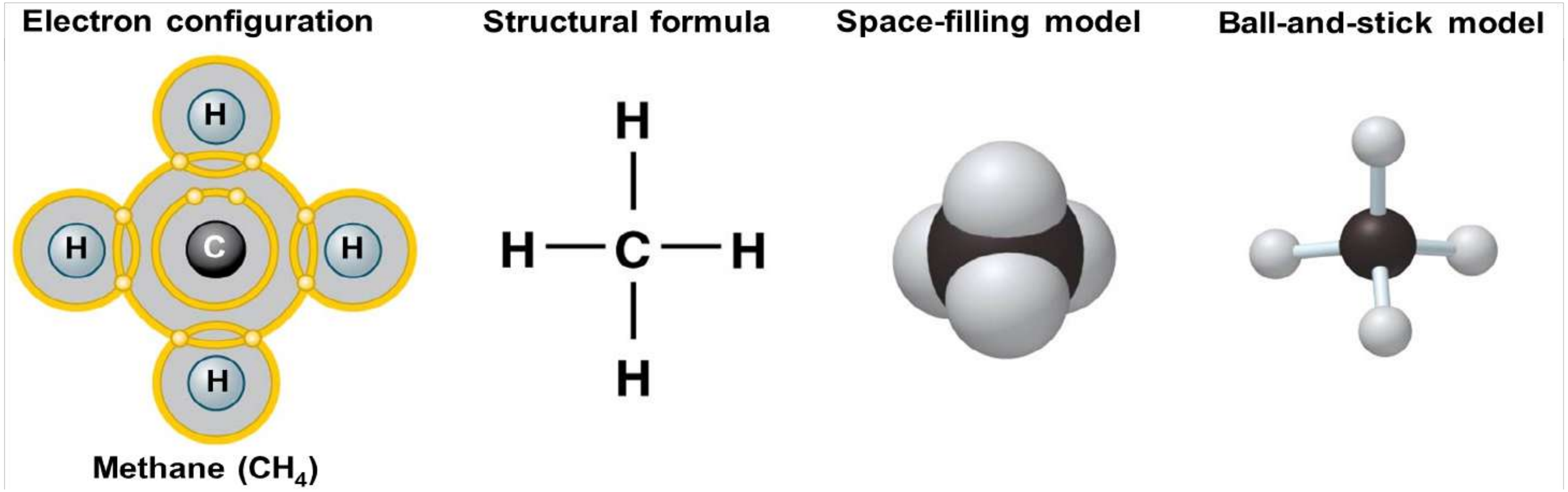
# BIO101: Life Science
# Unit 1: Cells
## Chapter 3: The Molecules of Life

Instructor: Dr. Li Lu
Office: CH 208C
Email: li.lu@kysu.edu

Organic molecules: most of them **contain carbon** and are **macromolecules.**

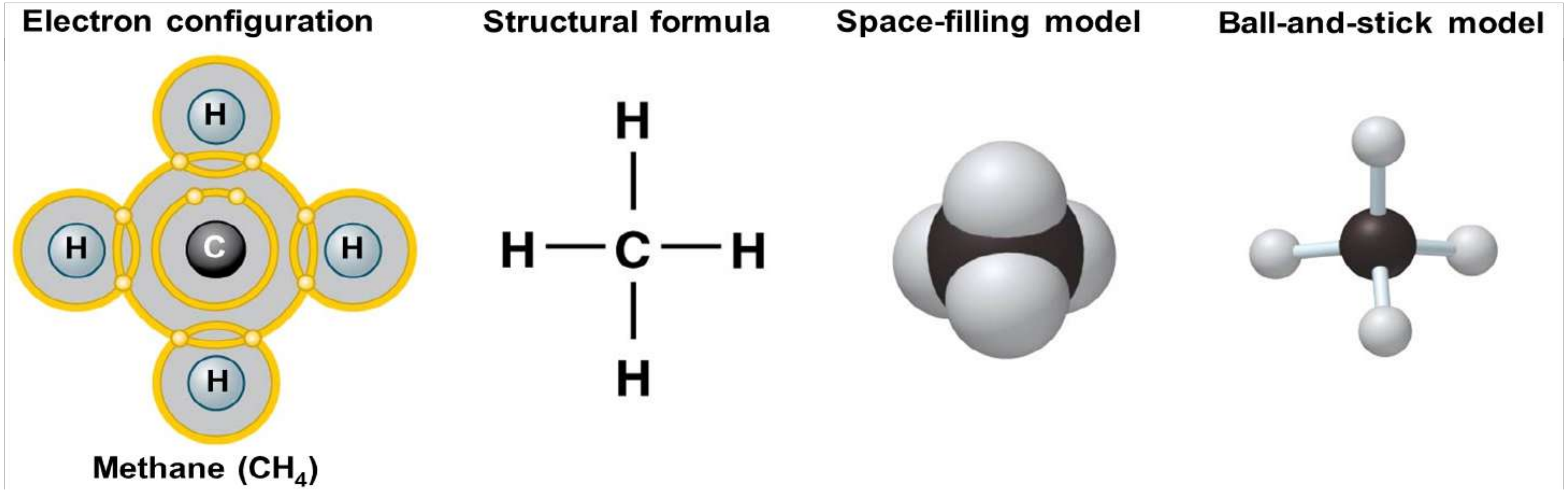
**“macro-”: big**

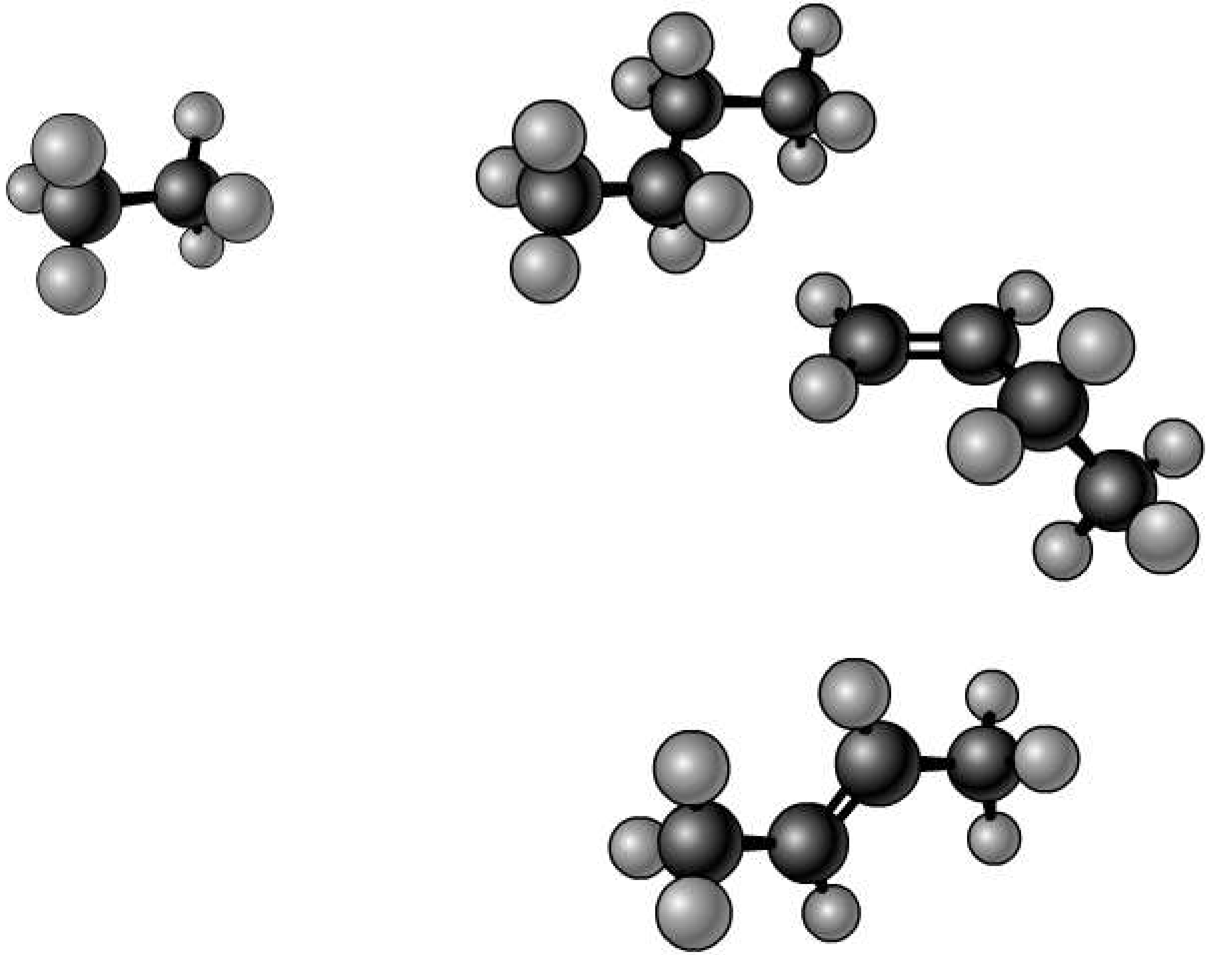


Each carbon can form up to four chemical bonds with other atoms/groups, and build various, complex organic molecules.

Most of these bonds are formed between:

- ✓ Carbon and hydrogen atoms
- ✓ Carbon and oxygen atoms
- ✓ Carbon and other carbon atoms





Animation: Carbon Skeletons

Right click slide / select “Play”

Countless organic molecules fall into four main categories in living organisms:

- Carbohydrates: sugars and polymers of sugars like starch
- Lipids: fat and fat-like compounds
- Proteins: polymers of amino acids
- Nucleic acids: polymers of nucleotides

Each category again has countless members. Living organisms, and most of our food, provide a mixture of all different kinds of organic molecules.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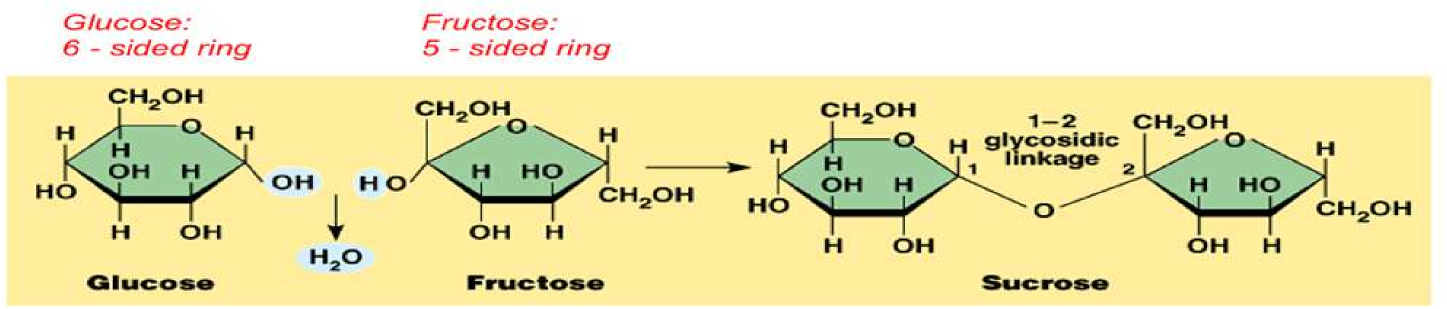
NATURALLY AND ARTIFICIALLY CARAMEL FLAVORED
FIBER ONE
Lightly Sweetened Crunchy Whole Wheat Squares
35% Daily Value of FIBER
9 Grams of Fiber
bestlife
NET WT 15.6 OZ (442g)
Nutrition Facts
Serving Size 1 cup (50g)
Servings Per Container about 9
Amount Per Serving | Fiber One Caramel Delight | with ½ cup skim milk
Calories 180 220
Calories from Fat 25 30
% Daily Value**
Total Fat 3g* 4% 5%
Saturated Fat 0g 0% 3%
Trans Fat 0g
Polyunsaturated Fat 0.5g
Monounsaturated Fat 1.5g
Cholesterol 0mg 0% 1%
Sodium 260mg 11% 13%
Potassium 140mg 4% 10%
Total Carbohydrate 14% 16%
Dietary Fiber 9g 35% 35%
Soluble Fiber 3g
Sugars 10g
Other Carbohydrate 22g
Protein 3g
Vitamin A 0% 4%
Vitamin C 10% 10%
Calcium 10% 25%
Iron 25% 25%
Thiamin 25% 30%
Riboflavin 25% 35%
Niacin 25% 25%

- **Three of them, carbohydrates, proteins, and nucleic acids, are regarded as macromolecules.**
- **Most macromolecules are polymers, which are made by stringing together many smaller molecules called monomers.**
- **“poly-” means “many, much”**
- **“mono-” means “single, the only one”.**

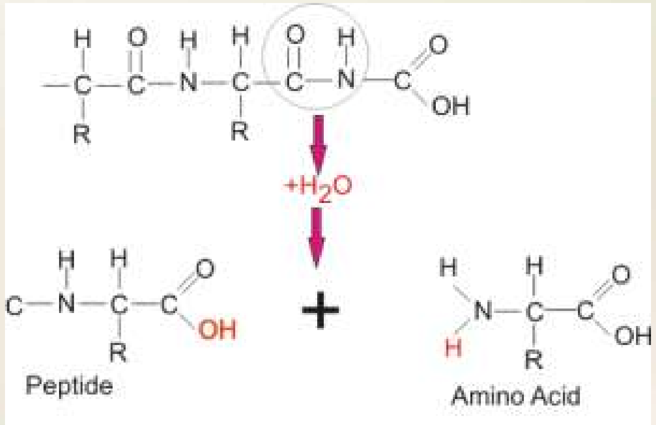
# Making and Breaking Macromolecules

When monomers are joined together, two hydrogens and one oxygen are removed from the molecules (one molecule of water). This process that joins the molecules is called **Dehydration Synthesis**.



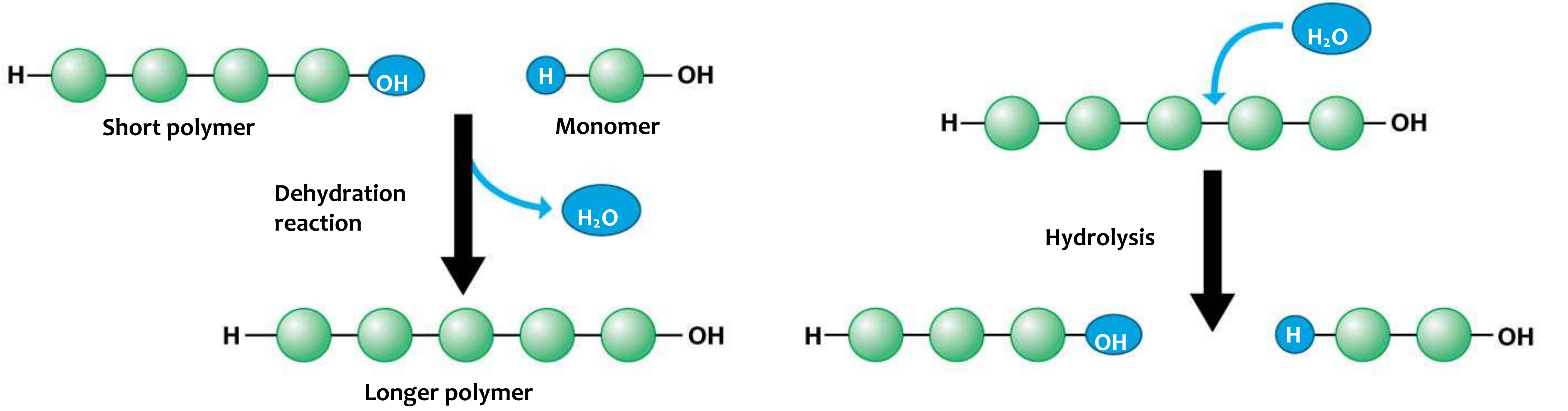
(b) Dehydration synthesis of sucrose

When these large molecules are broken down into smaller parts, a water molecule is used to separate them in a process called **Hydrolysis**.



Hydrolysis of Peptide Bond

- Monomers and small polymers can be “linked” together to form bigger polymers.
- Big polymers can be broken into smaller polymers and even monomers.
- These reactions happen in our body in every second.



(a) Building a polymer chain (building your body mass)
(b) Breaking a polymer chain (digestion of food)

**The first class of organic molecules we want to introduce:**

- **Carbohydrates: sugars and polymers of sugars**

# Carbohydrates: sugars and polymers of sugars, such as:

small sugar molecules in energy drinks and
long starch molecules in spaghetti and French fries.

In nature, carbohydrates are:

- the most abundant organic molecules;
- because they are the main components of plants!
- primary source of energy;
- raw material for manufacturing other kinds of organic compounds;

# Sugar: Monosaccharides and Disaccharides

"Saccharide" (originated from Latin) is another term for sugars.

The "sugar" in chemistry doesn't mean the same as the "sugar" in kitchen.

In science, "sugar" includes a group of carbohydrates, mainly different kinds of monosaccharides and disaccharides.

The table sugar, sucrose, is only one of them.

# Sugar: Monosaccharides and Disaccharides

"Mono-saccharides"→ "simple sugars"

- Are the monomers—the building blocks of carbohydrates.

  Eg. glucose and fructose

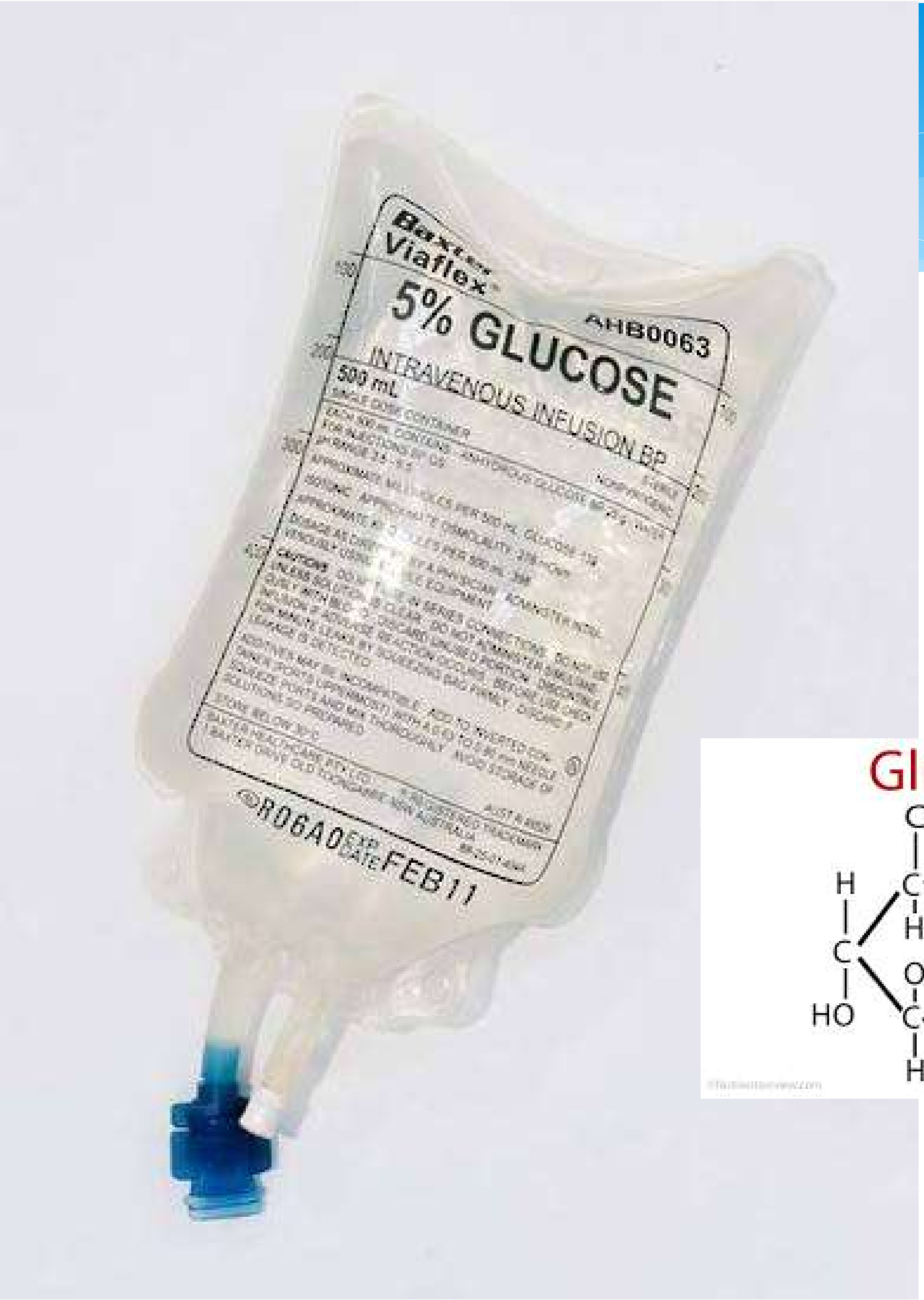
"Di-saccharides" → "two sugars"

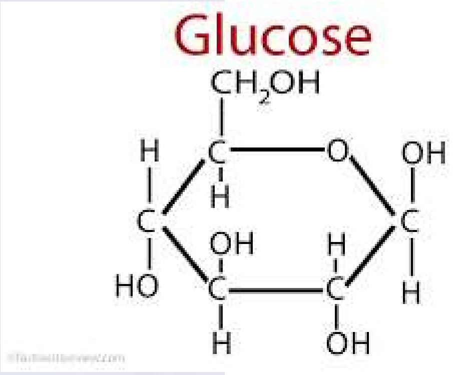
- Are constructed from two monosaccharides.

  Eg. sucrose (table sugar) and lactose

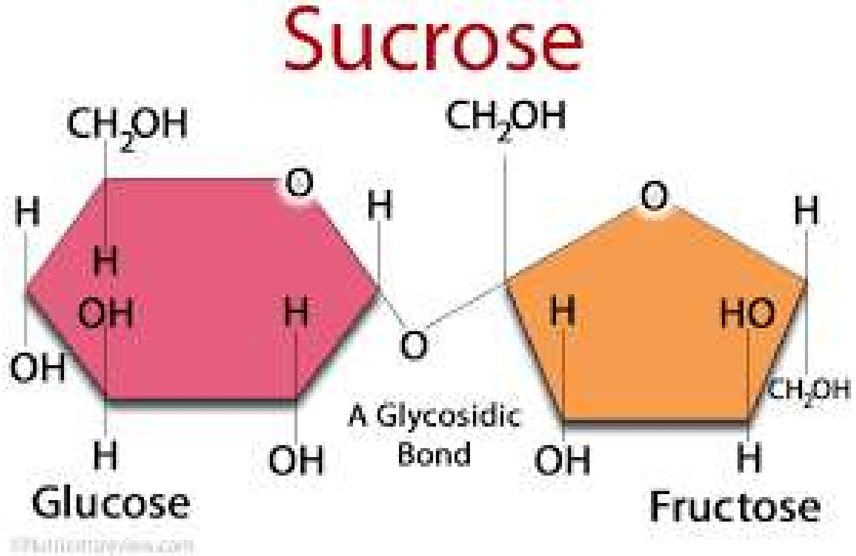
The names of the monosaccharides and disaccharides very often end in the suffix "-ose".

- **Gluc<u>ose</u> is the direct energy source for cellular work.**
- **It is often given to patients as an IV (intravenous) solution to provide direct energy.**



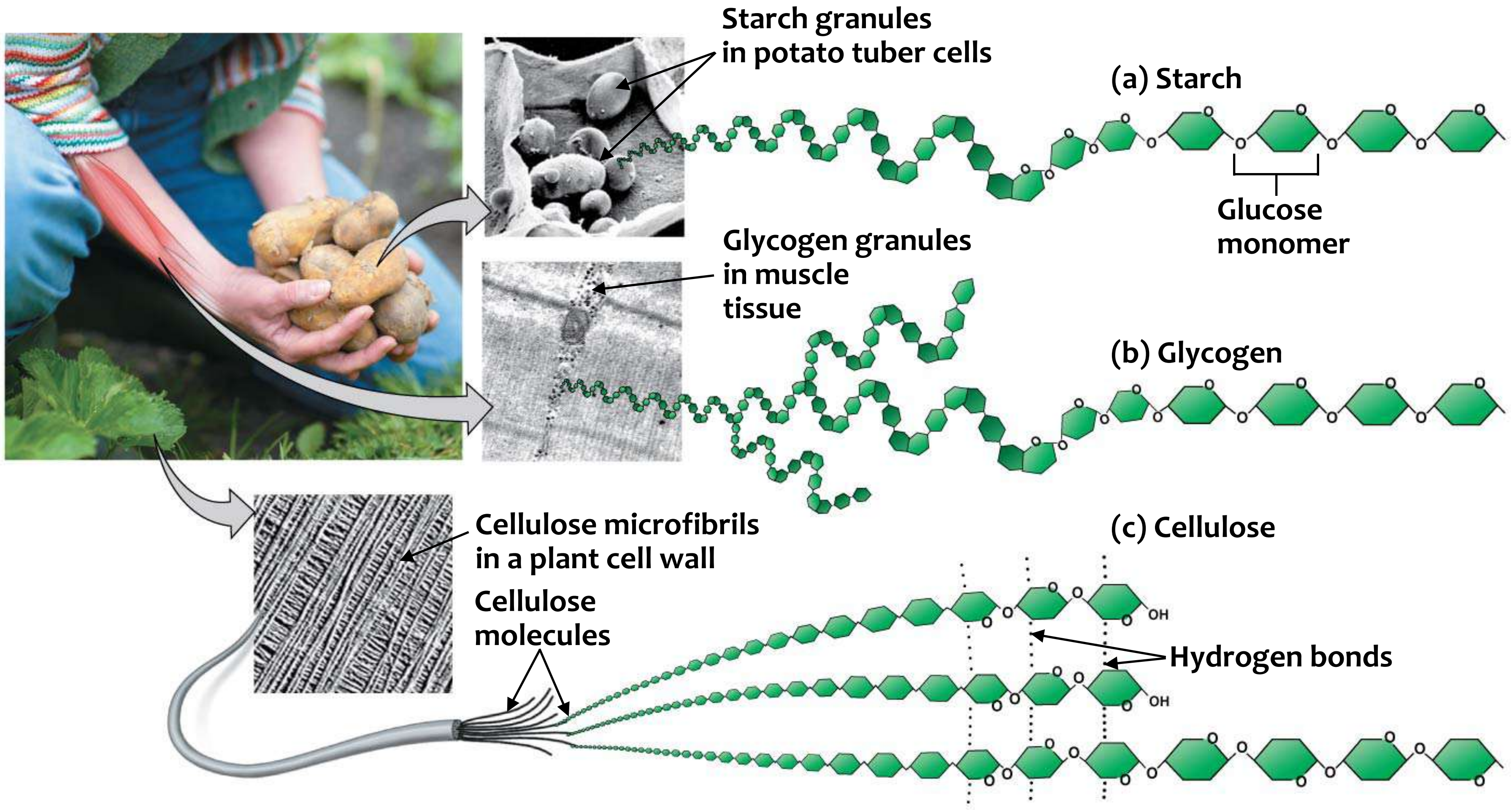



- Sucrose is the main carbohydrate in plant sap (sugarcane, sugarbeet).
- The main component of brown and white sugar



# Polysaccharides: polymers of monosaccharides

## Eg. starch and cellulose



**Starch**

- Used by plant cells to store energy,
- Potatoes and grains are major sources of starch in our diet.

**Cellulose**

- The most abundant organic compound on Earth,
- Mainly exist in plant cell walls --- abundant in wood and cotton fibers,
- Cannot be broken apart (digested) by most animals,
- Important component of dietary fibers.

**Glycogen**

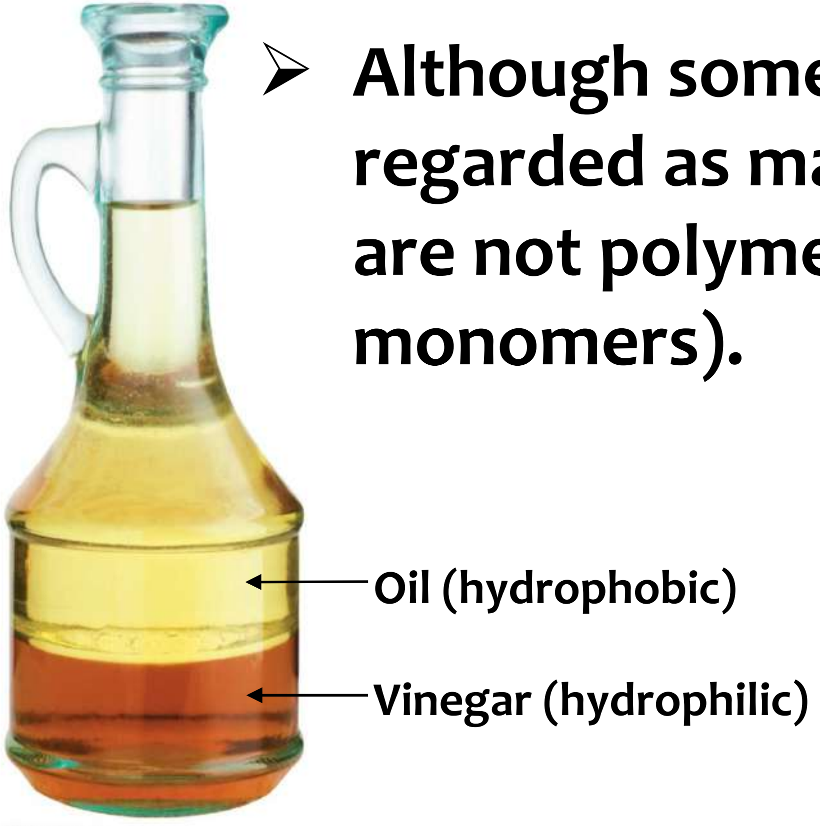
- Used by animal cells to store energy,
- Converted to glucose when it is needed.

## The second classes of organic molecules :

- **Lipids: fat and fat-like compounds**

# Lipids: fat and fatlike substances

- Energy-storage molecules in seeds and fruits,
- <u>Hydrophobic</u> (unable to mix with water),
- Although some are very big, generally are not regarded as macromolecules because they are not polymers (they have no special monomers).



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Serving Size 1 cup (50g)
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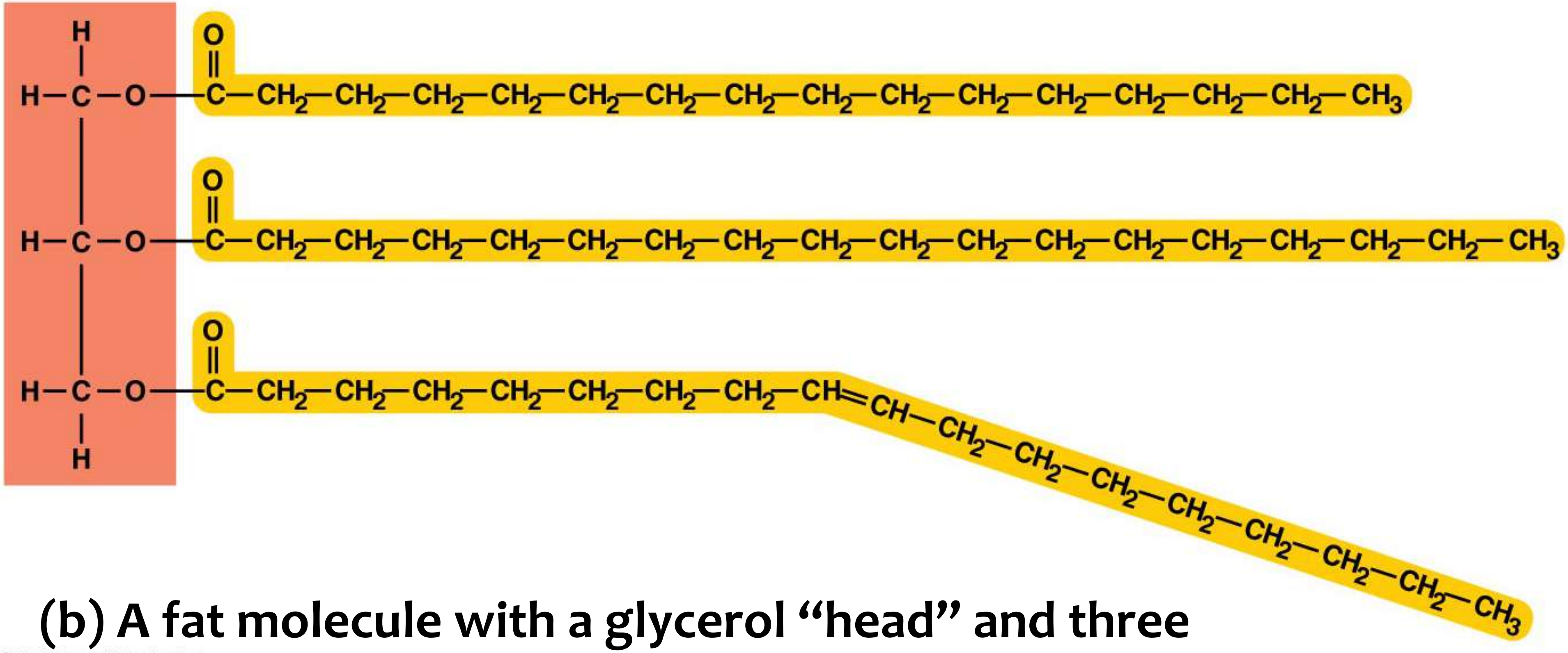
Fiber One Caramel Delight
with ½ cup skim milk
Calories 180 220
Calories from Fat 25 30
% Daily Value**
Total Fat 3g* 4%
Saturated Fat 0g 0%
Trans Fat 0g
Polyunsaturated Fat 0.5g
Monounsaturated Fat 1.5g
Cholesterol 0mg 0% 1%
Sodium 13%
Potassium 140mg 4% 10%
Total Carbohydrate 41g 14% 16%
Dietary Fiber 9g 35% 35%
Soluble Fiber 3g
Sugars 10g
Other Carbohydrate 22g
Protein 3g
Vitamin A 0% 4%
Vitamin C 10% 10%
Calcium 10% 25%
Iron 25% 25%
Thiamin 25% 30%
Riboflavin 25% 35%
Niacin 25% 25%

# Fats and oils: triglycerides

- Composed of one glycerol molecule and three fatty acid molecules linked together.



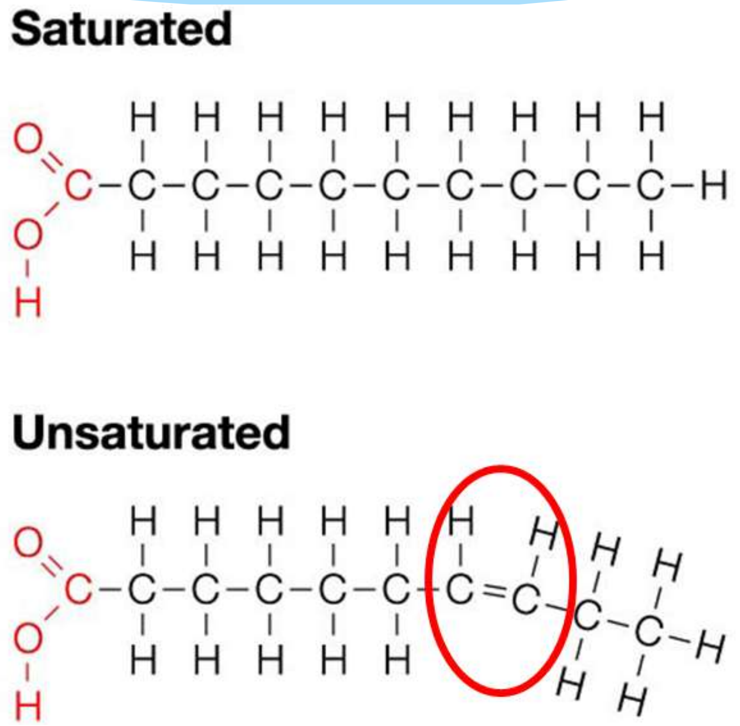

(b) A fat molecule with a glycerol "head" and three energy-rich hydrocarbon fatty acid "tails"

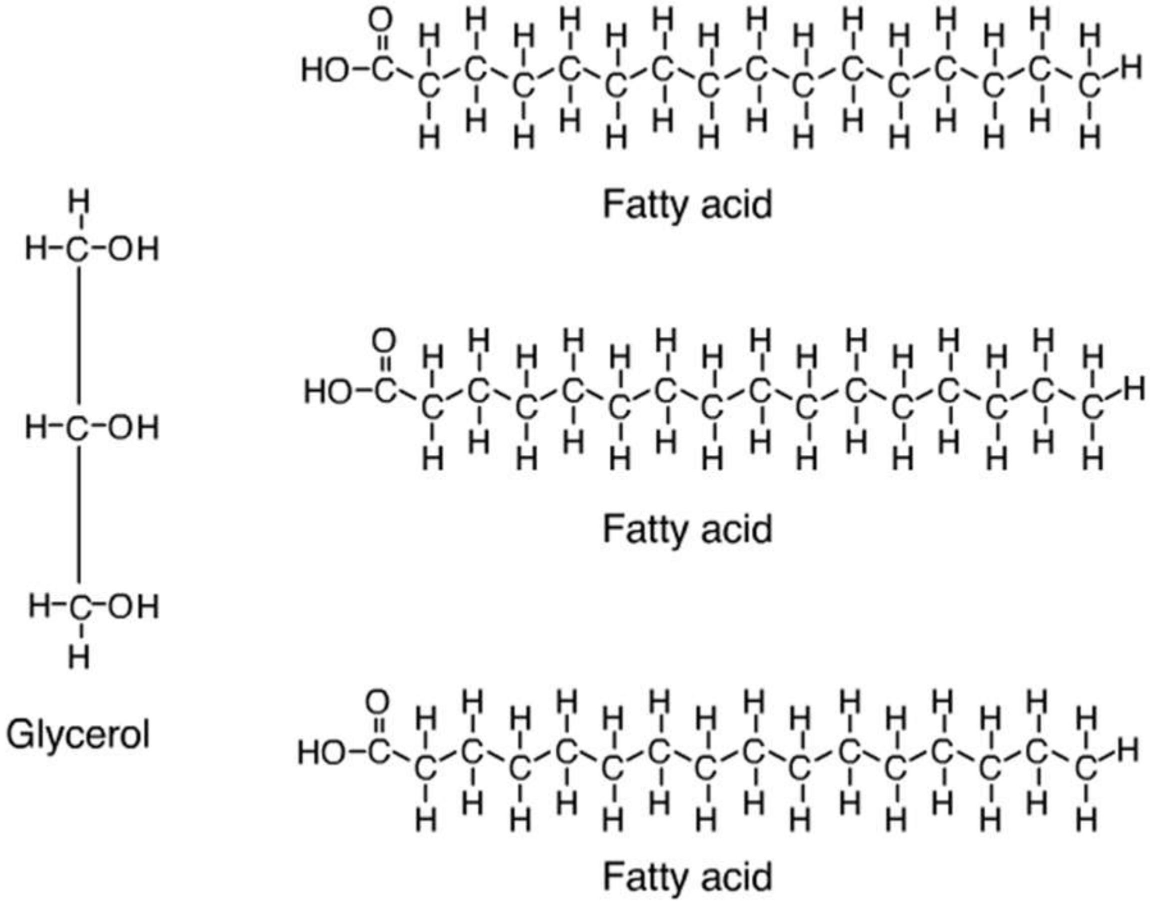
# Saturated fat vs. unsaturated fat

- If the carbon skeleton of the three fatty acids
  - has the maximum number of hydrogens and only single bonds, it is saturated.
  - has fewer than the maximum number of hydrogens,

    it is unsaturated;

Next slide will mention “single bond” and “double bond”, which are characteristics of chemical bonds that we did not cover. Just remember that double bonds mean unsaturated bonds here!





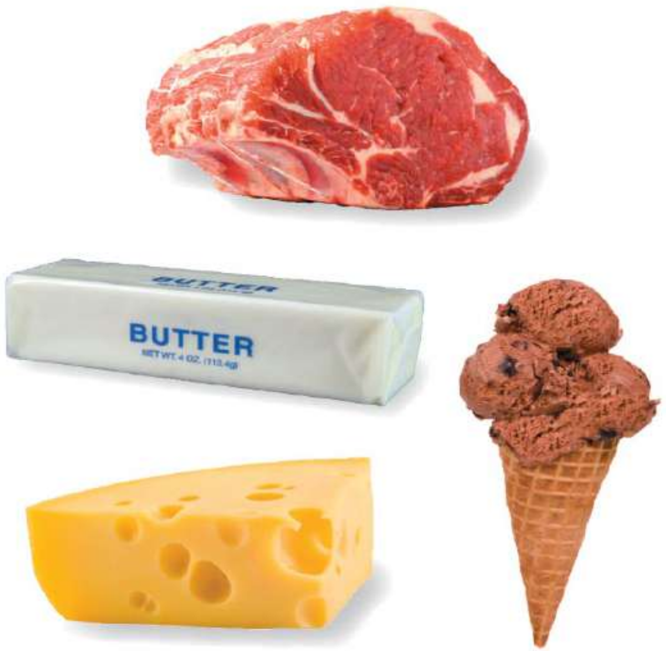

Animation: Fats

Right click slide / select “Play”

## Most animal fats:

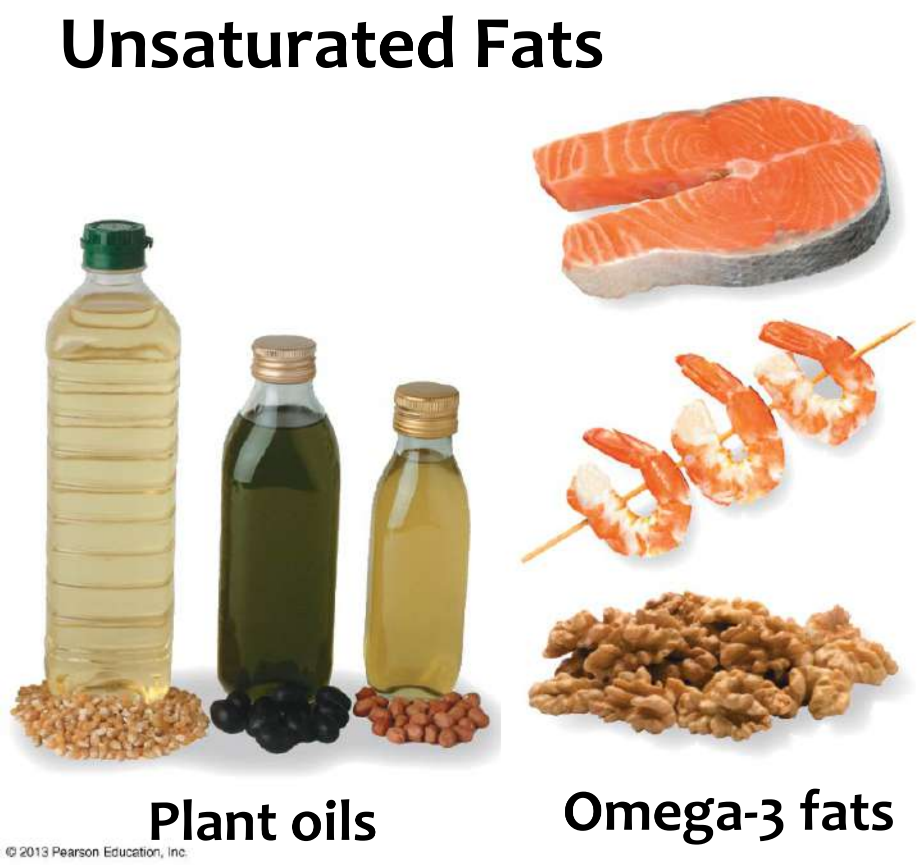
- have a high proportion of saturated fatty acids,
- can easily stack, tending to be solid at room temperature,
- contribute to atherosclerosis, in which lipid-containing plaques build up along the inside walls of blood vessels.

**Saturated Fats**



# Most plant and fish oils:

- high in unsaturated fatty acids,
- liquid at room temperature.
- Better for your health



**Hydrogenation**, a process of adding hydrogen to fatty acid chains.

- Converts unsaturated fats to saturated fats,
- Makes liquid fats solid at room temperature,
- Increases product shelf life and decreases refrigeration requirements in food industry,
- Creates trans fat, a type of unsaturated fat that is particularly bad for your health, especially for coronary heart diseases.

# Fats are important to living organisms!

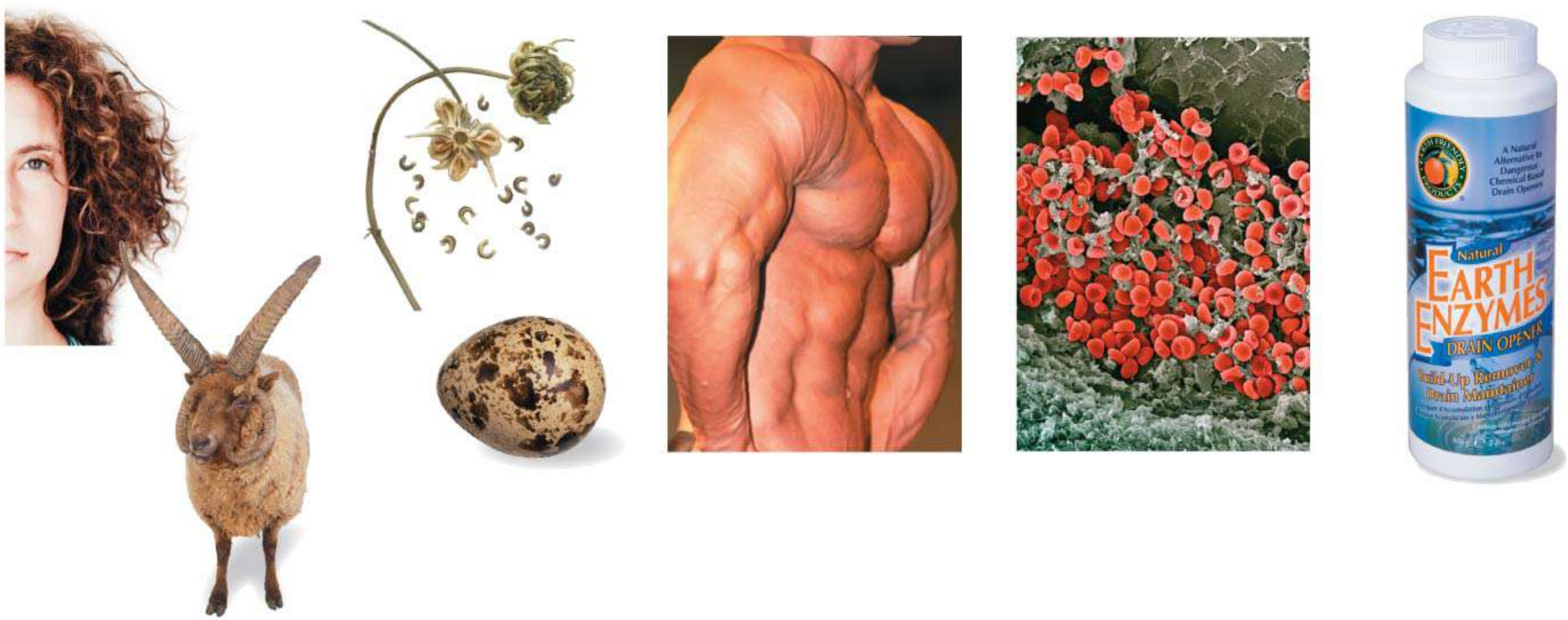
- Indispensable components of all living cells and living organisms.
- Provide energy, keep body warm, prevent water loss, provide a protective barrier around cells…… Too many critical functions of all kinds of fats!

**The third class of organic molecules:**

- **Proteins: polymers of amino acids**

# MAJOR TYPES OF PROTEINS

| Structural Proteins (provide support) | Storage Proteins (provide amino acids for growth) | Contractile Proteins (help movement) | Transport Proteins (help transport substances) | Enzymes (help chemical reactions) |
| --- | --- | --- | --- | --- |

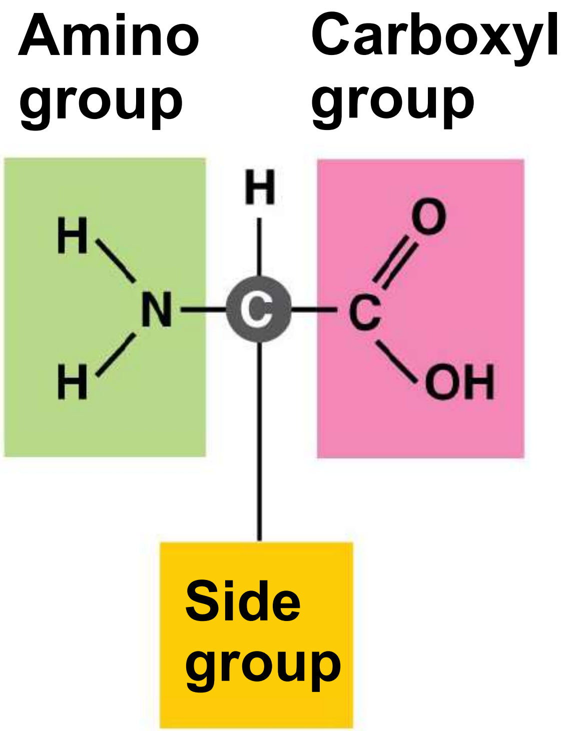


# Proteins

- Polymers constructed from 20 amino acid monomers,
- Perform most of the tasks required for life as enzymes, chemicals that change the rate of a chemical reaction without being changed in the process,
- Stored in large amount in seeds for the next generation.

# What do amino acids look like?

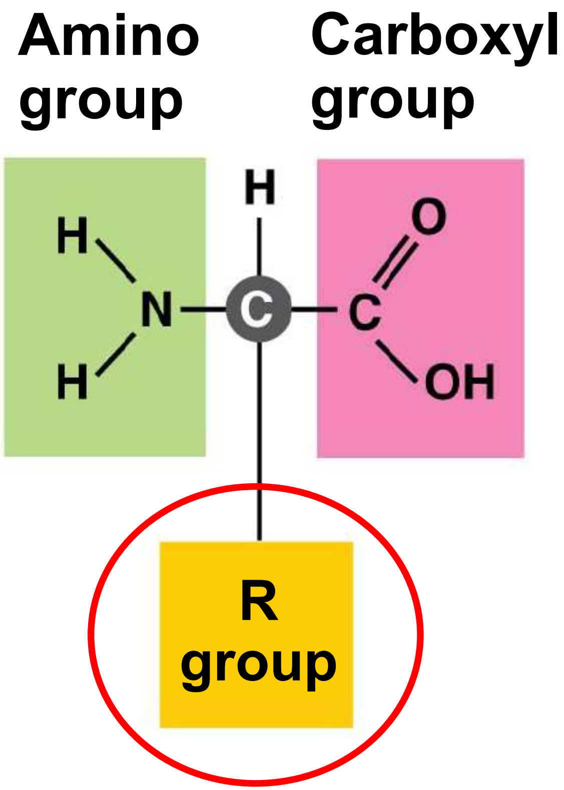
- **Each amino acid consists of a central carbon atom bonded to four partners.**




The general structure of an amino acid

# What do amino acids look like?

- Each amino acid consists of a central carbon atom bonded to four partners.
- Three of those attachment groups are common to all amino acids.
- But the R group varies between amino acids and determine their identities.

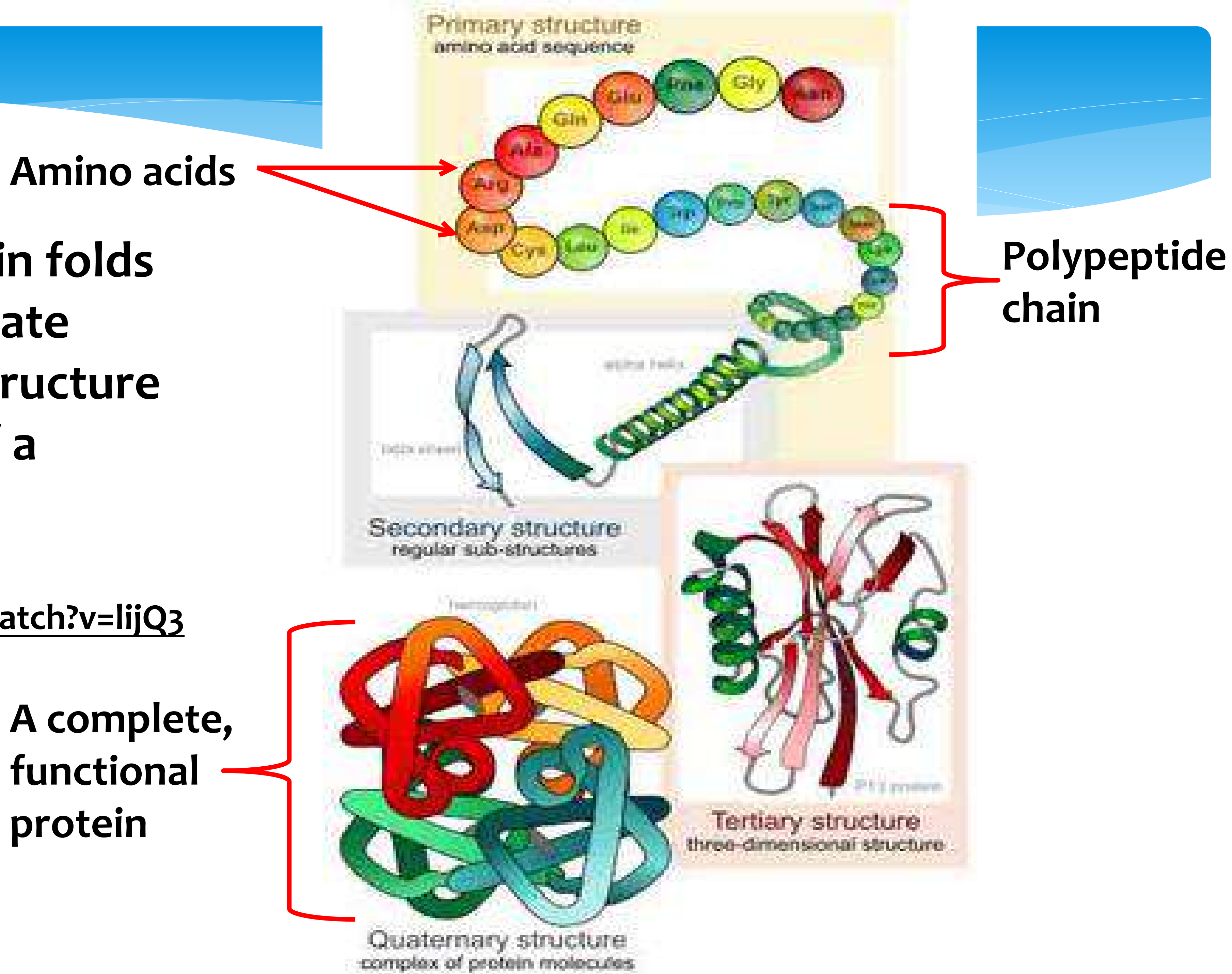



The general structure of an amino acid

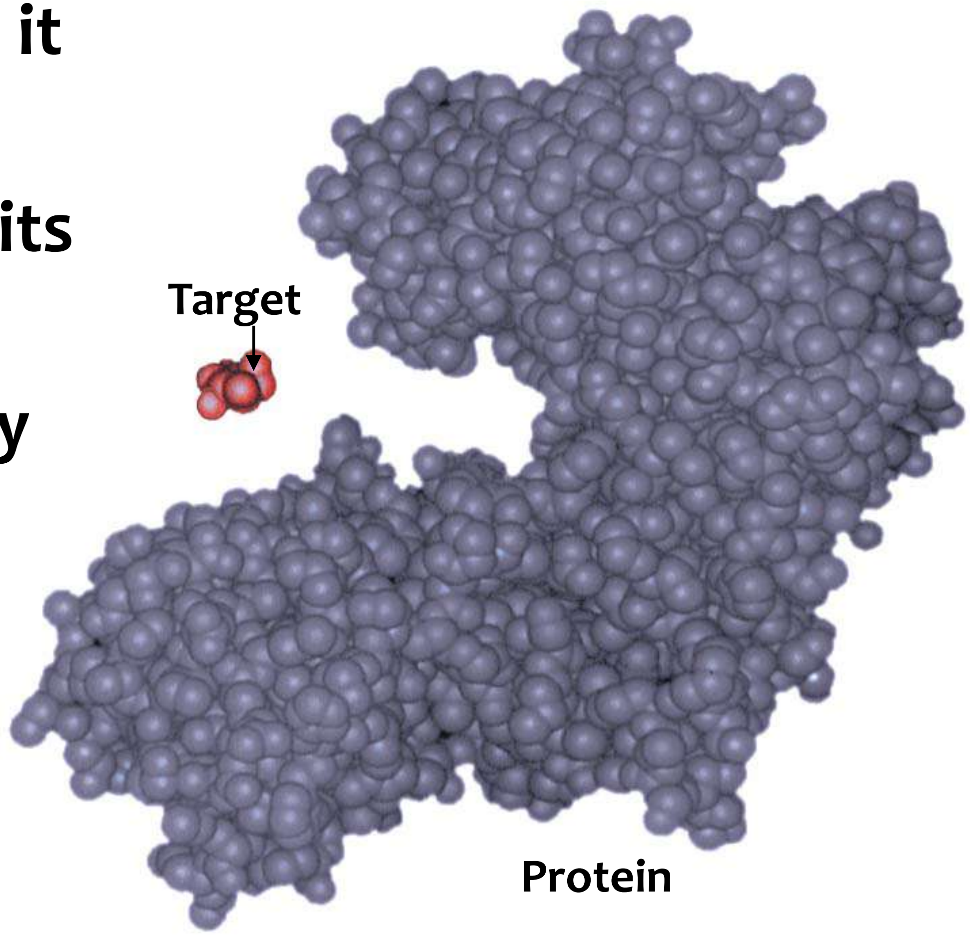
- **Amino acids are monomers, and can be linked together to form long chains of amino acids --- no branches will be formed!**
- **The chains of amino acids are called polypeptides, in this class, you can regard them as equal to proteins.**
- **The specific sequence of amino acids in a protein is its primary structure.**
- **Just as each word is constructed from a unique succession of letters, each protein has a unique linear sequence of amino acids --- the primary structure.**

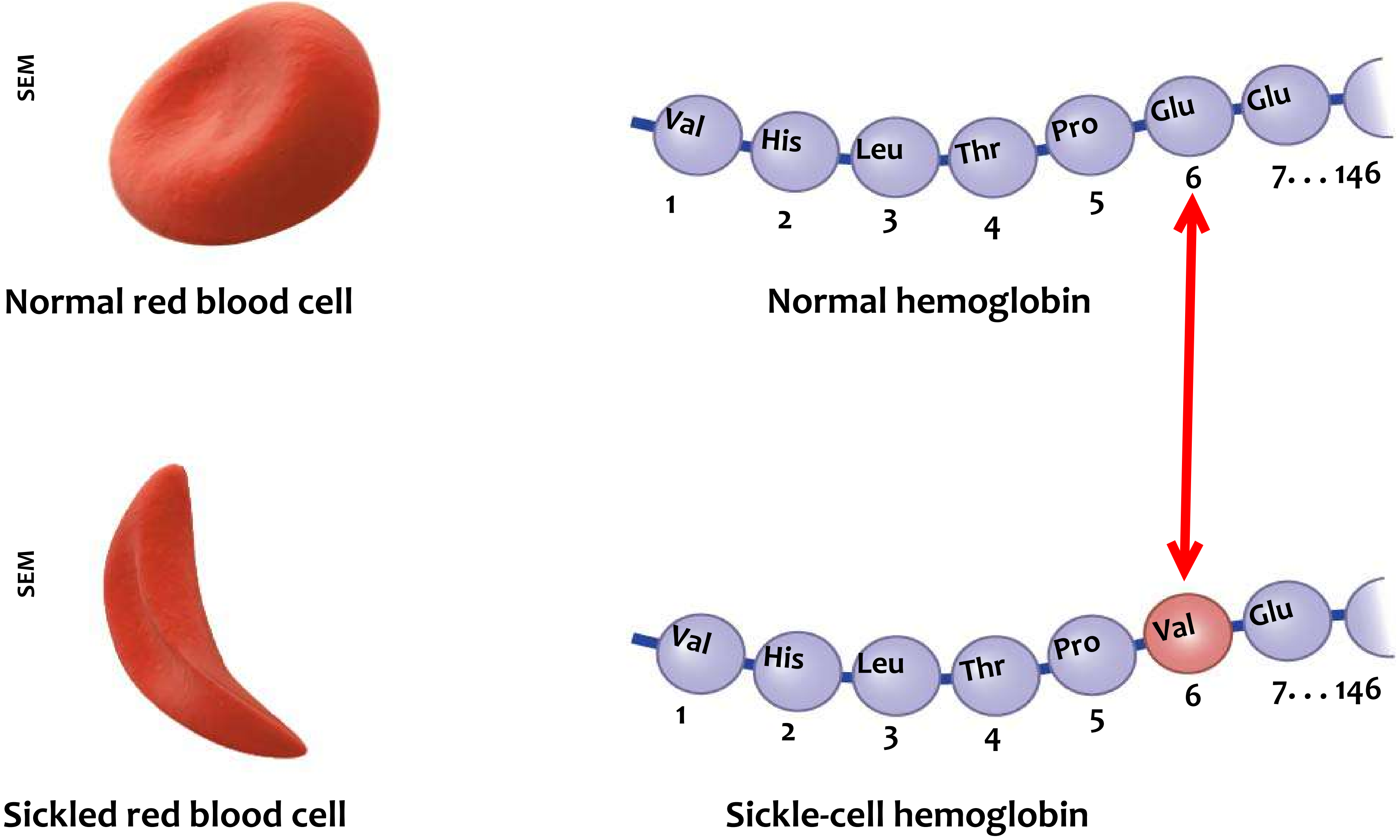
The polypeptide chain folds into a complex, delicate three-dimensional structure --- functional form of a protein.

https://www.youtube.com/watch?v=lijQ3a8yUYQ



- The three-dimensional structures of proteins enable it to recognize and bind with other molecules to carry out its specific functions.
- A slight change in the primary structure might damage the protein functions.








**The mistake of a single amino acid in hemoglobin causes <u>sickle-cell disease</u>, an inherited blood disorder.**

**Proteins with abnormal 3-D structures are associated with**

- **Alzheimer’s disease,**
- **Parkinson’s disease,**
- **and Mad Cow disease.**

- A protein's shape is also sensitive to the surrounding environment.
- An unfavorable change in temperature and/or pH can cause denaturation of a protein, in which it unravels and loses its shape.
- Cooking of food involves the denaturation of proteins, for example, cooking of an egg changes the clear, liquid-like egg white into opaque, solid state (denaturation).
- High fevers (above 104°F) in humans can cause some proteins to denature, that is why high fever is dangerous.

**The fourth class of organic molecules:**

- **Nucleic acids: polymers of nucleotides**

# Nucleic acids:

- macromolecules composed of <u>nucleotides</u>,
- include <u>DNA</u>: deoxyribonucleic acid

  "de-oxy-ribo-nucleic"

  and <u>RNA</u>: ribonucleic acid

  "ribo-nucleic"
- store genetic information,
- provide the directions for building proteins

- **DNA resides in cells in long fibers called chromosomes.**
- **A gene is a specific stretch of DNA that programs the amino acid sequence of a polypeptide.**
- **Each chromosome has hundreds, or even thousands of genes.**
- **The chemical code of DNA must be translated from "nucleic acid language" to "protein language."**

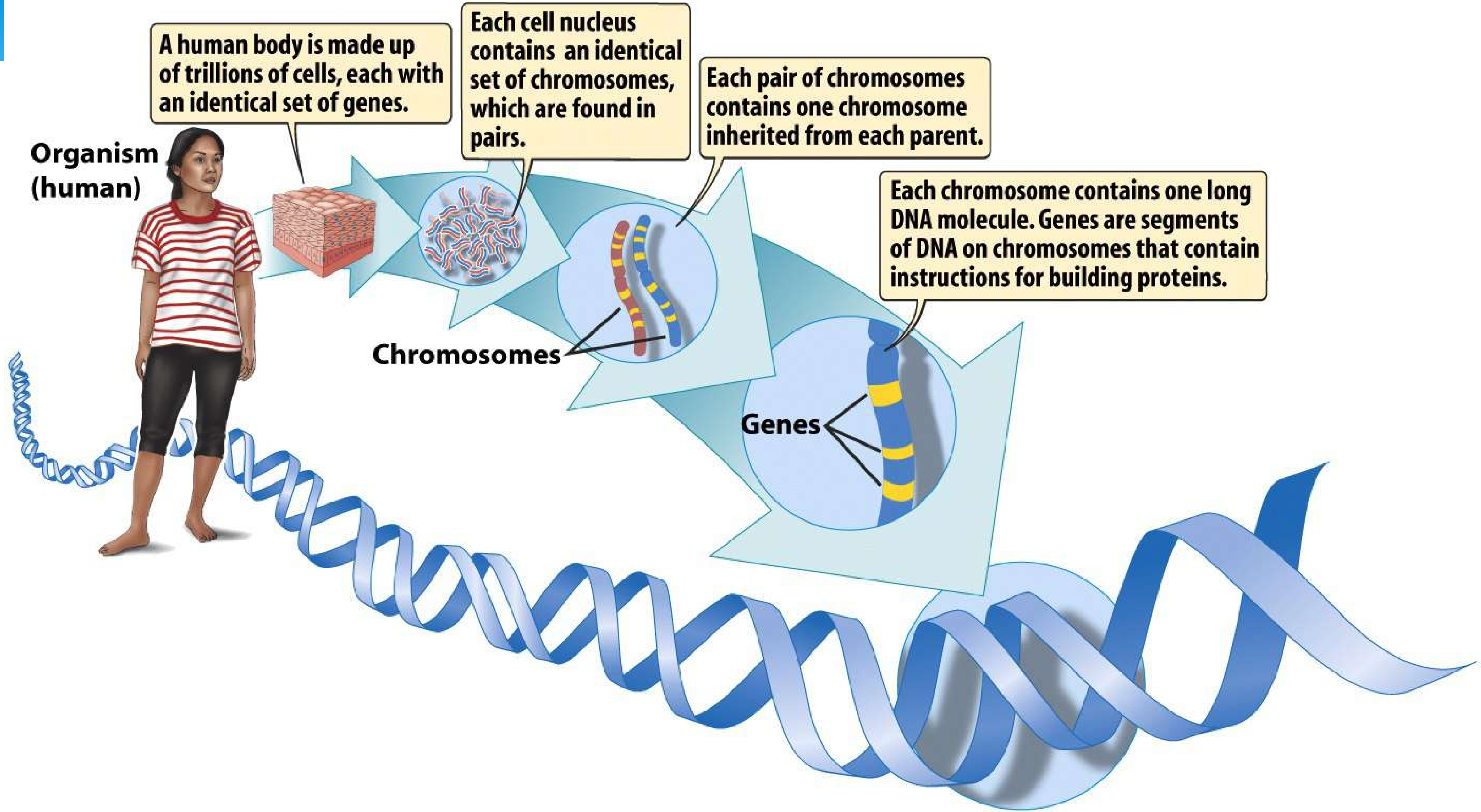
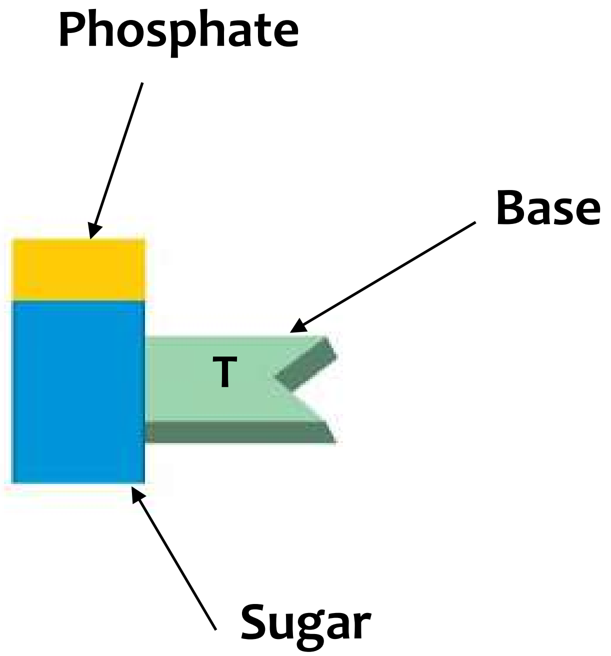



Figure 10-2 Discover Biology 3/e


http://www.csus.edu/indiv/l/loom/lect%2026-27.htm

- Nucleic acids are polymers made from monomers called nucleotides.
- Each nucleotide has three parts:
  - a five-carbon sugar,
  - a phosphate group, and
  - a nitrogen-containing base.

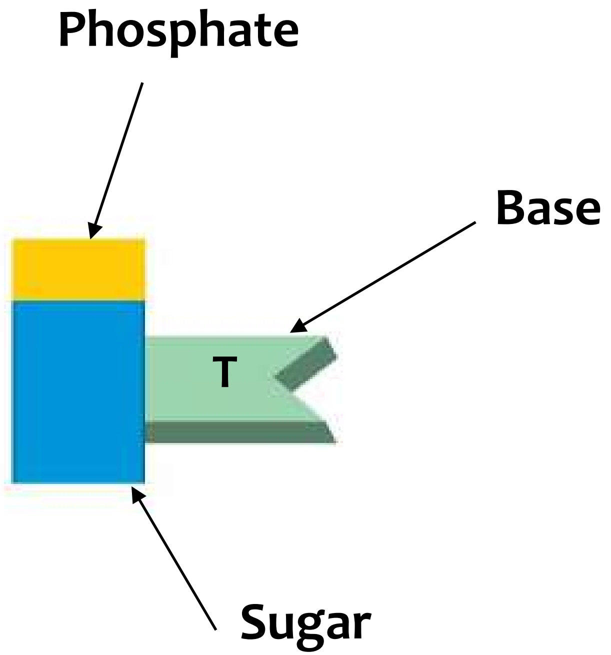



model of a nucleotide

## For DNA nucleotides,

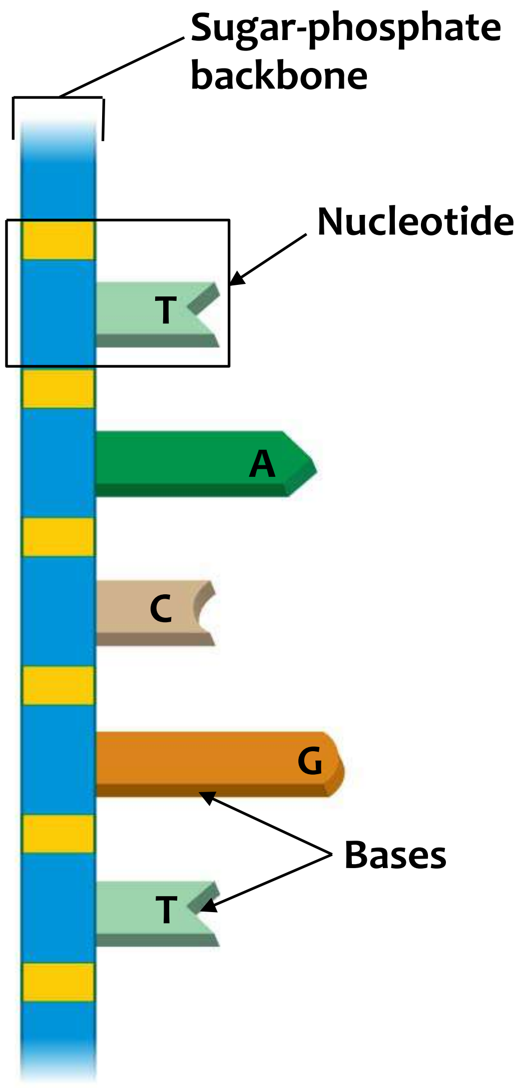
- The five-carbon sugar is deoxyribose (deoxy-ribose).

- There are four possible nitrogen-containing bases:
  - ✓ adenine (A),
  - ✓ guanine (G),
  - ✓ thymine (T),
  - ✓ cytosine (C).



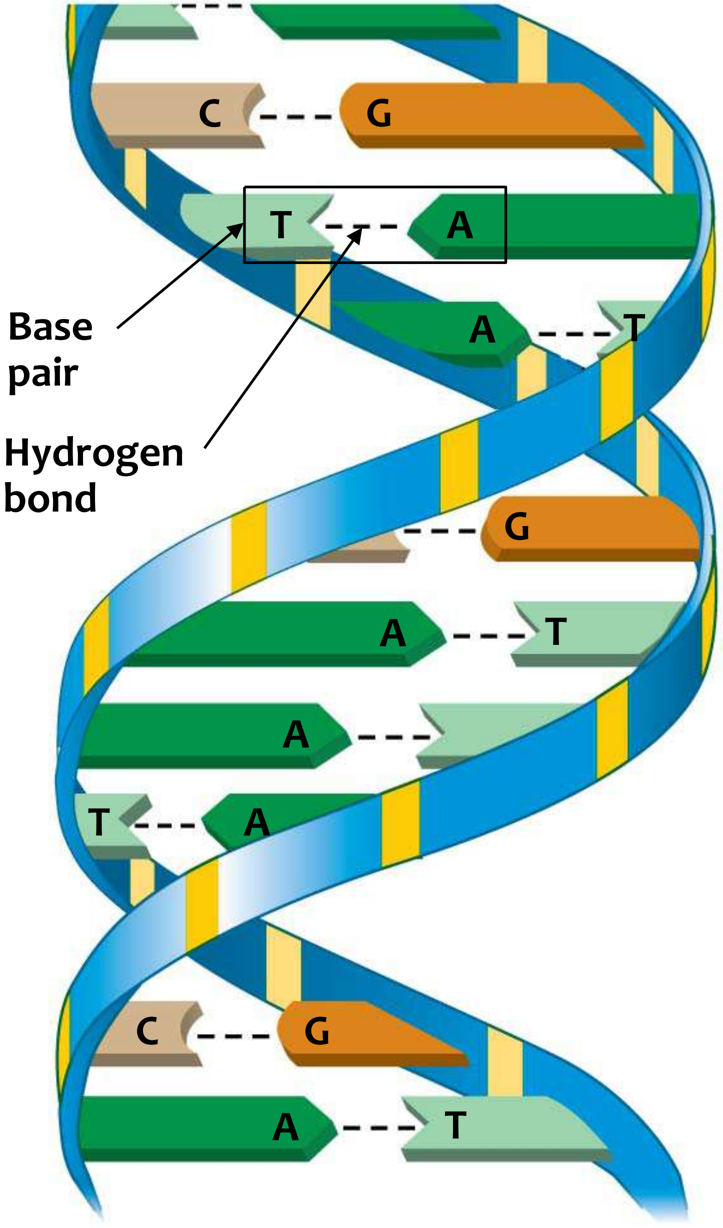

model of a nucleotide

- Nucleotide monomers link into long chains called polynucleotides – no branches!
- The sugar of one nucleotide link with the phosphate of the next nucleotide, forming a <u>sugar-phosphate backbone with nitrogen-containing bases hang on the side of it</u>.




(a) DNA strand (polynucleotide)

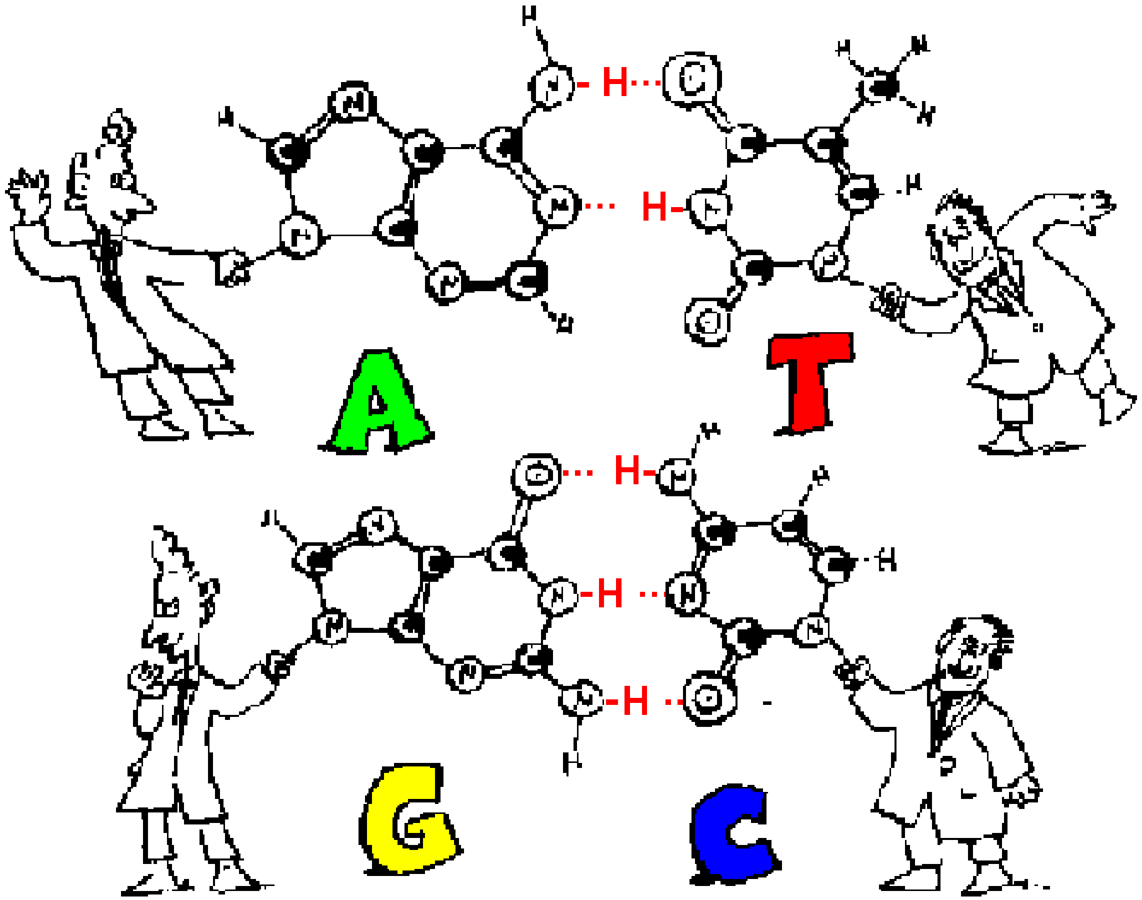
- Two strands of DNA join together to form a <u>double helix</u>.
- Bases along one DNA strand form <u>hydrogen-bonds</u> with bases along the other strand.
- The functional groups hanging off the base determine which bases pair up:
  - <u>A only pairs with T</u>
  - <u>G can only pair with C</u>.



(b) Double helix
(two polynucleotide strands)

- Base-pairing rule is determined by the structures of A, T, G, and C bases.
- It is the fundamental principle of genetics and molecular genetics.

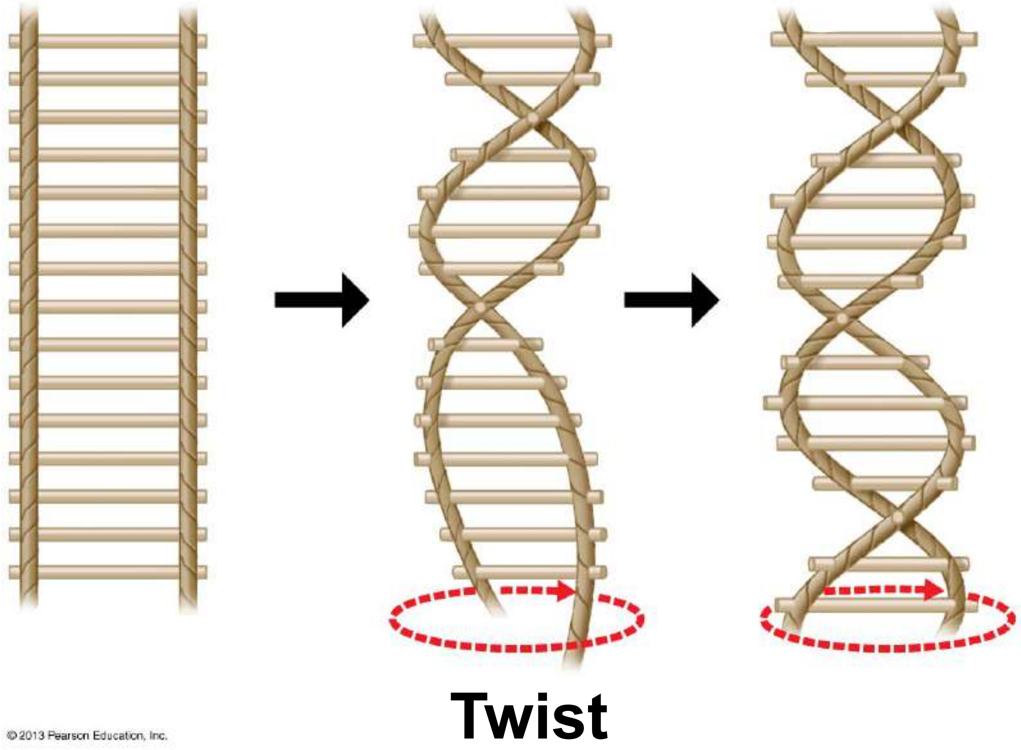
Why do children look like their parents? And how does DNA direct the daily functions of all living organisms?

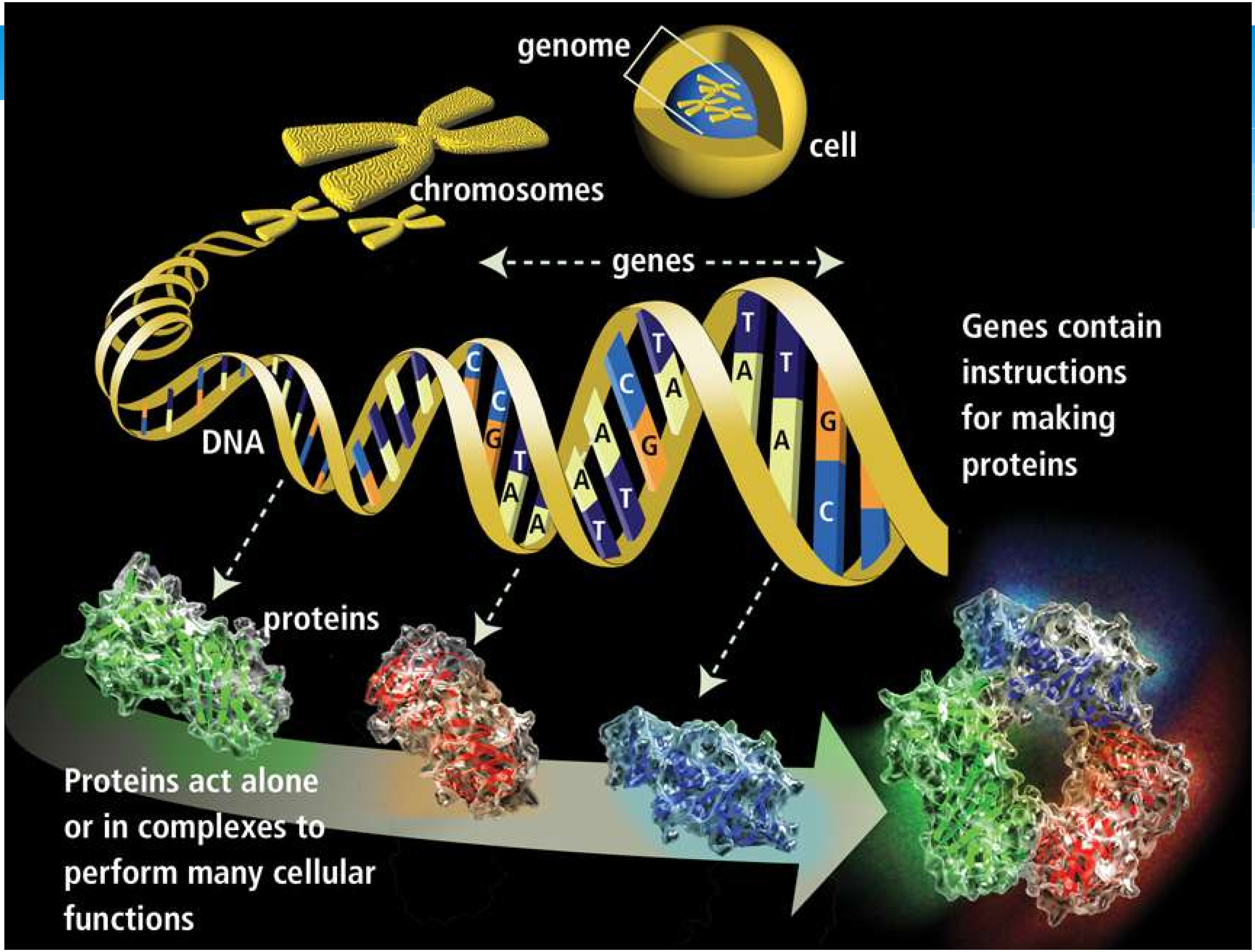



A only pairs with T

G only pairs with C.

- The model of DNA is like a rope ladder twisted into a spiral.
  - The ropes at the sides represent the sugar-phosphate backbones.
  - Each wooden rung represents a pair of bases connected by hydrogen bonds.



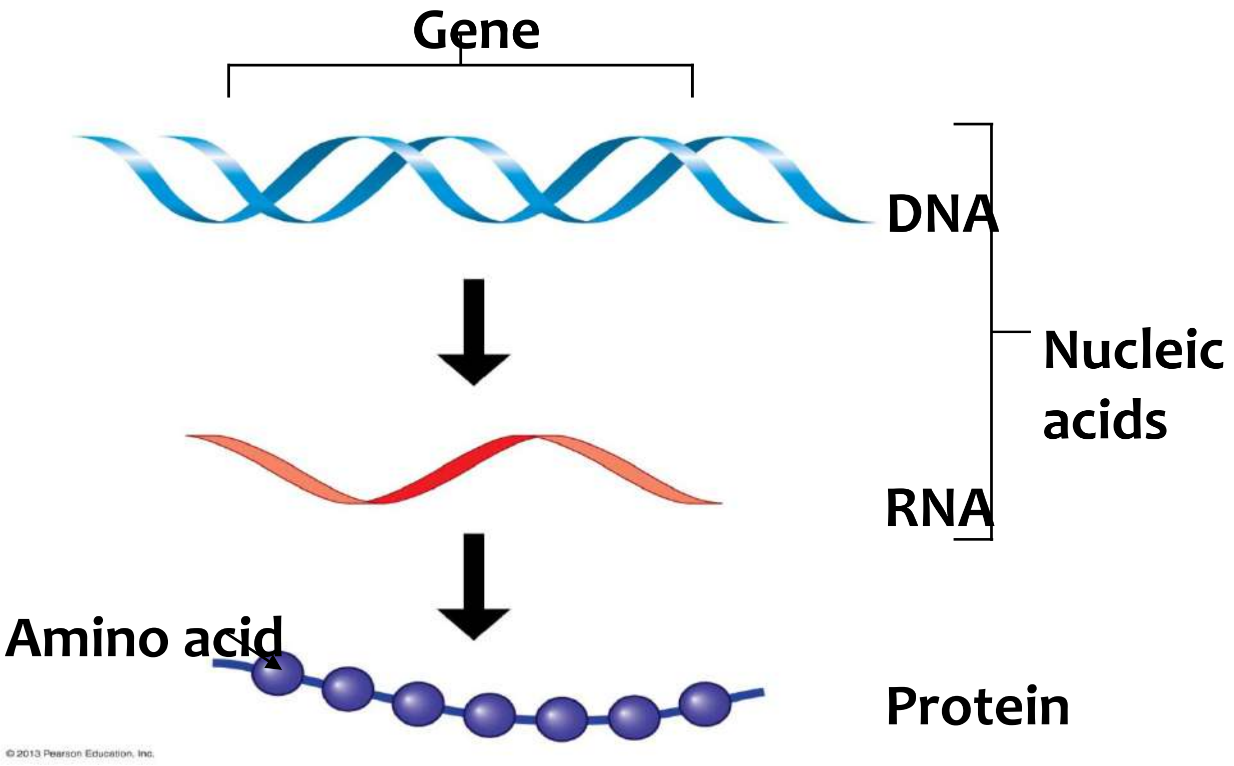



http://www.councilforresponsiblegenetics.org/geneticprivacy/DNA_sci.html

**RNA: ribonucleic acid.**

**RNA vs. DNA:**

- **RNA uses the sugar ribose instead of deoxyribose, and the base uracil (U) instead of thymine (T).**
- **RNA is usually single-stranded, but DNA usually exists as a double**



Summary of the four groups of organic molecules, very important!

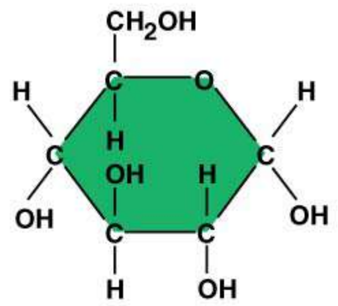
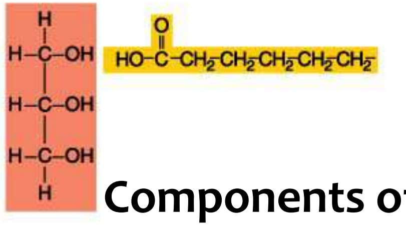
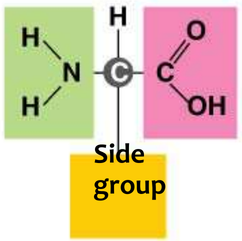
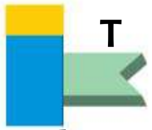
| Large biological molecules | Functions | Components | Examples |
|---|---|---|---|
| Carbohydrates | Dietary energy; storage; plant structure |   Monosaccharide | Monosaccharides: glucose, fructose; Disaccharides: lactose, sucrose; Polysaccharides: starch, cellulose |
| Lipids | Long-term energy storage (fats); hormones (steroids) |   Components of a triglyceride (a kind of lipids) | Fats (triglycerides); steroids (testosterone, estrogen) |
| Proteins | Enzymes, structure, storage, contraction, transport, etc. |   Amino acid | Lactase (an enzyme); hemoglobin (a transport protein) |
| Nucleic acids | Information storage |   Nucleotide | DNA, RNA |

Figure 3.UN02a

# Carbohydrates

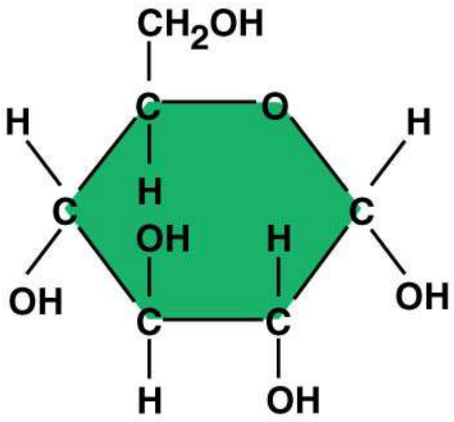
| Functions | Components | Examples |
|---|---|---|
| Dietary energy; storage; plant structure |  Monosaccharide | Monosaccharides: glucose, fructose: Disaccharides: lactose, sucrose: Polysaccharides: starch, cellulose |

Figure 3.UN02b

# Lipids

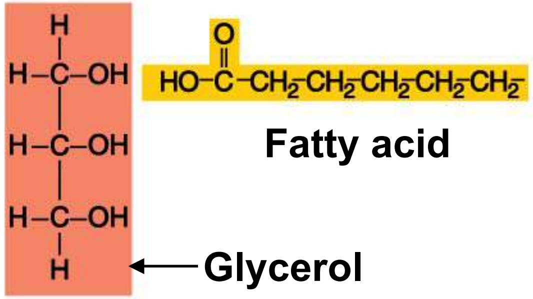
| Functions | Components | Examples |
|---|---|---|
| Long-term energy storage (fats); hormones (steroids) |   Components of a triglyceride(a kind of lipids) | Fats (triglycerides); steroids (testosterone, estrogen) |

Figure 3.UN02c

# Proteins

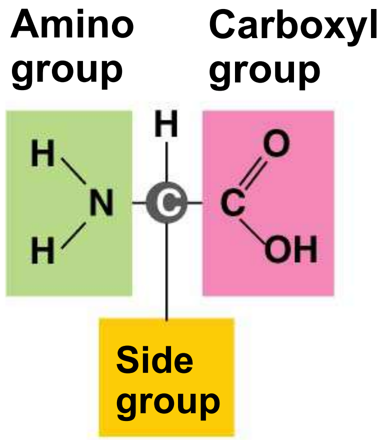
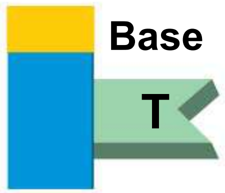
| Functions | Components | Examples |
| --- | --- | --- |
| Enzymes, structure, storage, contraction, transport, etc. | <br>Amino acid | Lactase (an enzyme); hemoglobin (a transport protein) |

Figure 3.UN02d

## Nucleic acids

| Functions | Components | Examples |
|---|---|---|
| Information storage | <br>Nucleotide | DNA, RNA |

## Expected Learning Outcomes:

1. Understand the basis of numerous organic molecules: carbon, which can form up to 4 chemical bonds with various atoms (slides 2, 3).

2. Fully understand the **DETAILS** of four main types of organic molecules:
--What are they? Sub-groups of them? Some examples for each group?
--Where can you find them? Their functions?
--The structures and building components (monomers)of them.
--Be able to distinguish between saturated and unsaturated fats.

A good summary table: the 50th slide of the lecture. But the whole Chapter 3 is a quite important chapter.

Suggested reading after the class:

The whole Chapter 3 is quite important, my suggestion is in fact to read the whole chapter. With limited time, what you must read and understand include:

“Summary of key concepts” at the end of the chapter, page 52.

And self-quiz questions 4, 7, 8,  11, 13 and 14 on page 53.

## Assignment 1B (need to study both Chapter 2 & 3):

1. List the four elements that make up the most (> 96%) of human body weight. Include your understanding of why they can make up so high percentage of living organisms (6 points).
2. List eight elements that make up only a tiny part (<4%) of human body weight but still are essential to human health (3 points).
3. Summarize the characteristics of the four groups of organic molecules, please include at least the following: their components, structures, functions, examples of each kind, and etc. (16 points).

## Attention:

1. This assignment should be submitted through Blackboard.
2. Plagiarism will not be tolerated.
3. Twenty-five points. Due day will be announced on Blackboard. I strongly suggest you to begin AS EARLY AS YOU CAN.