A QUICK REVIEW OF BIOCHEMISTRY HIGHLIGHTS

These are the most interesting and fundamental truths of chemistry and biochemistry, in my opinion. They are not the whole truth presented in chemistry, organic chemistry, and biochemistry texts. I hope you enjoy this brief collection of my favorite facts and concepts.

The vast majority of water molecules stay together, but a small fraction of them split apart. Water normally has about equal concentrations of Hydrogen ions (H^+) and Hydroxide ions (OH^-) that have split from water molecules (H_2O). That equal concentration is 10^{-7} ions per liter. That balance can be disturbed so that there are more H+ ions or more OH- ions, but the product of the two concentrations will always be the same.

$$[H+] * [OH-] = 10^{-14}$$
$$10^{-7} * 10^{-7} = 10^{-14}$$
$$10^{-1} * 10^{-13} = 10^{-14}$$

If the [H+] = 10^{-1}, then we say that the pH is 1; extremely acidic.
If the [H+] = 10^{-7}, then we say that the pH is 7; neutral.
If the [H+] = 10^{-8}, then we say that the pH is 8; extremely basic.

Some chemicals split apart almost completely, like table salt NaCl or hydrochloric acid HCl, which is extremely acidic. The more H+ ions that a chemical puts into solution with water, the more acidic that chemical is. Organic acids, which I'll discuss in a few minutes, are mild acids, compared to HCl.

H, C, O, N, P, and S are the most common biochemical elements in organic molecules. Na, K, Fe, and Ca are also common as electrolyte ions. Then there are lots of atoms that we need in **very** small quantities, like Se, which is toxic in small quantities. It would be theoretically possible for living organisms based on Silicon to evolve, because Si, like C, can make bonds with up to 4 other atoms. Earthlings, both plant and animal, use chains of C to make up the majority of our bodies.

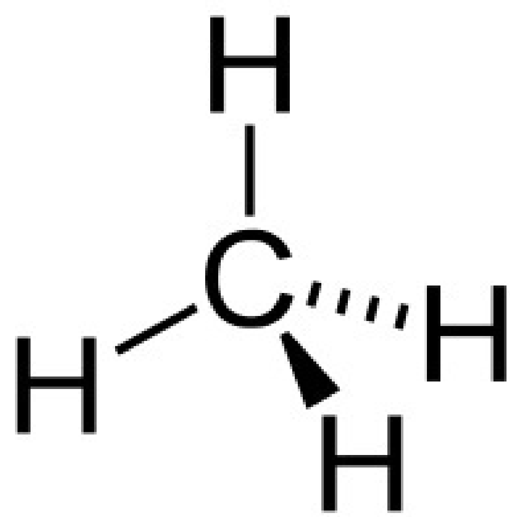

Figure 1: Carbon with four bonds to hydrogen is methane. https://commons.wikimedia.org/wiki/File:Methane_structure_1.png 1840460mahesh, CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons

A cluster of interconnected atoms is called a molecule. There are an infinite number of molecules that can exist, from just two atoms bonded together up to an infinite number of atoms bonded in an infinite number of patterns. However, the most common categories of molecules we see in the biochemistry of life are: Proteins, Carbohydrates, Lipids, and DNA.

PROTEINS

Proteins are made up of long chains of amino acids[1]. These chains bend and twist into very complex 3-dimensional structures. Proteins form into enzymes[2], collagen, elastin, muscles, hair, and other structures. Proteins form most of the machinery (and the architecture of most) animal bodies. Peptides are short proteins (2-20 amino acids). Some peptides act as chemical messengers for the nervous system. Our bodies are made of 20 or perhaps 22 different amino acids combined with each other to form proteins.

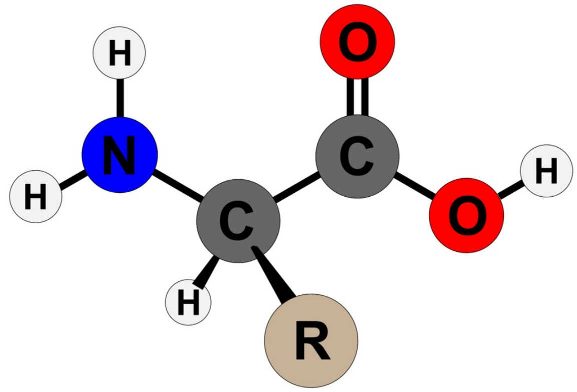

Figure 2: An amino acid. R represents any organic molecule.
https://commons.wikimedia.org/wiki/File:Amino_Acid_Structure.png

CARBOHYDRATES

Carbs come into our diet mostly in the form of the sugar polymers glycogen and starch. Sugars are short carbon chain alcohols[3] that usually have 5-6 carbon atoms and one oxygen atom per carbon atom. Almost every carbon has an O-H group and is therefore an alcohol. Table sugar is sucrose, a linked pair of sugar molecules called glucose and fructose. Glucose has 6 carbons, and fructose has 5.

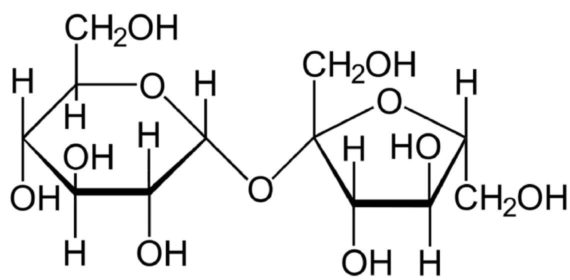

Figure 3 Sucrose comprises a glucose molecule and a fructose molecule.
https://commons.wikimedia.org/wiki/File:Sucrose_structure_formula.png

Insects make their exoskeleton bodies out of chitin, which is a glucose polymer, but we cannot digest chitin. Plants make their bodies from cellulose, and store their excess glucose in the form of starch. Both cellulose and starch are made from chains of glucose molecules (bound together in different ways). Animals store glucose as glycogen in muscle cells and the liver. Glycogen and starch are very similar branched polymers of glucose that differ only in the frequency of side branches. Our bodies can readily digest both starch and glycogen.

[1] Long chains of molecules are called polymers.

[2] An enzyme is a biochemical catalyst that reduces the energy (and perhaps the time) required to complete a specific chemical reaction.

[3] All alcohols are toxic to humans. Ethanol is merely the least toxic.

LIPIDS

Lipids comprise glycerol, fats, and oils. Fats and oils are polymers of carbon with a terminal carboxyl O=C-OH group. This group makes them mildly acidic. These polymers are short, like peptides; most are less than a couple dozen carbons long. Lipids have a 3-carbon molecule of glycerol that links three lipid or oil chains together[4]. Most fats in our diet come from animals, and most oils from plants. Oil polymers are shorter than fat polymers, so the shorter oils are less likely to get tangled around each other, and it is therefore easier for them to flow past one another. Therefore oils are less viscous and have lower boiling points.

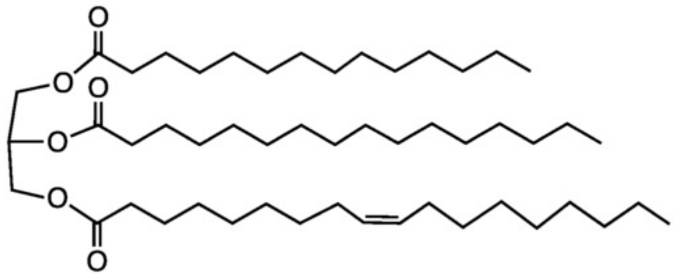

Figure 4 A Lipid comprises three fatty acid (oil) molecules bound to a Glycerol molecule. https://commons.wikimedia.org/wiki/File:TriglycerideDairyButter.png
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DNA

Refer to the DNA figure at the end of this chapter. A genome (of 6.4 billion DNA[5] molecules) contains all the data to code for the proteins that replicate and operate each human cell. A gene is a sequence of DNA molecules that codes for a protein. A codon is a sequence of three DNA molecules that codes for a specific amino acid. So a protein that has 10,000 amino acids in it needed 10,000 codons and 30,000 DNA nucleotide molecules (minimum) to code for it. An error in a DNA molecule causes the codon to code for a wrong amino acid. A wrong amino acid makes the protein fold into the wrong shape. It is then useless and possibly dangerous. Damaged proteins are actively destroyed and ejected from the cell.

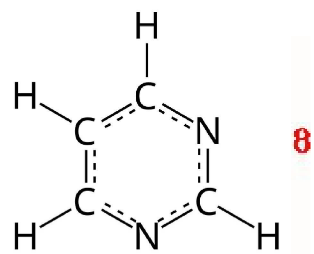

Figure 5 Pyrimidine By Jynto - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=2262173

Figure 6 Purine By NEUROtiker (talk) - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=4542866

DNA and RNA are called nucleic acids. They are polymers made of nucleotides. Nucleotides are purine or pyrimidine bases with attached ribose phosphate. Nucleosides are purine or pyrimidine bases with attached ribose only.

[4] Thus the name Triglyceride.

[5] DNA stands for deoxyribonucleic acid.

The purines each have a hexagon sharing one side with a pentagon. Each ring has 2 or 3 double bonds and two Nitrogen atoms. Purines are abbreviated as A & G.

Purines w/o sugar:	adenine	guanine
with sugar (nucleosides):	adenosine	guanosine

Pyrimidines have a single hexagon with two nitrogen atoms and 1 or 2 double bonds in the ring. Pyrimidines are abbreviated as C, U, & T. U replaces T in RNA.

Pyrimidines w/o sugar:	cytosine	thymine	uracil
with sugar (nucleosides):	cytidine	thymidine	uridine

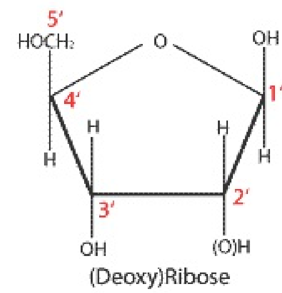

Figure 7 Deoxy Ribose https://commons.wikimedia.org/wiki/File:DeoxyriboseLabeled.png Adenosine (English Wikipedia User), CC BY-SA 3.0 <http://creativecommons.org/licenses/by-sa/3.0/>, via Wikimedia Commons

Nucleotides have one or more PO4 groups on the ribose #5 carbon in a nucleoside.

DNA is two polymeric strands of nucleotide monomers connected by bonds between base pairs.
The DNA base pairs are: T with A and G with C in DNA.

The deoxy in DNA is the loss of a hydroxyl group on the ribose carbon #2.

HOMEWORK - Test your comprehension. Open book. Open internet.

1 pH of 1 is extremely ____________________________

2 Name two chemicals that normally dissolve completely in water.

3 The four most common elements in all living things on earth.

4 Atoms bound together as a single unit are called a ____________________________.

5 The four most common elements in a protein:

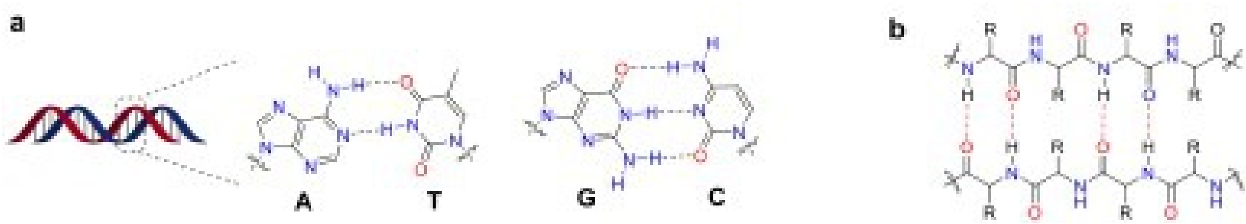

Figure 8 DNA helix, hydrogen-bonded DNA base pairs, and hydrogen-bonded protein strands.
https://commons.wikimedia.org/wiki/File:Hydrogen_bonds_in_(a)_DNA_duplex_formation_and_(b)_protein_%CE%B2-sheet_structure.png
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6 The three most common elements in a fatty acid:

7 The three most common elements in a carbohydrate.

8 Draw an amino acid molecule with side group R.

9 Draw a lipid molecule with 5-carbon oil chains

10 How many calories in a gram of fat?

11 How many calories in a gram of protein?

12 How many calories in a gram of carbohydrate?

13 Draw a sugar molecule

14 Draw a vinegar molecule

15 Draw an unwound chromosome segment (both strands) and circle a codon.

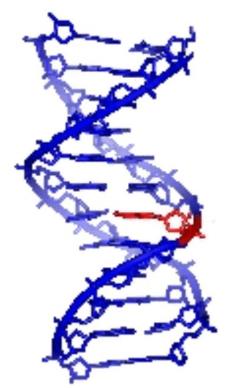

Figure 9 DNA helix
https://commons.wikimedia.org/wiki/File:DNA_helix-structures.jpg
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