Why do we care about chemistry?

- You wouldn't learn to ski, dance, or cook by taking an advanced class before a beginner class
- Similarly, we cannot learn anatomy without starting with the basic building blocks
- These 'blocks' are understanding how molecules interact with one another--chemistry

On the matter…of matter

- Matter = anything that has mass and occupies space

  Can exist in 3 forms:

  Solid

  Liquid

  Gas

We can move between these states by heating or cooling matter (think about freezing or boiling water)—this is a *physical change*.

…we can also change matter chemically—*by altering its chemical composition*.

Energy acts on matter

Energy = the ability to do work or to put matter into motion.

Can be *kinetic* or *potential* (ball example)

Energy can also come in many forms (e.g. chemical, electrical, mechanical, radiant)

→ Chemical energy is stored in the bonds of chemical substances (like your food). Thus your food has potential energy stored up; when you use the energy in your food for activity (like throwing a ball), that chemical potential energy is converted to kinetic energy.

Energy acts on matter

→ Chemical energy is stored in the bonds of chemical substances (like your food). Thus your food has potential energy stored up; when you use the energy in your food for activity (like throwing a ball), that chemical potential energy is converted to kinetic energy.

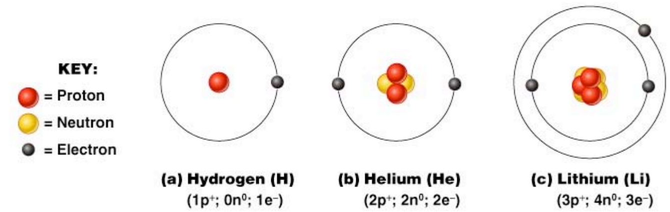
Conversions like this are easy to do (chemically, at least), but are often very inefficient. Much of the potential energy in your food is lost as heat, which is unusable by our cells.

Have you ever noticed how hot your car engine gets? Why do you think that is?

Elements and atoms make up matter

Atoms are made of 3 types of subatomic particles: *protons*, *neutrons*, *and electrons*

Elements are simply atoms with different numbers of these subatomic particles:



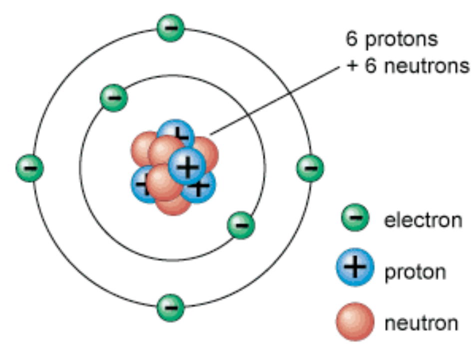
Elements and atoms make up matter

Neutrons and protons have greater mass than electrons; the *atomic mass* is the sum of the protons and neutrons.

We change the element by changing the number of protons; this is the *atomic number*.

If we change the # of neutrons, we get an *isotope*

If we change the # of electrons, we get an *ion*



Carbon atom

What is the atomic mass of carbon?

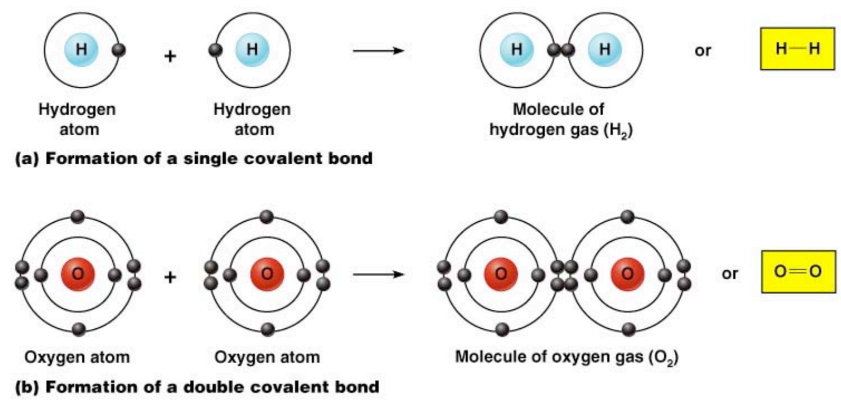
What is the atomic number of carbon?

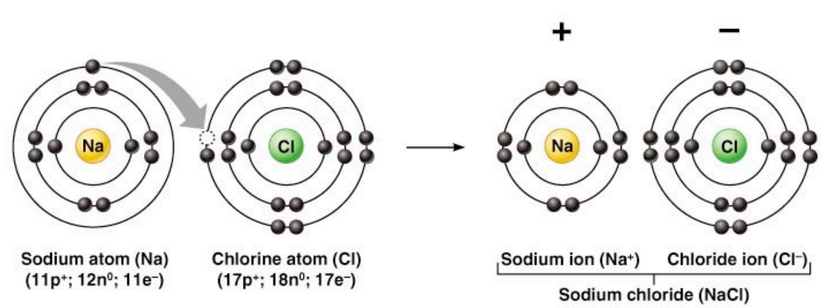
Chemical bonding

When bonds form between atoms, the number of electrons can be very important:

If electrons are *shared* between the atoms, a covalent bond is formed

If electrons are *transferred* between the atoms, ions are formed





Chemical bonding

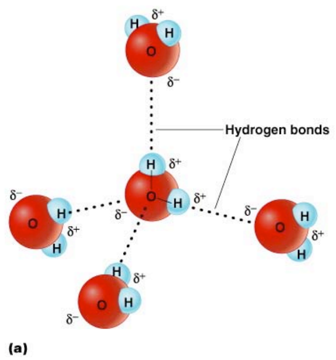
When bonds form between atoms, the number of electrons can be very important:

If electrons are *shared* between the atoms, a covalent bond is formed

If electrons are *transferred* between the atoms, ions are formed

The ions dissolved in our body fluids are what we call *electrolytes*, and are very important to body function.

Hydrogen bonding

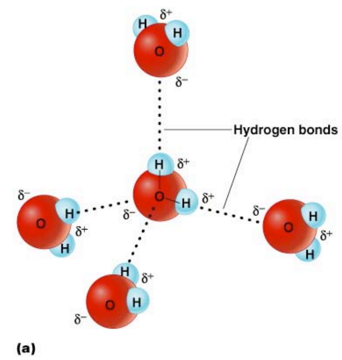


Although water is a covalently bonded molecule, its atoms do not "share" electrons equally.

Oxygen is a very *electronegative* atom, and pulls electrons towards it, even from other water molecules!

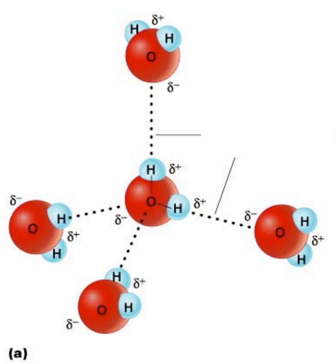
The resulting "interactions" are weak bonds called ***hydrogen bonds***.

Hydrogen bonding



Remember that hydrogen bonds don't only occur in water.

They are weak and short-lived (each one may last one-trillionth of a second!), but they are very important to stabilize proteins, or give water its unique, life-giving properties.



How do ionic bonds differ from covalent bonds?

What kind of bond forms between water molecules?

TABLE 2.1 Common Elements Making Up the Human Body

Element	Atomic symbol	Percentage of body mass	Role
Major (96.1%)			
Oxygen	O	65.0	A major component of both organic and inorganic molecules; as a gas, essential to the oxidation of glucose and other food fuels, during which cellular energy (ATP) is produced.
Carbon	C	18.5	The primary elemental component of all organic molecules, including carbohydrates, lipids, proteins, and nucleic acids.
Hydrogen	H	9.5	A component of most organic molecules; in ionic form, influences the pH of body fluids.
Nitrogen	N	3.2	A component of proteins and nucleic acids (genetic material).

Over 96% of your body weight consists of C, H, N, and O. However these atoms combine in very different ways to make you…you.

This is an excellent example of emergent properties!

While there are hundreds of molecules that make us up, most of them can be grouped as one of four ***organic macromolecules***: carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates are sugars and starches

Contain C, H, and O in the ratio CH_2O (hence carbo*hydrate*, or *hydrated* carbon)

glucose = $C_6H_{12}O_6$

ribose = $C_5H_{10}O_5$

Classified based on size:

monosaccharide

disaccharide

polysaccharide

Carbohydrates are sugars and starches

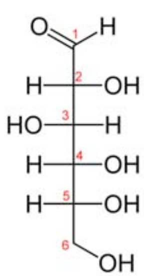
Monosaccharides

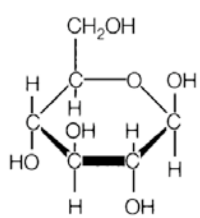
These are what we refer to as simple sugars.
Glucose is one of the most important monosaccharides as it is our main source of fuel.

Carbohydrates are sugars and starches

Monosaccharides

These are what we refer to as simple sugars.
Glucose is one of the most important monosaccharides as it is our main source of fuel.
We also use fructose and galactose, and ribose and deoxyribose

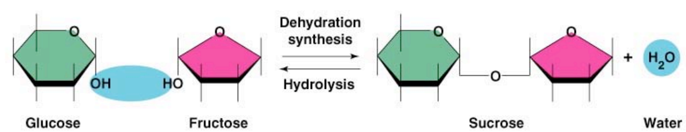




Carbohydrates are sugars and starches

Disaccharides

Formed by a ***dehydration synthesis*** reaction between two monosaccharides



By contrast, disaccharides are broken down in the digestive tract by hydrolysis.

(This pattern is true for almost every group of macromolecules…)

Carbohydrates are sugars and starches

Disaccharides

Formed by a ***dehydration synthesis*** reaction between two monosaccharides

We have many important dietary disaccharides:

sucrose (glucose-fructose)
lactose (glucose-galactose)
maltose (glucose-glucose)

Carbohydrates are sugars and starches

Polysaccharides

Many monosaccharides linked together

What process are they joined by?

Large, insoluble molecules; do not taste "sweet"

We really only care about ***starch*** and ***glycogen***

both are polymers of glucose
starch is plant-based energy storage
glycogen is found in our muscles and liver for energy storage

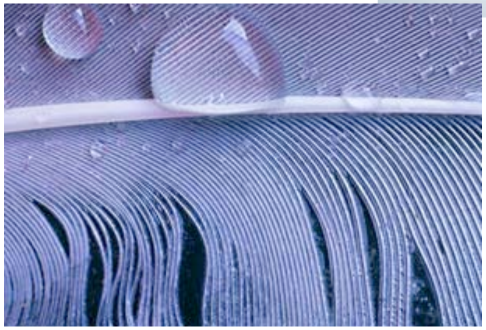
At a given time, your body stores ~2,000 kcal of glycogen (enough to fuel ~3 hrs of exercise)

Lipids also contain C, H, and O (but far less O than carbohydrates)

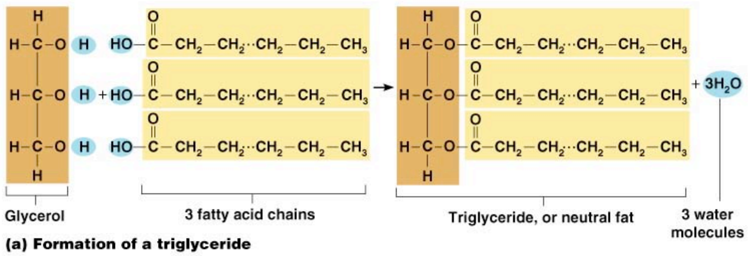
Lipids are a hugely complicated group; fats, steroids (cholesterol, sex hormones, etc), vitamins A, E, and K and prostaglandins are all lipids

They are all very important to proper physiological function, but one of the most important lipids are fats (triglycerides).

All lipids are hydrophobic (= water-fearing) because they are *nonpolar*



Triglycerides



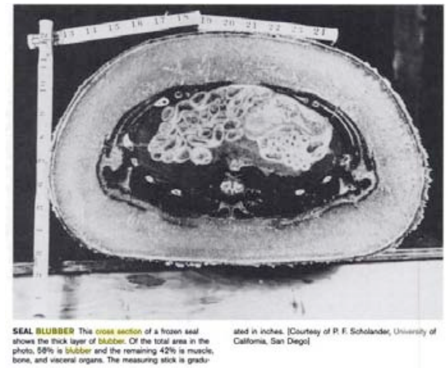
(a) Formation of a triglyceride

Lipids also contain C, H, and O (but far less O than carbohydrates)

Fats store ~85% of your body's energy

Much less bulky than carbohydrates

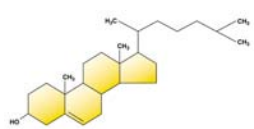
Cushion our vital organs and insulate us

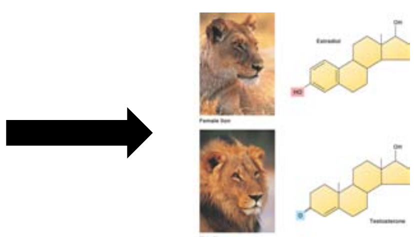


Lipids also contain C, H, and O (but far less O than carbohydrates)

Lipids exist in many other forms as well:

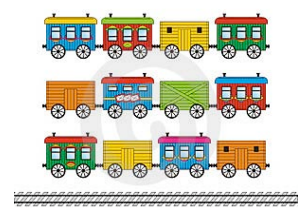
- **Phospholipids** are a major component of cell membranes
- Waxes form waterproof coatings (fruit, insects)
- **Steroids** form hormones





Proteins participate in every cellular activity

A protein is a polymer constructed from amino acid monomers.



Proteins participate in every cellular activity

A protein is a polymer constructed from amino acid monomers.

Enzymes are proteins that speed and regulate chemical reactions in cells

Structural proteins make up hair, tendons, and ligaments

Contractile proteins are found in muscles

Defensive proteins participate in immune system

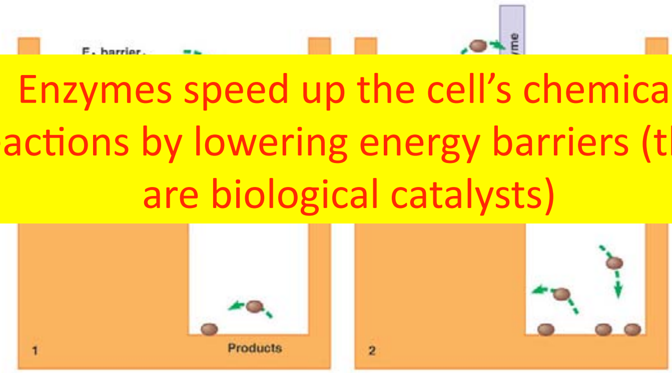
Signal proteins (e.g. some hormones) help in cell communication

Hemoglobin is specialized in oxygen transport

Storage proteins (e.g. ovalbumin) feed embryos and babies

How to enzymes work?

Enzymes reduce the amount of energy required to start a chemical reaction (="activation energy", E_A)



Enzymes speed up the cell's chemical reactions by lowering energy barriers (they are biological catalysts)

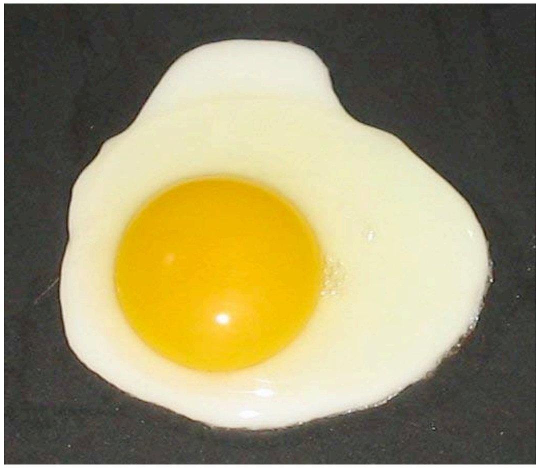
Enzymes are reaction-specific

Each enzyme molecule may act on millions of substrate molecules per second

Table 3.4 Catalytic Activity of a Variety of Enzymes

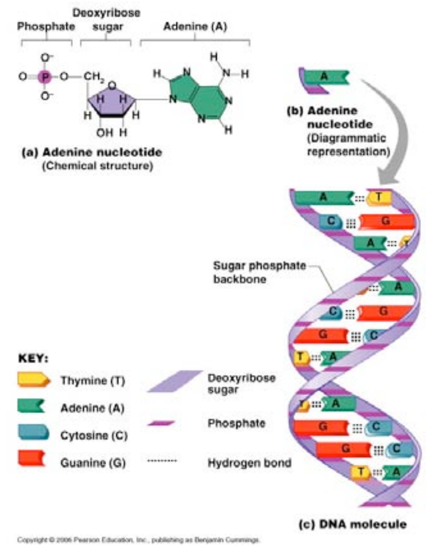
Enzyme	*Nonenzymatic* $t_{1/2}$[1]	*Turnover number*[2]	*Rate enhancement*[3]
OMP decarboxylase	78,000,000 yr	39	1.4×10^{17}
Staphylococcal nuclease	130,000 yr	95	5.6×10^{14}
Adenosine deaminase	120 yr	370	2.1×10^{12}
AMP nucleosidase	69,000 yr	60	6.0×10^{12}
Cytidine deaminase	69 yr	299	1.2×10^{12}
Phosphotriesterase	2.9 yr	2,100	2.8×10^{11}
Carboxypeptidase A	7.3 yr	578	1.9×10^{11}
Ketosteroid isomerase	7 wk	66,000	3.9×10^{11}
Triosephosphate isomerase	1.9 d	4,300	1.0×10^{9}
Chorismate mutase	7.4 hr	50	1.9×10^{6}
Carbonic anhydrase	5 sec	1×10^{6}	7.7×10^{6}
Cyclophilin, human	23 sec	13,000	4.6×10^{5}

Source: A. Radzicka and R. Wolfenden, *Science* 267, 91, 1995. Copyright 1995 American Association for the Advancement of Science.
[1]The time that would elapse for half the reactants to be converted to product in the absence of enzyme.
[2]The number of reactions catalyzed by a single enzyme molecule per second when operating at a saturating substrate concentration.
[3]The increase in reaction rate achieved by the enzyme-catalyzed reaction over the noncatalyzed reaction.



Nucleic acids carry information and energy

Deoxyribonucleic acid (DNA) is our genetic material; divided into genes, which are the primary structure for our proteins; DNA is inherited from our parents



Nucleic acids carry information and energy

Deoxyribonucleic acid (DNA) is our genetic material; divided into genes, which are the primary structure for our proteins; DNA is inherited from our parents

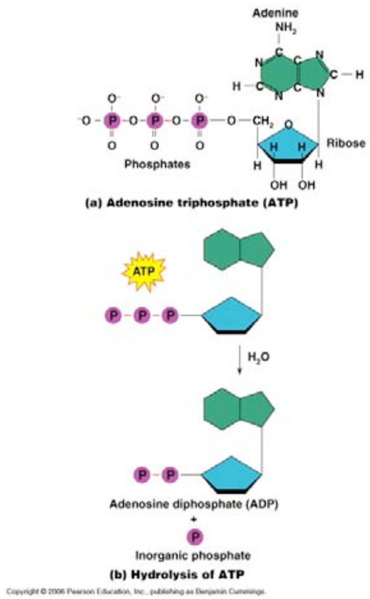
Ribonucleic acid (RNA) is similar in structure to DNA and is an important intermediary in protein synthesis

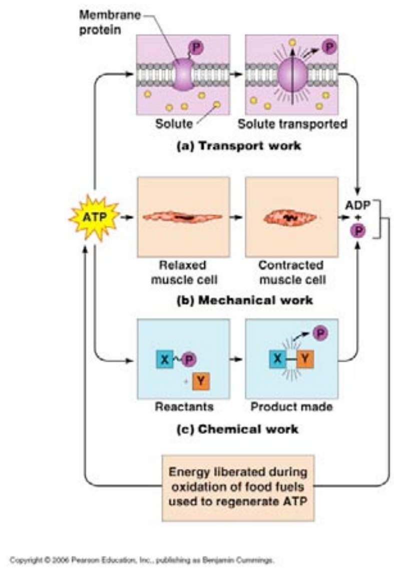
Nucleic acids carry information and energy

Deoxyribonucleic acid (DNA) is our genetic material; divided into genes, which are the primary structure for our proteins; DNA is inherited from our parents

Ribonucleic acid (RNA) is similar in structure to DNA and is an important intermediary in protein synthesis

Adenosine triphosphate (ATP) provides chemical energy to working cells





What are the building blocks of carbohydrates called?
What about proteins?

Which type of lipid is abundant in cellular membranes?

How do DNA and RNA differ structurally?