Water

Importance of Water to Living Things

Ted-Ed Water in Your Body

A. Water is the most abundant substance on the surface of Earth.

B. It is essential to all life.

C. It is a very unique molecule.

D. Life began in water, and all living organisms are "water-based."

E. All living organisms have adaptations for maintaining water levels. (e.g. human skin, plant stomata, bacterial cysts)

Water is important for living things

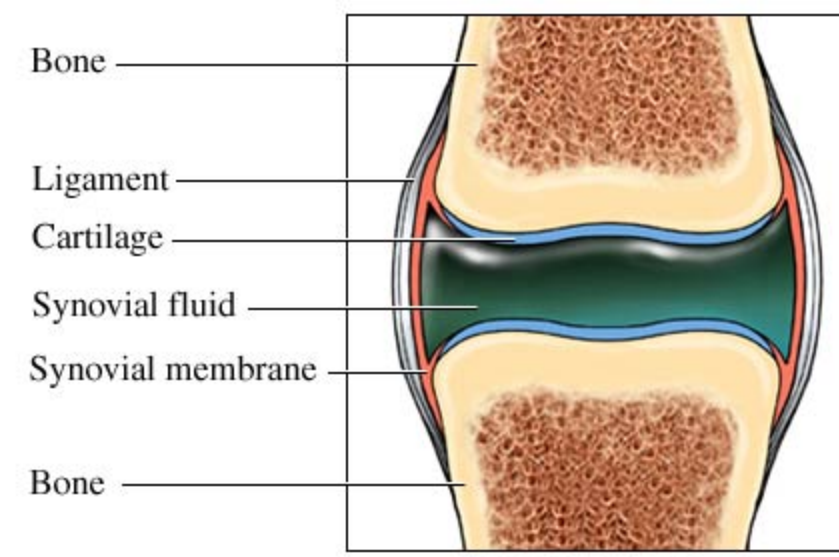
A. Human body is approx. 60 – 70% water

B. Only substances dissolved in water can enter the cell membrane of cells (eg. Glucose, AA's)

C. Water carries away dissolved substances from cells and wastes excreted in liquids (eg. Sweat and urine)

D. Ions are necessary for many body processes
   A. Ca^{++} for movement
   B. K^+ and Na^+ for generation of nerve impulses
   C. Ions are formed when an ionic substance is dissolved in water

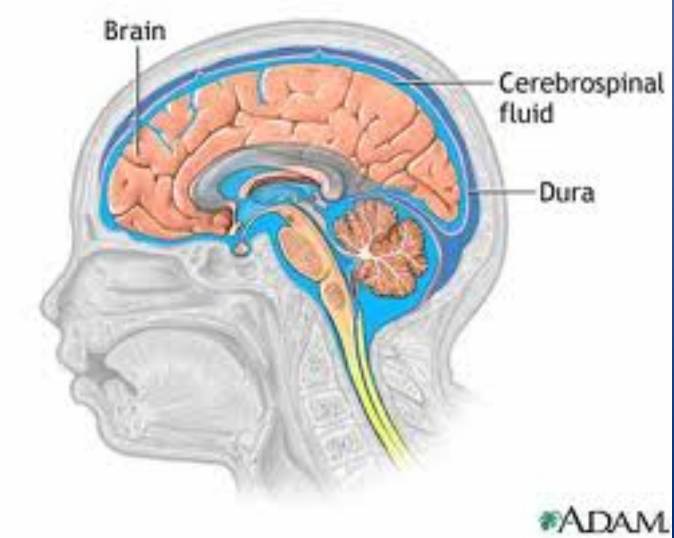
E. Water and water based solutions act as lubricants (e.g. your joints are lubricated by synovial fluids



Cross section of a healthy joint

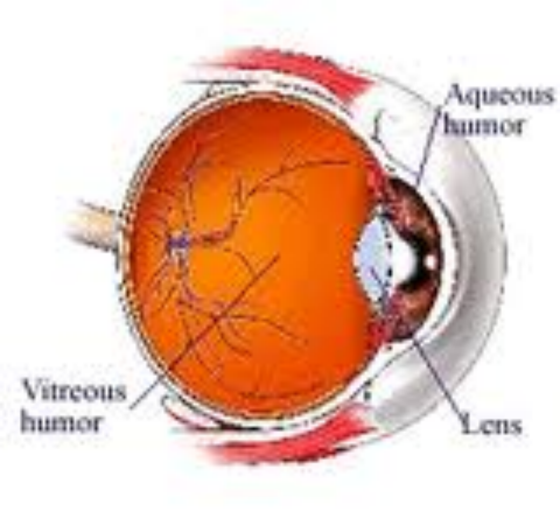
F. Water regulates temperature in living systems because water does not heat up easily or cool down easily when compared to metal or sand

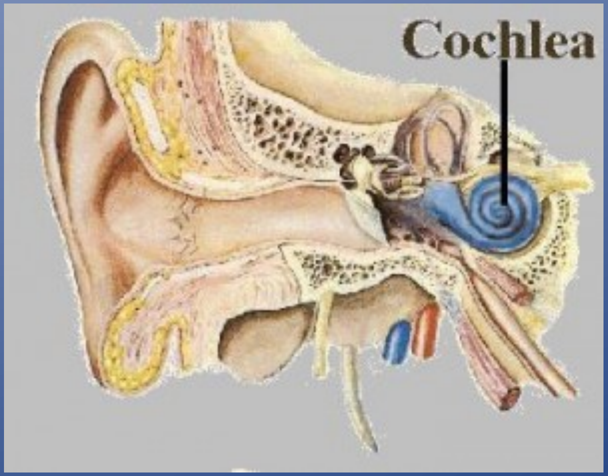
G. Human brains are partially protected against shock by a watery layer.



H. Sense organs require water

- Eyes are filled with a thick fluid
- Hearing depends upon a fluid filled structure called the cochlea that detects and transmits vibrations

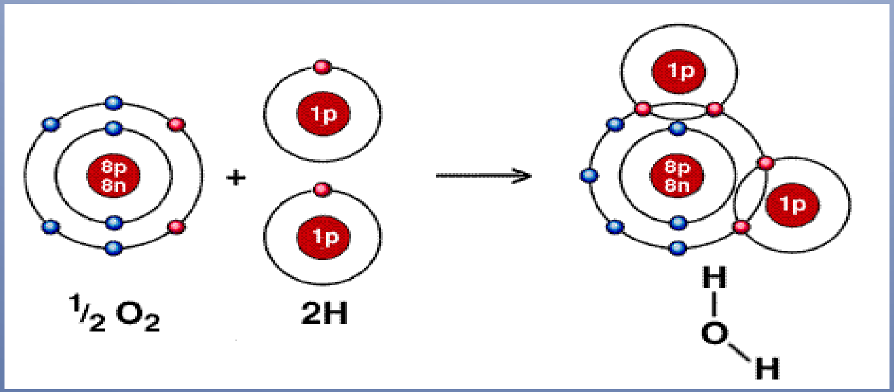




I. Hydrolytic enzymes are involved in breaking bonds between molecules and this requires water.

The Chemistry of Water

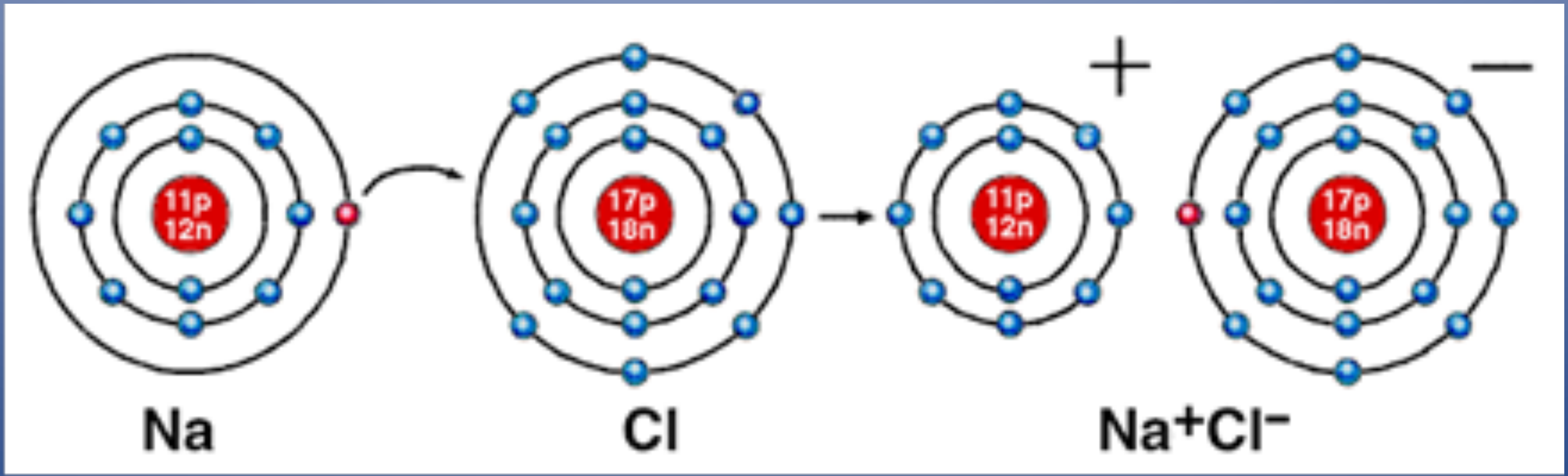
A. Water is covalently bonded



- Bonds are formed when atoms share electrons
- Covalent bonds are strong bonds when compared with ionic and hydrogen bonds

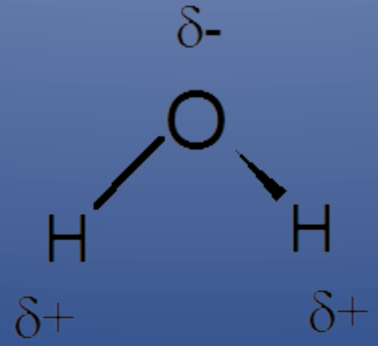
Preview Animation

- An ionic bond is a bond in which electrons are transferred between atoms



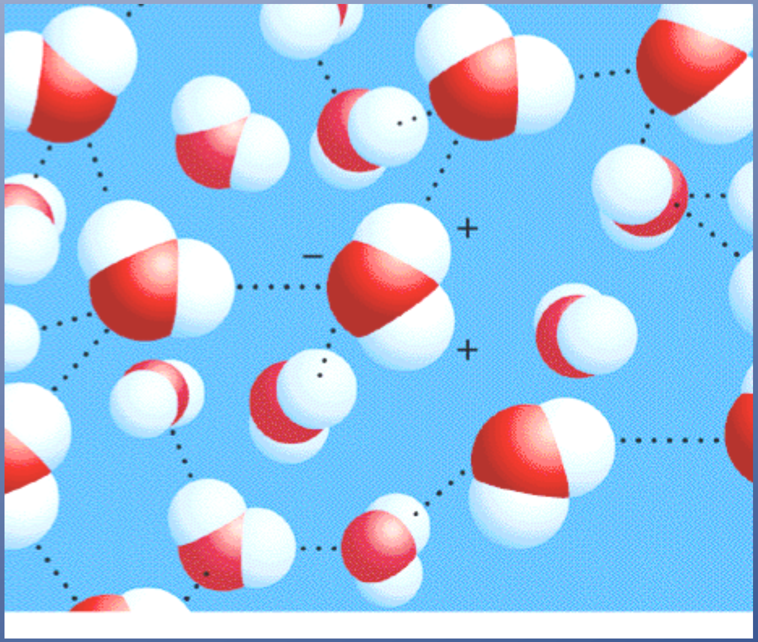
B. Water is polar TED Lesson

- The shared electrons spend more time circulating near the larger oxygen than the smaller hydrogen. Thus the oxygen has a slight net negative charge while the hydrogen have a small net positive charge

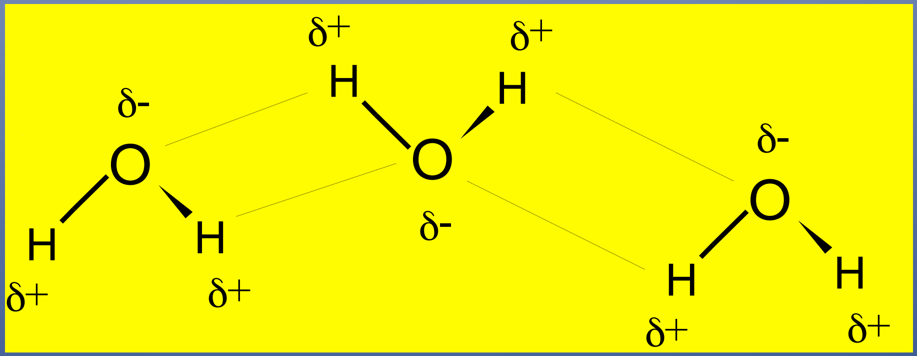


Polar bonding

- Hydrogen bonds occurs whenever a partially positive H is attracted to a partially negative atom (ex. oxygen and nitrogen)
- It is represented by a dotted line because it is weak and fairly easily broken compared to covalent and ionic bonds.



- There are lots of water molecules found in living systems so the net effect of all those weak H-bonds, can add up to have a large effect.



III. Water has Unique Characteristics

- It is abundant through the biosphere
- Hydrogen bonding makes it have a low freezing point and a high boiling point, so that it is liquid at body temperature
- Water absorbs much heat before it warms up or boils, and gives off much heat before it **freezes because it takes a lot of energy to break the hydrogen bonding. (Specific Heat Capacity)**

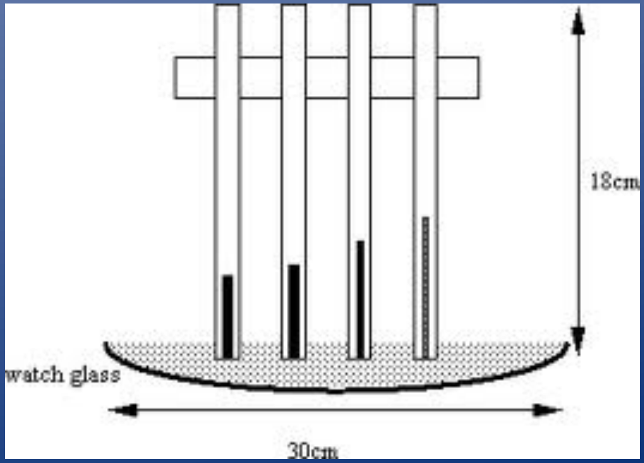
- Water has high cohesiveness

1. Water molecules tend to cling together and draw dissolved substances along with it.

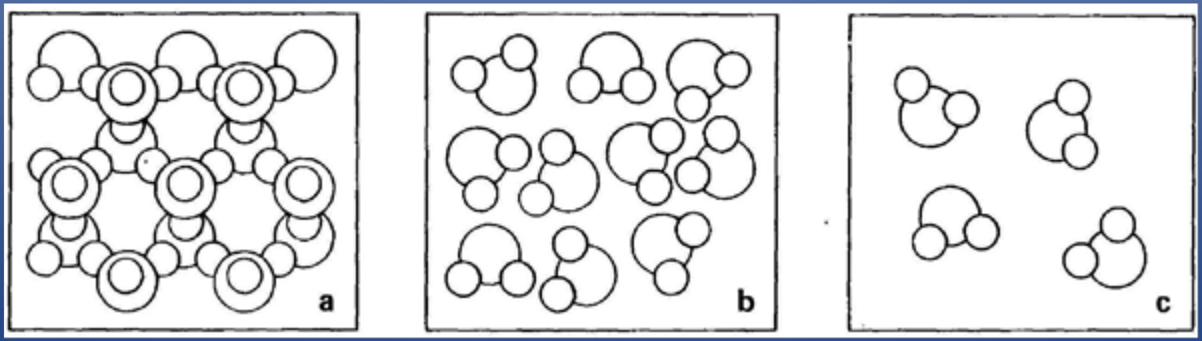
2. This makes it good for transporting materials through tubes.

- Water has high adhesiveness
  1. Water molecules tend to cling to surfaces

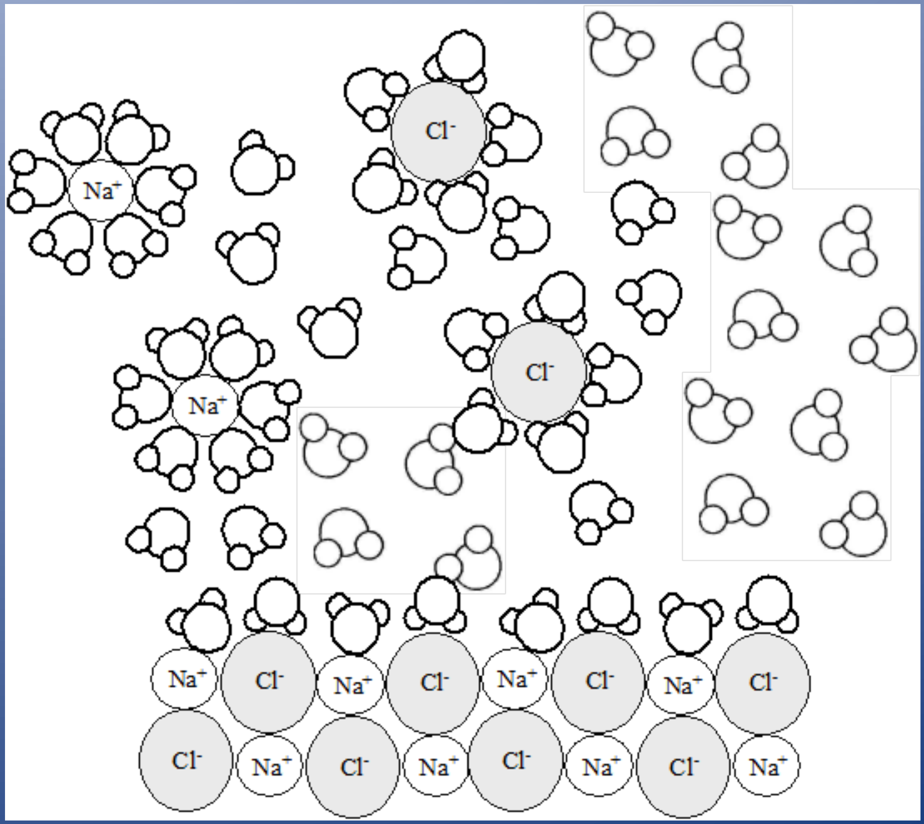
  2. ex. capillary action



- Liquid water is more dense than ice because of hydrogen bonding.
    1. Ice will float on top of the water
    2. The ice layers helps protect organisms below.



- Water dissolves other polar molecules and is one of the best solvents known so it is often called the "universal solvent."
- Animation 2

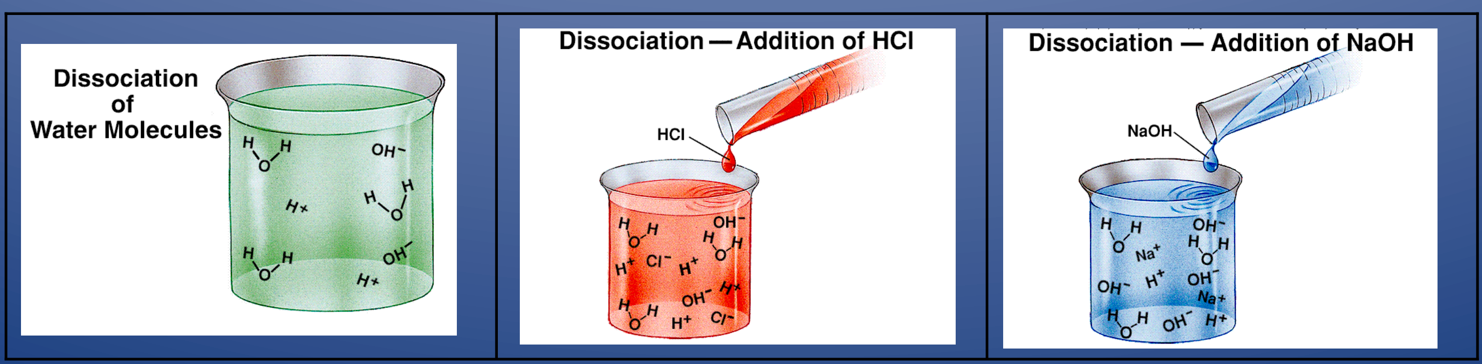


Acids, Bases & Buffers

Acids and Bases ANIMATION

A. ACIDS are compounds that dissociate in water and release H^+ ions. Ex) HCl, H_2CO_3

B. BASES are compounds that dissociate in water and release OH^- ions. Ex) NaOH, KOH



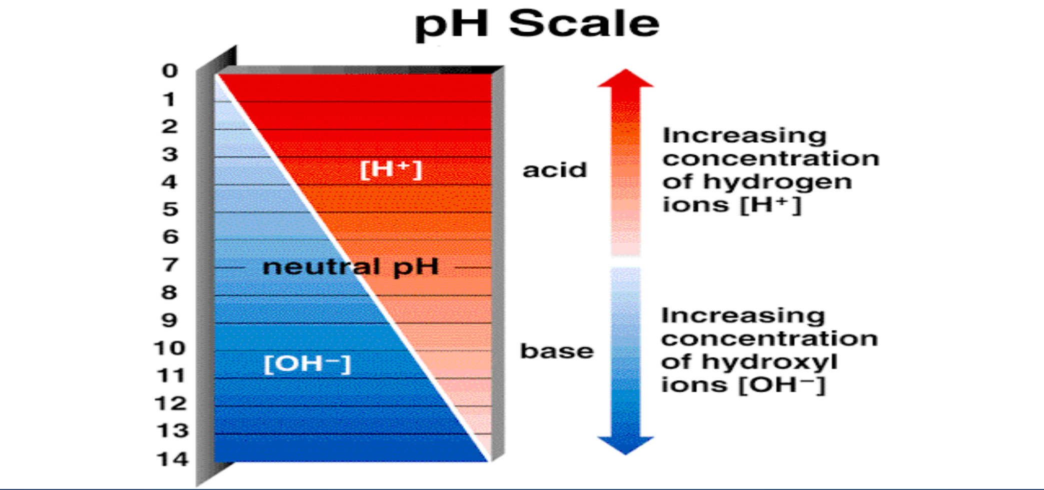
pH

A. pH is a measure of the concentration of hydrogen ions and ranges from 0 to 14.

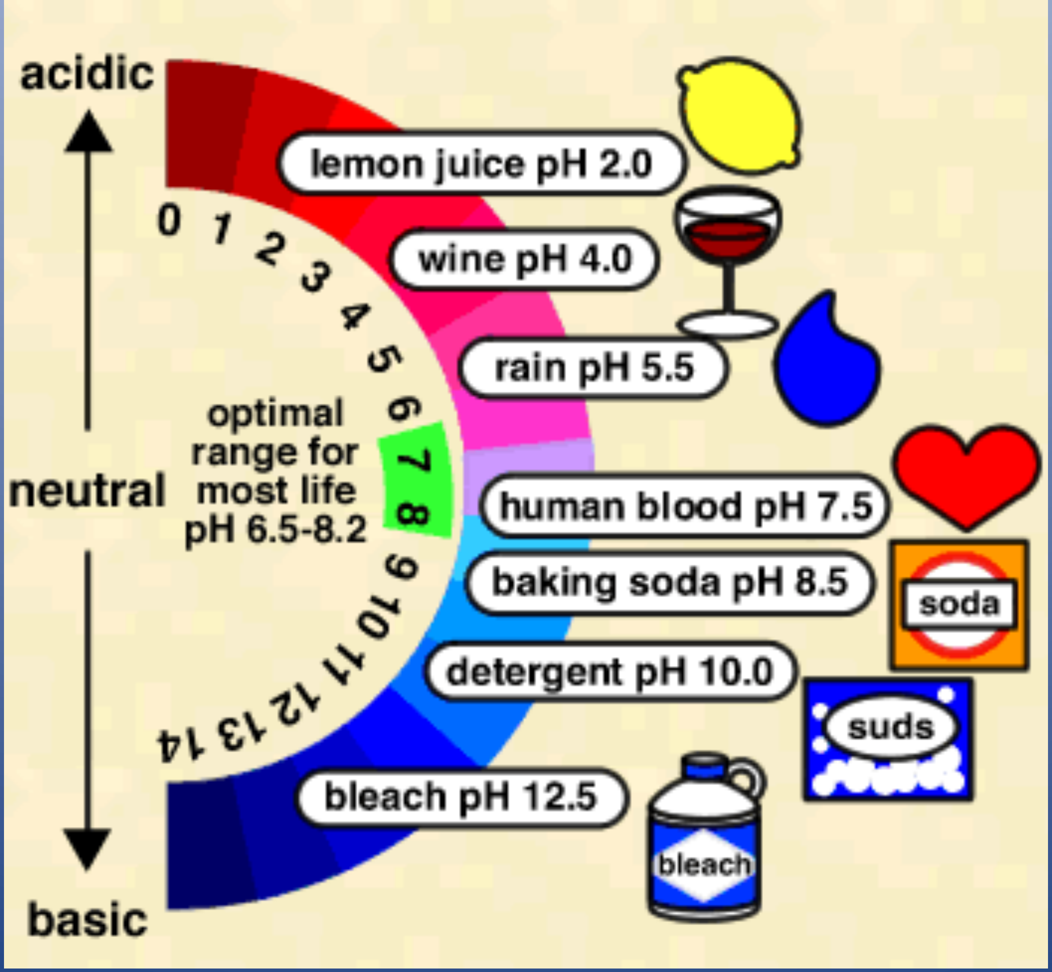
B. pH less than 7 is ACIDIC

C. The higher the number, the more basic (or alkaline) the solution

D. pH more than 7 is a BASIC solution.



E. pH of 7 is said to be NEUTRAL. Pure water has a pH of 7 Animation



F. pH can be calculated using the following formula: $pH = -\log [H^+]$. For example: if pH=3, $[H^+]=10^{-3}$

G. pH scale is a logarithmic scale

   A. Each number on the scale represents a difference of magnitude of 10.

   B. Ex) a pH of 2 is ten times more acidic than a pH of 3

   C. Ex) a pH of 2 is 100 times more acidic than a pH of 4

   D. Ex) a pH of 13 is 1000 times less acidic than a pH of 10

H. All living things need to maintain a constant pH

   A. Ex) human blood pH = 7.4

   B. pH changes can cause enzymes to "denature" (change shape).

Buffers

A. To keep the pH from changing, living cells contain buffers to keep pH constant
B. A BUFFER is a chemical or combination of chemicals that can take up excess hydrogen ions or excess hydroxide ions.
C. Buffers resist changes in pH when acid or base is added. However, buffers can be overwhelmed if acid or base continues to be added.

D. Two common buffers in living systems

A. Carbonic acid-bicarbonate ions (H_2CO_3, HCO_3^-) are present in human blood to act as buffers:

$H_2CO_3 \rightarrow H^+ + HCO_3^-$

a. If base is added……..

$OH^- + H_2CO_3 \rightarrow HCO_3^- + H_2O$

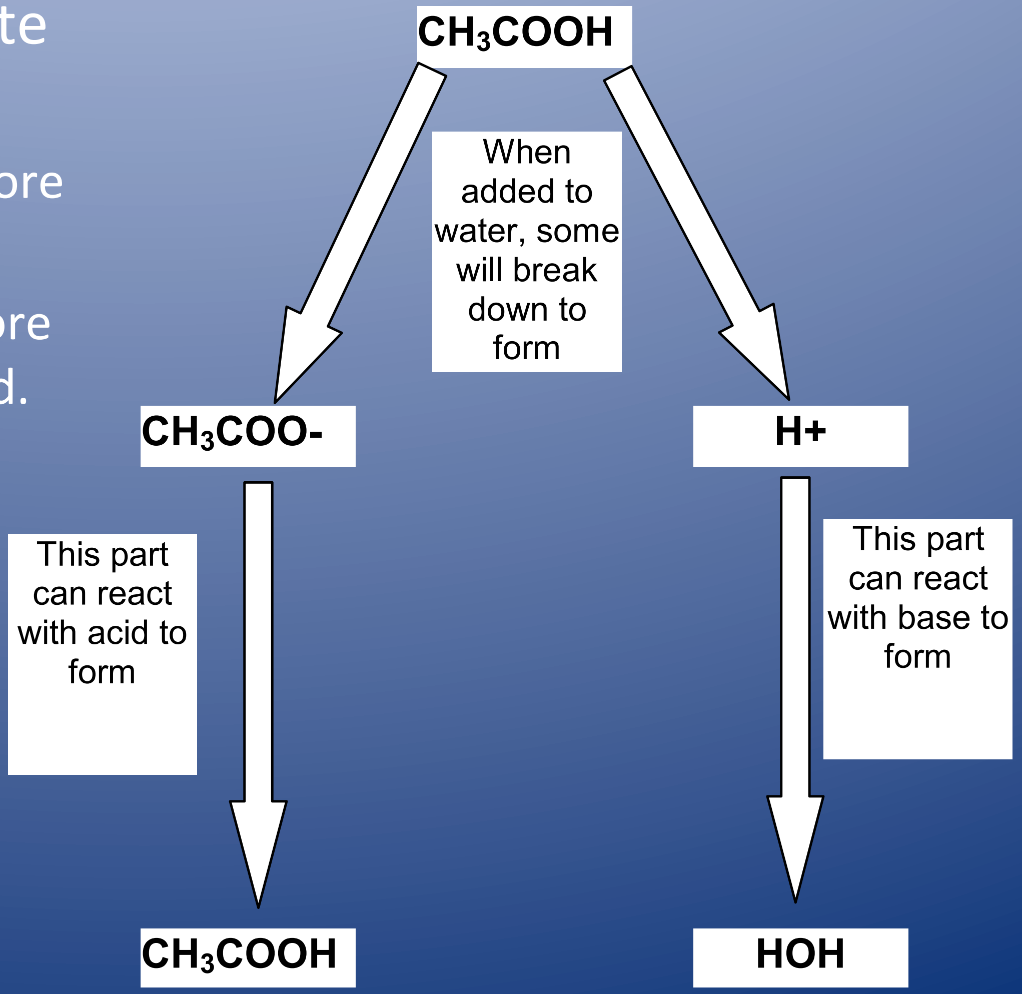
b. If acid is added………

$H^+ + HCO_3^- \rightarrow H_2CO_3$

B. Acetic acid – Acetate Ions

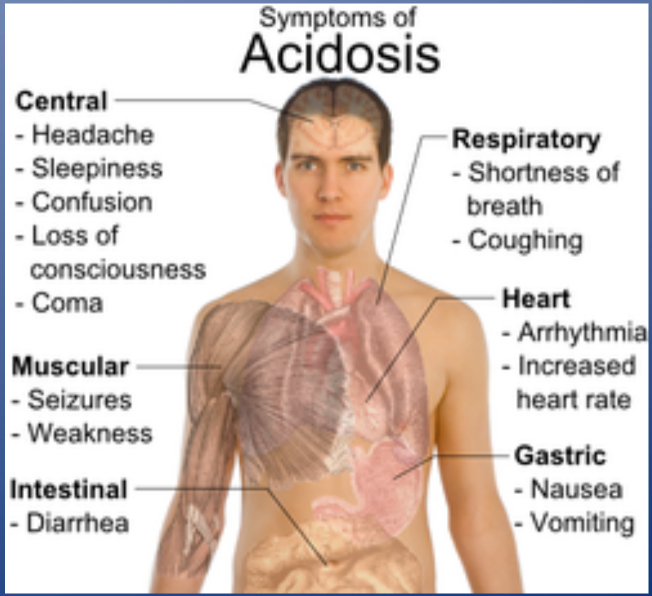
a. If base is added, more H_2O is formed.

b. If acid is added, more CH_3COOH is formed.



In Summary: pH in Biological Systems must be maintained within a narrow range or there are health consequences

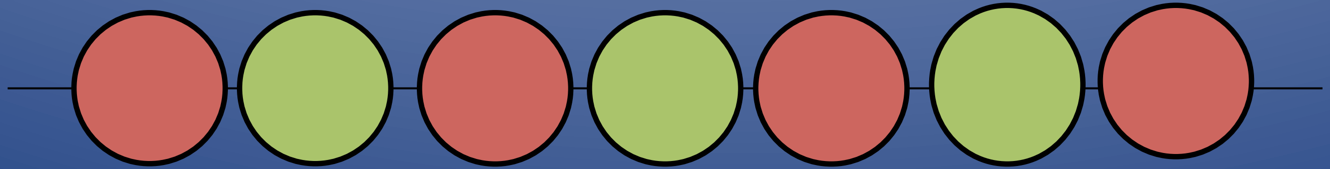
- Blood: If not normal acidosis may result
- Acids are a normal metabolic waste product
- Blood pH is 7.4 and must be buffered to keep it normal.
- A buffer is a chemical (or combo) that keeps pH within normal limits by reacting with or releasing H^+
- Blood is buffered by carbonic acid



Polymers! Ted Ed Polymers

I. Synthesis and Hydrolysis of Polymers

- The most important biological compounds are polymers
- Poly means “many”



Polymers

1. **Many piece chain of subunits (monomers)**
2. **Subunits are**
   a. **MONOSACCHARIDES (SIMPLE SUGARS)**

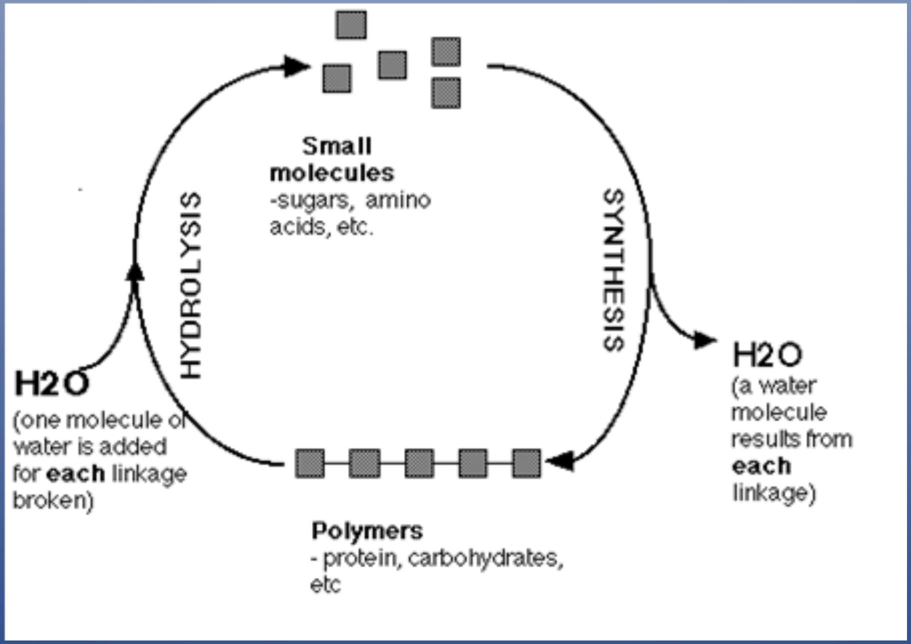
   b. **AMINO ACIDS**

   c. **NUCLEOTIDES**

   d. **FATTY ACIDS**

Polymers are:

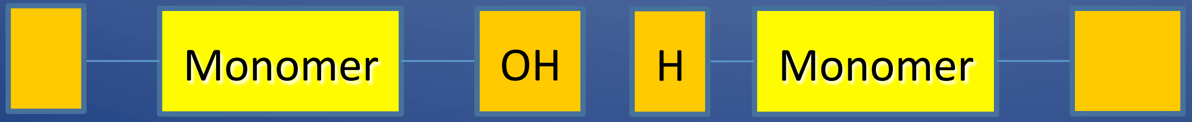
- **made (DEHYDRATION SYNTHESIS) or broken down (HYDROLYSIS) over and over in living cells**



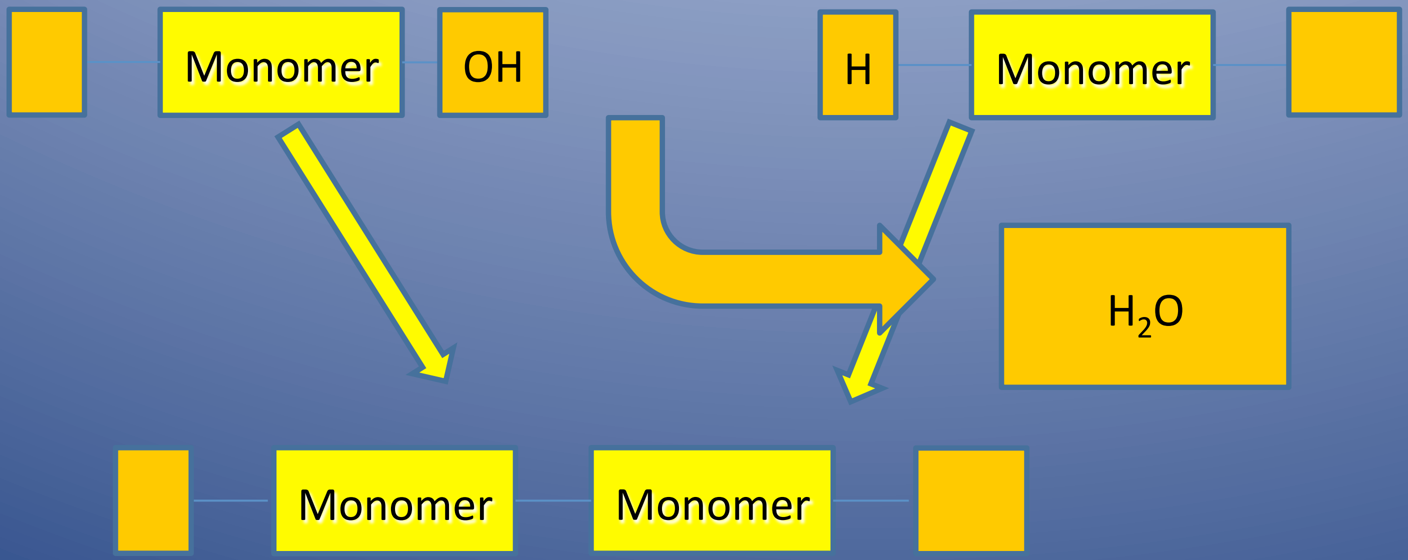
Cells have a common method of joining monomers together to make polymers

Background:

- Organic molecules contain Carbon (C) and hydrogen (H)
- Often organic molecule contain functional groups containing carboxyl (COOH) or hydroxyl groups (OH) or both.
- This is important because H and OH can be found hanging off monomers

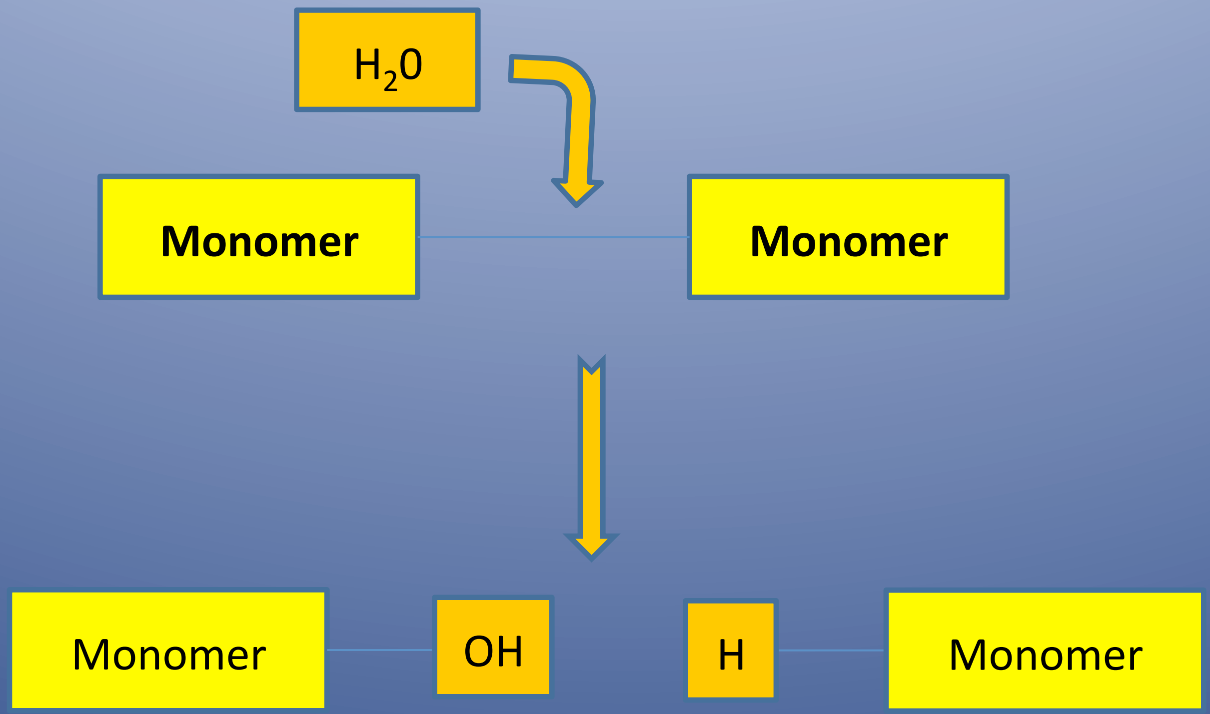


Dehydration Reaction



Synthesis occurs when subunits bond
Following the removal of H_20

Hydrolysis Reaction



Degradation or hydrolysis occurs when subunits in a Macromolecule separate after the addition of H_20

II. Types of Polymers

A. PROTEINS: Polymers of AMINO ACIDS

B. NUCLEIC ACIDS (DNA, RNA): Polymers of NUCLEOTIDES

C. CARBOHYDRATES: Polymers of MONOSACCHARIDES

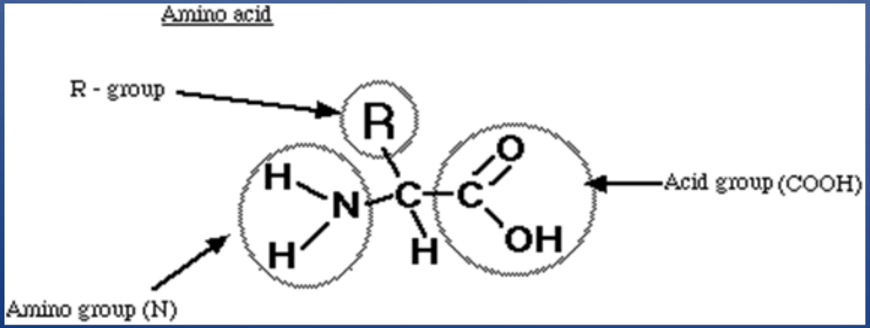
D. LIPIDS: Polymers of FATTY ACIDS and GLYCEROL

Amino Acids

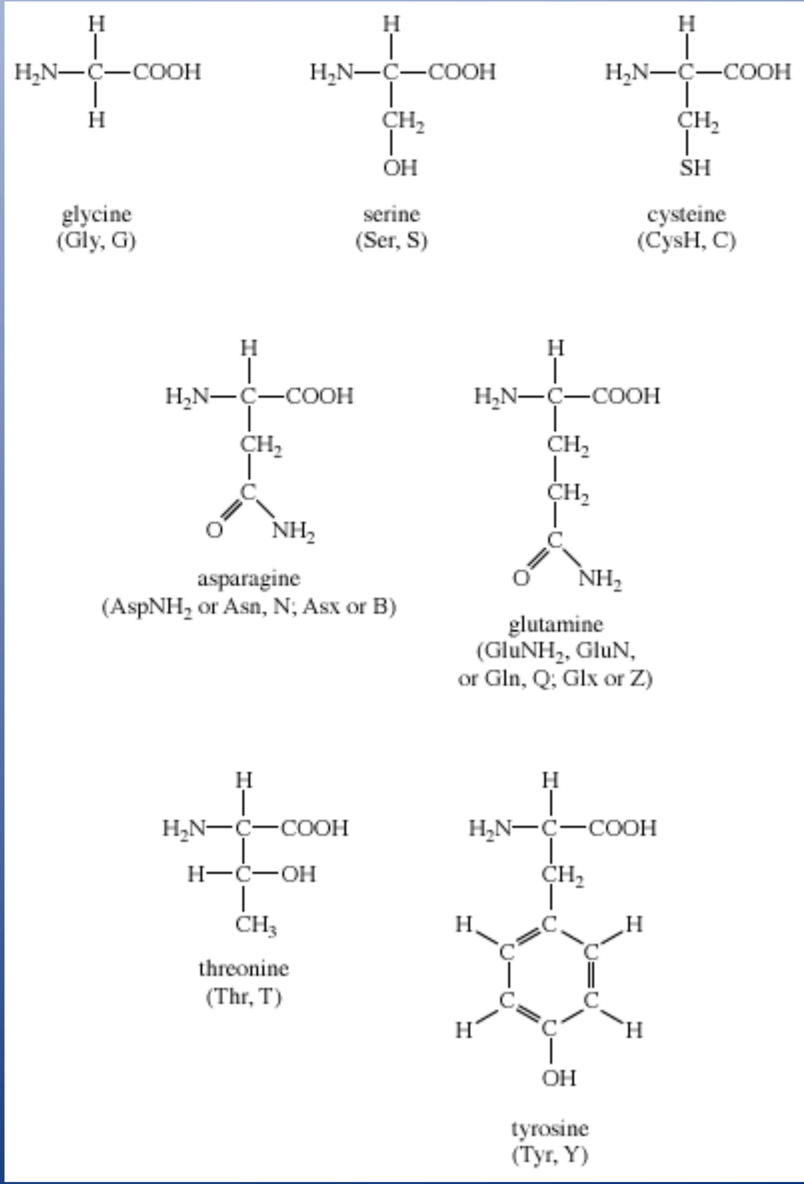
I. <u>Amino Acids</u>
   – Proteins are chains of amino acids

Amino acid basic structure consists of:

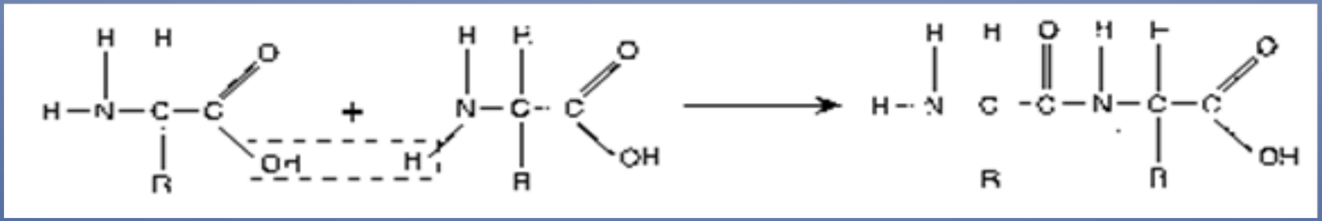
- Amino group (N)
- Acid Group (COOH)
- R- group (Remainder which individualizes the amino acid)



- The R group can vary from a single hydrogen atom (H) to a complicated ring structure



- **Peptide Bond:**
  - The bond linking two amino acids forms a dipeptide
  - One water molecule is given off in dehydration synthesis to form this bond.



  - H_2O is removed - bond between NITROGEN and CARBON forms a peptide bond

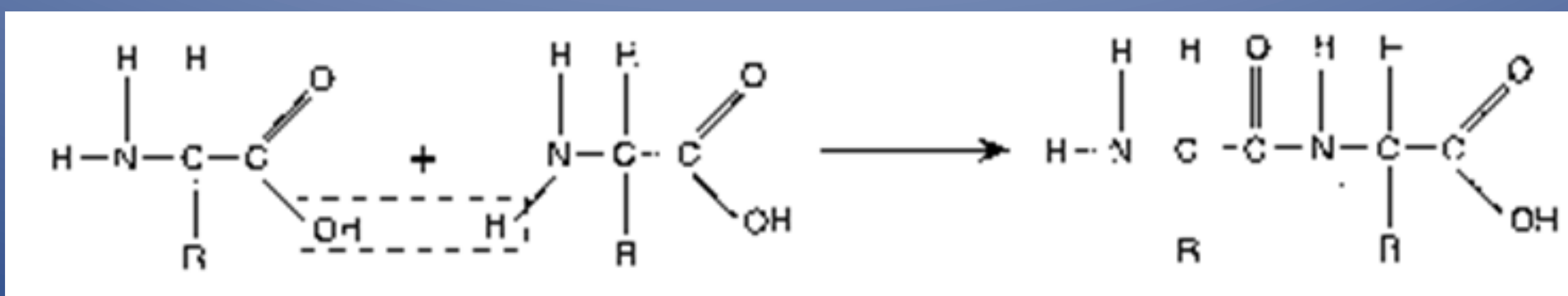
- TWO amino acids linked together – DIPEPTIDE
- THREE amino acids linked together –TRIPEPTIDE
- Many amino acids linked together – POLYPEPTIDE (30 to 30,000 amino acids)

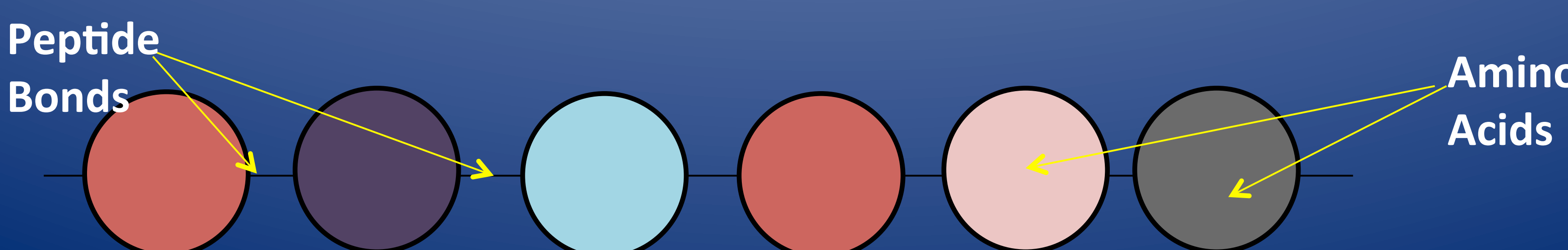
II. Levels of Protein Organization:

Primary, Secondary, Tertiary and Quaternary Structure

A. PRIMARY structure

1. POLYPEPTIDE chain
2. AMINO ACIDS linked together

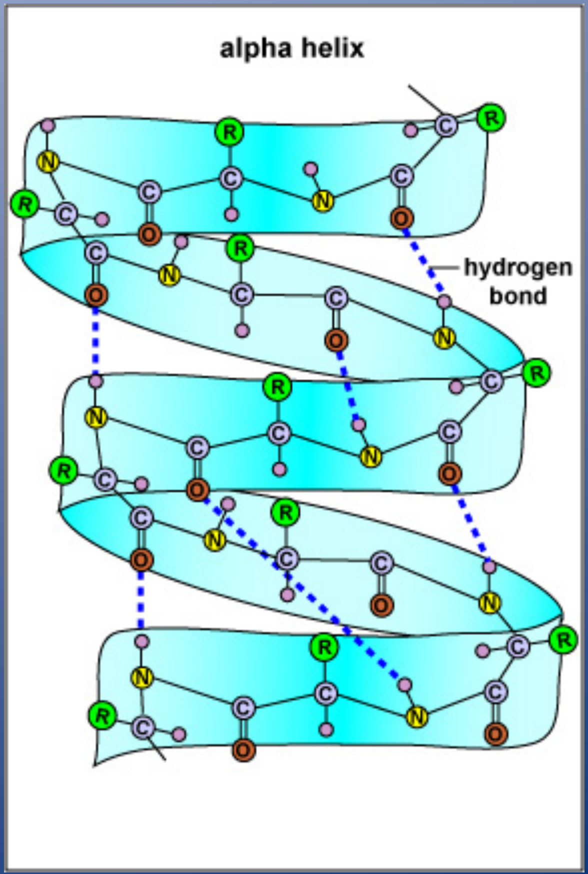




B. Secondary Structure

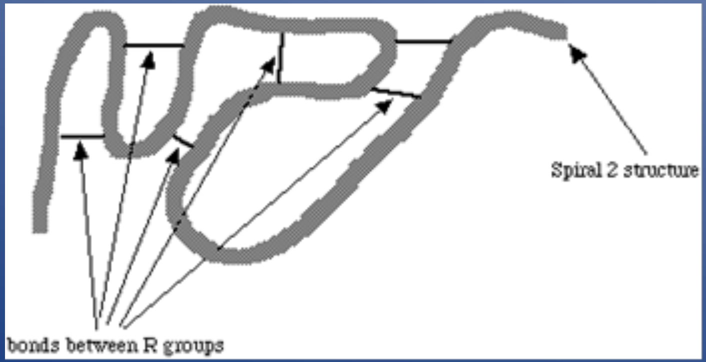
1. HYDROGEN BONDS form between the HYDROGEN on the amino group and the OXYGEN in the acid group of close amino acids to twist the first structure into an ALPHA HELIX

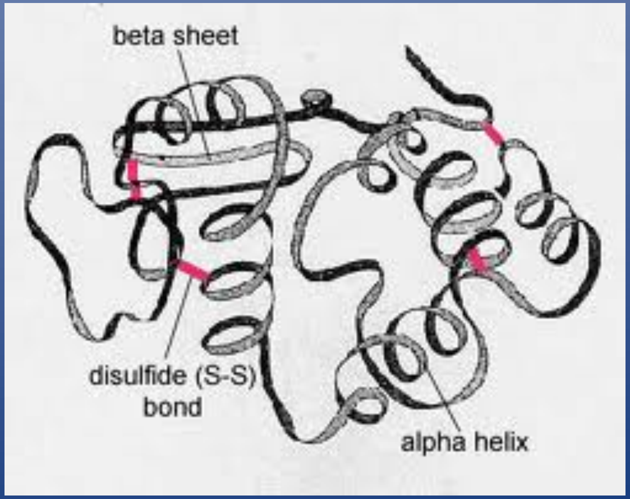
2. Coiling is due to hydrogen bonds



C. Tertiary Structure

- The spiral strand folds into a specific shape, due to the various kinds of bonds between R-groups
- This gives the protein its three dimensional shape (conformation)



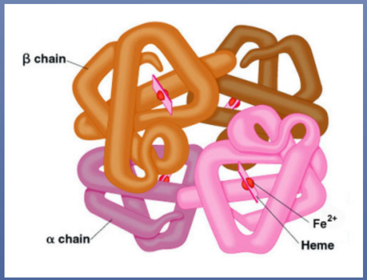


Quaternary Structure

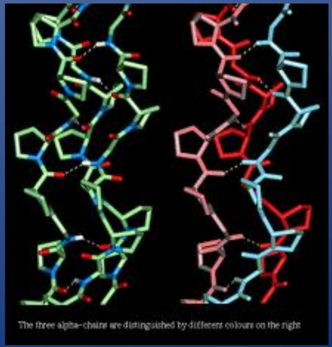
1. Some proteins (fairly often) are actually MACROMOLECULES of tertiary polypeptides joined to form a functional protein

2. **Examples:**

HEMOGLOBIN – 4 subunits (2 alpha chains, 2 beta chains)



COLLAGEN - 3 helical subunits coiled together



[Animation]

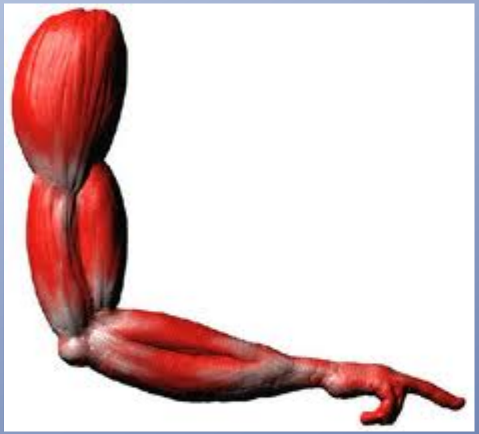
E. DENATURATION

1. Loss of protein's tertiary structure by breaking 'R' group bonds
2. Protein LOSES shape and function, becoming DENATURED
3. Caused by:
   a. TEMPERATURE ANIMATION addendum: Unboil
   b. pH CHANGE
   c. HEAVY METALS (ie. Lead, Mercury)
4. Example:

   HEATING an egg white

   Adding VINEGAR to milk

III. Functions of Proteins



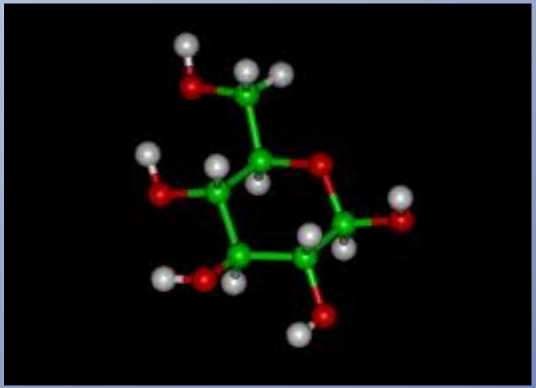
A. Polymers of AMINO ACIDS
B. Have 3 major functions

1. STRUCTURE & MOVEMENT
   a. KERATIN -- hair, nails
   b. COLLAGEN-- cartilage, tendons
   c. Actin, myosin -- muscle tissue

2. METABOLISM
   a. ENZYMES
   b. Are CATALYSTS:
   c. SPEED UP CHEMICAL REACTIONS and allow to happen at a lower temperature
   d. Therefore CRITICAL to all cell activity

3. ANTIBODIES and HORMONES

Carbohydrates



- Empirical Formula: $(CH_2O)_n$
- A repeating chain of sugars (saccharides)
- Polysaccharides – Many saccharides linked together
- To break the bond between two sugars, an H_20 is added back (hydrolysis)

[Carbs/Health Ted-Ed]

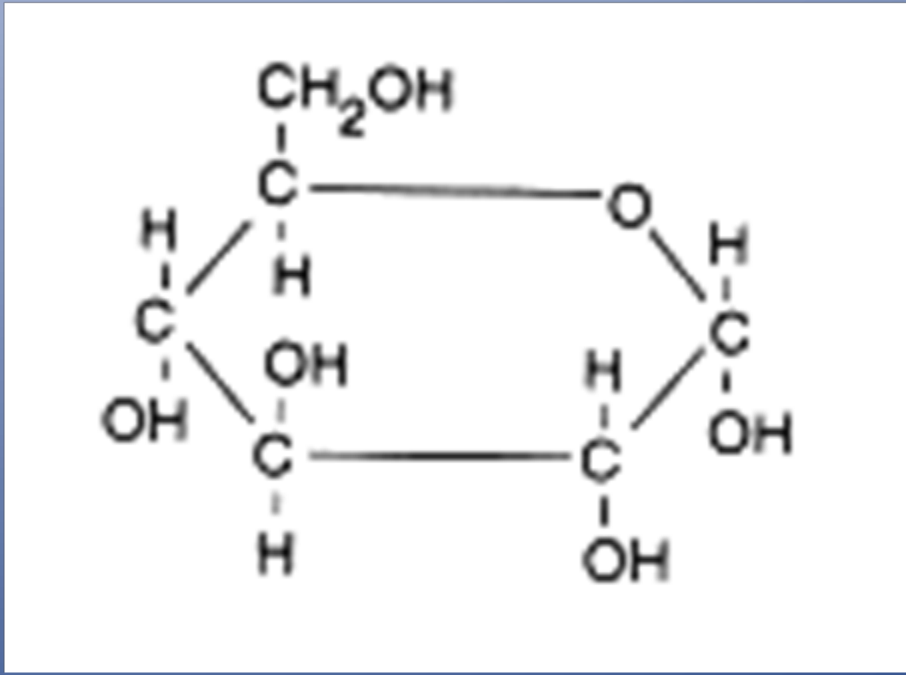
Carbohydrates

I. Carbohydrates

- Main functions of carbohydrates are:
  - Energy
    - Bonds between atoms can be broken, the hydrogen atoms are stripped off and energy released can be used by the cells
  - Structural
    - Cellulose is the major structural compound in plants
    - Used in the cell wall

II. Glucose

- A basic sugar
- $C_6H_{12}O_6$
- Has a ring structure
- This is a mono (one) saccharide
- Others include fructose, ribose, deoxyribose etc…



[Animation](#) Ted Ed Sugar

[How Sugar affects Brain Ted-Ed](#)

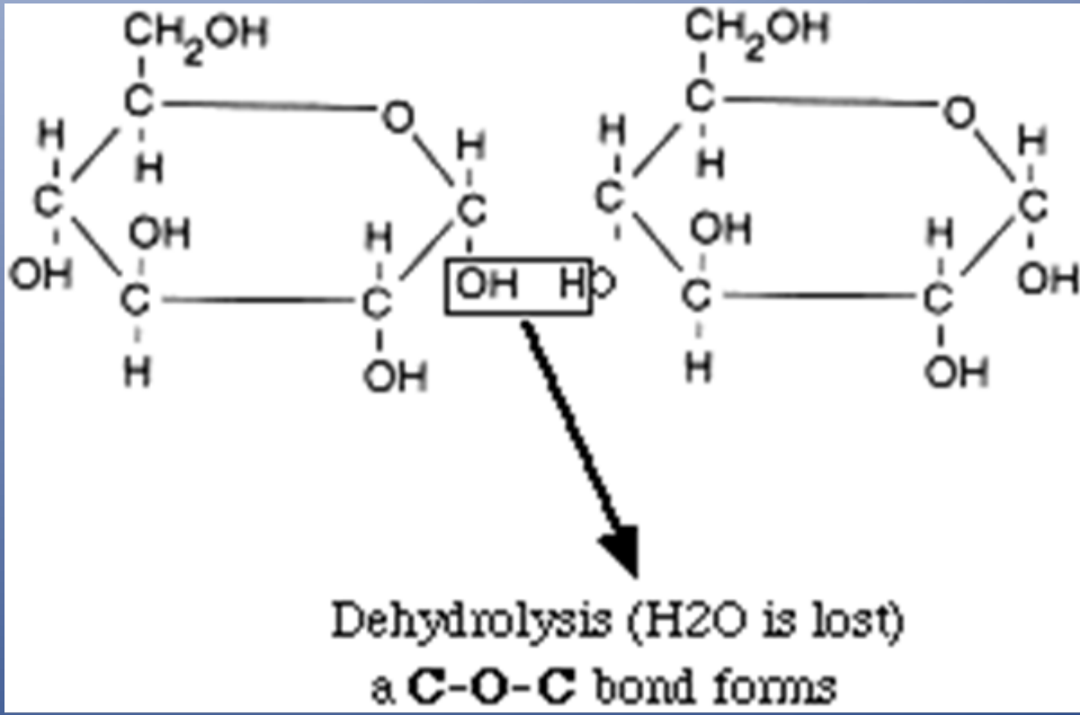
II. Dissacharide

- Two sugars joined together
- Examples of disaccharides :

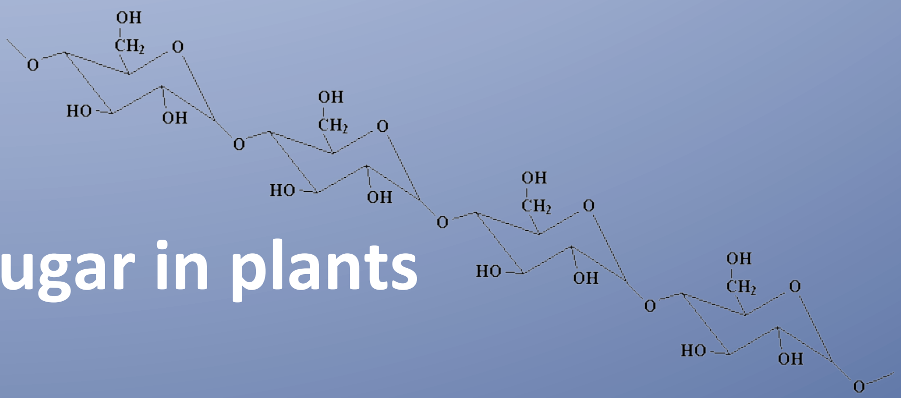
Maltose (two glucoses)

Sucrose (a glucose and fructose)

Lactose (galactose and glucose)

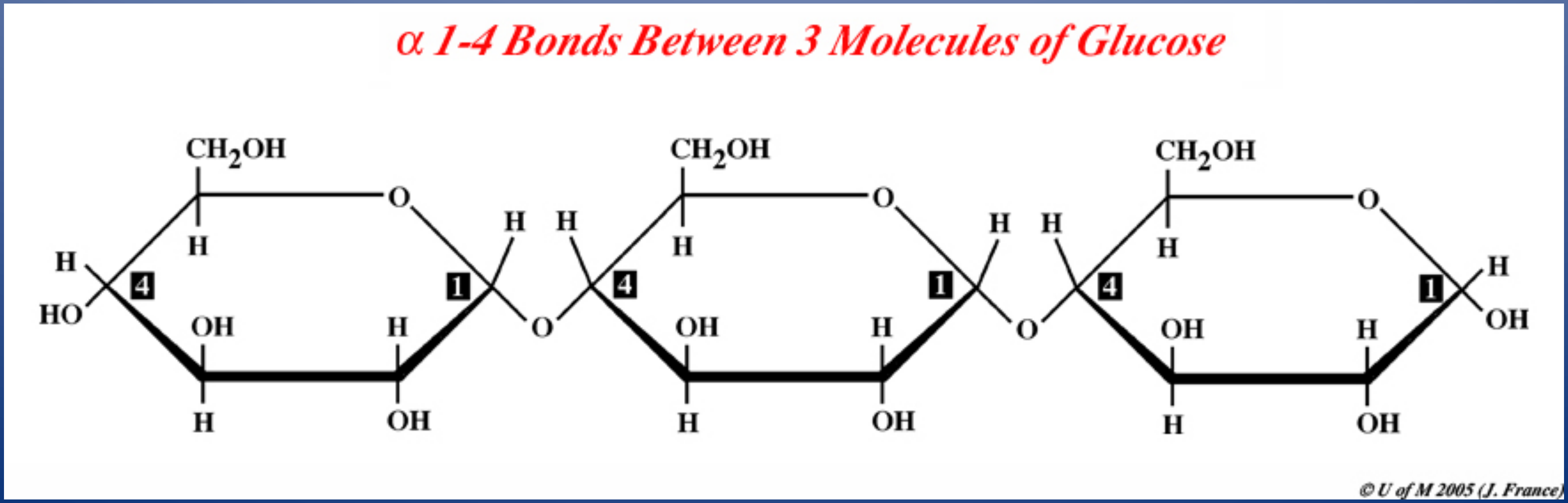


IV. Three Important Polysaccharides



A. Starch

1. Main storage form of sugar in plants
2. Few side chains
3. Many glucose molecules linked together



B. Glycogen

1. Main sugar storage in animals
2. Many side chains
3. Linked as for starch

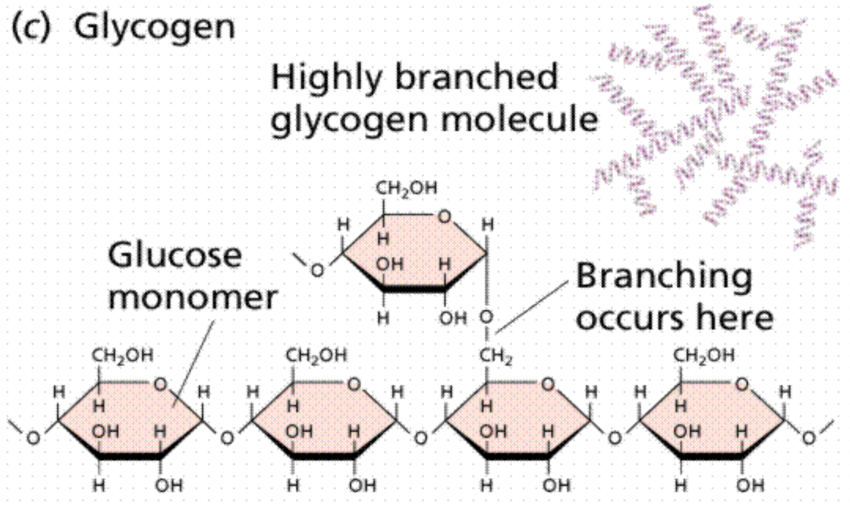
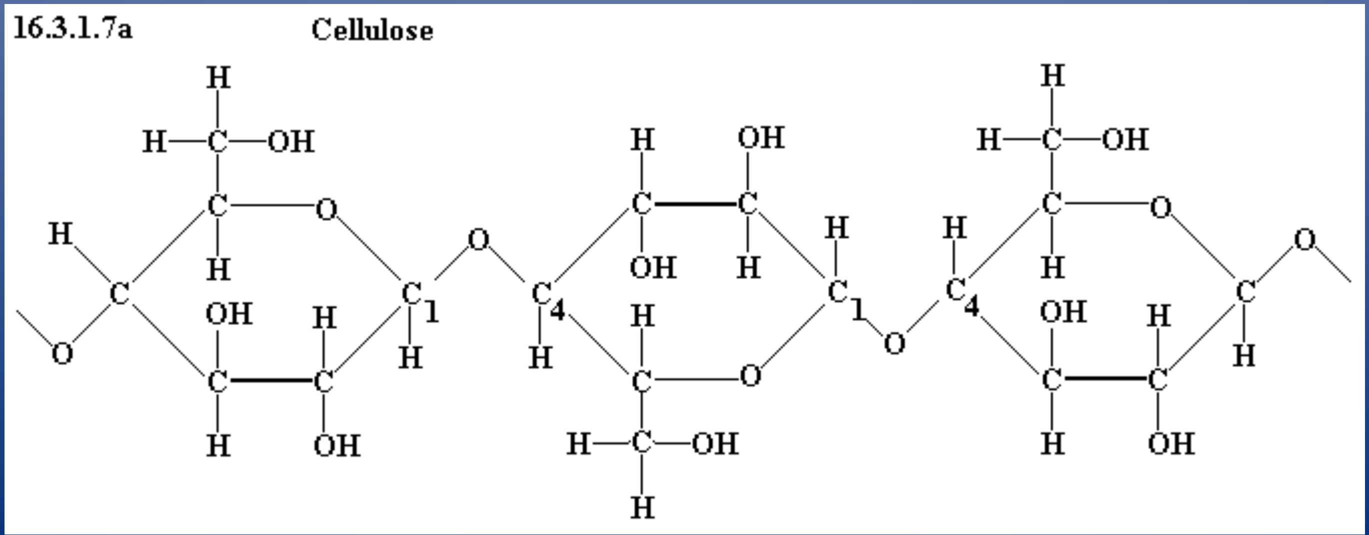


Figure 3.12 (3)

C. Cellulose

1. Structural (cell walls)
2. Long chains
3. Linkage between Carbon atoms of adjacent chains sugars is different than starch and glycogen
4. No mammals can break this bond



Neutral Fats, Steroids and Phospholipids

I. General Info

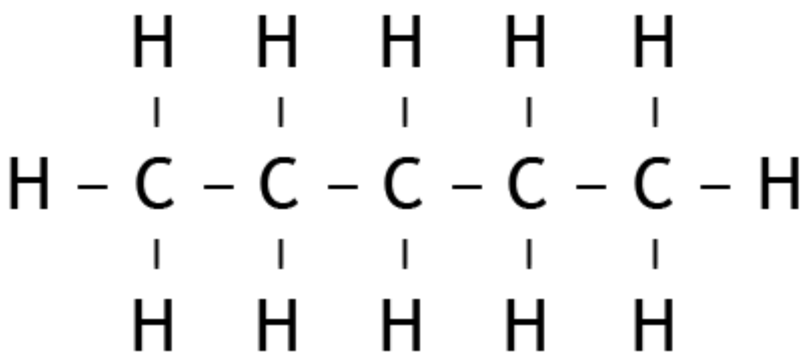
Animation

A. Large molecules, insoluble in water (non-polar)

B. Used for long-term storage for energy (more efficient [more E stored per cm^3] than glycogen or starch)

C. Examples: Vegetable oils, animal fats

Fig. 1 Saturated Fat

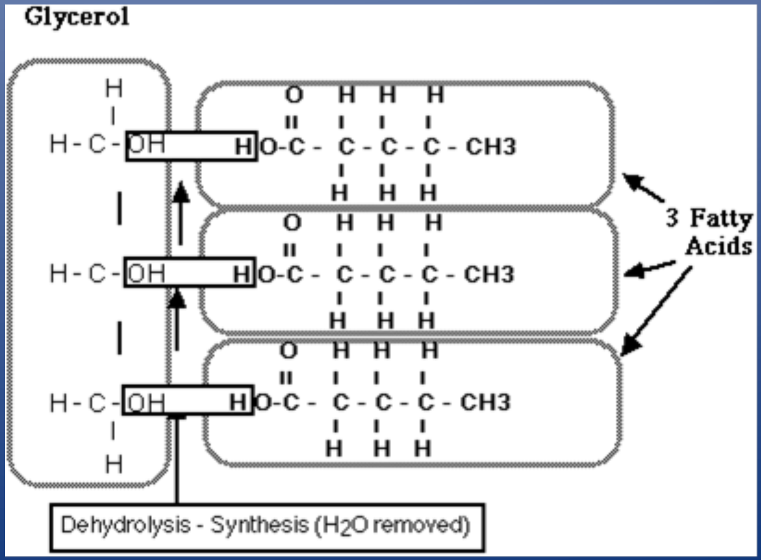


II. Structure

A. Neutral Fat

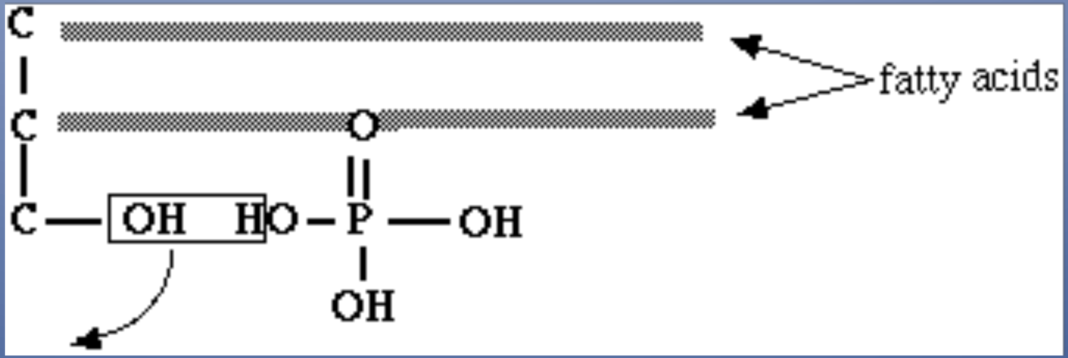
1. A glycerol (1,2,3-propantriol, for you IUPAC fans!) (3-Carbon) backbone with 3 fatty acids.

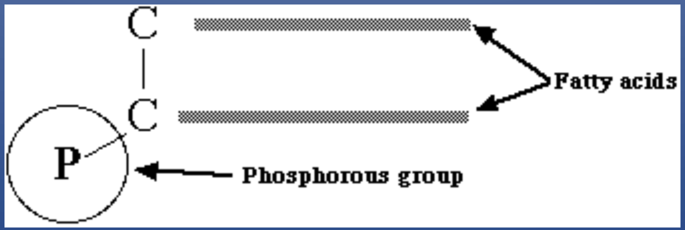
   A fatty acid = hydro- carbon chains with a carboxylic acid at one end) attached:



B. Phospholipids

- Same as fat, but with the third fatty acid group replaced by a phosphate group! (simplified)

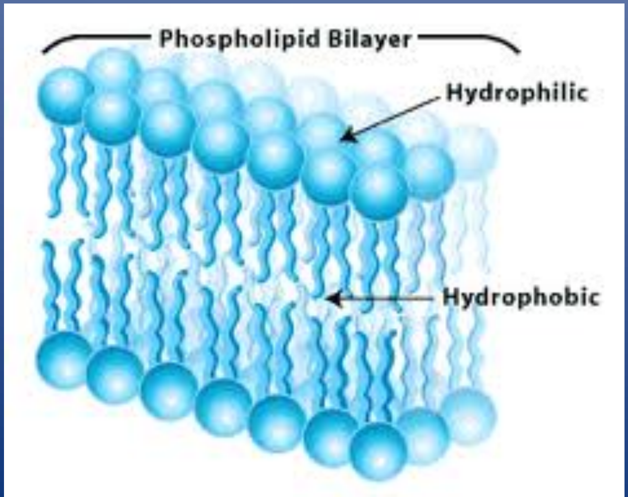




Phospholipids cont'd

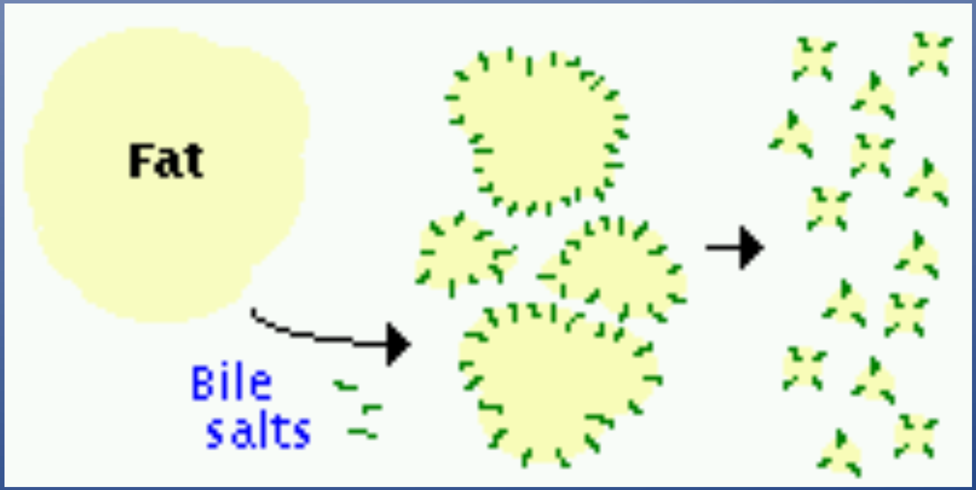
- The phosphate head is polar
- The hydrocarbon chains are non-polar
- The major component of cell membrane

  a) membrane structure: a double layer of these, positioned w/heads "out", tails "in":



- When added to dishwater, soap will disperse through it, and form droplets with any non-polar greasy guck in the dishwater (called EMULSIFICATION)
- Same principle used in mammal digestive system: BILE is the emulsifier that breaks up fatty foods

[Animation]

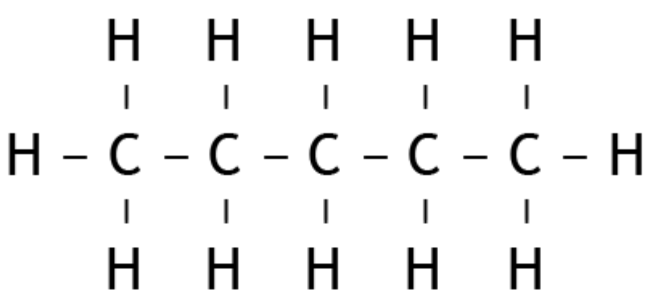


III. Saturated and Unsaturated Fats

A. Saturated

1. All C-C bonds are SINGLE
2. Tend to be solids at room temperature
3. Examples: lard, butter, animal fats
4.

Fig. 1 Saturated Fat

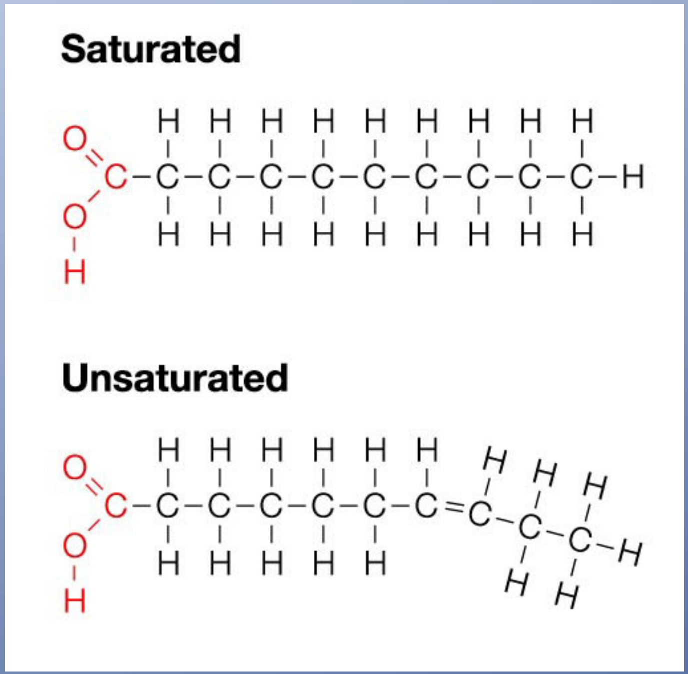


B. Unsaturated

1. Some C-C bonds are DOUBLE

2. Tend to be liquid at room temperature ("kinks" in the chain formed by dbl bonds prevent close packing)

3. Examples: olive oil, corn oil, peanut oil



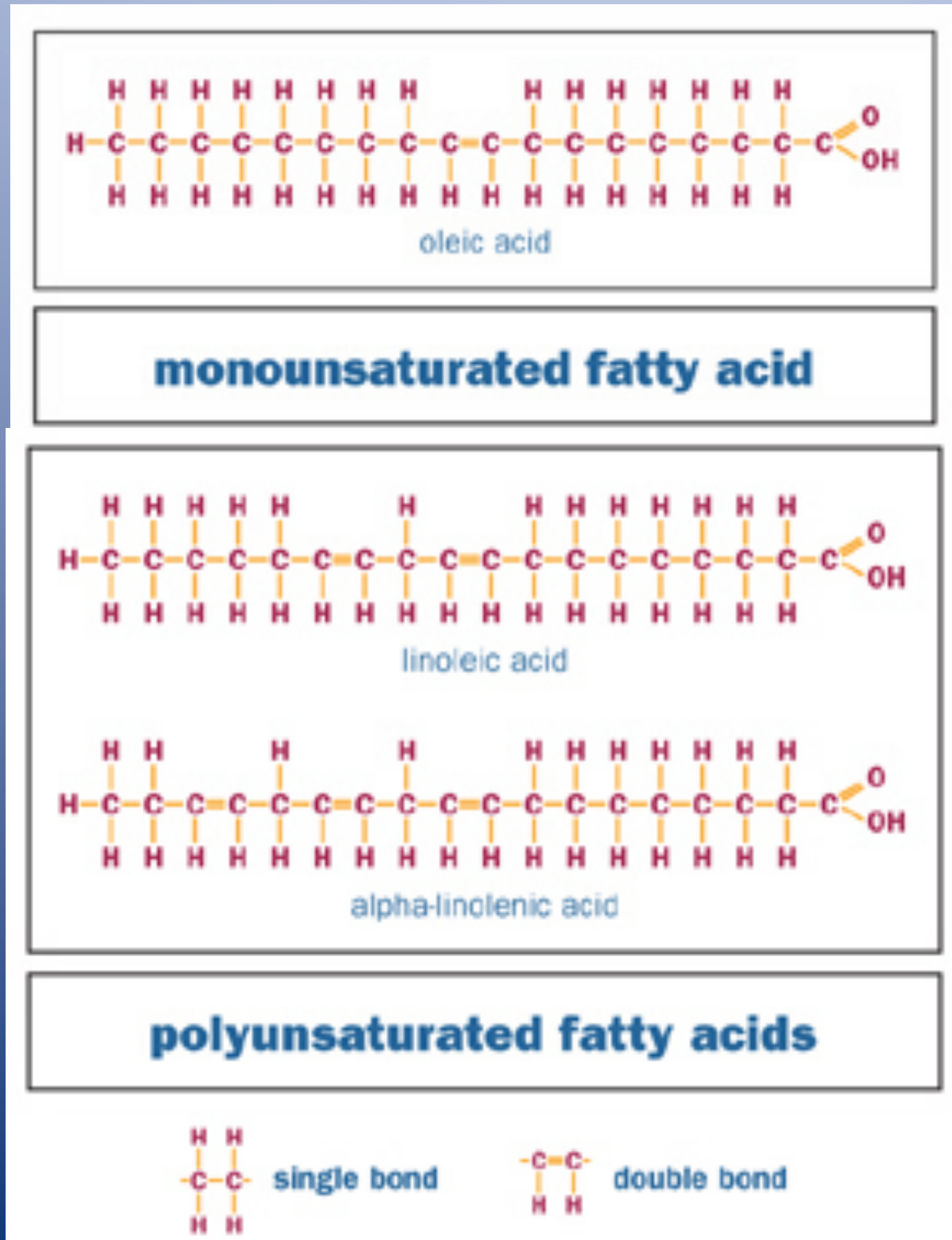
4.
```
      H H   H H     H
    H-C-C=C-C-C=C=C-C-H
      H    H H     H H
```

5. Monounsaturated

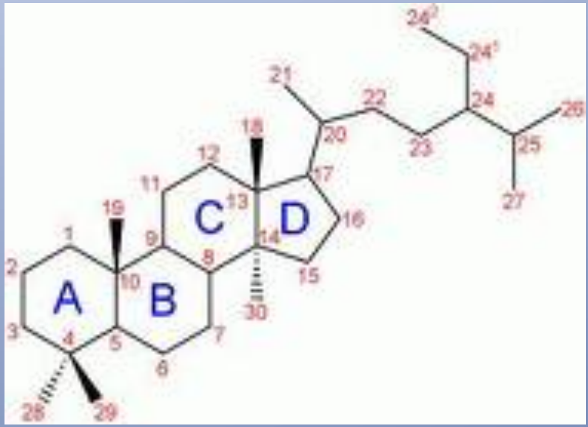
a) One carbon atom not saturated

6. Polyunsaturated

a) Many double bonds (therefore fewer Hs)


oleic acid
monounsaturated fatty acid
linoleic acid
alpha-linolenic acid
polyunsaturated fatty acids
single bond
double bond

IV. Steroids

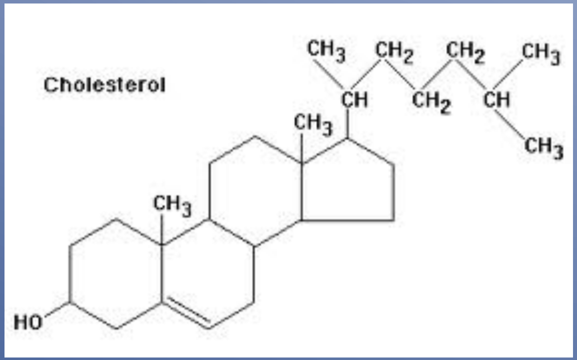


A. 4 carbon rings

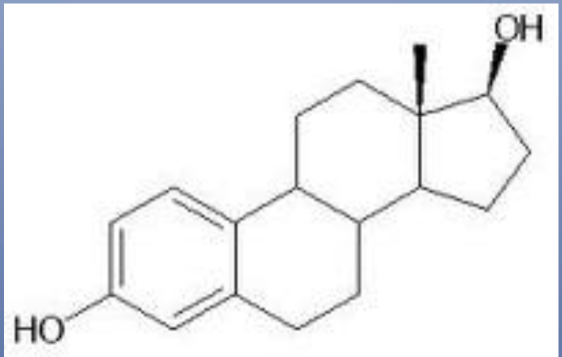
(5 or 6 carbons per ring)

B. Example: Cholesterol
   1. A vital component of eukaryotic cell membranes
   2. Is modified to synthesis hormones like estrogens, testosterone, aldosterone

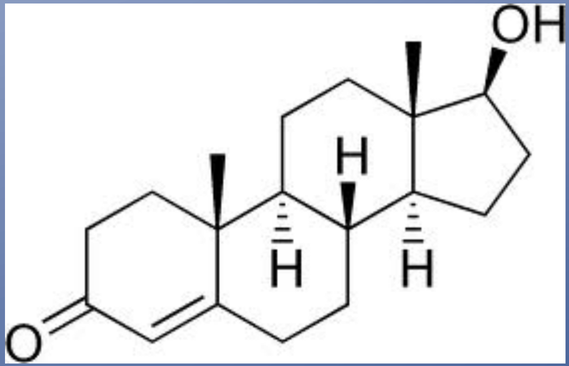
C. Synthesized by body and eaten in animal flesh/fat



Cholesterol



Estradiol

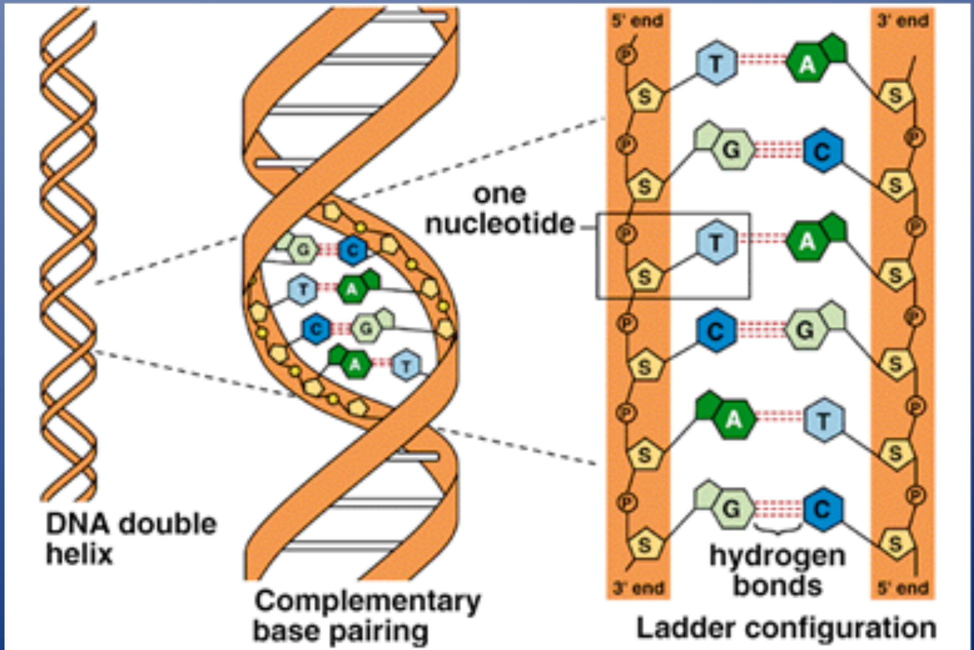


Testosterone

What is DNA????

1. The structure of DNA and RNA

- DNA = deoxyribonucleic acid
- DNA is the control molecule of cells (and, hence life)

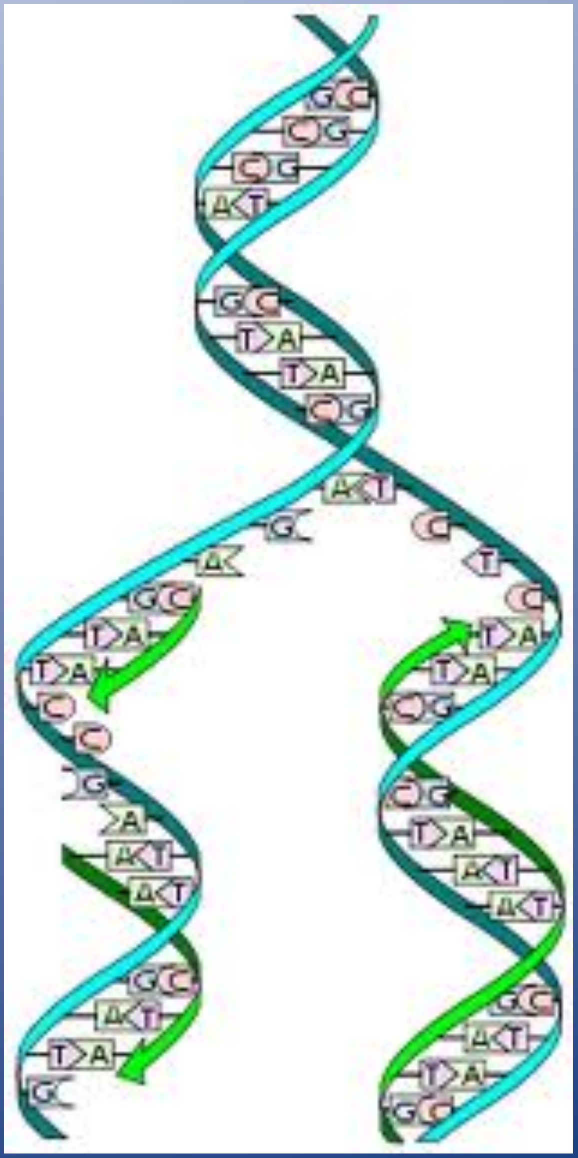


- DNA has three major functions!

1. DNA controls cellular activities including reproduction
   - DNA carries a code. Genetic instructions are encoded in the sequence of bases strung together in DNA.
   - DNA from male and DNA from female together become the **genetic information of offspring** in sexual reproduction.
   - **RNA** molecules function in the processes by which those DNA instructions are used in building the **proteins** on which all forms of life are based.

2. <u>**DNA MAKES EXACT COPIES OF ITSELF**</u> to pass onto other cells.

- DNA does this through a process called "**replication.**"



3. DNA Undergoes Mutations

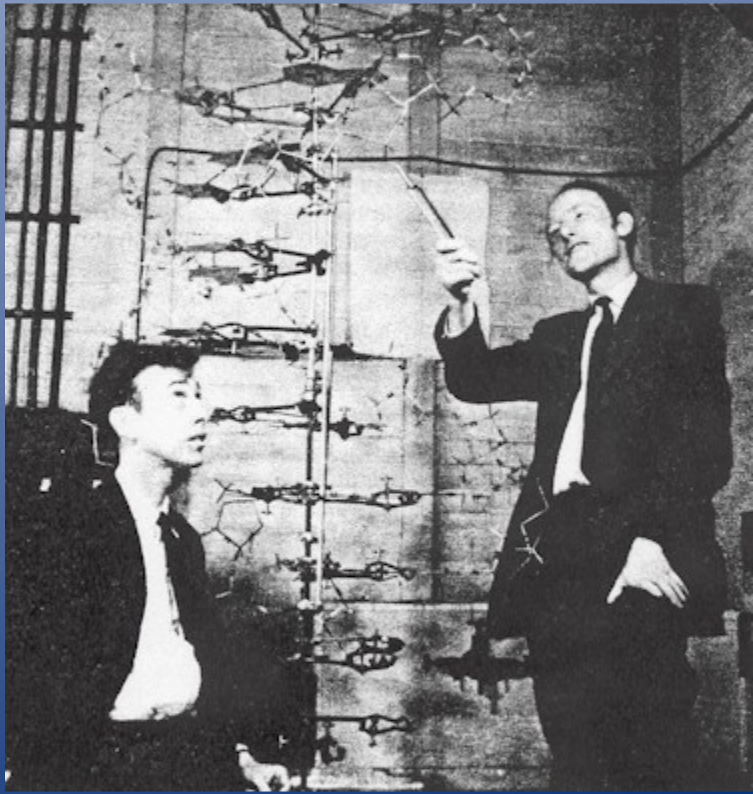
- **Mutations** and **recombinations** in the structure and number of DNA molecules are the source of life's **diversity**.
- **Evolution**, in essence, proceeds from the level of DNA.
- Different combinations of DNA sequences due to mutations and sexual reproduction explain the existence of all the different species that have lived on this Earth.

- ***Furthermore…***
- DNA is the source of the **unity of life**
- **Life most likely began as a nucleic acid.** (recall that there are **TWO** Types of Nucleic acids: **DNA** & **RNA**).
- The first form of life on this planet is thought by many biologists to be a **self-replicating strand** of **RNA**

A BRIEF HISTORY OF DNA RESEARCH (no, this is not on the test!)

DNA was first isolated by the Swiss biochemist JOHANN FRIEDRICH **MIESCHER** n **1869**. Because DNA molecules are acidic and are found in the nucleus, Miescher called them nucleic acids. Over 80 years passed, however, before scientists understood that DNA contains the information for carrying out the activities of the cell. How this information is coded or passed from cell to cell was unknown. To break the code, scientists first had to determine the structure of DNA..

During the 1950's, a fierce competition to determine the three dimensional structure of DNA took place. The race was won in **1953** by **JAMES WATSON**, an American biologist, and **FRANCIS CRICK**, a British physicist.



Working together at Cambridge University in England, Watson and Crick solved the puzzle using scale modes of nucleotides. Their success depended a great extent on evidence collected by other biologists, especially X-ray data from British biochemists **ROSALIND FRANKLIN** and **MAURICE WILKINS**.

In 1958, the mechanism for DNA replication was determined by **MESELSON** and **STAHL**. In the **GENETIC CODE** of **3 DNA nucleotides for 1 amino acid** was worked out by **Crick** and his coworkers

Important Dates in Early DNA Research

Date	Discovery
1869	Nucleic Acids identified
1928	Transfer of genetic material between bacteria observed (Frederick Griffith)
1944	DNA carries genetic code (Oswald Avery and coworkers)
1950	Protein chains sometimes helical; DNA structure similar (Linus Pauling)
1951	X-ray data for DNA structure produced (Franklin, Wilkins)
1951	Nitrogen base ratio related to genetic code (Chargaff)
1953	DNA double helix discovered (James Watson, Francis Crick)
1958	Mechanism for DNA replication determined (Matthew Meselson, Franklin Stahl)
1961	3 DNA nucleotide code for 1 amino acid (Crick and coworkers)

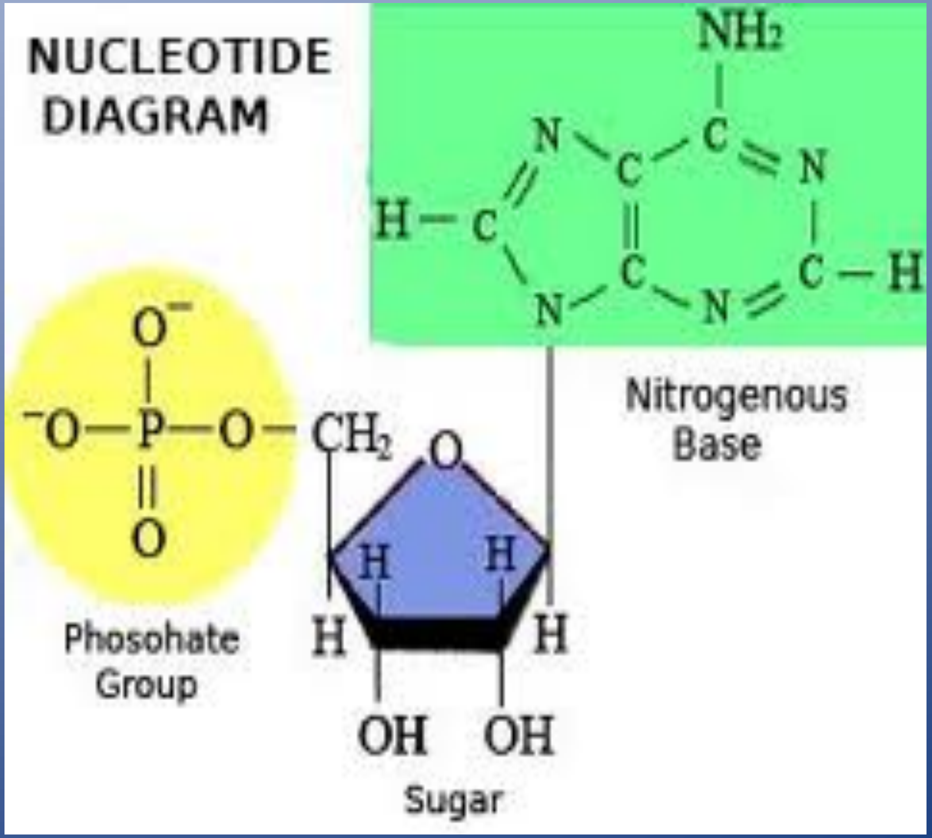
The Structure of Nucleic Acids

ANIMATION

DNA AND RNA ARE POLYMERS OF NUCLEOTIDES

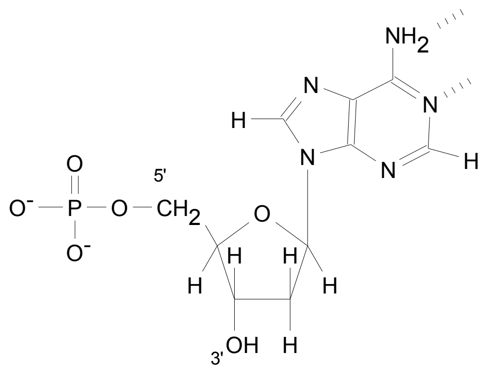
- **Each nucleotide** is composed of three parts:

1. a **pentose** (5 carbon) **SUGAR**
2. a **PHOSPHATE group**
3. a **nitrogenous BASE**

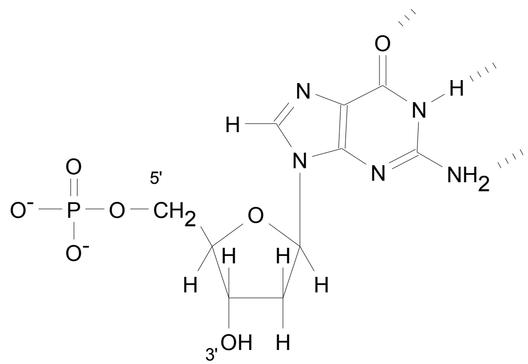


There are two types of bases

- i) **PURINES** - have a ***double ring structure*** (adenine & guanine)

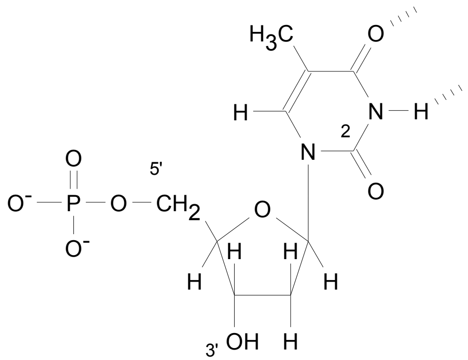


nucleotide: base = **A**denine

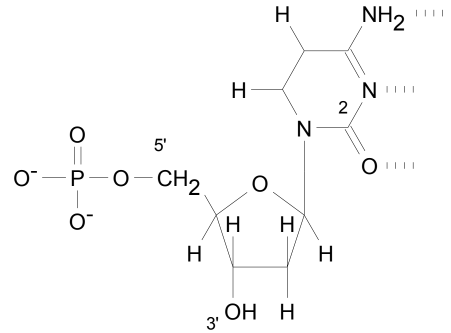


nucleotide: base = **G**uanine

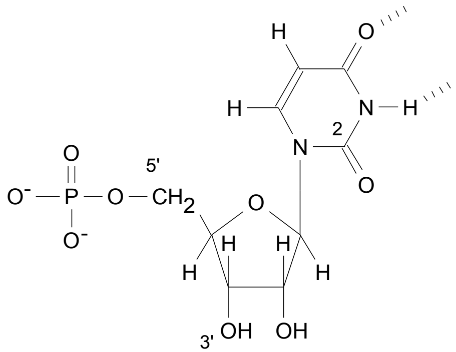
ii) **PYRIMIDINES** - have a ***single ring structure*** (thymine, cytosine, uracil)



nucleotide: base = **T**hymine

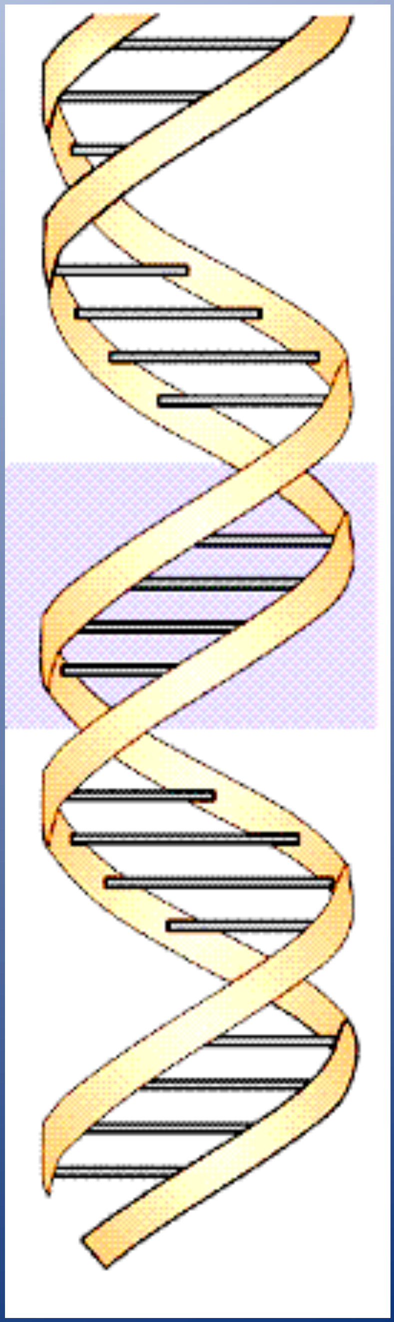


nucleotide: base = **C**ytosine



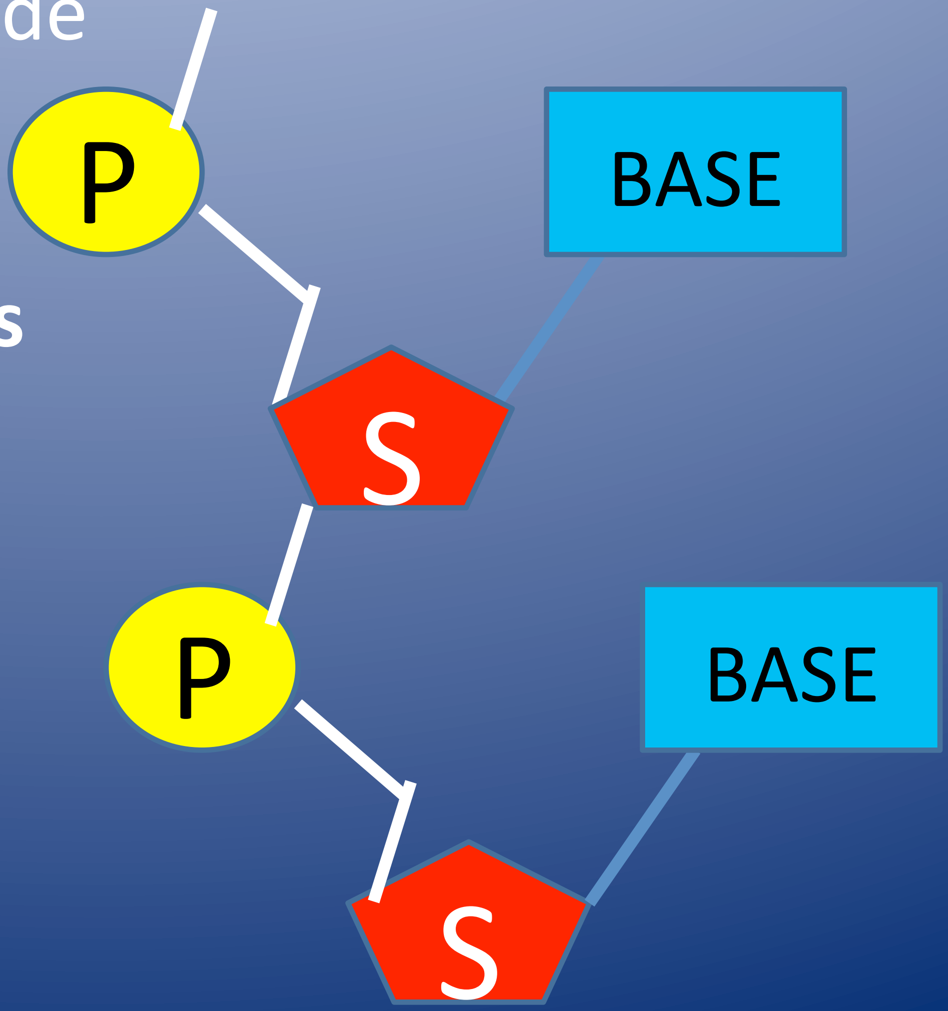
nucleotide: base = **U**racil
RNA ONLY

- The DNA strand consists of a sequence of nucleotides linked together to form a **DOUBLE HELIX** that can be visualized as an immensely **long, twisted ladder**

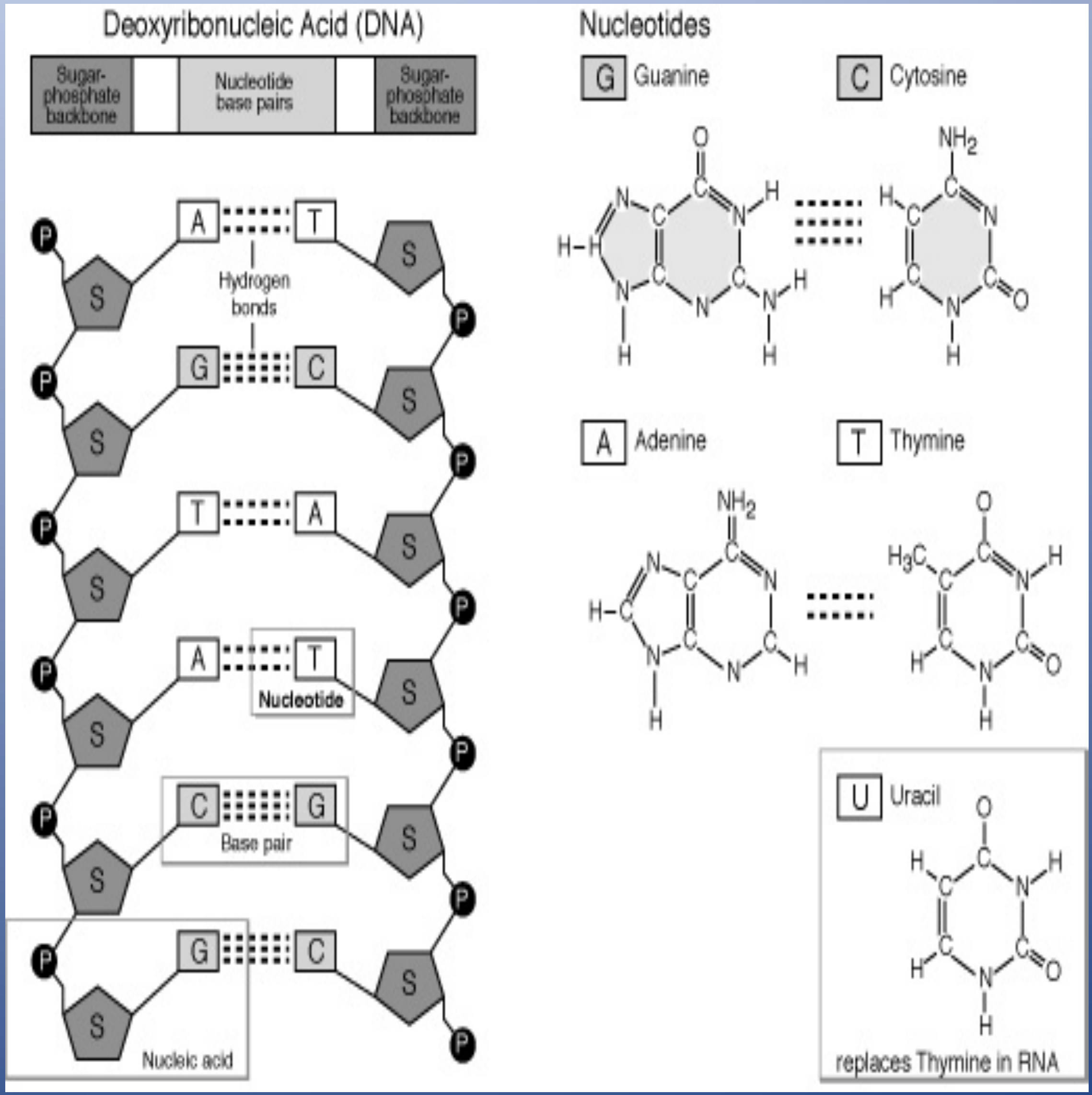


Phosphate – Sugar backbone

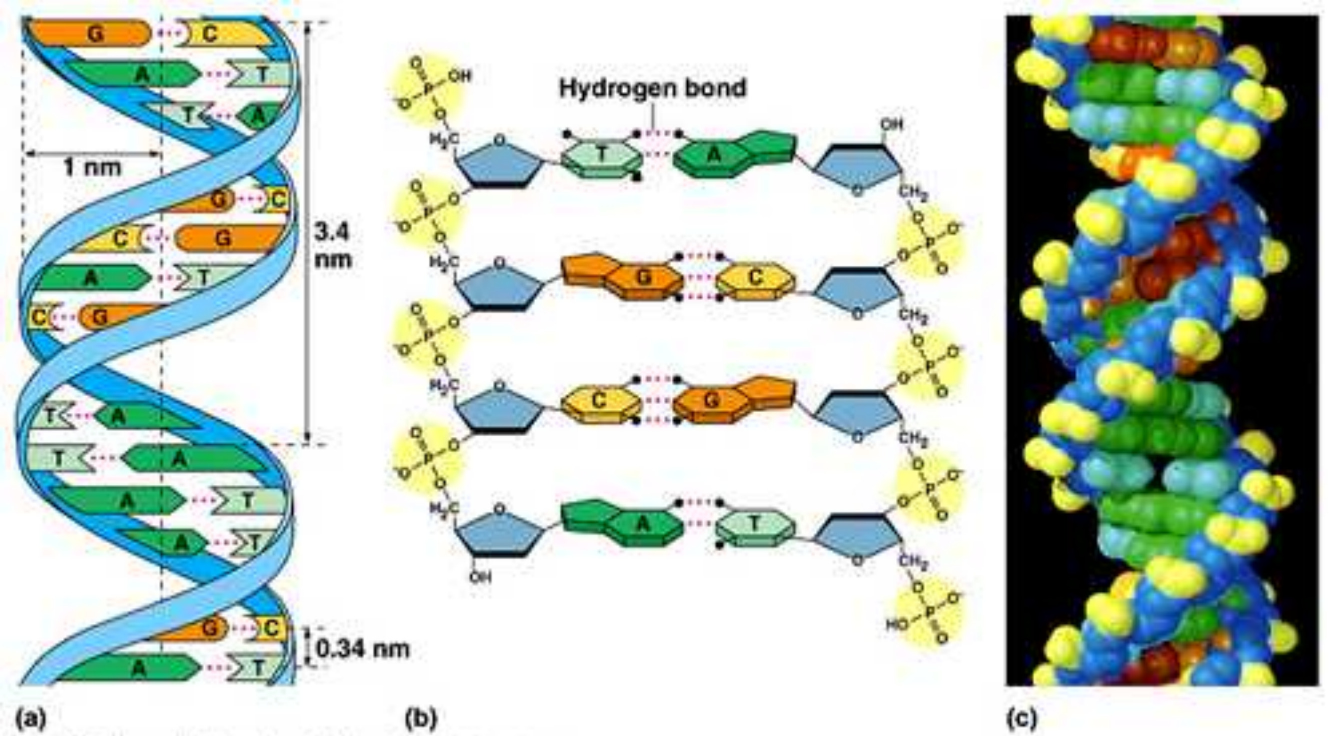
Each strand, or one side of the ladder, is composed of **alternating molecules of deoxyribose and phosphate** with a nitrogenous base attached to each deoxyribose unit.



- Nucleotides are connected by joining the bases of one nucleotide to the bases of the adjacent nucleotide (the ‘sugar-phosphate backbone’).

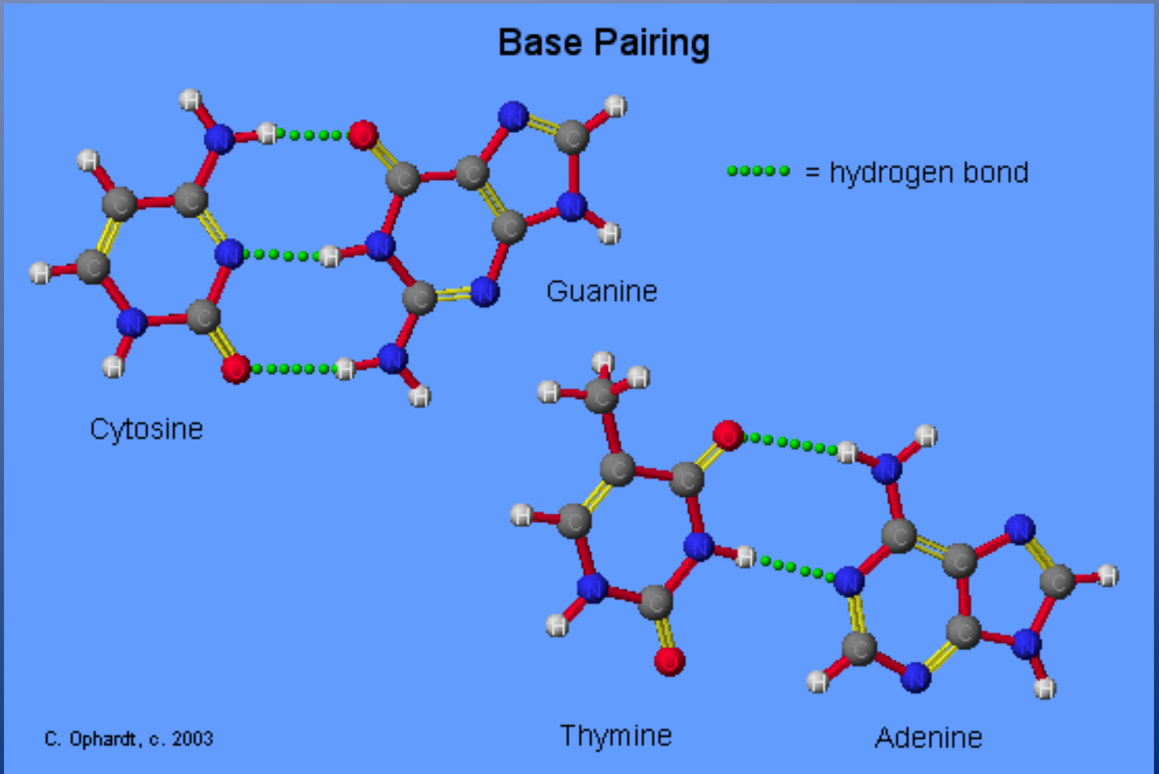


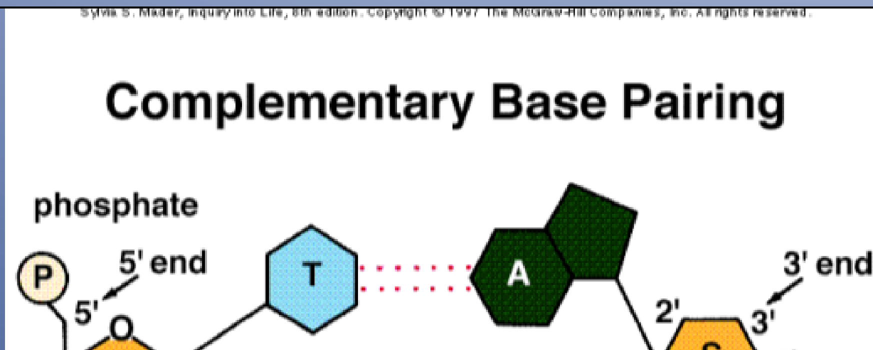
- Pairs of **joined bases project crosswise**, forming the **rungs** of the ladder. The bases stick out the side of the sugar molecules, and are linked to the bases of the other strand by **<u>hydrogen bonds</u>** in a very strict pattern. Always a **purine** with a **pyrimidine**.

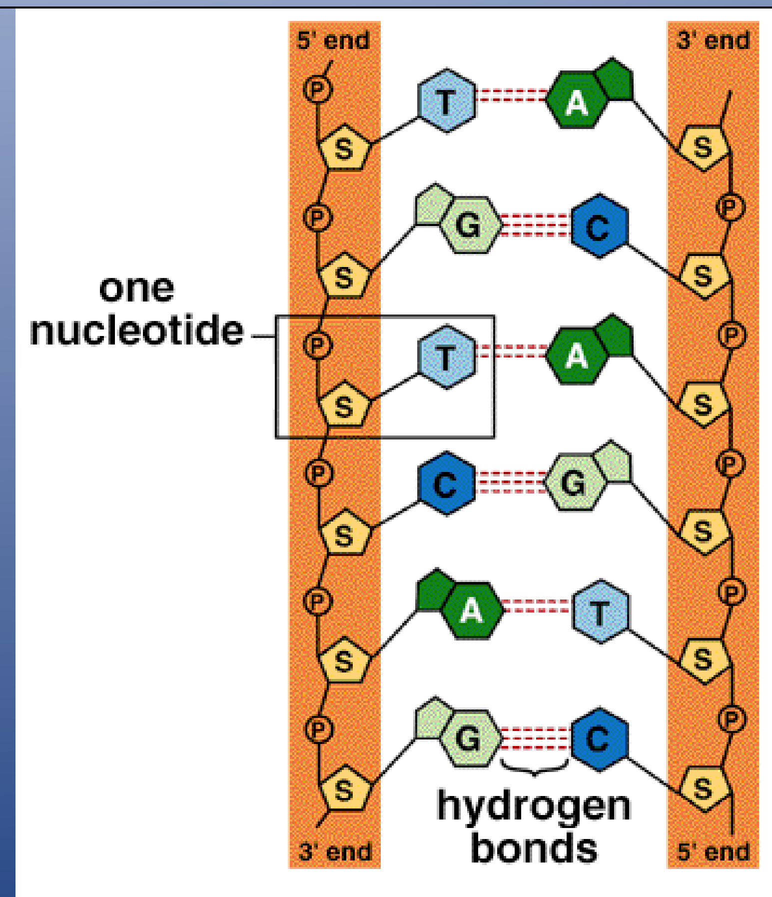


There is <u>COMPLEMENTARY BASE PAIRING</u> BETWEEN STRANDS

- **ADENINE (A) bonds with THYMINE (T)**
- **GUANINE (G) binds with CYTOSINE (C)**



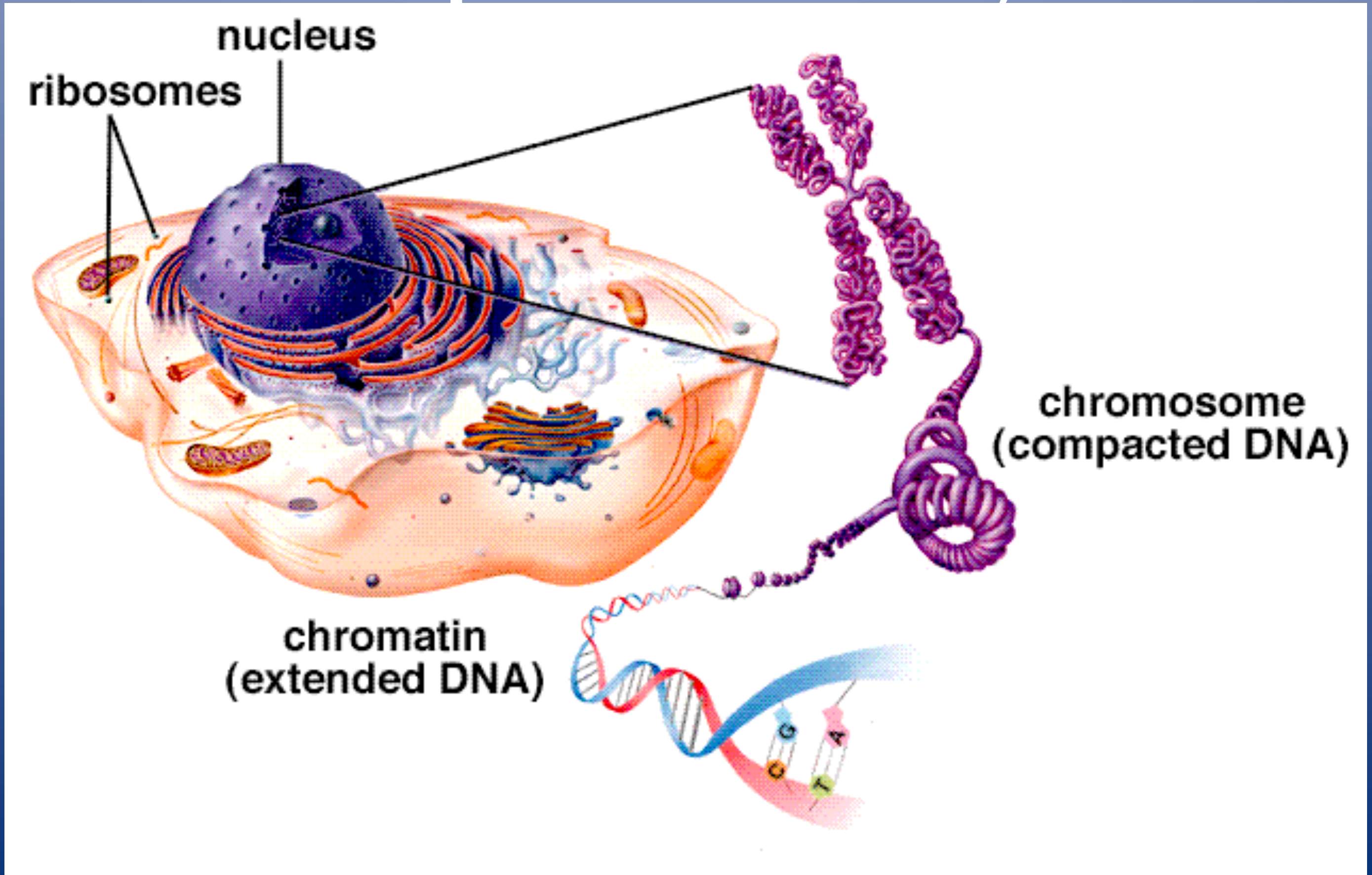

Sylvia S. Mader, Inquiry into Life, 8th edition. Copyright © 1997 The McGraw-Hill Companies, Inc. All rights reserved.
Complementary Base Pairing
phosphate
P
5' end
5'
O
T
A
2'
3'
3' end


5' end
3' end
one nucleotide
P
S
T
A
G
C
hydrogen bonds
3' end
5' end

- Note that the **number** of **purine** bases equals the number of **pyrimidine** bases.
- the bases **can be in any order**, but **always** pair as above
- It is the **SEQUENCE OF BASES** that **codes heredity information** in the genetic code in DNA and RNA.
- Review the rules of complementary base pairing below

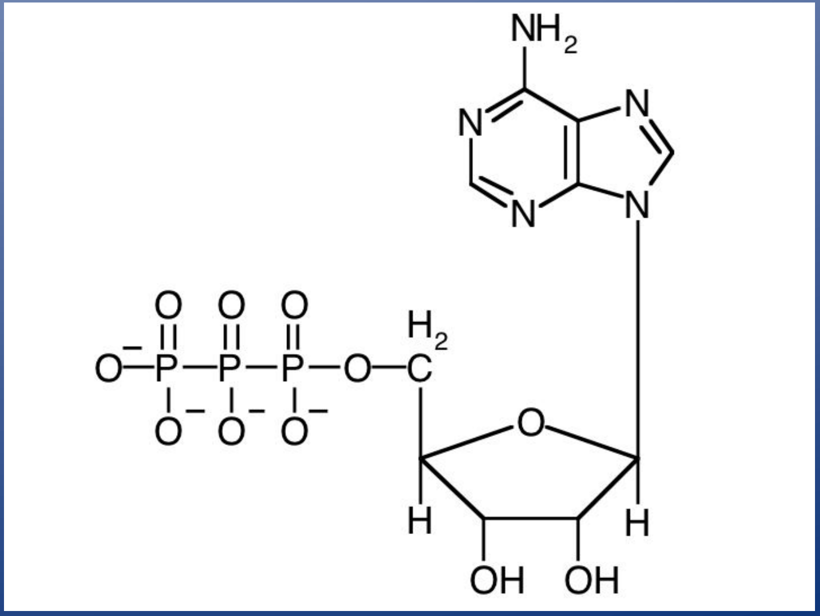
A	T	G	T	G	A	T	C	C	A	C	G	C	G	T
II	II	III	II	III	II	II	III	III	II	III	III	III	III	II

- DNA strands are **extremely long**, each one containing **millions** of atoms. Every human cell contains about one meter of these twisted strands. (this amounts to about **4 billion pairs** of bases).

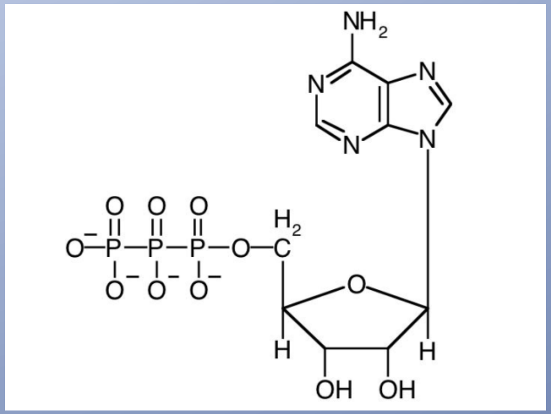


ATP - Adenosine Triphosphate - the Molecule of ENERGY

- ATP is a type of **nucleotide** that is used as the **primary CARRIER OF ENERGY** in cells
- Consists of the sugar **Ribose**, the **base Adenine**, and **3 phosphate groups** attached to the ribose.



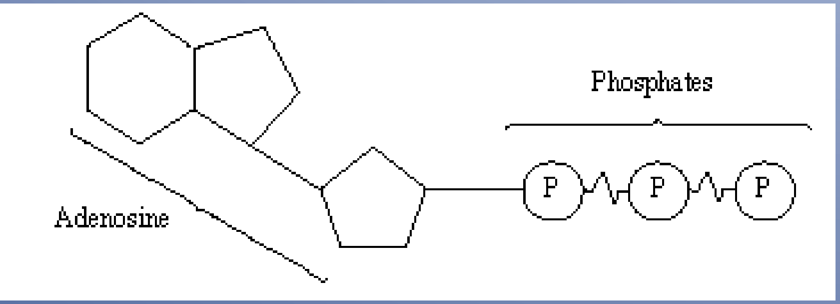
- The bond between the **outer two phosphates** is **very high in energy**: when it is broken, *much energy is released*, which can be used by the cell (for example, for muscle contraction).

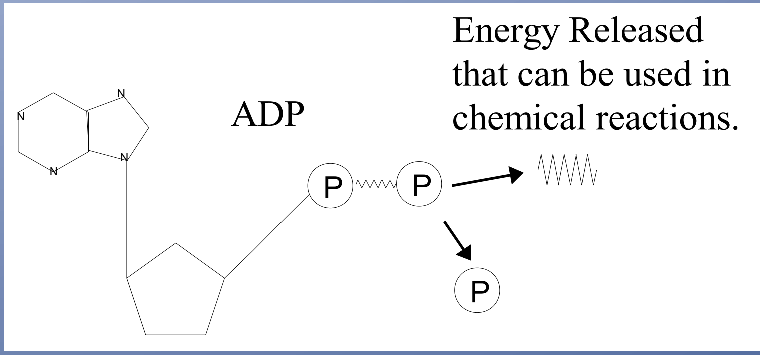


- The bond between the first and second phosphate is also high in energy, but not as high as between the two end phosphates

- ATP is produced mostly inside **<u>mitochondria</u>** during the process of **<u>cellular respiration</u>**.

ATP breaks down to release 1 P and E





Compare and Contrast DNA and RNA

	DNA	RNA
Sugar	Deoxyribose (5 C sugar with one less oxygen)	Ribose (5 C. sugar with one more oxygen)
Bases	Adenine, Guanine, Thymine, Cytosine	Adenine, Guanine, Uracil, Cytosine
Strands	Double stranded, with base pairing	Single stranded
Shape	Double helix shaped	Not double helix shaped
Location	Nucleus	Nucleus and cytoplasm
Length	Longer than RNA	Shorter
Kinds	1	3 kinds (messenger - mRNA, transfer - tRNA, ribosomal - rRNA)

Ted-Ed Biochem Lessons

Biochemistry Animation Ted-Ed

Polymer Animation Ted-Ed

Fat Ted-Ed

Phospholipid Ted-Ed

Acid/Base Ted-Ed

Water Ted-Ed

Bonding Atoms Ted-Ed

Molecular Shape Ted-Ed

If Molecules were People Ted-Ed