2·7–2·10
Carbohydrates are fuel for living machines.

2.7 Carbohydrates include macromolecules that function as fuel.

Health topics of the year

- Low-carb diet?
- Hi-carb diet?
- "Carbo-loading"?
- Fiber intake?

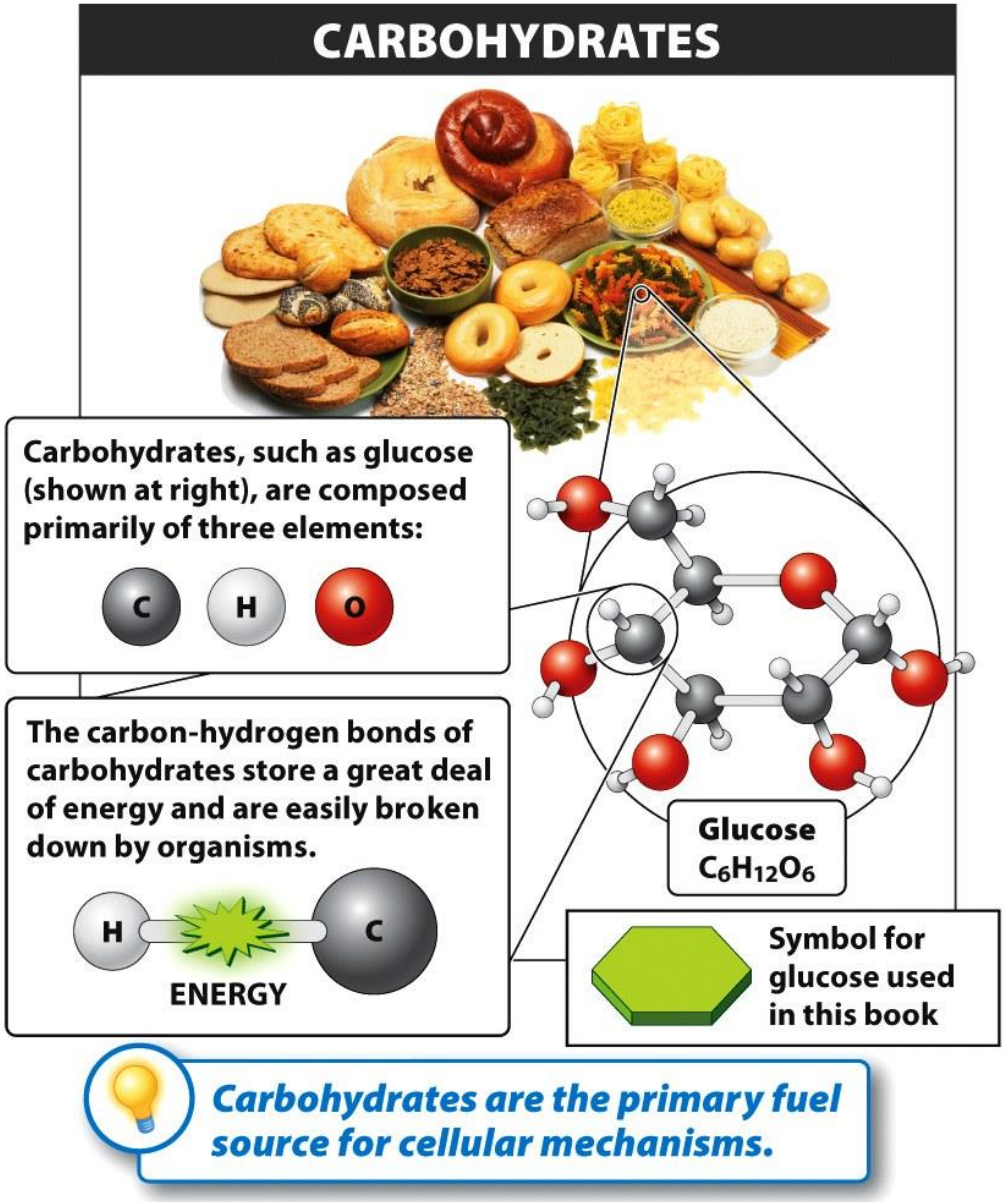
What are carbohydrates?

Four Types of Macromolecules

- Carbohydrates
- Lipids
- Proteins
- Nucleic acids

Carbohydrates

- C, H, and O
- Primary fuel for organisms
- Cell structure



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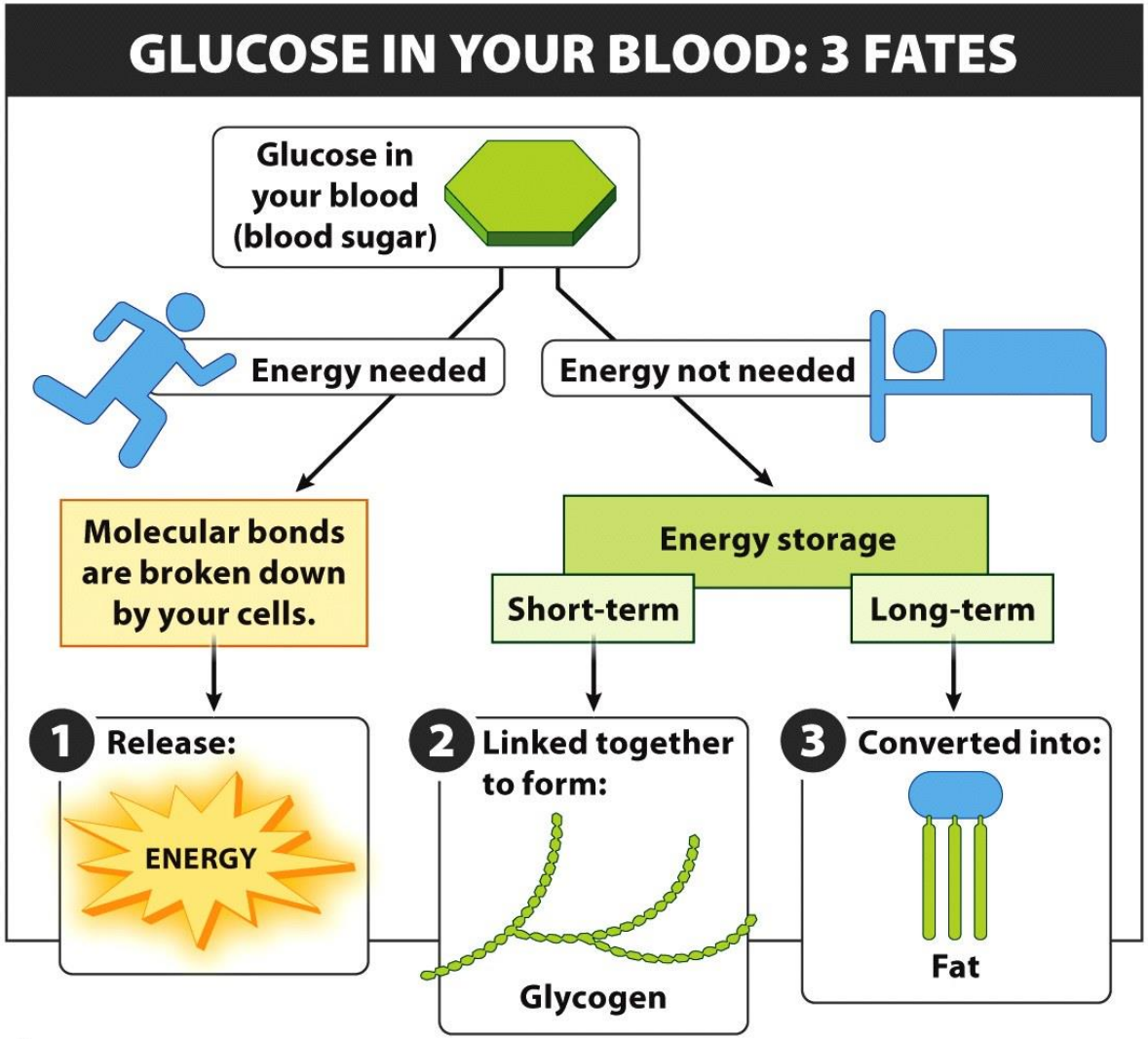
Energy is in the chemical bonds!

2.8 Glucose provides energy for the body's cells.

- Fuel for cellular activity
- Stored temporarily as glycogen
- Converted to fat

Glucose

- Most carbohydrates — ultimately converted into glucose
- **Blood sugar**



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What is “carbo-loading”?

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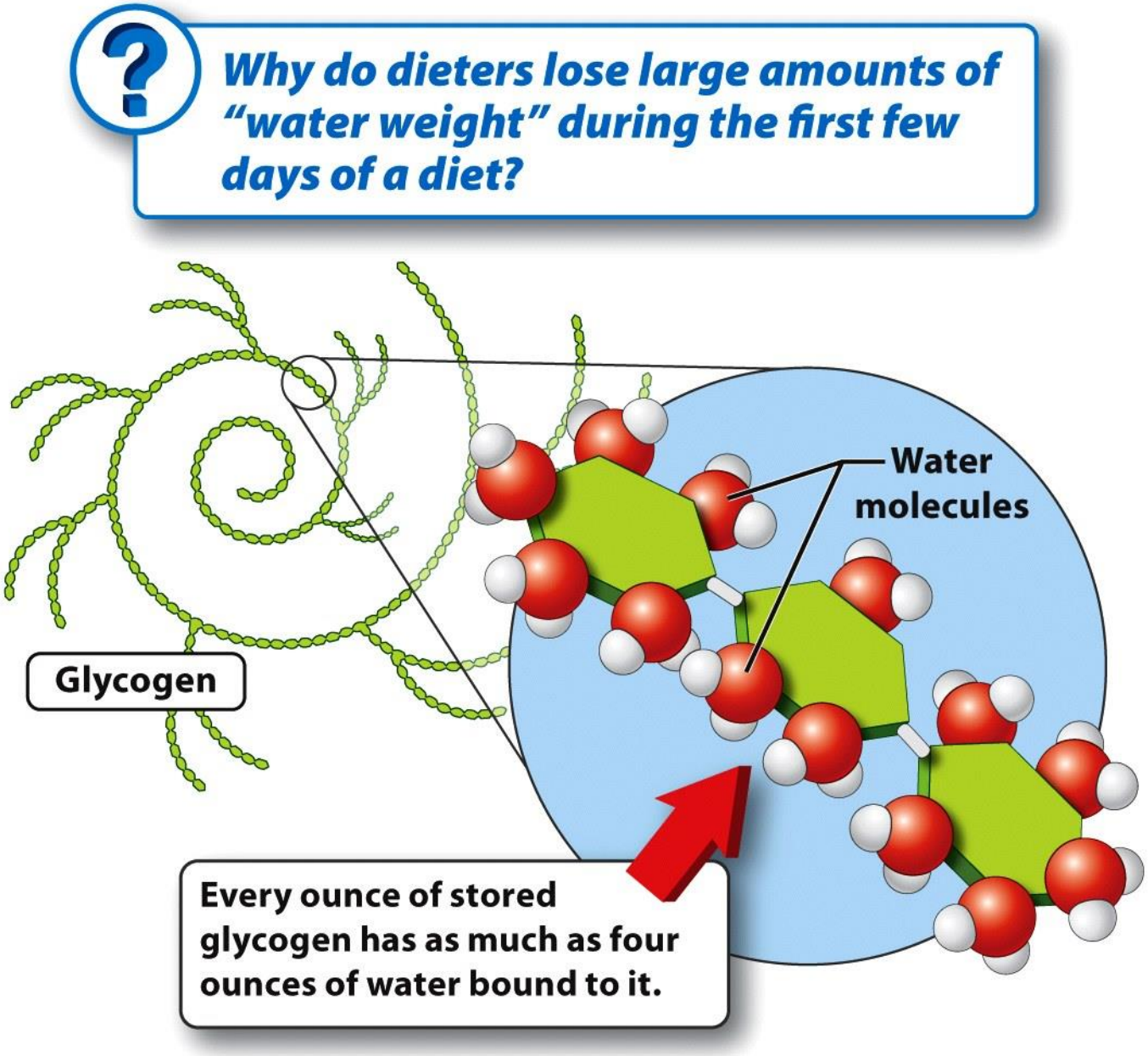

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2.9 Many complex carbohydrates are time-released packets of energy.

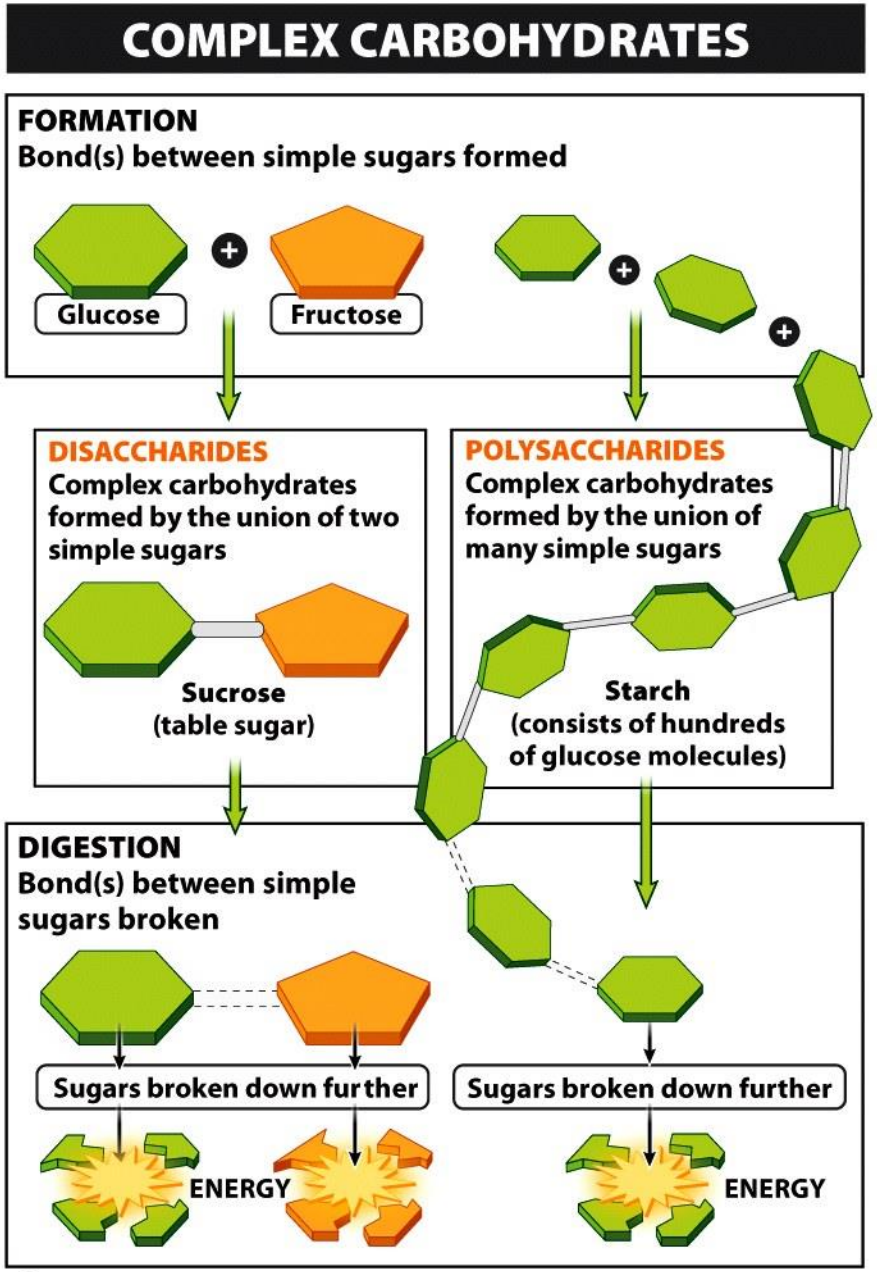
- More than 1 sugar (monosaccharide) unit

- Disaccharides
  - sucrose
  - lactose

- Polysaccharides
  - starch
  - cellulose

Chemical Fuel

Preliminary Processing



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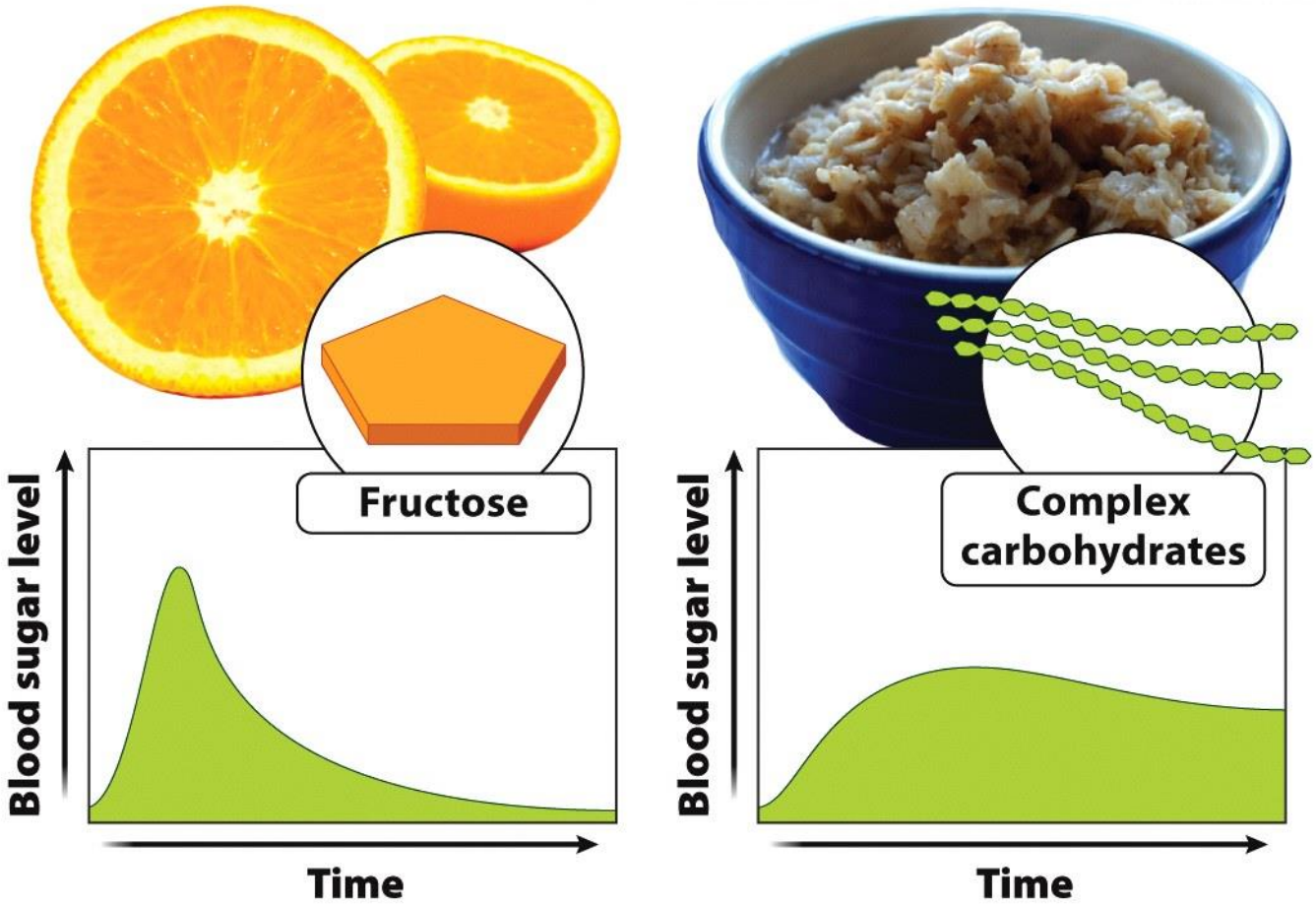
Starch

- $\geq$ 100's of glucose molecules joined together
- Barley, wheat, rye, corn, and rice
- Glycogen—"animal starch"

Complex Carbohydrates

“Time-release” fuel pellets

Depending on their structure, dietary carbohydrates can lead to quick-but-brief or slow-but-persistent increases in blood sugar.



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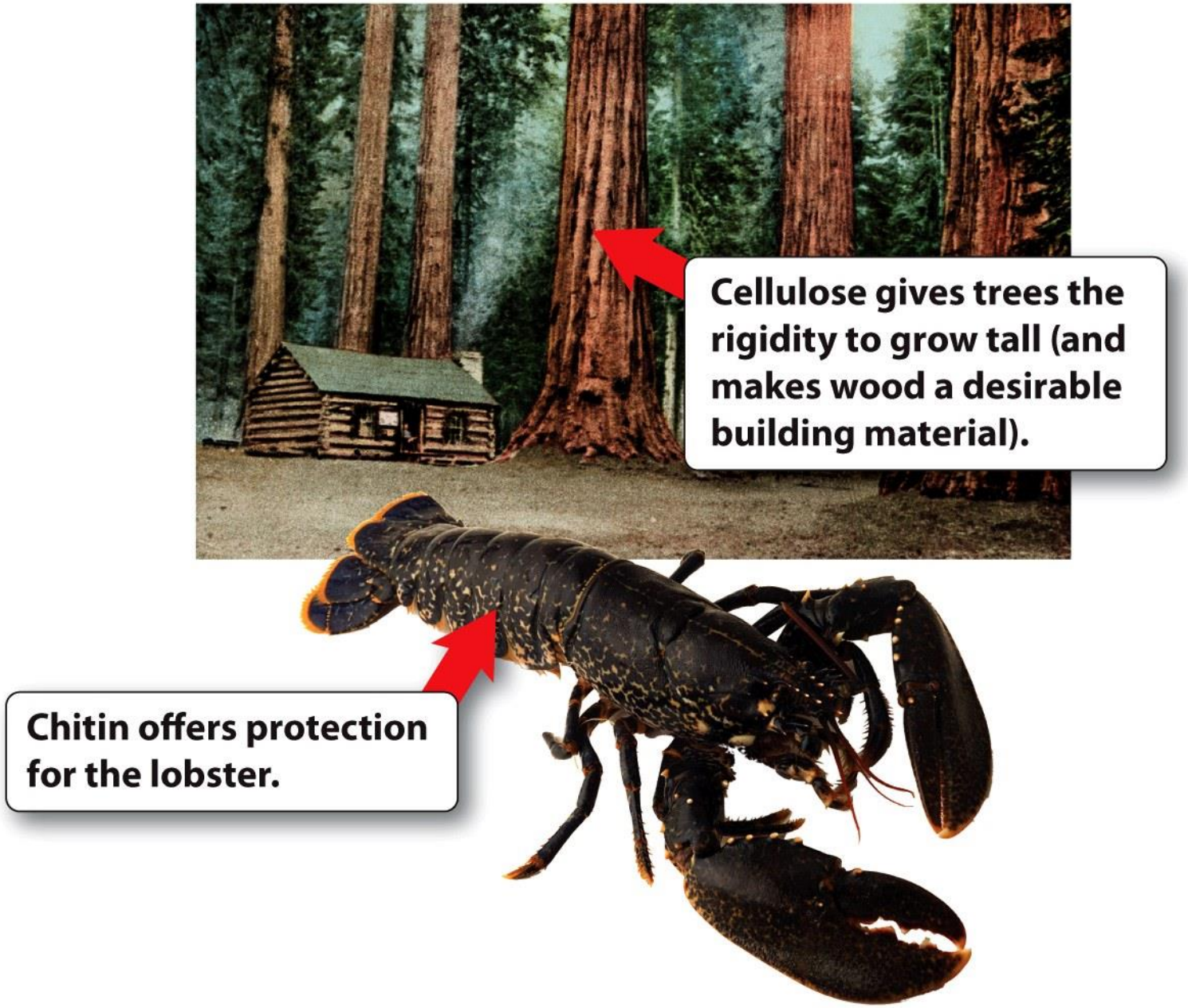
2.10 Not all carbohydrates are digestible.

- Chitin
- Cellulose



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Though indigestible in humans, fiber still aids in digestion and has numerous health benefits.

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Fiber

- “Roughage”
- Colon cancer prevention/reduction
- Termites ecological role

2.11–2.13
Lipids store energy for a rainy day.

2.11 Lipids are macromolecules with several functions, including energy storage.

Why does a salad dressing made with vinegar and oil separate into two layers shortly after you shake it?

- Hydrophobic
- Hydrophilic

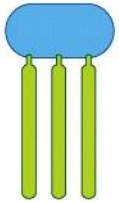
INTRODUCTION TO LIPIDS

TYPICAL FEATURES OF LIPIDS

- Non-polar molecules that do not dissolve in water
- Greasy to the touch
- Significant source of energy storage

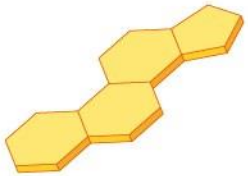
THREE TYPES OF LIPIDS

FATS



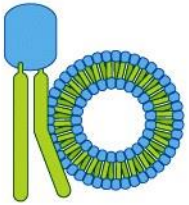
FUNCTION
Long-term energy storage and insulation

STEROLS



FUNCTION
Regulate growth and development

PHOSPHOLIPIDS



FUNCTION
Form the membranes that enclose cells

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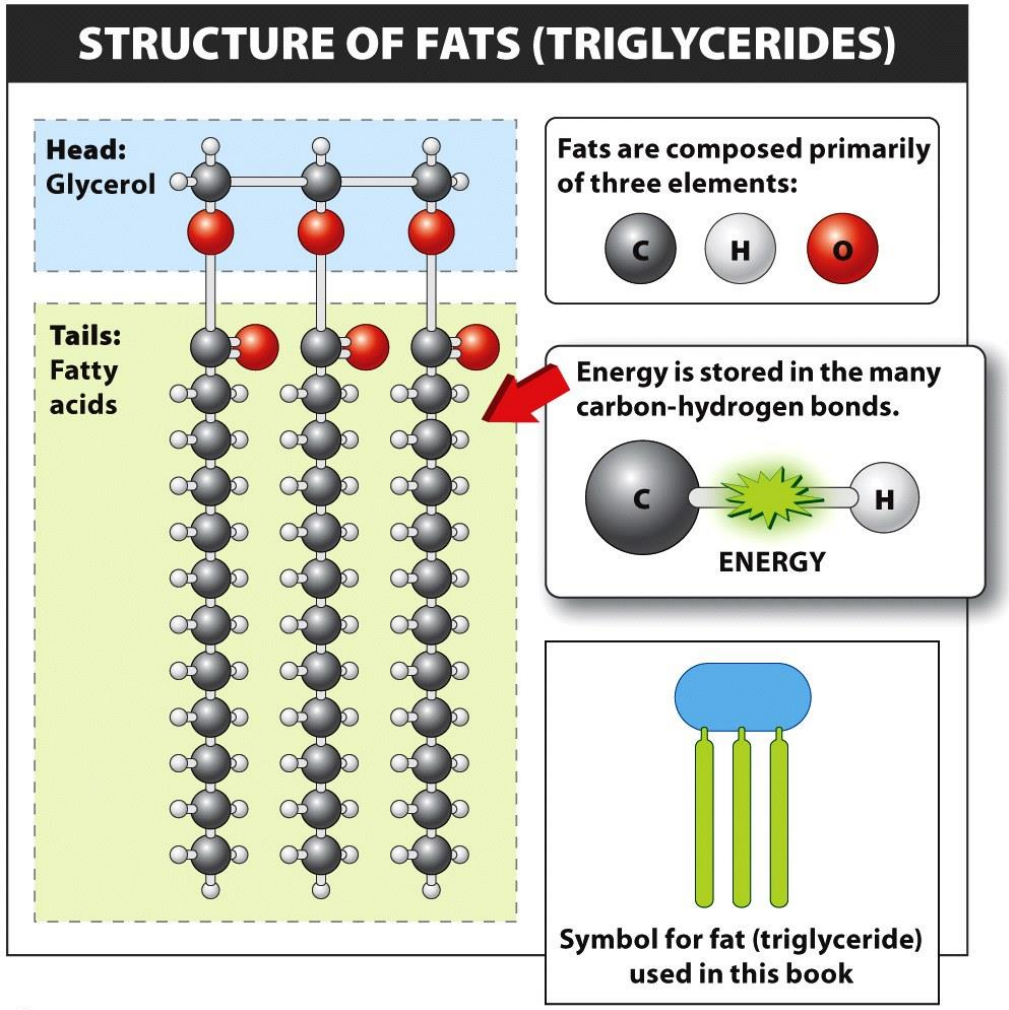
2.12 Fats are tasty molecules too plentiful in our diets.

- Glycerol: "head" region
- Fatty acid "tails"
- Triglycerides



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Fat molecules contain much more stored energy than carbohydrate molecules.

Because fats store such large amounts of energy, animals have evolved a strong taste preference for fats over other energy sources.

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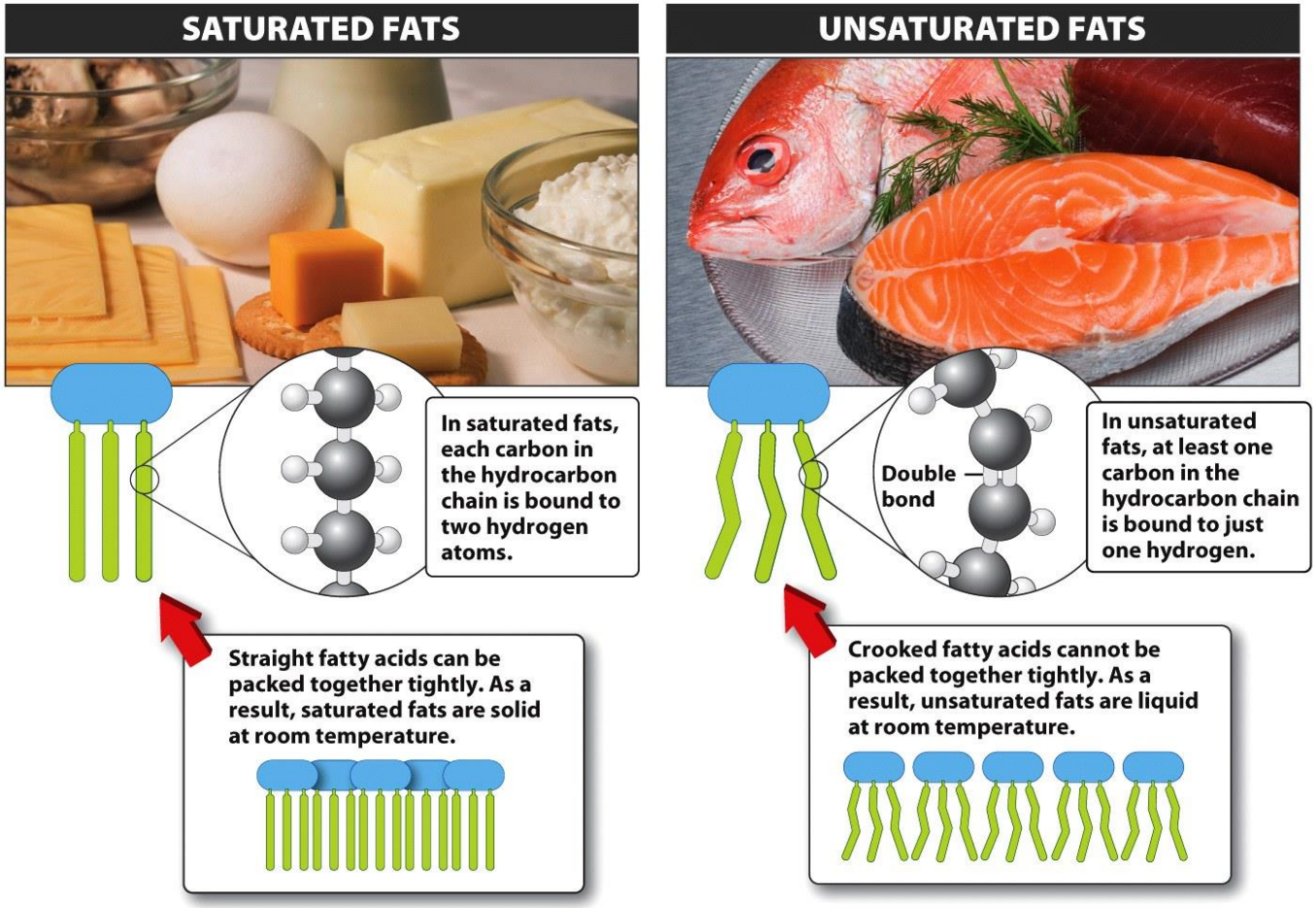
Saturated and Unsaturated Fats

- # of bonds in the hydrocarbon chain in a fatty acid
- Health considerations



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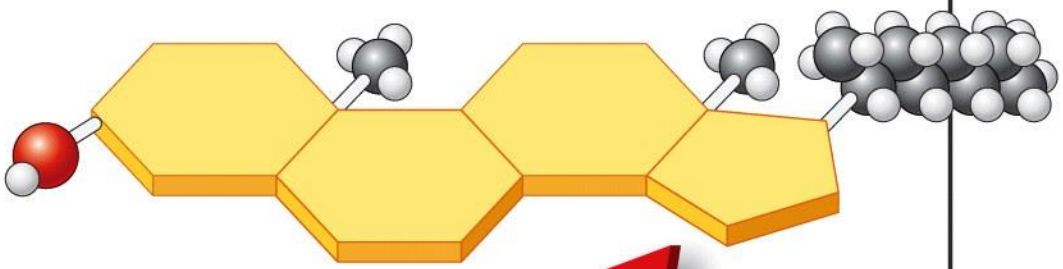
2.13 Cholesterol and phospholipids are used to build sex hormones and membranes.

- Not all lipids are fats
- The sterols

STEROLS

CHOLESTEROL

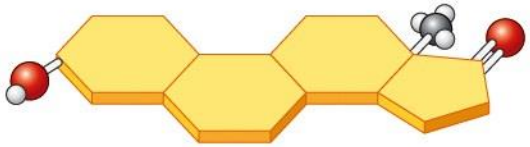
- Important component of cell membranes in animals
- Can attach to vessel walls and cause them to thicken, which may lead to high blood pressure, stroke, and heart attack



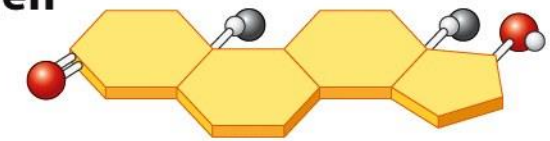
Sterols are all based on a structure featuring four carbon rings.

STEROID HORMONES

- Regulate sexual development, maturation, and sex cell production
- Estrogen influences memory and mood
- Testosterone stimulates muscle growth



Estrogen



Testosterone

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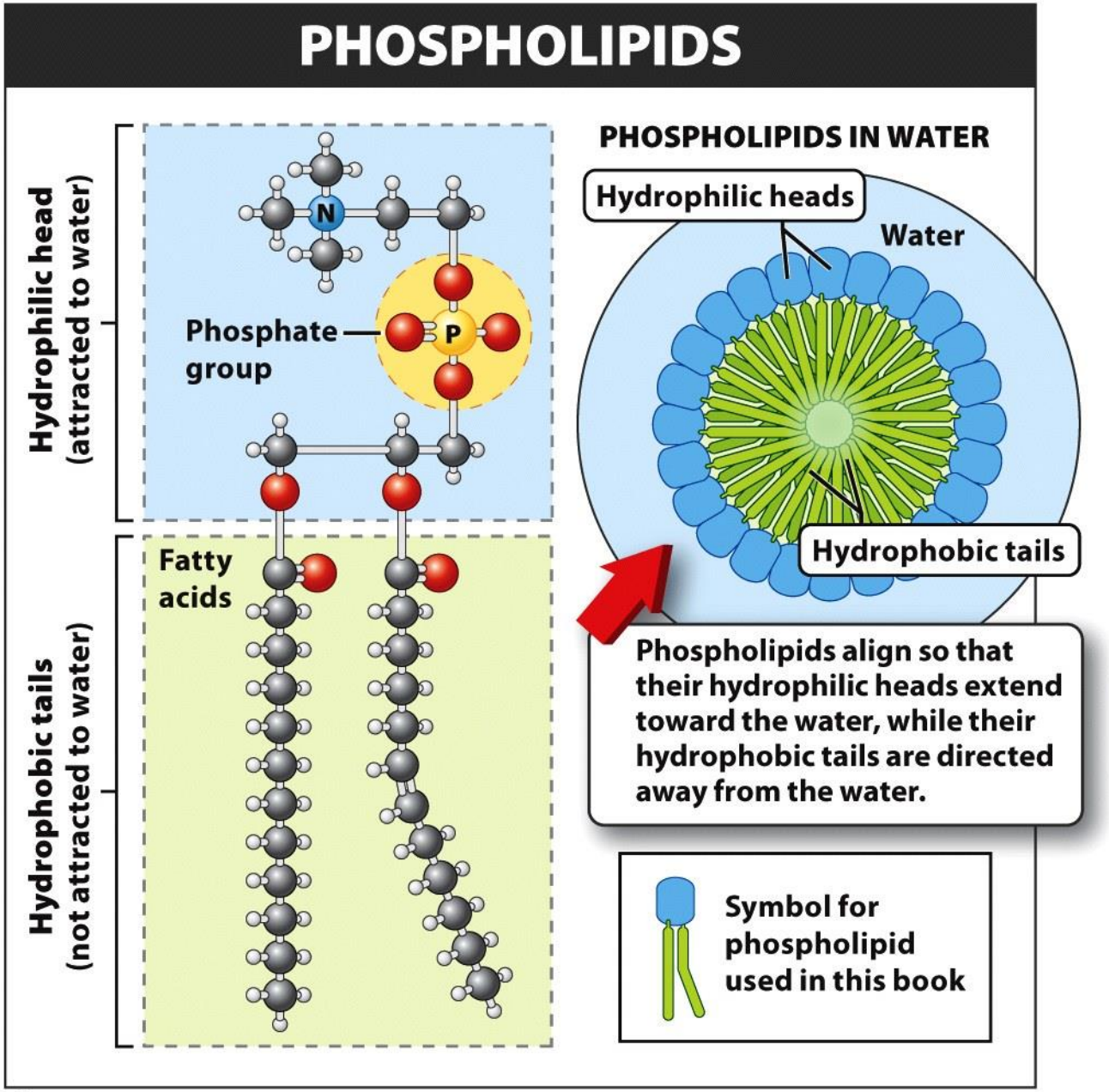
Phospholipids and Waxes

- **Phospholipids** are the major component of the cell membrane.

- Waxes are strongly hydrophobic.



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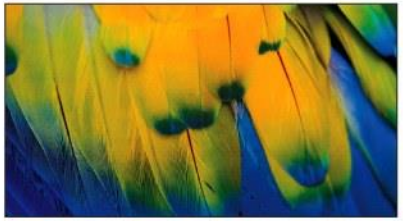
2.14–2.18
Proteins are versatile macromolecules that serve as building blocks.

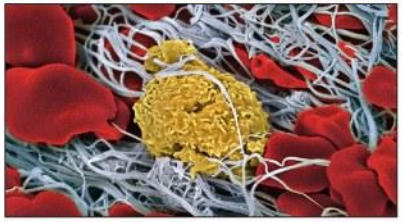
2.14 Proteins are bodybuilding macromolecules.

PROTEIN DIVERSITY

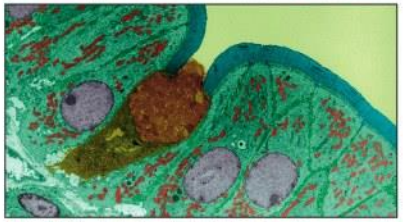
Proteins perform a variety of different functions. They all, however, are built the same way and from the same raw materials in organisms.



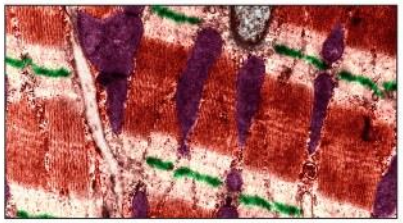
STRUCTURAL
Hair, fingernails, feathers, horns, cartilage, tendons



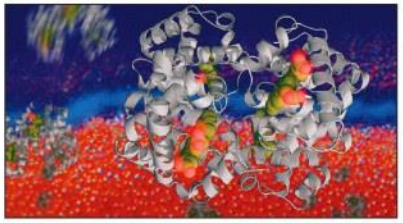
PROTECTIVE
Help fight invading microorganisms, coagulate blood



REGULATORY
Control cell activity, constitute some hormones



CONTRACTILE
Allow muscles to contract, heart to pump, sperm to swim



TRANSPORT
Carry molecules such as oxygen around your body

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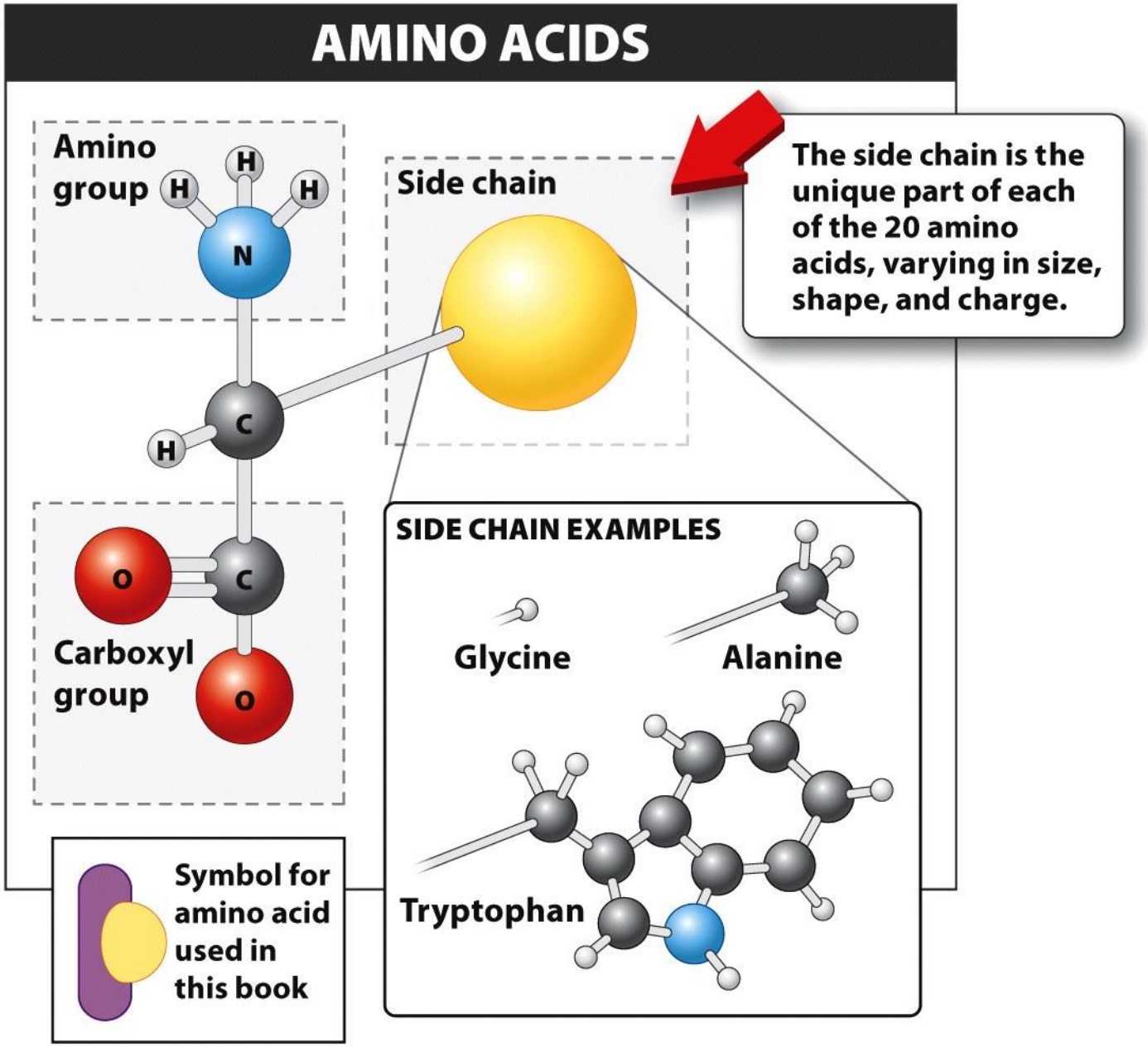
Amino Acids

- Twenty different amino acids
- Strung together to make proteins



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2.15 Proteins are an essential dietary component.

- Growth
- Repair
- Replacement

- Food labels indicate an item's protein content.

- Why is this insufficient for you to determine whether you are protein deficient, even if your protein intake exceeds your recommended daily amount?

Complete Proteins

- Have all essential amino acids
- Incomplete proteins
- Complementary proteins

COMPLETE vs. INCOMPLETE PROTEINS

ESSENTIAL AMINO ACID CONTENT OF COMMON FOODS

	Apples	Almonds	White rice	Lentils	Milk - 2% fat	Tofu - firm (coagulated soy milk)	Chicken	Beef - T-bone steak
Histidine	●	●	●	●	●	●	●	●
Isoleucine	○	●	●	●	●	●	●	●
Leucine	●	●	●	●	●	●	●	●
Lysine	●	○	○	●	●	●	●	●
Methionine + Cysteine	○	○	●	○	●	●	●	●
Phenylalanine + Tyrosine	○	●	●	●	●	●	●	●
Threonine	○	●	●	●	●	●	●	●
Tryptophan	○	●	●	●	●	●	●	●
Valine	●	●	●	●	●	●	●	●

● Present at optimal levels

○ Not present at optimal levels

Optimal levels determined by the Institute of Medicine's Food and Nutrition Board

Traditional dishes in many cultures combine proteins, bringing together all essential amino acids.

Figure 2-38

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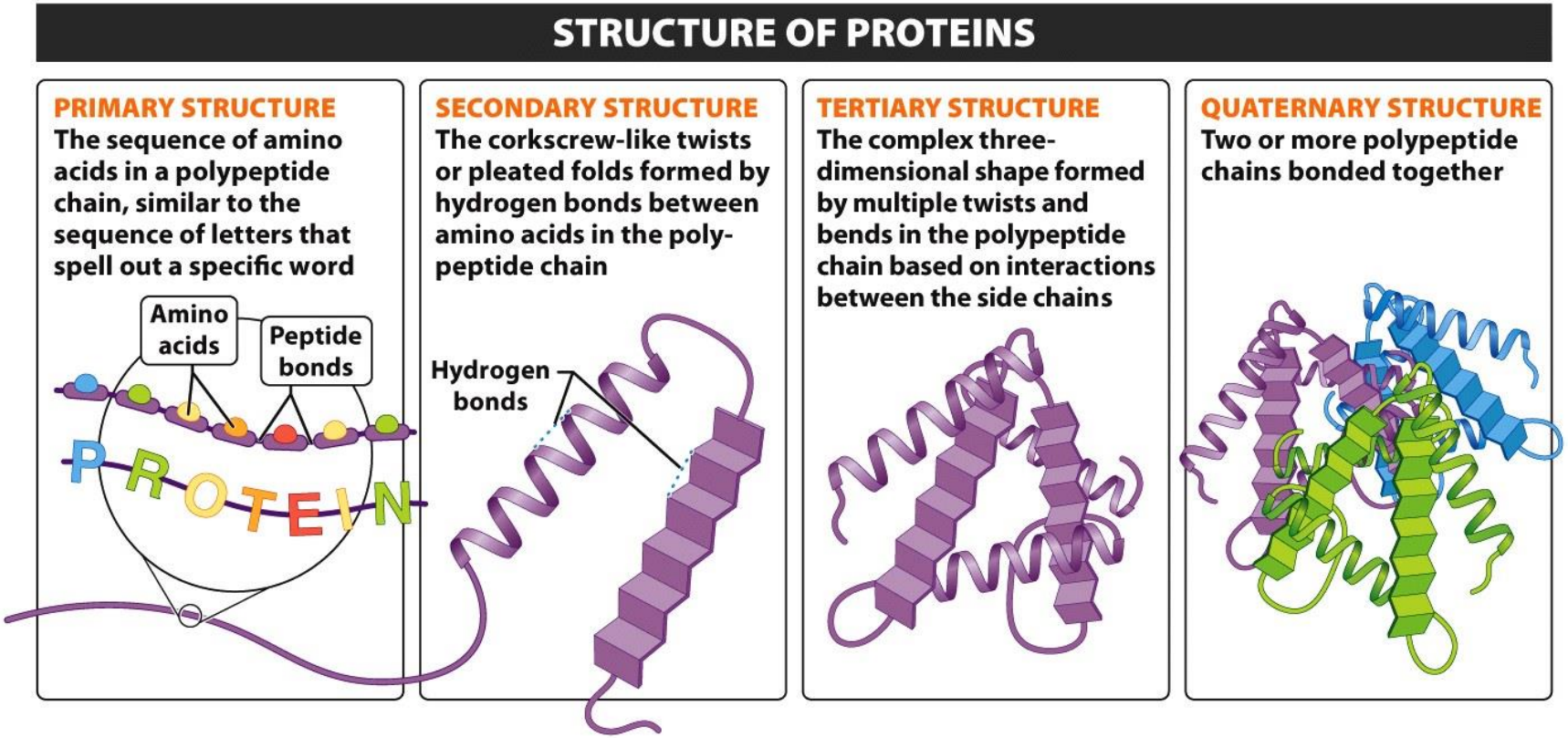
2.16 A protein's function is influenced by its three-dimensional shape.

- Peptide bonds



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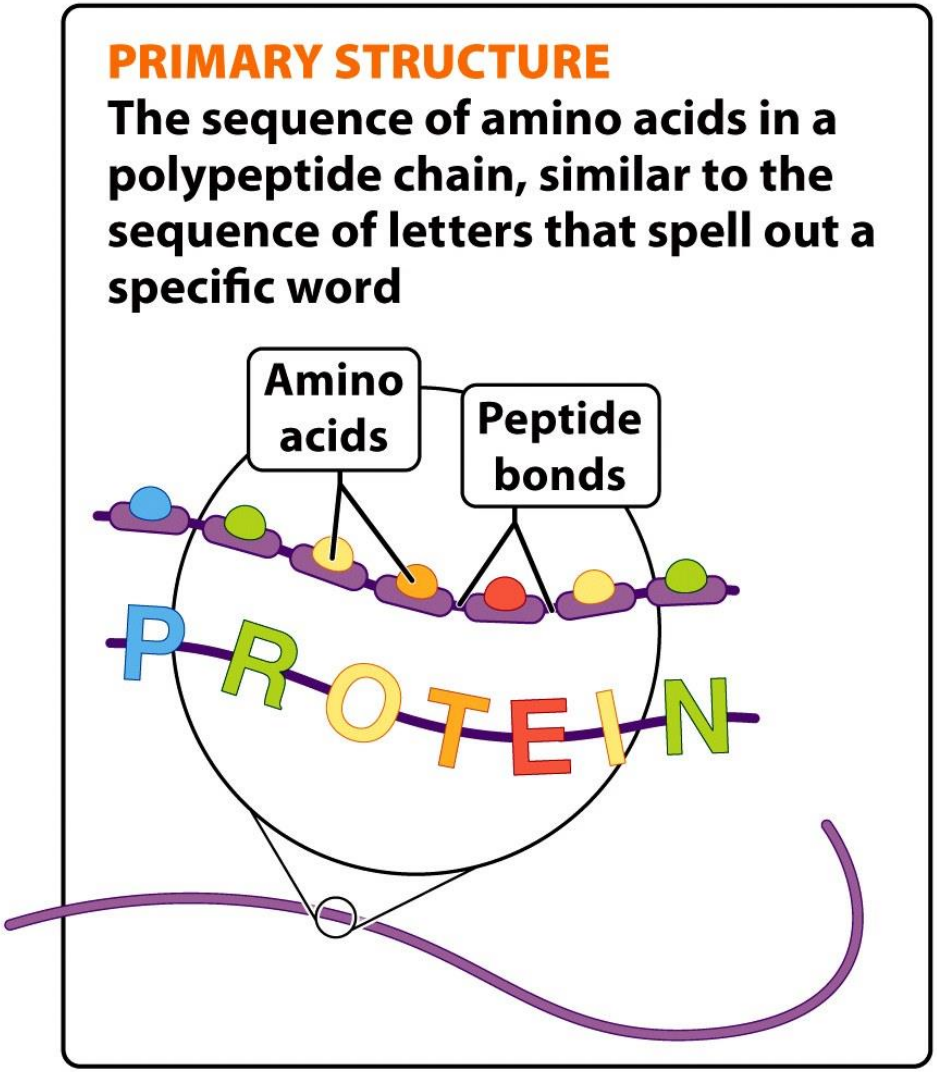
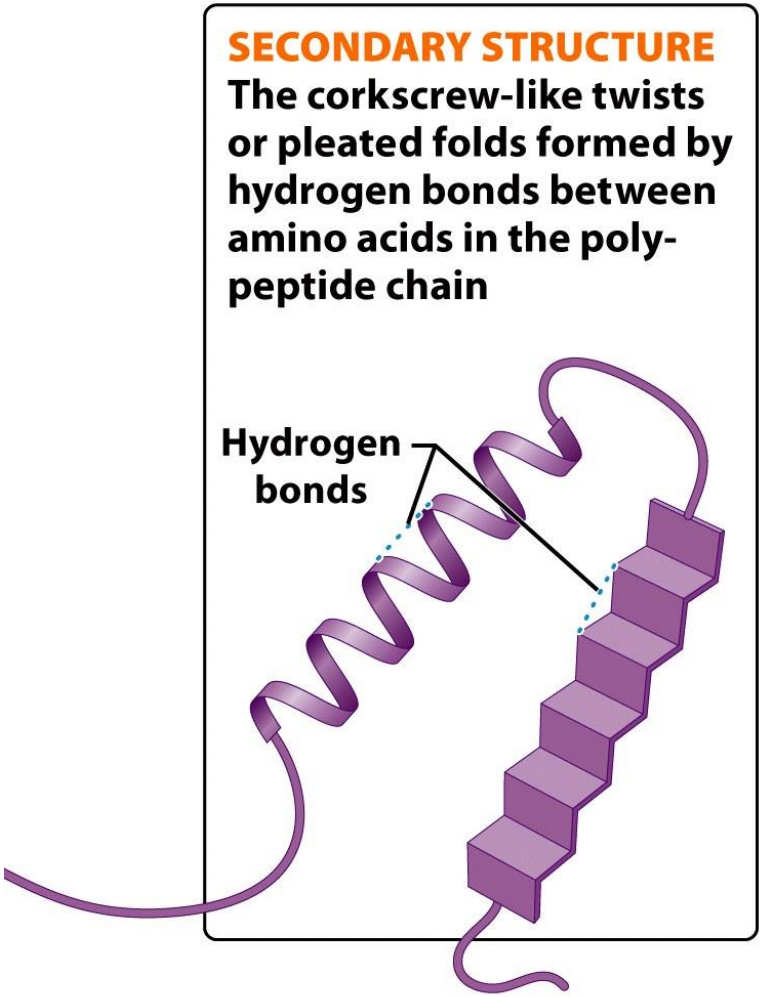
Primary Structure

- The sequence of amino acids



Secondary Structure

- Hydrogen bonding between amino acids
- The two most common patterns:
  - twist in a corkscrew-like shape
  - zig-zag folding

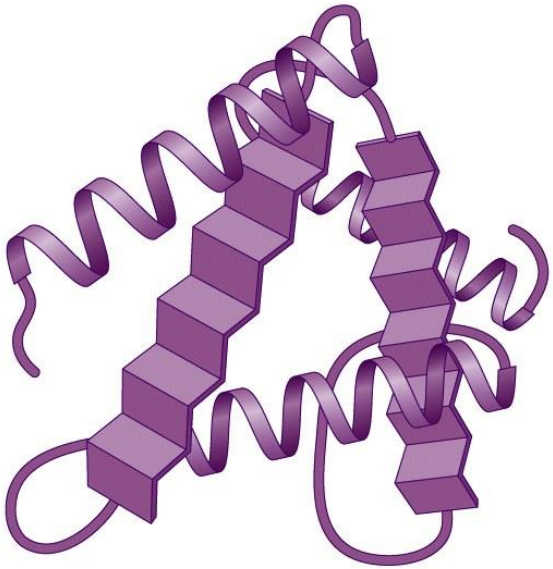


Tertiary Structure

- Folding and bending of the secondary structure
- Due to bonds such as hydrogen bonds or covalent sulfur-sulfur bonds.

TERTIARY STRUCTURE

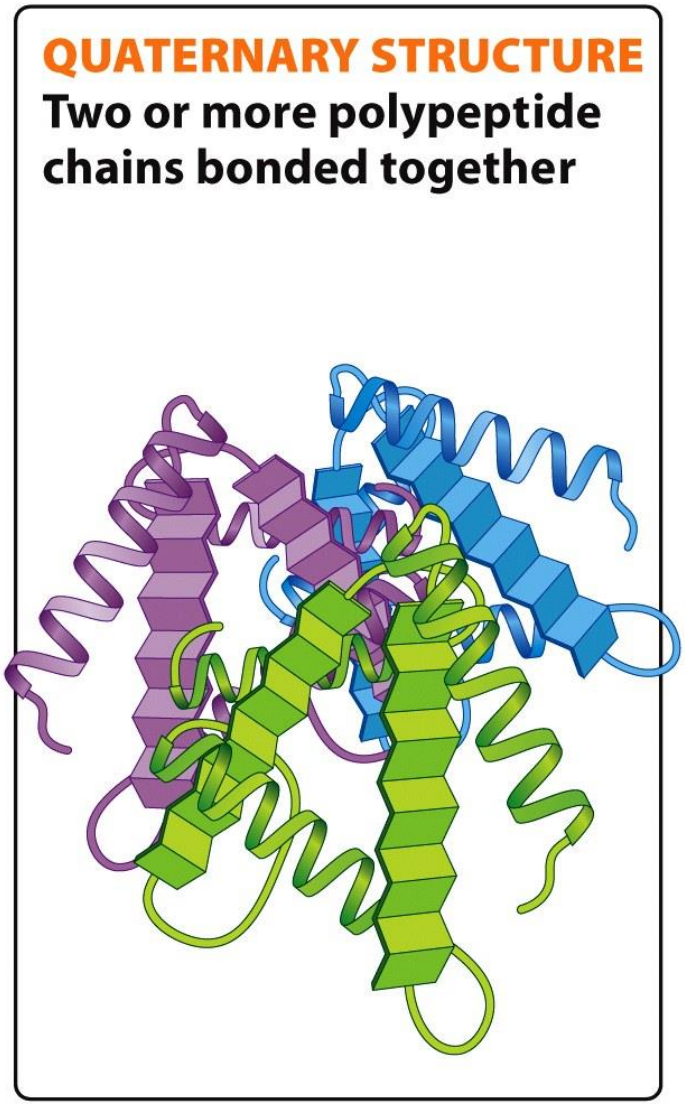
The complex three-dimensional shape formed by multiple twists and bends in the polypeptide chain based on interactions between the side chains



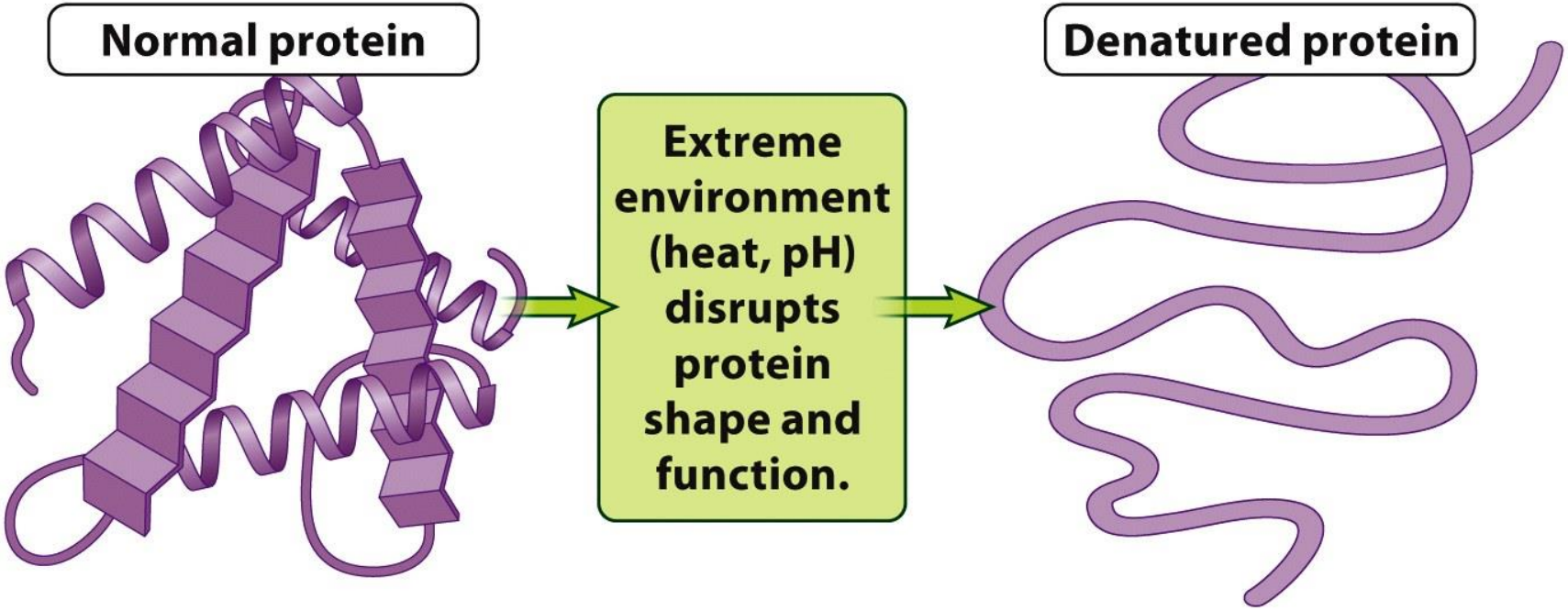
Quaternary Structure

- When two or more polypeptide chains are held together by bonds between the amino acids on the different chains.

- Hemoglobin



- Egg whites contain much protein.
- Why does beating them change their texture, making them stiff?



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- Egg whites contain much protein.

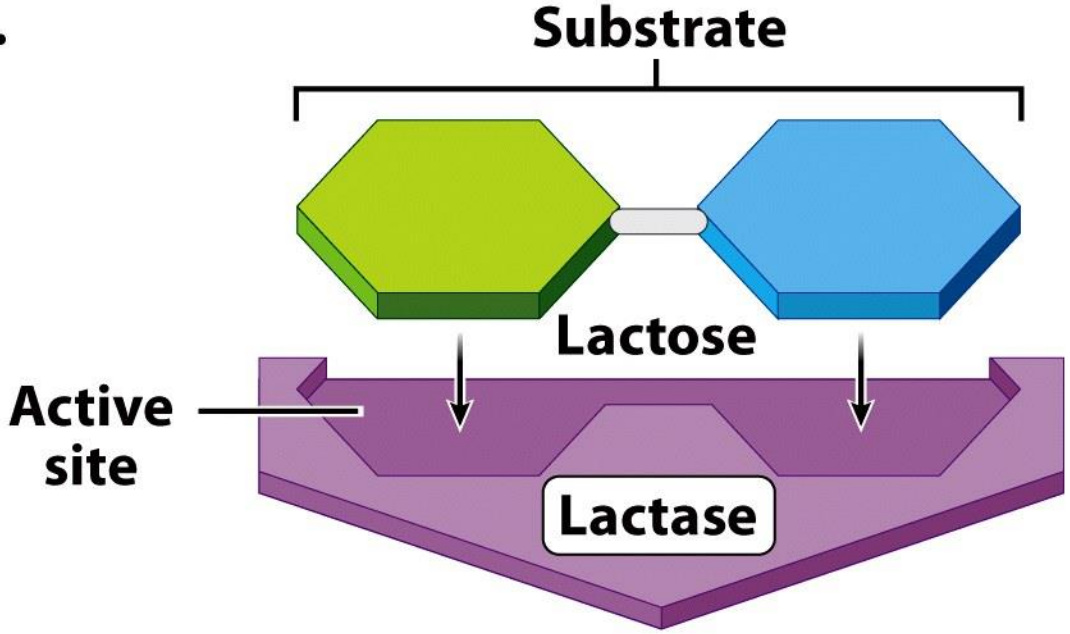
- Why does beating them change their texture, making them stiff?

2.17 Enzymes are proteins that initiate and speed up chemical reactions.

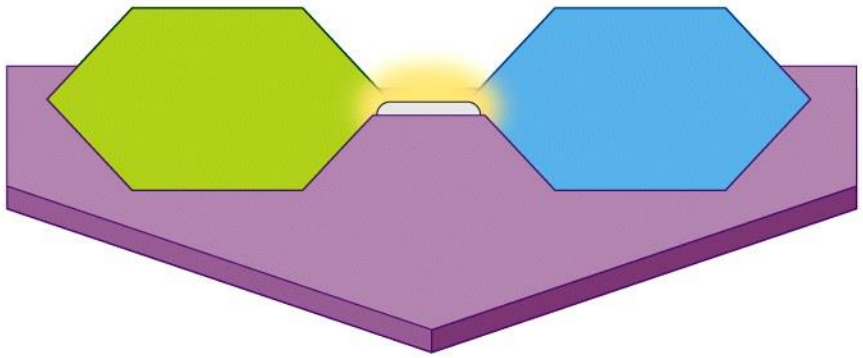
ENZYMES FACILITATE CHEMICAL REACTIONS

Enzymes can help to bring about chemical reactions in a variety of ways. The enzyme lactase, for example, breaks down the milk sugar lactose into two simple sugars that can be used for energy.

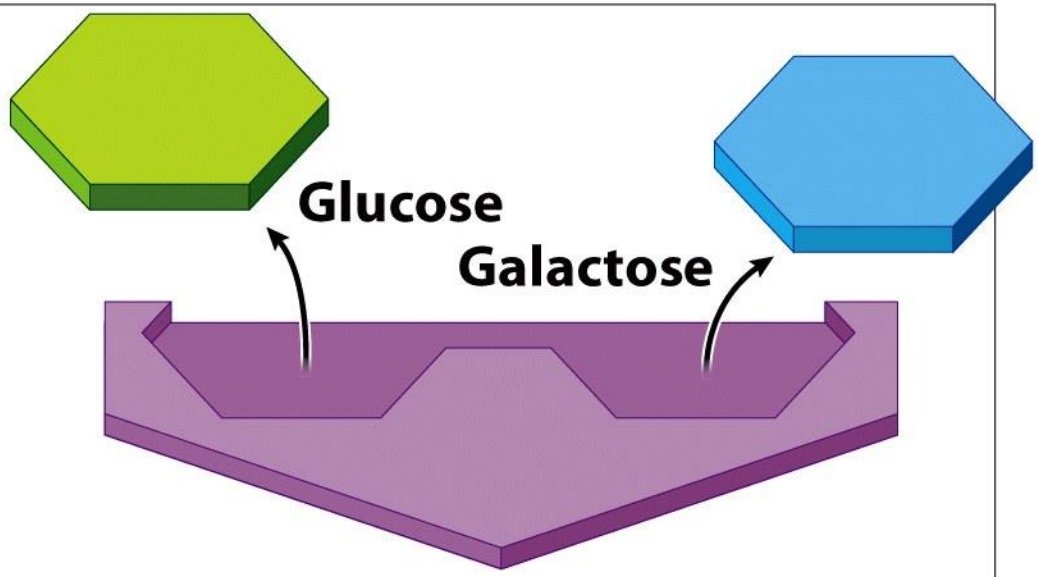
1 **Each enzyme has an active site that is a perfect fit for its substrate.**



2 Like a key in a lock, lactose fits in the active site in lactase. The bond between the simple sugars is then broken.



3 The two simple sugars making up lactose are then released.



Activation Energy

- Chemical reactions occurring in organisms can either release energy or consume energy.
- In either case, the reaction needs a little "push" in order to initiate the reaction—called **activation energy.**
- Enzymes act as catalyst by lowering the activation energy.

An enzyme can reduce the activation energy in a variety of ways.

1. By stressing, bending, or stretching critical chemical bonds
2. By directly participating in the reaction
3. By creating a microhabitat that is conducive to the reaction
4. By simply orienting or holding substrate molecules in place so that they can be modified.

Classroom Catalyst

- Why can't we digest cellulose?

The polysaccharides amylose and cellulose are both made of glucose. Why can't the enzyme salivary amylase breakdown both?

1. The orientation of the covalent bonds are different.
2. The active site of the enzyme cannot bind to glucose.
3. The enzyme cannot digest cellulose at normal body temperatures (32°C).
4. The covalent bonds in cellulose are stronger than in amylose.

Take-home message 2.17

- Enzymes are proteins that help initiate and speed up chemical reactions.
- They aren't permanently altered in the process but rather can be used again and again.

2-18 Enzymes regulate reactions in several ways (but malformed enzymes can cause problems).

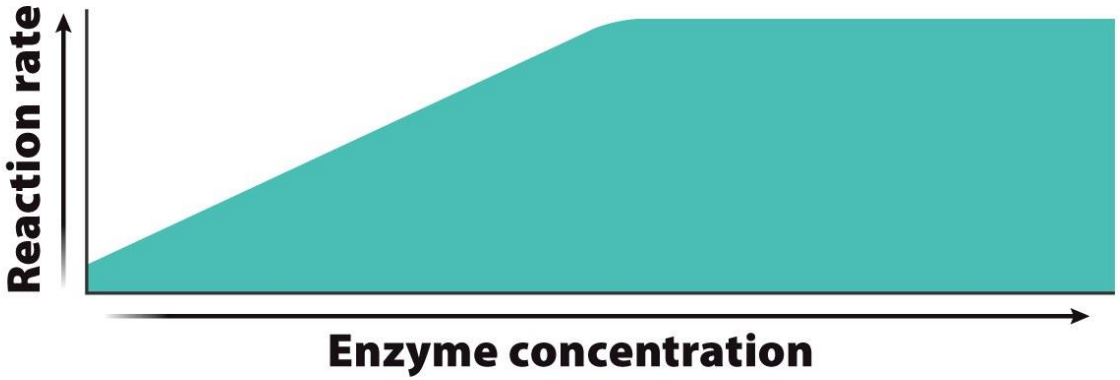
The rate at which an enzyme catalyzes a reaction is influenced by several chemical and physical factors.

ENZYME ACTIVITY

The rate at which an enzyme catalyzes a reaction is influenced by several chemical and physical factors.

ENZYME AND SUBSTRATE CONCENTRATION

Reaction rates increase with increased amounts of enzyme (or substrate), but only up to the point at which all of the enzyme molecules are bound to substrate. At that point, additional enzyme (or substrate) no longer increases the reaction rate.



ents

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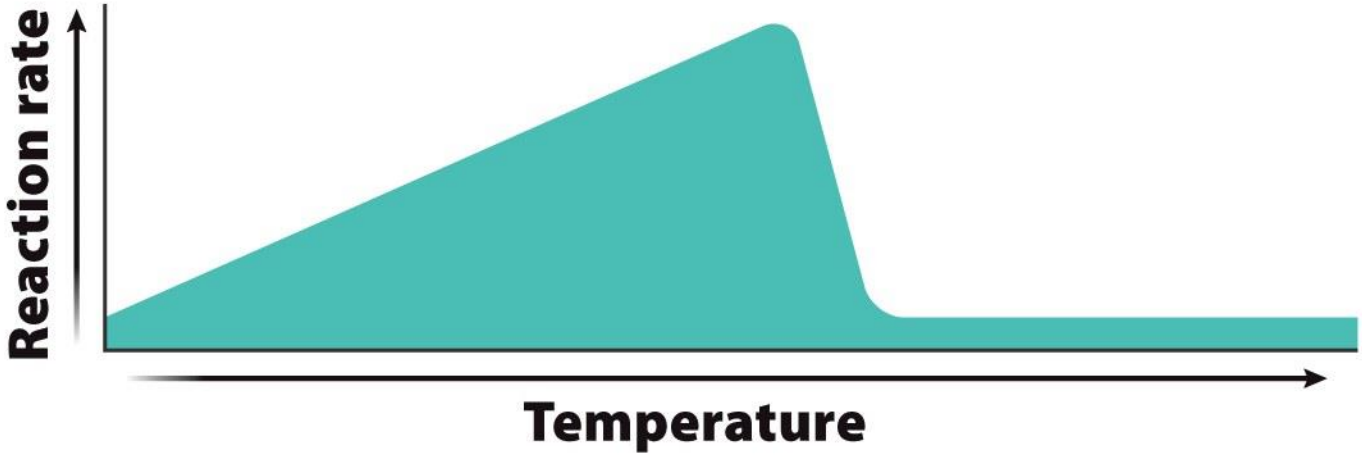
ENZYME ACTIVITY

The rate at which an enzyme catalyzes a reaction is influenced by several chemical and physical factors.

TEMPERATURE

Reaction rates generally increase at higher temperatures, but only up to the optimum temperature for an enzyme. At temperatures above the optimum, reaction rates decrease as enzymes lose their shape or even denature.



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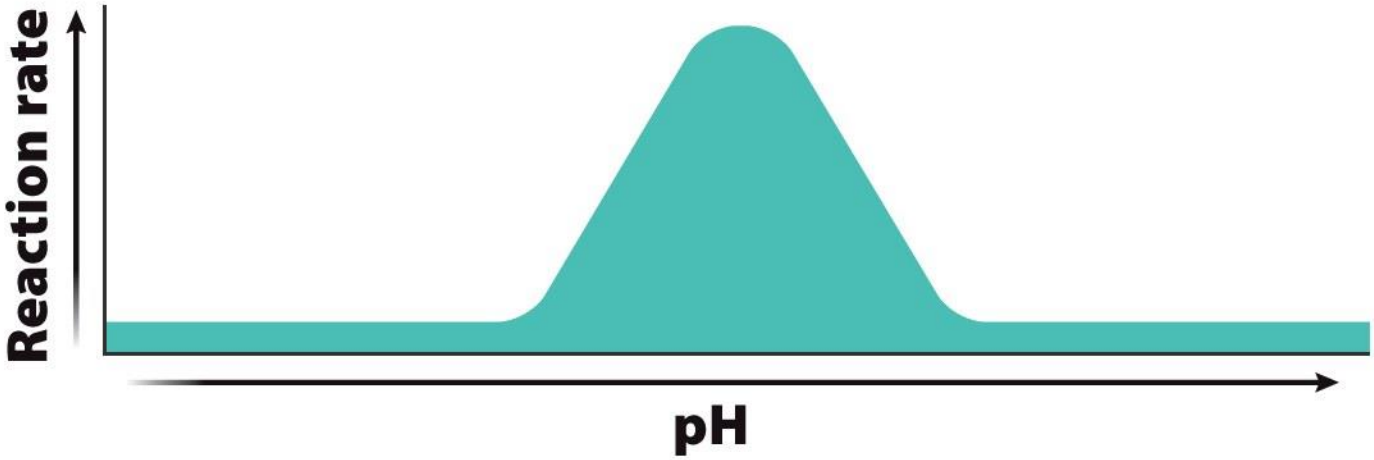
ENZYME ACTIVITY

The rate at which an enzyme catalyzes a reaction is influenced by several chemical and physical factors.

pH

Reaction rates generally increase as pH nears the optimum level for an enzyme. Above or below this pH, enzyme function can be disrupted and reaction rates decrease.



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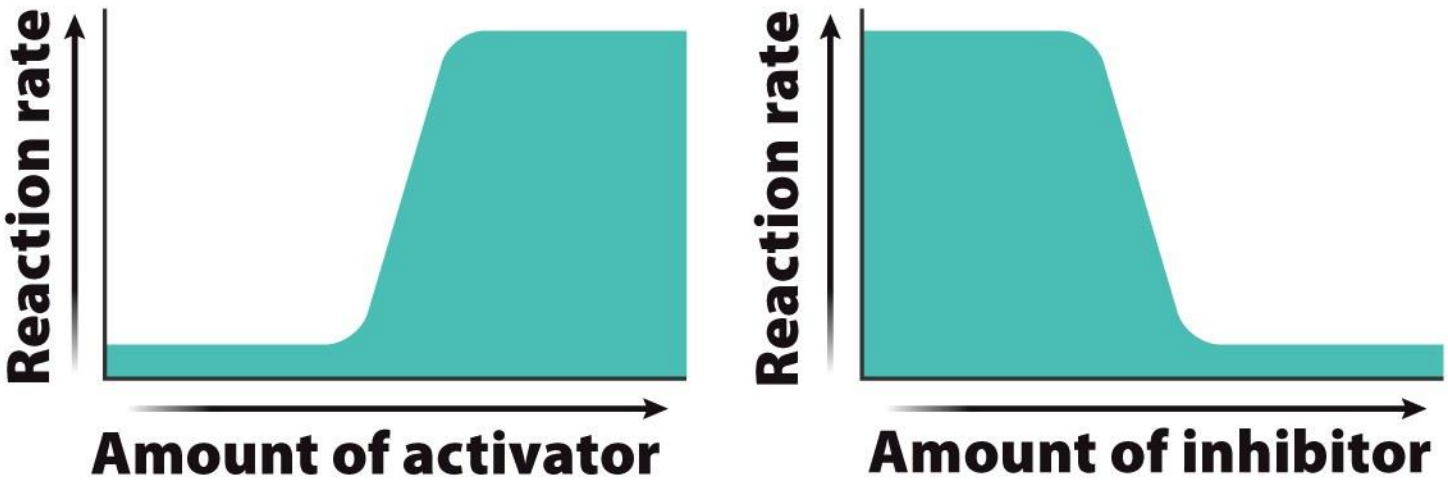
ENZYME ACTIVITY

The rate at which an enzyme catalyzes a reaction is influenced by several chemical and physical factors.

PRESENCE OF INHIBITORS OR ACTIVATORS

Reaction rates increase in the presence of activators and decrease in the presence of inhibitors.



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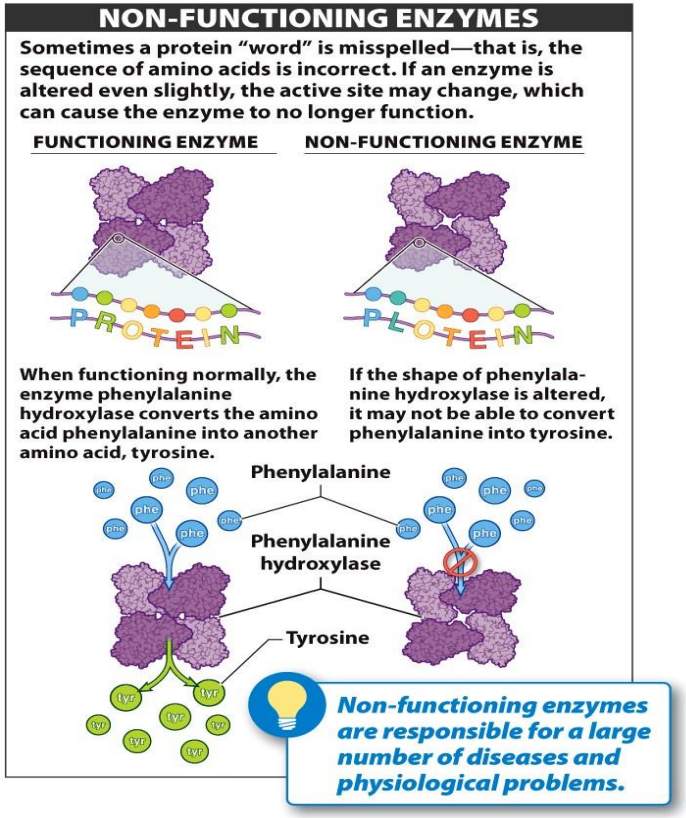
“Misspelled” Proteins

- Incorrect amino acid sequence
- Active site disruptions
- Phenylketonuria



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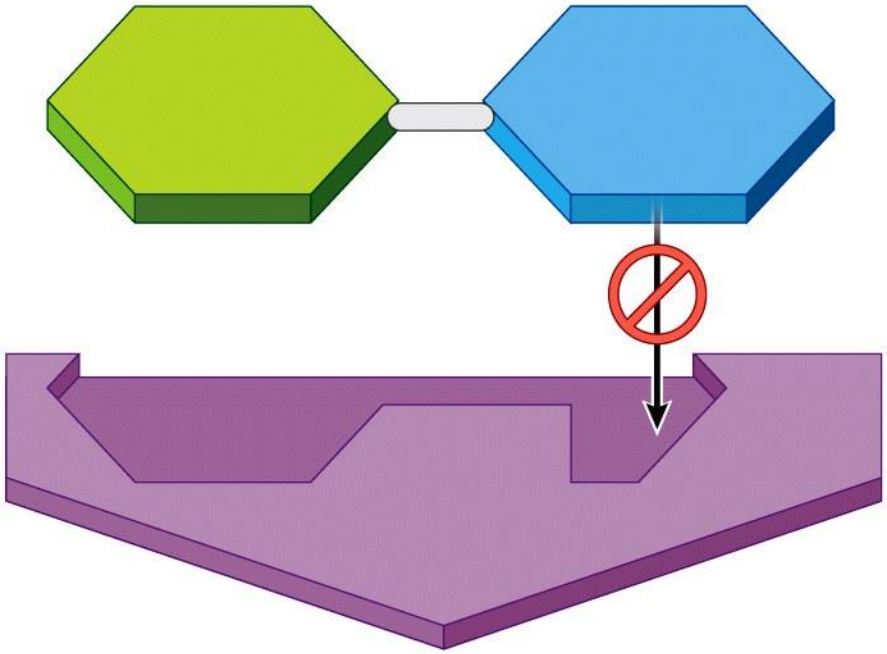
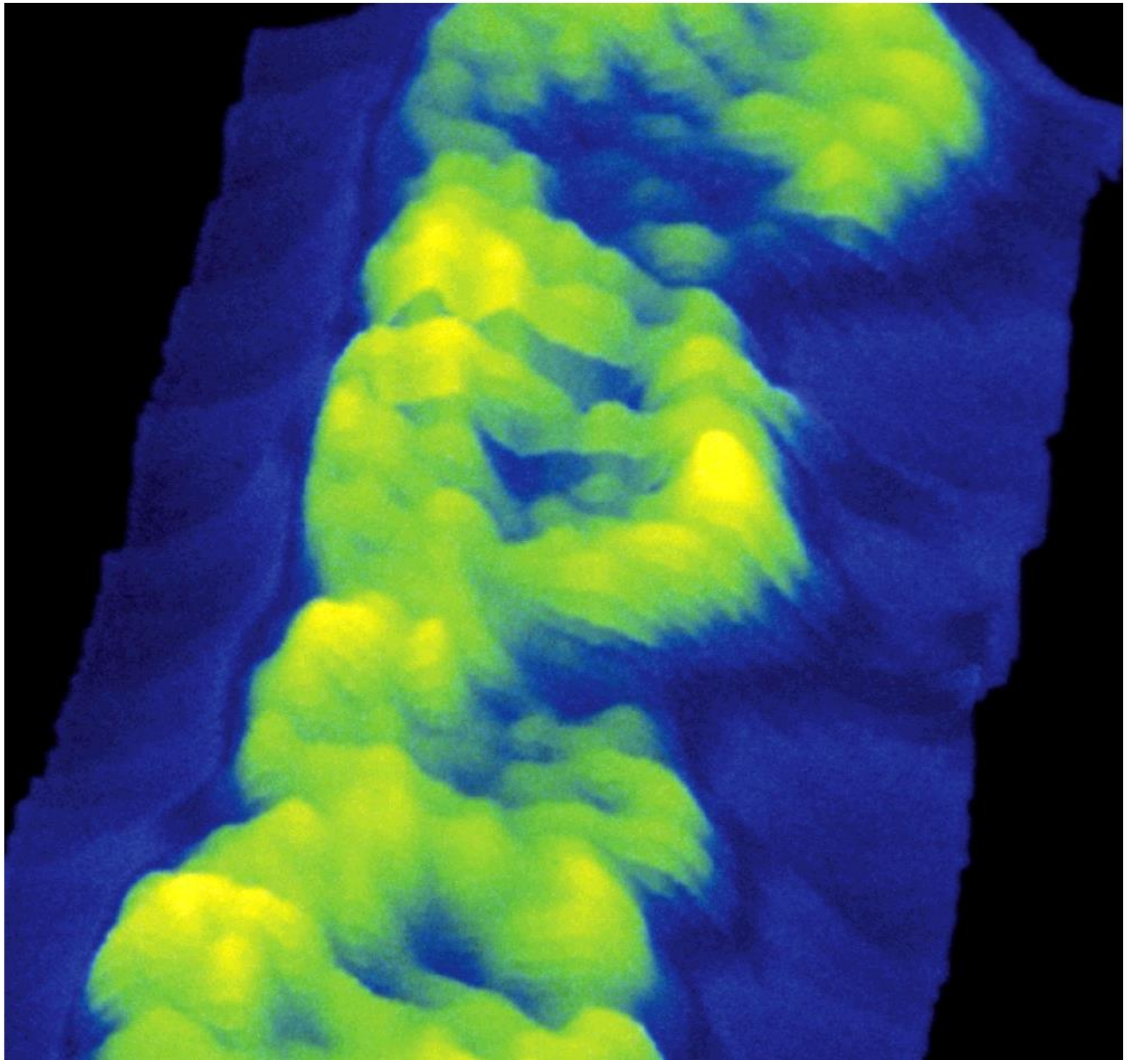
Why do some adults get sick when they drink milk?

LACTOSE INTOLERANCE

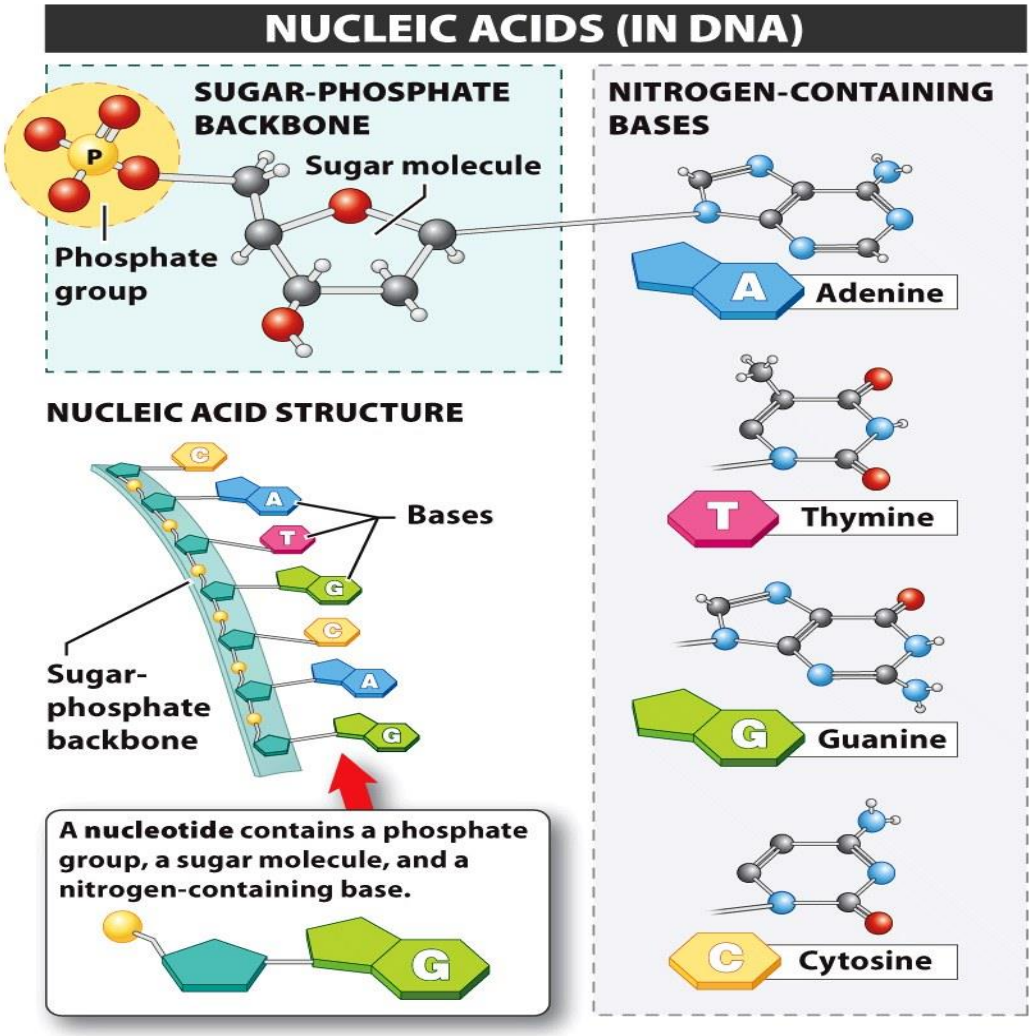
Even a slight alteration to an enzyme's active site can disrupt its functioning. If the enzyme lactase is not built just right, an individual cannot digest milk properly, a condition called lactose intolerance.



2.19–2.21
Nucleic acids store information on how to build and run a body.



2.19 Nucleic acids are macromolecules that store information.



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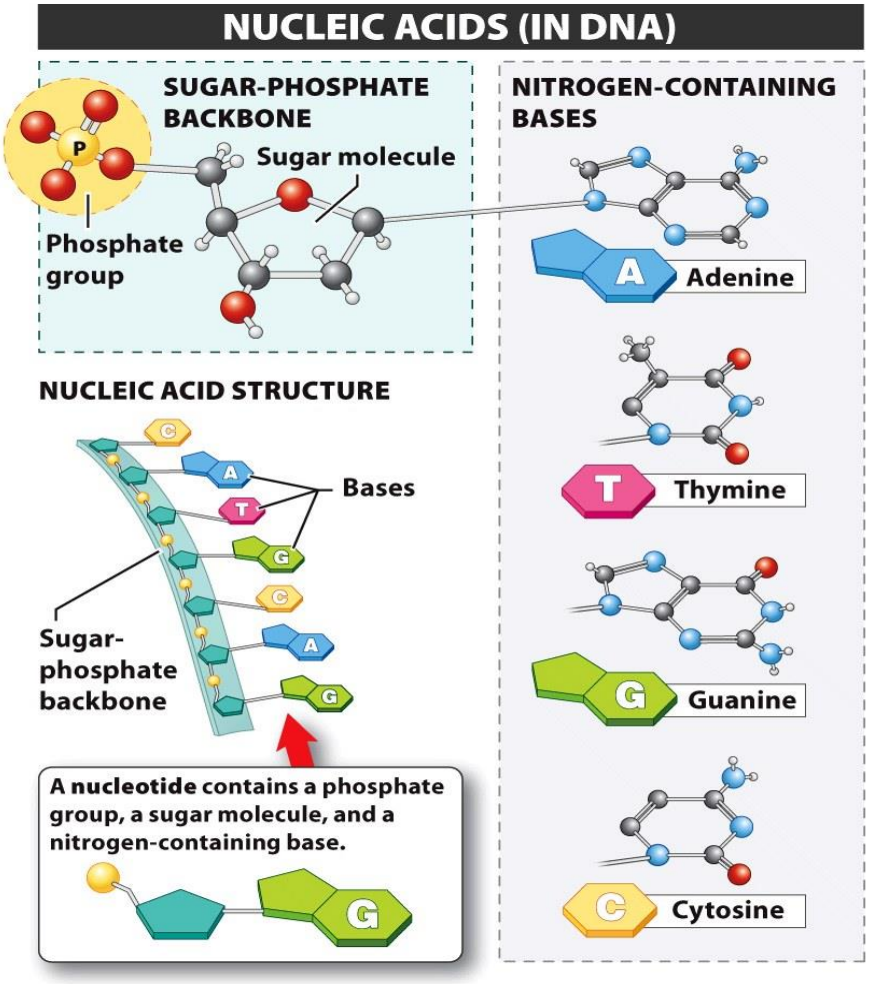
Two Types of Nucleic Acids

- **Deoxyribonucleic acid (DNA)**
- **Ribonucleic acid (RNA)**
- Both play central roles in directing the production of proteins.



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Information Storage

- The information in a molecule of DNA is determined by its sequence of bases.

- Adenine, guanine, cytosine, and thymine

  - CGATTACCCGAT

Learning Objectives

- Describe what atoms are, their structure, and how they bond.
- Understand water's features that help it support all life.
- Describe carbohydrates—their structure and function.
- Describe lipids—their structure and function.
- Describe proteins—their structure and function.
- Describe nucleic acids—their structure and function.