Life and Health Science

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Chapter 2: The Chemistry of Life

- All things are made up of atoms
- Atoms link together using chemical bonds to form molecules
- Why are molecules of water so important?

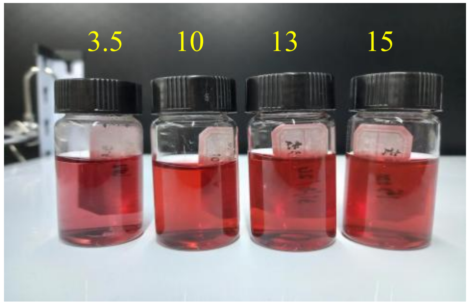
Corresponds with OpenStax Biology 2e Chapter 2

All things are made up of atoms

- All matter that takes up space (solids, liquids, & gases) is made up of **elements**
  - – Element = a substance that cannot be broken down chemically into other substances
    - e.g. oxygen, gold, aluminum, calcium, iron, etc.

gold

https://pixabay.com/images/id-4131091/



aluminum

https://snl.no/aluminium

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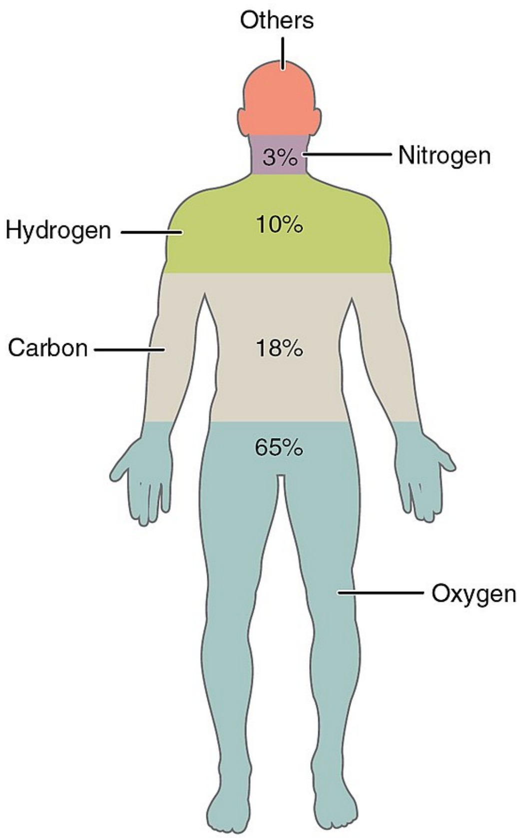
- There are over 100 elements that we know of
- But there are only ~25 elements essential to life
  - if a living thing is deficient in any one element they can become ill or die



Element	Symbol	Percentage in Body
Oxygen	O	65.0
Carbon	C	18.5
Hydrogen	H	9.5
Nitrogen	N	3.2
Calcium	Ca	1.5
Phosphorus	P	1.0
Potassium	K	0.4
Sulfur	S	0.3
Sodium	Na	0.2
Chlorine	Cl	0.2
Magnesium	Mg	0.1
Trace elements include boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).		less than 1.0

Figure: https://commons.wikimedia.org/wiki/File:201_Elements_of_the_Human_Body-01.jpg

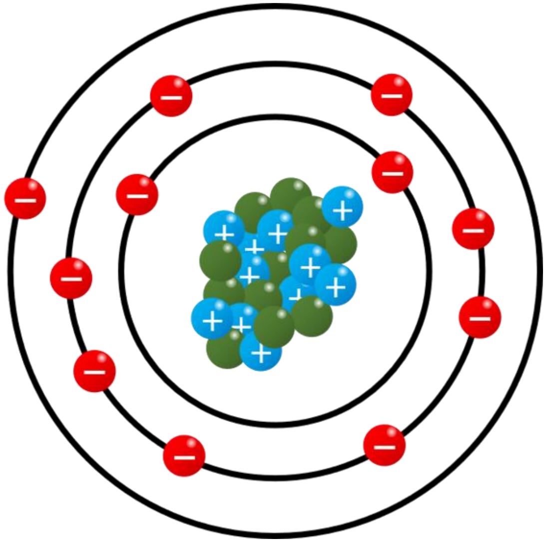
- e.g. an iron deficiency = anemia (low red blood cells), which causes fatigue, impaired immune function, & eventually death

- e.g. a potassium deficiency = muscle cramps, weakness, eventually the heart will stop beating

- e.g. an iodine deficiency = goiters (swollen thyroid glands, located in the neck), depression, & eventually deficits in mental function
  - *You don't need to know these examples, they are just to emphasize the importance of each element, even if you only need small amounts.*

Figure: https://commons.wikimedia.org/wiki/File:Goiter.JPG

- The smallest unit of an element = an **atom**
  - e.g. one unit of oxygen is an atom of oxygen (smallest you can get)



A single atom of the element sodium

"Because they are so long lived, atoms really get around. Every atom you possess has almost certainly passed through several stars and been part of millions of organisms on its way to becoming you. We are each so atomically numerous and so vigorously recycled at death that a significant number of our atoms – up to a billion for each us, it has been suggested – probably once belonged to Shakespeare."

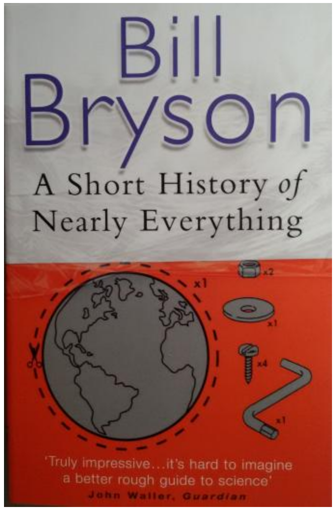


Figure: https://commons.m.wikimedia.org/wiki/File:Sodium_Atom.png

- <u>Atoms themselves are all made up of 3 components:</u>
  - **Protons** = positive charge (+)
  - **Neutrons** = no charge
  - **Electrons** = negative charge (-)
    - orbit around the nucleus within *electron shells*
    - *electrons are in constant motion orbiting the nucleus - the shells just represent where they are orbiting (virtual)*

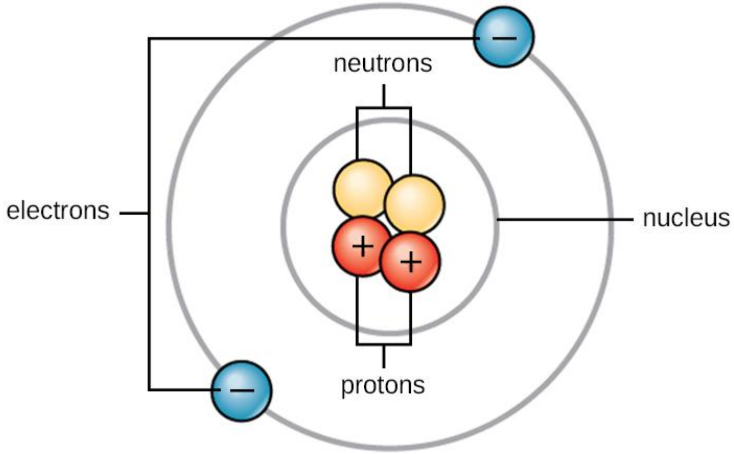
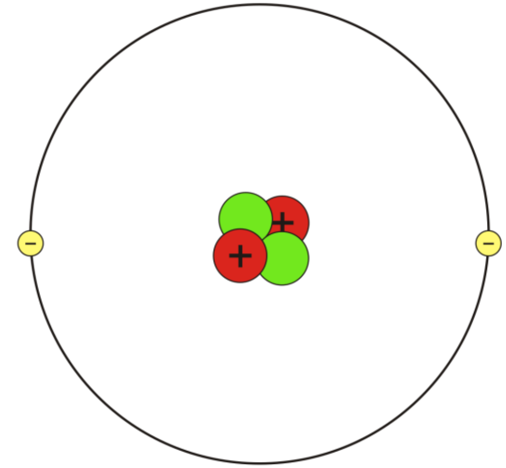


Figure: https://commons.wikimedia.org/wiki/File:OSC_Microbio_00_AA_atom.jpg

- Atoms are electrically neutral because the number of protons (+) is equal to the number of electrons (-)

- Other than hydrogen (a special case), a regular atom also has the same amount of neutrons
  - – e.g. helium atom = 2 protons, 2 neutrons, 2 electrons

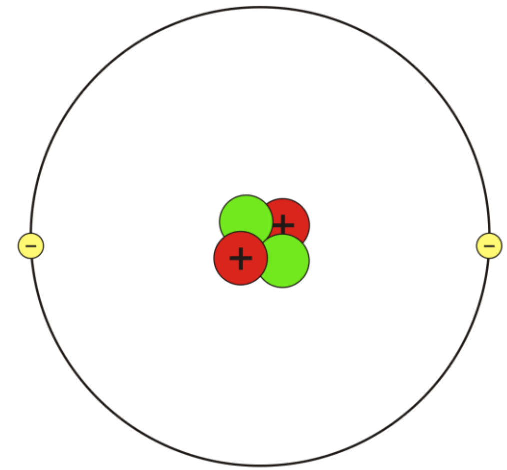
- *If an atom does not have the same number of everything, it will have a special name – we'll talk about these soon*



Helium (He)

Figure: https://commons.wikimedia.org/wiki/File:Helium-Bohr.svg

- **Protons**
  - Each element has a unique number of protons
    - e.g. hydrogen ALWAYS has one
    - e.g. helium ALWAYS has two
    - e.g. carbon ALWAYS has six
  - If you change the number of protons, you change the element completely
    - *e.g. if you add a proton to hydrogen, it becomes helium*



Helium (He)

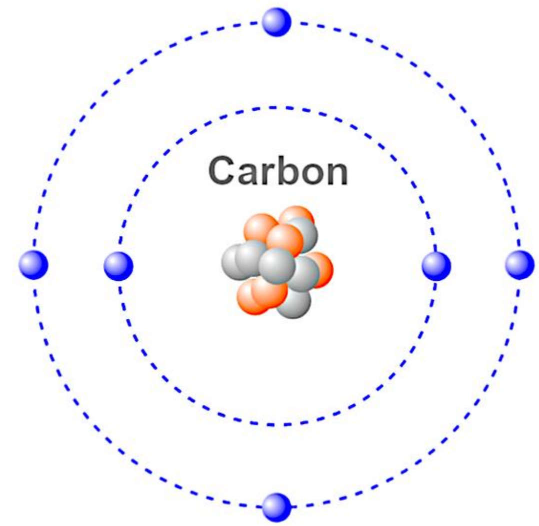
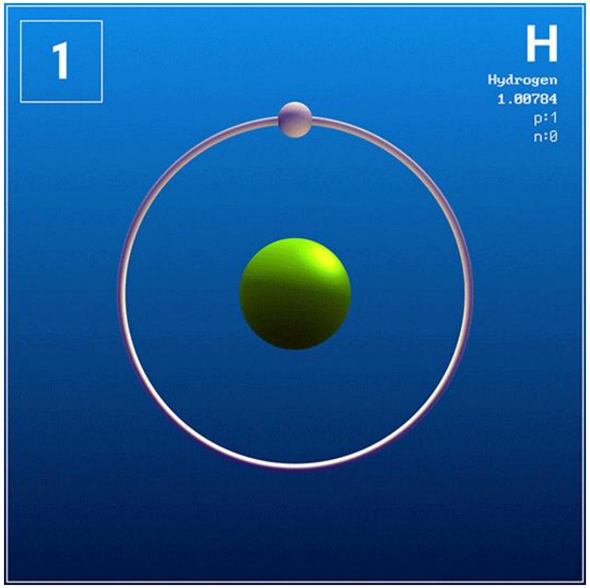


Figure: https://commons.wikimedia.org/wiki/File:Helium-Bohr.svg
Figure: https://pixabay.com/images/id-4426054/

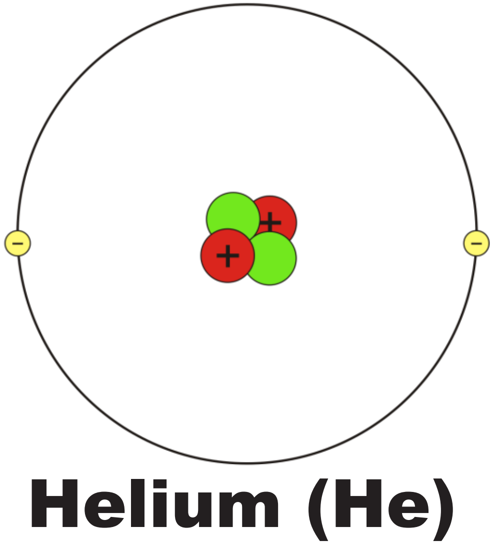
- Because an atom of hydrogen always has one proton no matter what, we can define hydrogen by this unchanging fact – we call this its atomic number
  - **Atomic number** = the number of protons an atom has

Hydrogen has an atomic number of 1



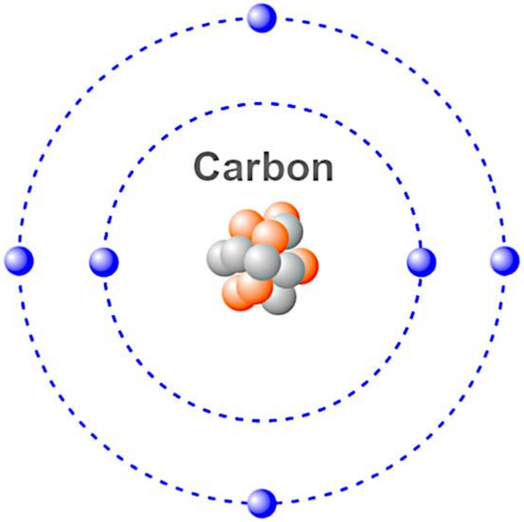
https://commons.wikimedia.org/wiki/File:Hydrogen_GIF.gif

Helium = 2



https://commons.wikimedia.org/wiki/File:Helium-Bohr.svg

Carbon = 6



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- On a periodic table of elements, you’ll always see the atomic number for each element listed

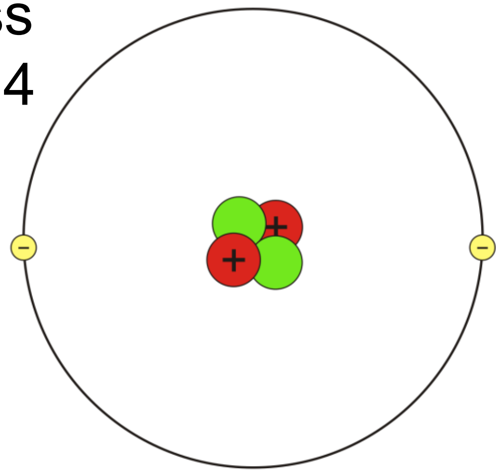
1 H																		2 He
3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Figure: https://commons.wikimedia.org/wiki/File:Simple_Periodic_Table_Chart-blocks.svg

- We can also describe an atom by its atomic mass
  - **Atomic mass** = number of protons + neutrons
    - *Electrons are so light, we usually ignore them in biology*

Atomic mass of helium = 4



Helium (He)

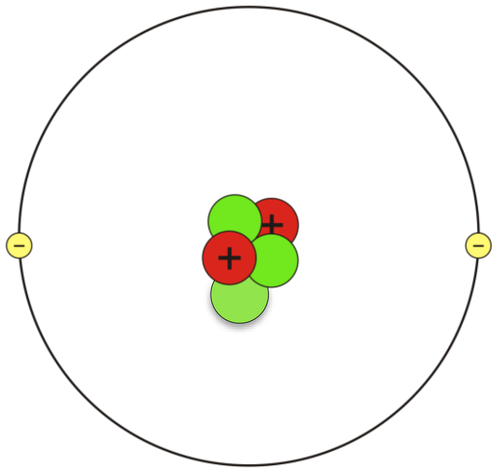
Protons, Neutrons, and Electrons

	Charge	Mass (amu)	Location
Proton	+1	1	nucleus
Neutron	0	1	nucleus
Electron	−1	0	orbitals

Figure: https://commons.wikimedia.org/wiki/File:Helium-Bohr.svg

Figure from OpenStax Biology 2e

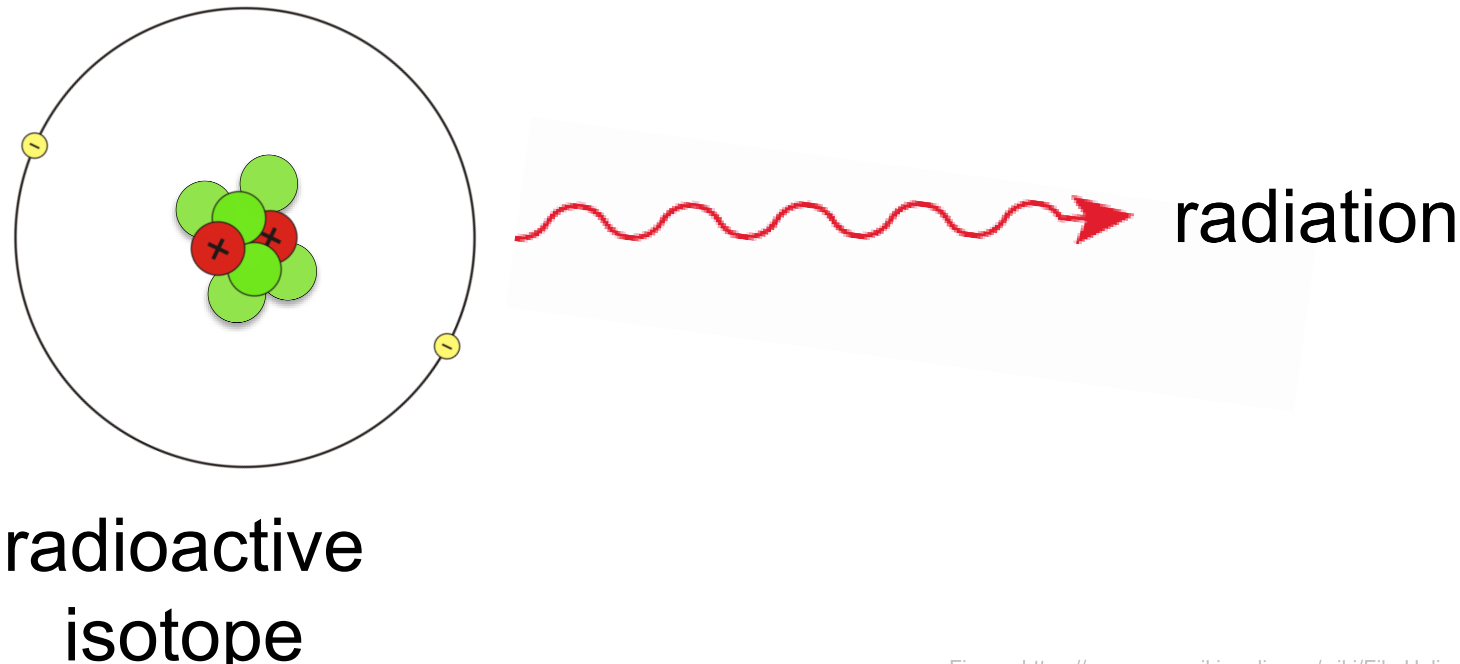
- **Neutrons**
  - The number of protons never changes, but the number of neutrons an atom has can change
    - A regular helium atom has 2 P+, 2 N, & 2 E-
  - An **isotope** = an atom with a different number of neutrons
    - e.g. helium with 2 P+, **3 N**, & 2 E-



Helium (He)

Figure: https://commons.wikimedia.org/wiki/File:Helium-Bohr.svg

- Why are isotopes important in biology?
  - Some isotopes are stable, but some are unstable
    - Unstable isotopes are **radioactive**
      - They break apart, releasing radiation



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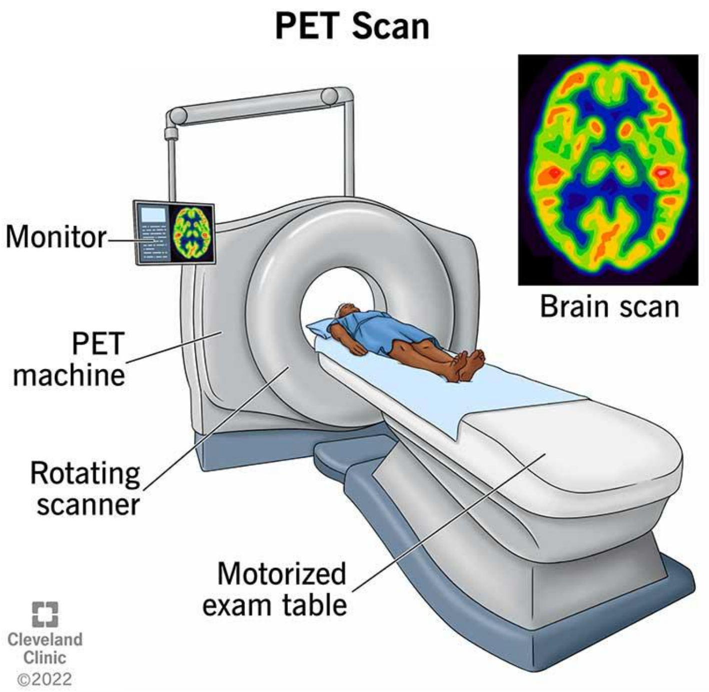
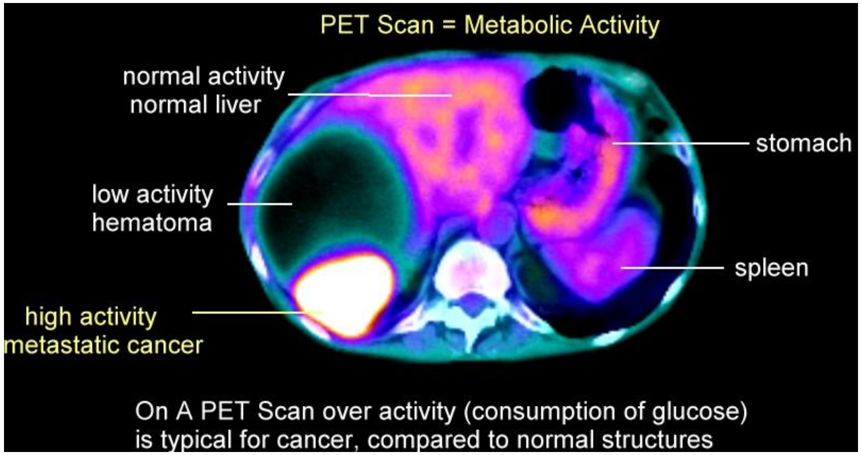


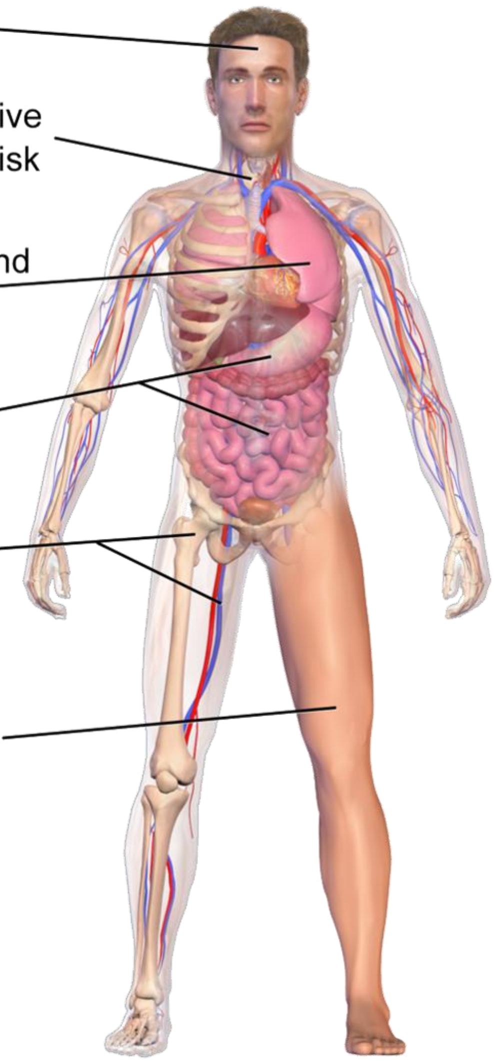
- **<u>How radioactivity / radiation benefits science:</u>**
  - – Harnessed for energy
  - – Treatment for cancer
  - – Determining the age of fossils
  - – Medical imaging (PET scans)
    - PET scan = low dose of radioactive glucose injected into patient
      - – *Positron Emission Tomography*
      - – *glucose is broken down for energy, releasing radio-activity, which we can measure*



Red indicates high radioactivity, showing a cancerous tumor using a lot of energy

http://www.aboutcancer.com/pet_scan.htm

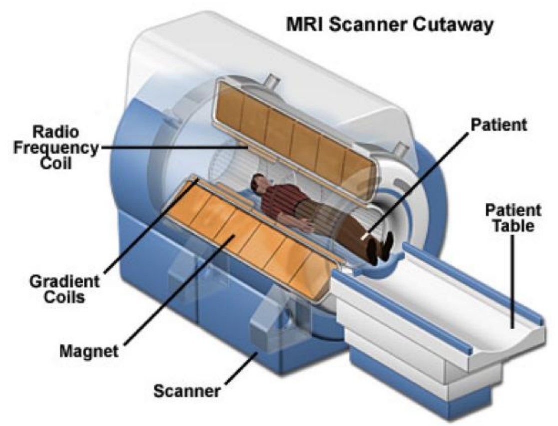
- Too much exposure to radiation can cause:
  - cancer
  - radiation sickness
  - severe birth defects
  - even death

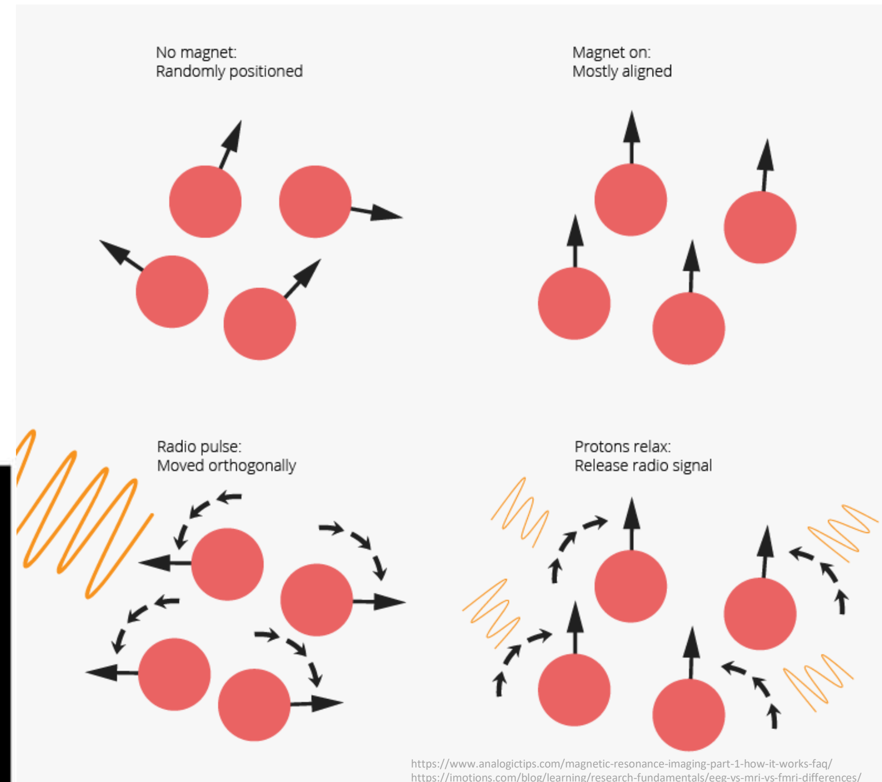


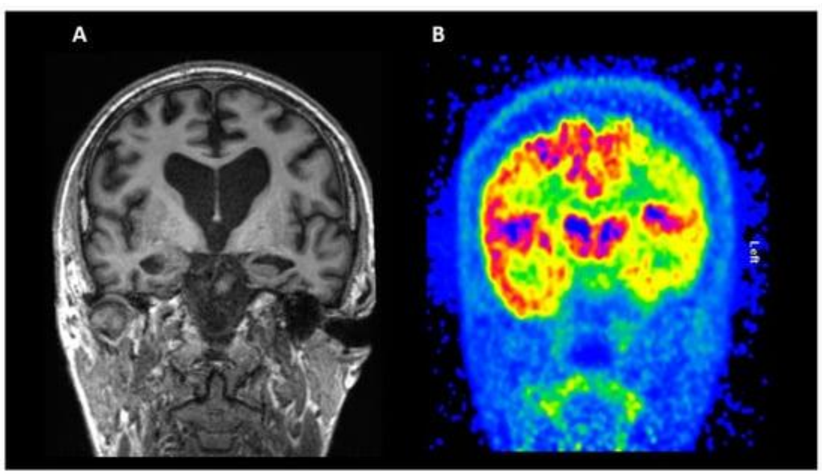
Selected Risks from Radiation Sickness

Figure: https://commons.wikimedia.org/wiki/File:Radiation_Sickness.png

MRI：Nuclear Magnetic Resonance Imaging



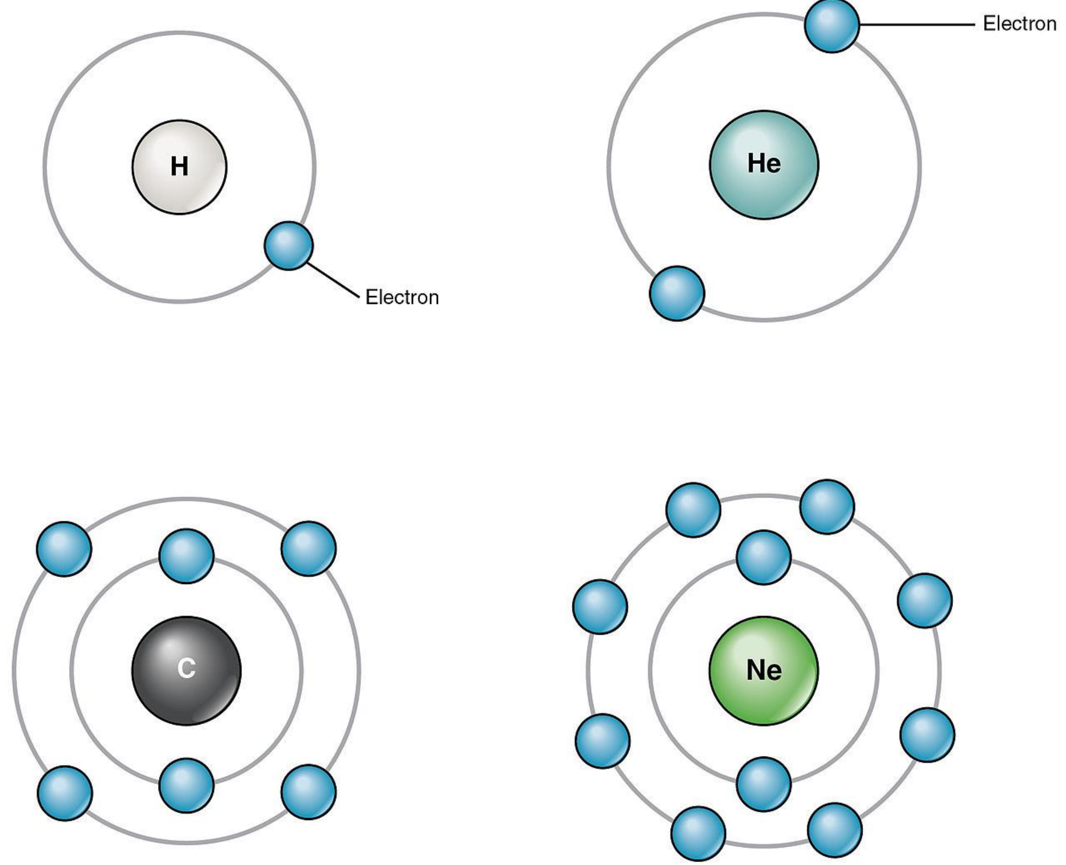




Imaging biomarkers of neurodegeneration. Coronal structural MRI section (panel **A**) and 18F-fluorodeoxyglucose (FDG) PET (panel **B**) from a patient with Alzheimer's disease (AD). *Int. J. Mol. Sci.* **2018**, *19*(12), 3702

- **Electrons** (-) are distributed around the atomic nucleus in electron shells, where they are in constant motion
  - The first electron shell holds up to 2 electrons
  - The second electron shell holds up to 8 electrons
  - The third electron shell also holds up to 8 or 18 electrons

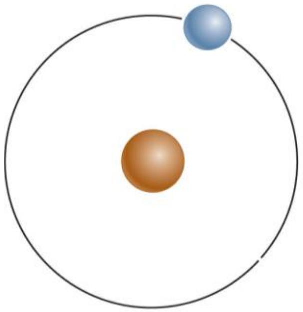
Hydrogen only has 1 electron but 2 can fit in this first shell



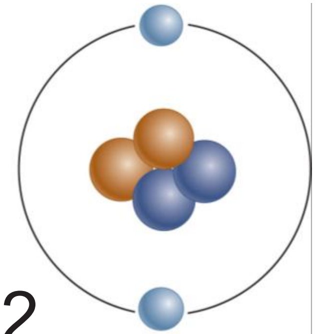
Carbon has 6 electrons, with 2 in the first shell and the remaining 4 in the second shell (which could hold up to 8)

Figure: https://commons.wikimedia.org/wiki/File:206_Electron_Shells-01.jpg

- Electrons are most stable when the outer shell of the atom is full
  - To fill their shells, atoms interact with other atoms, **losing**, **gaining**, or **sharing** electrons



Hydrogen (H)
- Atomic # = 1
- Outer shell not filled
- **Unstable**
- Will interact with other atoms



Helium (He)
- Atomic # = 2
- Outer shell filled
- **Stable**
- Will NOT interact with other atoms

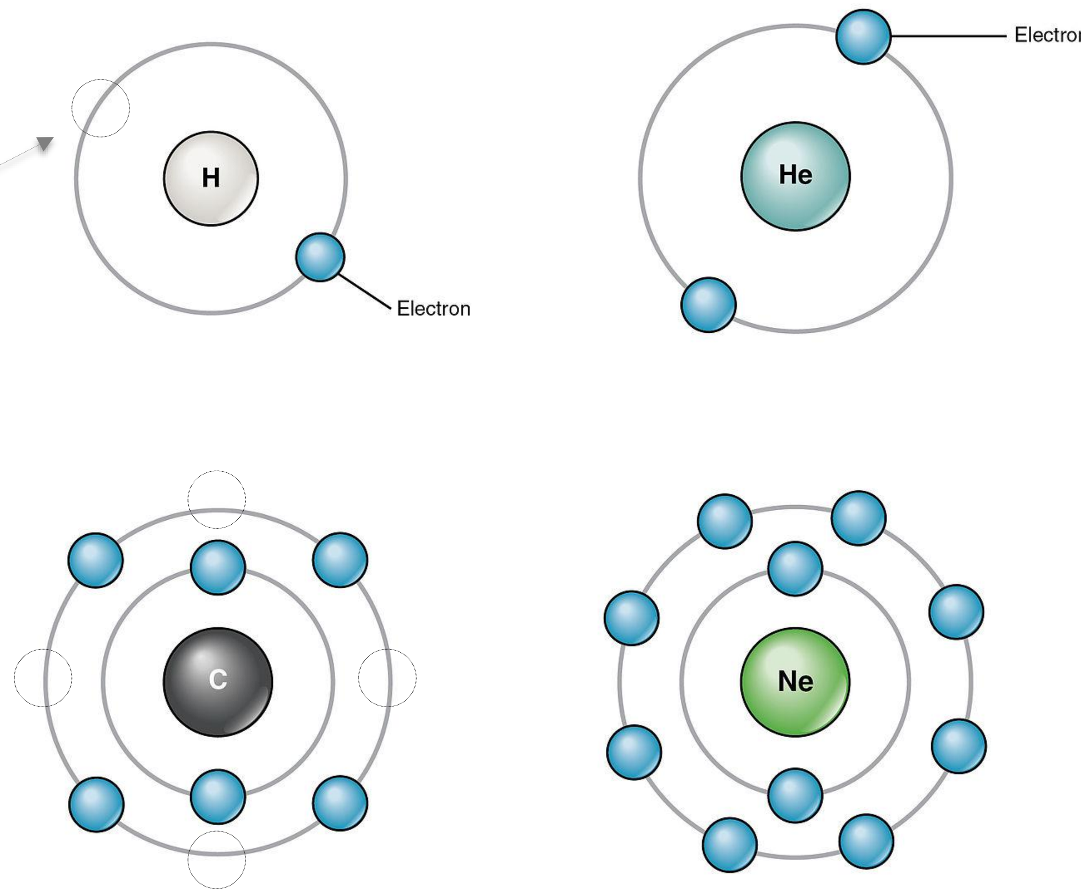
ELECTRON SHELLS AND ATOM STABILITY

ATOM STABILITY

Atoms become stable when their outermost shell is filled to capacity. Stable atoms tend not to react or combine with other atoms.

UNSTABLE ATOMS | **STABLE ATOMS**

can hold 1 more

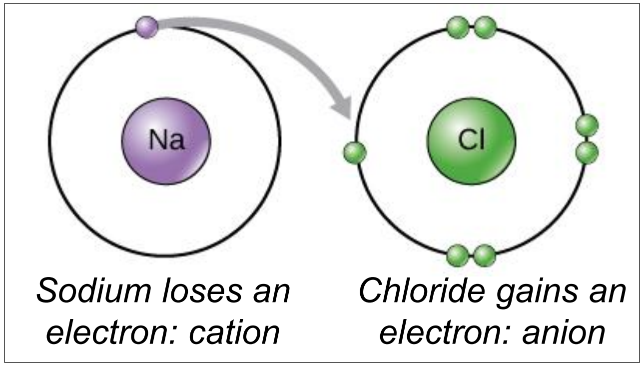


Only when atoms have electron vacancies in their outermost shell are they likely to interact with other atoms.

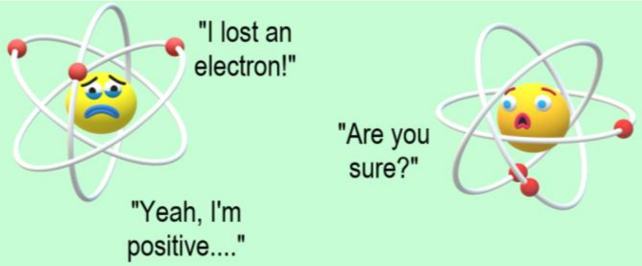
can hold 4 more

Figure: https://commons.wikimedia.org/wiki/File:206_Electron_Shells-01.jpg

- Atoms that lose or gain electrons to become stable are called **ions**



  - An atom that loses an electron (-) will have a positive charge = **cation**
    - e.g. carbon with 6 P+, 6 N, & 5 E-

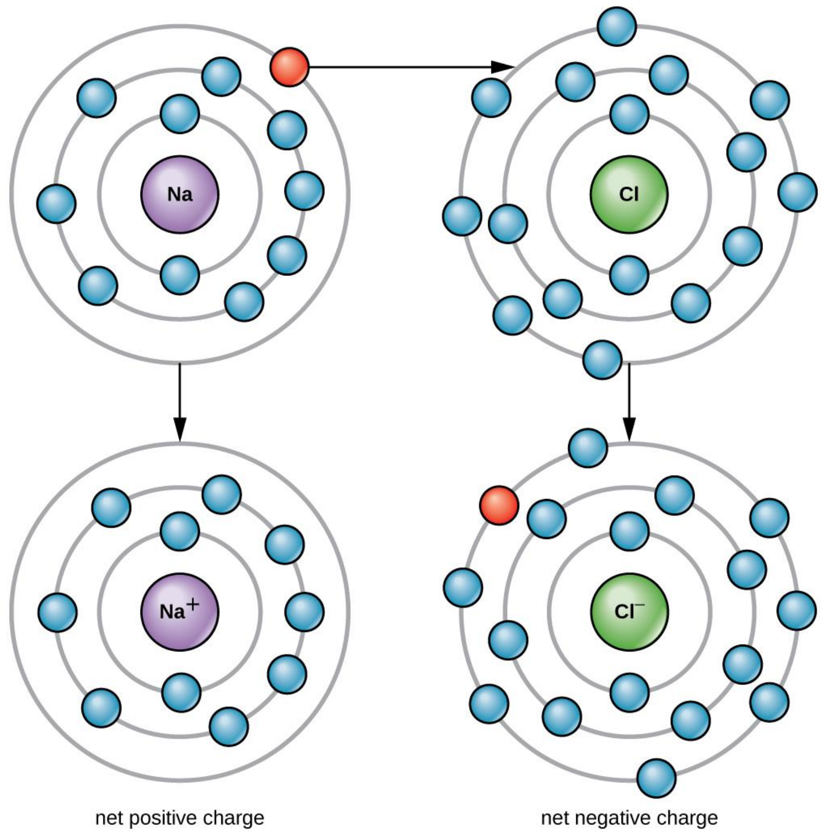


  - An atom that gains an electron (-) will have a negative charge = **anion**
    - e.g. carbon with 6 P+, 6 N, & 7 E-

Figure: https://commons.wikimedia.org/wiki/File:Figure_02_01_10.jpg
Figure: https://commons.wikimedia.org/wiki/File:Lost_an_electron_joke.png

IONS ARE CHARGED ATOMS

An atom that loses one or more electrons becomes positively charged, while an atom that acquires electrons becomes negatively charged. This transfer of electrons is driven by the fact that atoms with full outer electron shells are more stable.



cation

SODIUM ION

- ⊕ 11 Protons
- 11 Neutrons
- ⊖ 10 Electrons

CHLORIDE ION

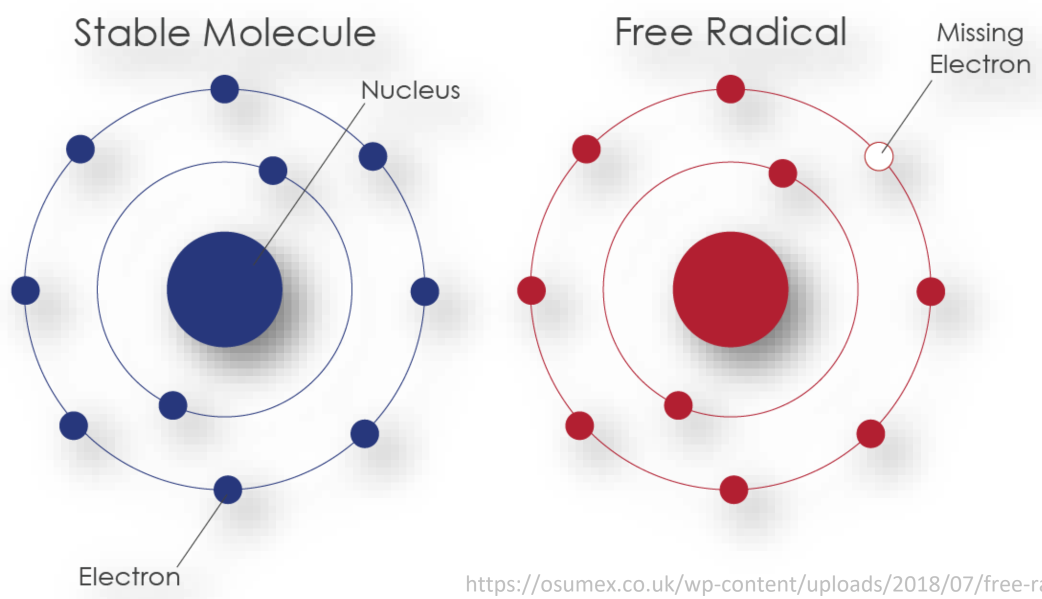
- ⊕ 17 Protons
- 17 Neutrons
- ⊖ 18 Electrons

anion

Free Radical *(in biology)*

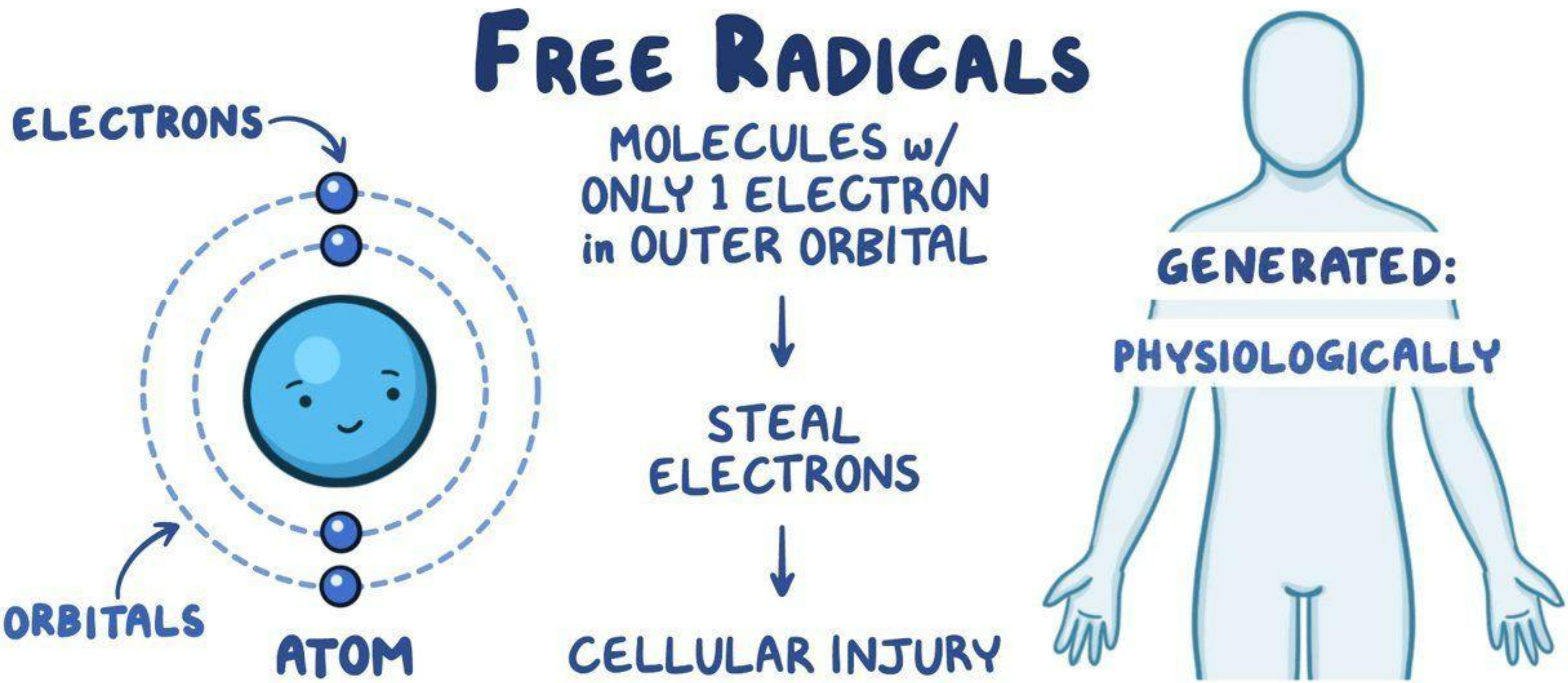
- Atoms interact with each other in order to stabilize
  - Some chemical reactions cause an atom or molecule to be stripped of its electrons
    - Can be caused by radiation, UV light, some chemicals & food additives, pesticides, pollution, cigarette smoke, etc.

An atom or molecule that has been stripped of its electrons & is highly unstable = free radical



https://osumex.co.uk/wp-content/uploads/2018/07/free-radicals.png

- **Free radicals** are HIGHLY unstable: grab electrons from any nearby source to stabilize themselves
  - Stealing electrons = new free radicals, plus it damages the molecules so they can't do their jobs in the body anymore



https://d16qt3wv6xm098.cloudfront.net/NH5khCmqQiyorEyBcI0d-GLOSNy8eq-T/_.jpg

- Free radicals are more & more common as pesticides, pollution, etc. increase in our environment

- How can we fight free radicals?
  - There are special molecules that can stabilize free radicals without becoming free radicals themselves = **antioxidants**

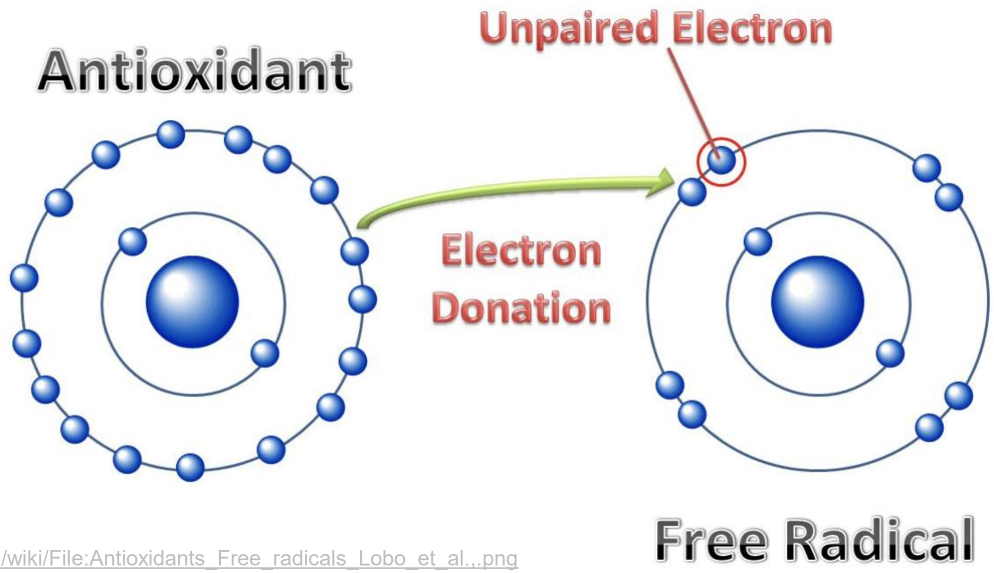


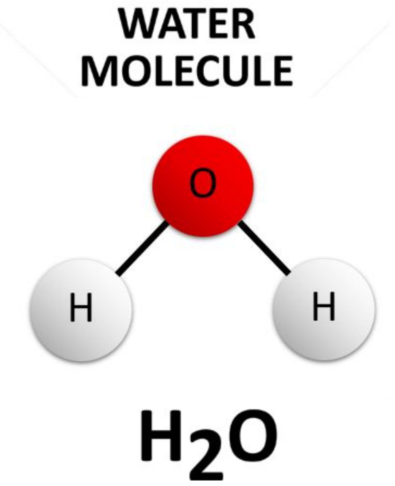
Figure: https://commons.wikimedia.org/wiki/File:Antioxidants_Free_radicals_Lobo_et_al..png

- Antioxidants include vitamins A, E, & C, flavenoids, carotenoids, etc.
  - Found in high amounts in fruits & vegetables (especially raw)
  - Moderate amounts in nuts, tea, & coffee
  - Low amounts in red wine & dark chocolate
    - *watch out for milk proteins in chocolate or coffee though – bind to & negate antioxidants*

https://pixabay.com/photos/antioxidant-apple-avocado-5954193/ https://commons.wikimedia.org/wiki/File:Dark_chocolate_Blanxart.jpg
https://commons.wikimedia.org/wiki/File:Mint_tea_-_Petr_Kratochvil.jpg

Atoms link together using chemical bonds to form molecules

- The interaction of atoms can cause them to attach together through **chemical bonds**
  - 2 or more atoms joined together by chemical bonds = **molecule**
    - e.g. oxygen joins to 2 hydrogen atoms through chemical bonds to make a water molecule



  - *Remember: life is organized – atoms make up* ***molecules****, which make up cells, which make up us*
  - *Remember: life requires energy & nutrients, which we get through eating* ***molecules*** *like fats & proteins*

Figure: https://commons.wikimedia.org/wiki/File:Water_Molecule_Ball_and_Stick.png

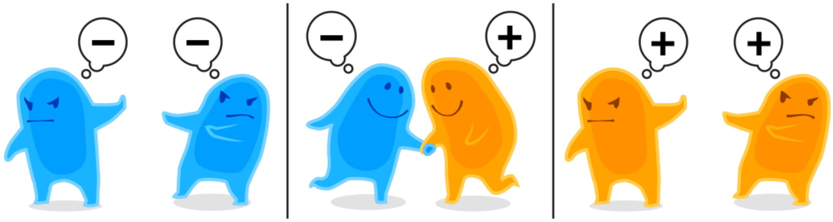
- There are many types of chemical bonds that hold molecules together
  - 3 types are important for biology: they hold together our bodies & the foods that we eat

Type of Bond	Chemical Interaction	Strength
Ionic	An electron is transferred, creating positive & negative ions that attract one another	Moderate – breaks easily in water
Covalent - Nonpolar - Polar	Electrons are shared between atoms - Equally - Unequally	Strong
Hydrogen	A positive atom within a molecule is attracted to a negative atom in a different molecule	Weak

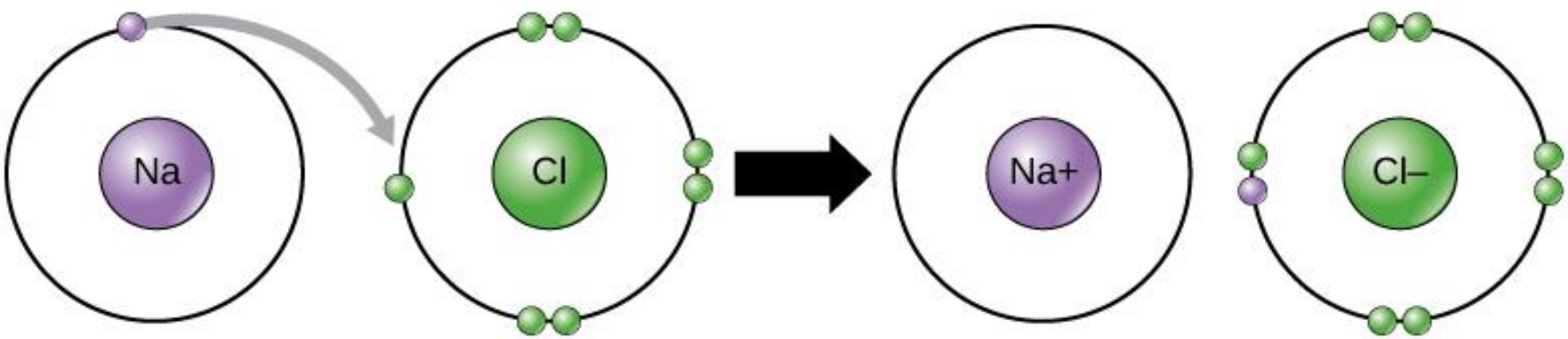
Ionic Bonds

– The electrical attraction between cations (+) & anions (-) pulls atoms together

- *similar to magnets*

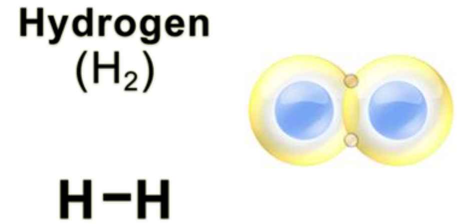


cations (+) and anions (-) attract, forming ionic bonds



cation *anion* *ionic bond forms between them*

Figure: https://commons.wikimedia.org/wiki/File:Ion-attraction-snd.svg
Figure: https://commons.wikimedia.org/wiki/File:Figure_02_01_10.jpg

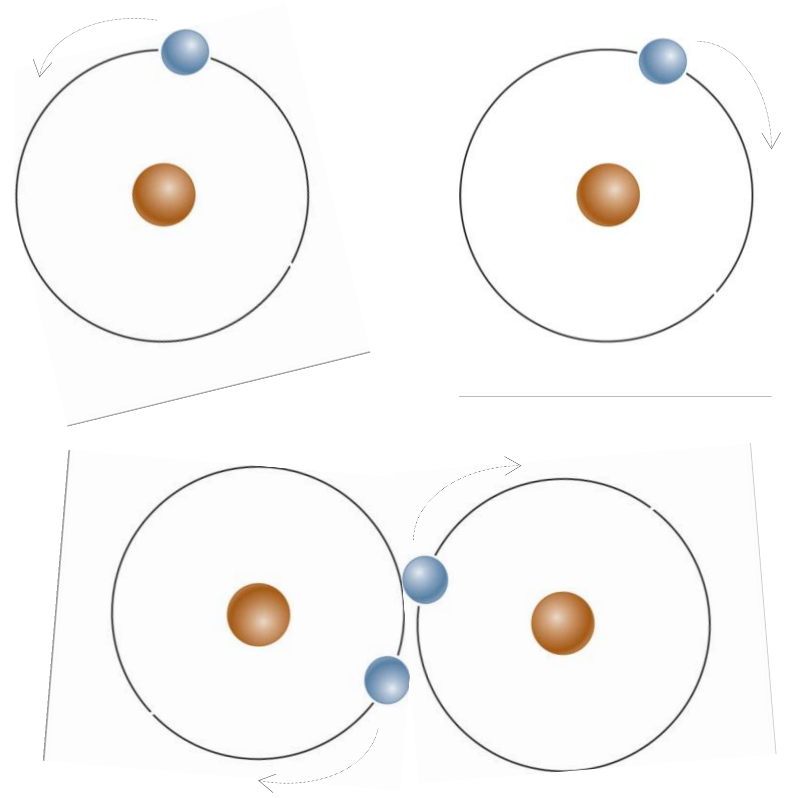


Covalent Bonds

- Two atoms <u>share</u> electrons
  - this means each shared electron will orbit its own atom, but also orbit the other atom

1 **An atom of hydrogen has one electron in its first shell. One more electron is needed to fill the shell.**

2 **The nuclei of two hydrogen atoms come closer together and share the two electrons, which circle around both of them. The new H_2 molecule is more stable.**

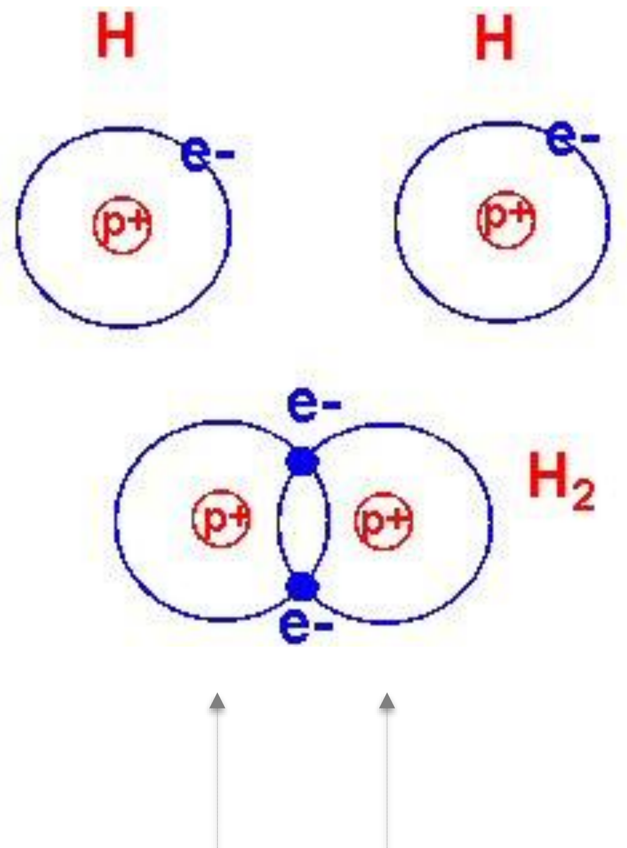


Remember, electrons are constantly orbiting in the shell.
These are 2 unstable atoms.

Now the shells overlap and each electron is orbiting both atoms.
This is now a stable molecule.

Figure: https://commons.wikimedia.org/wiki/File:Covalent_Bonds.png

- 2 types of covalent bonds:
  - **Nonpolar** = electrons shared evenly = uncharged
    - No charge builds up on either side

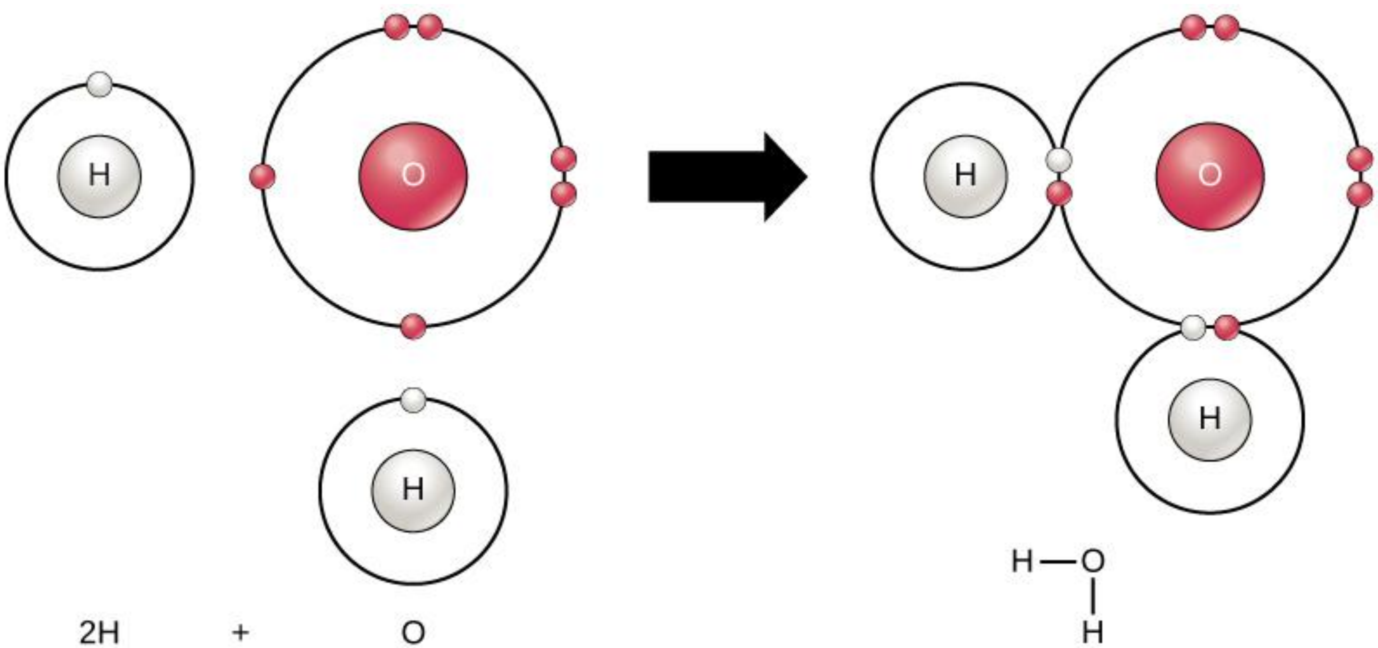


Same charge on either side (1 positive proton each), & electrons spend equal time near each nucleus

So no charge builds up on either side of this H_2 molecule: **nonpolar**

Figure: https://www.flickr.com/photos/loufcd/2811714713/

- 2 types of covalent bonds:
  - **Polar** = electrons NOT shared evenly = charged
    - A charge builds up on either side of the bond

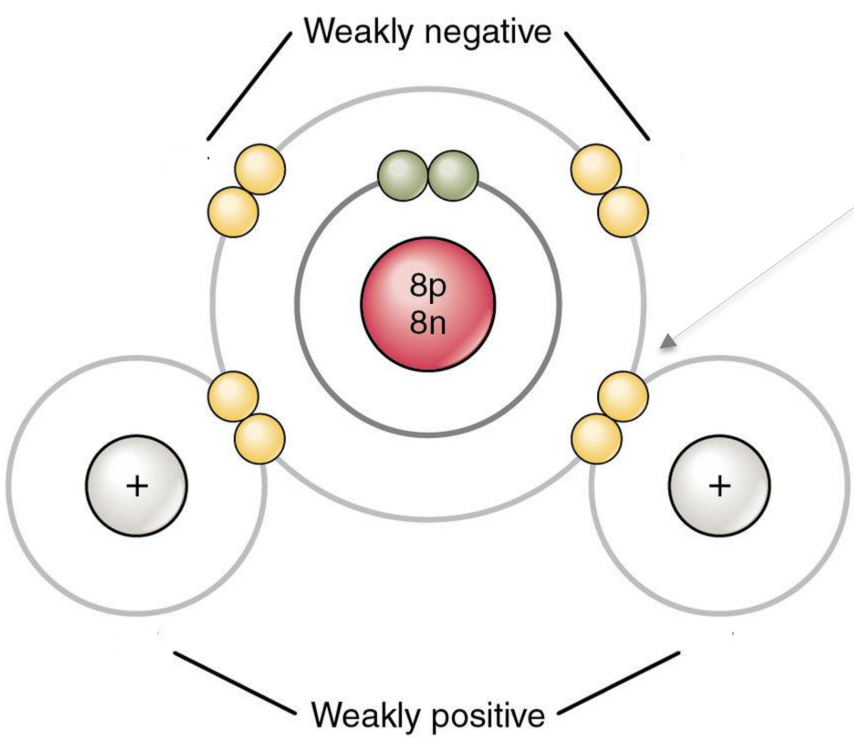


three unstable atoms

stable H_2O molecule

Figure: https://commons.wikimedia.org/wiki/File:Figure_02_01_08.jpg

- Polar = electrons NOT shared evenly = charged
  - Some atoms pull more on electrons than others *(based on "electronegativity," which is more detail than we will go into)*
    - Shared electrons now spend more time around one atom & less time around the other atom



Remember: electrons are in constant orbit but they're more often orbiting Oxygen here. That means the Hydrogen atoms have a positive proton but no negatives around them most of the time, so they're now kind of positive.

In a water molecule (H_2O) the oxygen pulls more on the electrons

Figure: https://commons.wikimedia.org/wiki/File:209_Polar_Covalent_Bonds_in_a_Water_Molecule.jpg

- Because oxygen pulls more on the electrons (-), which spend more time around it, it now has a slight negative charge
- The hydrogen atoms don't have electrons (-) around them very often, so now they are slightly positive

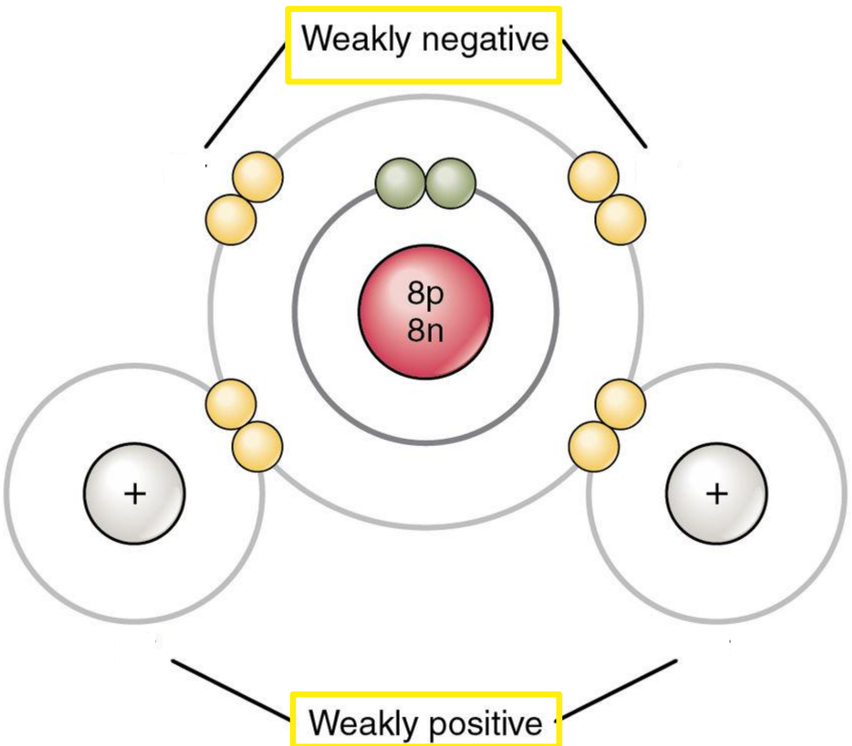


Figure: https://commons.wikimedia.org/wiki/File:209 Polar Covalent Bonds in a Water Molecule.jpg

Hydrogen Bonds

– Polar covalent bonds (like in H_2O) produce positive & negative regions

- These regions repel & attract each other, just like ions (or magnets)
- *Notice the negative ends attract the positive ends & vice versa, so the entire molecules stick to each other*

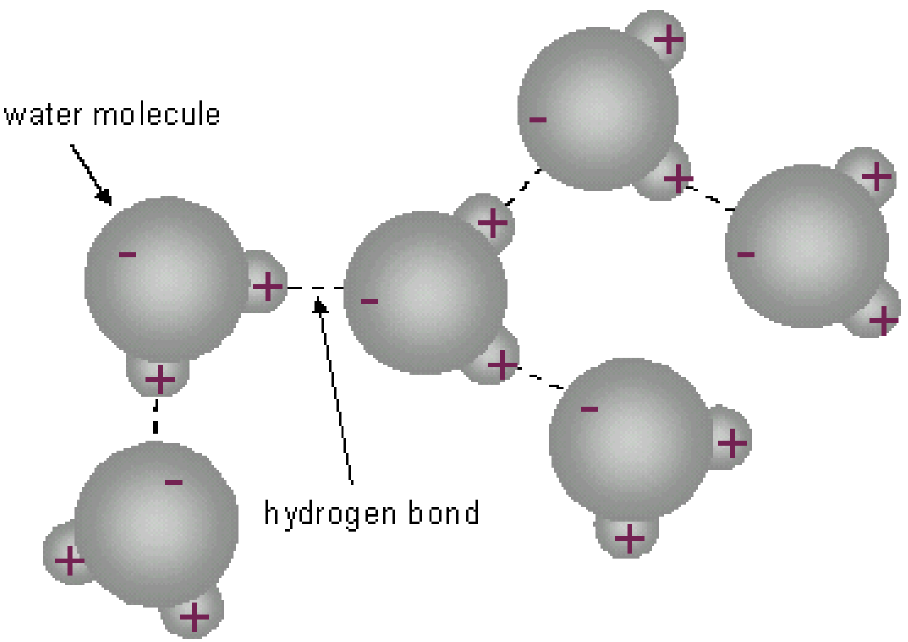


Figure: https://en.wikiversity.org/wiki/File:Water_molecules,_hydrogen_bonds.gif

Intermolecular forces

The force that holds the molecules together (van der Waals force)

Cooling Cooling

Gaseous State Liquid state Solid

Molecular distance reduction Shortened molecular distance

Molecules move irregularly Molecules are arranged in a regular way

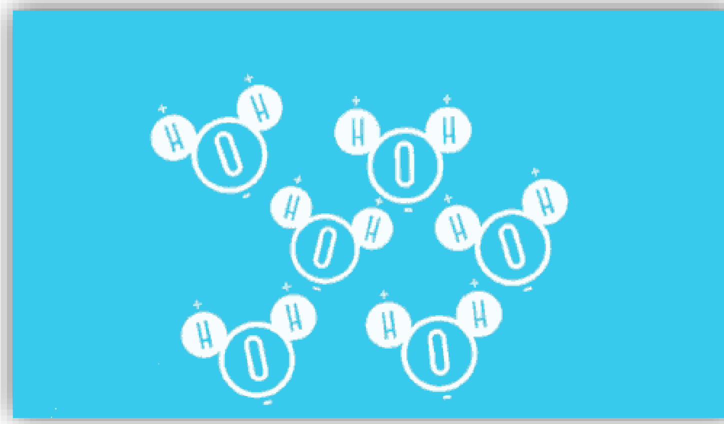
It shows that there are forces between the molecules of matter

This intermolecular force is called the van der Waals force

Intermolecular forces 《 chemical bonding

Intermolecular force is an electrostatic action

J.d. van der Waals (1837-1923) was a Dutch physicist.
He was the first to study intermolecular forces, hence the van der Waals force, also called the van der Waals force.



1. Being:

Van der Waals forces are common between solid, liquid, and gas molecules

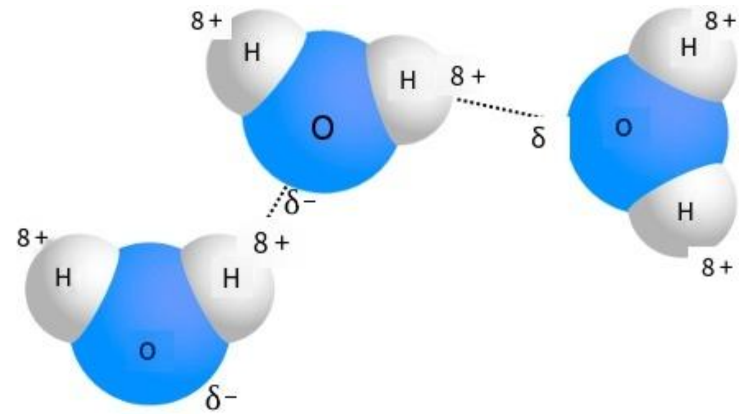
2. Directivity and saturation:

Van der Waals forces are generally not directional, saturated, as long as the space around the molecule permits, when the gas molecules condensed, it always attracts as many other molecules as possible

3. Aggregation and separation:

Affect melting, boiling point and other physical properties; And interaction between macromolecules

Intermolecular forces
Hydrogen bond

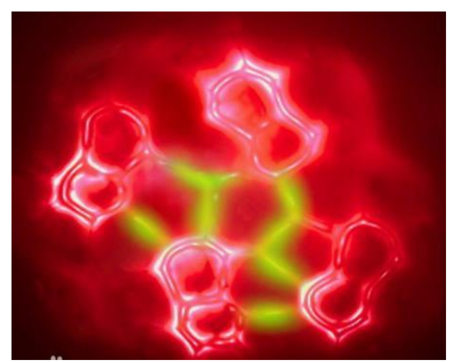


The pair of electrons shared between the O and H atoms is predominantly localized in the region between the two atoms. Given that the H atom possesses only this single pair of electrons, it can be likened to a half-peeled orange, with a significant portion of its nucleus exposed, resulting in a certain degree of positive charge. In contrast, oxygen, with its eight electrons, exhibits electronegativity to some extent.
When an O atom from one water molecule approaches a H atom from another water molecule, an electrostatic attraction occurs; this interaction is referred to as a hydrogen bond.

The hydrogen atom is covalently bonded to the electronegative atom X.

When it is in proximity to a small-radius electronegative atom Y (such as O, F, or N), a unique interaction occurs between X and Y, with H serving as a medium to facilitate the formation of an X-H...Y interaction known as a hydrogen bond.

X and Y may consist of identical atoms, exemplified by the hydrogen bonds present between water molecules; alternatively, they can be different types of atoms, such as ammonia hydrate ($NH_3 \cdot H_2O$).



Professor Qiu Xiaohui:

A hydrogen bond is like two people holding hands; they can easily pull apart or let go.

On the other hand, a chemical bond is more like their own hands and feet being tied together, making it impossible to separate.

Why does water possess a greater density than ice?

What implications does this phenomenon hold for the origin and sustenance of life?

DISCUSSION

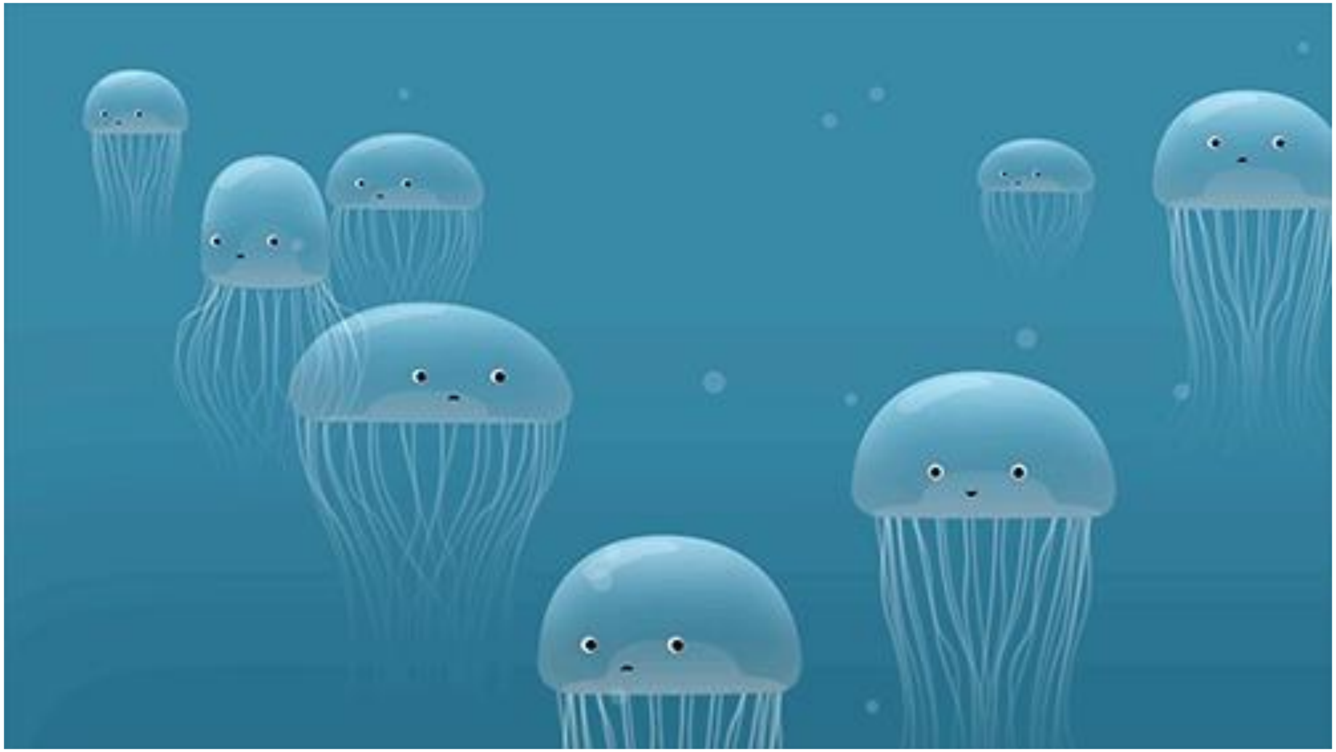
Tips:

No length restrictions or requirements; within 1 week.

Use what you know and think to make your point clearly and smoothly.

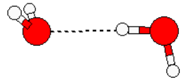
Just remember to do your own writing, because our Tas are really experienced.

Hydrogen bonds



The existence of living organisms relies on water.

Life is fundamentally dependent on hydrogen bonds.



The 6 principles governing hydrogen bonding:

1. The formation of hydrogen bonds primarily arises from electrostatic forces. A partial covalent bond is established between the hydrogen atom (H) and the electronegative atom (Y) due to electrostatic interactions resulting from charge transfer between donor and acceptor species. The creation of this covalent bond is a consequence of discrete actions.

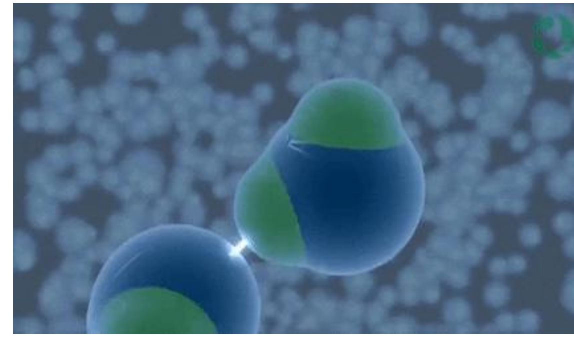
2. The typical covalent bond formed between atom X and hydrogen (X–H) is characterized as a polar bond. The strength of the interaction H…Y increases with the increasing electronegativity of atom X.

3. The dihedral angle formed by X—H…Y approaches linearity, ideally close to 180 degrees; stronger hydrogen bonds correspond to shorter distances between H and Y.

4. Hydrogen bonding causes an increase in the X-H distance, and the longer the X-H…Y bond length, the stronger the H…Y hydrogen bond will be, and some new vibrational modes will also be formed.

5. Hydrogen bonds also generate distinctive NMR signals, including the spin coupling interactions between atoms X and Y resulting from hydrogen bonding.

6. The Gibbs free energy associated with these hydrogen bonds exceeds that of thermal energy within the system.



The average bond energy data for common hydrogen bonds is:

F—H … F (155 kJ/mol or 40 kcal/mol)

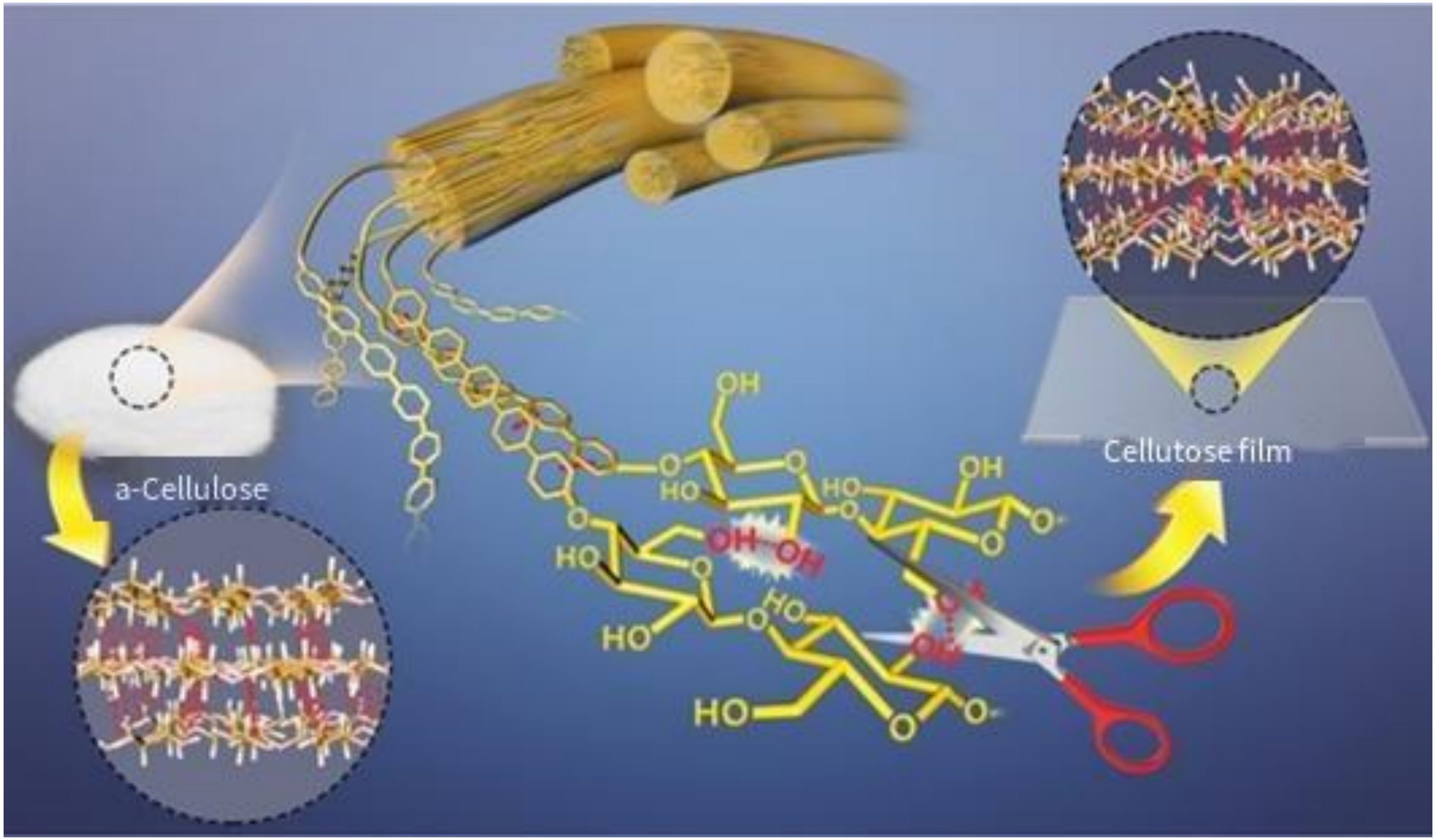
O—H … N (29 kJ/mol or 6.9 kcal/mol)

O—H … O (21 kJ/mol or 5.0 kcal/mol)

N—H … N (13 kJ/mol or 3.1 kcal/mol)

N—H … O (8 kJ/mol or 1.9 kcal/mol)

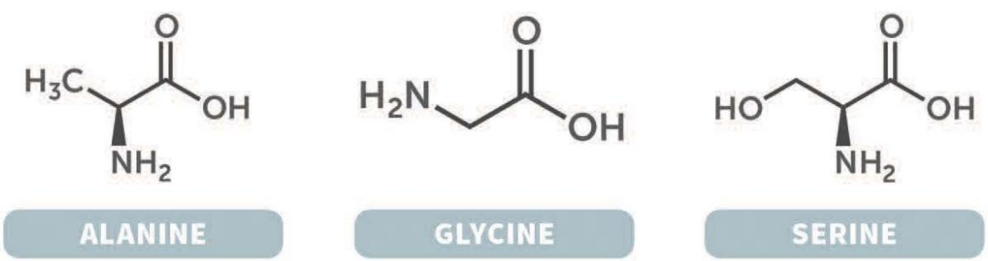
https://taylorsciencegeeks.weebly.com/blog/archives/02-2019/5


Cellutose film
a-Cellulose
OH
HO
O
OH OH

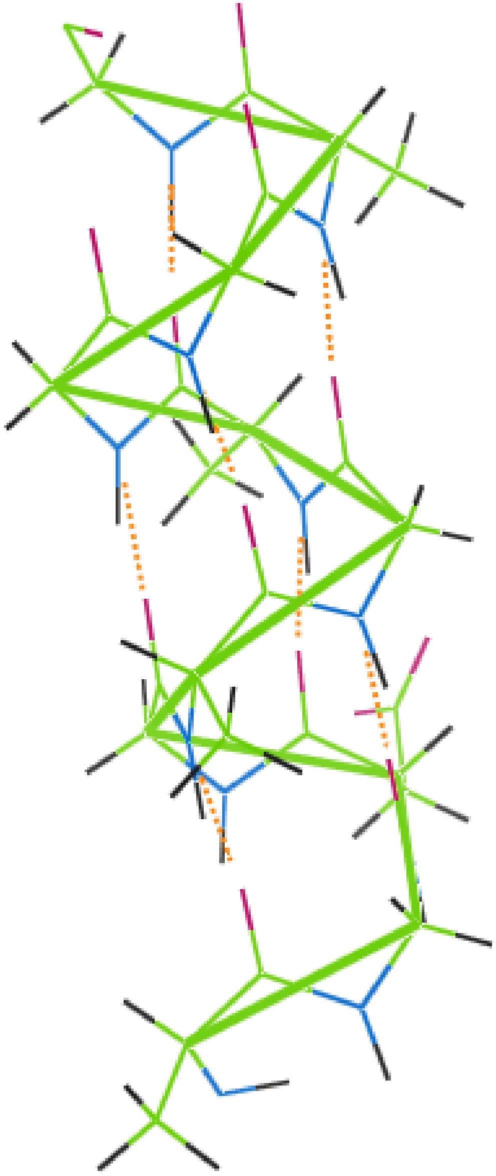
THE CHEMISTRY OF SPIDERWEBS

October is mating season for some spiders. Like them or loathe them, these arachnids use some fascinating biochemistry to spin webs with unique material properties that scientists want to emulate.

SPIDER SILK'S ELASTICITY AND STRENGTH



Spider silk is a protein fiber. Major amino acids in the silk proteins are alanine and glycine. Serine and proline are also present in significant quantities in some types of silk. Glycine-rich regions give spider silk its elasticity, forming amorphous areas in its structure. Alanine-rich regions link together through hydrogen bonds to form crystalline areas that give spider silk its strength.



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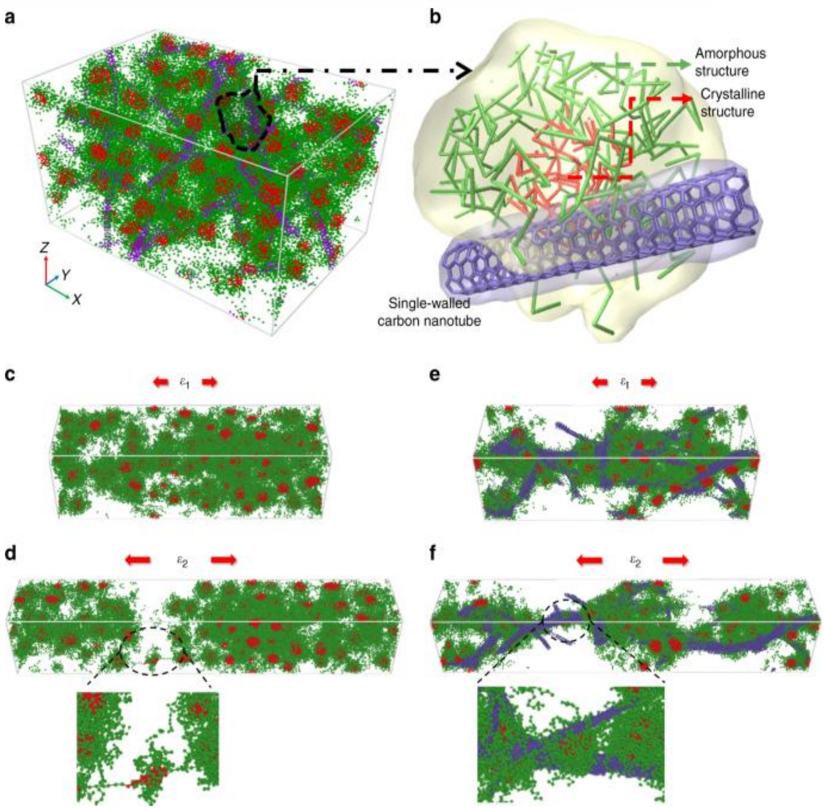
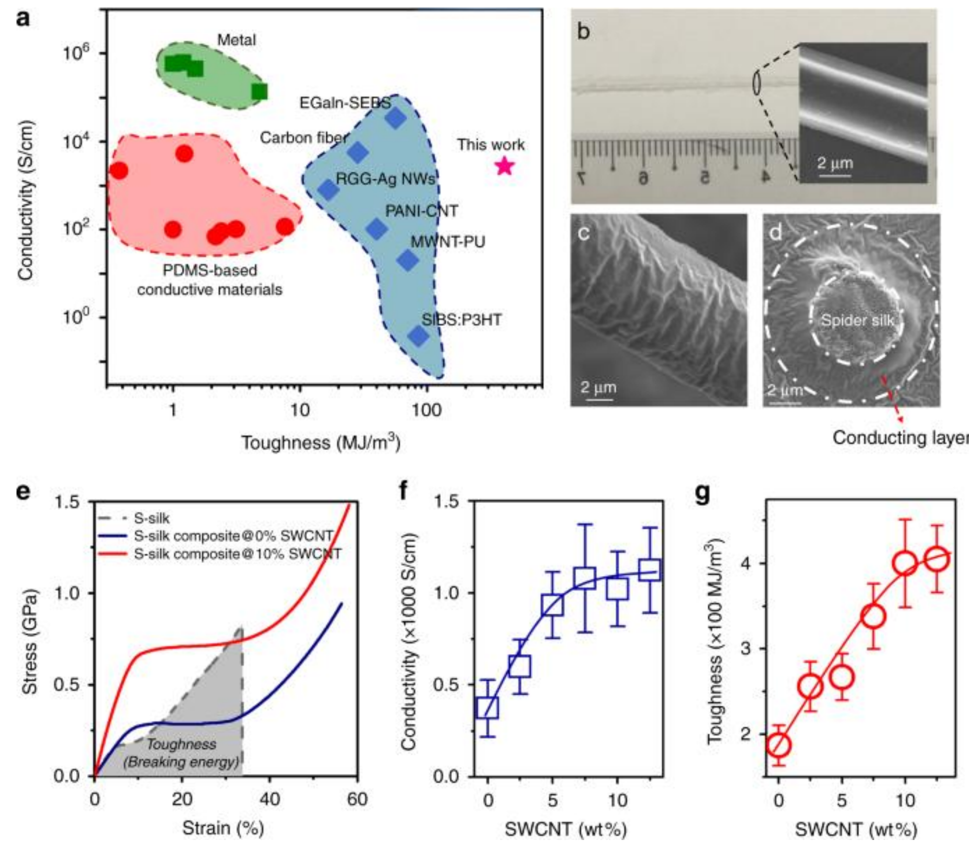
A supertough electro-tendon based on spider silk composites

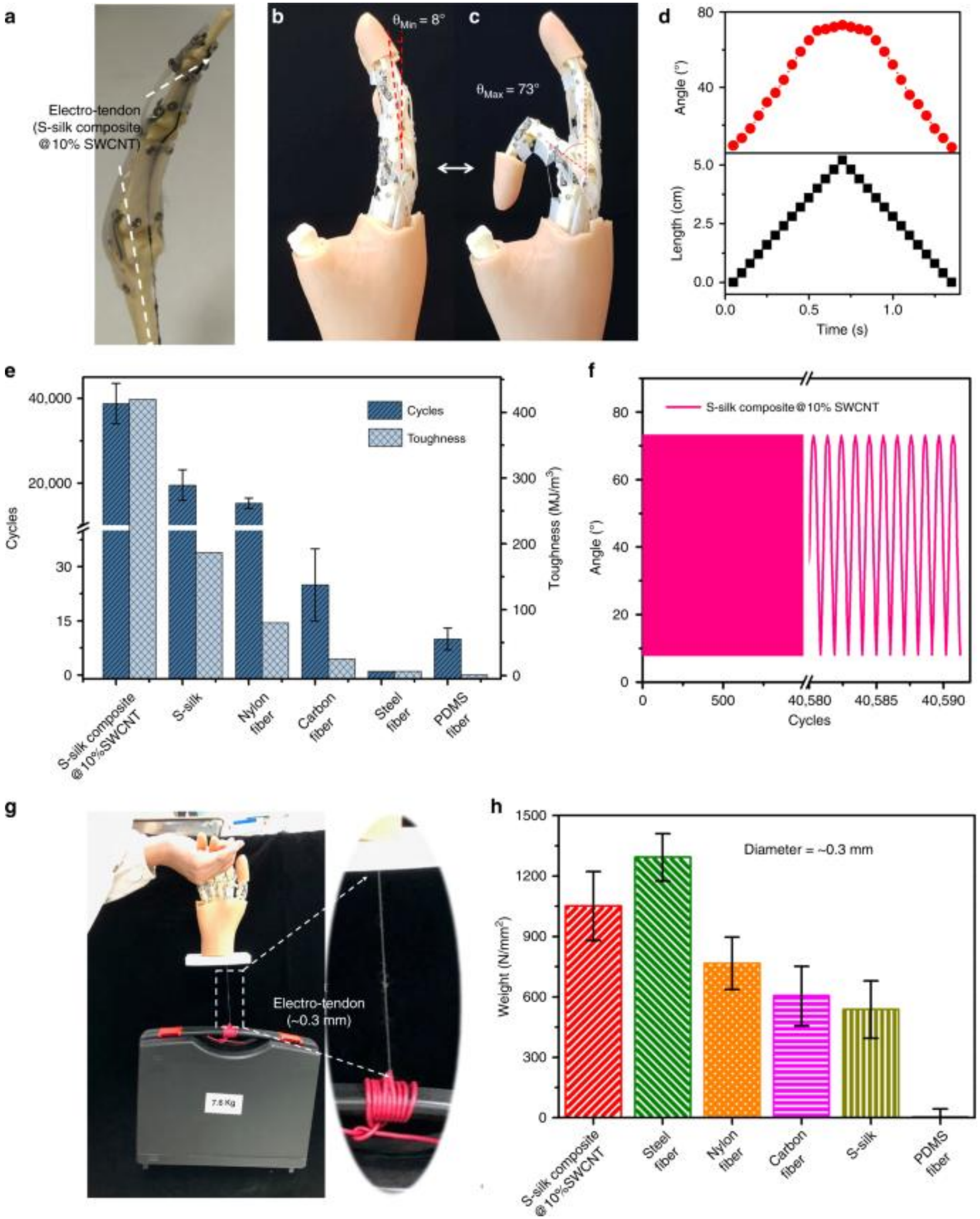


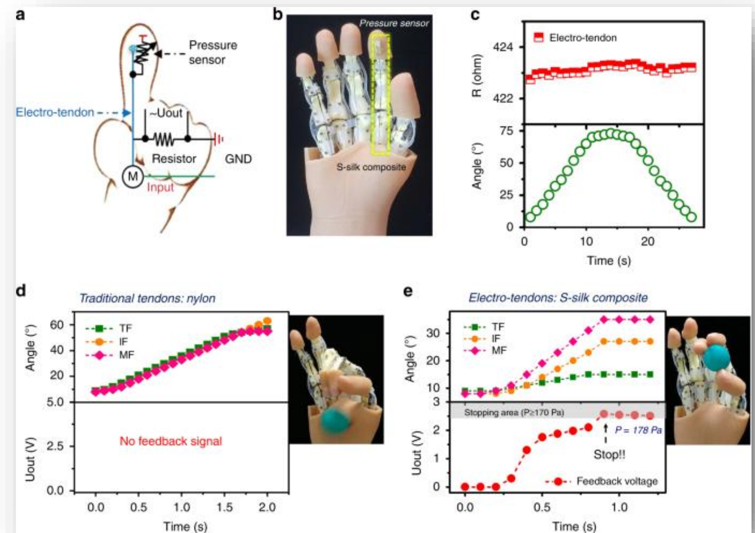
A typical mechanical test of the silk-SWCNT nanocomposite in DPD simulation.



Toughness and conductivity of spider silk composites.

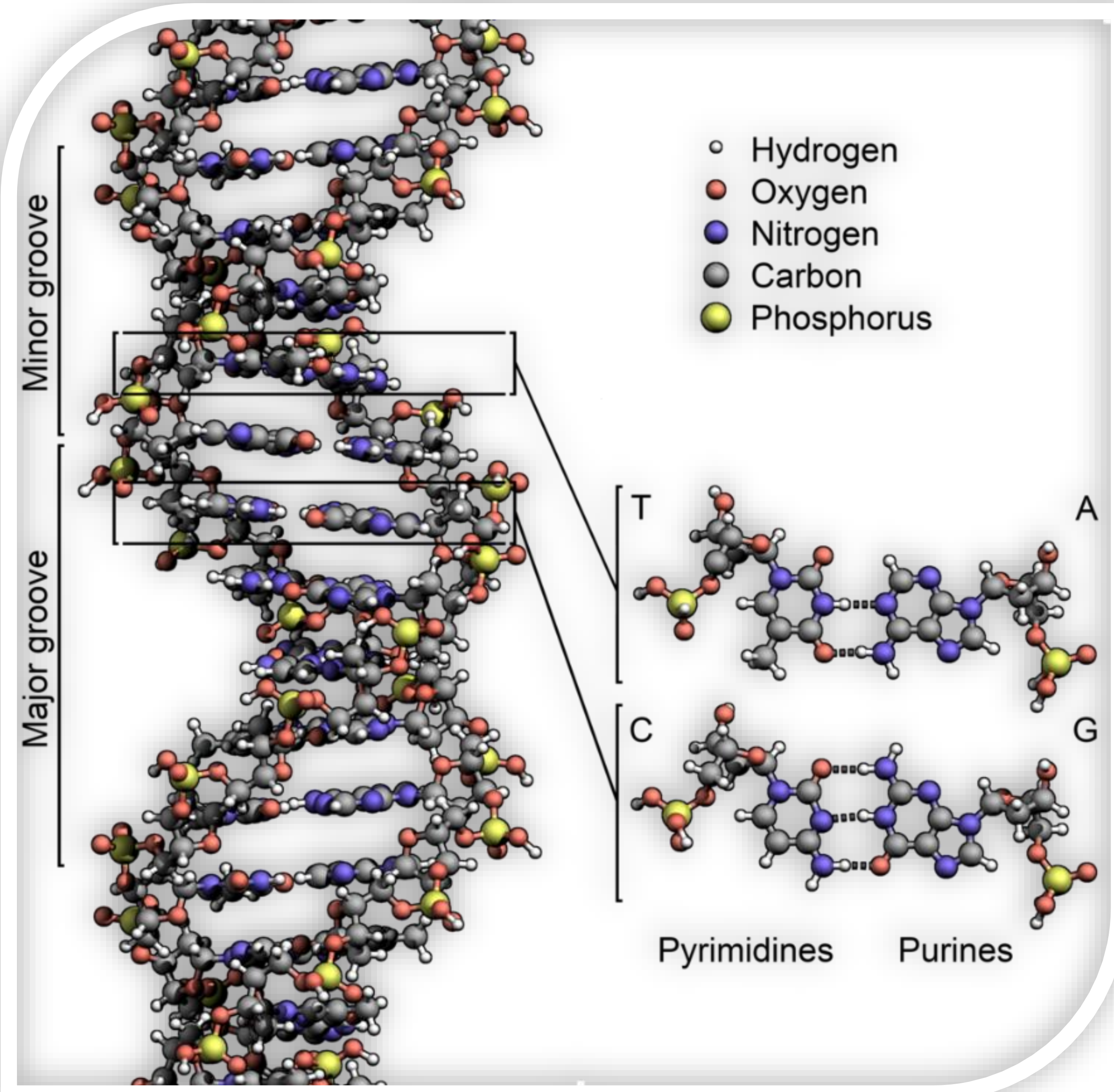
Applications of LHS

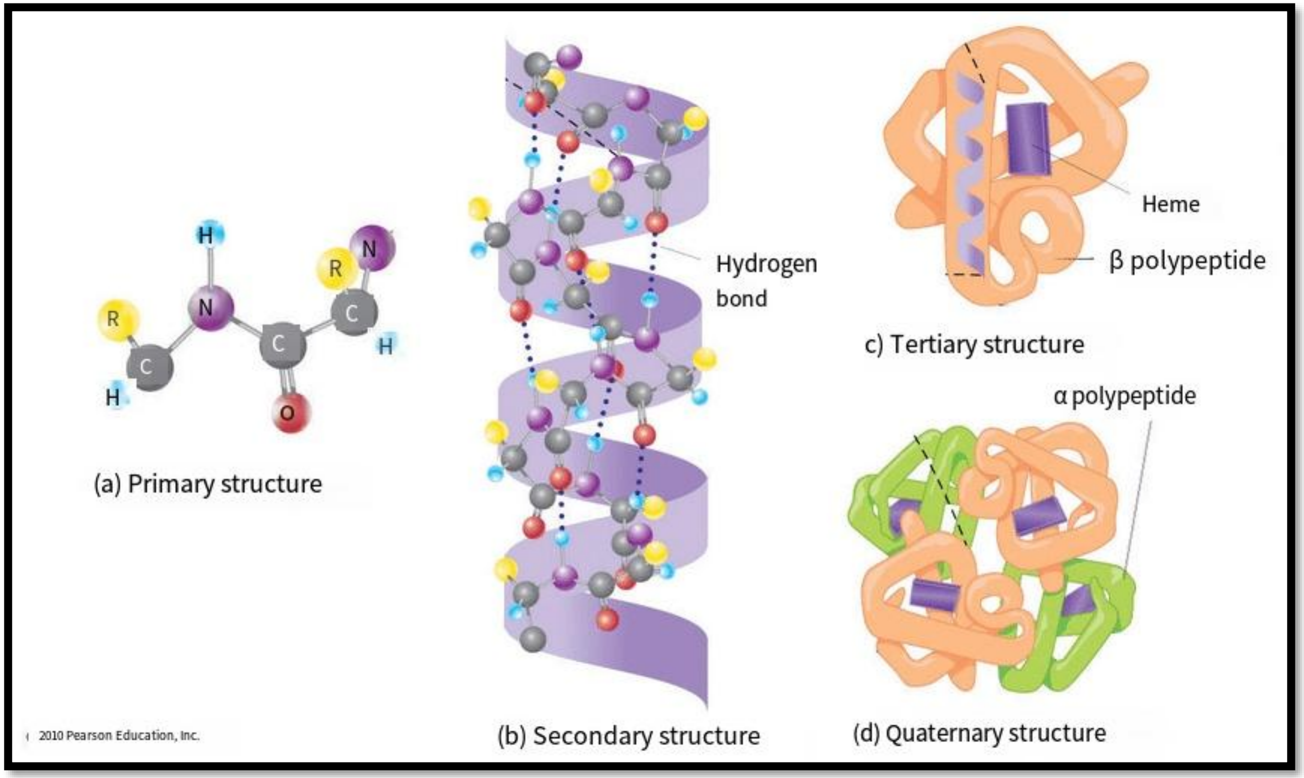




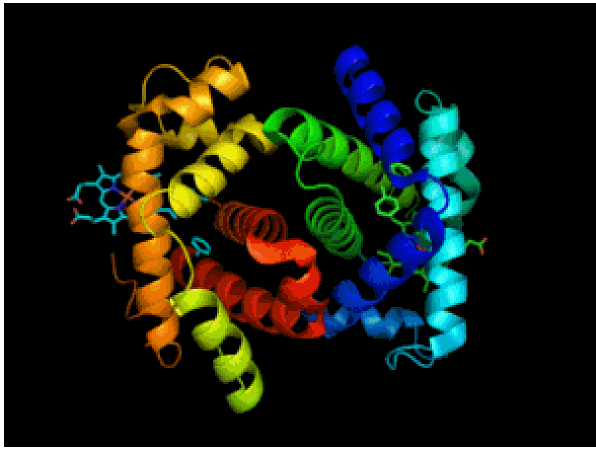
Performance of humanoid robotic hands assembled with S-silk composite as electro-tendon.

The significance of hydrogen bonds for life


Hydrogen
Oxygen
Nitrogen
Carbon
Phosphorus
Minor groove
Major groove
T
A
C
G
Pyrimidines
Purines


H
R
N
C
C
O
R
C
N
H
H
(a) Primary structure
Hydrogen
bond
(b) Secondary structure
Heme
β polypeptide
c) Tertiary structure
α polypeptide
(d) Quaternary structure
2010 Pearson Education, Inc.

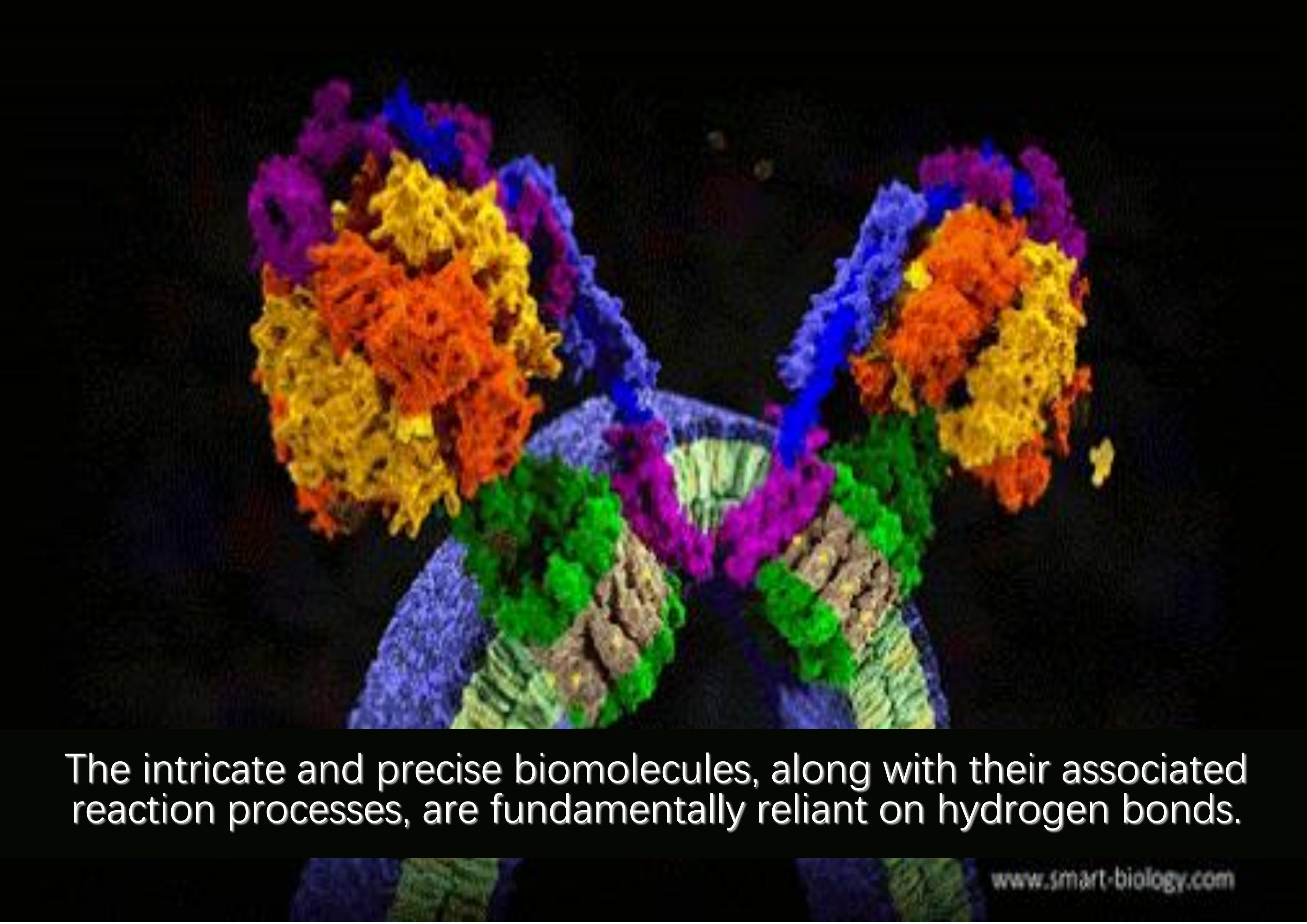

An animation of the gradient descent method
predicting a structure for CASP13 target T1008



Convene at the opportune moment and location

Hydrogen Bond: Coming together and Falling apart

- ✓ Hydrogen bond binding energy is 2-8 Kcal (Kcal)
- ✓ Hydrogen bonding is an interaction that is stronger than intermolecular forces (van der Waals forces) and much weaker than covalent and ionic bonds
- ✓ Saturability, directivity, asymmetry



The intricate and precise biomolecules, along with their associated reaction processes, are fundamentally reliant on hydrogen bonds.

Why are molecules of water so important?

- **Water** is essential to life (as we know it)
  - This is why the search for life on other planets often begins with a search for water

  - Some properties of water that make it able to support life:
    - Water is cohesive
    - Many substances dissolve in water
    - Water solutions come in a range of pH values

Figure: https://commons.wikimedia.org/wiki/File:Hot_Watering_Hole_Action.jpg

- <u>Water is cohesive</u>
  - **Cohesion** = the tendency of water molecules to stick together through hydrogen bonds
    - *remember hydrogen bonds!*
    - allows water to move to the top of the tallest trees, defying gravity

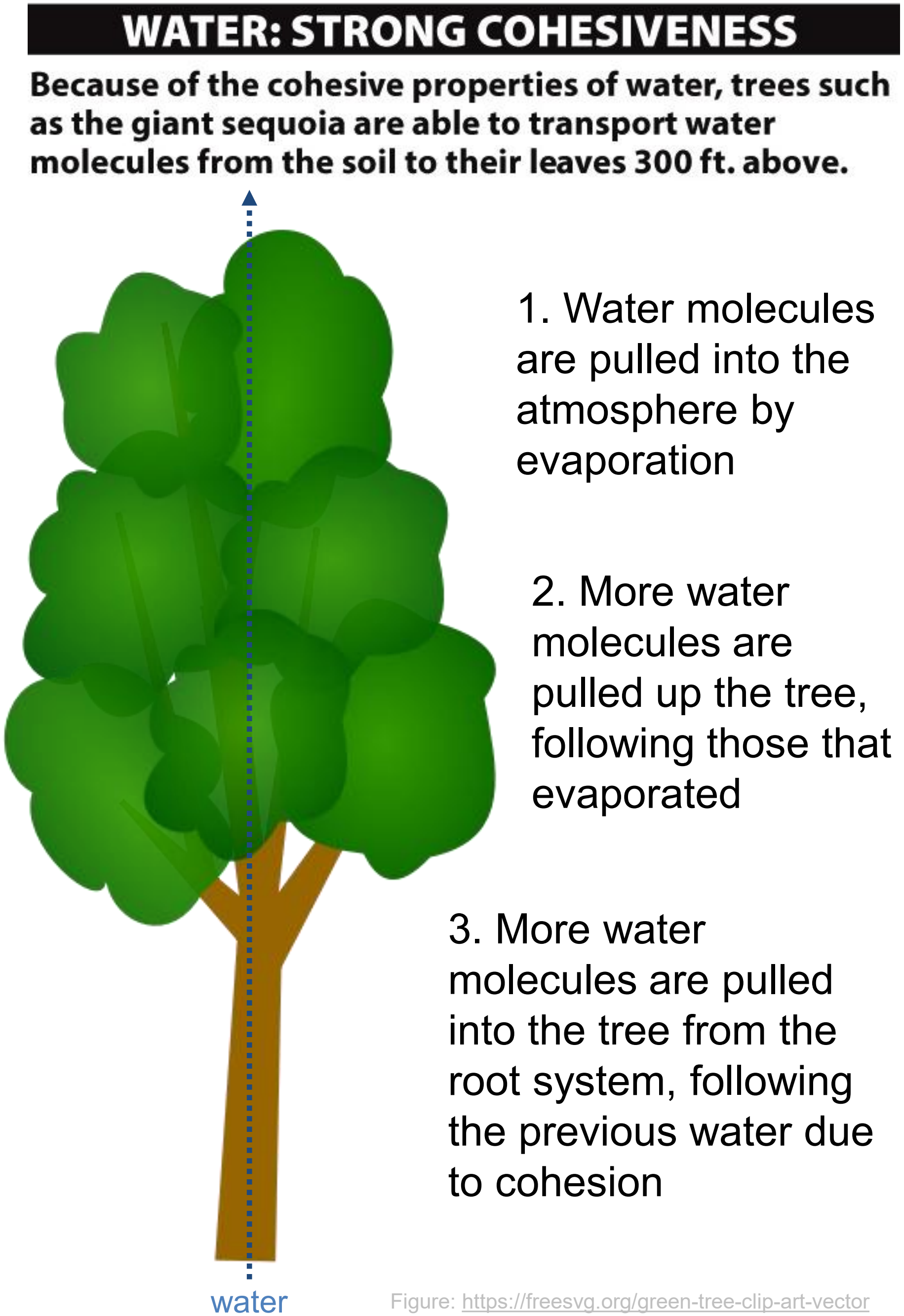


Figure: https://freesvg.org/green-tree-clip-art-vector

Also why belly flops hurt!

https://www.flickr.com/photos/lewishamdreamer/4060481490

- <u>Many substances dissolve in water</u>
  - Substances that dissolve in water = **hydrophilic**
    - "water-loving"
    - e.g. salts, sugars, & electrolytes
      - important because we need these things to move through our blood stream (which is mostly water) easily

Notice how water molecules happily surround these salts, allowing them to move in the blood stream easily

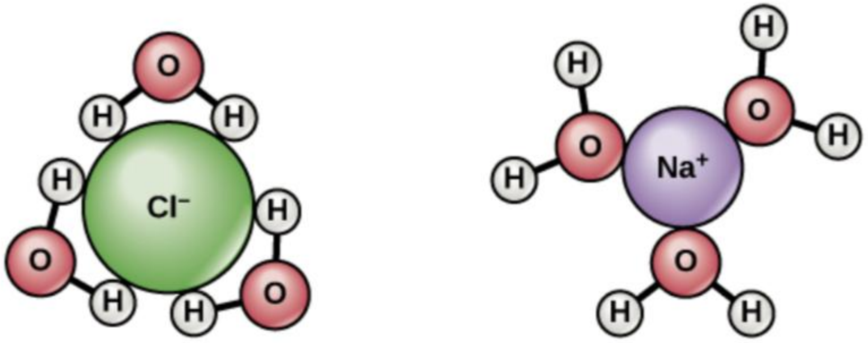
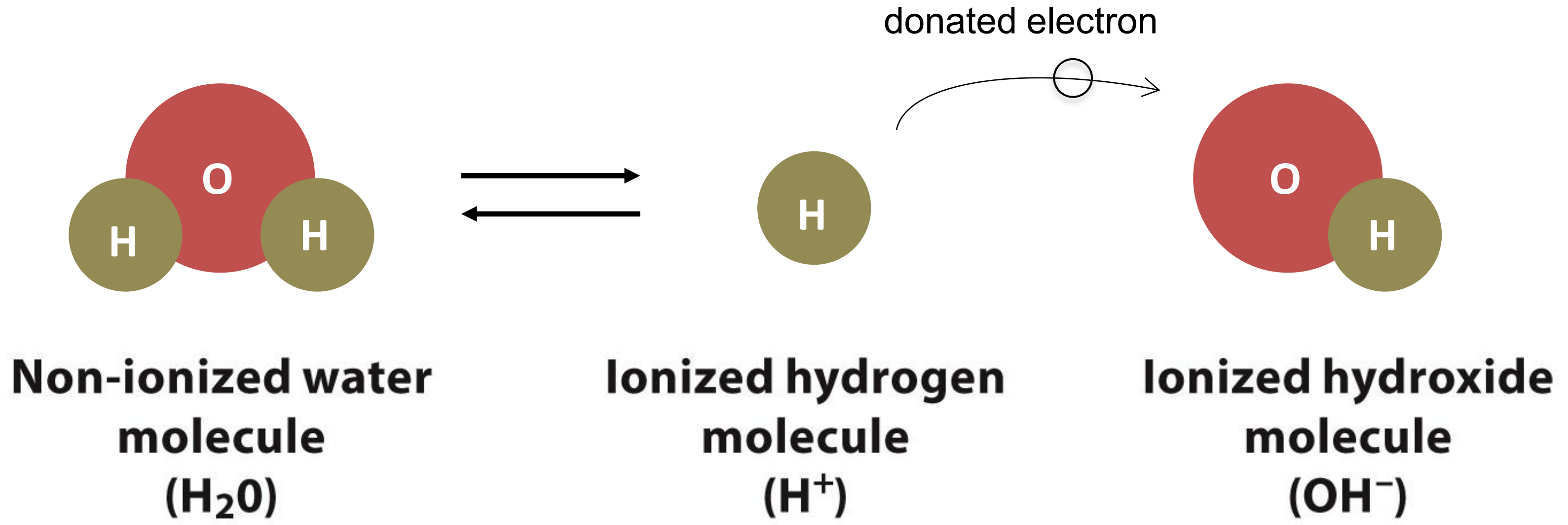


Figure from OpenStax Biology 2e

- <u>Water solutions come in a range of pH values</u>
  - – In a solution of water, some molecules become “ionized” – they break apart & become charged
    - $H_2O \rightarrow OH^- + H^+$



cation

anion

- Solutions where $OH^- = H^+$ are **neutral** *(equal)*
  - pH 7
  - e.g. pure water
- Solutions where $OH^- < H^+$ are **acidic** *(more H+)*
  - pH 0-6
  - e.g. lemon juice & vinegar
- Solutions where $OH^- > H^+$ are **basic** *(more OH-)*
  - pH 8-14
  - e.g. ammonia & bleach

- The **pH scale** is a way of referring to the acidic, basic, or neutral quality of a solution

BASES

Bases are fluids that have a greater proportion of OH^- ions to H^+ ions.

- **OH^- ions bind with H^+ ions, neutralizing acids.**
- **Strong bases are caustic to your skin.**
- **Bases can be found in many household cleaners.**
- **Bases are generally bitter in taste and slippery.**

ACIDS

Acids are fluids that have a greater propotion of H^+ ions to OH^- ions.

- **H^+ ions are very reactive.**
- **Strong acids are corrosive to metals.**
- **Acids break down food in your digestive tract.**
- **Acids are generally sour in taste.**

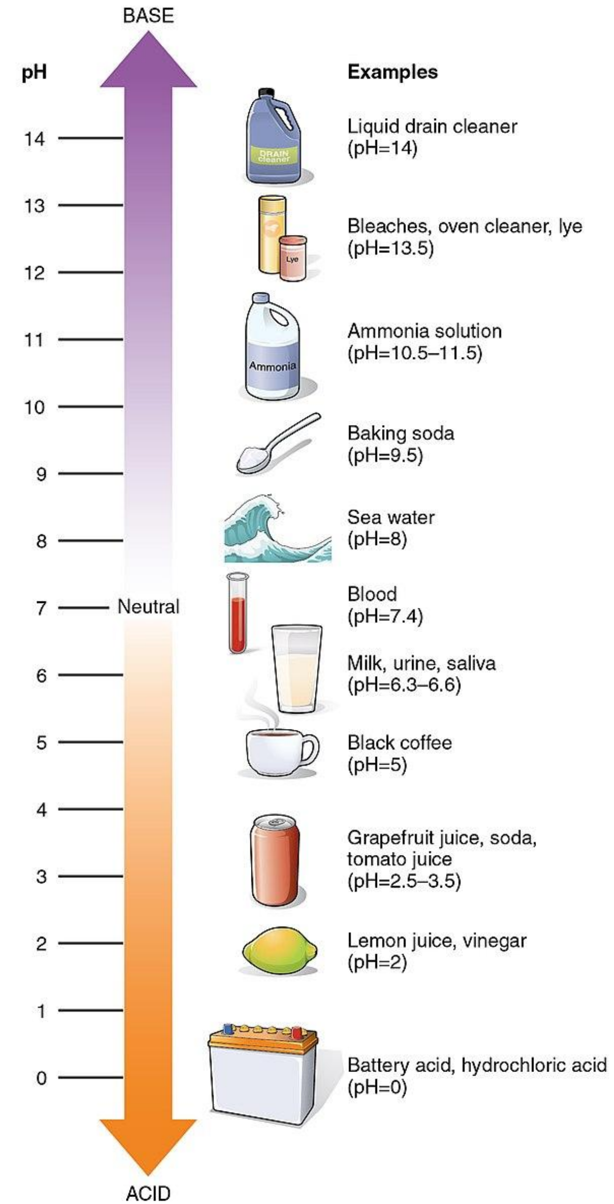
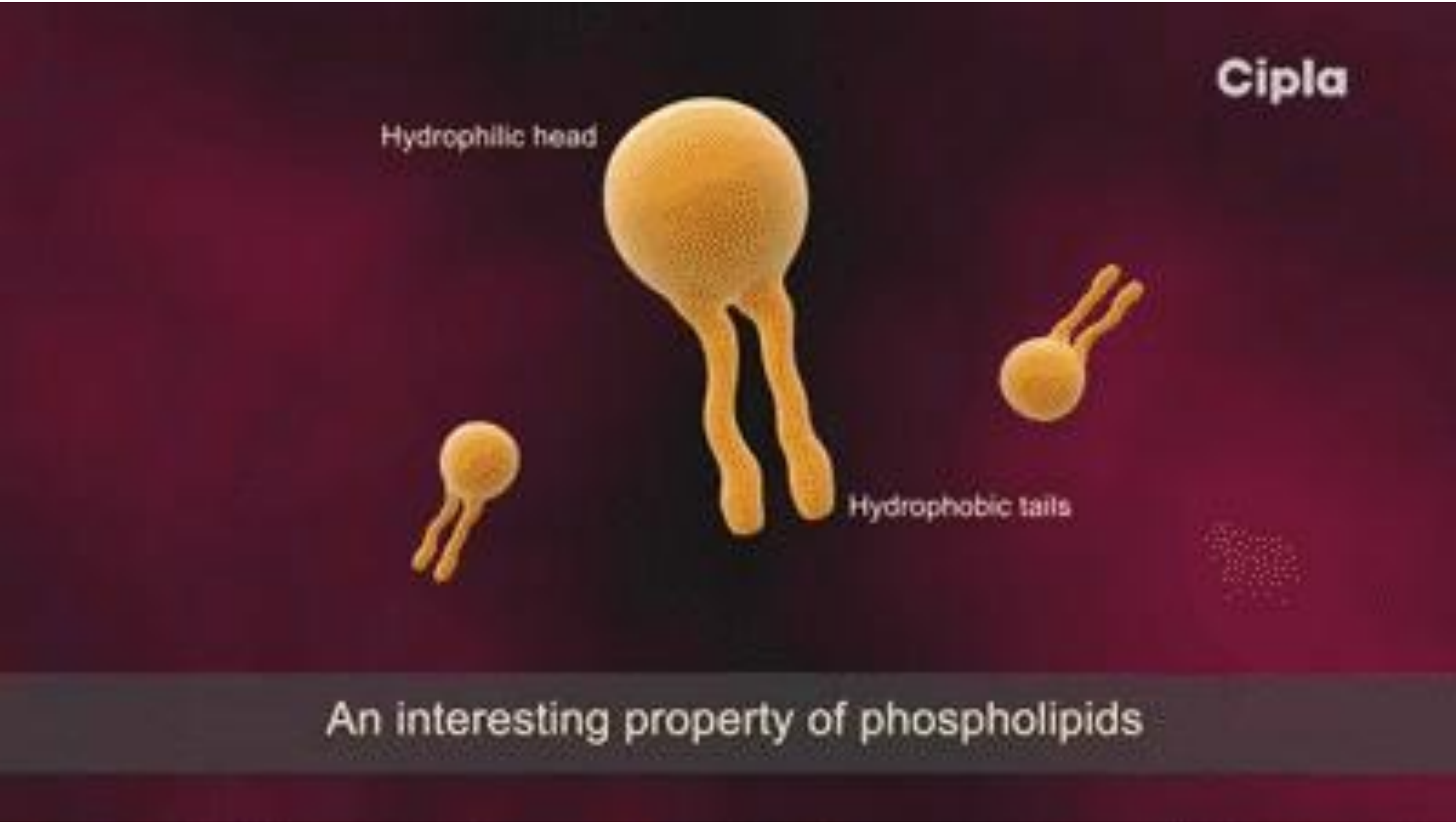


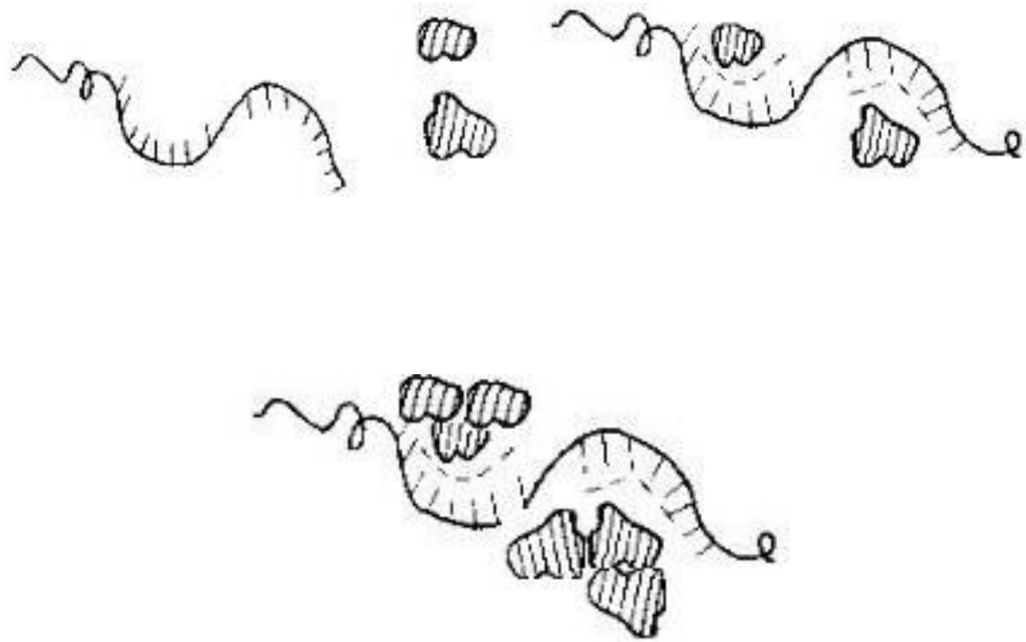
Figure: https://commons.wikimedia.org/wiki/File:216_pH_Scale-01.jpg

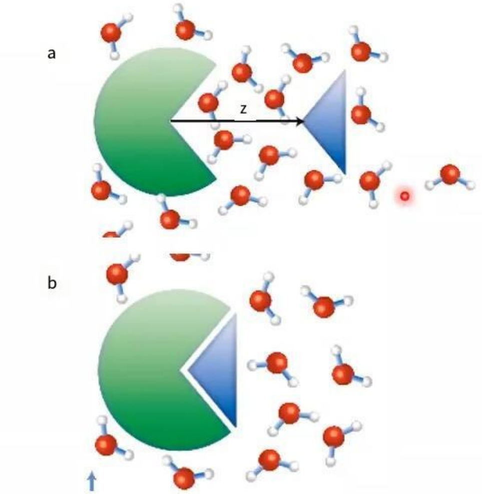
- Many substances dissolve in water – some don't
  - Substances that do NOT dissolve in water = **hydrophobic**
    - "water-fearing" – clump up in water
    - e.g. fats, oils, & cell membranes
      - it is important that our cells do not dissolve when we get wet, or when they contact our watery blood stream, so we use these things to waterproof ourselves & form barriers

Figure: https://www.maxpixel.net/Water-Drink-Crystal-Glass-Oil-Liquid-Drip-Glass-101666

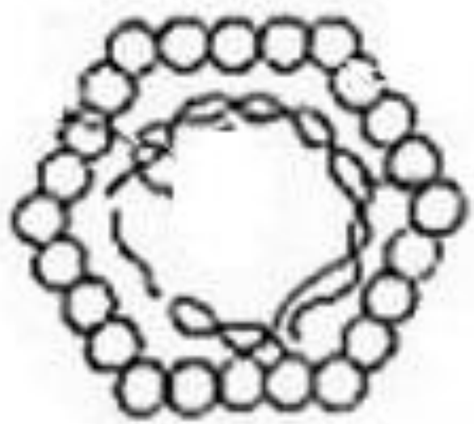
Hydrophobic Force

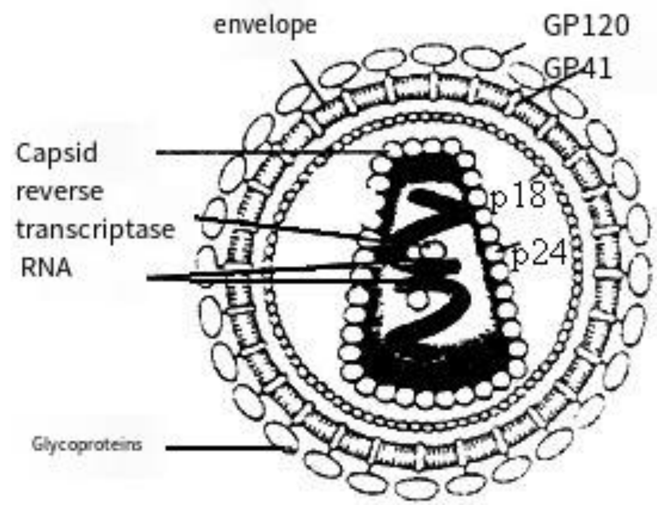


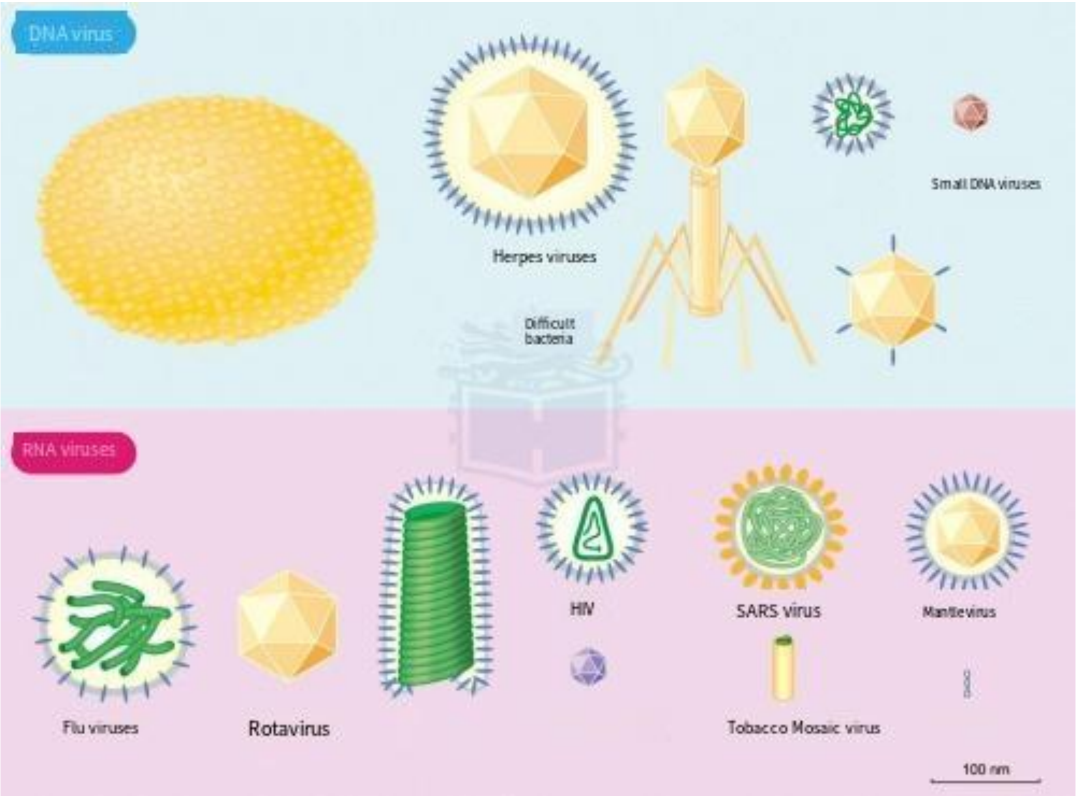


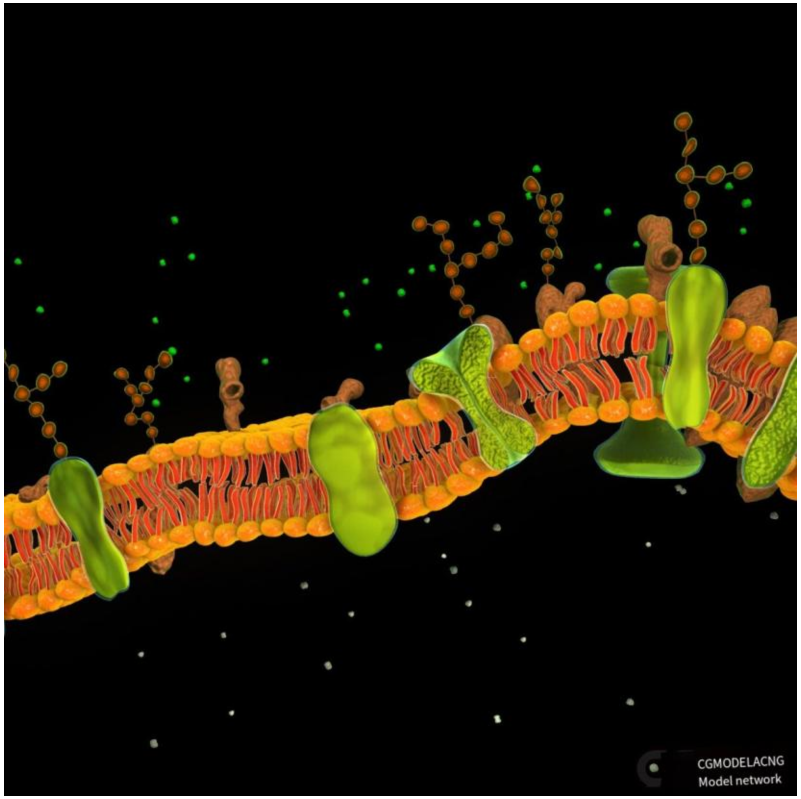


Hydrophobic action is when spherical proteins fold up in water and hide their hydrophobic parts inside. You could also say that this process changes the free energy because it increases entropy by releasing bound water during interactions between molecules.

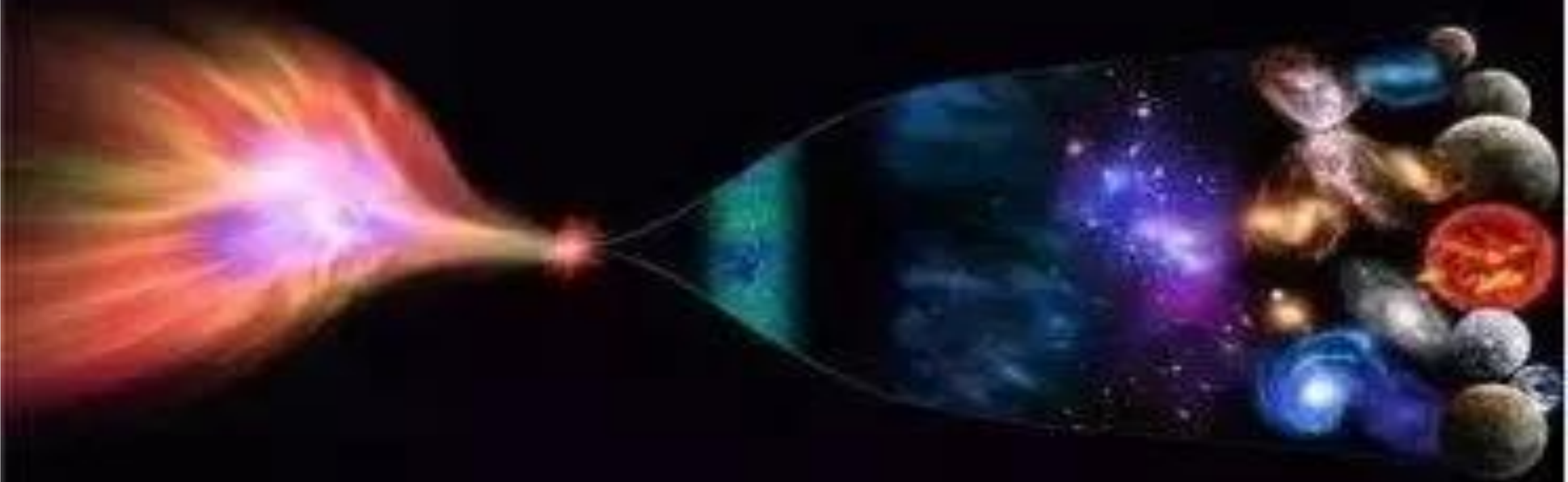





DNA virus
Herpes viruses
Small DNA viruses
Difficult bacteria
RNA viruses
HIV
SARS virus
Mantlevirus
Flu viruses
Rotavirus
Tobacco Mosaic virus
100 nm


CGMODELACNG
Model network

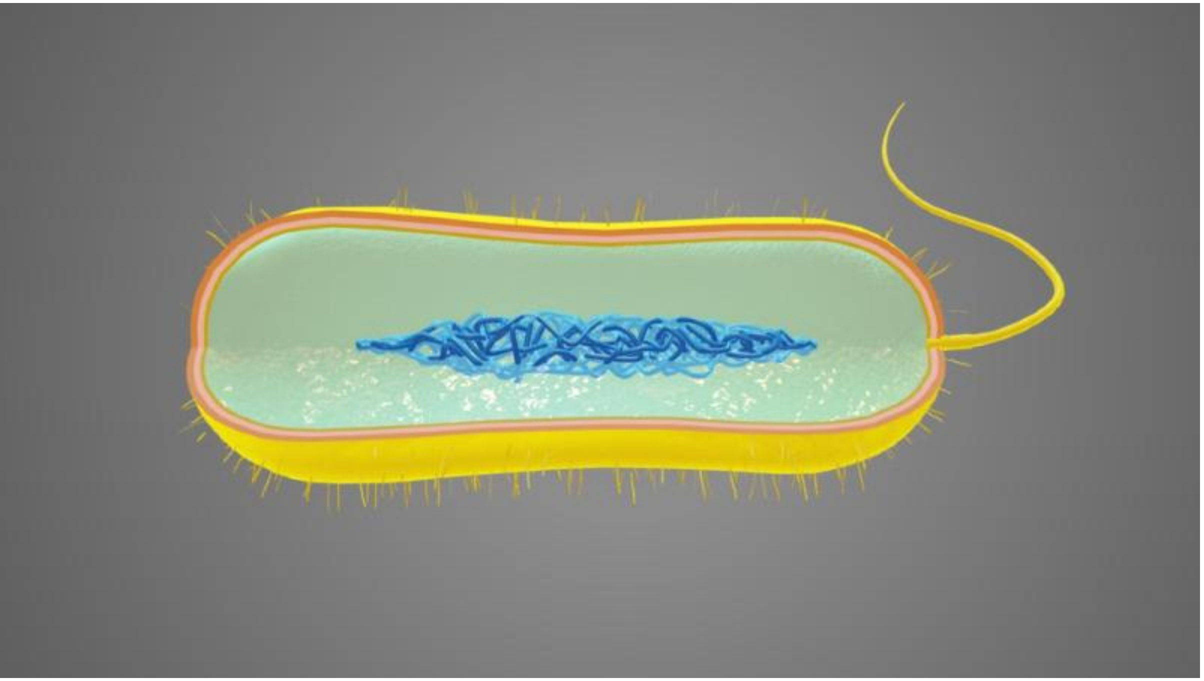
The origin and evolution of the universe

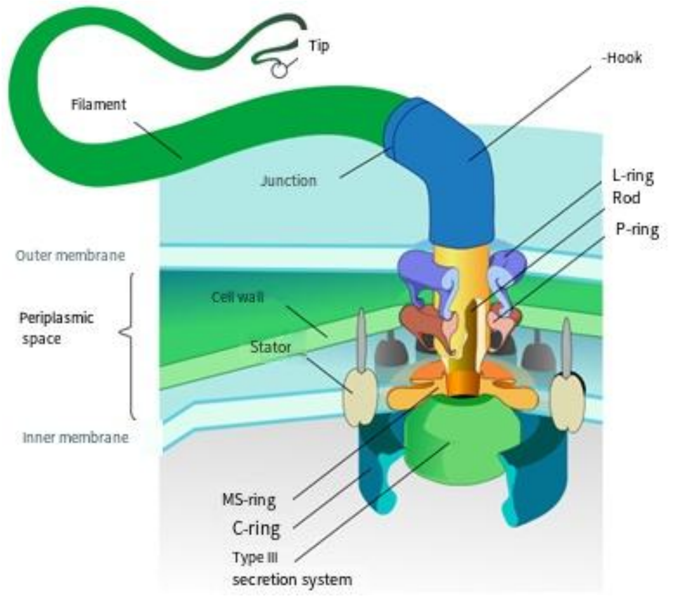


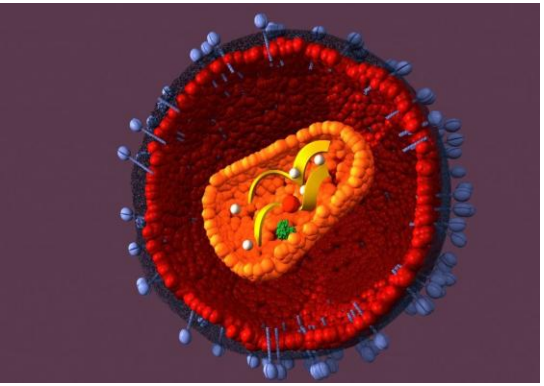
13.5 billion years ago, the Big Bang created matter, energy, time and space in the universe. (Physics)

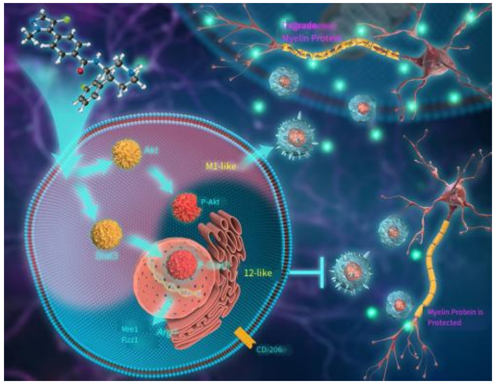
After 300,000 years, matter and energy form complex structures and atoms and molecules appear (chemistry)

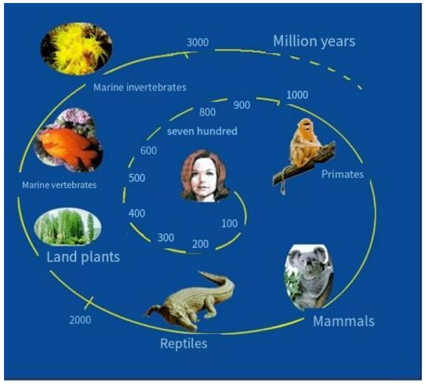
3.8 billion years ago, molecules joined together to form organisms (biology)

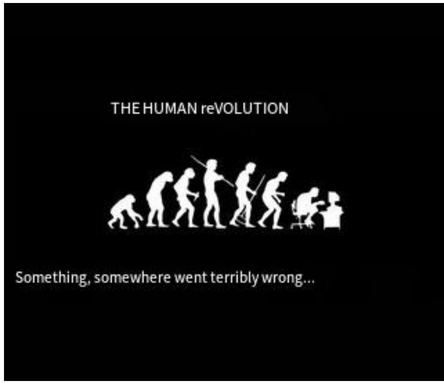


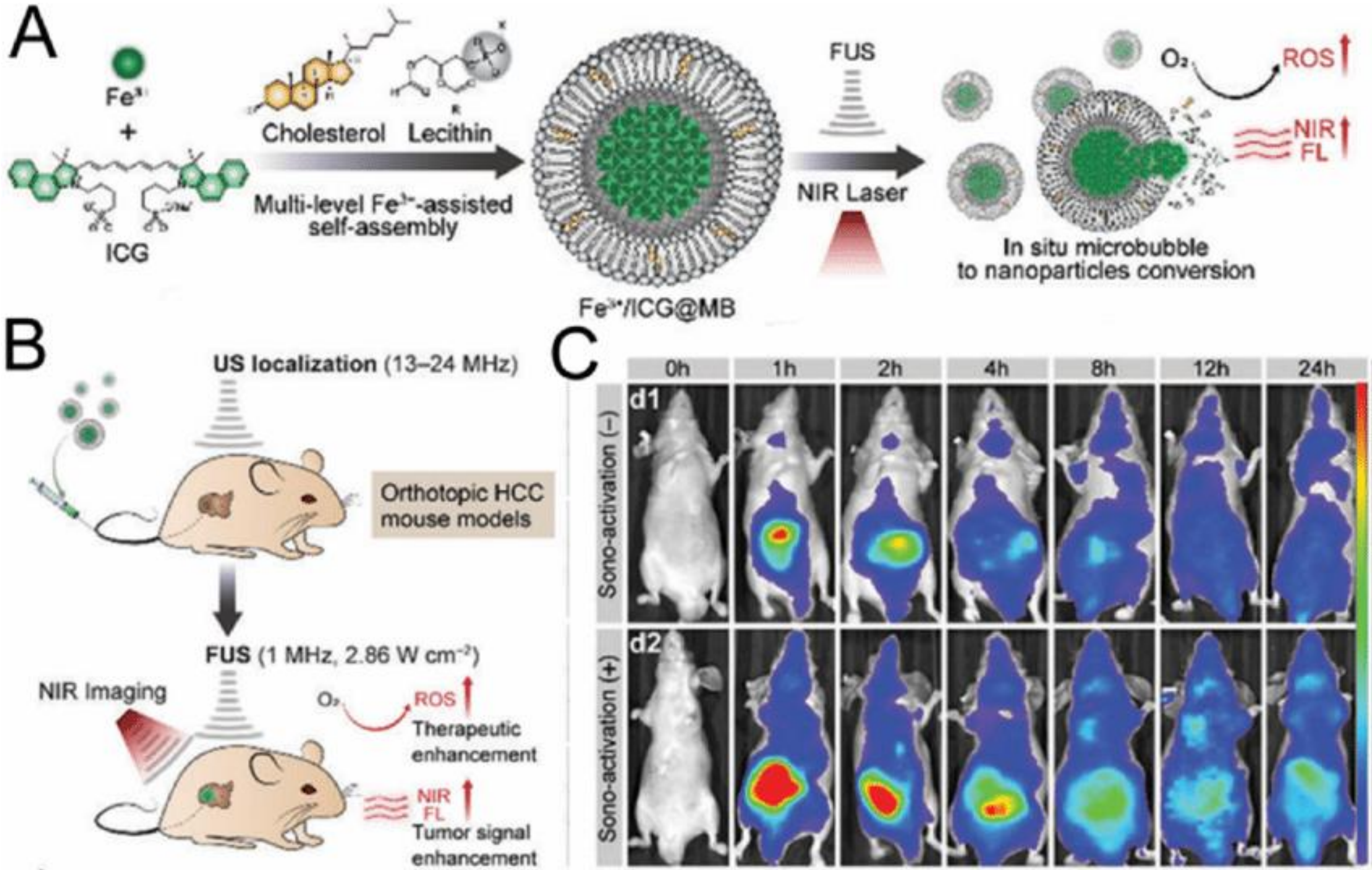

Tip
-Hook
Filament
Junction
L-ring
Rod
P-ring
Outer membrane
Periplasmic space
Cell wall
Stator
Inner membrane
MS-ring
C-ring
Type III
secretion system






3000
Million years
Marine invertebrates
900
1000
800
seven hundred
600
500
Marine vertebrates
Primates
400
100
Land plants
300
200
2000
Reptiles
Mammals


THE HUMAN reVOLUTION
Something, somewhere went terribly wrong...


A
Fe3+
+
ICG
Cholesterol
Lecithin
Multi-level Fe3+-assisted self-assembly
Fe3+/ICG@MB
FUS
NIR Laser
O2
ROS
NIR FL
In situ microbubble to nanoparticles conversion
B
US localization (13–24 MHz)
Orthotopic HCC mouse models
FUS (1 MHz, 2.86 W cm-2)
NIR Imaging
ROS
Therapeutic enhancement
NIR FL
Tumor signal enhancement
C
0h
1h
2h
4h
8h
12h
24h
d1
Sono-activation (-)
d2
Sono-activation (+)

- Water will come up over & over as we learn more about how our cells & bodies work
  - We'll talk about the other molecules that make up our bodies – how they interact with water will be important (e.g. hydrophilic vs. hydrophobic)
  - We'll talk about why it's so important to keep our blood neutral, & not acidic or basic

- Up next: water is essential to life & our bodies contain a lot of it, but it is not what living things are actually built of
  - **So what molecules are we built of?**

Chapter 3: Biological Molecules

- What kind of molecules make up living bodies?
- How do we build & break down (digest) those molecules?
- What are the four classes of molecules that build our bodies & that we have to eat?

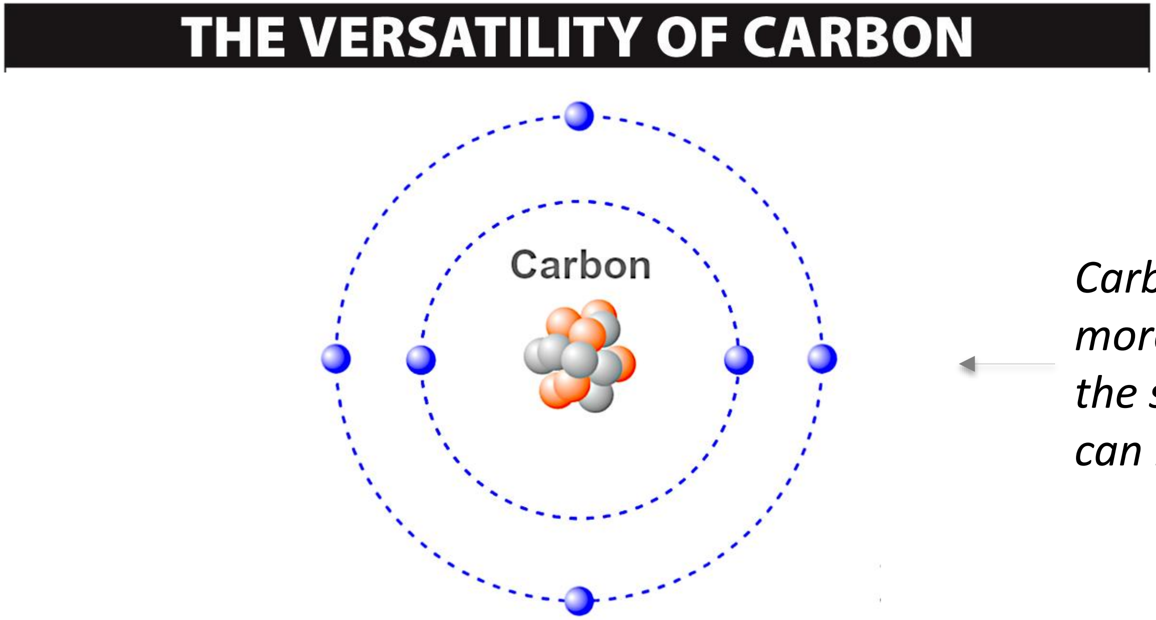
Corresponds with OpenStax Biology 2e Chapter 3

What class of molecules make up life?

- Living things are made up of **organic molecules**
  - Plants make their own organic molecules, plus gain some through their roots
  - Animals eat organic molecules to build & fuel their bodies

- **Organic molecules** = all have <u>carbon</u> & <u>hydrogen</u>
  - Must have both – if a molecule only has 1 of those elements (or neither), it is inorganic
  - Organic molecules contain other elements too

- Why are all organic molecules (& thus all living things) carbon based?
  - **Carbon** = small & versatile: can make 4 different bonds with many different atoms
    - *at least 1 must be hydrogen to be organic*

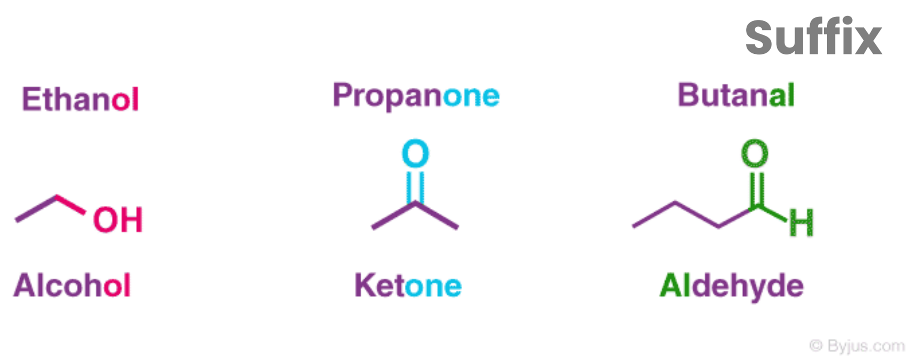


Carbon can hold 4 more electrons in the second shell, so can make 4 bonds

Figure: https://pixabay.com/images/id-4426054/

- Organic molecules have functional groups
  - **Functional group** = small groups of non-hydrogen atoms in organic molecules
    - *they make each organic molecule unique: protein vs. carbohydrate vs. fat…*
    - *responsible for the chemical reactions that the molecule they are attached to participate in*

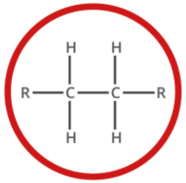
- *the same functional group will behave similarly and experience comparable reactions*



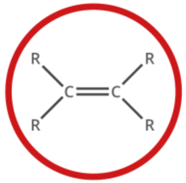
FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

FUNCTIONAL GROUPS ARE GROUPS OF ATOMS IN ORGANIC MOLECULES THAT ARE RESPONSIBLE FOR THE CHARACTERISTIC CHEMICAL REACTIONS OF THOSE MOLECULES. IN THE GENERAL FORMULAE BELOW, 'R' REPRESENTS A HYDROCARBON GROUP OR HYDROGEN, AND 'X' REPRESENTS ANY HALOGEN ATOM.

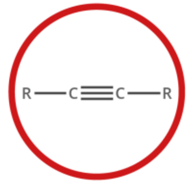
HYDROCARBONS | SIMPLE OXYGEN HETEROATOMICS | HALOGEN HETEROATOMICS | CARBONYL COMPOUNDS | NITROGEN BASED | SULFUR BASED | AROMATIC



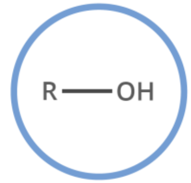
ALKANE
Naming: -ane
e.g. ethane



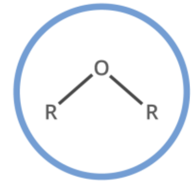
ALKENE
Naming: -ene
e.g. ethene



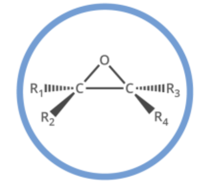
ALKYNE
Naming: -yne
e.g. ethyne



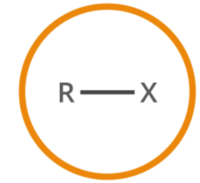
ALCOHOL
Naming: -ol
e.g. ethanol



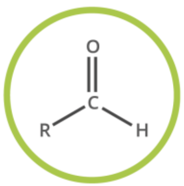
ETHER
Naming: -oxy -ane
e.g. methoxyethane



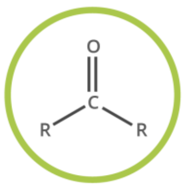
EPOXIDE
Naming: -ene oxide
e.g. ethene oxide



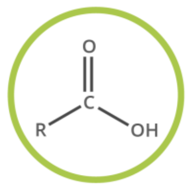
HALOALKANE
Naming: halo-
e.g. chloroethane



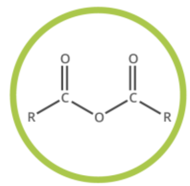
ALDEHYDE
Naming: -al
e.g. ethanal



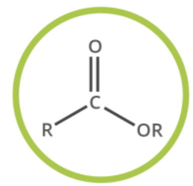
KETONE
Naming: -one
e.g. propanone



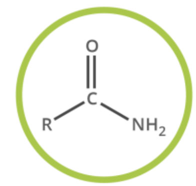
CARBOXYLIC ACID
Naming: -oic acid
e.g. ethanoic acid



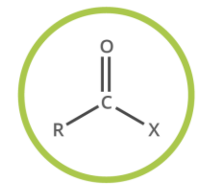
ACID ANHYDRIDE
Naming: -oic anhydride
e.g. ethanoic anhydride



ESTER
Naming: -yl -oate
e.g. ethyl ethanoate



AMIDE
Naming: -amide
e.g. ethanamide

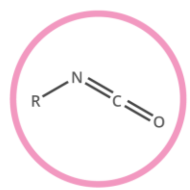


ACYL HALIDE
Naming: -oyl halide
e.g. ethanoyl chloride

AMINE
Naming: -amine
e.g. ethanamine

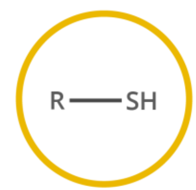
NITRILE
Naming: -nitrile
e.g. ethanenitrile

IMINE
Naming: -imine
e.g. ethanimine

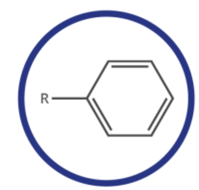


ISOCYANATE
Naming: -yl isocyanate
e.g. ethyl isocyanate

AZO COMPOUND
Naming: azo-
e.g. azoethane

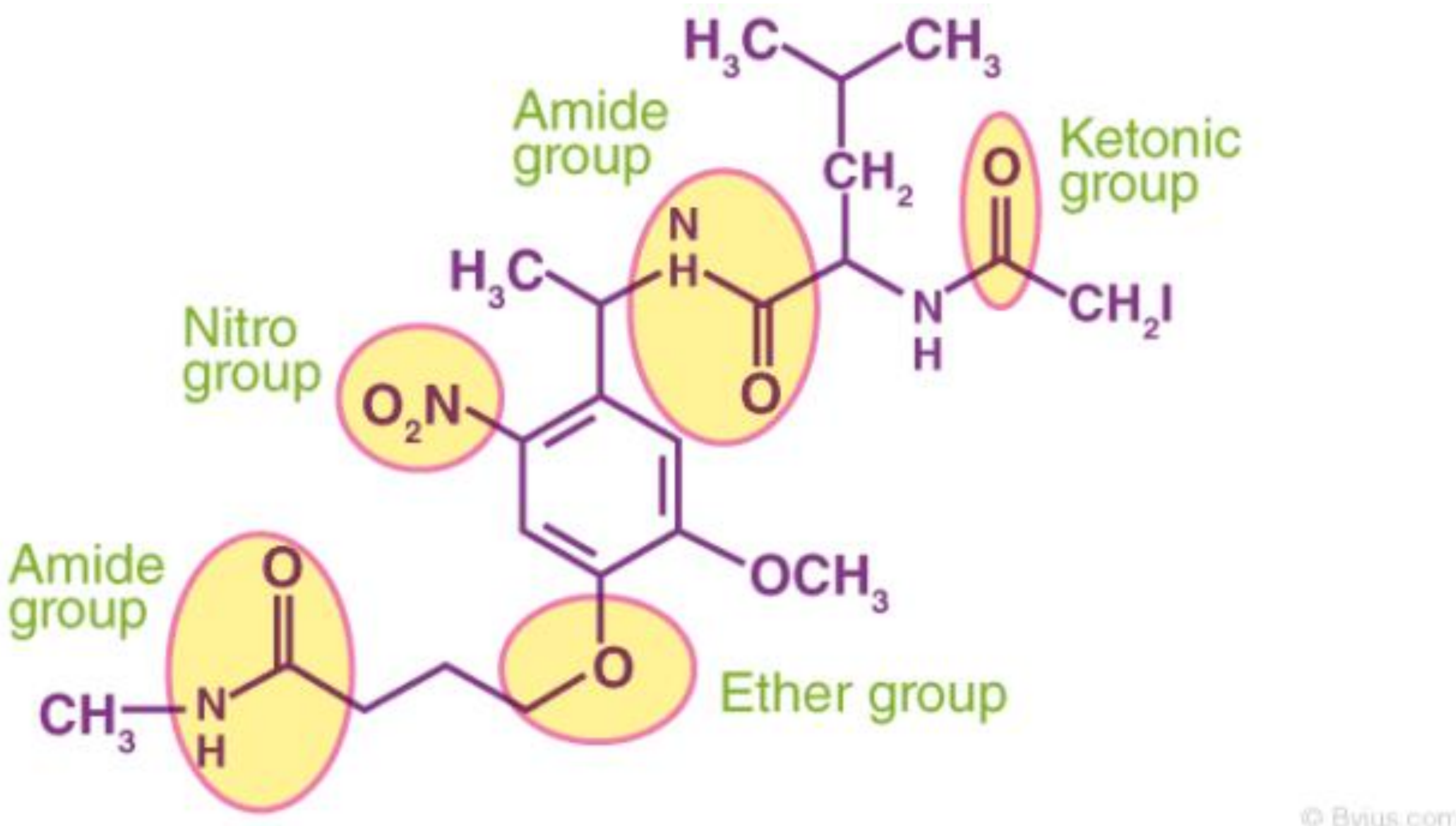


THIOL
Naming: -thiol
e.g. methanethiol



ARENE
Naming: -yl benzene
e.g. ethyl benzene

Functional groups are the moieties which exhibit their own **distinct features** and properties independent of the molecule they are attached to.



How do we build & digest organic molecules?

- Small organic molecules = **monomers**
- Monomers are joined to form bigger organic molecules = **polymers**

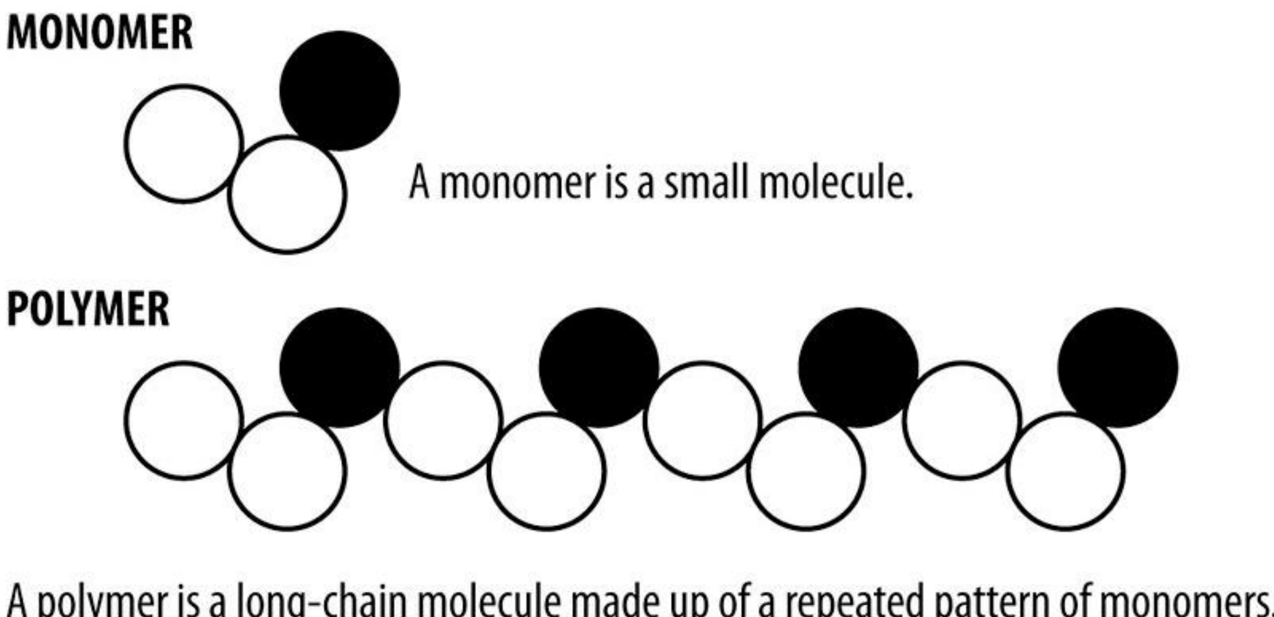
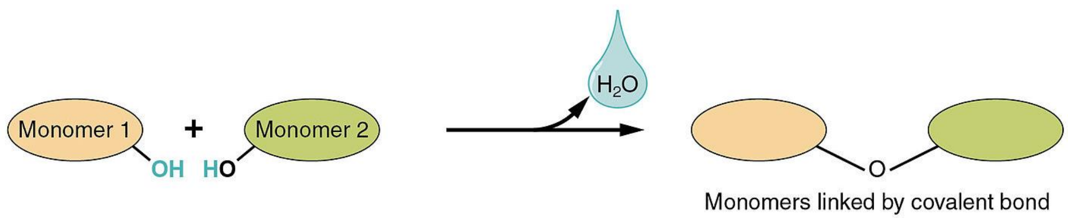


Figure: https://commons.wikimedia.org/wiki/File:1123ghjkghjk.jpg

- Monomers are linked together into polymers through **dehydration synthesis**
  - e.g. building muscle & other complex molecules

Monomers are joined by removal of OH from one monomer and removal of H from the other at the site of bond formation.



- Polymers are broken down into monomers through **hydrolysis**
  - e.g. digestion & breakdown of molecules for energy

Monomers are released by the addition of a water molecule, adding OH to one monomer and H to the other.

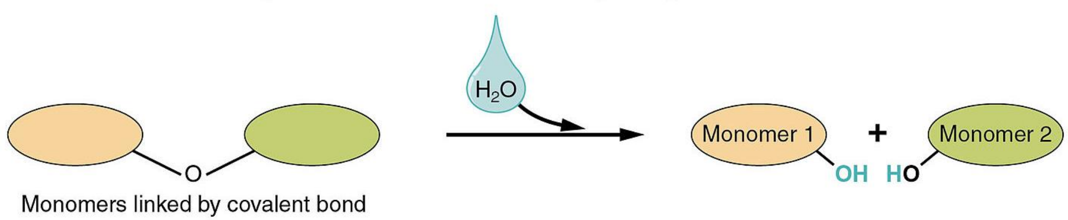
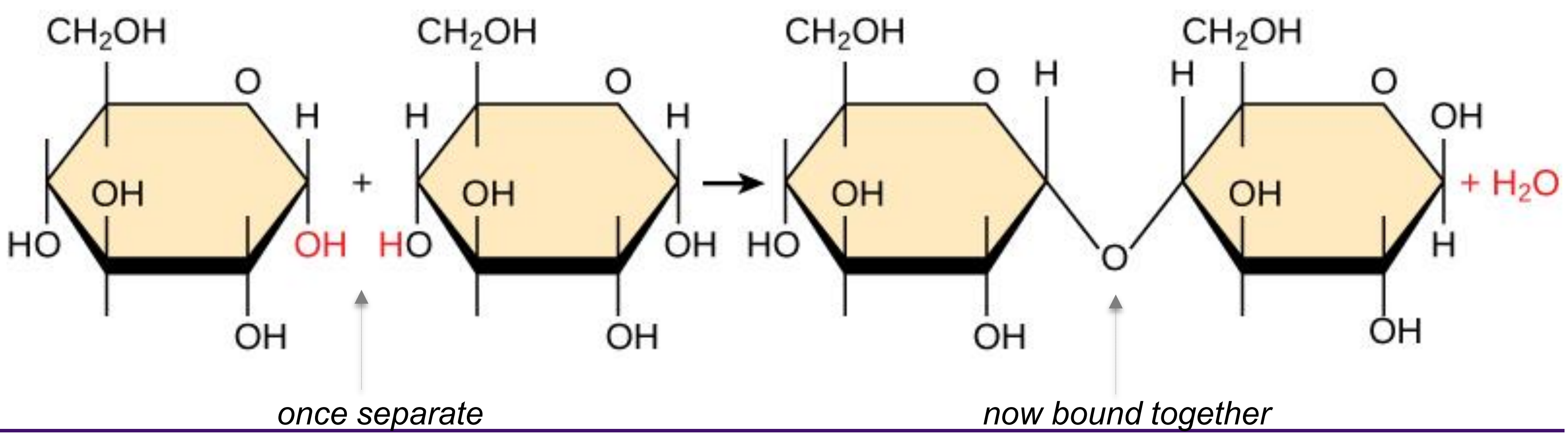


Figure: https://commons.wikimedia.org/wiki/File:213_Dehydration_Synthesis_and_Hydrolysis-01.jpg

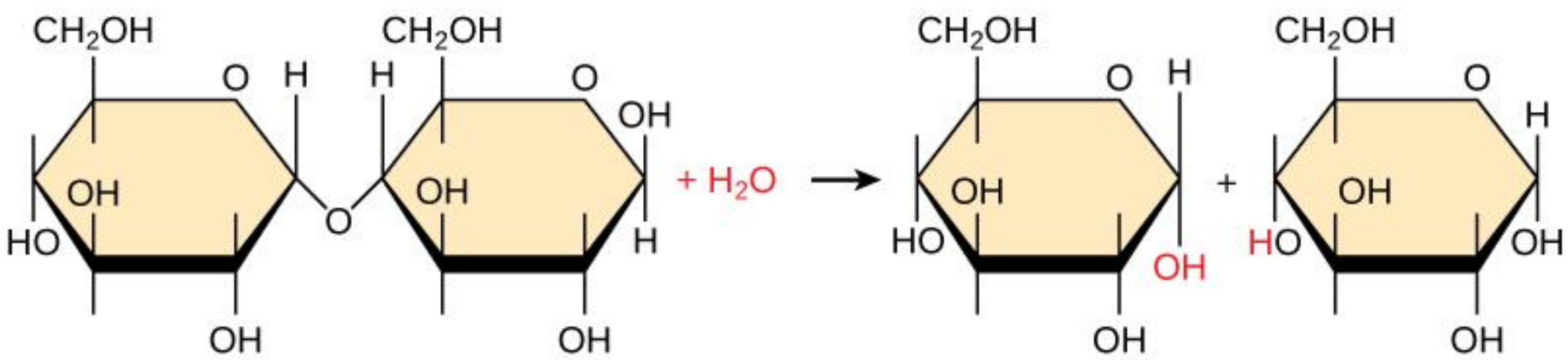
- In **dehydration synthesis**:
  - H & OH removed = loss of water molecule (H_2O)
  - Loss of H_2O means atoms want to bond to stabilize (by forming covalent bonds)
    - Bond together: monomer + monomer = polymer

dehydration synthesis



- In **hydrolysis**:
  - Add water, which is separated into H & OH
  - H & OH are inserted, breaking the bond between monomers
    - Digestion occurs: polymer broken down into individual monomers

hydrolysis



What are the four classes of molecules that build our bodies & that we have to eat?

- Organic molecules fall into 4 main categories
  - **Carbohydrates**: our main energy source & some for structure
  - **Proteins**: do nearly everything that keeps us alive
  - **Nucleic Acids**: energy carriers, cell messengers, & hereditary information
  - **Lipids**: energy storage, waterproofing, hormones, & cell membranes

- **Carbohydrates** = sugars, hydrophilic
  - 3 types based on size: monosaccharides, disaccharides, polysaccharides
  - **Monosaccharide =** a carb of just 1 sugar molecule
    - “simple sugar”
    - sweet-tasting on the tongue
    - *monomer*

Monosaccharide examples
(glucose is the most common)

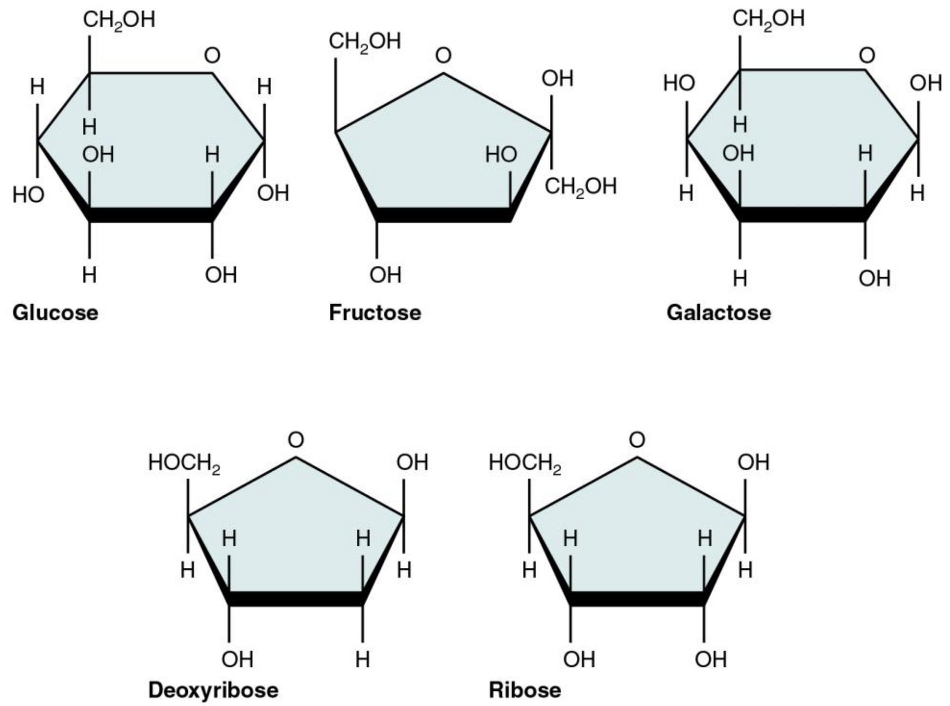
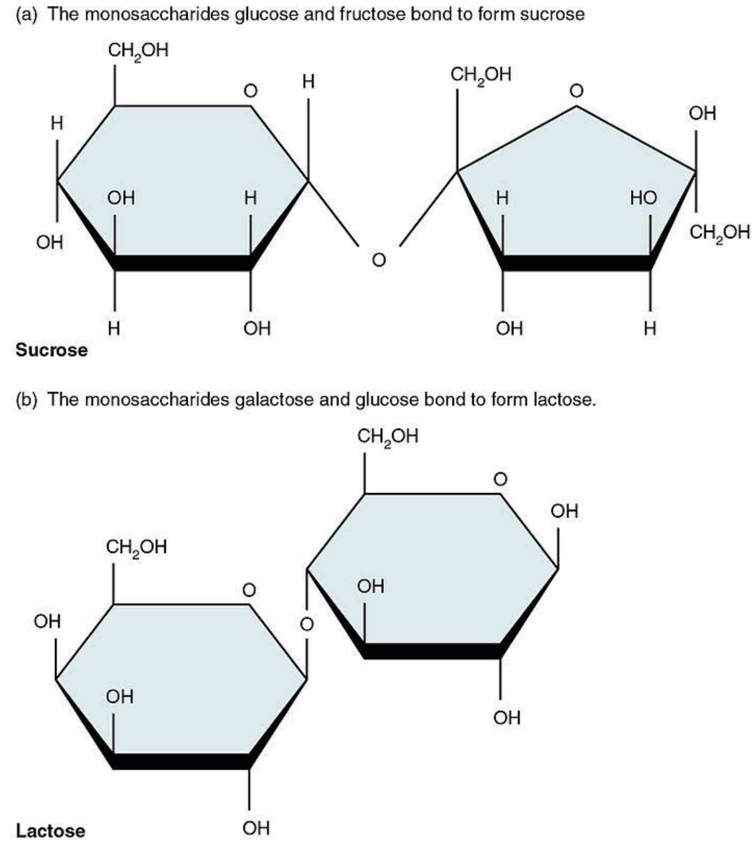


Figure: https://commons.wikimedia.org/wiki/File:217_Five_Important_Monosaccharides-01.jpg

disaccharide examples

- **Disaccharide** = 2 monosaccharides linked together
  - also sweet (table sugar)
  - *small polymer*



- **Polysaccharide** = a *polymer* of many monosaccharides linked together
  - “complex carb”
  - NOT sweet-tasting

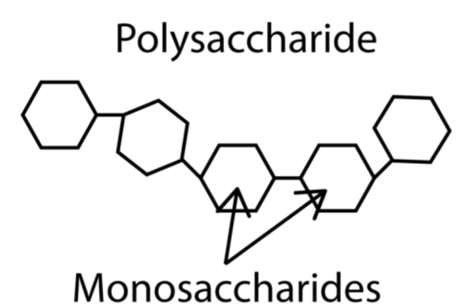


Figure: https://commons.wikimedia.org/wiki/File:218_Three_Important_Disaccharides-01.jpg
Figure: https://commons.wikimedia.org/wiki/File:Simple_Polysaccharide_Hydrolysis.png

- In the body, **monosaccharides** are:
  - – used for immediate energy
  - – or joined together (dehydration synthesis) as polysaccharides or fats & stored for later energy use

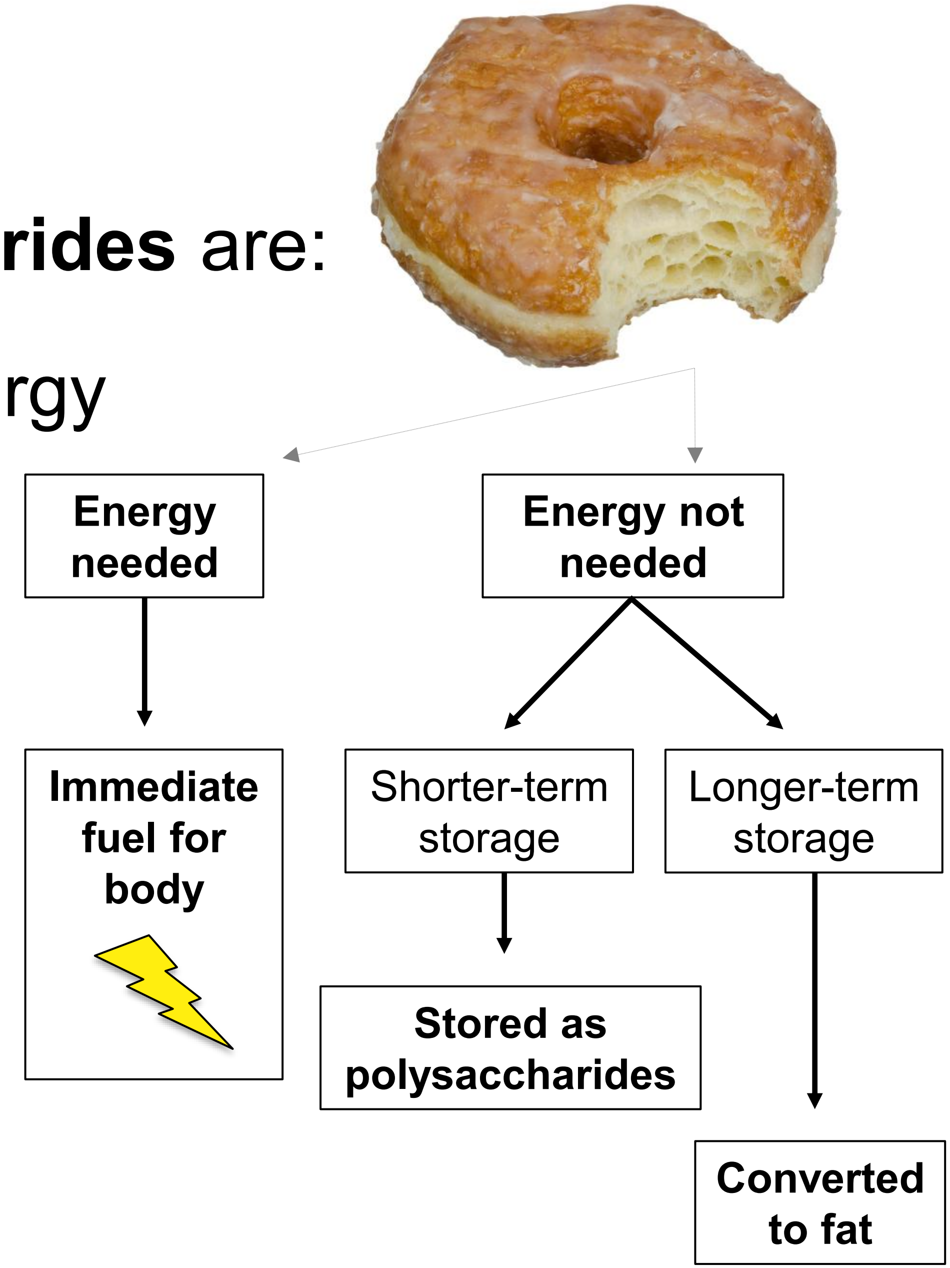
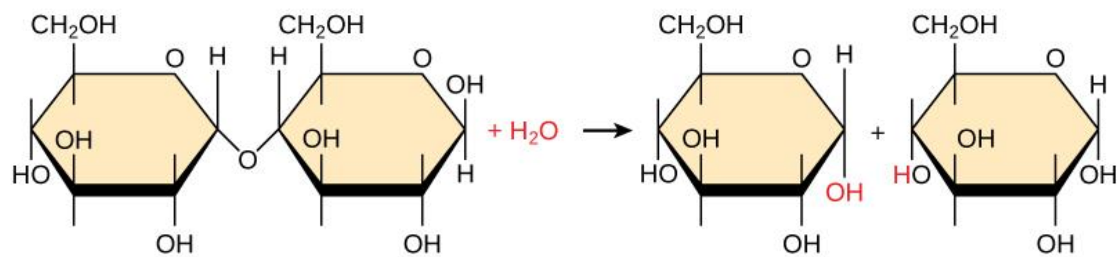


Figure: https://www.maxpixel.net/Dessert-Donut-Icing-Sugar-Donuts-Pastry-Crescent-1200370

- In the body, **disaccharides** are:
  - – used for short-term energy storage
    - when energy is needed, they are broken apart into monosaccharides (by hydrolysis)
    - sucrose = table sugar, the most common disaccharide

hydrolysis



disaccharide *monosaccharides*

Figure: https://world.openfoodfacts.org/cgi/product_image.pl?code=4864394070294&id=front_ka

Figure: https://commons.wikimedia.org/wiki/File:Figure_03_01_02.jpg

- In the body, **polysaccharides** are used for:
  - long-term energy storage
    - starch (in plants) & glycogen (in animals)
  - structural support
    - e.g. cellulose (fiber) in plants

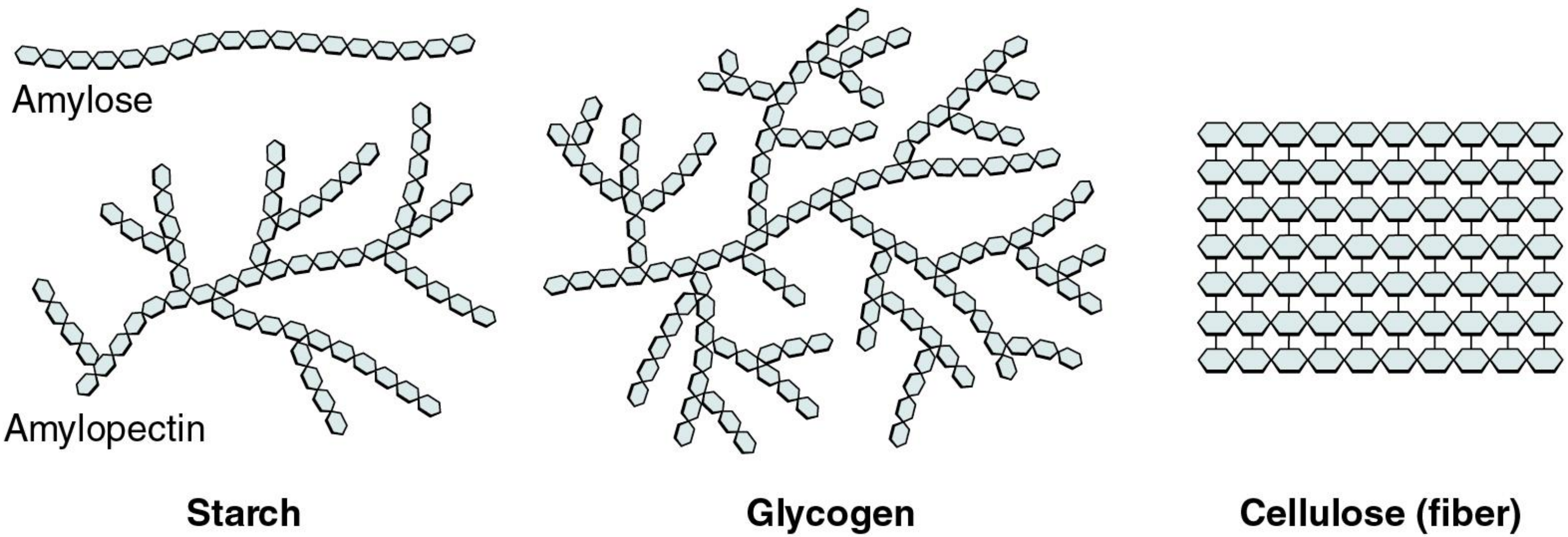
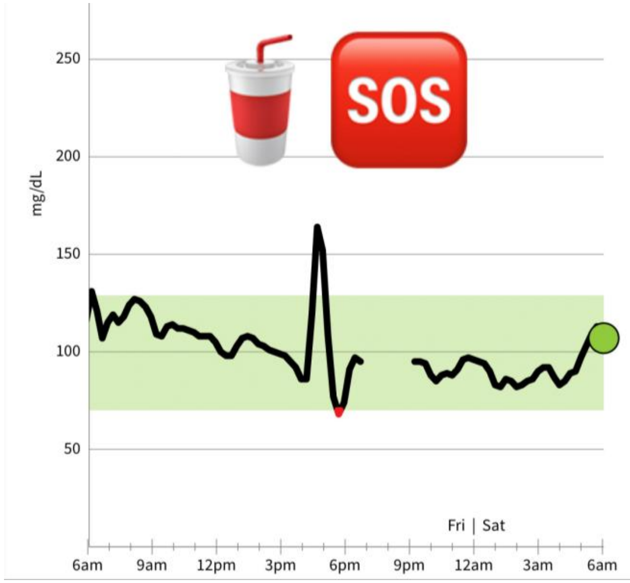


Figure: https://commons.wikimedia.org/wiki/File:219_Three_Important_Polysaccharides-01.jpg

- Carbohydrates (sugars) & blood sugar levels
  - Monosaccharides & disaccharides lead to quick, short increases in blood sugar
    - *if a lot of sugar is consumed, it may even crash afterward, leading to fatigue, headaches, hunger, etc.*
  - Polysaccharides lead to slow, longer-lasting increases or maintenance



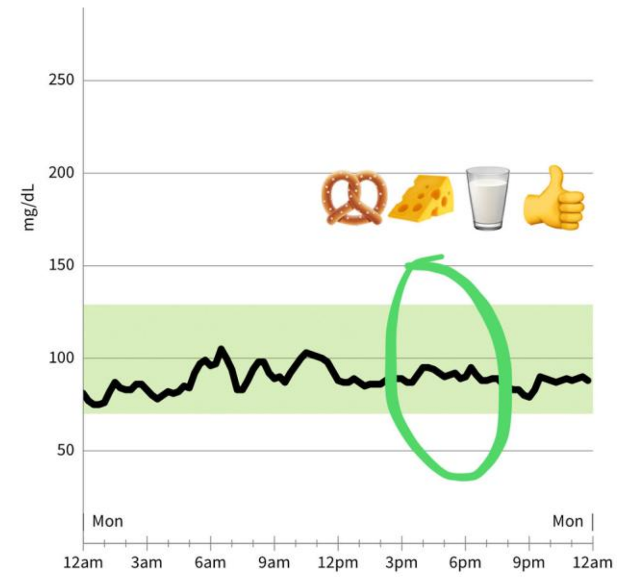


Figure: https://www.tedeytan.com/2019/05/13/33492

Figure: https://www.tedeytan.com/2019/04/28/32835

- Carbohydrates on nutrition labels
  - "Sugars" = monosaccharides & disaccharides
  - "Dietary Fiber" = not digested carbs
    - helps with movement through digestive system
    - helps regulate blood sugar
  - Rest of "Total Carbohydrates" = polysaccharides

Nutrition Facts

3 servings per container

Serving size	**(75g)**
Amount Per Serving	
Calories	**20**
	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Sodium 140mg	**6%**
Total Carbohydrate 4g	**1%**
Dietary Fiber 2g	**7%**
Total Sugars 0g	
Includes 0g Added Sugars	**0%**
Protein 2g	**4%**

Not a significant source of cholesterol, vitamin D, calcium, iron, and potassium

*The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Figure: https://commons.wikimedia.org/wiki/File:Palmini_Nutrition_Label.jpg