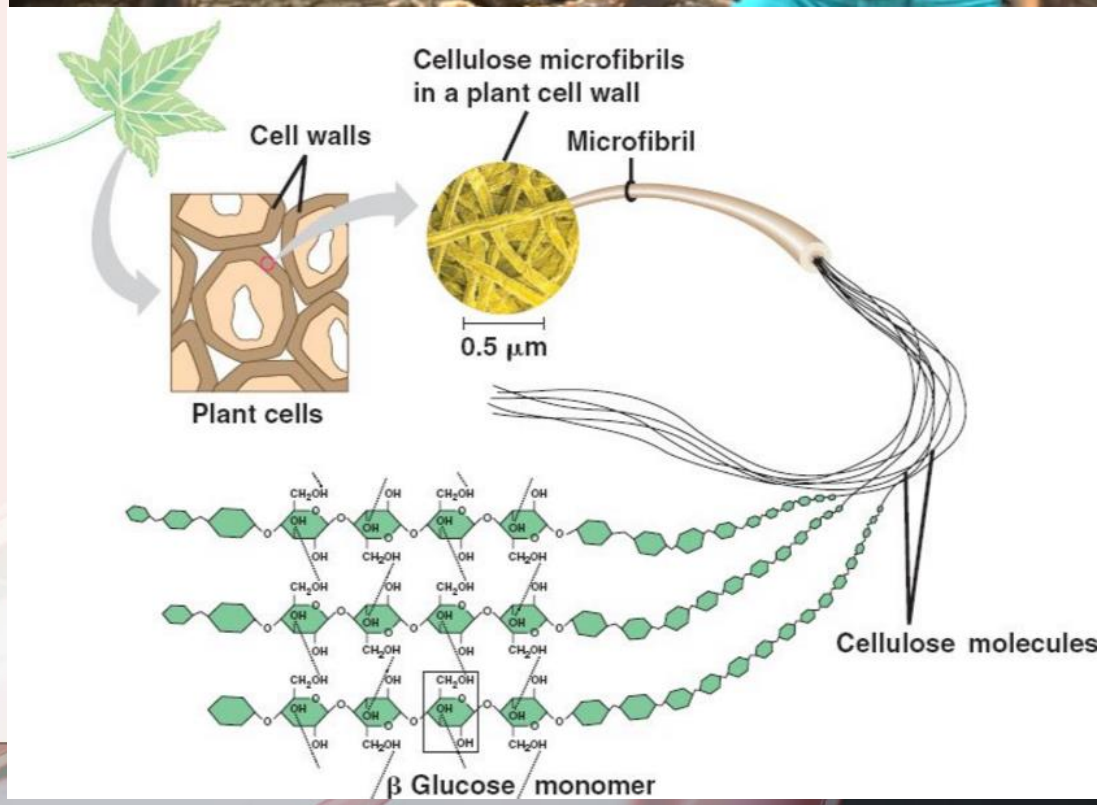


Polysaccharides

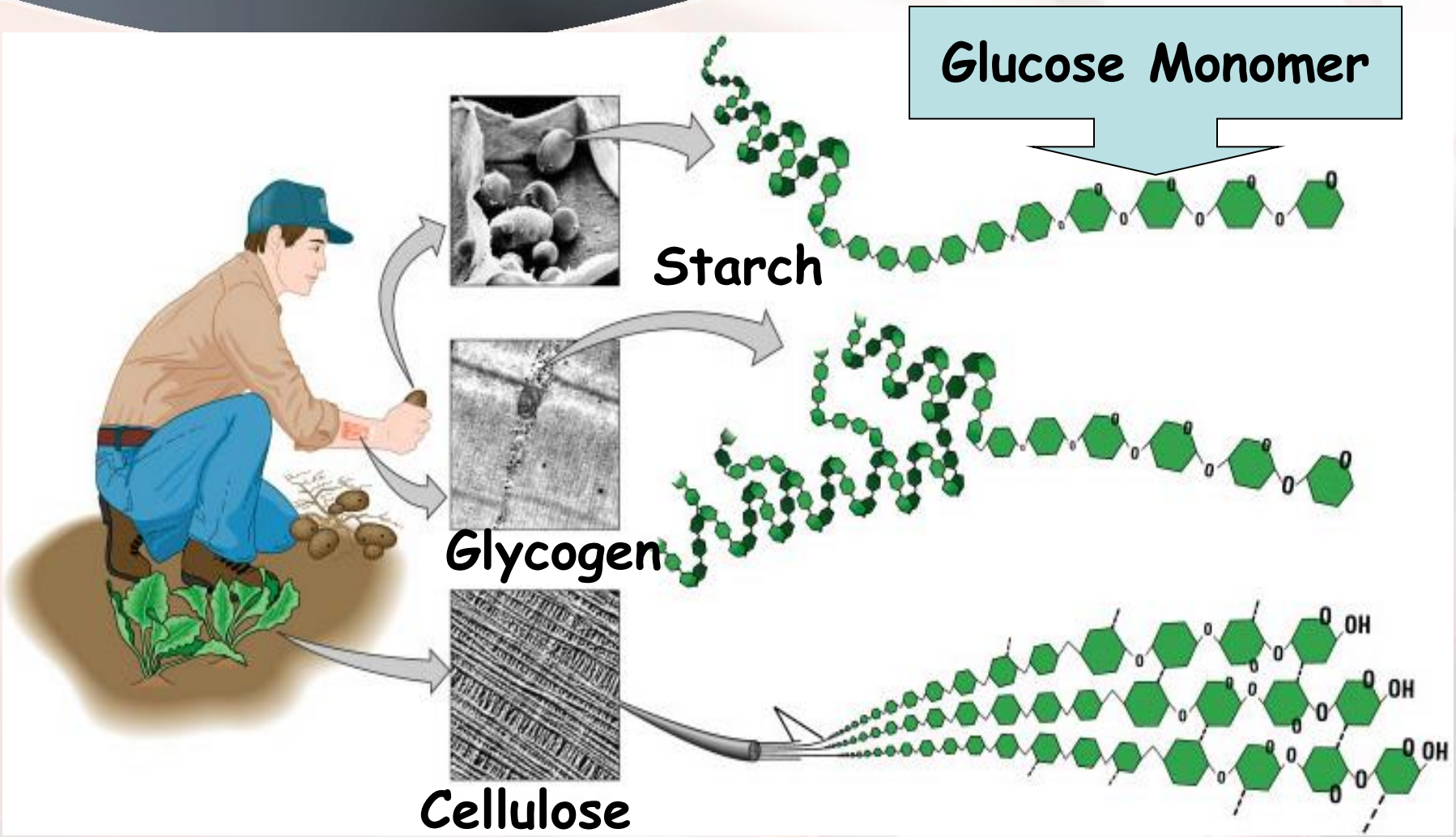
Structural Molecules:

Cellulose

- Chain of molecules of Glucose.
- Primary constituent of Plant Cell Walls.
- Major component of wood and paper.
- Indigestible by most animals.



Polysaccharides



Types of Carbohydrates

There are three kinds of carbohydrates.

Monosaccharides

Disaccharides

Polysaccharides

Review

QUICK CHECK

Explain how biochemical molecules are formed.

List the general types of carbohydrates from simplest to most complex, giving examples/definitions of each.

What monomer exists in all the above di- & polysaccharides?

The TWO major functions of complex sugars:

Review

QUICK CHECK

Explain how biochemical molecules are formed.

Monomers combined through dehydration synthesis to form polymers.

List the general types of carbohydrates from simplest to most complex, giving examples/definitions of each.

Monosaccharide (glucose, fructose, galactose),

Disaccharide (sucrose [table], maltose [grain], lactose [milk])

Polysaccharide (starch [plant excess glucose], glycogen [animal excess glucose], cellulose [plant cell walls])

What monomer exists in all the above di- & polysaccharides? *Glucose*

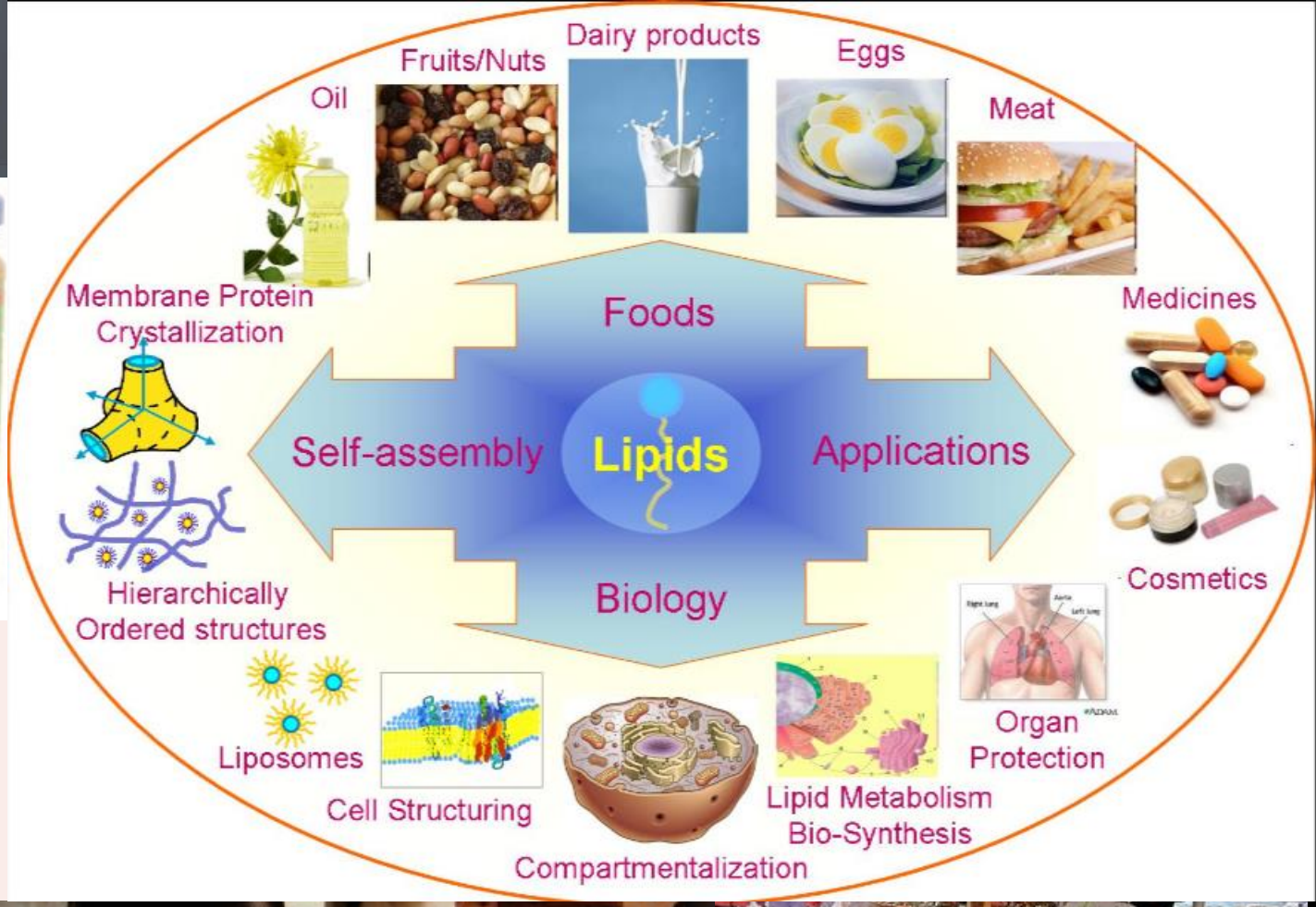
The TWO major functions of complex sugars:

Energy Storage Molecules & Structural Molecules

Lipids


WHOLE KIDS
ORGANIC
SMOOTH
Peanut Butter
WHOLE KIDS
ORGANIC
CRUNCHY
Peanut Butter

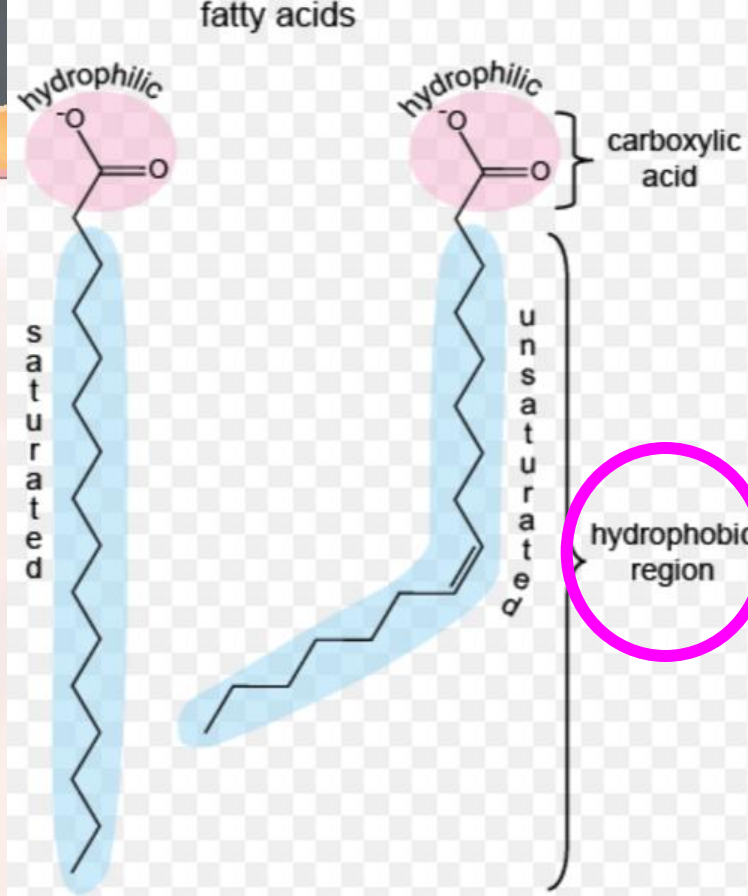

BRING OUT THE BEST
HELLMANN'S
REAL
MAYONNAISE
16 FL OZ (1PT) 473L


Fruits/Nuts
Dairy products
Eggs
Oil
Meat
Membrane Protein
Crystallization
Foods
Medicines
Self-assembly
Lipids
Applications
Hierarchically
Ordered structures
Biology
Cosmetics
Liposomes
Organ
Protection
Cell Structuring
Lipid Metabolism
Bio-Synthesis
Compartmentalization

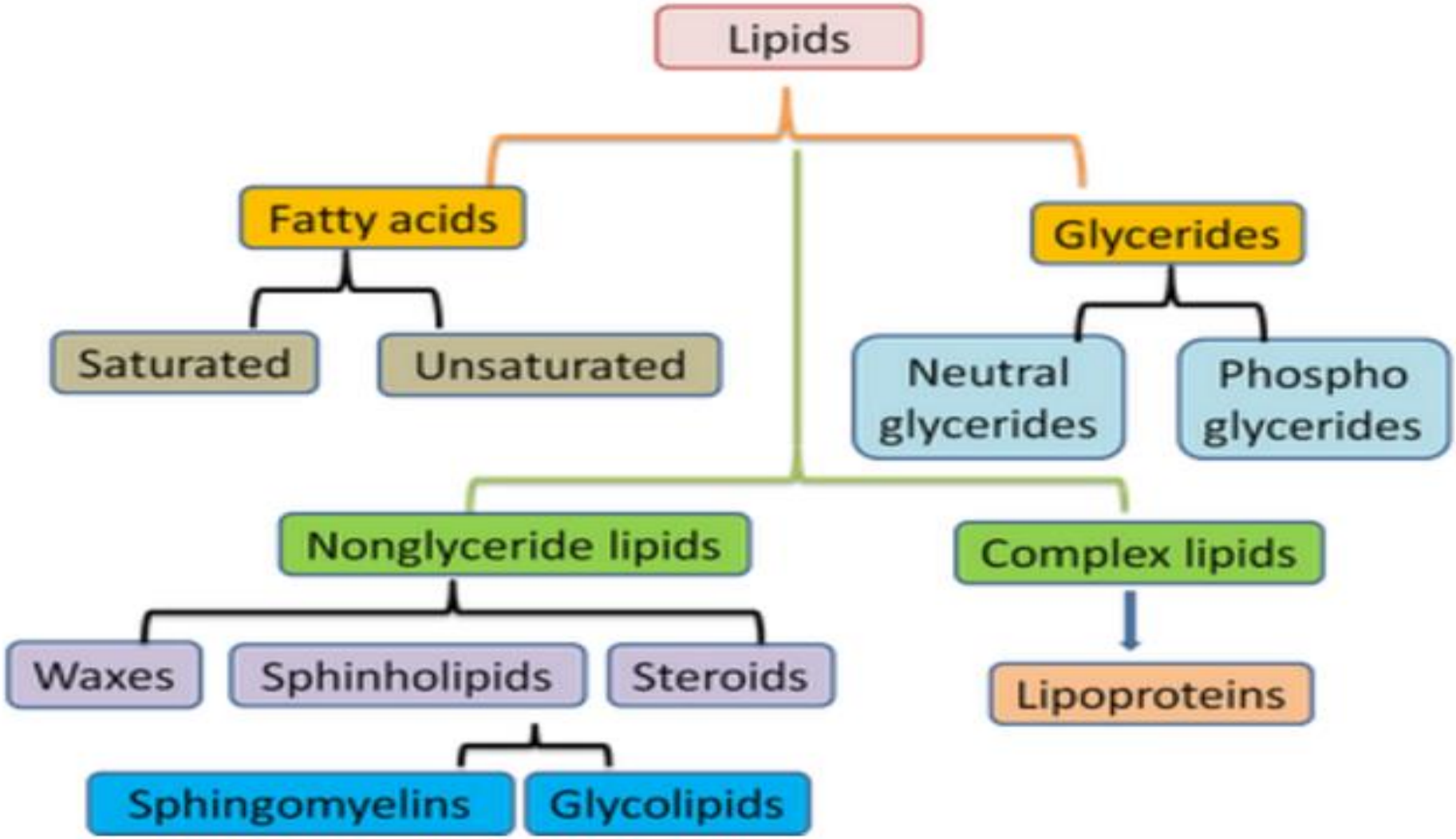

BUTTER

Lipids

- Contain **Carbon**, **Hydrogen**, & **Oxygen.**
- Hydrophobic – "Water-fearing"; Insoluble in water.
- **Protects** & **insulates** body organs.
- **Mostly Energy-Storage molecules.**
- Type of Lipid we will consider: **Fats (Triglycerides)**



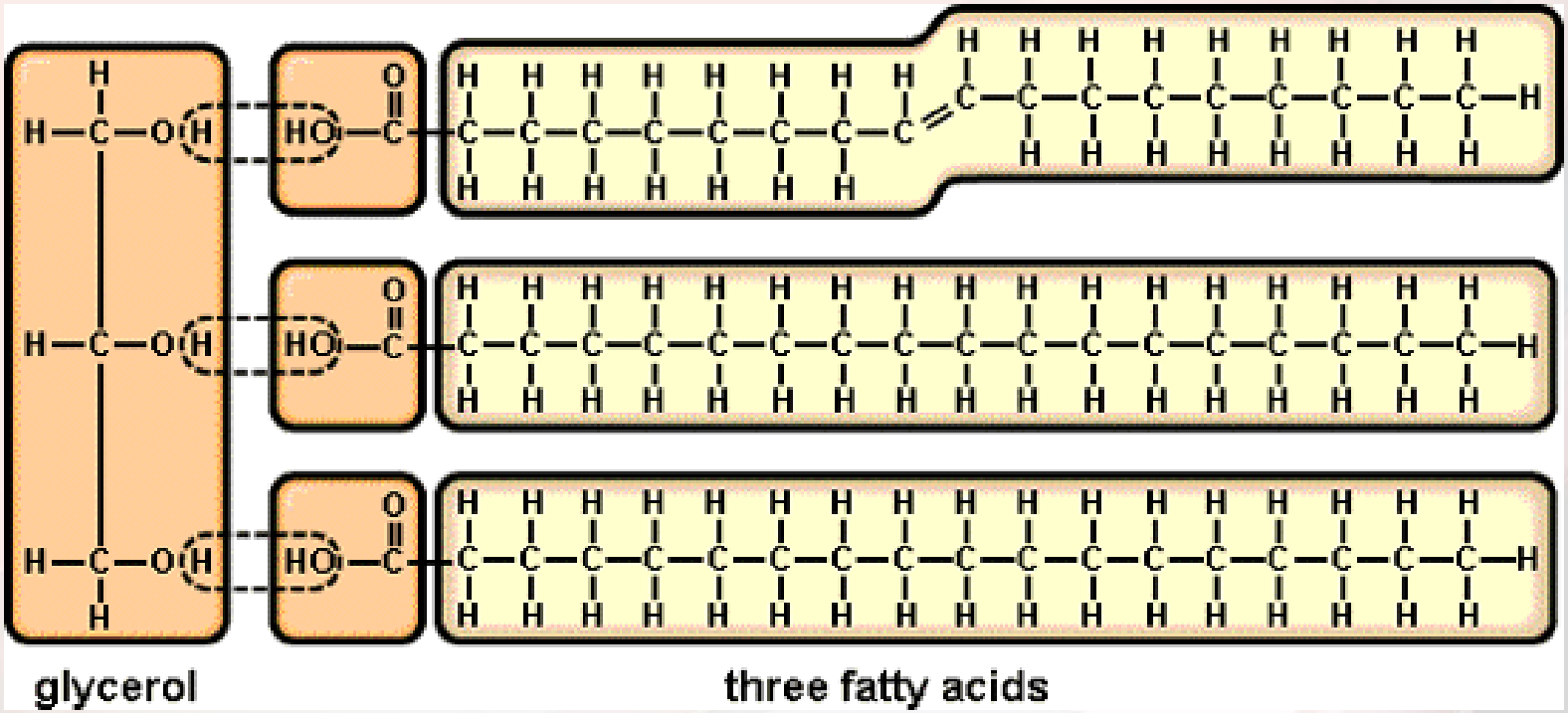
Lipids


Lipids
Fatty acids
Glycerides
Saturated
Unsaturated
Neutral glycerides
Phospho glycerides
Nonglyceride lipids
Complex lipids
Waxes
Sphinholipids
Steroids
Lipoproteins
Sphingomyelins
Glycolipids

Lipids Triglycerides (Fats)

Lipids are composed of two **MONOMERS,**

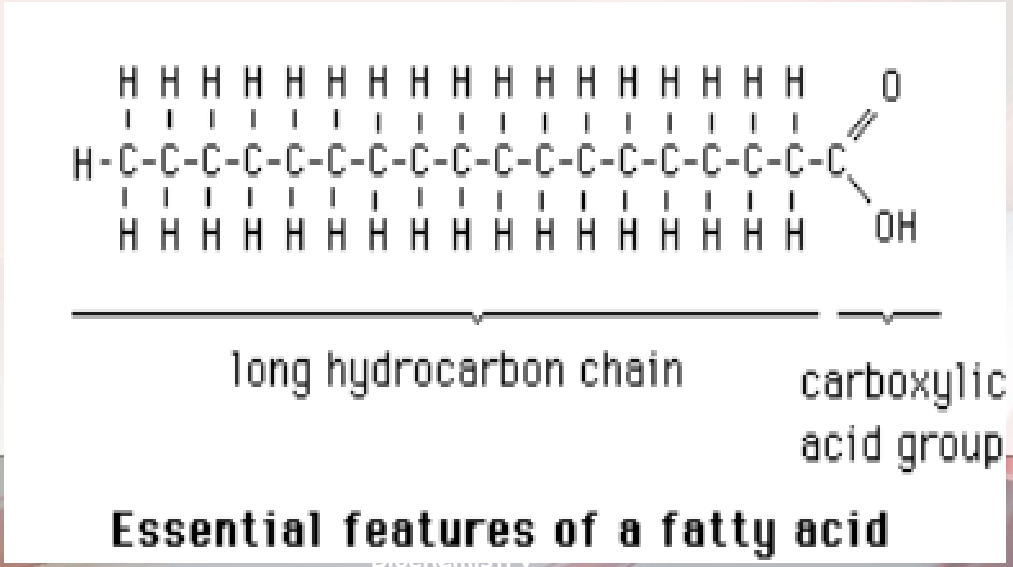
glycerol (1 molecule) + fatty acids tails (3)



Lipids Triglycerides (Fats)

The components of fatty acids (2 essential features):

1. A long hydrocarbon chain.
   a. Chain length ranges from 4 to 30 carbons
   b. The chain is typically linear, containing an even number of carbon atoms bonded to each other.
2. A carboxylic acid group



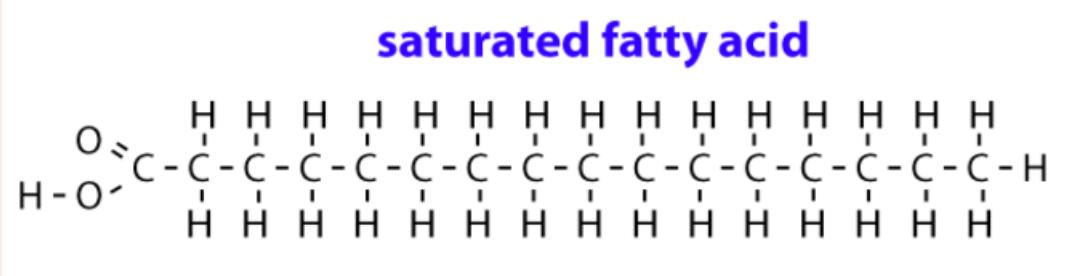
Essential features of a fatty acid

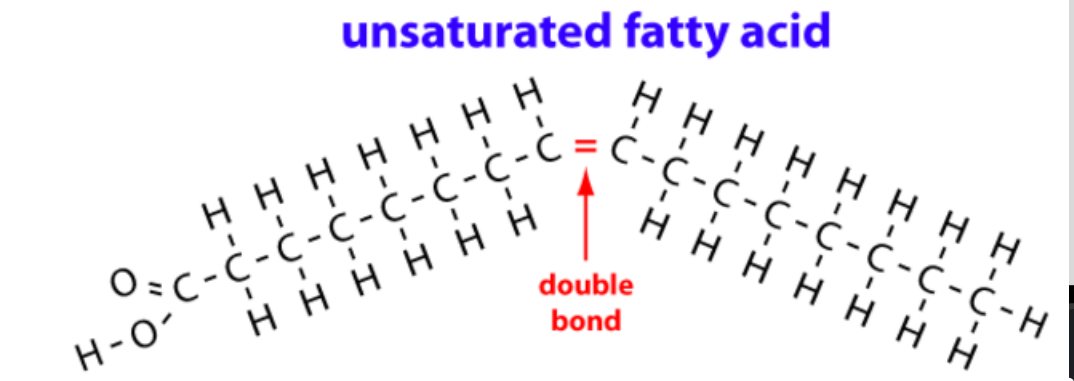
Lipids Triglycerides (Fats)

Types of **Fatty Acids** tails:

- **Saturated** fatty acids have the maximum number of hydrogens bonded to the carbons (all single covalent bonds between carbons); Animal Fats.

- **Unsaturated** fatty acids contain one or more double bonds; Oils.





Types of Fatty Acids

Saturated fatty acids

liquids **at room temperature**

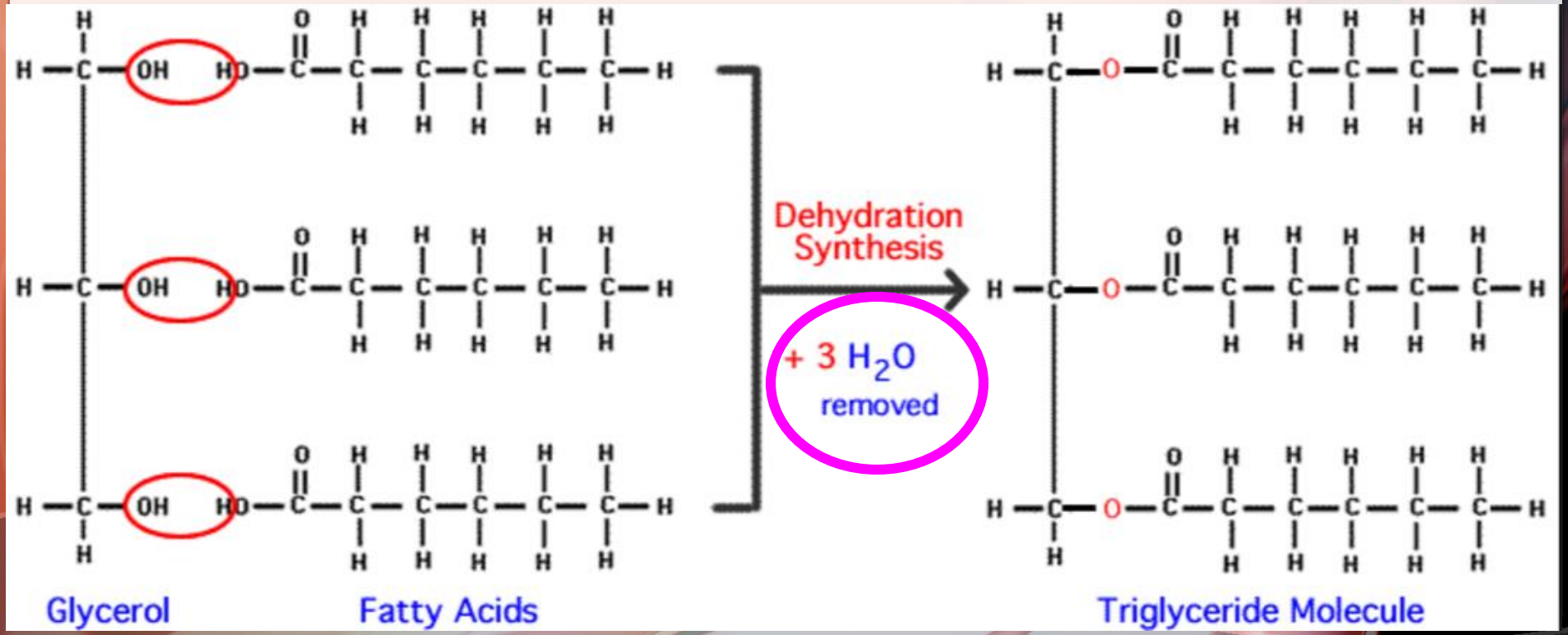
Unsaturated fatty acids

solids at room temperature

SATURATED FAT	VS	UNSATURATED FAT
		
Butter, coconut oil, whole milk, meat, peanut, butter, margarine, cheese, vegetable oil, fried foods, & frozen dinners		Avocado, soybean oil, canola oil and olive oil, sunflower oil, fish oils walnuts, flax, & red meats

Lipids Triglycerides (Fats)

Triglycerides are made by the Dehydration Synthesis of 1 Glycerol + 3 Three Fatty Acids forming ESTER BONDS



Proteins

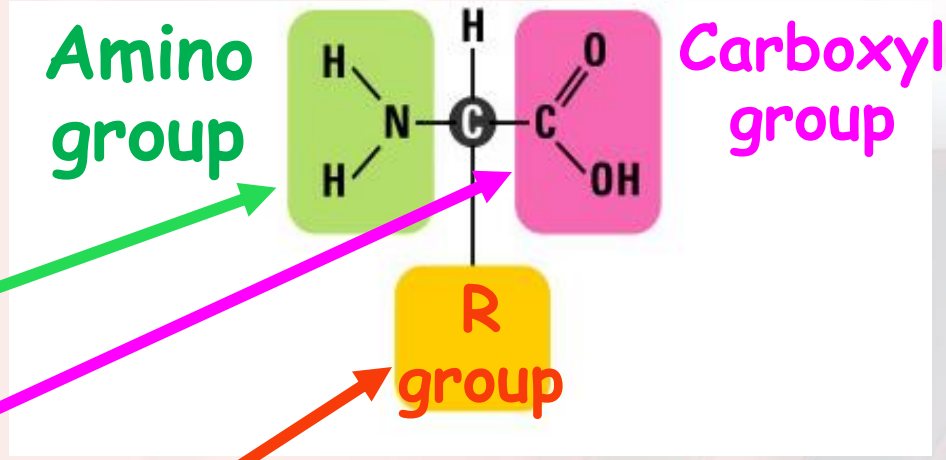
Proteins

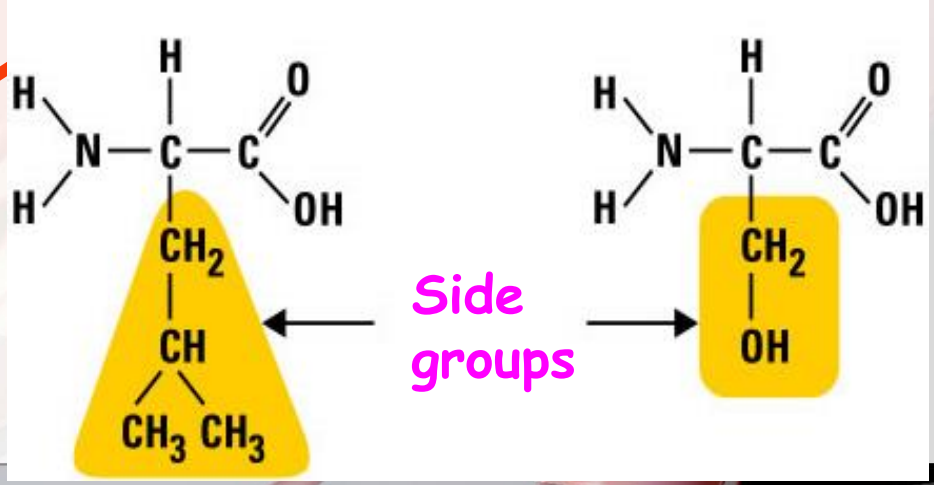
- Account for over half of the body's organic matter (skin, bones, hair, muscle, organs, tissues, enzymes, hormones)
- **Main Functions:**
  - Provide the **construction materials** for body tissues.
  - Play a vital role in cell function.
  - Act as **enzymes**, **hormones**, and **antibodies.**
  - Contain **Carbon**, **Hydrogen**, **Oxygen**, **Nitrogen**, and sometimes **Sulfur.**
- **MONOMERS: Amino Acids (20 types in humans)**

Proteins

Amino acids have a central carbon with 4 groups attached to it:

- **Amino Group: NH_2**
- **Carboxyl Group: COOH**
- **Hydrogen: H**
- **Side group: R**



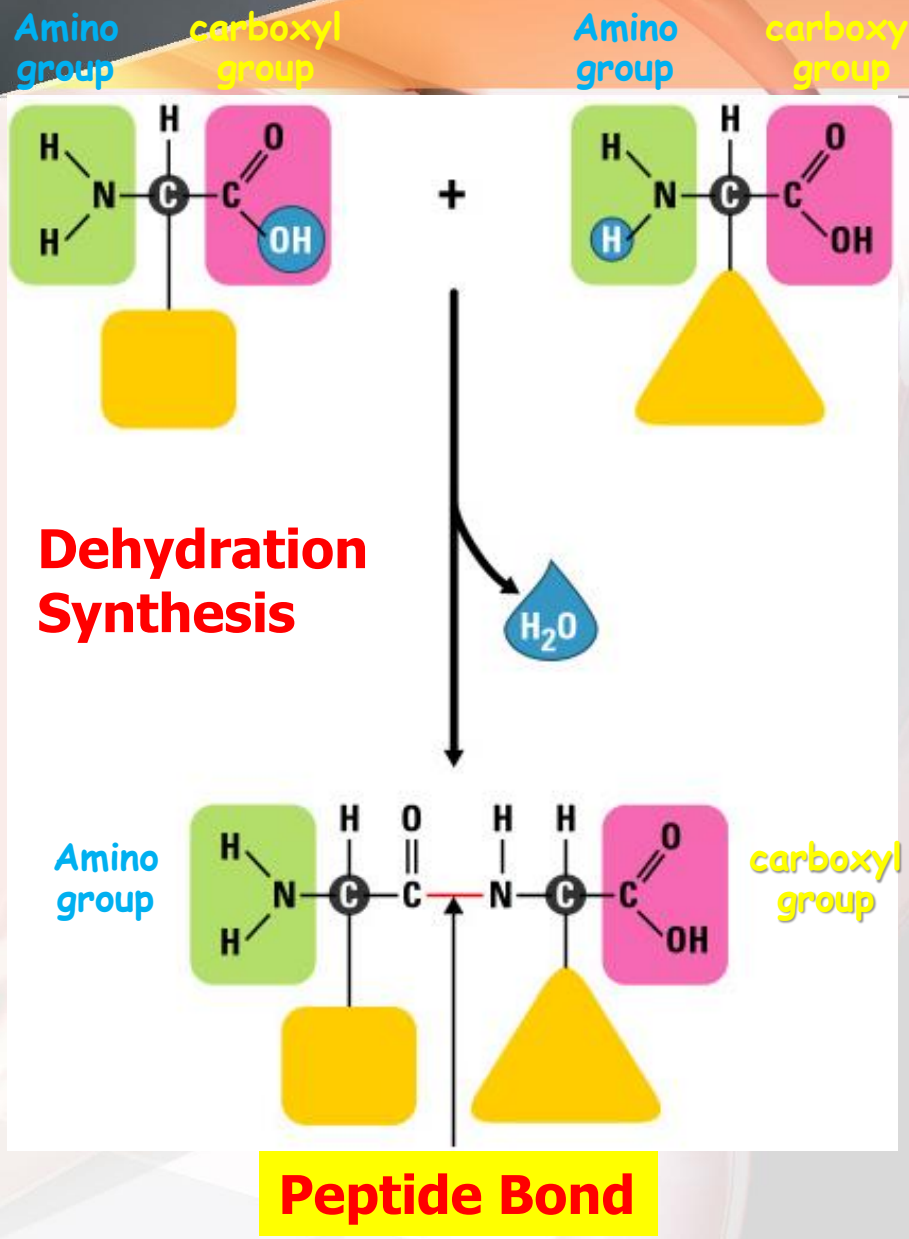


Leucine

Serine

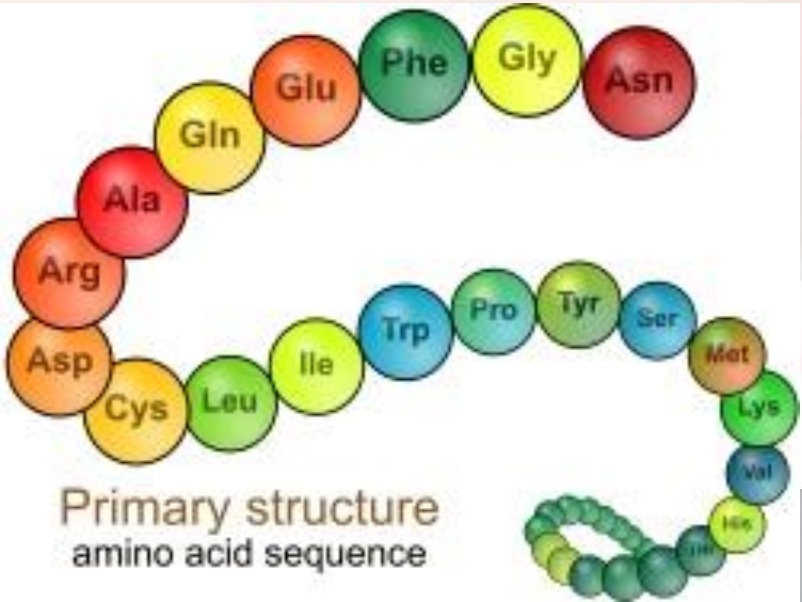
Proteins

- Cells link amino acids together to make proteins by dehydration synthesis.
- **PEPTIDE BONDS form to hold the amino acids together.**



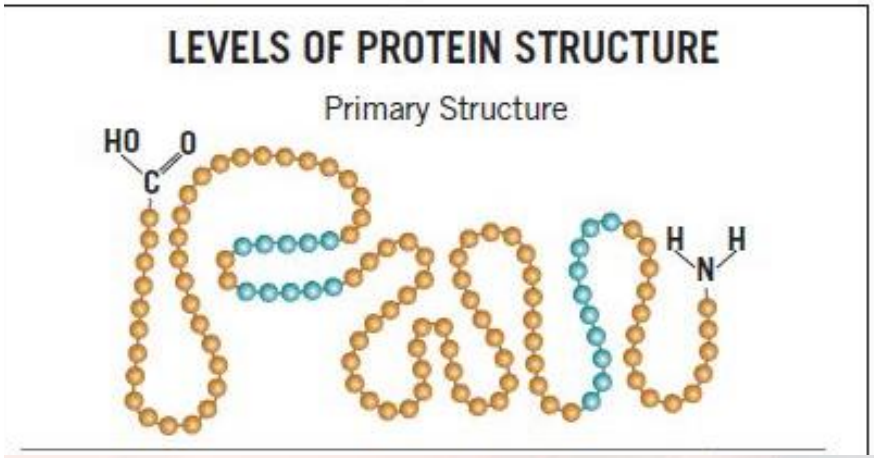
Protein Structure

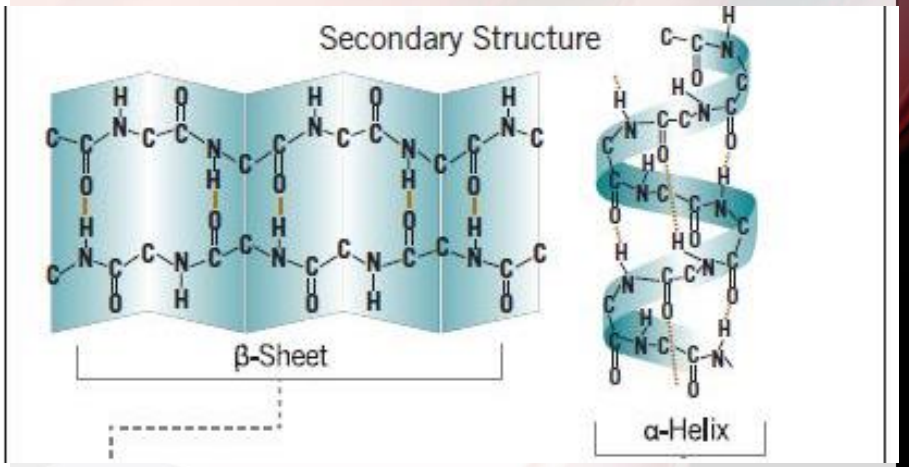
- The **functions** of different types of proteins depend on their individual **shapes.**
- A **polypeptide chain** contains hundreds or thousands of **amino acids** linked by **peptide bonds.**
- **The amino acid sequence causes the polypeptide to assume a particular shape.**



Protein Structure

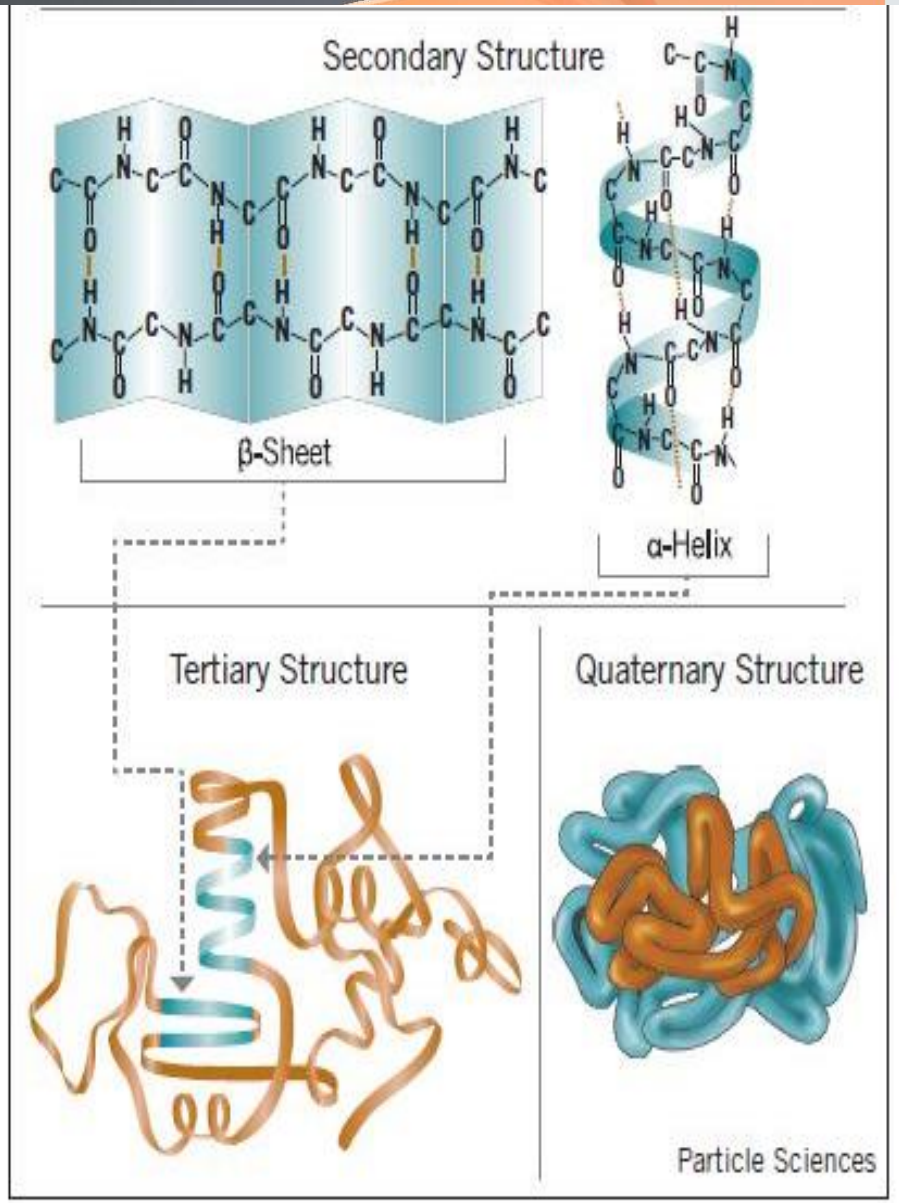
- Sequences with fewer than 50 amino acids are generally referred to as *peptides*, while the terms protein or *polypeptide* are used for longer sequences.
- The amino acid sequence makes up the *primary structure* of the protein.
- Stretches or strands of peptides compose *secondary structure*, depending on hydrogen bonding.

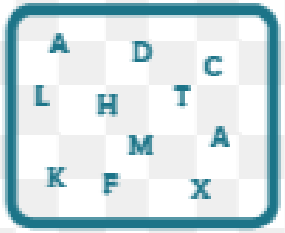




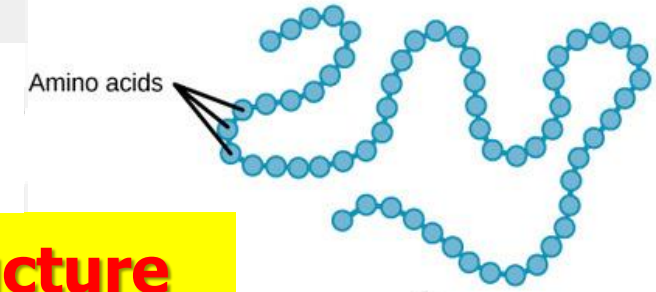
Protein Structure

- The overall three-dimensional shape of an entire protein molecule is the *tertiary structure*. The protein molecule will bend and twist in such a way as to achieve **maximum stability or lowest energy state**.
- The *quaternary structure* refers to how these protein subunits interact with each other and arrange themselves to form a larger aggregate protein complex.





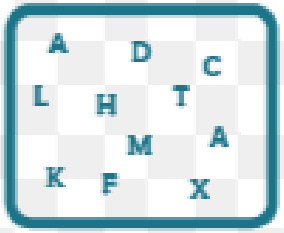
Alphabets



Primary Protein structure
sequence of a chain of animo acids

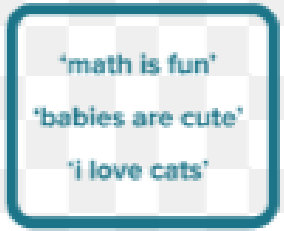
Protein Structure

Protein Structure

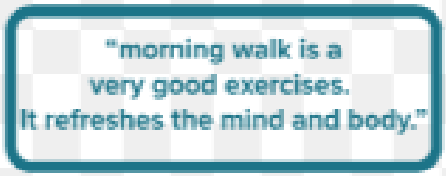


Alphabets

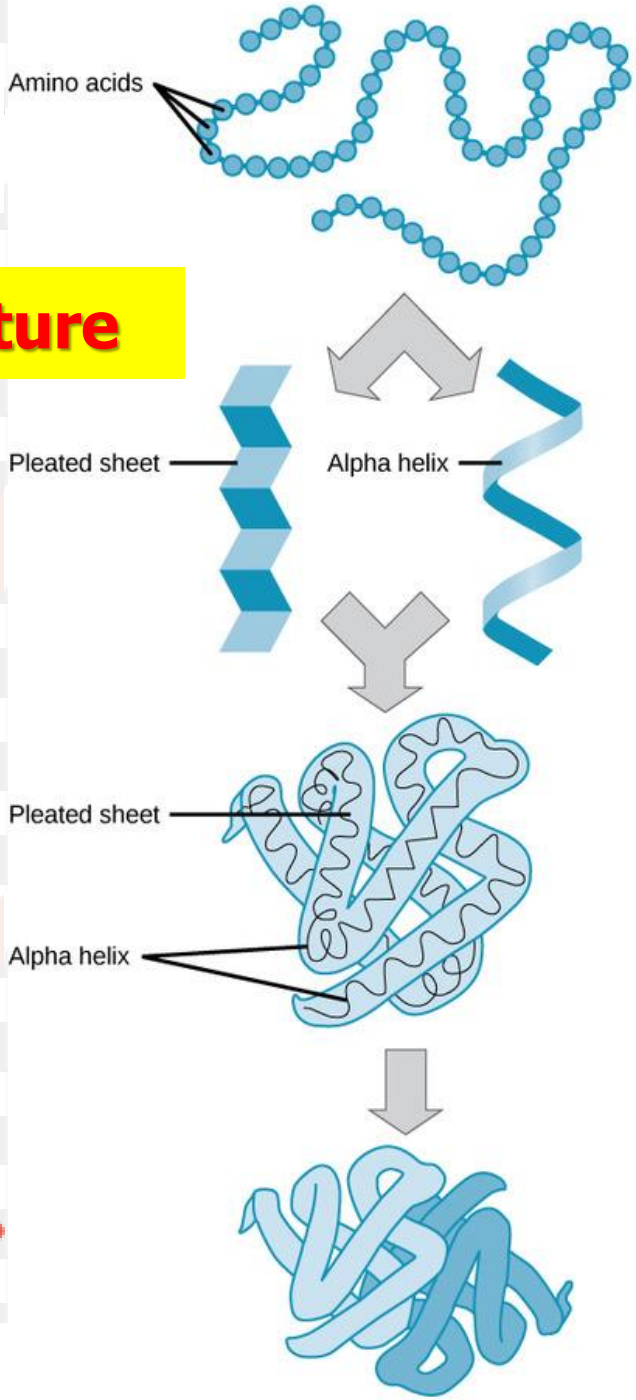
Words



Sentences



Paragraph



Primary Protein structure
sequence of a chain of animo acids

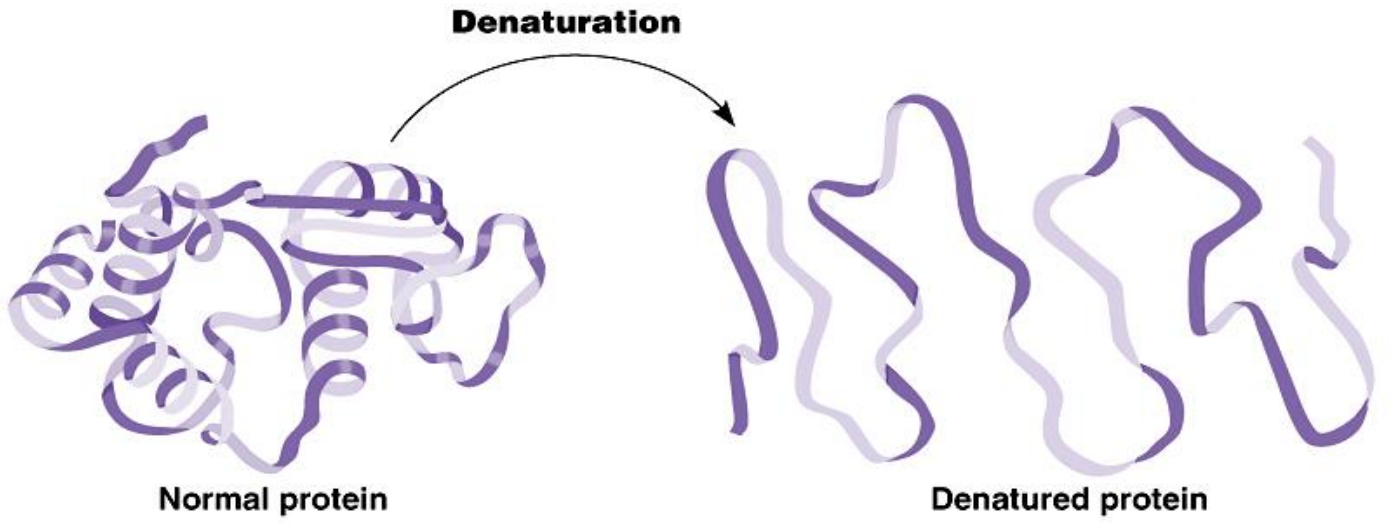
Secondary Protein structure
hydrogen bonding of the peptide backbone causes the amino acids to fold into a repeating pattern

Tertiary protein structure
three-dimensional folding pattern of a protein due to side chain interactions

Quaternary protein structure
protein consisting of more than one amino acid chain

Protein Structure

- **If a protein's shape is altered, it can no longer function.**
- In the process of **denaturation**, a protein
  - unravels
  - loses its specific shape
  - loses its function.
- Proteins can be denatured by changes in salt concentration, changes in pH, or high heat.



Review

QUICK CHECK

What are the monomers of lipids?

Function of Lipids?

Distinguish the types of fatty acids.

Monomer & function of proteins?

Describe how to produce an amino acid.

What determines the shape of proteins?

What is denaturation & what causes it?

Review

QUICK CHECK

What are the monomers of lipids?

Glycerol (1) & fatty acids (3)

Function of Lipids?

Protects, insulates, stores energy

Distinguish the types of fatty acids.

Saturated (all single bonds with carbon) … liquids, animal fat

Unsaturated (at least one double/triple bond with carbon) … solids, oils

Monomer & function of proteins?

Amino acids; construction materials, enzymes, hormones, antibodies

Describe how to produce an amino acid.

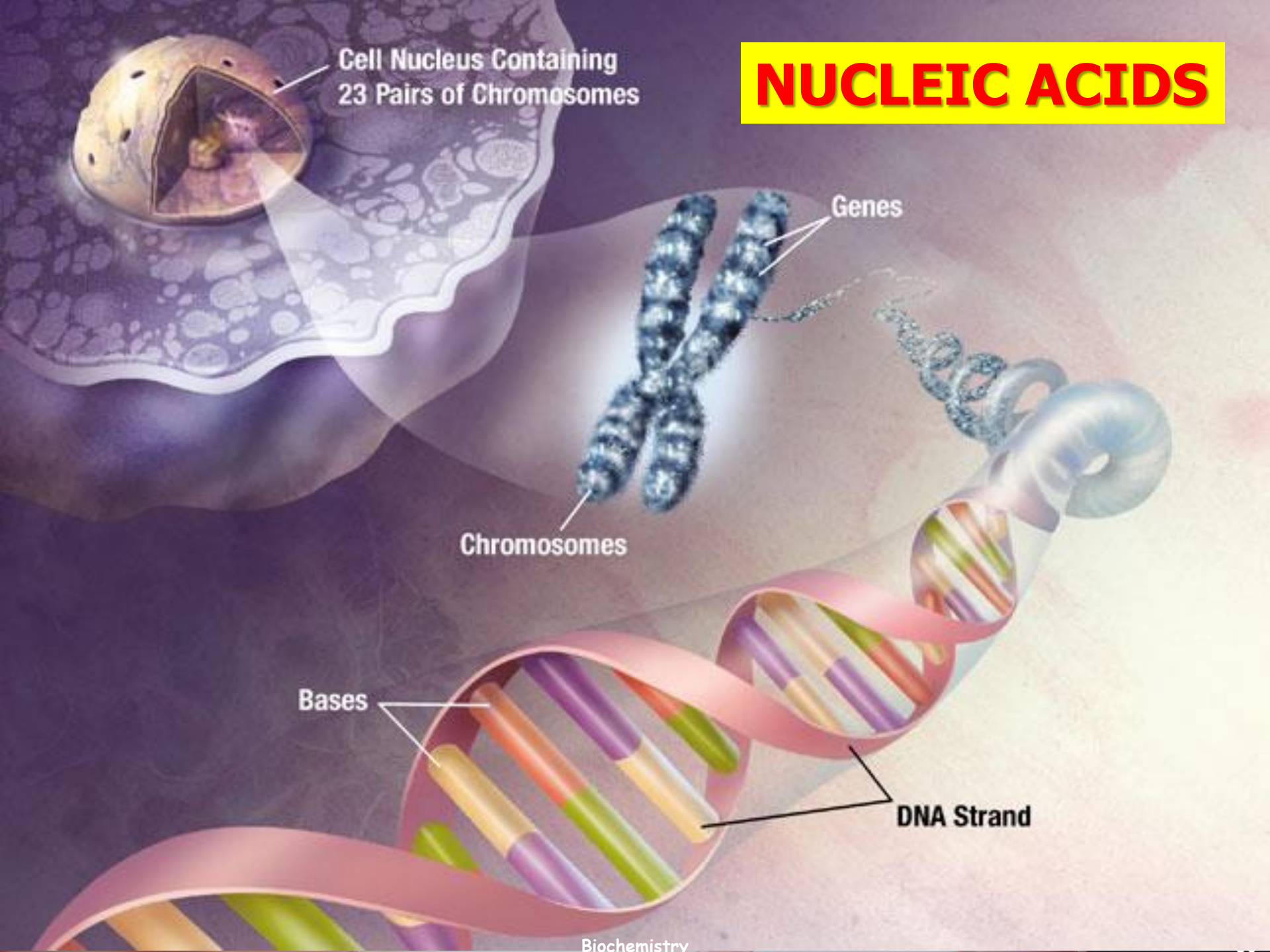
Amine group + carboxyl group (dehydration synthesis) forming a peptide bond

What determines the shape of proteins? *Amino acid sequence*

What is denaturation & what causes it?

A protein's shape is altered; changes in salt concentration, changes in pH, high heat

NUCLEIC ACIDS



Nucleic Acids

- Make up the **GENES**: units of inheritance.
- Determine what type of organism you will be.
- Controls growth and development mainly by **dictating protein structure**.
- Composed of: **Carbon**, **Hydrogen**, **Oxygen**, **Nitrogen**, and **Phosphorous.**
- Two types exist:

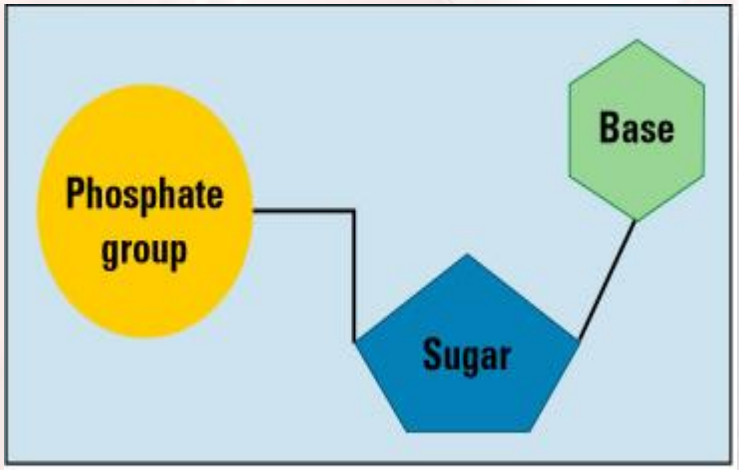
Deoxyribonucleic Acid (DNA)

Ribonucleic Acid (RNA)

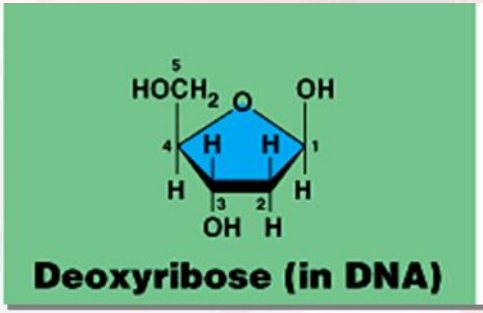
Nucleic Acids

Built from **NUCLEOTIDES** (**Monomers**):

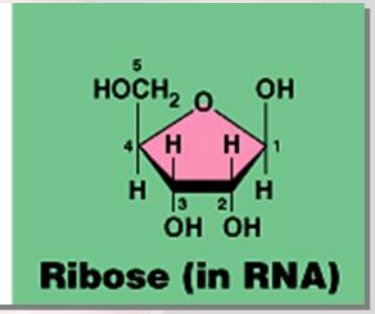
- **Pentose** (5-carbon) **Sugar**
  - **Ribose** in **RNA**
  - **Deoxyribose** in **DNA**
- **Phosphate Group**
- **Nitrogenous Base:**
  - **A = Adenine**
  - **G = Guanine**
  - **C = Cytosine**
  - **T = Thymine** (only in DNA)
  - **U = Uracil** (only in RNA)



DNA nucleotide

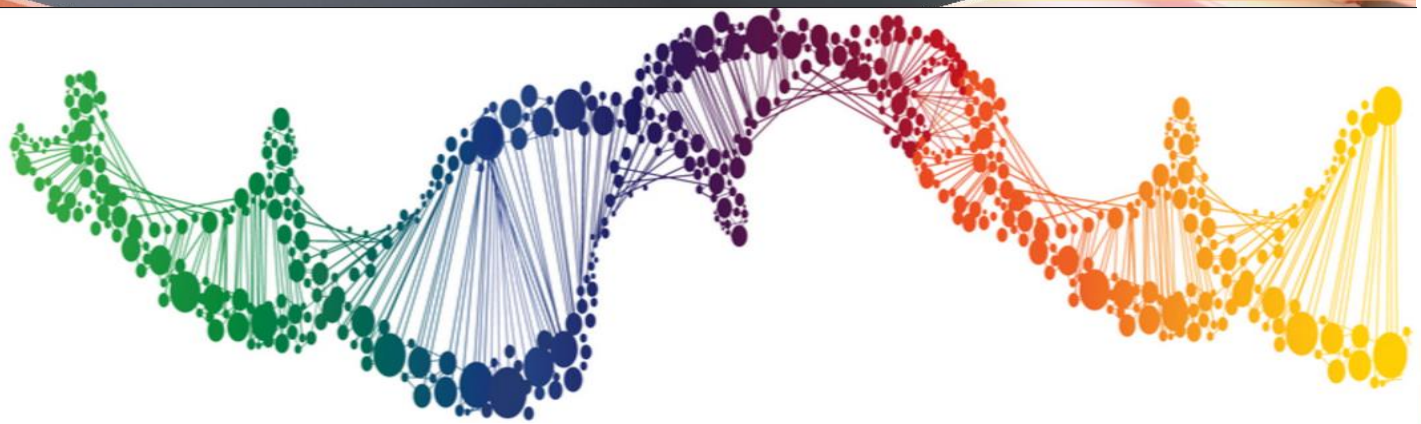


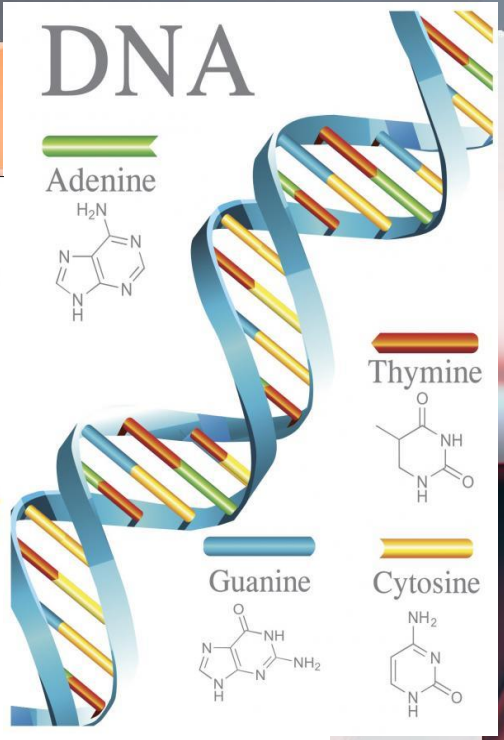
Deoxyribose (in DNA)



Ribose (in RNA)

Nucleic Acids





Deoxyribonucleic acid (DNA)

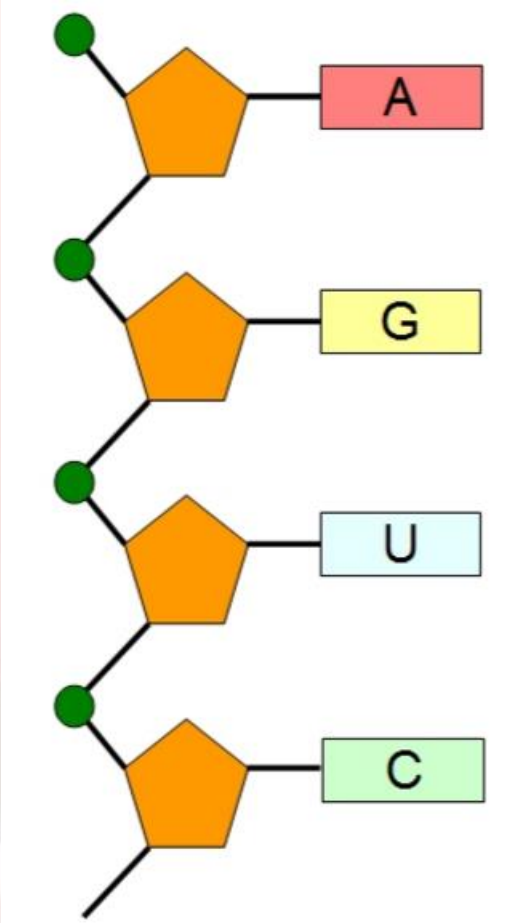
- The genetic material found within the cell's nucleus.
- Provides instructions for every protein in the body.
- Organized by complimentary bases to form a **double-stranded helix.**
- Contains the sugar *deoxyribose* and the nitrogen bases ***A**denine, **T**hymine, **C**ytosine,* & ***G**uanine.*
- Replicates before cell division.

Nucleic Acids

Ribonucleic acid (RNA)

- Carries out DNA's instructions for Protein Synthesis (Translation) in the cytoplasm.
- Created from a template of DNA (Transcription) in the nucleus.
- Organized by complimentary bases to form a **single-stranded helix.**
- Contains ***ribose*** sugar and nitrogen bases

***A**denine, **U**racil, **C**ytosine,* & ***G**uanine.*



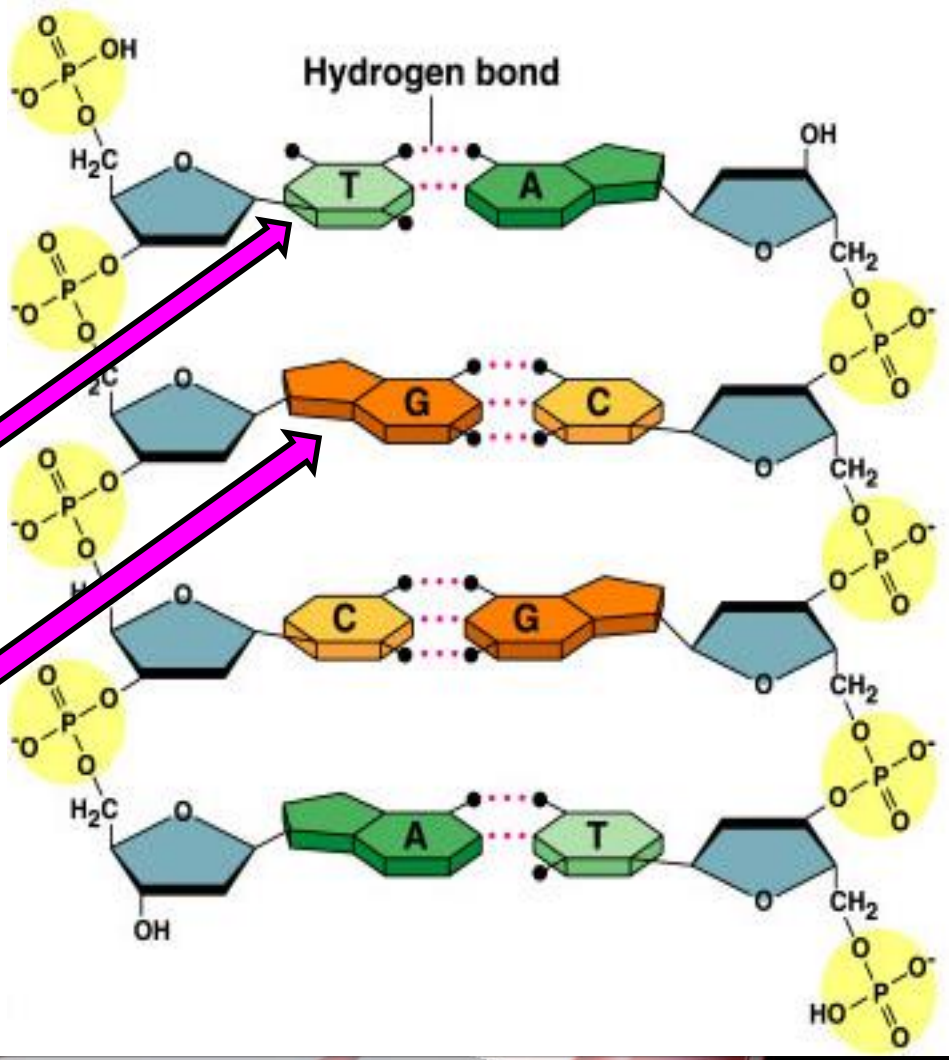
Bonding in Nucleic Acids

Hydrogen Bonds:

Hydrogen bonds form between the 2 Nucleic Acid strands (in DNA).

A :: T 2 H bonds

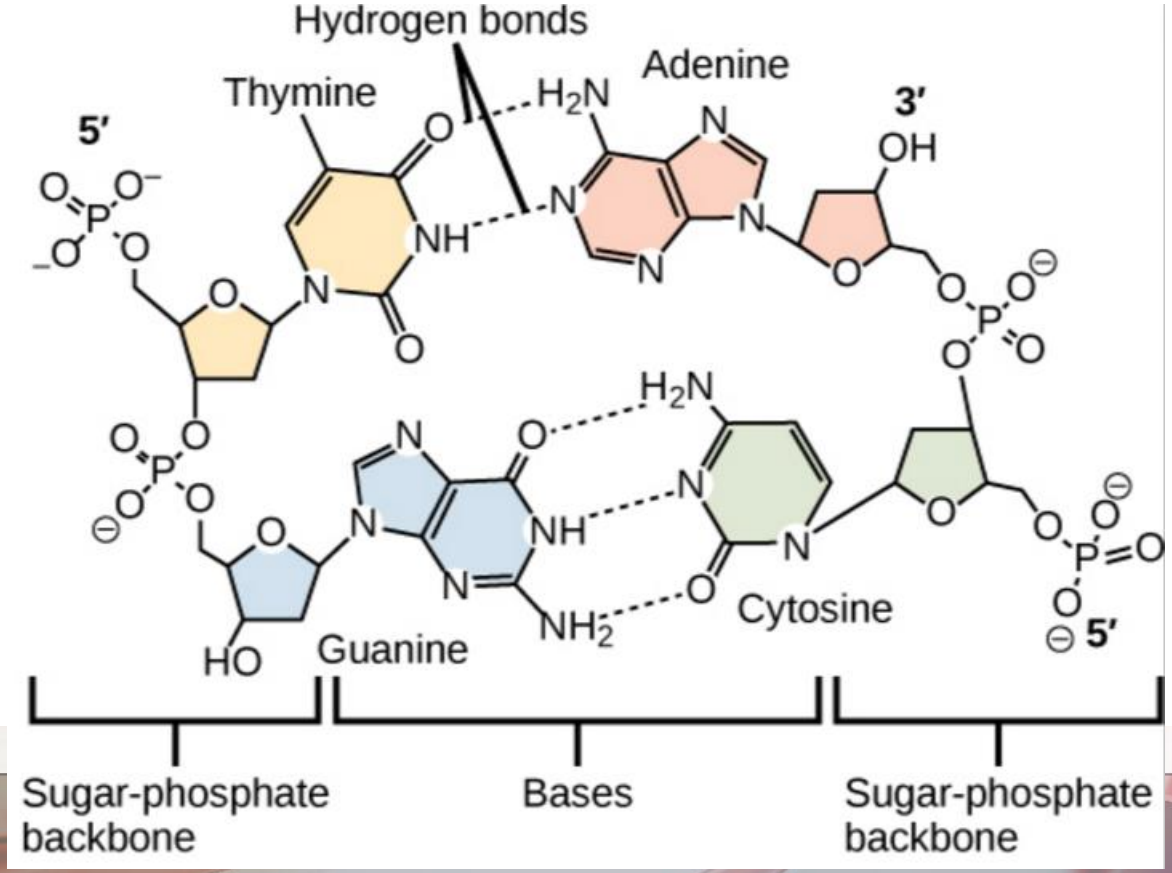
G ::: C 3 H bonds



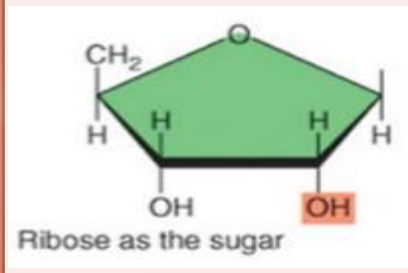
Bonding in Nucleic Acids

Sugar-Phosphate Backbone

Sugar of one Nucleotide subunit is connected to Phosphate of the next nucleotide (dehydration synthesis).



RNA



Cytosine **C**

Guanine **G**

Adenine **A**

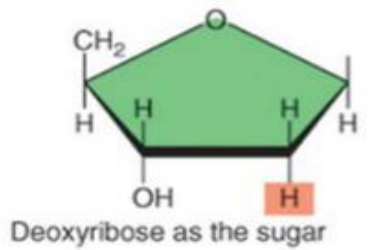
Uracil **U**

Nucleobases of RNA

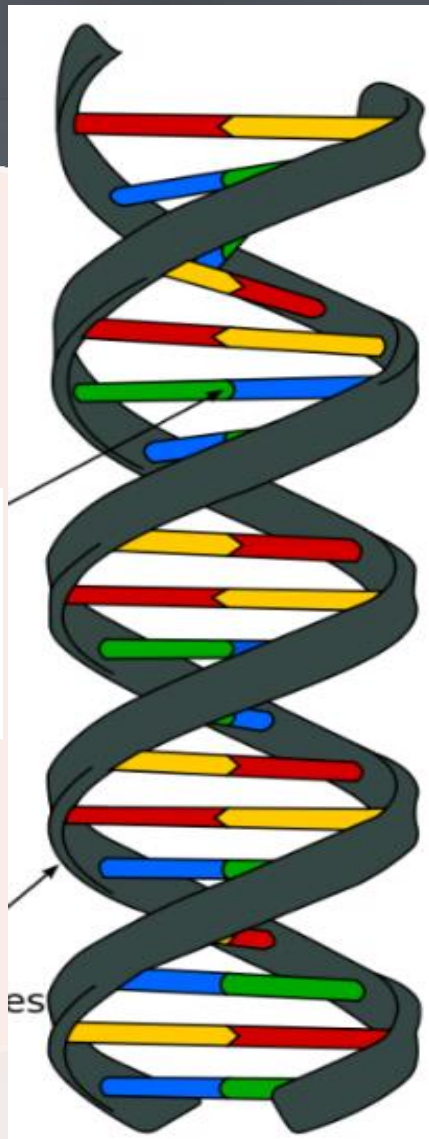
RNA
Ribonucleic acid

Generally single-stranded

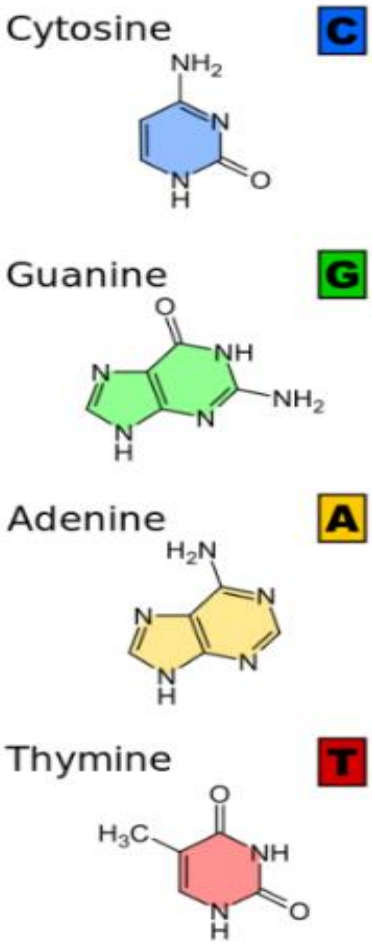
DNA



Deoxyribose as the sugar

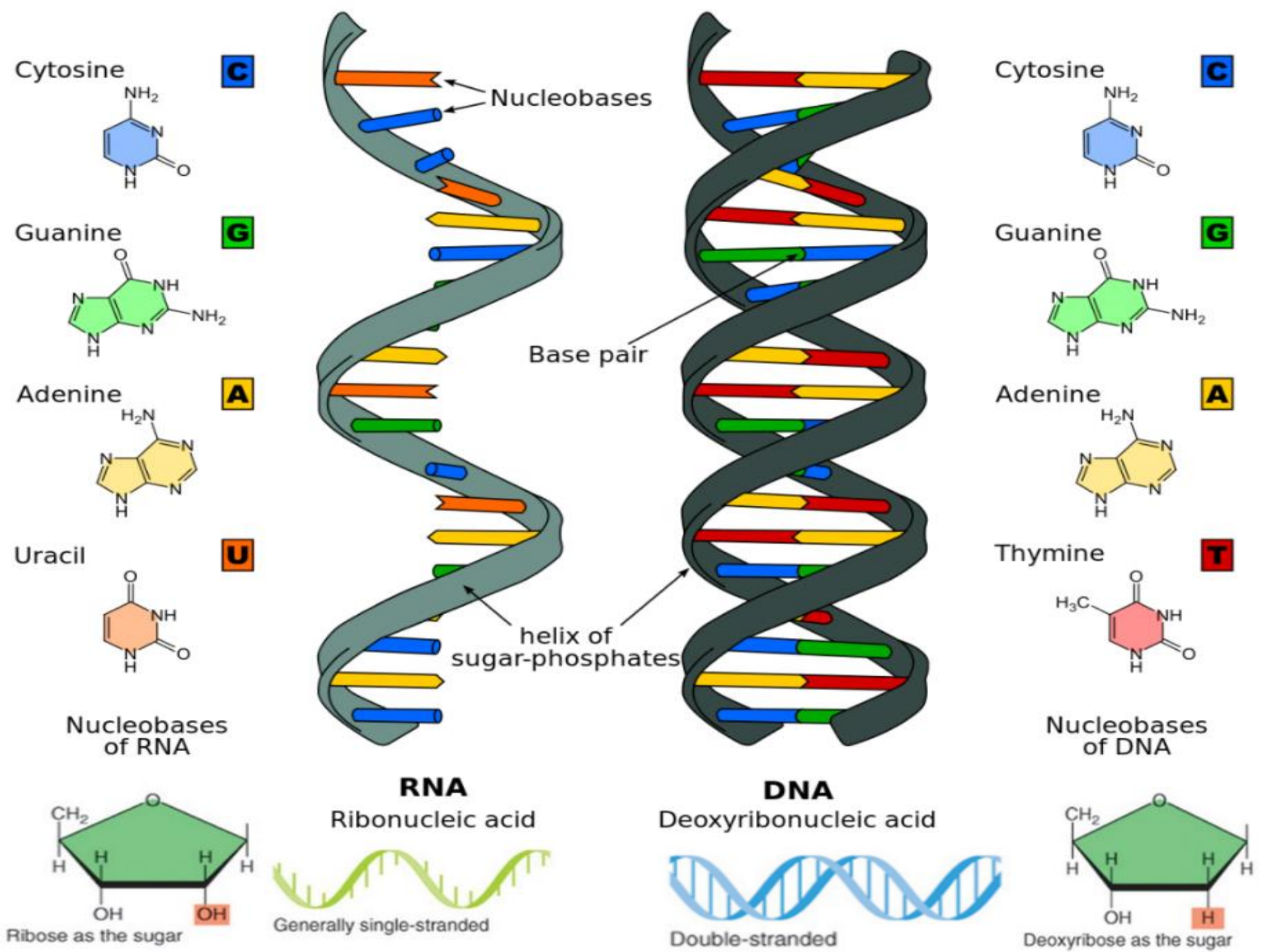


DNA
Deoxyribonucleic acid



Nucleobases of DNA


Double-stranded


Cytosine
C
Guanine
G
Adenine
A
Uracil
U
Nucleobases of RNA
Nucleobases
Base pair
helix of sugar-phosphates
Cytosine
C
Guanine
G
Adenine
A
Thymine
T
Nucleobases of DNA
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid
Ribose as the sugar
Generally single-stranded
Double-stranded
Deoxyribose as the sugar

Review

What elements are each macromolecule made of?

What are the components of a nucleotide?

Which nitrogenous bases bond with which … & how?

Distinguish between RNA & DNA

What is the ultimate function of nucleic acids?

Review

QUICK CHECK

What elements are each macromolecule made of?

Carbohydrates → C, H, O … 1:2:1

Lipid → C, H, O

Proteins → C, H, O, N, S

Nucleic Acids → C, H, O, N, P

What are the components of a nucleotide?

Sugar (ribose, deoxyribose), phosphate group, nitrogen base

Which nitrogenous bases bond with which … & how?

A :: T with 2 H bonds; G ::: C with 3 H bonds … RNA has U instead of T

Distinguish between RNA & DNA

RNA: single stranded; mainly operates in the cytoplasm

DNA: double stranded; located in the nucleus

What is the ultimate function of nucleic acids?

Protein synthesis; controlling cell function

Review: General Terms

QUICK CHECK

? MOLECULES

Category	?	Polymer
?	monosaccharide	?
?	amino acids	?
Lipids	?	Lipid
Nucleic Acids	?	?

Review: General Terms

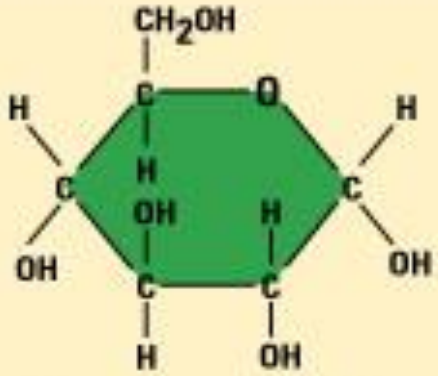
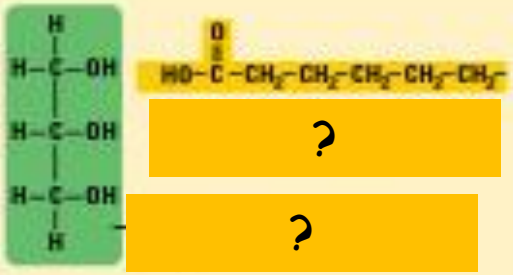
QUICK CHECK

ORGANIC MOLECULES

Category	Monomer	Polymer
Carbohydrates	monosaccharide	polysaccharide
Proteins	amino acids	polypeptide
Lipids	Fatty acid, Glycerol	Lipid
Nucleic Acids	Nucleotide	Nucleic acid

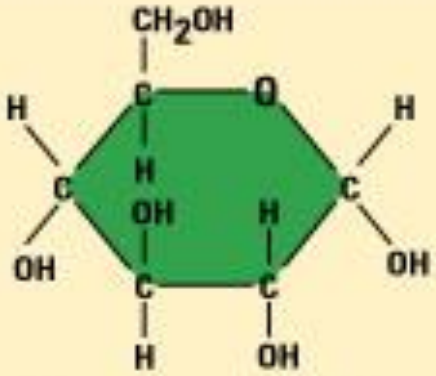
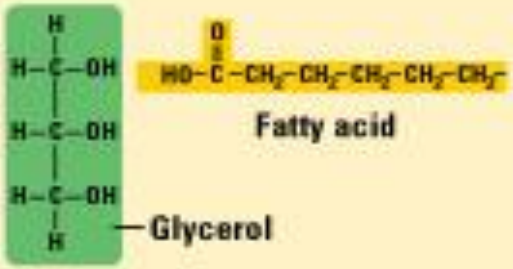
Macromolecules

QUICK CHECK

Biological macromolecule	Function	Monomer	Examples
?	Dietary energy; storage; plant structure Bonds: ?	 ?	Monosaccharides: ? dissaccharides: ? Polysaccharides: ?
?	Long-term energy storage (for fats); hormones (for steroids) Bonds: ?	 ? ? Components of a fat molecule	?

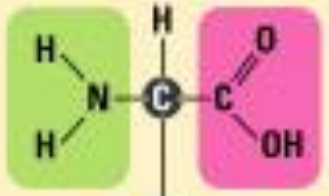
Macromolecules

QUICK CHECK

Biological macromolecule	Function	Monomer	Examples
Carbohydrates	Dietary energy; storage; plant structure Bonds: **Glycosidic**	 Monosaccharide	Monosaccharides: glucose, fructose. dissaccharides: lactose, sucrose. Polysaccharides: starch, cellulose. glycogen
Lipids	Long-term energy storage (for fats); hormones (for steroids) Bonds: **Ester**	 Components of a fat molecule	Fats, oils, steroids

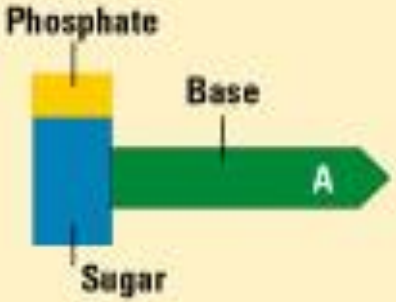
Macromolecules

QUICK CHECK

Biological macromolecule	Function	Monomer	Examples
?	Enzymes, structure, storage, contraction, transport, etc. Bonds: ?	? group, ? group  ?	? (an enzyme), ?
?	Information storage Bonds: ?	? ?  ? Nucleotide	?

Macromolecules

QUICK CHECK

Biological macromolecule	Function	Monomer	Examples
Proteins	**Enzymes, structure, storage, contraction, transport, etc.** Bonds: **Peptide**	 **Amino acid**	**Lactase (an enzyme), hemoglobin**
Nucleic acids	**Information storage** Bonds: **Hydrogen**	 **Nucleotide**	**DNA, RNA**