Lecture notes Jan 23: Biochemistry I, atoms etc.

Living organisms - and all solids, liquids, and gasses on Earth - are comprised of **matter**

Matter: anything that occupies space and has mass (i.e., has weight).

All matter is made of 1 or more of the **elements** (see periodic table).

Element: components of matter that cannot be broken down (turned into a new or different element) by ordinary chemical means (but can combine to make new substances).

Some elements exist in nature in their pure form; EX: gold (Au), silver (Ag), oxygen (O)

The smallest tiny bit of matter that an element can be reduced to is an **atom**. Alternatively;
Atom: The smallest unit of matter that retains the properties of an element.

Atoms – word origin "a" (not/non) + "tom" divide = non dividable. Indicates cannot be divided (few noteworthy exceptions…).

What makes atoms (elements) different from each other, and makes certain combinations likely? Dictated by the composition of different atoms:

Atoms are built from (for the most part…) 3 different **subatomic particles**:
1) **Protons**: + charge (in atomic nucleus)
2) **Neutrons**: no charge (in atomic nucleus)
3) **Electrons** (notation: $\mathbf{e^-}$) : negative charge. Orbit around the nucleus in **valence shells**.

Electron valence shells (aka orbitals):
Innermost valence shell: 2 e^-
All other valence shells (in this class): 8 e^-

Protons: The element to which an atom belongs (i.e., the type of element an atom "is") is dictated by the number of protons.

Neutrons: Important in more subtle ways – isotopes – more later…

Electrons: Electrons are where action is!!! (in case ya didn't know…). The # of electrons in an atom's outermost valence shell determines how atoms (elements) react with other atoms.

…nearly all individual atoms contain equal #'s of protons, neutrons, and electrons…(exceptions are neutrons…which we will not cover…)

Atomic number = number of protons in an atom (this number appears in the upper right corner of each element in most periodic tables)

Atomic mass = # protons + the # of neutrons in an atom (usually appears under the elemental symbol in a periodic table)

There are many different types of elements (atoms), and although some exist in their pure form, atoms of different elements often combine to make new types of matter called **compounds**.

Compound (aka molecule for Bot 100): A substance (or type of matter) containing two or more elements in a fixed ratio. In Bot 100 we will use the term **molecule** synonymously with compound! (Technically speaking though, a molecule is a compound bonded together with covalent bonds.)

Chemical bond: An attraction between two atoms resulting from the sharing or transfer of electrons.

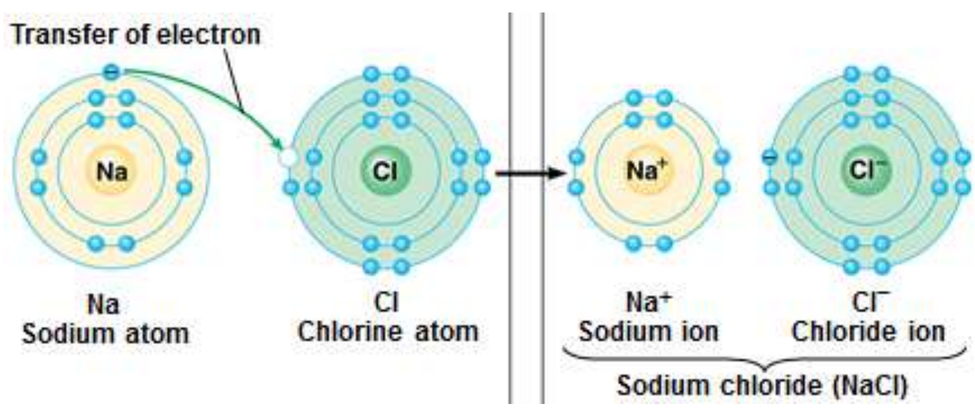
Chemical reactions: The making and breaking of chemical bonds

Reactants: the starting atoms/molecules that are "used up" in a chemical reaction
Products: the atoms/molecules that are produced in a chemical reaction

Balancing reactions – matter (atoms) is neither created nor destroyed during reactions, so make sure all atoms are accounted for on both sides of equation!!

Atoms "want" outermost valence shell to be full of electrons – so they either share or transfer electrons among compatible atoms, when this happens the participant atoms remain in very tight proximity and are said to be **chemically bonded.**

You will not be tested on any aspect of ionic bonds!
Ionic Bond: A chemical bond in which outermost valence shells are filled through transfer of an electron (EX: NaCl).



Ion: Atom or molecule with a net positive or negative charge due to loss or gain of 1 or more electrons (EX: Na^+, Cl^-).

Covalent Bond: A chemical bond in which outermost valence shells are filled through sharing of electrons (EX H_2, O_2). Think of root of word "co-valent". Covalent bonds are stronger than ionic bonds.

Single covalent bond – 1 electron from each atom is shared (Example: H_2)

Double covalent bond – 2 electrons from each atom are shared (EX: O_2)

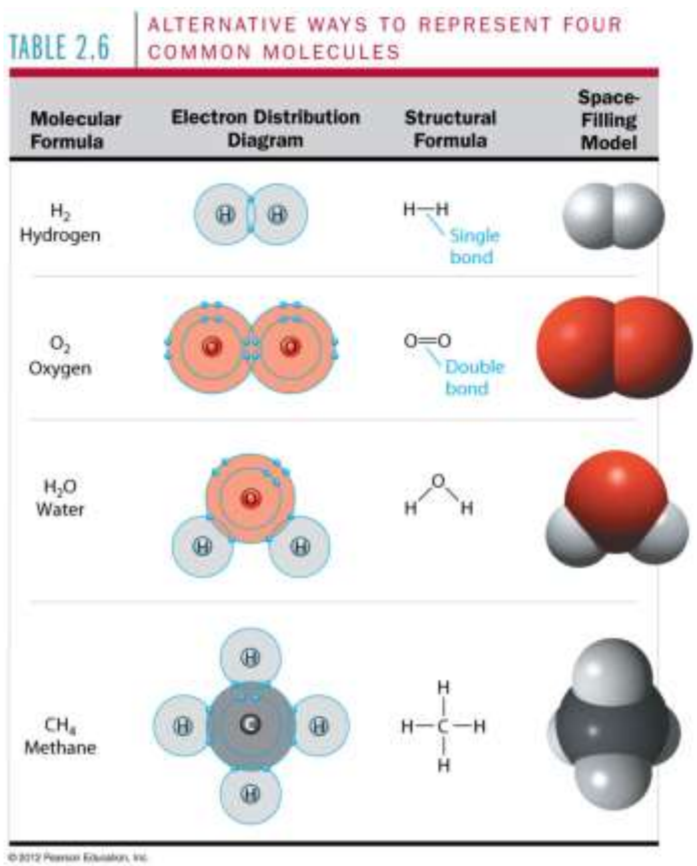
Nonpolar covalent bonds – electrons are "shared" evenly

Polar covalent bonds – covalent bonds in which one atom has a stronger affinity for the 'shared' electron(s), and the electron therefore spends more time near the atom with higher affinity. As a consequence there is a slight polarity (uneven charge) around the molecule. Often, this results in a polar molecule that has uneven charge around it (EX: H_2O)

Molecule: two or more atoms held together by covalent bonds.

Hydrogen bonds: weak bond within or among molecules containing a charged hydrogen atom – THE key example in biology is water.

ATOMIC STRUCTURE / MODELS – (be able to provide examples for basic molecules.
Molecular Formula (e.g., H_2O, O_2, etc…)
Structural Formula (aka, "ball-and-stick")
Electron dot diagram (aka, electron distribution diagram)



Essential element: An element required for normal growth and reproduction.
The essential elements that comprise the tissue of plants are often divided into two categories:

M**icronutrients** (a.k.a. micro essential elements, or trace elements): essential elements required in very low quantities.
(We will not explore how/why these elements are needed and used in plant tissues)

M**acronutrients** (aka; macro essential elements): essential elements required in large quantities by plants.

The useful mnemonic device for remembering the **macronutrients** is as follows:
C H O P K N S Ca Fe Mg (pronounced as: "C Hopkins Café, Mmmm Good"), in which each letter (or two letters in the case of Ca, Fe, and Mg) represents atomic symbols on the periodic table:

Macronutrient	(importance/role in plants)	(Approximate % of dry weight in non-woody plant tissue)
C – Carbon	(abundant in biomolecules)	(45%)
H – Hydrogen	(abundant in biomolecules, water)	(6%)
O – Oxygen	(abundant in biomolecules, water)	(45%)
P – Phosphorous	(in ATP, DNA, phospholipids; basic cell function)	(0.2%)
K – Potassium	(stomata guard cell opening/closing; basic cell function)	(1.0%)
N – Nitrogen	(in amino acids [thus proteins], DNA, many other molecules)	(1.5%)
S – Sulfur	(in some amino acids – *you will not be asked about* S *on exams*)	(0.1%)
Ca – Calcium	(in cell wall – *you will not be asked about* Ca *on exams*)	(0.5%)
Fe – Iron	(needed for synthesis of chlorophyll)	(0.01%)
Mg – Magnesium	(in chlorophyll molecule)	(0.2%)

As we progress through the semester, we will revisit in detail the importance or role of each macronutrient – but a summary is provided next to each element above. Prior to midterm #1, we should cover all of these – so you'll want to know this material for prior to that exam!!

(You do not need to memorize the relative composition of these elements in plants (here, reported as % dry weight), but after our "biomolecules lecture" you should be able to explain why C, O, and H dominate. The answer – they are most abundant in biomolecules…)

Sources of macronutrients:
C, O, H – from air and/or water
N, P, K – from soil and <u>heavily utilized</u> ("1^o macronutrients"). In Ag/horticulture, the main ingredients of fertilizer (be able to identify/explain an **<u>N-P-K fertilizer formula</u>** on exams). We discussed that N, P, and K have many fundamental roles in cell function and are essential to plant function throughout life – BUT - high N is most important during vegetative growth, while P and K support/enhance flowering & fruiting. Thus, how might an ideal **N-P-K fertilizer ratio** change during the course of your gardening season?)
Ca, Fe, Mg – from soil and less heavily utilized ("2^o macronutrients"). Also included in small (aka "trace") amounts (along with some micronutrients in some fertilizers. Use of the term "trace nutrients/minerals" is inconsistent but usually this word refers to micronutrients). Ca deficiency mentioned as a cause of "blossom end rot" in fruits.

The biology of water. Water essential to life – all life evolved from organisms in the ocean long, long ago. (In a sense; all biology is marine biology!!)

Properties of water that make it fundamental to life on Earth:
Arise from molecular structure: polarity and H bonds
[NOTE: Four properties of water are listed here – but there are more, most notably cohesion-adhesion, which is critically important in plants - but we'll study this in great detail in week 7!

1) H_20 is "universal solvent" (can dissolve most chemical compounds)
Solution: a liquid consisting of a uniform mixture of two or more substances
Solvent: the dissolving agent in a solution
Solute: the substance that is dissolved by the solvent

2) H_20 Moderates temperature
2a) Resistance to temperature change,

Temperature – A measure of heat, in degrees, indicating the average speed (kinetic energy) of molecules.

> Temperature of any given matter is directly related to the motion of it's constituent particles (atoms and molecules). Increases/decreases in temperature in matter correspond to increased/decreased motion of atoms. (hot matter has actively "jiggling" or moving atoms & moelcules that collide with each other and rub against each other (friction) and generate heat.

With regard to changing the motion of atoms - **H_20** is a special case. For water to change temperature (i.e., for motion or "jiggling" of atoms to change) H bonds must be broken or formed before water changes temperature – and doing so takes heat input…and time! In lecture, we discussed the fact that coastal climates are relatively moderate (less extreme) than interior (mid-continent) climates b/c large bodies of water do not experience daily/seasonal temp fluctuations to the same extremes as the atmosphere.) We looked at climate maps, satellite vegetation maps, and USDA plant hardiness maps for North America and/or USA, and we related these patterns to the influence of oceans and the chemistry of water. In summary, water buffers against fluctuations to extreme temperatures – and maintains temperature ranges in which life can exist.

2b) Evaporative cooling: The process by which the surface of an object cools due to evaporation
Evaporation: The process by which water is converted from its liquid form to its vapor form

Water evaporates through the stomata in leaves during a process called transpiration. We'll study transpiration in GREAT(!) detail in week 7, so don't worry about it for now. However, that process helps cool leaf tissues, and at the scale of a landscape, it helps regulate the temperature of large areas such as forests. (FYI - The cooling effect of trees is also due to shading and reflection of light that would otherwise be absorbed by rocks and soil, but the contribution of evaporation is important as well.)

The cooling effect of trees/vegetation on landscapes is one of many the benefits and motives for urban forestry.

Urban forestry: The care and management of urban forests, (i.e, tree populations in urban settings) for the purpose of improving the urban environment.

There are many benefits of urban forestry: improved aesthetics (beauty and privacy), higher property values, attraction of residents, tourists, and businesses, preservation of biodiversity, absorption of rainwater, recycling of wood-based waste as mulch, carbon sequestration (more on this in week 4) that combats global warming, dampening of high winds, and to our point here: temperature moderation (this can save $ in air conditioning).

The fact that vegetation in urban environments can moderate temperatures is important because urban landscapes often cause locally higher temperatures. This is known as the:

Heat Island Effect: The phenomenon by which a metropolitan area is significantly warmer than its surrounding rural areas.

Urban areas are heat islands due to heat generated by human activities (automobiles, industry, heating/cooling of homes) and removal of vegetation from the landscape. Typically that vegetation is replaced by surfaces that absorb light energy and convert it to heat (think: asphalt parking lot, streets, etc..).

Restoring vegetation to the urban landscape can combat the heat island effect via:
1) Shading
2) reflection of light from plant surfaces
3) Evaporation via transpiration – our focus here as we discuss the chemistry of H_2O!

Urban forestry is one way to restore vegetation to urban landscapes. Green roofs are another – and often times the distinction is not quite so clear (i.e., are large roofs “small forests”??!!). Recall the amazing examples of progressive / green architecture that incorporates vegetation that we viewed in class.

3) H_20 is less dense as a solid (ice) than when a liquid
This insulates large bodies of water prevents them from freezing solid!!

There you have it….
H_20 – the wonder molecule of biology!!

Next lecture, we will look at two large biomolecules: sugars and proteins, and in lab 3 we’ll examine lipids, and eventually nucleic acids…yeeeeeeeeehaw!