Life and Health Science

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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?

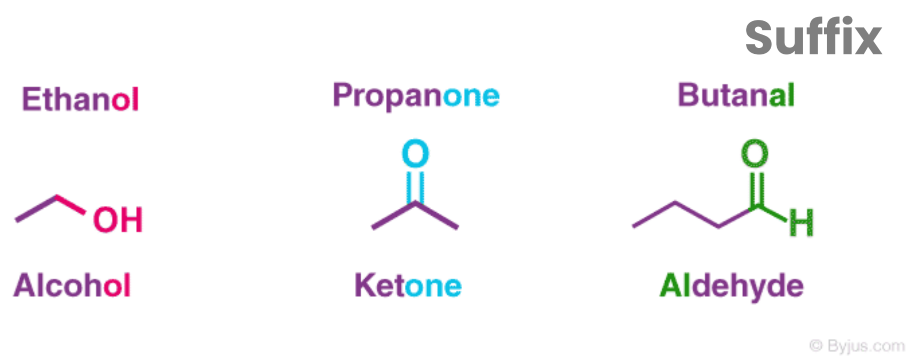
Corresponds with OpenStax Biology 2e Chapter 3

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

- 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*

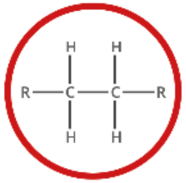
- *the same functional group will behave similarly and experience comparable reactions*



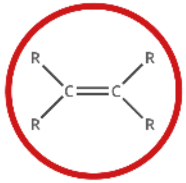
FUNCTIONAL GROUPS IN ORGANIC CHEMISTRY

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.

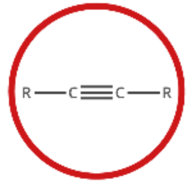
HYDROCARBONS · SIMPLE OXYGEN HETEROATOMICS · HALOGEN HETEROATOMICS · CARBONYL COMPOUNDS · NITROGEN BASED · SULFUR BASED · AROMATIC



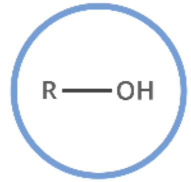
ALKANE
Naming: -ane
e.g. ethane



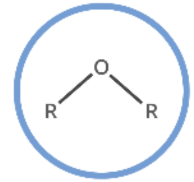
ALKENE
Naming: -ene
e.g. ethene



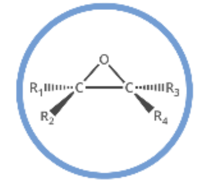
ALKYNE
Naming: -yne
e.g. ethyne



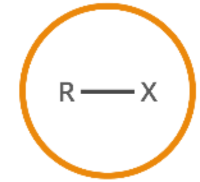
ALCOHOL
Naming: -ol
e.g. ethanol



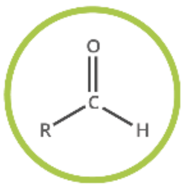
ETHER
Naming: -oxy -ane
e.g. methoxyethane



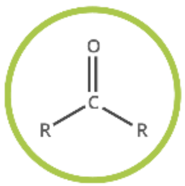
EPOXIDE
Naming: -ene oxide
e.g. ethene oxide



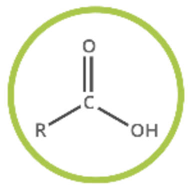
HALOALKANE
Naming: halo-
e.g. chloroethane



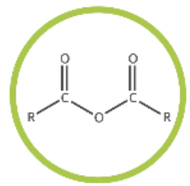
ALDEHYDE
Naming: -al
e.g. ethanal



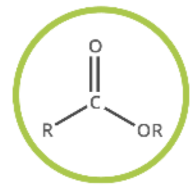
KETONE
Naming: -one
e.g. propanone



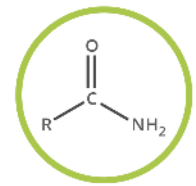
CARBOXYLIC ACID
Naming: -oic acid
e.g. ethanoic acid



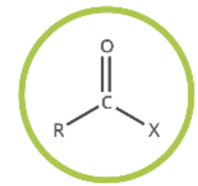
ACID ANHYDRIDE
Naming: -oic anhydride
e.g. ethanoic anhydride



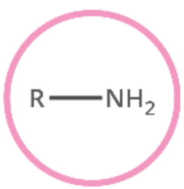
ESTER
Naming: -yl -oate
e.g. ethyl ethanoate



AMIDE
Naming: -amide
e.g. ethanamide



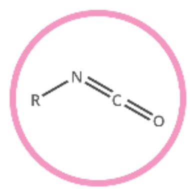
ACYL HALIDE
Naming: -oyl halide
e.g. ethanoyl chloride



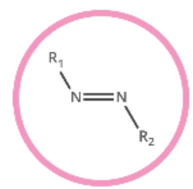
AMINE
Naming: -amine
e.g. ethanamine

NITRILE
Naming: -nitrile
e.g. ethanenitrile

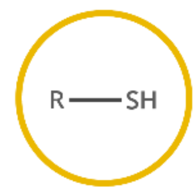
IMINE
Naming: -imine
e.g. ethanimine



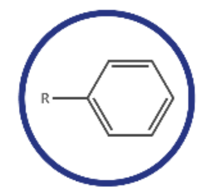
ISOCYANATE
Naming: -yl isocyanate
e.g. ethyl isocyanate



AZO COMPOUND
Naming: azo-
e.g. azoethane

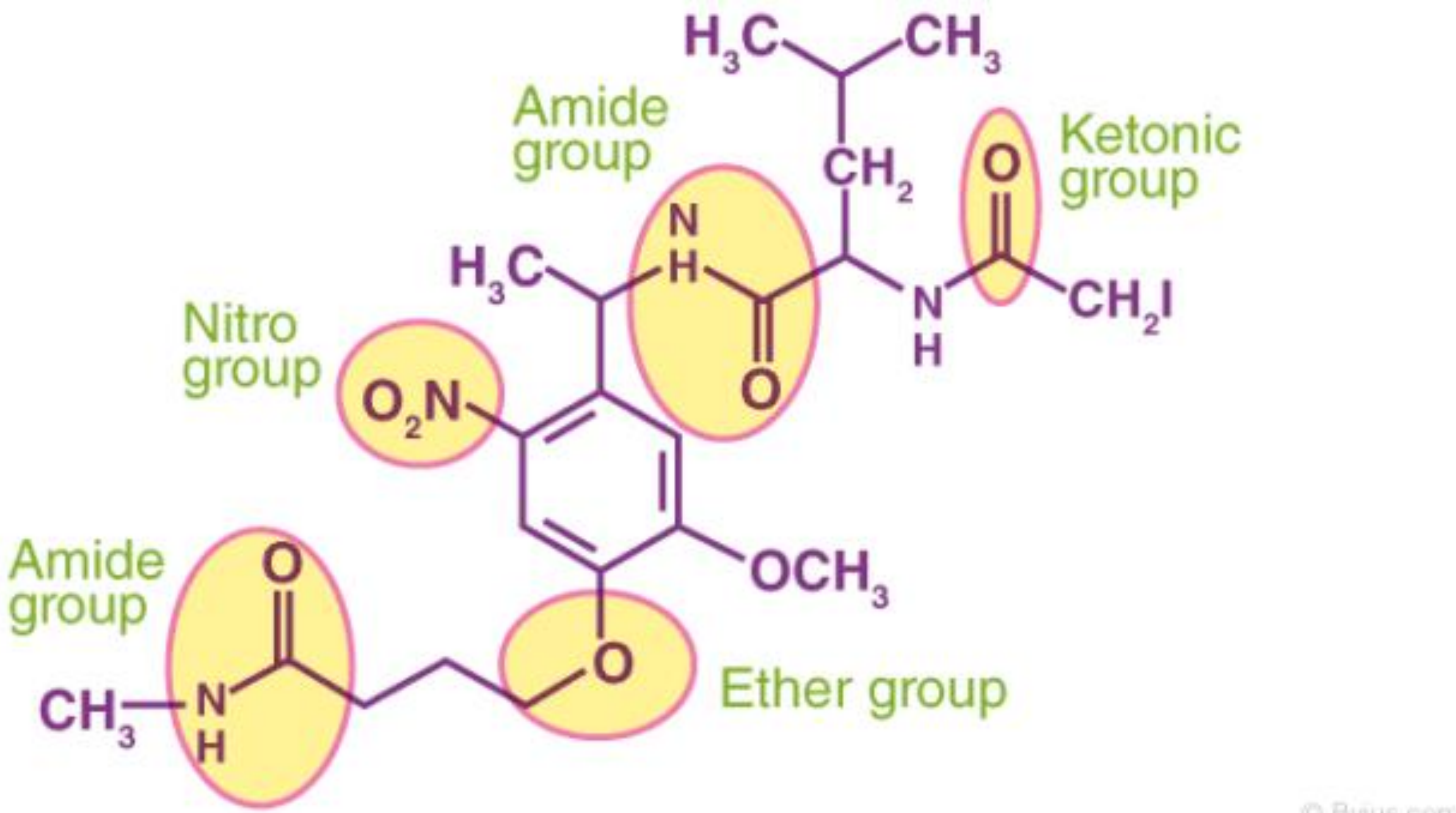


THIOL
Naming: -thiol
e.g. methanethiol



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**

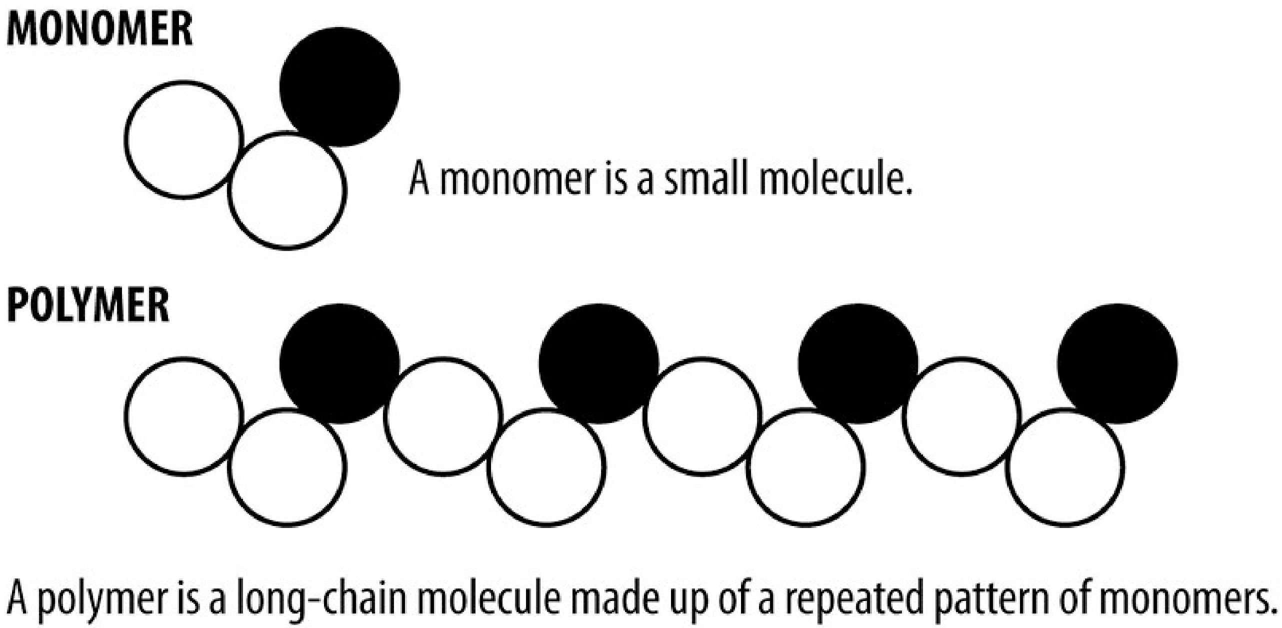
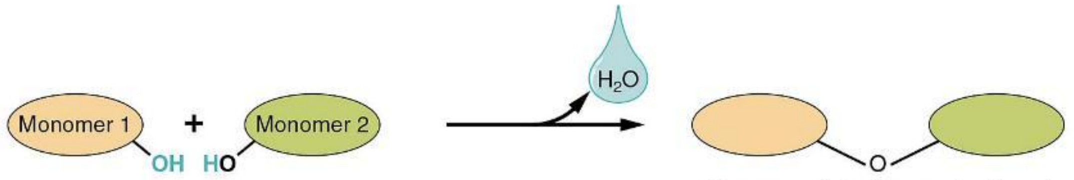


Figure: https://commons.wikimedia.org/wiki/File:1123ghjkghjk.jpg

- 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.

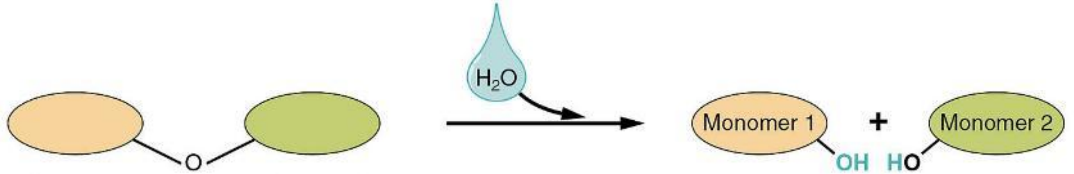
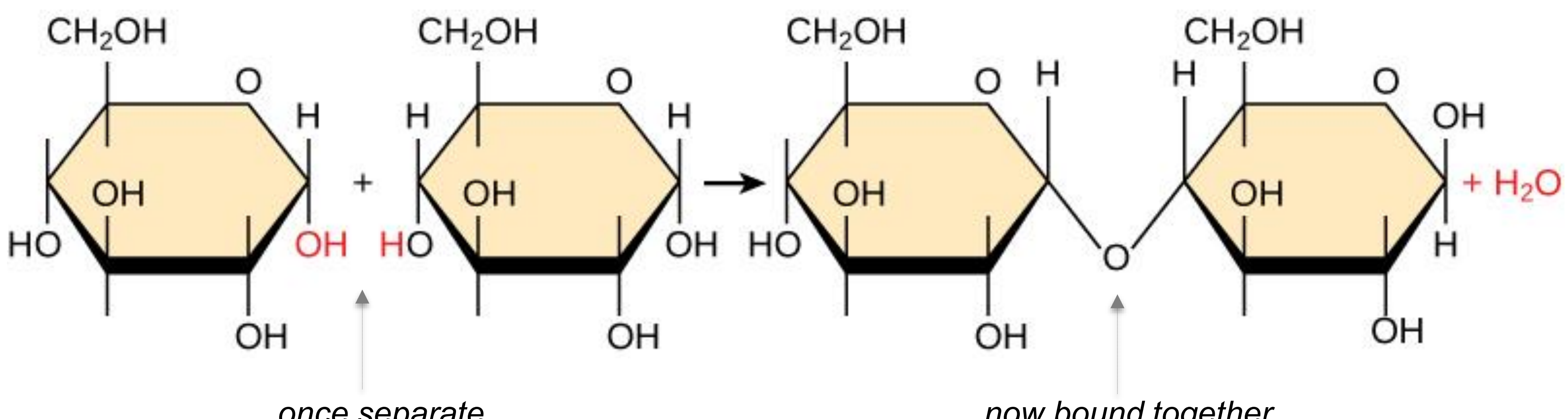


Figure: https://commons.wikimedia.org/wiki/File:213_Dehydration_Synthesis_and_Hydrolysis-01.jpg

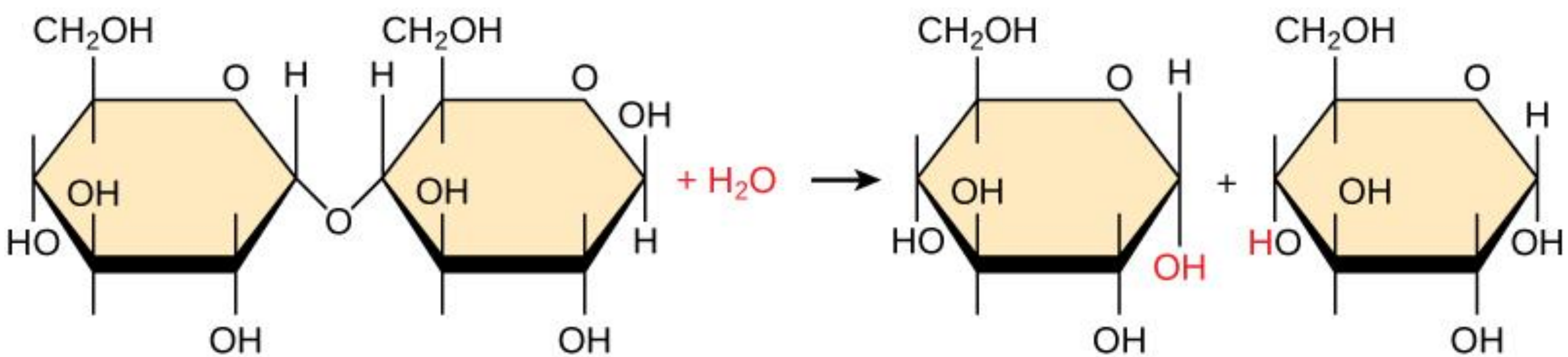
- In **dehydration synthesis**:
  - H & OH removed = loss of water molecule (H_2O)
  - Loss of H_2O means atoms want to bond to stabilize (by forming covalent bonds)
    - Bond together: monomer + monomer = polymer

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)

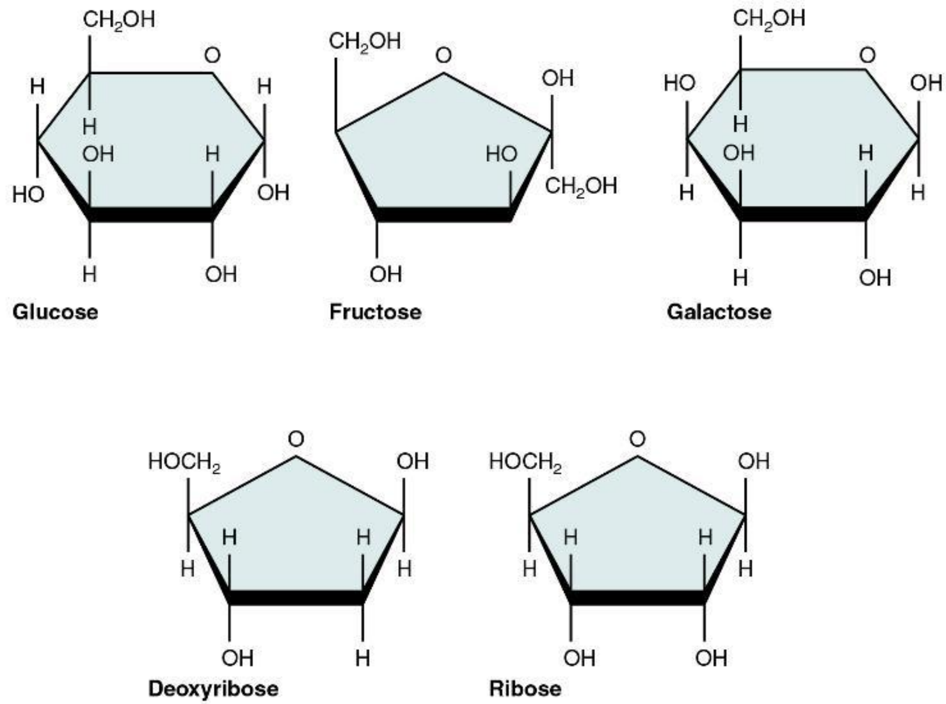
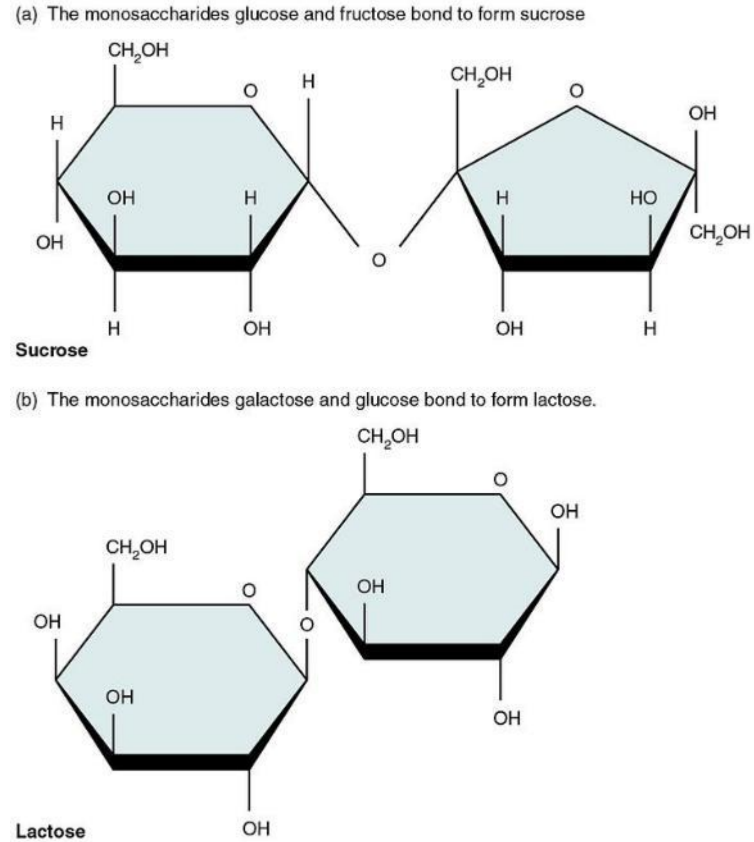


Figure: https://commons.wikimedia.org/wiki/File:217_Five_Important_Monosaccharides-01.jpg

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



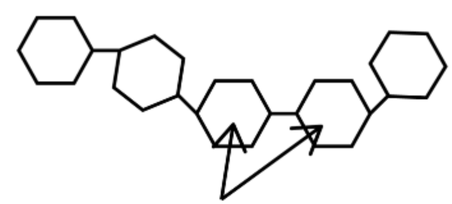


Figure: https://commons.wikimedia.org/wiki/File:218_Three_Important_Disaccharides-01.jpg
Figure: https://commons.wikimedia.org/wiki/File:Simple_Polysaccharide_Hydrolysis.png

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

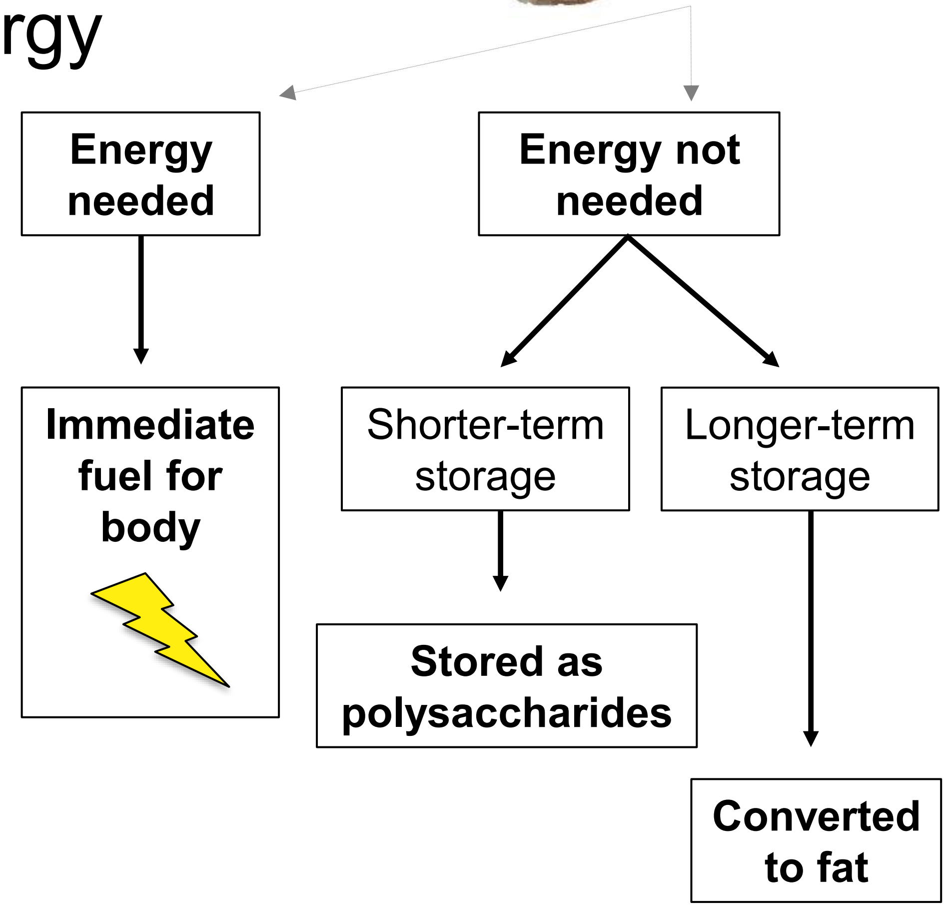


Figure: https://www.maxpixel.net/Dessert-Donut-Icing-Sugar-Donuts-Pastry-Crescent-1200370

- 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

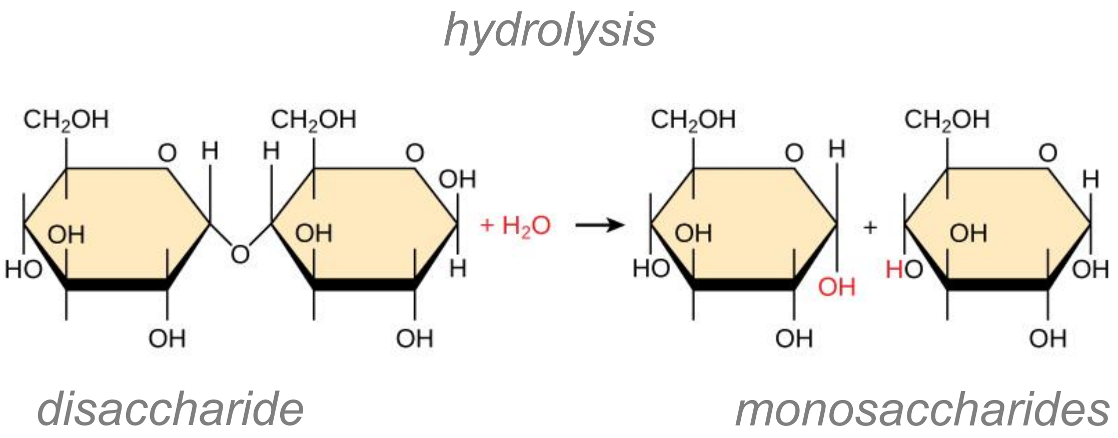


Figure: https://world.openfoodfacts.org/cgi/product_image.pl?code=4864394070294&id=front_ka

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

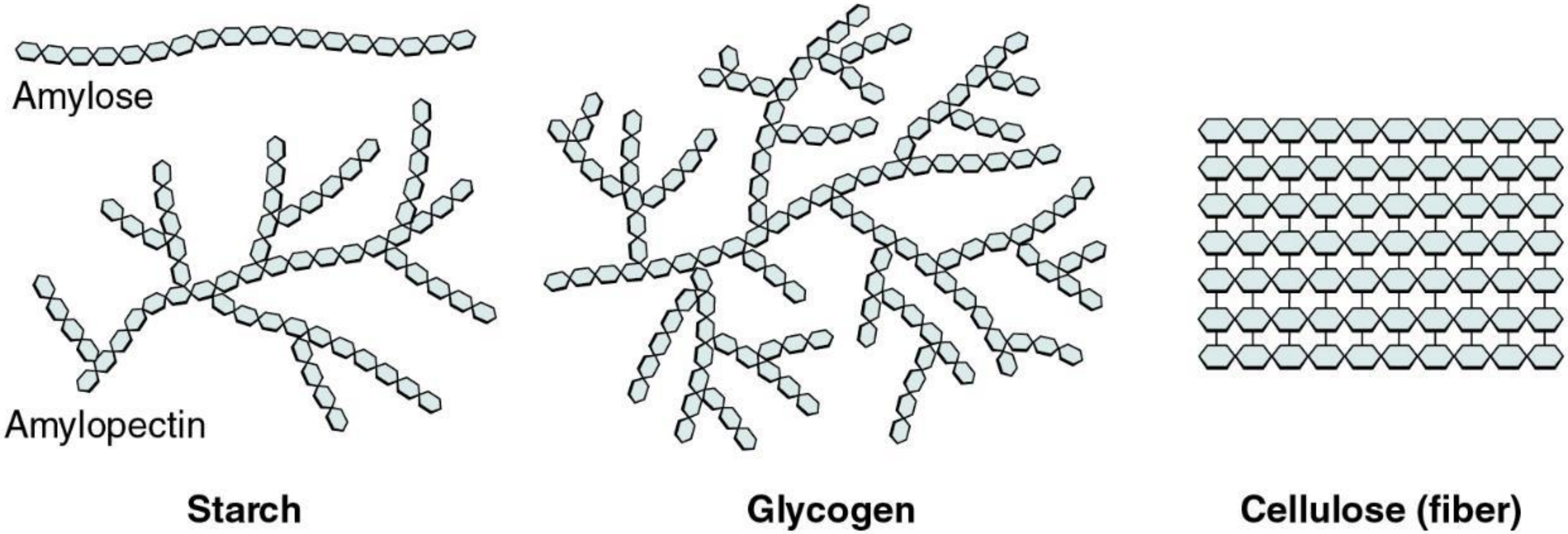
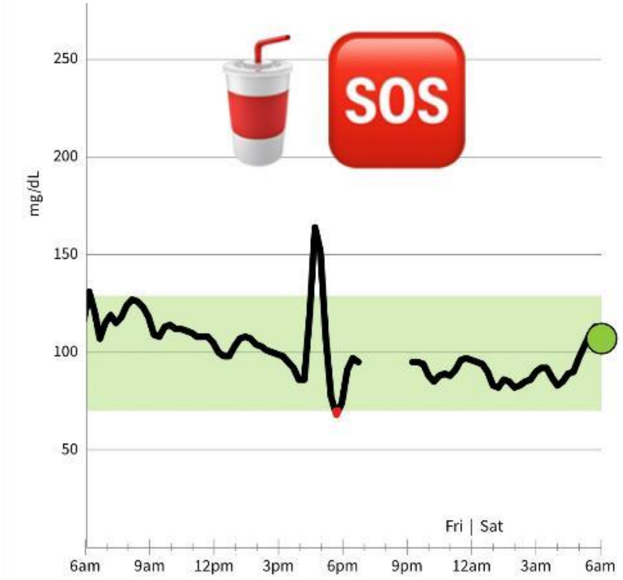


Figure: https://commons.wikimedia.org/wiki/File:219_Three_Important_Polysaccharides-01.jpg

- 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



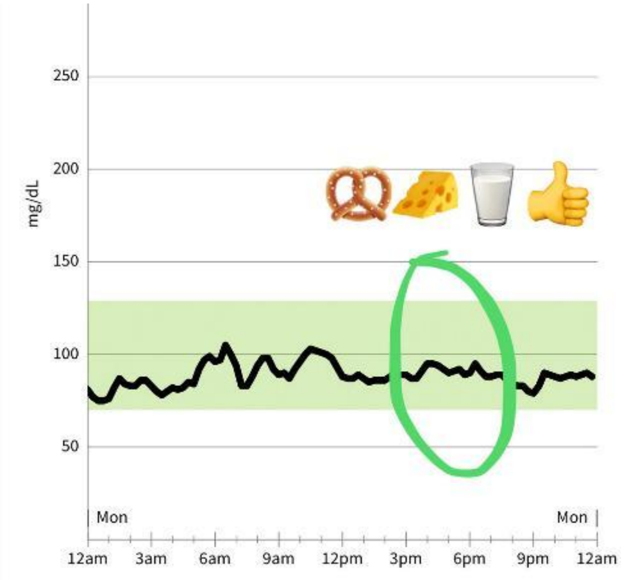


Figure: https://www.tedeytan.com/2019/05/13/33492
Figure: https://www.tedeytan.com/2019/04/28/32835

- Fructose = a monosaccharide
  - **High fructose corn syrup** = high amounts of fructose & some glucose
    - made in a manufacturing plant
    - has replaced table sugar in many food & drinks
      - cheaper than sugar

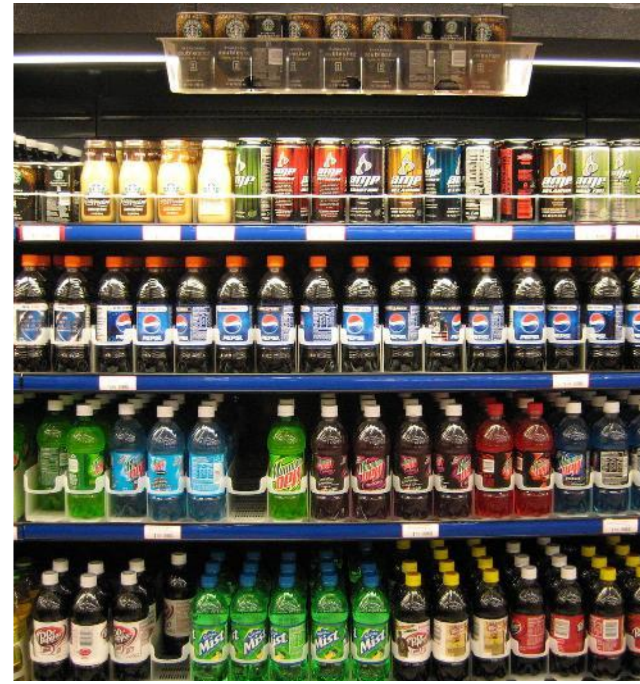


Figure: https://commons.wikimedia.org/wiki/File:Sodas.JPG

Figure: https://www.flickr.com/photos/fanofretail/35636132533

- <u>High Fructose Corn Syrup & health – dangers?</u>
  - fructose is immediately stored as fat in the liver (instead of used as energy or stored as fat elsewhere in the body)
    - likely linked to:
      - diabetes & other metabolic disorders
      - fatty liver disease
      - inflammation
    - best to avoid or in moderation

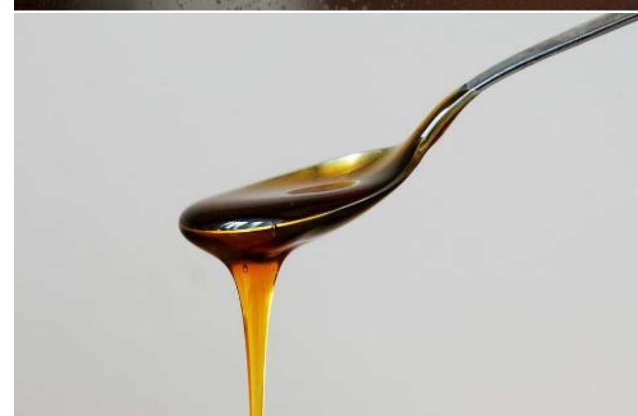


Figure: https://www.flickr.com/photos/oregonstateuniversity/8167345874
Figure: https://www.pxfuel.com/en/free-photo-expxe

- **Artificial sweeteners** = disaccharides similar to table sugar, but are non-digestible: have no calories
  - Found in diet, sugar-free, & low-carb food & drinks
  - Common artificial sweeteners:
    - <u>Sucralose</u>: e.g. “Splenda”
    - <u>Saccharin</u>: e.g. “Sweet ’N Low”
    - <u>Aspartame</u>: e.g. “Equal”

Figure: https://en.wikipedia.org/wiki/Sugar_substitute#/media/File:No-Calorie-Sweetener-Packets.jpg

- <u>Artificial sweeteners & health issues</u>
  - It's hard to know how safe the traditional artificial sweeteners are:
    - many studies show they are safe, but others have found links to insulin resistance/ diabetes, weight gain, migraines, changes in gut health, & other issues

Screenshot = pubmed.com search for review articles covering "artificial sweeteners"

1 Cite Share

The Association Between **Artificial Sweeteners** and Obesity.
Pearlman M, Obert J, Casey L.
Curr Gastroenterol Rep. 2017 Nov 21;19(12):64. doi: 10.1007/s11894-017-0602-9.
PMID: 29159583 Review.
RECENT FINDINGS: Although **artificial sweeteners** were developed as a sugar substitute to help reduce insulin resistance and obesity, data in both animal models and humans suggest that the effects of **artificial sweeteners** may contribute to metabolic synd ...

2 Cite Share

Non-caloric **artificial sweeteners** and the microbiome: findings and challenges.
Suez J, Korem T, Zilberman-Schapira G, Segal E, Elinav E.
Gut Microbes. 2015;6(2):149-55. doi: 10.1080/19490976.2015.1017700. Epub 2015 Apr 1.
PMID: 25831243 Free PMC article. Review.
Non-caloric **artificial sweeteners** (NAS) are common food supplements consumed by millions worldwide as means of combating weight gain and diabetes, by retaining sweet taste without increasing caloric intake. ...

3 Cite Share

Artificial sweeteners: a systematic review of metabolic effects in youth.
Brown RJ, de Banate MA, Rother KI.
Int J Pediatr Obes. 2010 Aug;5(4):305-12. doi: 10.3109/17477160903497027.
PMID: 20078374 Free PMC article. Review.
However, recent animal studies provide intriguing information that supports an active metabolic role of **artificial sweeteners**. This systematic review examines the current literature on **artificial** sweetener consumption in children and its health effects. ...Ra ...

4 Cite Share

The role of **artificial** and natural **sweeteners** in reducing the consumption of table sugar: A narrative review.
Mooradian AD, Smith M, Tokuda M.
Clin Nutr ESPEN. 2017 Apr;18:1-8. doi: 10.1016/j.clnesp.2017.01.004. Epub 2017 Feb 4.
PMID: 29132732 Review.
Commonly used non-caloric **artificial sweeteners** may have unfavorable effect on health including glucose intolerance and failure to cause weight reduction. The nutritive **sweeteners** include sugar alcohols such as sorbitol, xylitol, lactitol, mannitol, erythrito ...

5 Cite Share

Artificial sweeteners: safe or unsafe?
Qurrat-ul-Ain, Khan SA.
J Pak Med Assoc. 2015 Feb;65(2):225-7.
PMID: 25842566 Review.
Artificial sweeteners or intense **sweeteners** are sugar substitutes that are used as an alternative to table sugar. ...There is some ongoing debate over whether **artificial** sweetener usage poses a health threat .This review article aims to cover thehealth ...

6 Cite Share

Artificial sweeteners--do they bear a carcinogenic risk?
Weihrauch MR, Diehl V.
Ann Oncol. 2004 Oct;15(10):1460-5. doi: 10.1093/annonc/mdh256.
PMID: 15367404 Free article. Review.
Artificial sweeteners are added to a wide variety of food, drinks, drugs and hygiene products. ...However, according to the current literature, the possible risk of **artificial sweeteners** to

- Some of the newer artificial sweeteners are more naturally derived & seem to have better health effects
  - Monk fruit: e.g. nectresse
  - Sugar alcohols: e.g. sorbitol, xylitol, & erythritol
  - Stevia: also called RebA, Truvia, PureVia, etc.

Figure: https://www.flickr.com/photos/jeepersmedia/14977306178

Figure: https://world.openfoodfacts.org/product/6600426740982/erythritol-sugar-replacement-buy-trusted-food

Figure: https://www.flickr.com/photos/jeepersmedia/16384420261

- **Proteins** do nearly everything that make us "us" & keep us alive
  - Human bodies make over 10,000 different proteins
    - a problem with only ONE can = illness or death

These are just a few types of proteins & their functions

Protein Types and Functions

Type	Examples	Functions
Digestive Enzymes	Amylase, lipase, pepsin, trypsin	Help in food by catabolizing nutrients into monomeric units
Transport	Hemoglobin, albumin	Carry substances in the blood or lymph throughout the body
Structural	Actin, tubulin, keratin	Construct different structures, like the cytoskeleton
Hormones	Insulin, thyroxine	Coordinate different body systems' activity
Defense	Immunoglobulins	Protect the body from foreign pathogens
Contractile	Actin, myosin	Effect muscle contraction
Storage	Legume storage proteins, egg white (albumin)	Provide nourishment in early embryo development and the seedling

Figure from OpenStax Biology 2e

- Proteins have so many functions
  - Make up muscles
  - Act as hormones
  - Regulate blood sugar
  - Carry oxygen to all cells
  - Allow sperm cells to swim
  - Significant component of bone
  - Clot blood when wounds occur
  - Make up skin, feathers, horns, & hair
  - Make up the pigments that define eye, hair, & skin color
  - Act as enzymes, assisting chemical reactions in our bodies
  - Make up immune system to fight foreign invaders
  - Allow us to see the world in color (instead of black & white)

curly vs. straight hair, darker vs. lighter skin: it's all about proteins

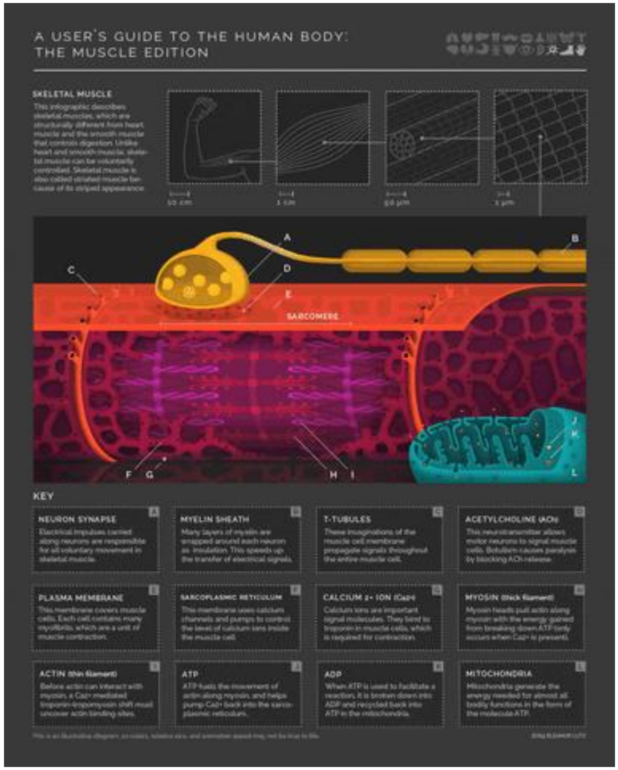
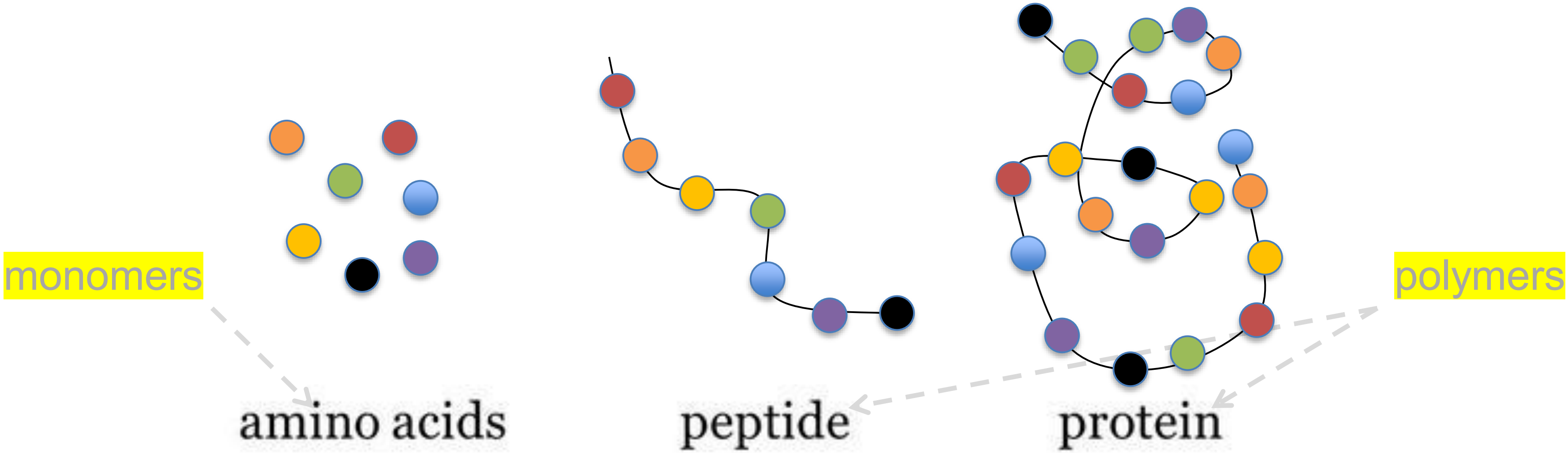


Figure: https://commons.wikimedia.org/wiki/File:Kelly_Rowland_1.jpg
Figure: https://pxhere.com/en/photo/903073

- Even though proteins do so many different things, they are all made the same way out of the same building blocks: amino acids
  - **Amino acids** = monomers of proteins, the basic building blocks
    - Join together to make short **peptides**
    - Long peptides = **polypeptides** = proteins



Fill the blank(s) Points: 2

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- There are [填空1] different amino acids
  - The sequence of amino acids is different for each protein, which is how we can make so many different kinds of proteins
  - Human body can make [填空2] from scratch
    - Other 9 must come from our diet: called **essential amino acids**

Essential	Nonessential
Histidine	Alanine
Isoleucine	Arginine
Leucine	Asparagine
Lysine	Aspartate
Methionine	Cysteine
Phenylalanine	Glutamate
Threonine	Glutamine
Tryptophan	Glycine
Valine	Proline
	Serine
	Tyrosine

作答

- Some foods have “complete proteins” with all 9 essential amino acids
  – e.g. meats & dairy, plus plenty of plant sources such as soy & quinoa
  – can combine foods to get all 9: e.g. beans + rice

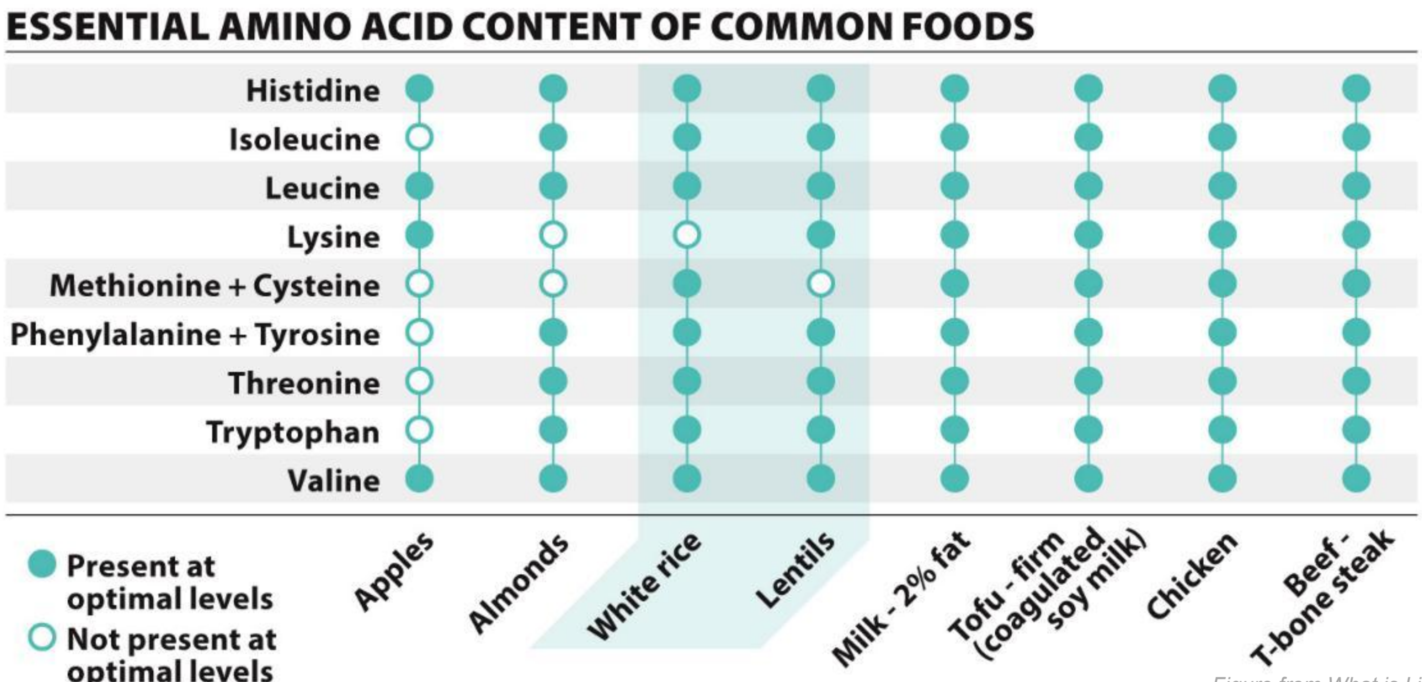


Figure from What is Life? A Guide to Biology

- Amino acids join together to make a long polypeptide chain / protein

  – <u>Proteins must be folded into the correct shape/structure before they can function</u>

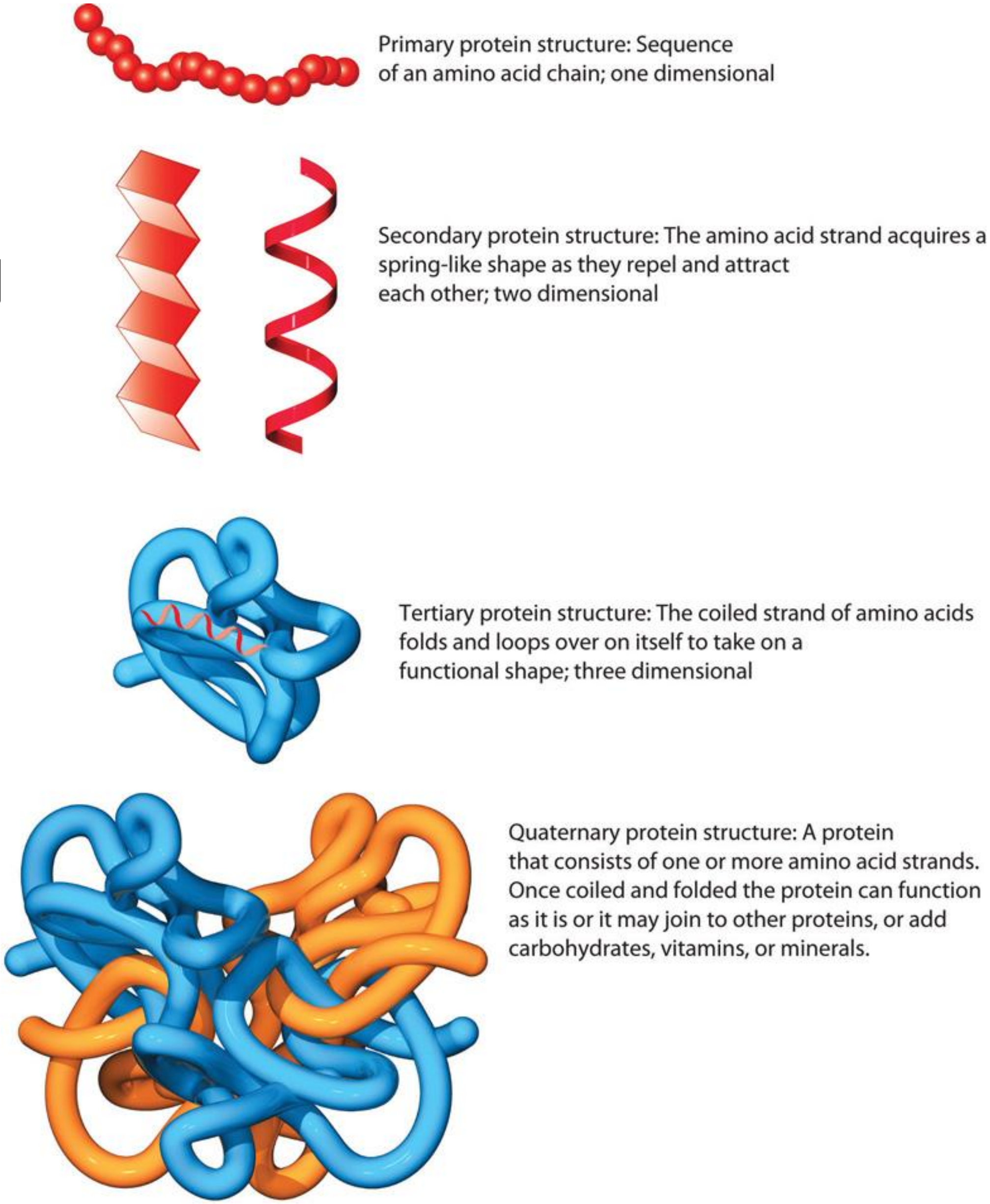
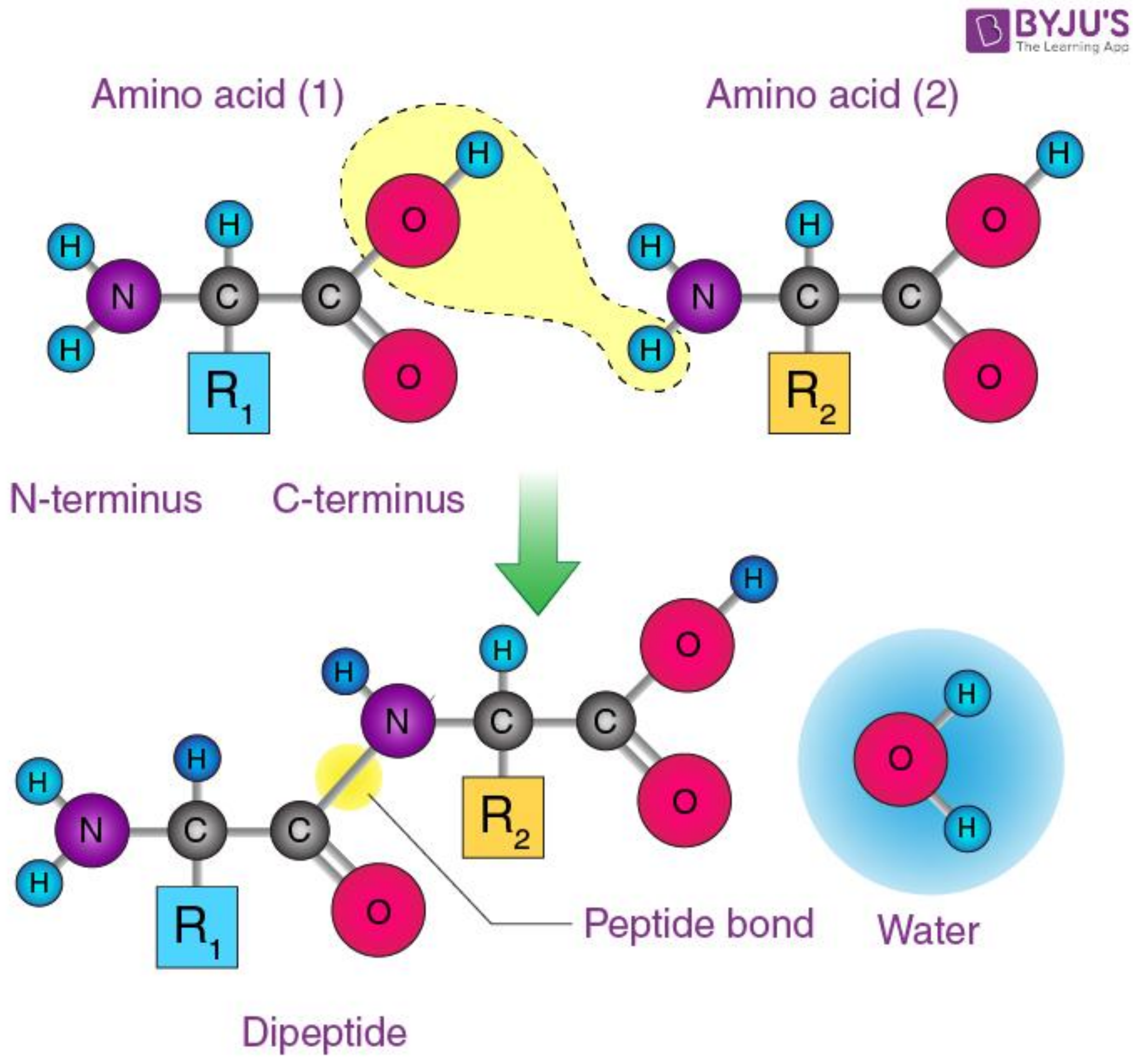


Figure: https://en.wikiversity.org/wiki/File:4organizationsofproteins.jpg

Peptide Bond



- **Characteristics of Peptide Bonds**
- 1. Peptide bonds are strong with partial double bond character:
    - They are not broken by heating or high salt concentration.
    - They can be broken by exposing them to strong acids or bases for a long time at elevated temperature, and also by some specific enzymes (digestive enzymes).
- 2. Peptide bonds are rigid and planar bonds; therefore, they stabilise protein structure.
- 3. Peptide bond contains partial positive charge groups (polar hydrogen atoms of amino groups) and partial negative charge groups (polar oxygen atoms of carboxyl groups).

- **Different Forms of Peptide Bond**
    - **Dipeptide =** contains 2 amino acid units.
    - **Tripeptide =** contains 3 amino acid units.
    - **Tetrapeptide =** contains 4 amino acid units.
    - **Oligopeptide =** contains not more than 10 amino acid units.
    - **Polypeptide =** contains more than 10 amino acid units, up to 100 residues.
    - **Macropeptides =** made up of more than 100 amino acids.

- **Primary structure**: amino acids have just been joined together (with peptide bonds) to make a long polypeptide chain
  - *not functional yet*

- **Secondary structure**: the polypeptide chain begins to fold up (through hydrogen bonding)
  - *still not functional yet*

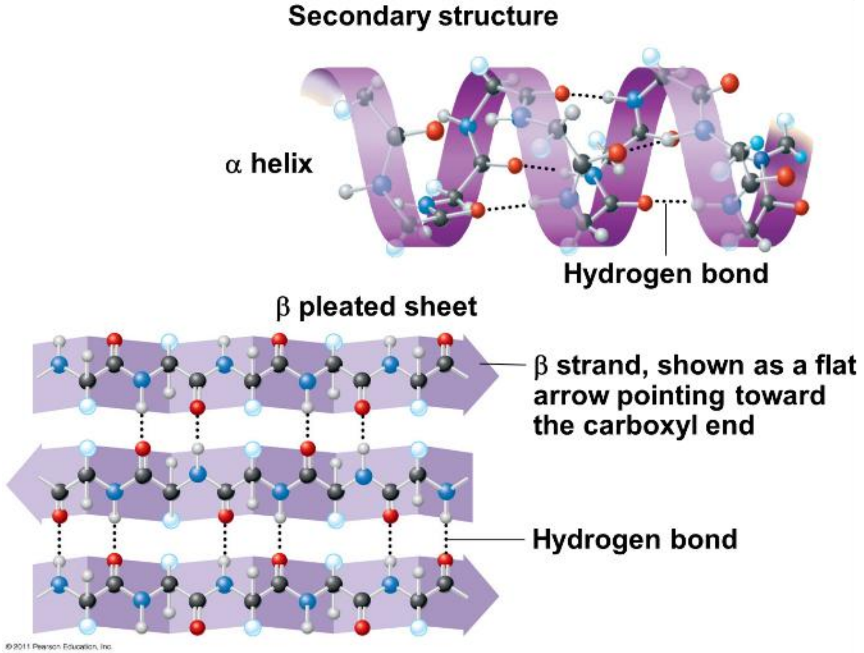


Figure: https://en.wikiversity.org/wiki/File:4organizationsofproteins.jpg

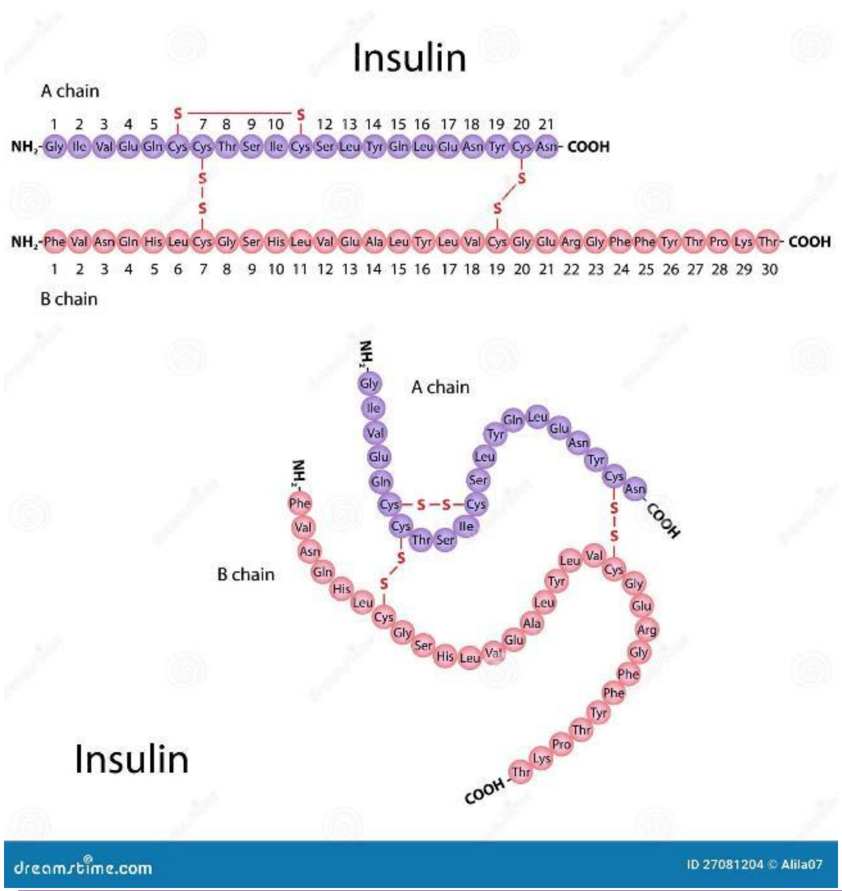
Open Question

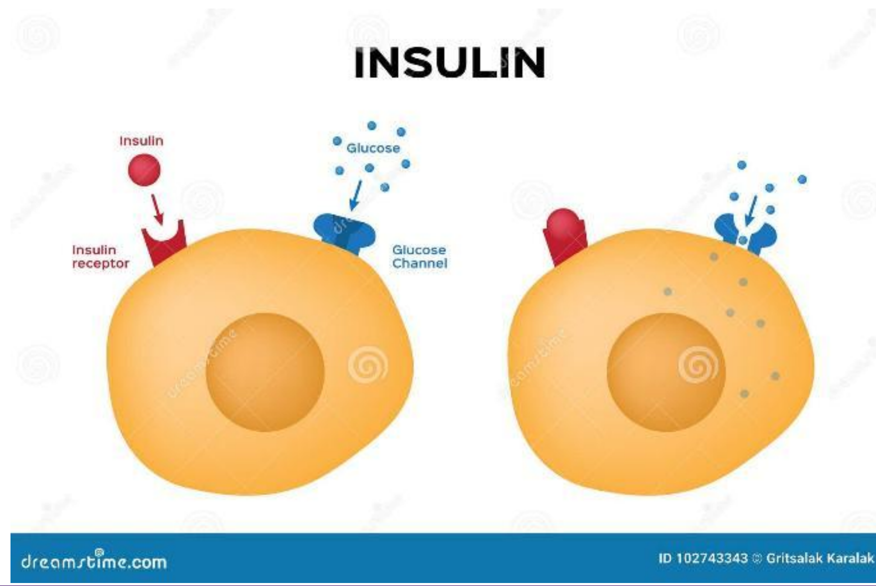
Points: 1

设置

Insulin can react with glucose to lower blood sugar levels.

作答

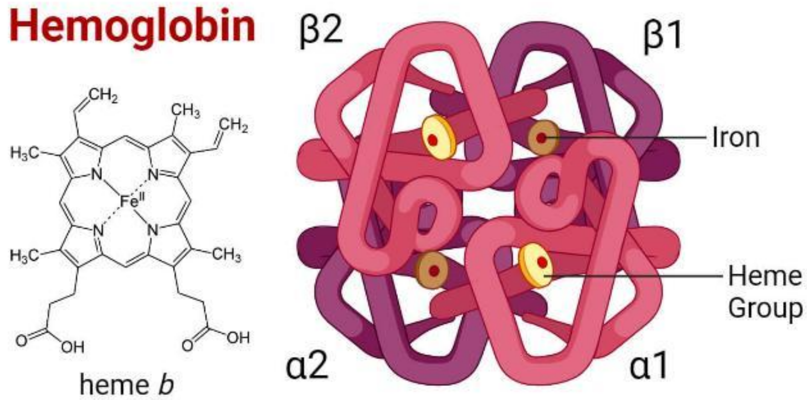


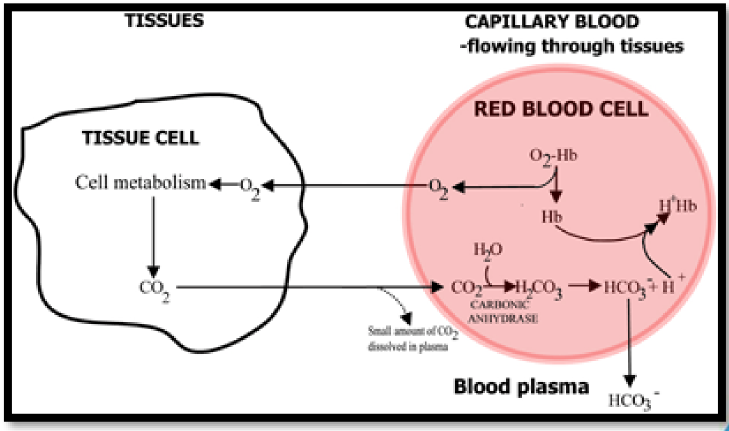


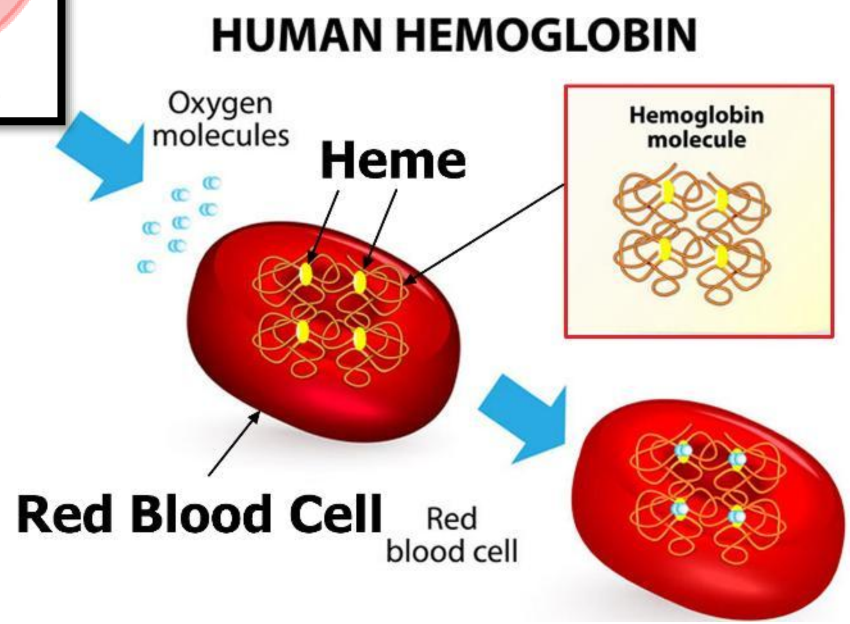
- **Tertiary structure**: polypeptide chain is now fully folded & ready to do simple work
  - 1st point a protein is functional
  - *e.g. a simple antibody in immune system*

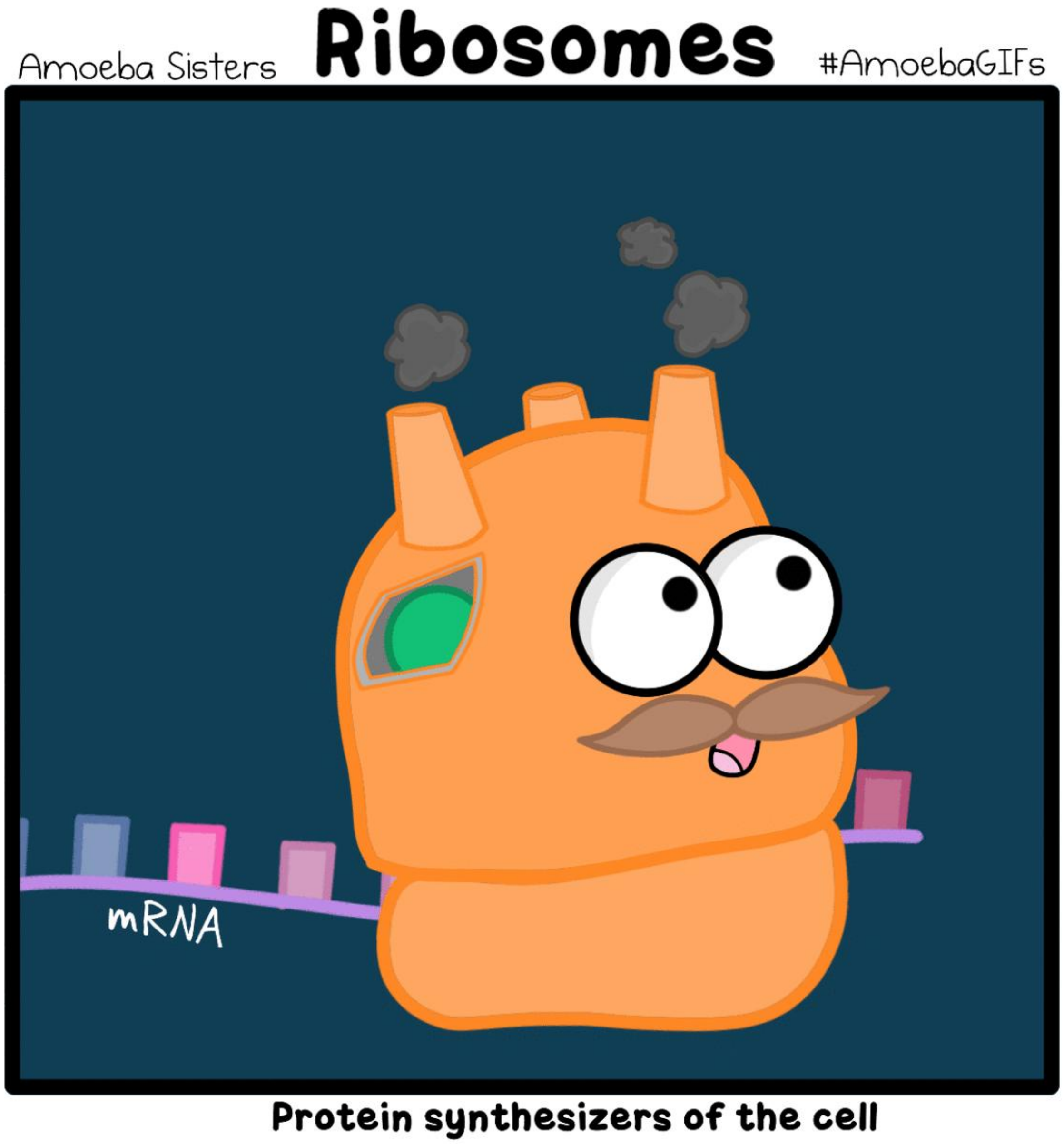
- **Quaternary structure**: 2 or more polypeptide chains bind together to do more complex work
  - *e.g. four join together to make hemoglobin, which carries oxygen from lungs all around the body*
  - *e.g. dozens join together to make ribosomes, which build new proteins*

Figure: https://en.wikiversity.org/wiki/File:4organizationsofproteins.jpg


Hemoglobin
heme b
β2
β1
Iron
Heme Group
α2
α1


TISSUES
CAPILLARY BLOOD
-flowing through tissues
RED BLOOD CELL
TISSUE CELL
Cell metabolism
Small amount of CO2 dissolved in plasma
CARBONIC ANHYDRASE
Blood plasma


HUMAN HEMOGLOBIN
Oxygen molecules
Heme
Hemoglobin molecule
Red Blood Cell
Red blood cell



https://www.deviantart.com/sarinasunbeam/art/Ribosome-GIF-554636710

- If a protein becomes unfolded or mis-folded, it can no longer function
  - **Denaturation** = unfolding of a protein
    - Many things can cause a protein to denature, thereby losing its function permanently

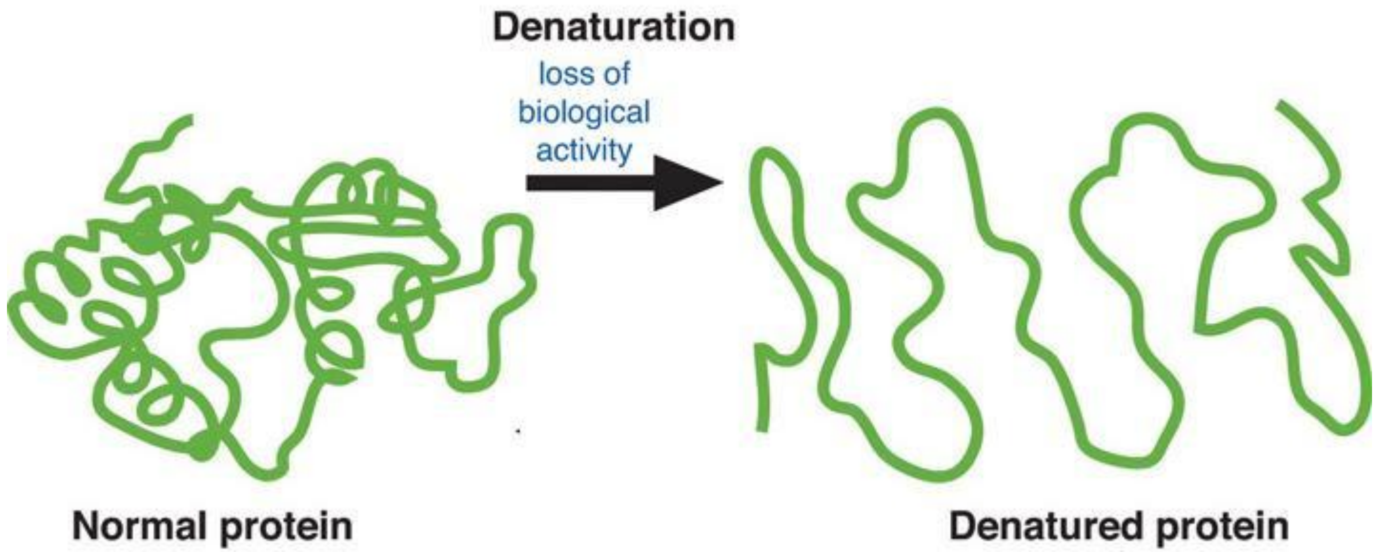


Figure: https://pressbooks.bccampus.ca/nutr1100/chapter/protein-digestion-and-absorption/

- <u>Remember</u>: proteins do nearly everything to keep us alive & many things can cause proteins to denature
  - – If our bodies get too hot, too acidic, too basic, too salty, etc., our proteins will denature & we die
- <u>Remember</u>: living things must maintain homeostasis – now you know why!

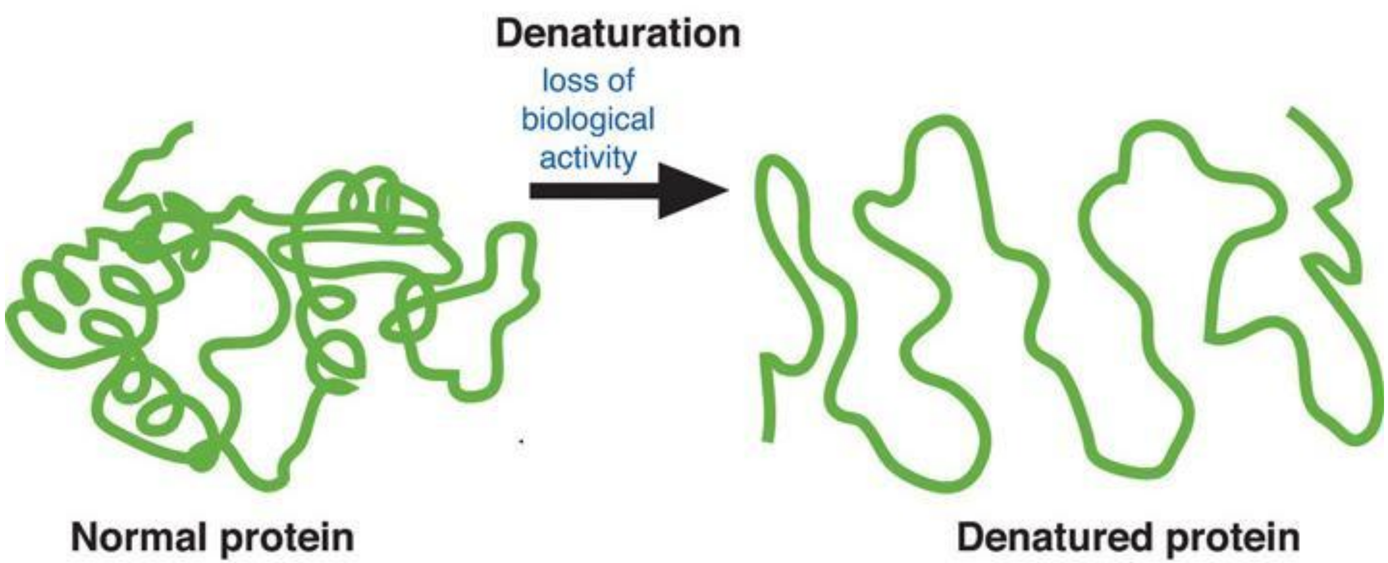


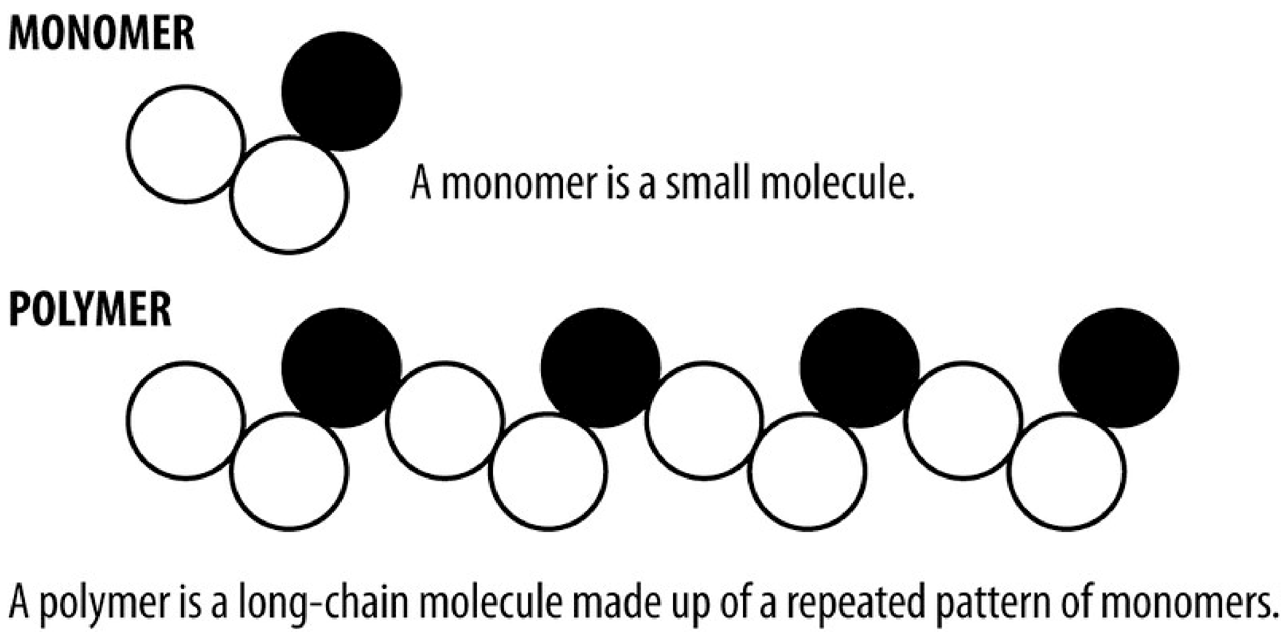
Figure: https://pressbooks.bccampus.ca/nutr1100/chapter/protein-digestion-and-absorption/

- How does a cell know which *proteins* to make in order to build & maintain our bodies?
  - the information is stored in **nucleic acids**
    - e.g. DNA & RNA

- How does a cell get the energy out of *carbohydrates* & send it to where it's needed in our bodies?
  - the energy is carried by **nucleic acids**
    - e.g. ATP

Figure: https://innovativegenomics.org/glossary/nucleic-acid/

- **Nucleic acids** are polymers made up of chains of nucleotides
  - **Nucleotides** = monomers, each of which has at least 1 phosphate, a sugar, & a base



- **Nucleic acids** are polymers made up of chains of nucleotides
  - **Nucleotides** = monomers, each of which has at least 1 phosphate, a sugar, & a base

one nucleotide monomer has 3 components

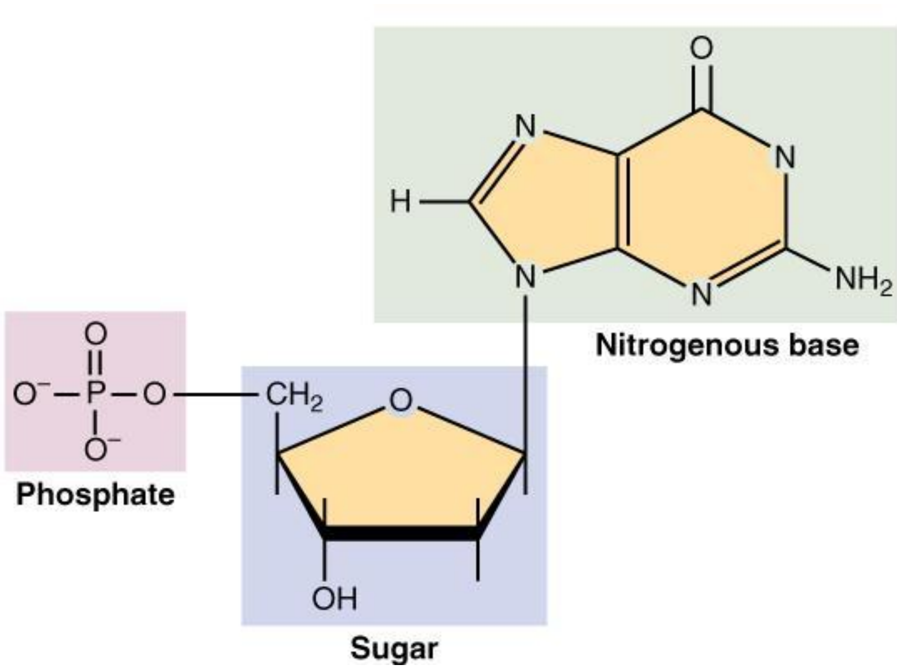


Figure: https://commons.wikimedia.org/wiki/File:0322_DNA_Nucleotides.jpg

Fill the blank(s) Points: 1

设置

How many types of bases are there in total? [填空1]

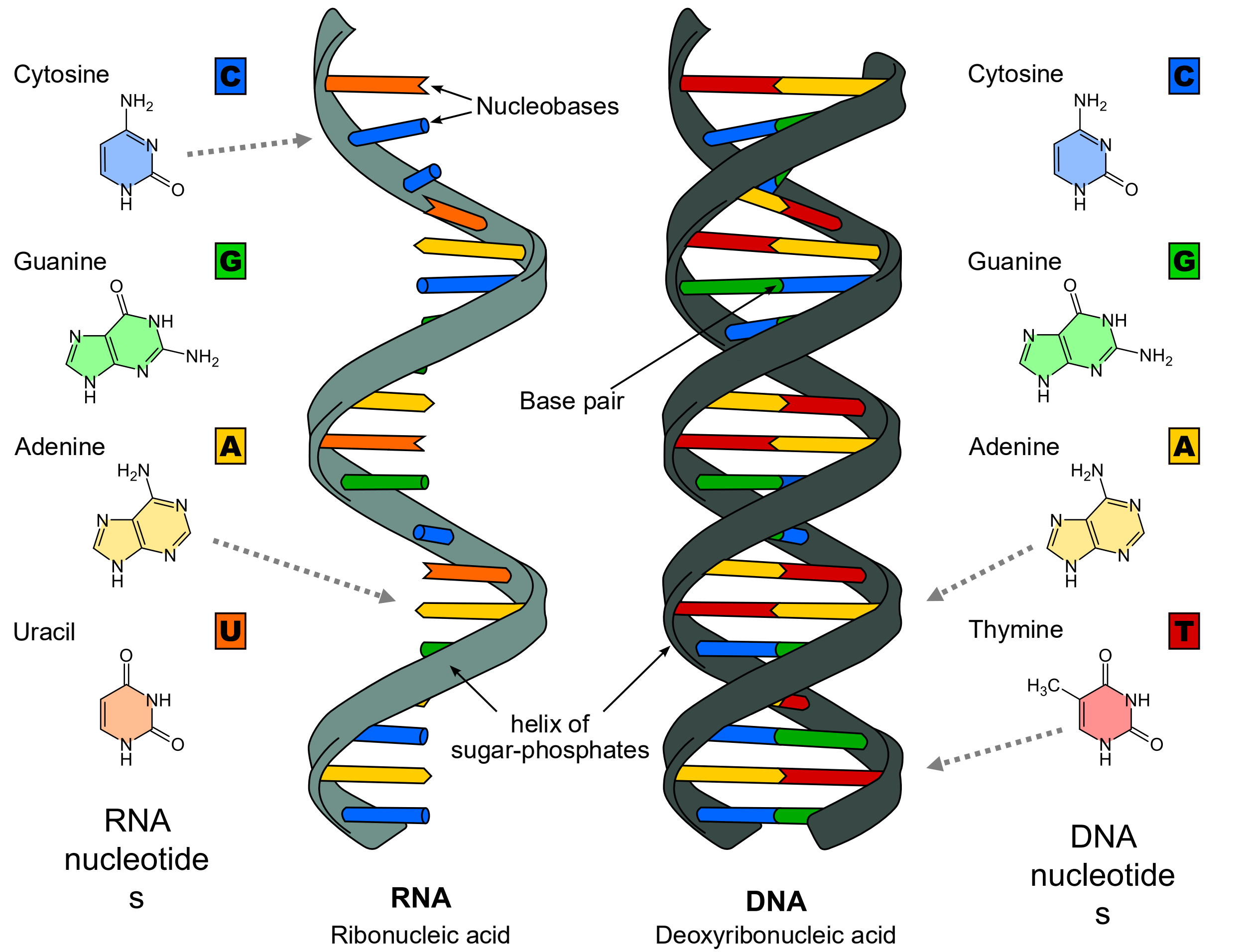


Figure: https://commons.wikimedia.org/wiki/File:Difference_DNA_RNA-EN.svg

作答

- A chain of nucleotides make up a nucleic acid

- **DNA**: locked in the nucleus of cells, stores our genetic information

- **RNA**: acts as a messenger, carrying instructions from DNA out to the rest of the cell

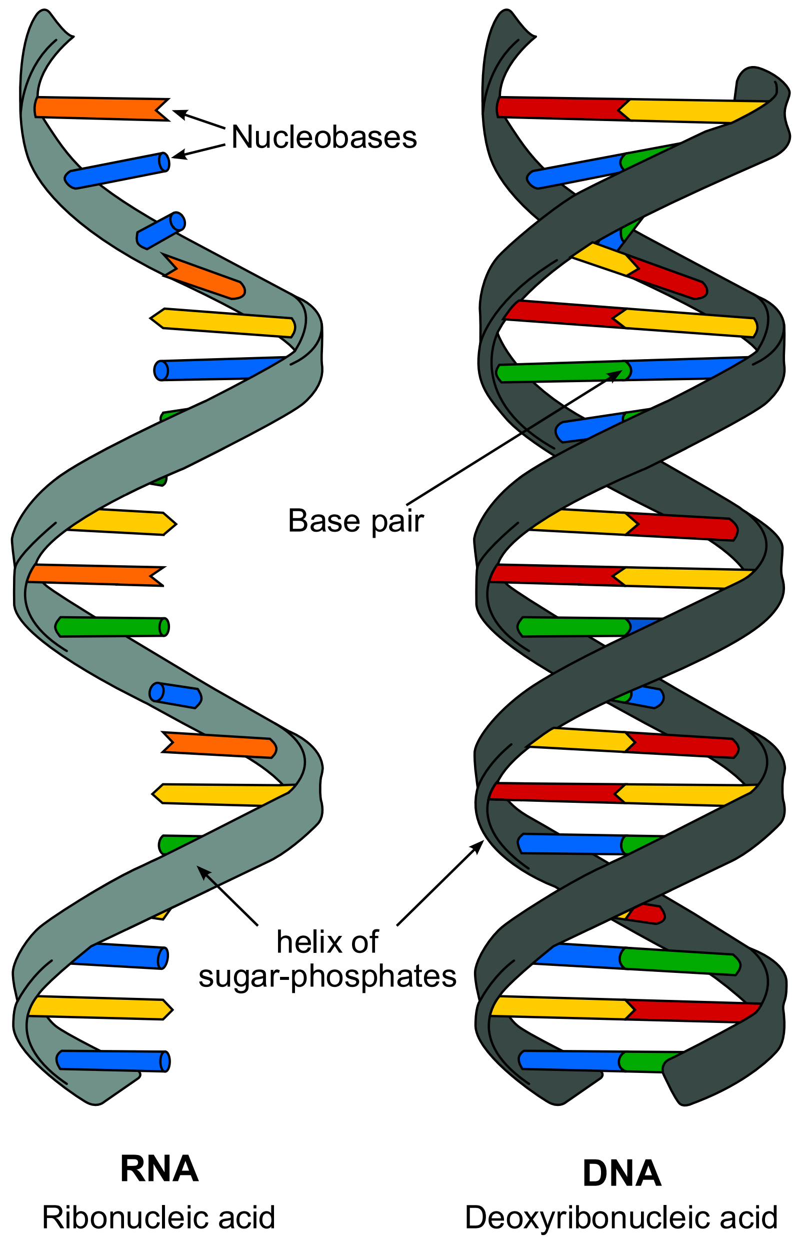
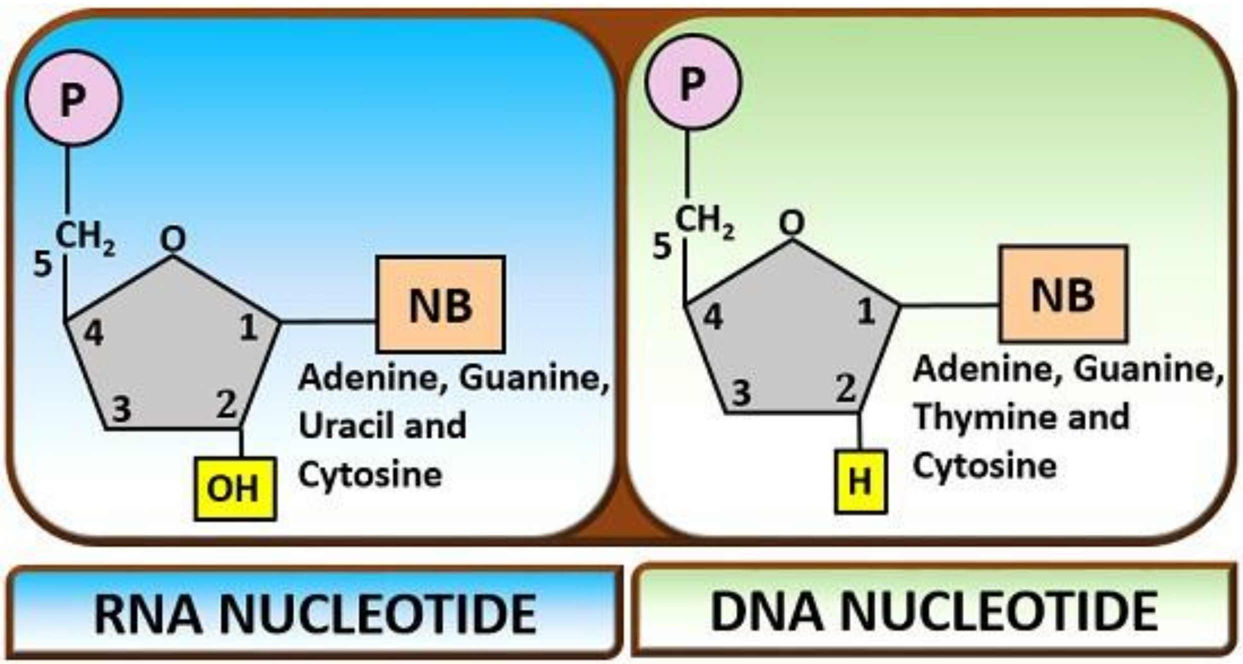


Figure: https://commons.wikimedia.org/wiki/File:Difference_DNA_RNA-EN.svg

Fill the blank(s) Points: 1

设置

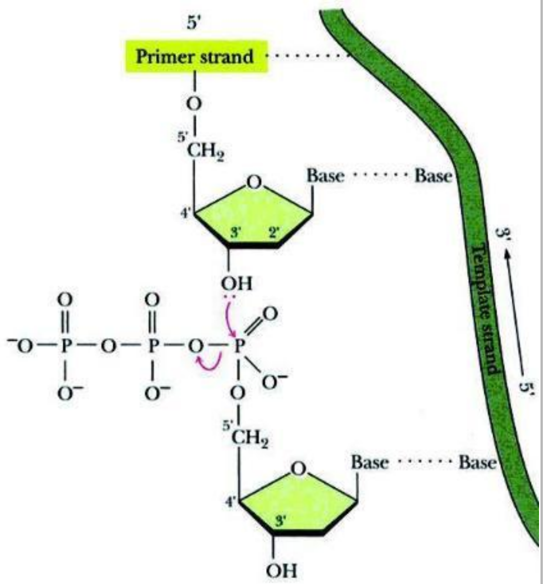
How many types of nucleotides are there in total? [填空1]

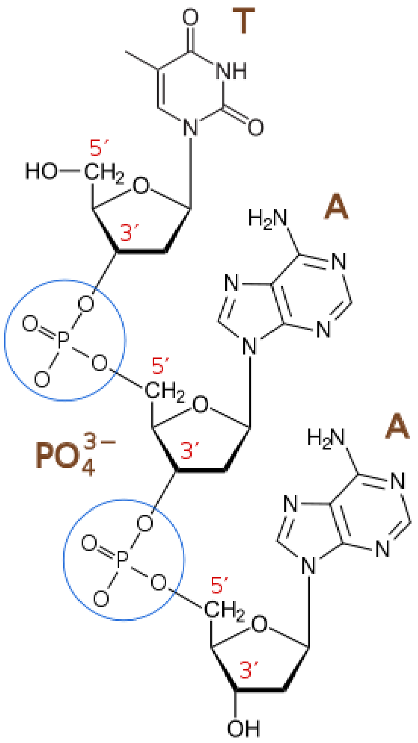


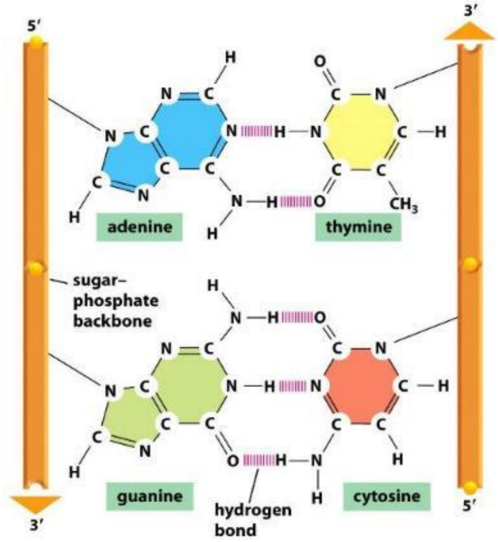
https://biologyreader.com/nucleotide.html

作答

Phosphodiester bond







We can define a phosphodiester bond as the bond which occurs when phosphate forms two *ester bonds*.

- Some nucleotides stay as monomers permanently (never join together to make a nucleic acid)
  - e.g. **ATP**: carries energy (from breaking down carbohydrates) around the cell to where it's needed

ATP = <u>adenosine triphosphate</u>: 3 phosphates help the molecule carry energy

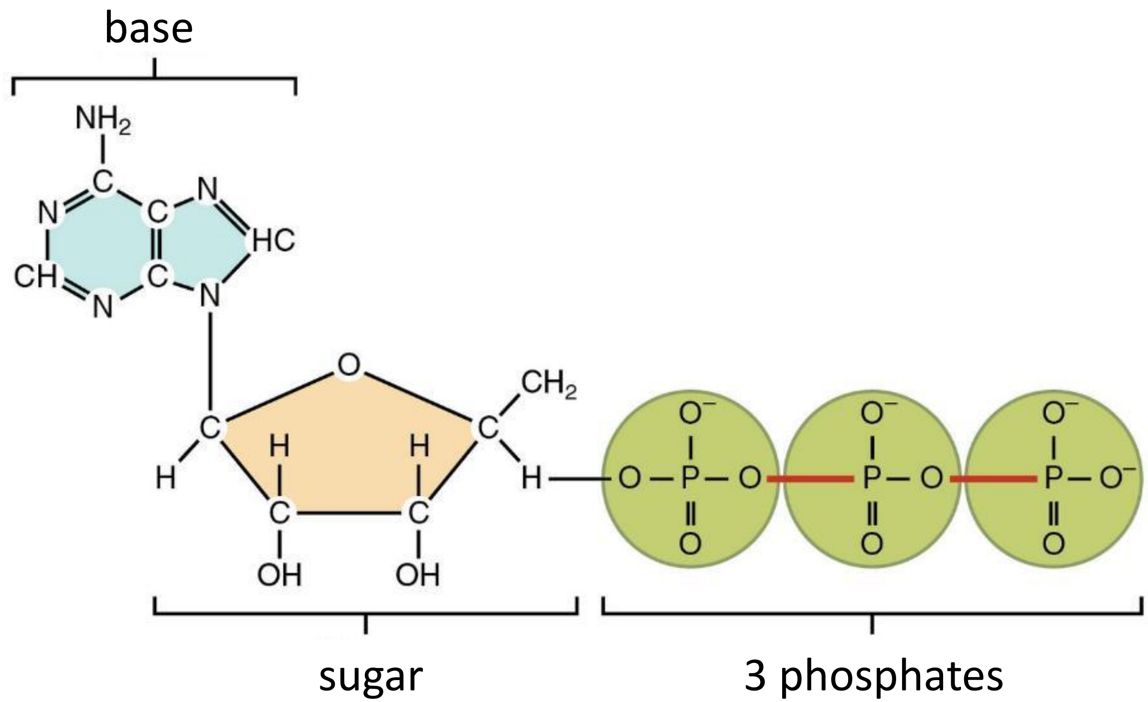


Figure: https://commons.wikimedia.org/wiki/File:230_Structure_of_Adenosine_Triphosphate_(ATP)-01.jpg

Report 4

Discuss the biological importance/significance of (1) peptide bonds, and (2) phosphodiester bonds, individually;

and analyze why life chooses nucleic acids as the carrier of genetic information based on the chemical principles of phosphodiester bonds.

Tips:

>1 page with A4 paper; 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.

Same Email LifeHealthScience@yeah.net

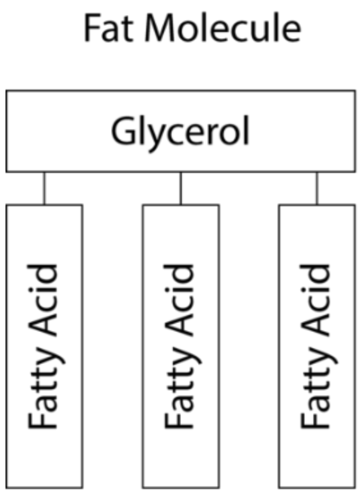
- **Lipids** = all are hydrophobic molecules
    - *Made by proteins, which are directed by nucleic acids, using the energy from carbohydrates*

  – Many uses, including energy storage, waterproofing, hormones, cell membranes, etc.
    - have diverse chemical structures, with no defined monomers or polymers

  – Can break them up into 4 main groups:

1. **Fats**
   - long-term energy storage & insulation
2. **Waxes**
   - waterproof molecules
3. **Sterols**
   - hormones, support cell membranes, etc.
4. **Phospholipids**
   - form cellular membranes

- *<u>Lipid group 1: </u>* **Fats**
  - Fats (& oils too) are molecules called triglycerides
    - **triglyceride** = 3 fatty acids attached to a glycerol
    - **fatty acids** = long chains of C & H (with some O)
      - *will be important to know to distinguish between saturated & unsaturated fats*



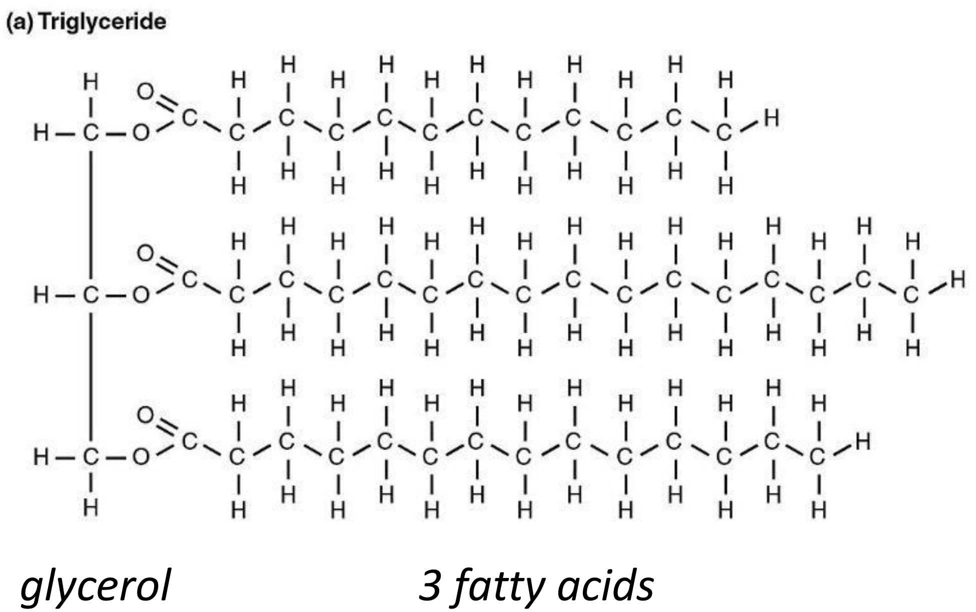


Figure: https://commons.wikimedia.org/wiki/File:Simple_Triglyceride_Hydrolysis.png
Figure: https://commons.wikimedia.org/wiki/File:2511_A_Triglyceride_Molecule_(a)_Is_Broken_Down_Into_Monoglycerides_(b).jpg

- Fats & oils are used for <u>energy storage & insulation</u>
  - One molecule of fat stores twice as much energy as one molecule of carbohydrates
  - Fat also provides insulation

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

The Emperor penguin benefits from the insulating effect of fat and is able to thrive in the extreme cold of Antarctica.

Figure: https://pixabay.com/photos/hamburger-p-french-fries-belly-2683042/
Figure: https://commons.wikimedia.org/wiki/File:Emperor_Penguin_Manchot_empereur.jpg

- Fats & oils can be <u>saturated or unsaturated</u>
  - Fatty acids that have carbon chains “saturated” with hydrogen (completely filled) = **saturated fats**
  - They are straight, so they line up well & stack tightly = solid at room temperature

(a) Saturated

(b) Unsaturated

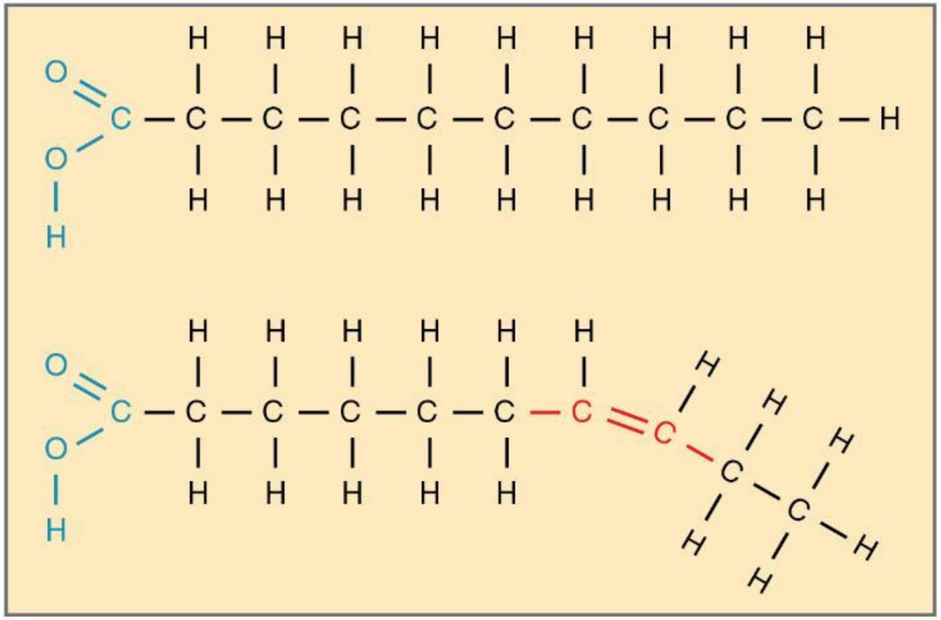


Figure: https://commons.wikimedia.org/wiki/File:221_Fatty_Acids_Shapes-01.jpg

- Fats & oils can be saturated or unsaturated
  - Fatty acids that have carbon chains missing some hydrogen (not saturated) = **unsaturated fats**
  - Don’t line up or stack well together = liquid at room temperature = Usually call these **oils**

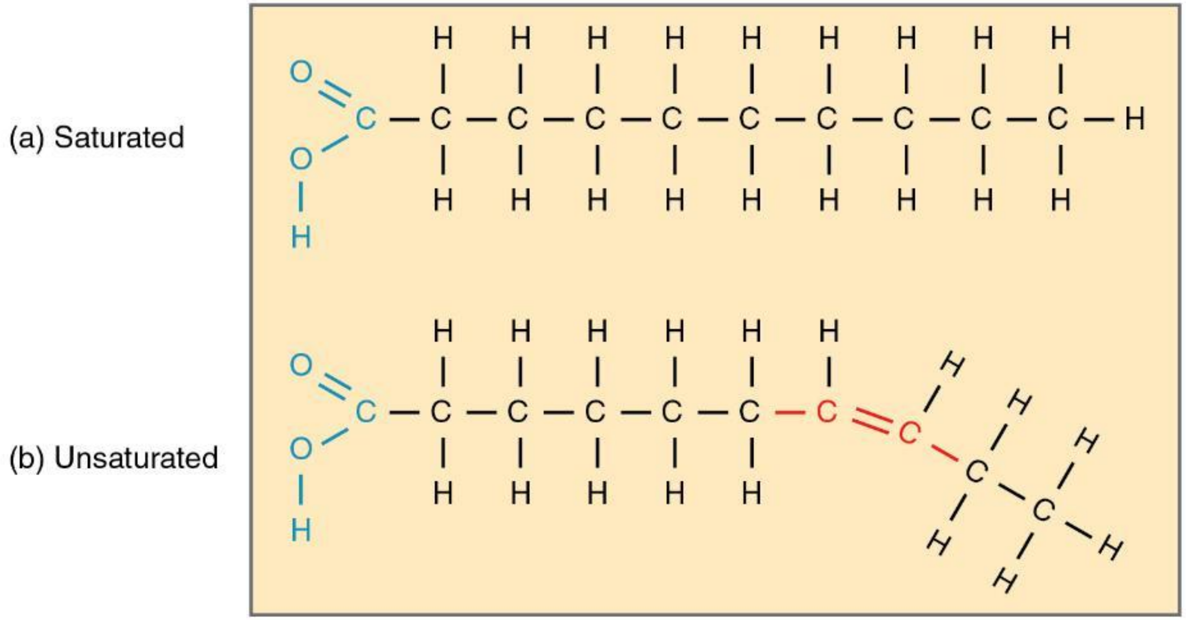


Figure: https://commons.wikimedia.org/wiki/File:221_Fatty_Acids_Shapes-01.jpg

- Fats & oils can be <u>saturated or unsaturated</u>

  – Animals tend to make saturated fats
    - e.g. beef fat & butter

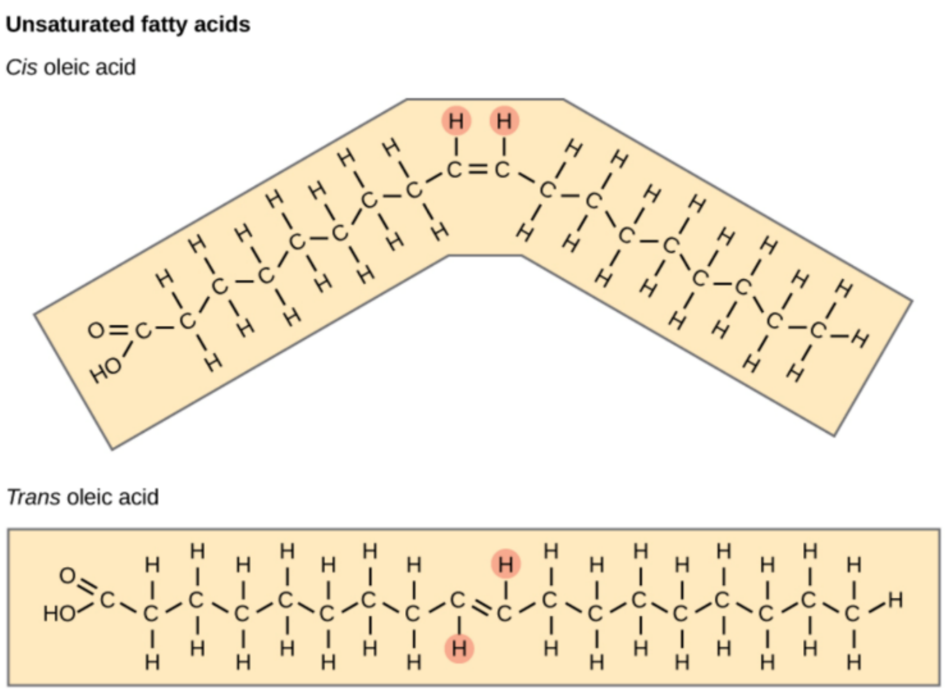
  – Plants tend to make unsaturated fats
    - e.g. vegetable, corn, & olive oils

Figure: https://www.flickr.com/photos/30478819@N08/48612236702
Figure: https://www.pxfuel.com/en/free-photo-odsys

- Unsaturated fats can become “**hydrogenated**” or “partially hydrogenated”
  - – Hydrogenation = process that adds hydrogen to unsaturated fats to make them more saturated
    - Partially hydrogenated = some have been made saturated, but not all
  - – Hydrogenated fats don’t exist in nature
  - – So why hydrogenate?
    - –Store better
    - –Preserve flavor longer
    - –Cheaper than saturated fats

Figure: https://www.flickr.com/photos/taestell/12375573525

- Trans fats are made during the hydrogenation process
  - **Trans fats** = unsaturated fats that have been hydrogenated AND have had their molecular confirmation altered



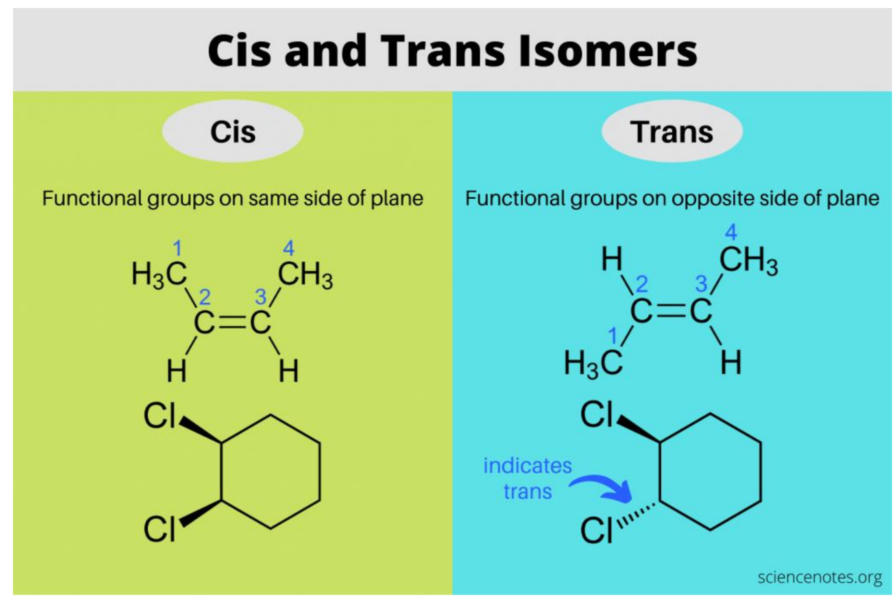


Figure from OpenStax Biology 2e
https://sciencenotes.org/cis-and-trans-isomers/

- Different fats are processed differently in the body
  - Unsaturated fats (that are not hydrogenated) are *generally* healthier (in moderation) & have been linked to:
    - Lower bad cholesterol
    - Reduced heart disease
    - Lower blood pressure

Figure: https://www.pxfuel.com/en/free-photo-odsys

- Different fats are processed differently in the body
  - <u>Hydrogenated & trans</u> fats are VERY <u>unhealthy</u> & linked to:
    - Rise in bad cholesterol
    - Heart disease
    - Diabetes & other metabolic disorders
  - Unfortunately, hydrogenated & trans fats are now incredibly common in our food supply
    - fried foods,
    - commercial baked goods,
    - highly processed foods

Figure: https://commons.wikimedia.org/wiki/File:Fast_food_01_ebru.jpg

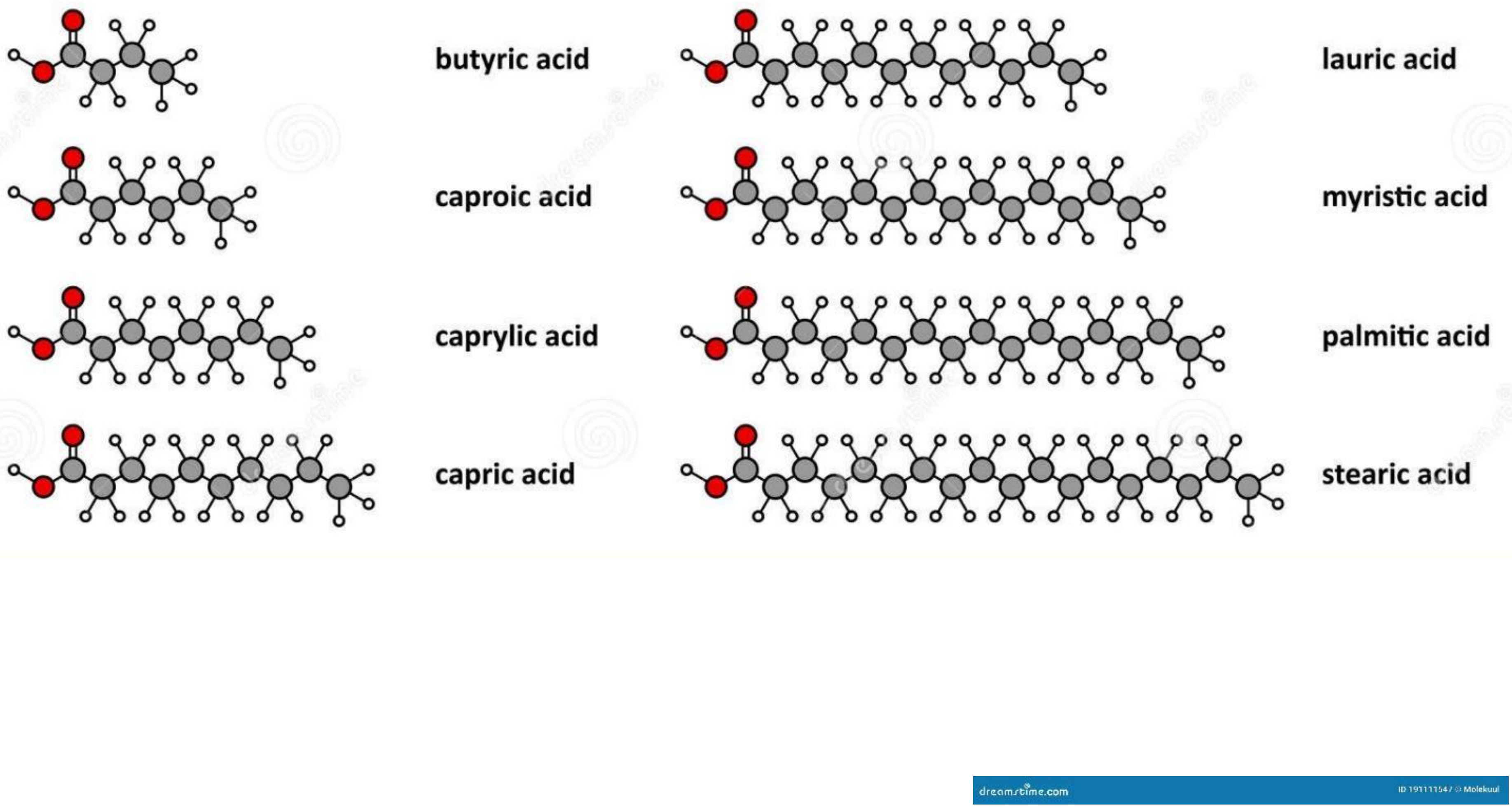
- Different fats are processed differently in the body
  - <u>Saturated</u> fats are *generally* <u>unhealthy</u> & linked to:
    - Colon, breast, ovarian & other cancers
    - Rise in bad cholesterol
    - Heart disease
    - *See next slide for the saturated fats that might be an exception*

Figure: https://www.flickr.com/photos/30478819@N08/48612236702
Figure: https://pixabay.com/photos/high-fat-foods-pastries-cheeses-1487599/

- There are several different types of saturated fats
  - Foods with saturated fat have some combination of the different types, each in different amounts
    - Most types of saturated fats are generally unhealthy, but some are generally healthy

- e.g. foods with higher levels of palmitic or myristic saturated fat = unhealthy
  - dairy, meat, & eggs
- e.g. foods with higher levels of lauric or stearic saturated fat = healthy
  - coconut & dark chocolate

Figure: https://www.flickr.com/photos/30478819@N08/48612236702
Figure: https://www.shutterstock.com/image-photo/coconut-half-chocolate-pieces-green-leaf-671340883


butyric acid
caproic acid
caprylic acid
capric acid
lauric acid
myristic acid
palmitic acid
stearic acid
dreamstime.com

- *<u>Lipid group 2:</u>* **waxes**
  - **Waxes** = fatty acids combined with other molecules, forming a stiff, waterproof material
    - Make up stiff honeycombs
    - Keep fur, feathers, leaves, & fruits waterproof

Figure: https://www.hippopx.com/en/otter-wet-lutra-lutra-zoo-fur-marten-154984

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

- *<u>Lipid group 3:</u>* **sterols**
  – Includes hormones & cholesterol

Steroid hormones

- *Examples = testosterone and estrogen*
- *Regulate sexual development, maturation, sex cell production, mood, and body growth*

Cholesterol

- *Important component of cell membranes in animals*
- *Can attach to and thicken vessel walls and may cause serious health problems*

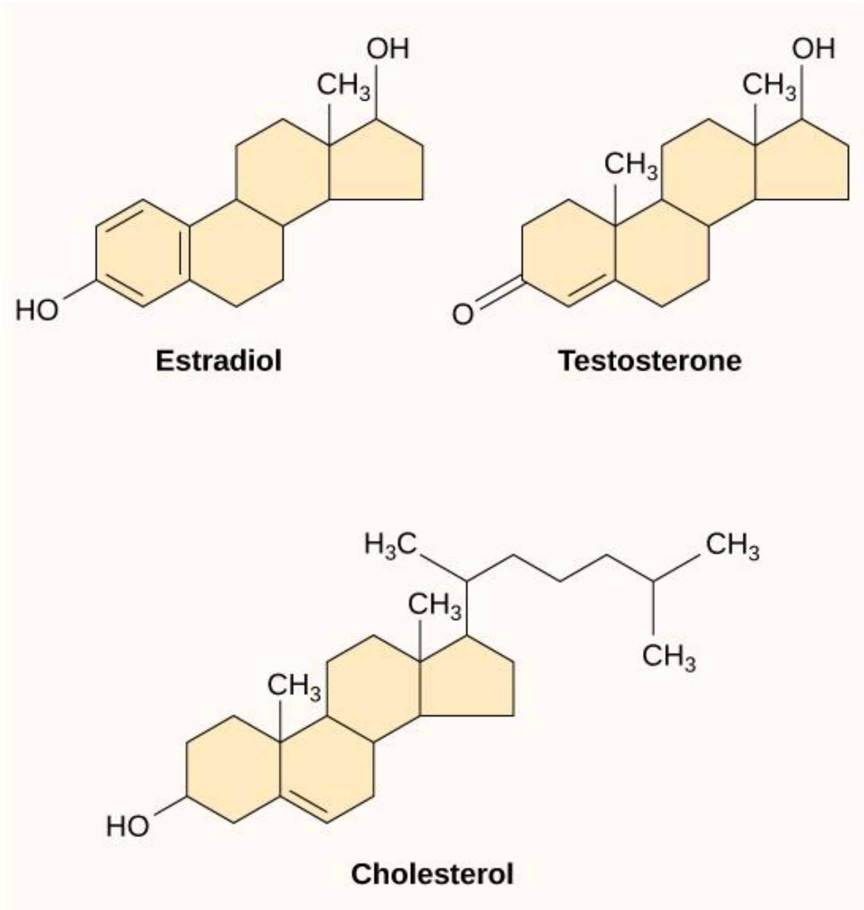


Figure: https://commons.wikimedia.org/wiki/File:Figure_09_01_08.jpg

- **Cholesterol** = necessary for cell health
  - Animals make their own – no need to eat any
  - Remember: lipids like cholesterol are hydrophobic, which means they clump up in water – blood is mostly water
    - Cholesterol doesn't travel well in the blood stream (clumps up)

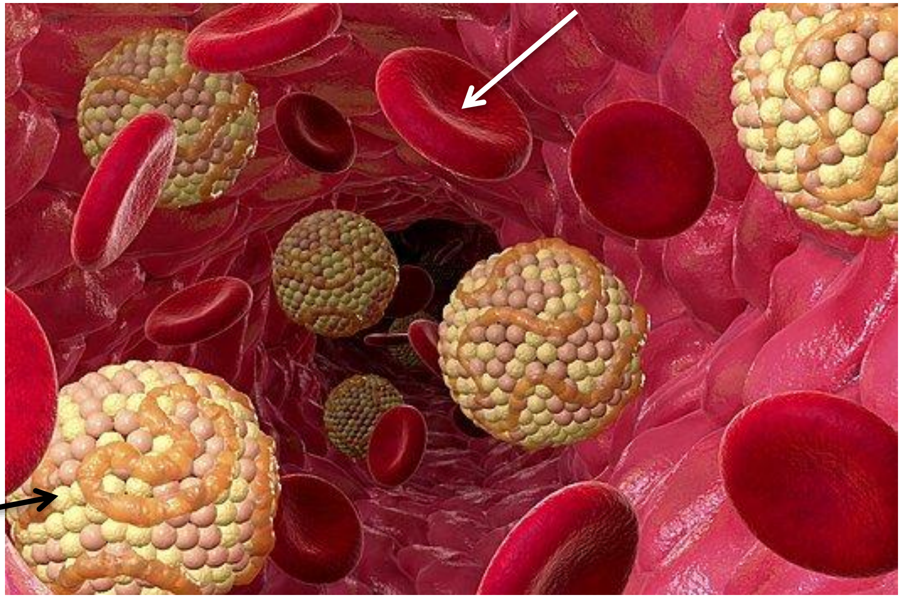


Figure: https://commons.wikimedia.org/wiki/File:Dislipidemias1.jpg

- Proteins bind on to cholesterol to carry it through the blood stream = **lipoproteins**
  - <u>2 types of lipoproteins</u>
    - **HDL** (high density lipoproteins)
      - Carry cholesterol to liver → processed and removed by the body
      - Often referred to as "good cholesterol"

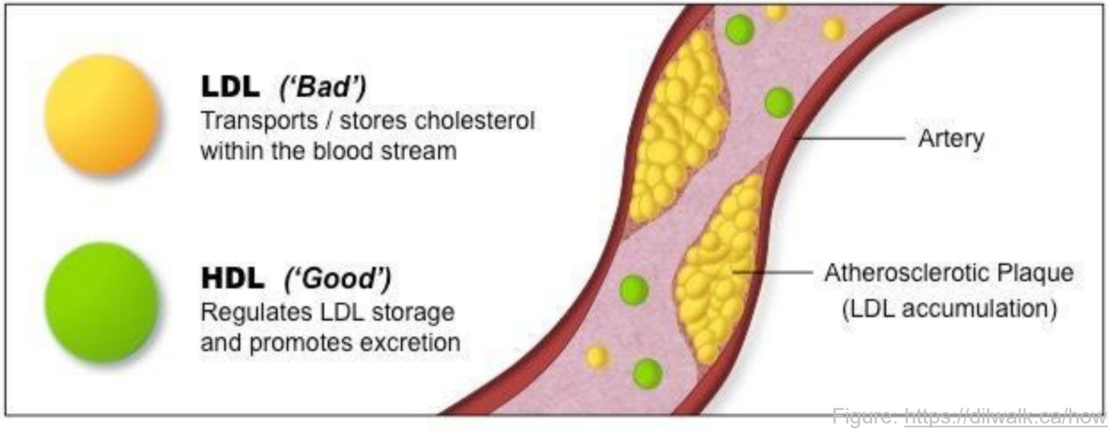


Figure: https://dilwalk.ca/how-does-saturated-fat-affect-cholesterol/

– <u>2 types of lipoproteins</u>

- **LDL** (low density lipoproteins)
  - –Keep cholesterol inside bloodstream → deposited on artery walls
  - –Increases the chance of heart attack and stroke – “bad cholesterol”

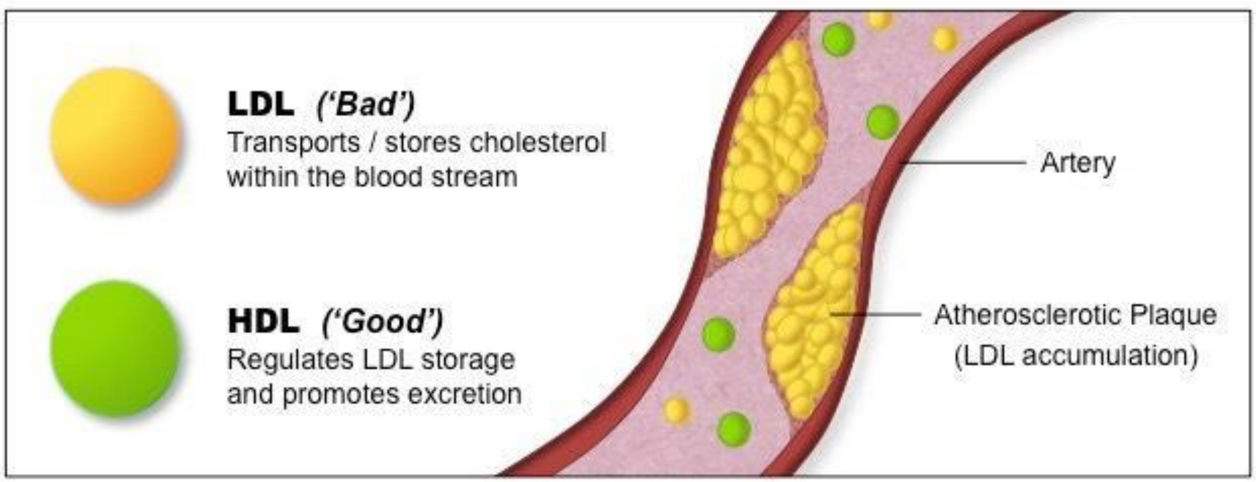
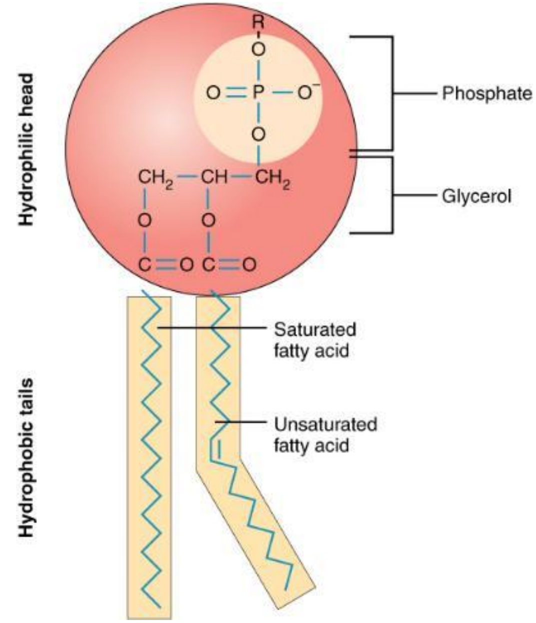


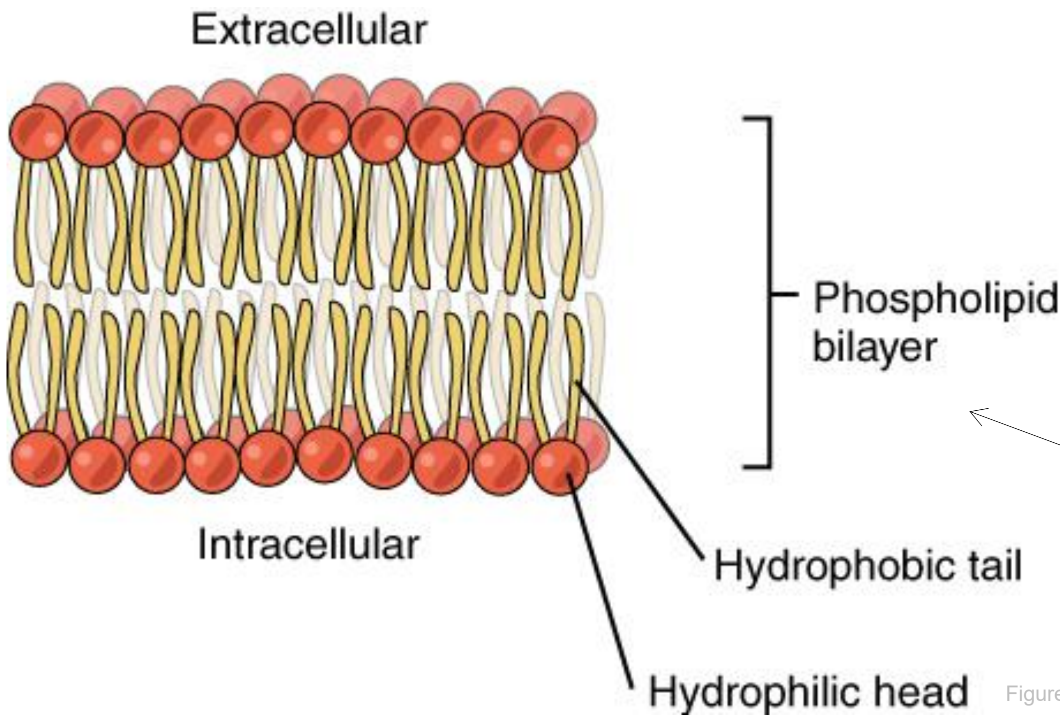
Figure: https://dilwalk.ca/how-does-saturated-fat-affect-cholesterol/

- <u>Cholesterol, lipoproteins, & health</u>
  - These things **raise LDL** (bad) levels:
    - Too much saturated, hydrogenated, & trans fat in diet
    - Too much cholesterol in diet (comes from meat, eggs, & dairy)
    - Tobacco use (through lungs, skin, or ingestion)
  - These things **raise HDL** (good) levels:
    - Exercise – *activity causes HDL production*
    - Eating healthy (good fats, low/no cholesterol)
    - Avoiding tobacco

- *Lipid group 4:* **phospholipids**
  - Make cell membranes
  - *Will cover extensively soon*



one phospholipid



many phospholipids gather to create cell membranes

Figure: https://commons.wikimedia.org/wiki/File:0301_Phospholipid_Structure.jpg
Figure: https://commons.wikimedia.org/wiki/File:0302_Phospholipid_Bilayer.jpg

- Animals, plants, mushrooms (fungi), & bacteria seem to be very different

- However, they all use & are built of the same basic organic molecules (carbohydrates, proteins, nucleic acids, & lipids)

- All are also made up of cells

- Up next: *How are cells built & how do they use those organic molecules to keep us alive?*

Figure: https://www.wallpaperflare.com/squirrel-mushroom-animals-nature-plants-rodent-tree-animal-wildlife-wallpaper-pzjsy

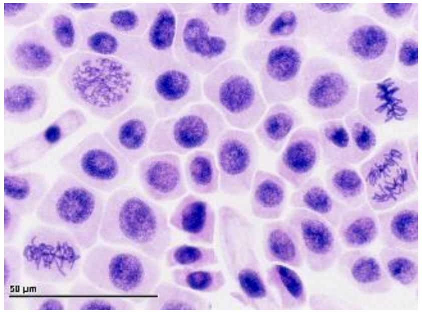
Chapter 4: Cell Structure

- Cells are the units of life
- What do all cells have in common?
- What are the different cell types & what makes each unique?
- How do cells stick together & communicate?

Corresponds with OpenStax Biology 2e Chapter 4

Cells are the units of life

- An animal, a plant, a mushroom, & bacteria seem very different, but all are made up of cells
  - **Cell** = the smallest unit of life
    - events that occur inside a cell make life possible



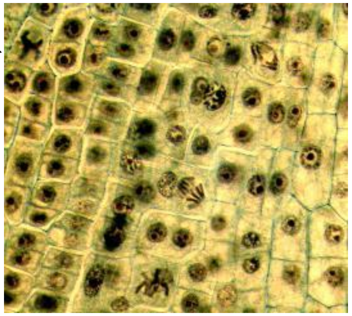


Figure: https://commons.wikimedia.org/wiki/File:Mitosis_(261_13)_Pressed;_root_meristem_of_onion_(cells_in_prophase,_metaphase,_anaphase,_telophase).jpg

Figure: https://www.flickr.com/photos/foundanimalsfoundation/8055195809

Figure: https://www.flickr.com/photos/71183136@N08/6947182364

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

- The invention of microscopes allowed us to see that all living things were made entirely of cells
- Further studies showed that every cell came from another, pre-existing cell
  - e.g. an adult human is made up of trillions of cells, all of which came from just one cell: a single fertilized egg

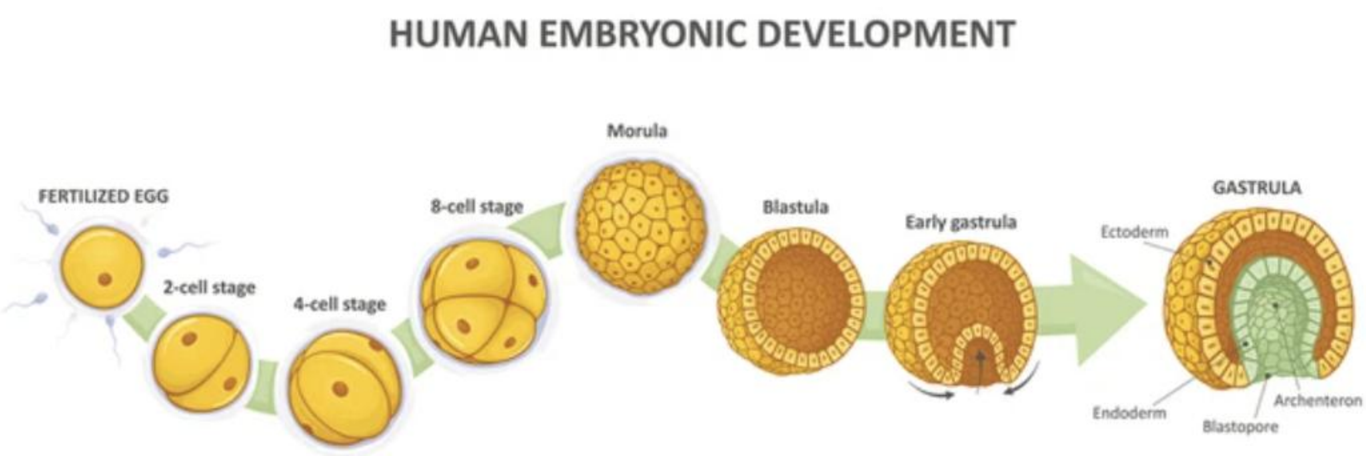


Figure: https://www.shutterstock.com/image-vector/human-embryonic-development-embryogenesis-zygote-gastrula-1850260765

- The facts that all living organisms are made up of one or more cells & that all cells arise from preexisting cells are the foundations of **cell theory**
  - 3 main principles of cell theory:
    - 1. all living things are made up of one or more cells
    - 2. the cell is the basic unit of life
    - 3. all cell come from preexisting cells

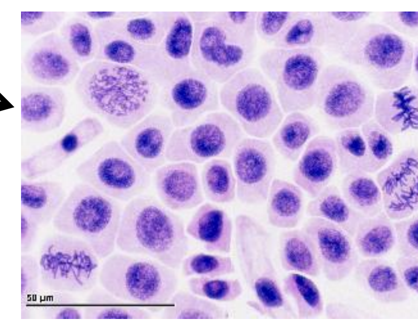
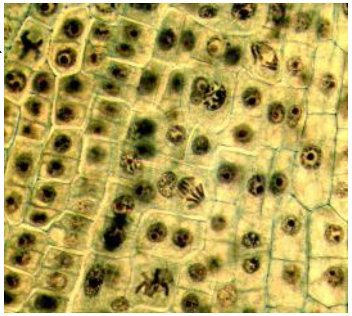


Figure: https://www.flickr.com/photos/foundanimalsfoundation/8055195809

Figure: https://commons.wikimedia.org/wiki/File:Mitosis_(261_13)_Pressed;_root_meristem_of_onion_(cells_in_prophase,_metaphase,_anaphase,_telophase).jpg

- The cell theory is still evolving to become more powerful, with additional modern ideas



Early cell theory
All organisms are made of one or more cells.
The cell is the fundamental unit of life.
All cells come from preexisting cells.

Remember from chs 2 & 3

Coming up in ch 6

Coming up in chs 7, 8, & 9

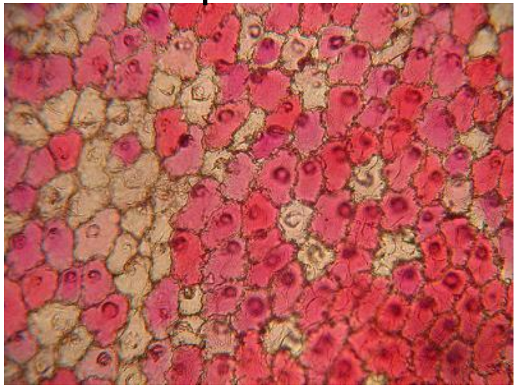
Additional ideas in modern cell theory
All cells have the same basic chemical composition.
All cells use energy.
All cells contain DNA that is duplicated and passed on as each cell divides.

Figure: https://www.flickr.com/photos/71183136@N08/6947182364 Figure: https://commons.wikimedia.org/wiki/File:Uraro_plant.jpg

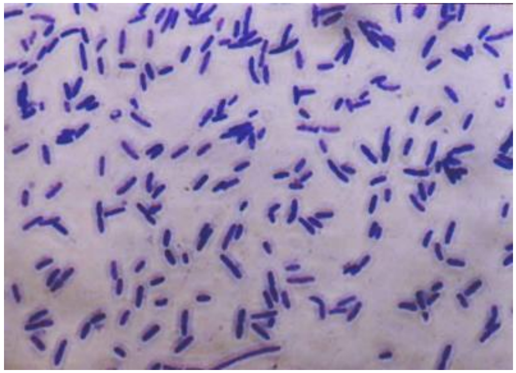
What do all cells have in common?

- Cells have a common characteristic: <u>most are small</u>
  - Bacteria, flea, whale, rose, oak… all made of small cells
    - a "bigger" being has MORE cells, not bigger cells
  - Why?
    - Molecules must move in & out of a cell fast & efficiently: speed matters for life
      - not fast enough if cells are large

rose petal cells



bacterial cells



human blood cells

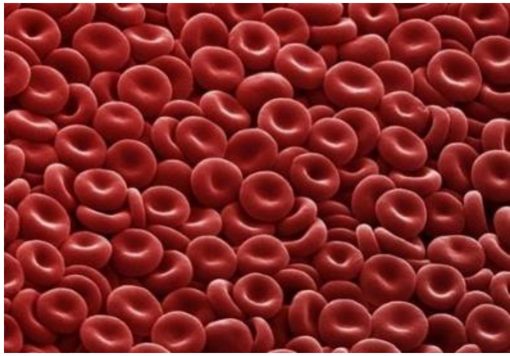


Figure: https://www.flickr.com/photos/figgy/2956281142

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

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

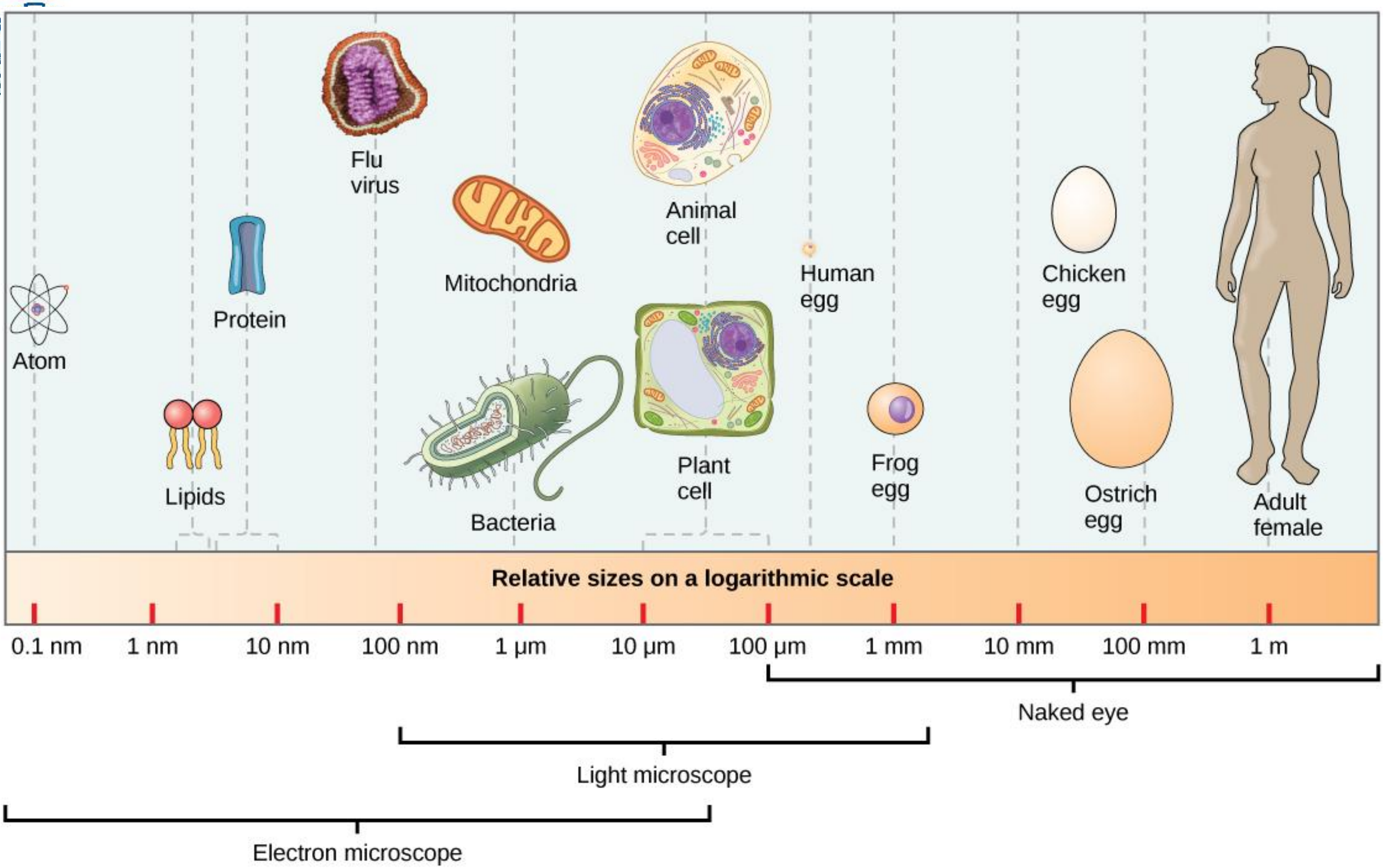
- Vast majority of cells are too small to see with the naked eye, but a few don't need to get things in & out: egg cells
  - egg cells can be large because they are filled with nutrients that nourish a growing embryo throughout development

chicken eggs

ostrich eggs can weigh 3lbs!

fish eggs (caviar)

Figure: https://archapter.com/ostrich-eggs/ Figure: https://commons.wikimedia.org/wiki/File:Sushi_fish_eggs_Moscow.JPG



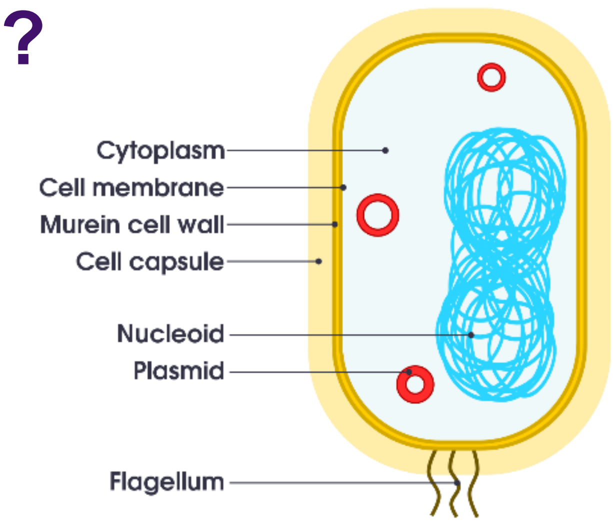
This figure shows the relative sizes of microbes on a logarithmic scale (each unit of increase in a logarithmic scale represents a 10-fold increase in the quantity measured).

Figure: https://commons.wikimedia.org/wiki/File:Figure_04_02_02.jpg

What do all cells have in common?

- Cells have many different parts (structures), each of which is responsible for a different function

Bacterial cell



- And different kinds of cells have different parts

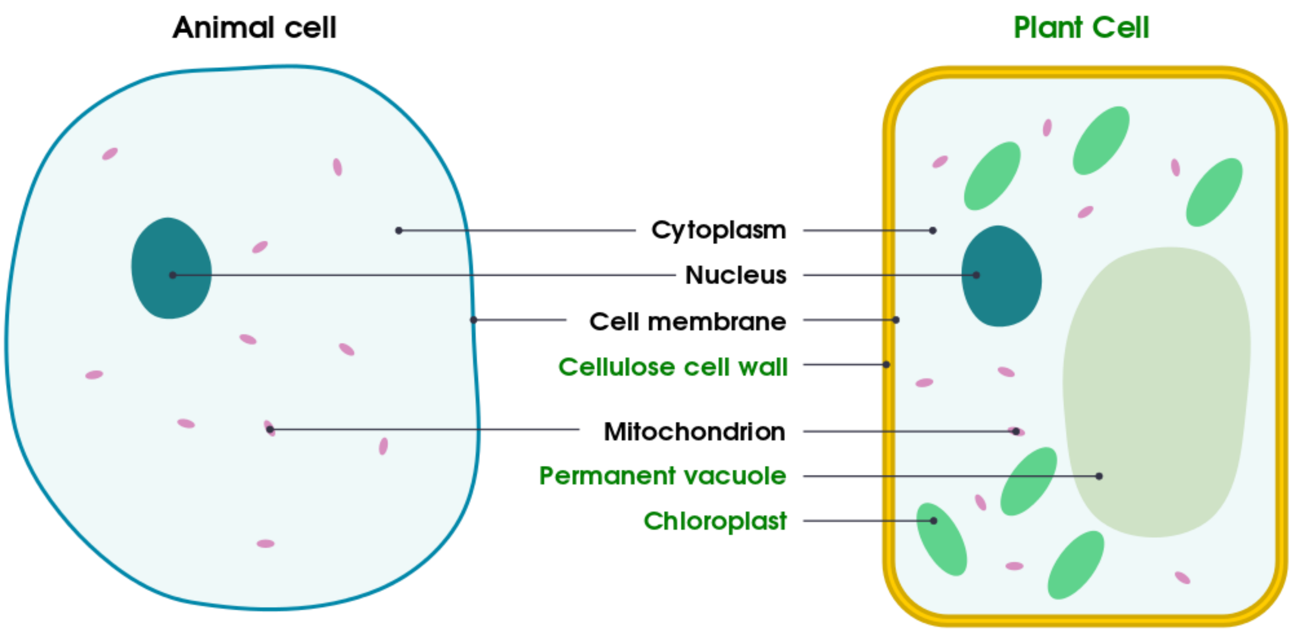
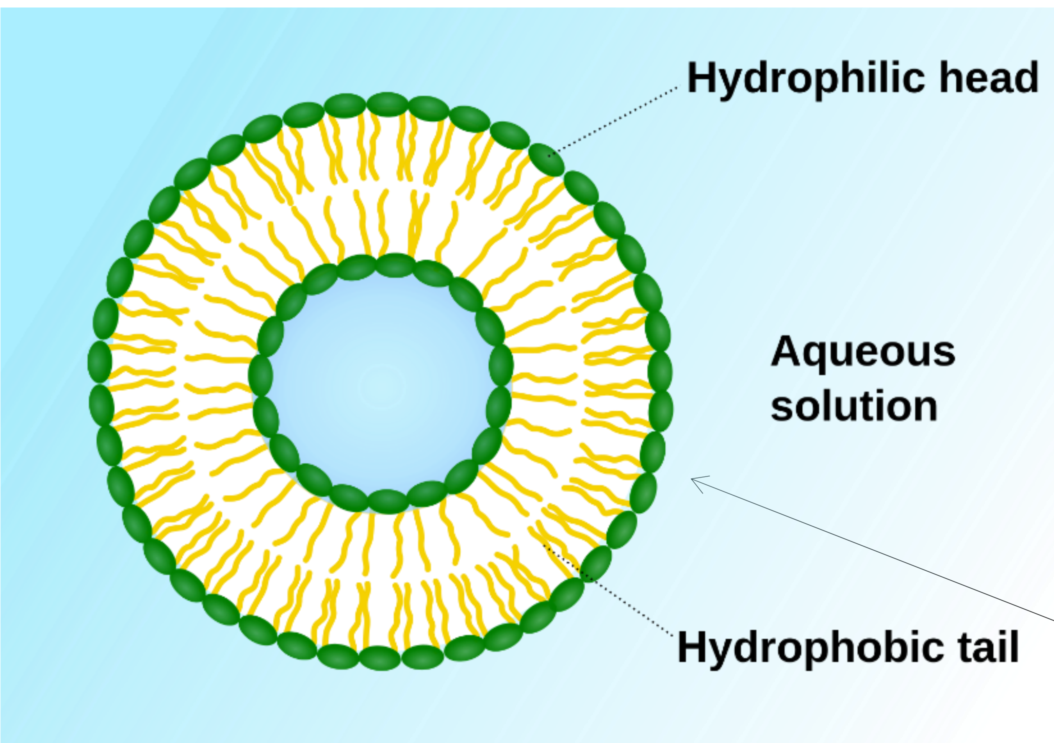
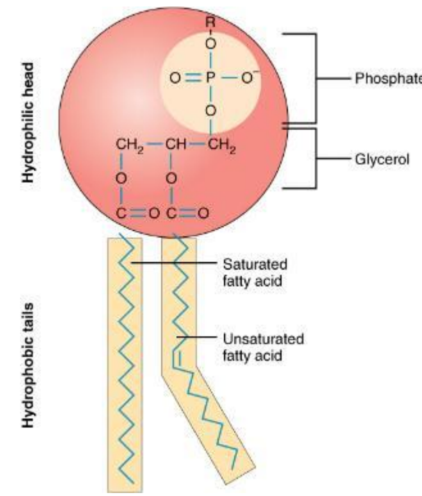


Figure: https://commons.wikimedia.org/wiki/File:Differences_between_simple_animal_and_plant_cells_(en).svg
Figure: https://commons.wikimedia.org/wiki/File:Simple_diagram_of_bacterium_(en).svg

- However: <u>ALL cells have the same 4 parts</u>:
- 1. **Cell membrane**
  - – encloses the cell & regulates what goes in & out
  - – made of phospholipids





one phospholipid

many phospholipids gather to create cell membranes

Figure: https://commons.wikimedia.org/wiki/File:0301_Phospholipid_Structure.jpg
Figure: https://commons.wikimedia.org/wiki/File:Liposome_scheme-en.svg

2. **Cytoplasm** = all fluid & structures inside the cell membrane but outside of the nucleus

- What about bacterial cells, which have no nucleus?
  - then everything inside is cytoplasm!

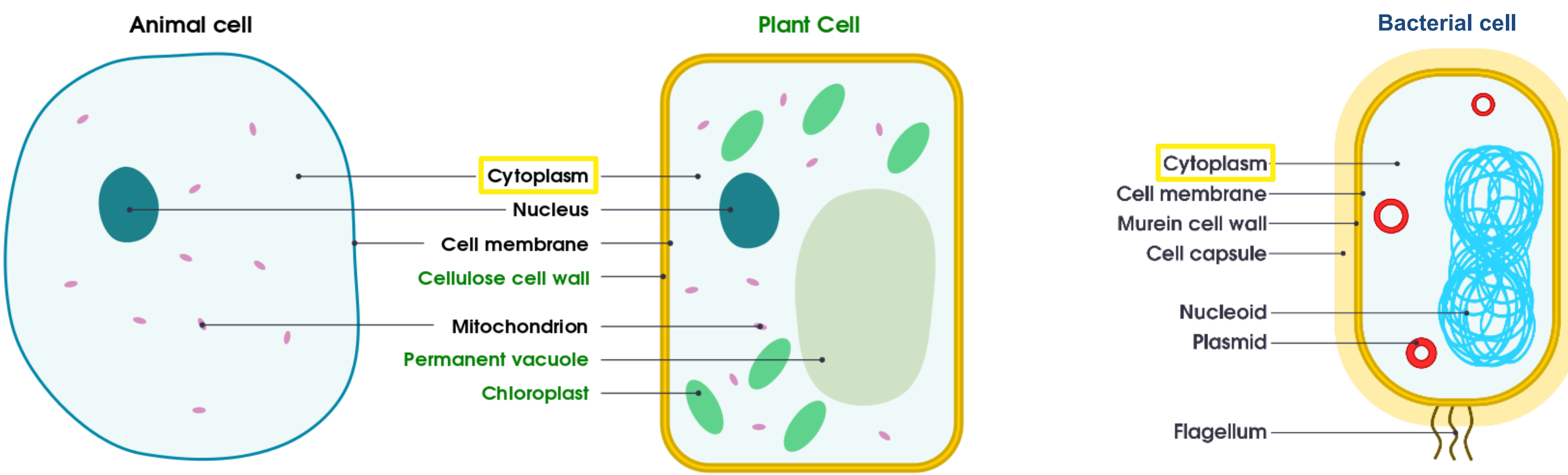


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Figure: https://commons.wikimedia.org/wiki/File:Simple_diagram_of_bacterium_(en).svg

- 3. **DNA, RNA, proteins** (& other organic molecules)
  - *Remember from ch 2: we need organic molecules to build & fuel our cells, which make up our bodies*
- 4. **Ribosomes**
  - Make proteins (using directions from DNA & RNA)
    - since proteins do nearly everything, all living things (& their cells) must have ribosomes to build proteins

This is a diagram of a very important process for all cells that you'll learn about in chapter 7 – notice it involves proteins (polypeptides), RNA, and ribosomes, which are found in all cells.

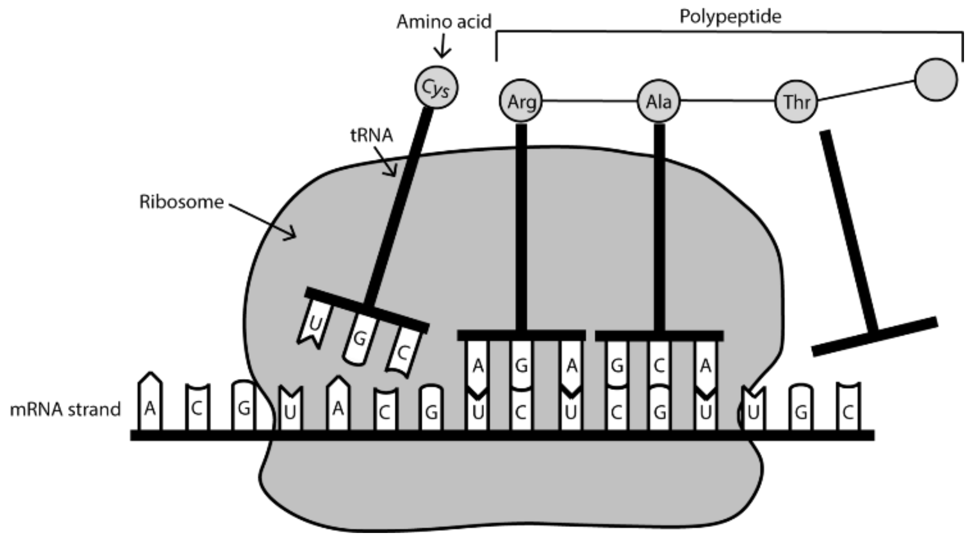
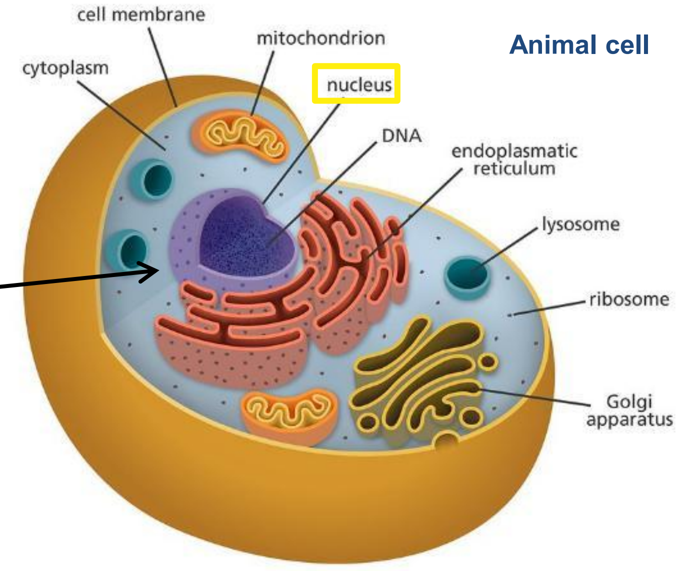


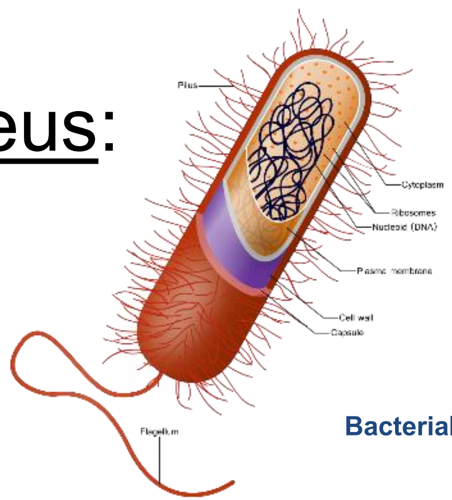
Figure: https://commons.wikimedia.org/wiki/File:Protein_Synthesis-Translation.png

What are the different cell types & what makes each unique?

- There are 2 basic types of cells
  - Some <u>have a nucleus</u>: **eukaryotic cells**
    - form bodies of animals, plants, fungi, & protists
  - Some <u>do NOT have a nucleus</u>: **prokaryotic cells**
    - form bodies of bacteria & archaea



Animal cell



Bacterial cell

Figure: https://www.flickr.com/photos/yourgenome/26676266160
Figure: https://commons.wikimedia.org/wiki/File:Prokaryote_cell.svg

Prokaryotic cells (prokaryotes)

- smallest & most simple of cell types
  - have very few specialized structures inside
- make up single-celled organisms
  - *can't see with the naked eye – need a microscope*
- Instead of a nucleus, they have a **nucleoid region**: refers to where the DNA is located

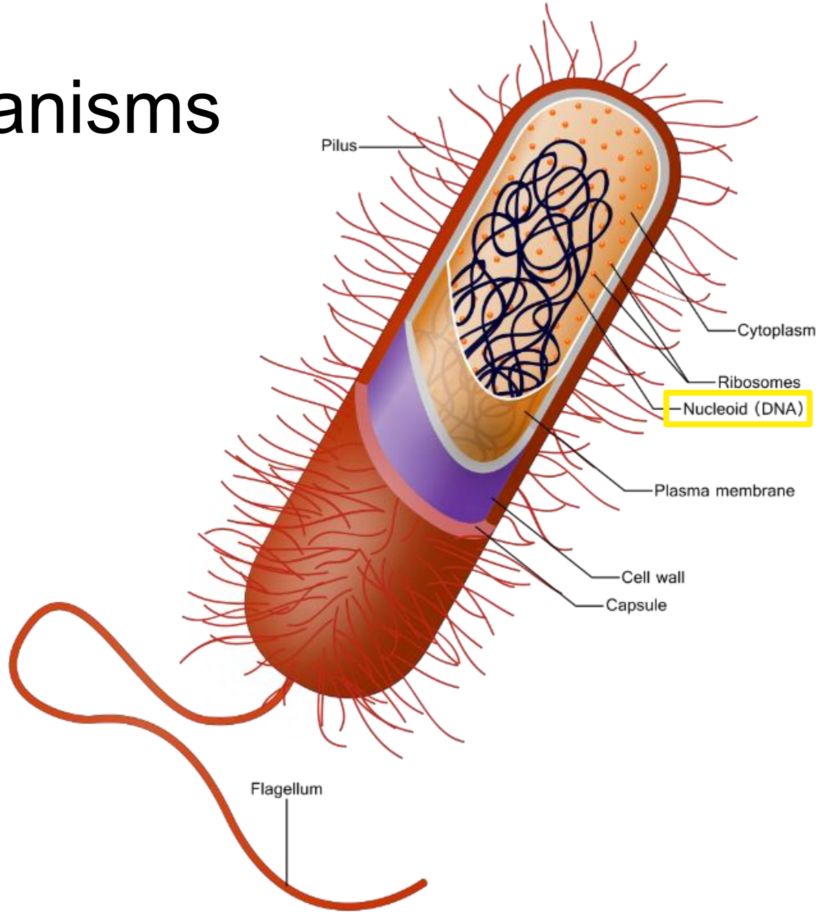
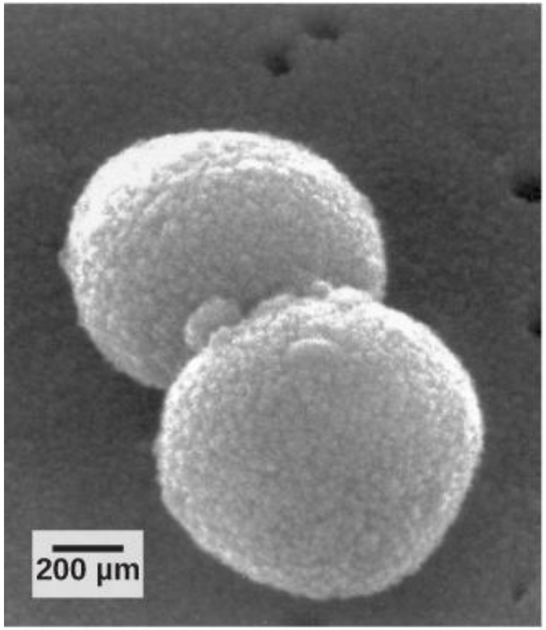


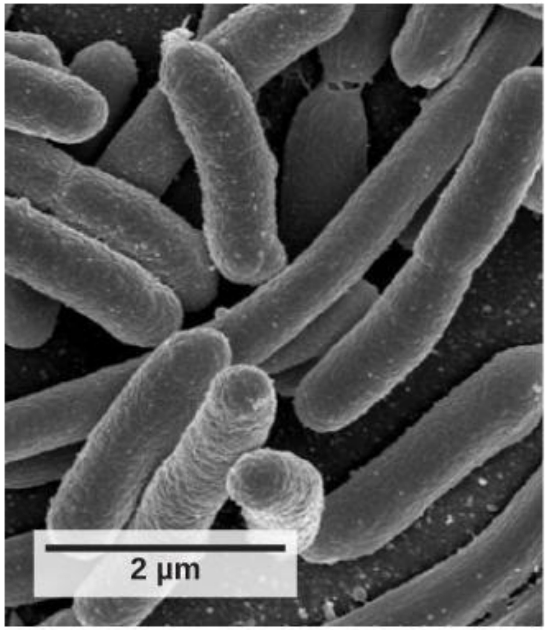
Figure: https://commons.wikimedia.org/wiki/File:Prokaryote_cell.svg

- Prokaryotic cells are so simple they usually take one of <u>3 common shapes</u>
  - – rod-shaped, spherical, or corkscrew-shaped

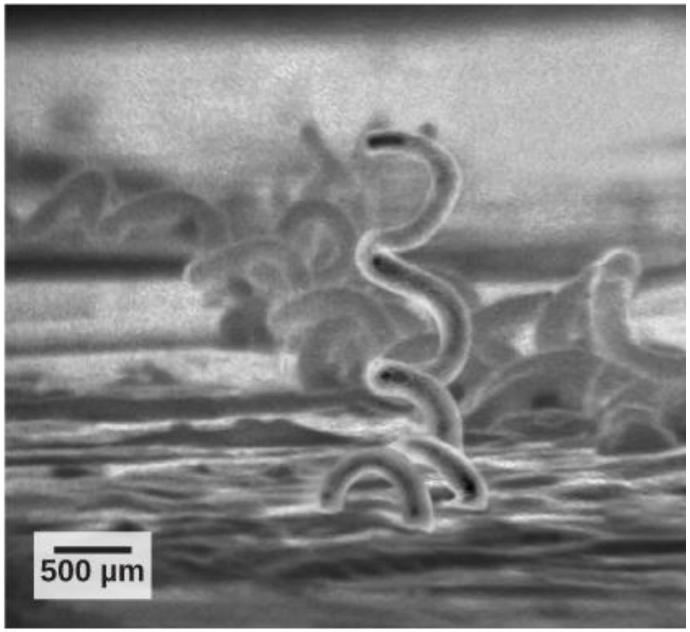
bacteria examples



spherical



rod-shaped



corkscrew-shaped

Figure: https://commons.wikimedia.org/wiki/File:Figure_22_02_01abc.jpg

- **Eukaryotic cells** (eukaryotes)
  – larger & more complex than prokaryotes
  – have a nucleus & many specialized structures called organelles
    - **Organelles** = compartments that carry out specialized functions (little organs)
    - Example organelles:
      – mitochondria generate energy
      – chloroplasts capture sunlight

plant cell

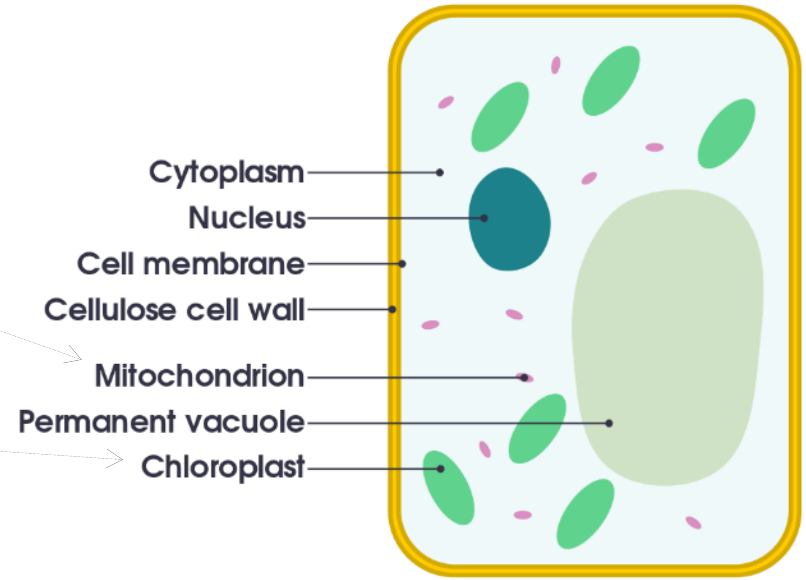
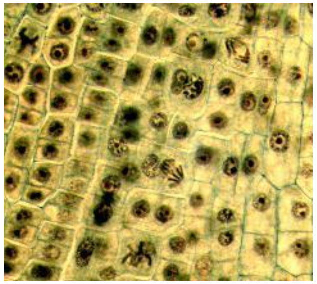


Figure: https://commons.wikimedia.org/wiki/File:Simple_diagram_of_plant_cell_(en).svg

Eukaryotic cells (eukaryotes)

- make up all the multi-cellular organisms we can see (e.g. animals, plants, & fungi)
- make up some single-celled living things we can't see (e.g. protists & yeast – single-celled fungi)
  - our focus will be on plant & animal cells



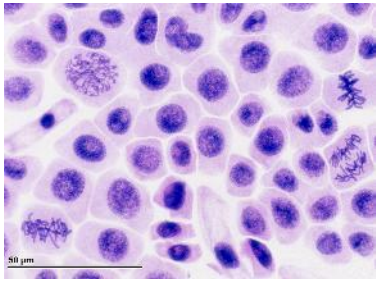


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Figure: https://www.flickr.com/photos/foundanimalsfoundation/8055195809

Figure: https://www.flickr.com/photos/71183136@N08/6947182364

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

- Although eukaryotic cells make up so many different living things, they all have similar structures

- So what structures do we find in eukaryotic cells & what do they do to keep us alive?

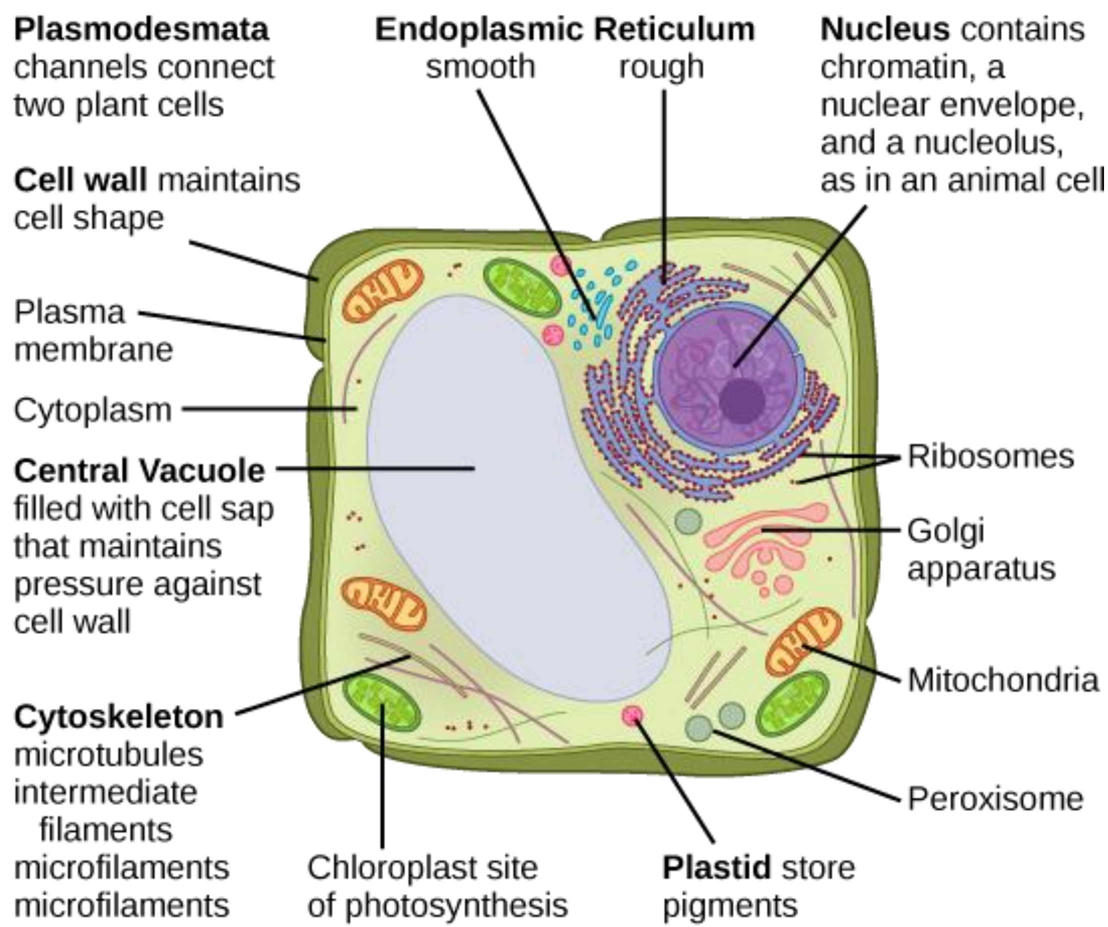


Figure: https://commons.wikimedia.org/wiki/File:Figure_04_03_01b.png

- **Nucleus** = control center of a eukaryotic cell
  - contains chromosomes, which are made of DNA
    - message in DNA leaves nucleus in the form of RNA & goes into *cytoplasm* to build proteins

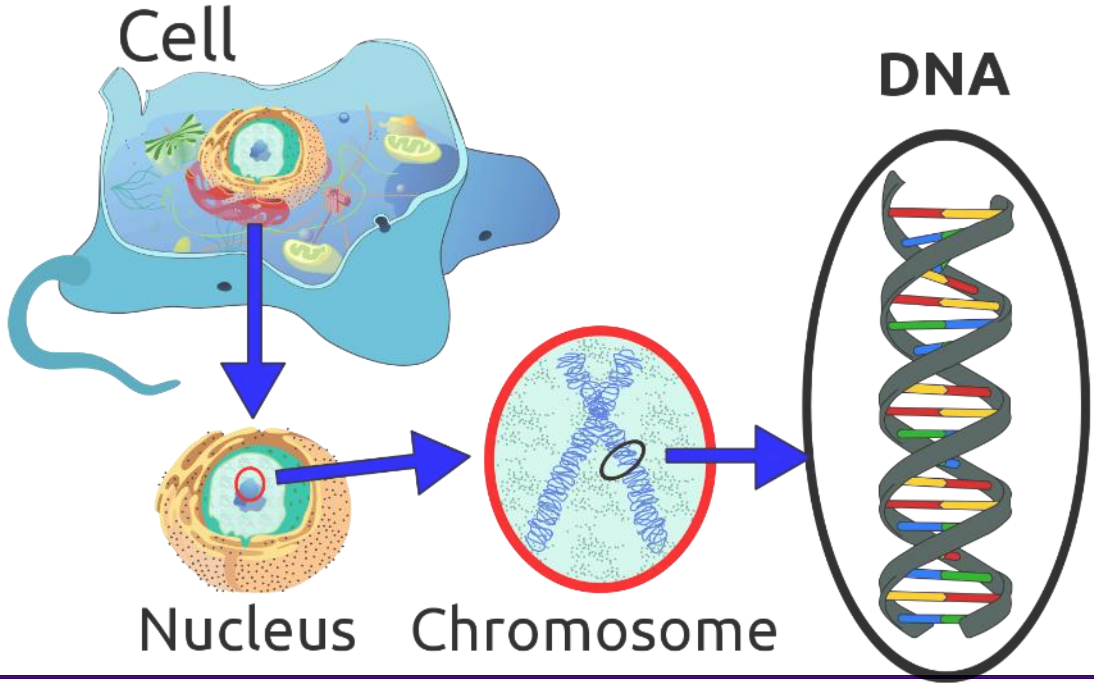


Figure: https://commons.wikimedia.org/wiki/File:Eukaryote_DNA-en.svg

Ribosomes & rough endoplasmic reticulum (ER)

- Rough ER = “rough” because it is studded with ribosomes

- RNA leaves the nucleus & travels to ribosomes on the rough ER
  - <u>makes proteins</u>

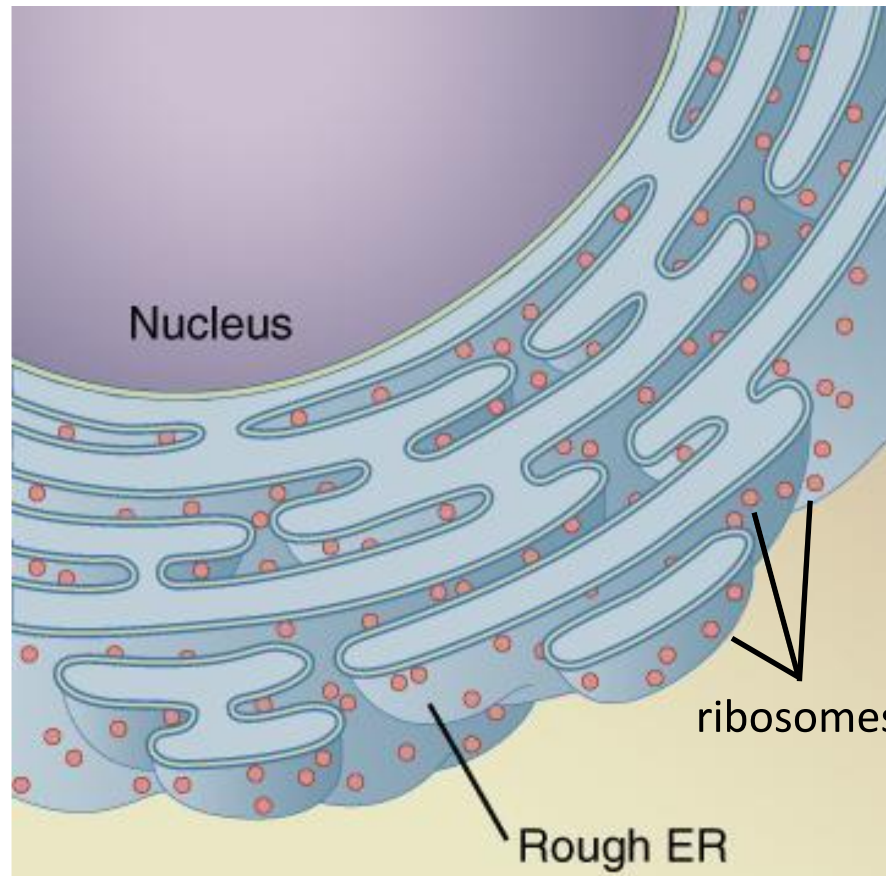
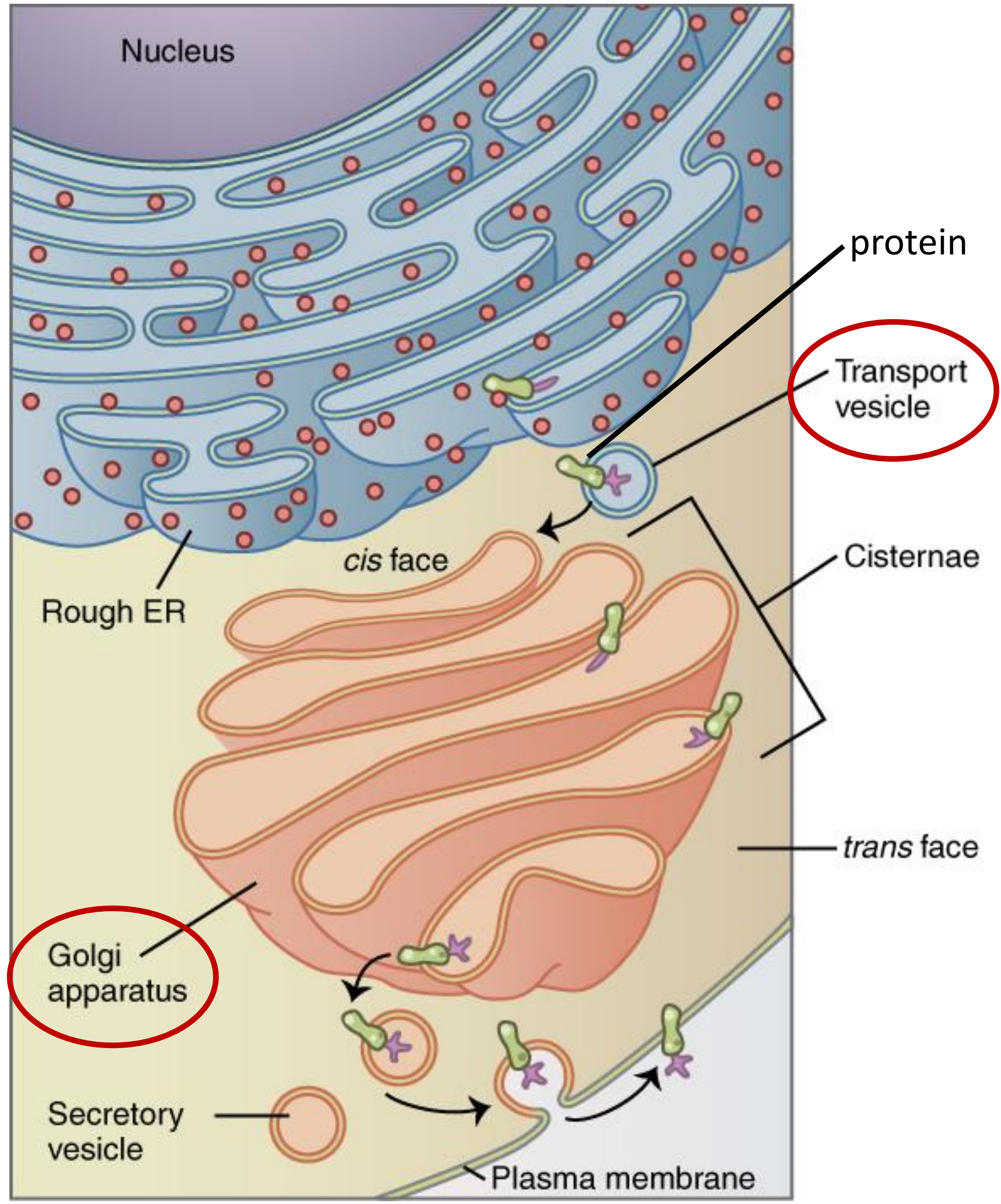


Figure: https://commons.wikimedia.org/wiki/File:0313_Endoplasmic_Reticulum_a_en.png

Golgi apparatus: folds & packages proteins, then sends them to other parts of the cell or out to the blood stream

- also packages other molecules, like lipids
- packages are called **vesicles**



- **Smooth Endoplasmic Reticulum (ER)** makes lipids
  - sends the lipids through the Golgi apparatus to get sent out to other parts of the cell or to the blood stream
  - Smooth ER also detoxifies drugs & poisons

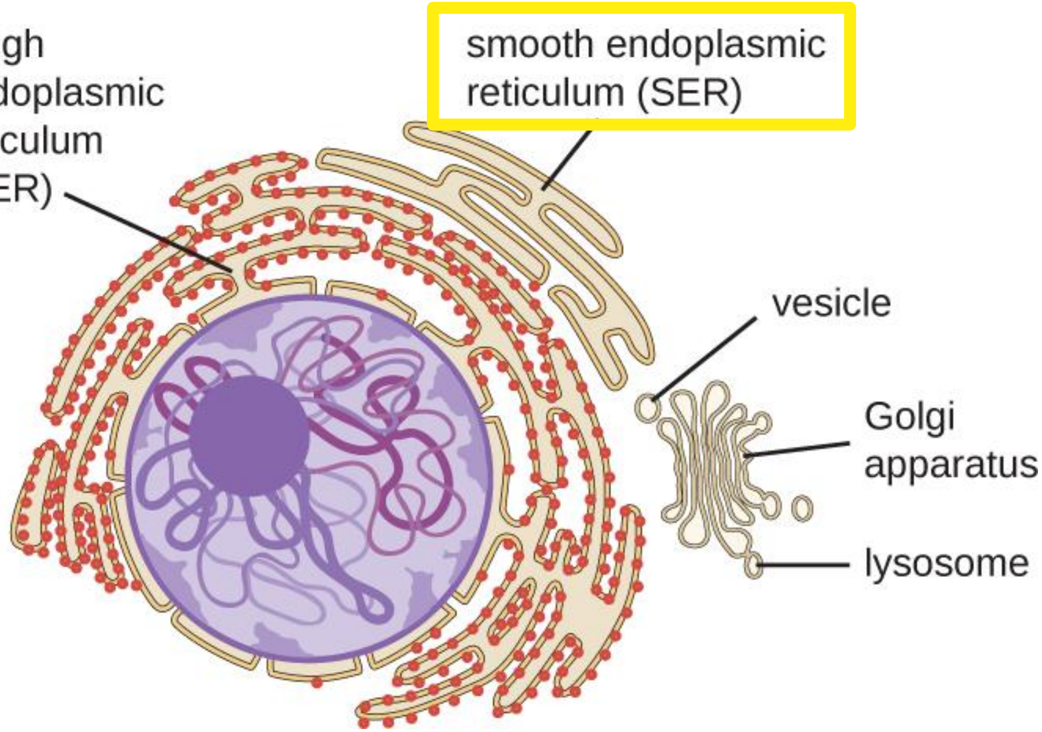
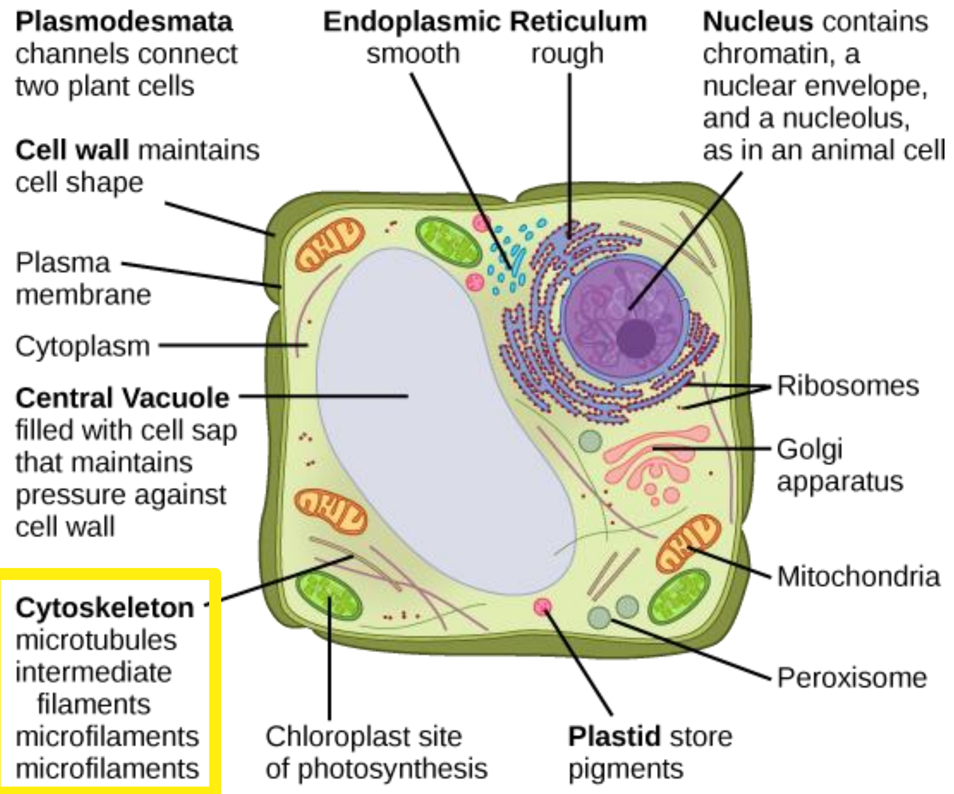


Figure: https://commons.wikimedia.org/wiki/File:CSC_Microbio_03_04_Endomemb.jpg

- How are packages sent around the cell without just floating around randomly?

  – The cell uses a network similar to train tracks: the **cytoskeleton**

    - gives a cell shape & support, but also allows for movement/ travel in the cell



- Where do cells process energy? (to move things around on cytoskeleton & do all things to stay alive)
  - **Mitochondria** = "powerhouse of the cell"
    - breaks apart glucose (mono-saccharides) to <u>provide energy</u> to the cell
      - *this process is called "glucose breakdown" - more on this in a future chapter*

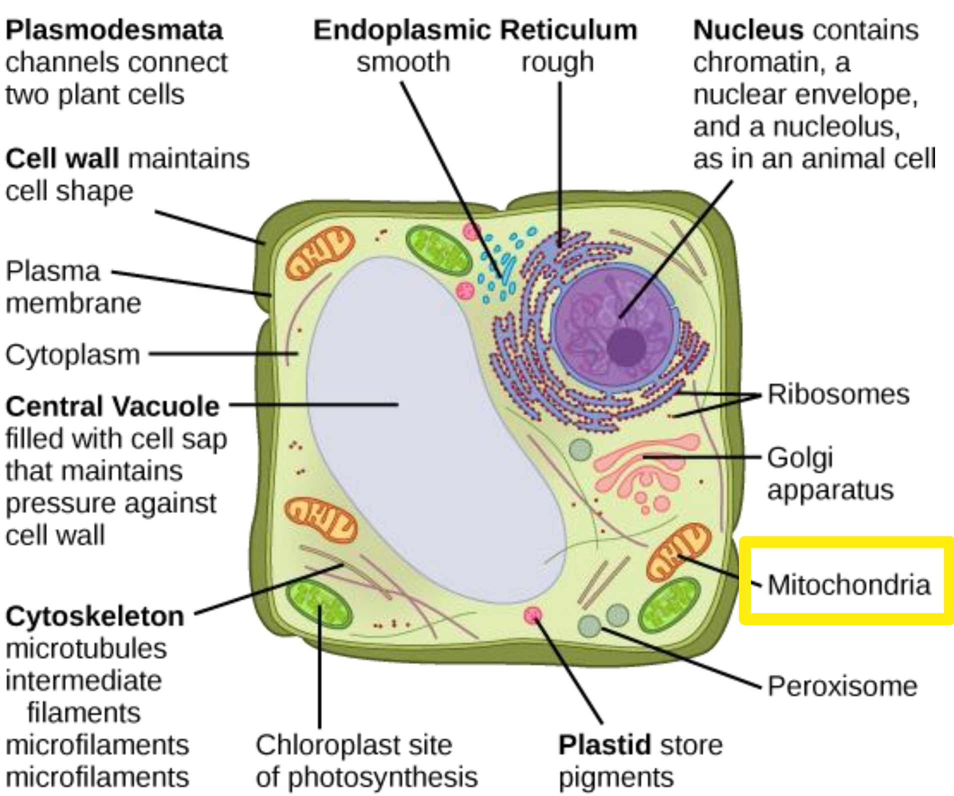


Figure: https://commons.wikimedia.org/wiki/File:Figure_04_03_01b.png

- Do <u>animal cells</u> have anything that plant cells don't?
  - Some animal cells have cilia or flagella
    - **Cilia** = short, numerous extensions of the membrane that <u>move fluid past</u> a cell
    - **Flagella** = long tails that propel cells, allowing for <u>locomotion</u>

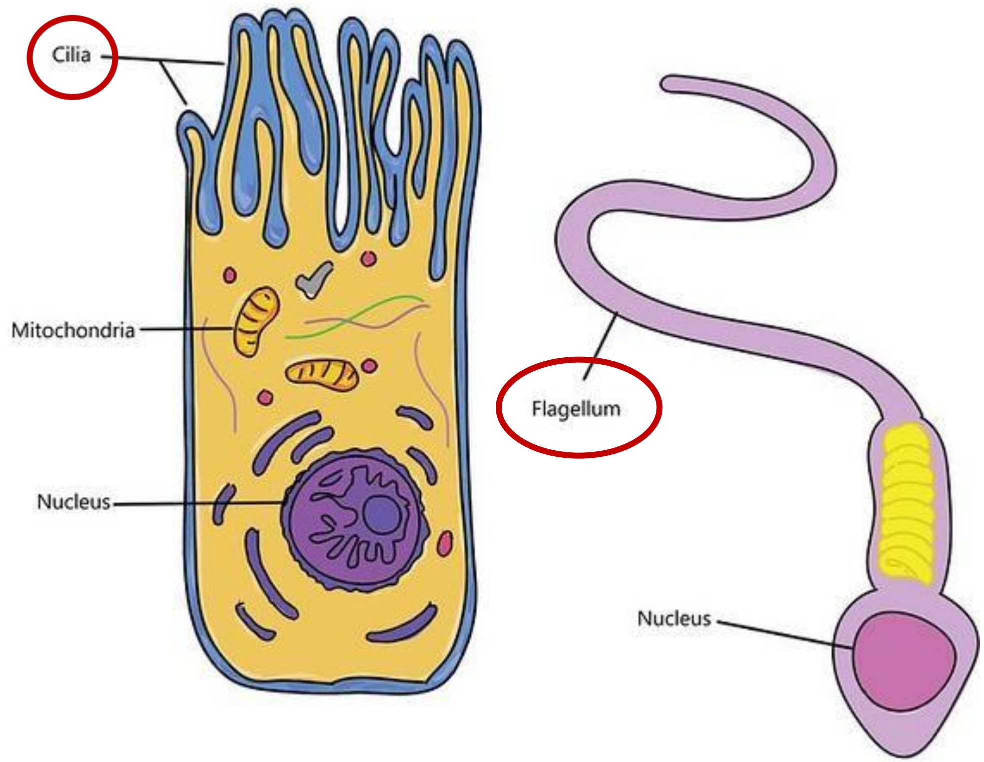


Figure: https://www.flickr.com/photos/187096960@N06/51169565422

- Do plant cells have anything that animal cells don't?
  - Plants have a cell wall, chloroplasts, & a central vacuole
  - **Cell wall** = coating over/outside the cell membrane that protects & supports cells
    - *more on what helps support animal cells later*

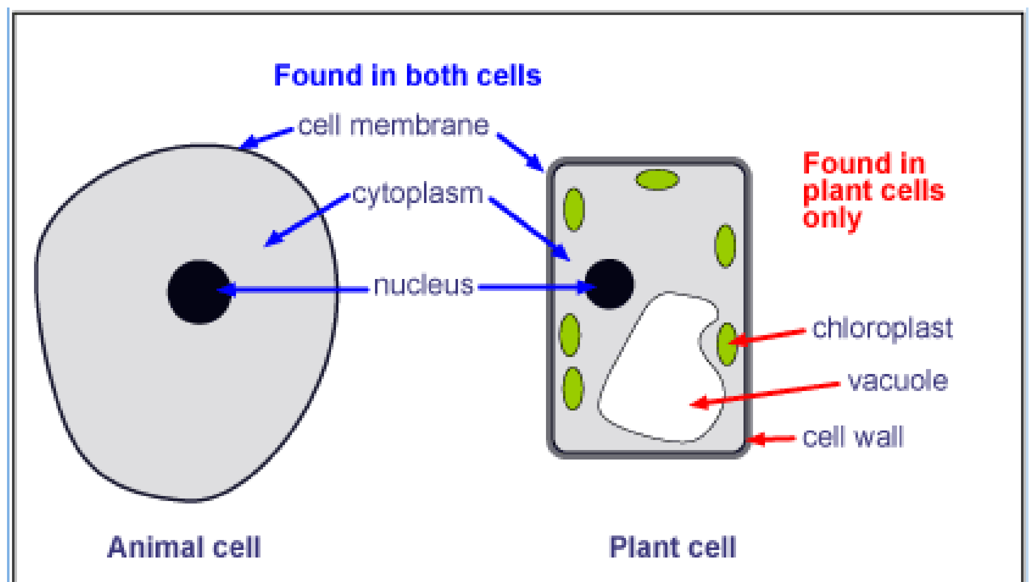


Figure: https://en.wikipedia.org/wiki/File:Sci_dia_126.gif

- Do plant cells have anything that animal cells don’t?
  - **Chloroplasts** = site of photosynthesis
    - contains pigments (usually green) that capture the energy of sunlight & store it in sugar
      - *more on this in a future chapter*

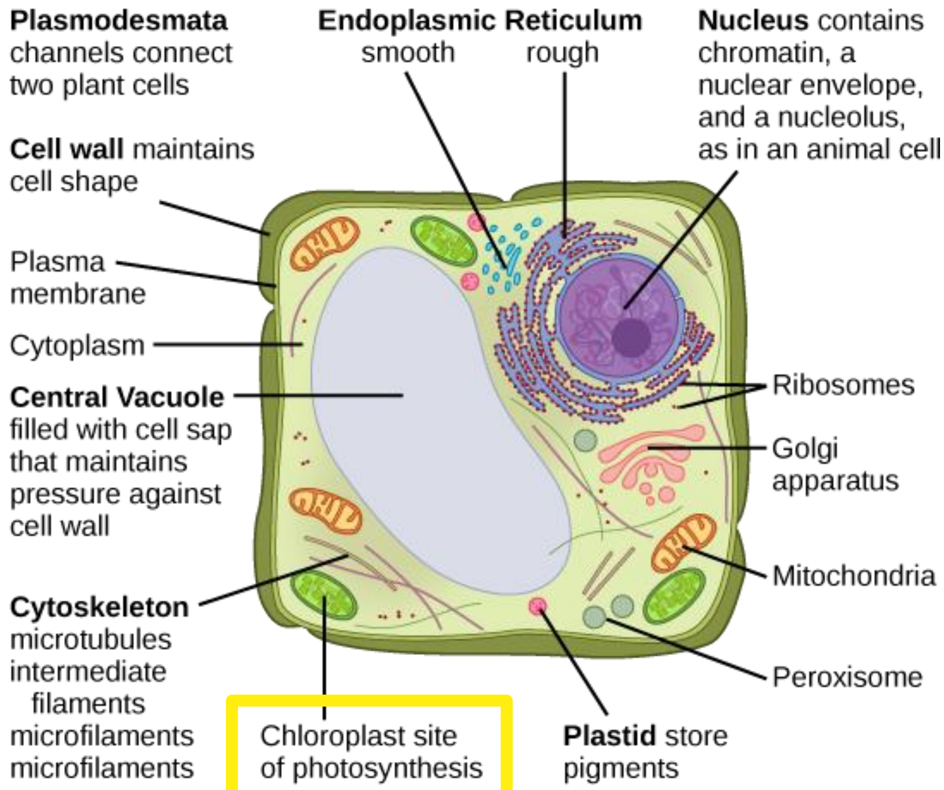


Figure: https://commons.wikimedia.org/wiki/File:Figure_04_03_01b.png

- Do plant cells have anything that animal cells don’t?
  - **Central vacuole**: very large – takes up half or more of a plant cell & has many functions
    - filled with fluid – helps maintain water balance
    - stores wastes & nutrients
    - contains pigments that give flowers their color
    - provide pressure called “turgor pressure” to keep cells rigid

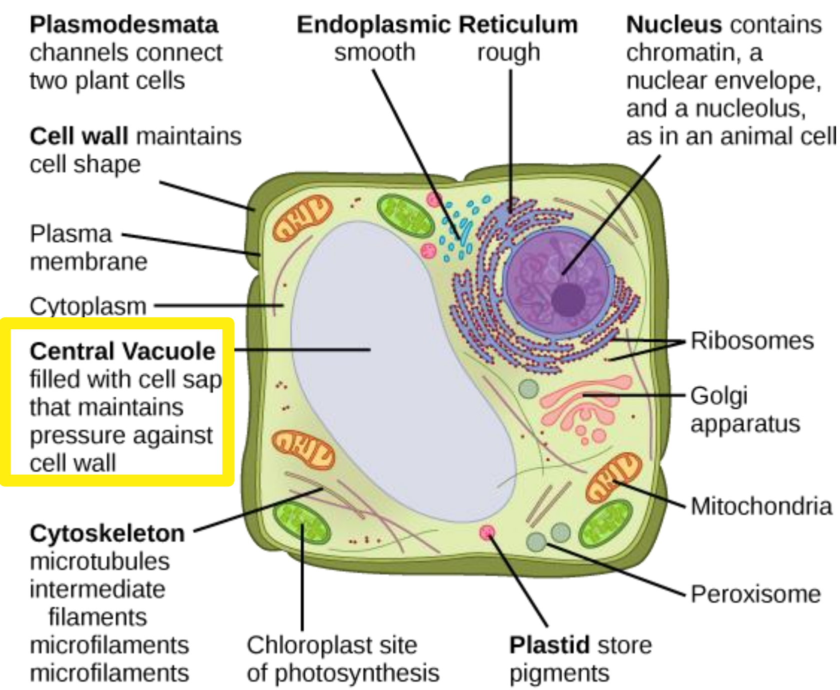
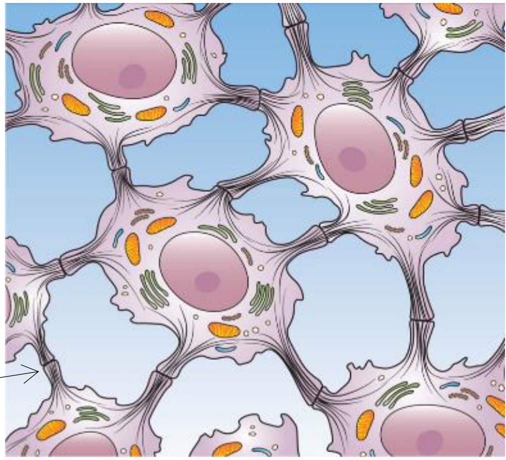


Figure: https://commons.wikimedia.org/wiki/File:Figure_04_03_01b.png

How do cells stick together & communicate?

- Single-celled organisms exist on their own
- But multi-cellular eukaryotic organisms (like plants & animals) have to stick together & communicate with each other in order to work as a unit



  – **Cell junctions** allow for attachment & communication between cells
    - 3 types: desmosomes, tight junctions, & gap junctions (animals) or plasmodesmata (plants)

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

Desmosomes attach cells together

- Found where cells need to adhere tightly together under the stresses of movement
  - e.g. the skin, intestine, & bladder

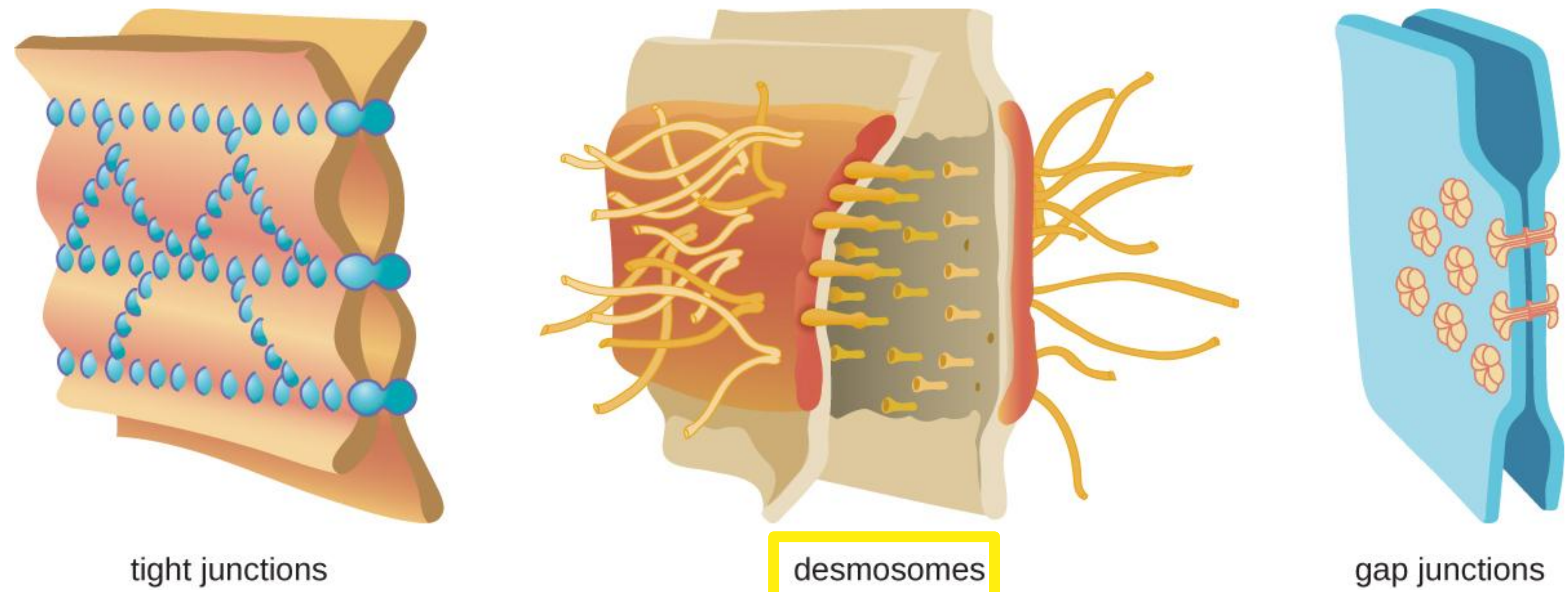


Figure: https://commons.wikimedia.org/wiki/File:OSC_Microbio_17_02_Junction.jpg

- **Tight Junctions** attach cells together & make them leak proof
  - Found where tubes & sacs must hold contents without leaking
    - e.g. the skin, bladder, & stomach

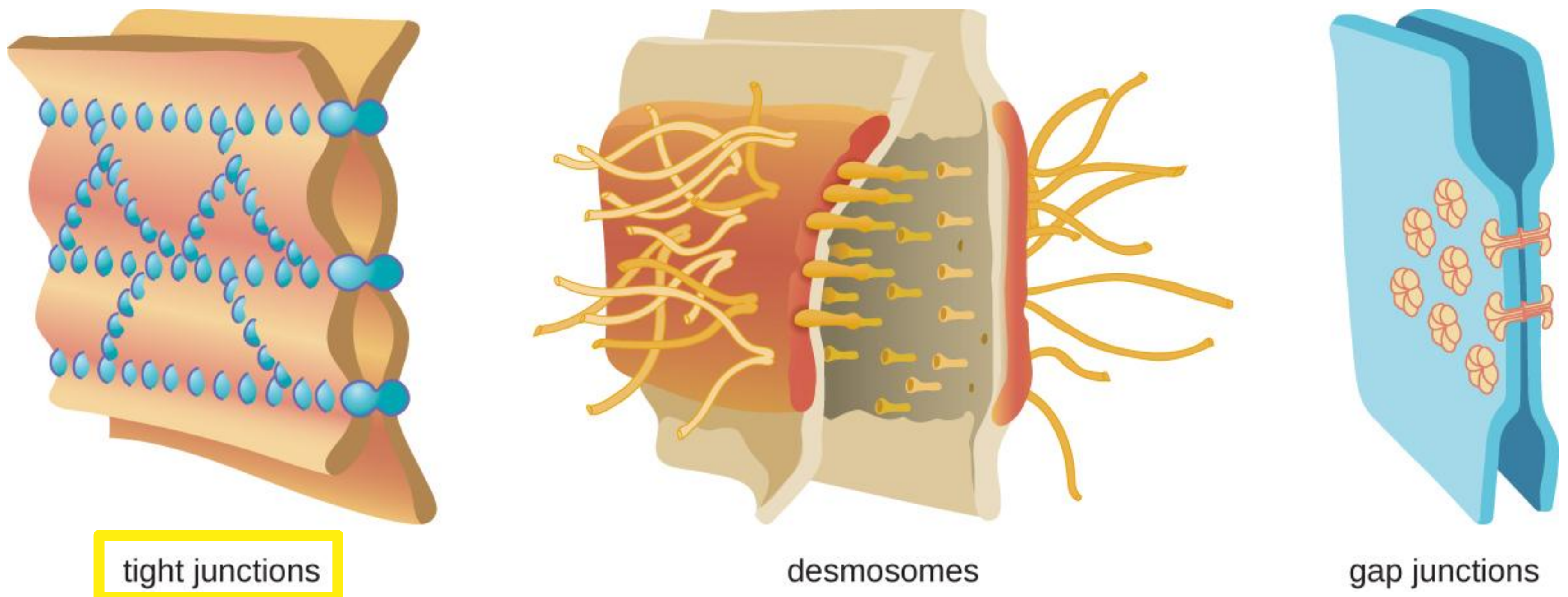
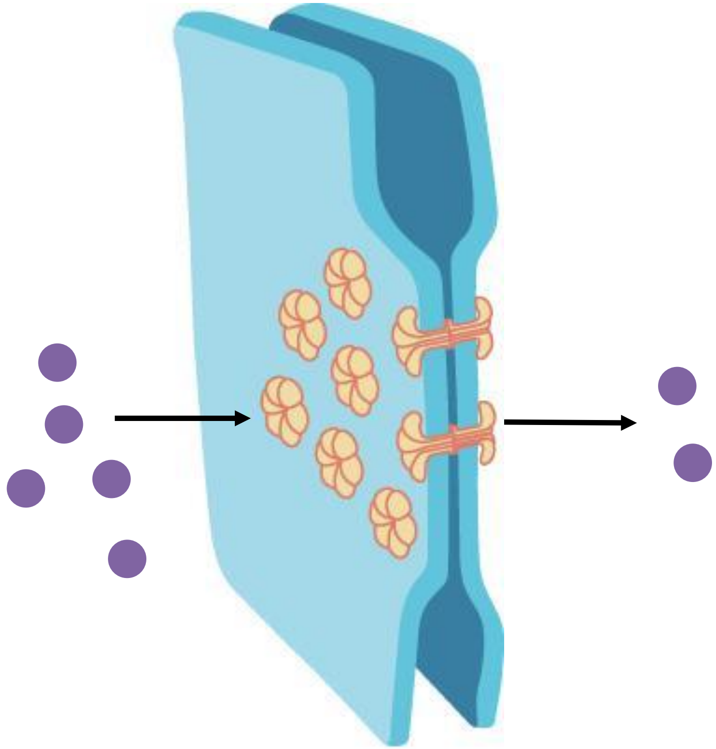


Figure: https://commons.wikimedia.org/wiki/File:OSC_Microbio_17_02_Junction.jpg

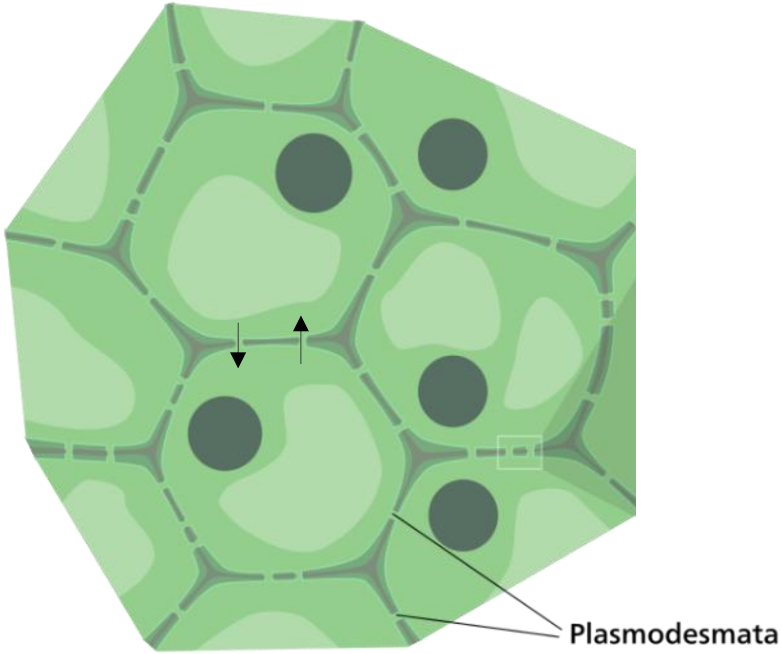
- **Gap Junctions** allow for <u>communication</u> between animal cells
  - – allow passage of hormones, nutrients, & ions – this synchronizes cells
    - e.g. link heart cells together so that all contract at once
    - e.g. coordinate cells in digestive tract so that food is propelled in only one direction



gap junctions

Figure: https://commons.wikimedia.org/wiki/File:OSC_Microbio_17_02_Junction.jpg

- **Plasmodesmata** allow for <u>communication</u> between plant cells
  - Tunnels in the cell wall of plants allow hormones, nutrients, etc. to pass



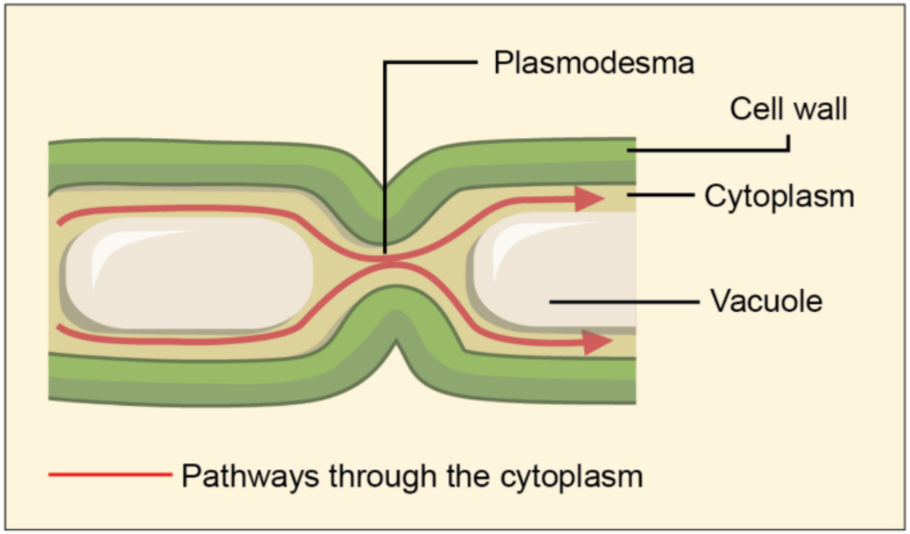


Figure: https://commons.wikimedia.org/wiki/File:Plasmodesmata_en.svg
Figure from OpenStax Biology 2e

- We now know:
  - cells have organelles & other structures that build materials (proteins, lipids, etc.)
    - some of these materials must leave the cell to get to the blood stream (e.g. hormones, insulin, or antibodies of the immune system)
  - cells have mitochondria: break apart glucose for energy
- So we must be able to get things (like glucose) into the cell & things (like antibodies) out of a cell
- BUT: we also learned that the cell membrane encloses the cell, keeping the insides in & the outsides out…

So how do we get things across the cell membrane?

- *Up next:*
  - **Cell membranes** – how do things cross?

- *Up soon:*
  - **Chloroplasts & mitochondria** – how do we get energy on Earth & then break it apart to use it?

- *Up later:*
  - **Nucleus, ribosomes, rough ER** – how do we go from DNA to us, & how can we predict what our offspring could be like?

Chapter 5: Cell Membranes

- What is a cell membrane made of & what does it do?
- What molecules can & can not cross cell membranes on their own?
- How do molecules know whether to move in or out of a cell?
- What are the possible ways to move across a cell membrane?

Corresponds with OpenStax Biology 2e Chapter 5

What is a cell membrane made of & what does it do?

- All living things are composed of cells & all cells have a cell membrane
  - Cell membranes have 3 components:
    - Phospholipids
    - Cholesterol
    - Proteins

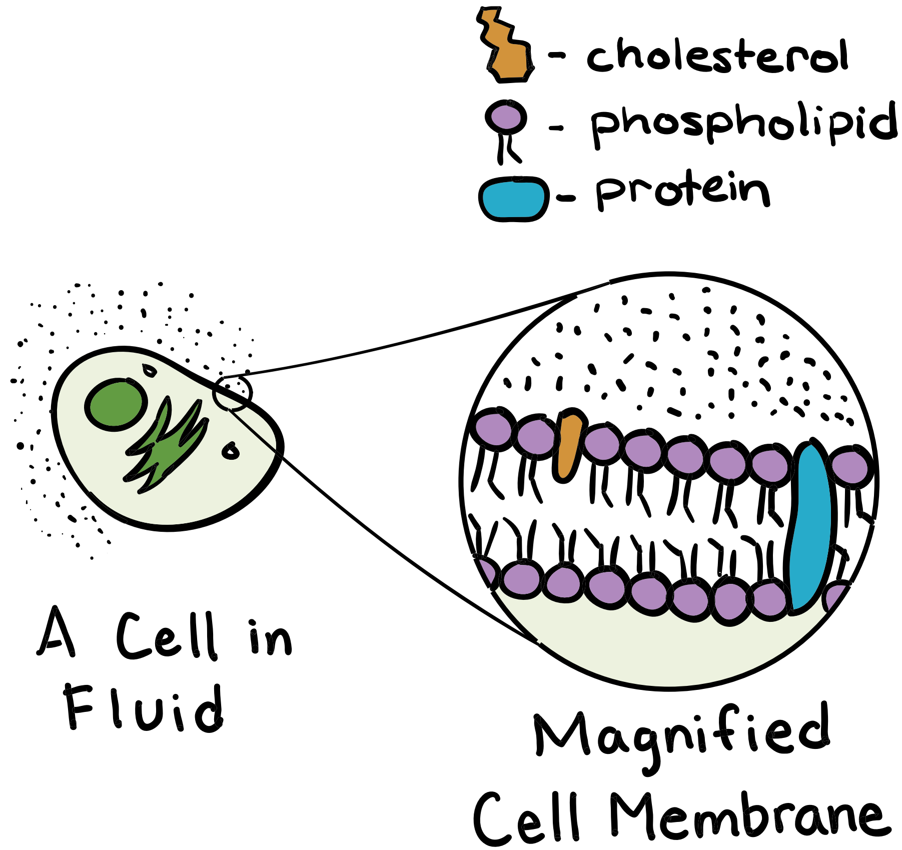
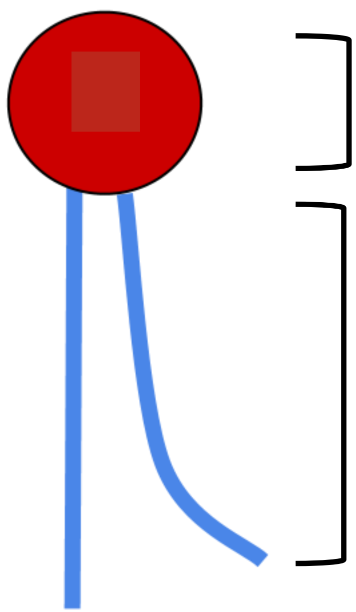


Figure: https://www.khanacademy.org/science/ap-biology/cell-structure-and-function/membrane-permeability/a/fluid-mosaic-model-cell-membranes-article

- Component 1: **Phospholipids** – a unique lipid
  - – Remember: lipids are hydrophobic
    - However: **phospholipids** have hydrophobic AND hydrophilic portions



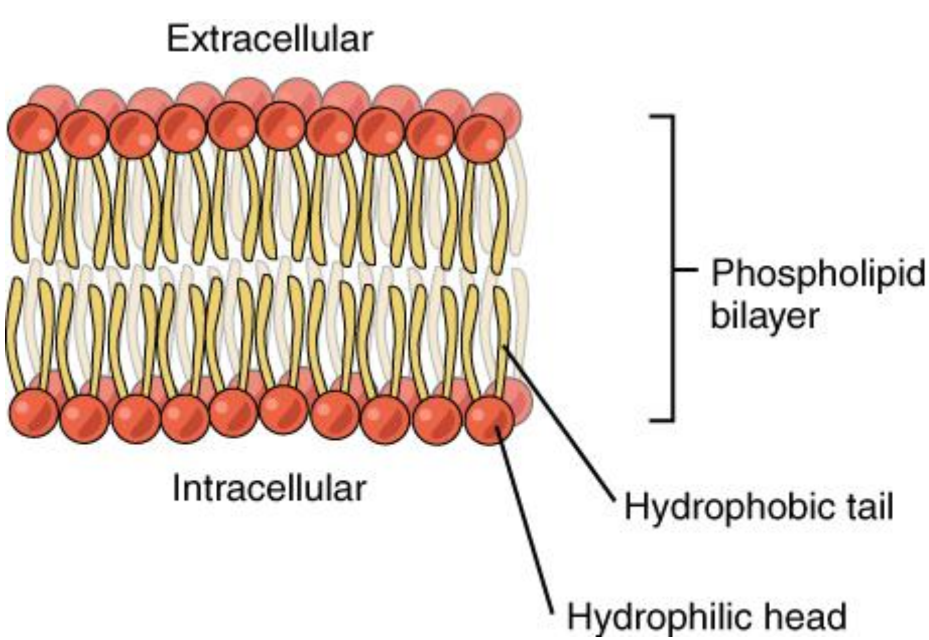
Hydrophilic head (attracted to water)

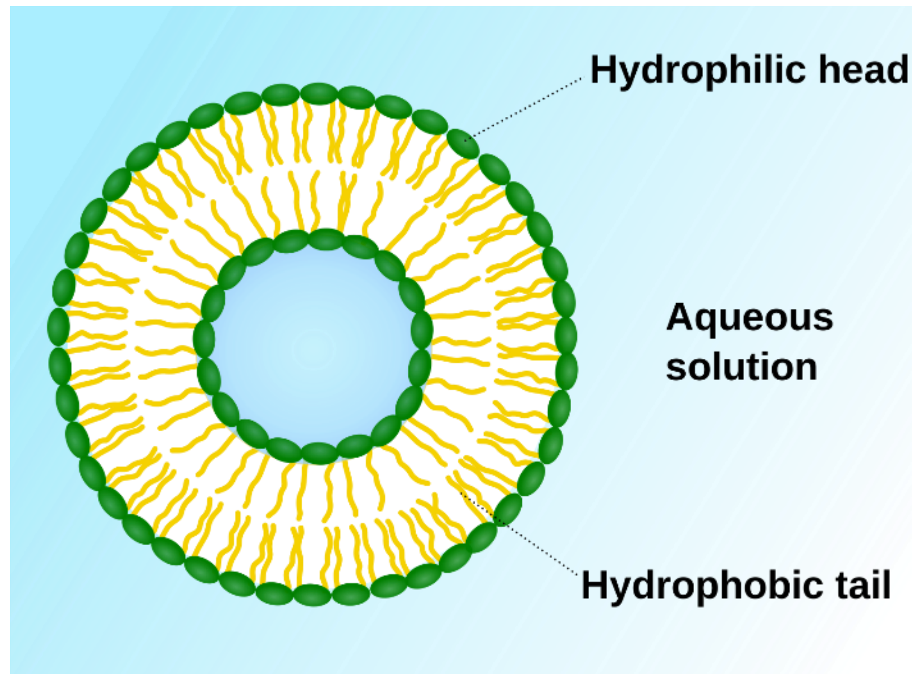
Hydrophobic fatty acid tails (repel water, attracted to other lipids: **lipophilic**)

A phospholipid with a hydrophilic head and a hydrophobic tail

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

- When placed in water, hydrophilic heads have no trouble, but hydrophobic tails clump together
  - Cells have watery insides AND watery outsides, so phospholipid tails clump in such a way that 2 layers are formed: **phospholipid bilayer**





- Phospholipids are not bound together – they only take their shape because of the clumping of the tails

- The resulting phospholipid bilayer functions to <u>enclose the cell</u>
  – the hydrophilic & hydrophobic layers restrict movement, keeping the insides in & the outsides out

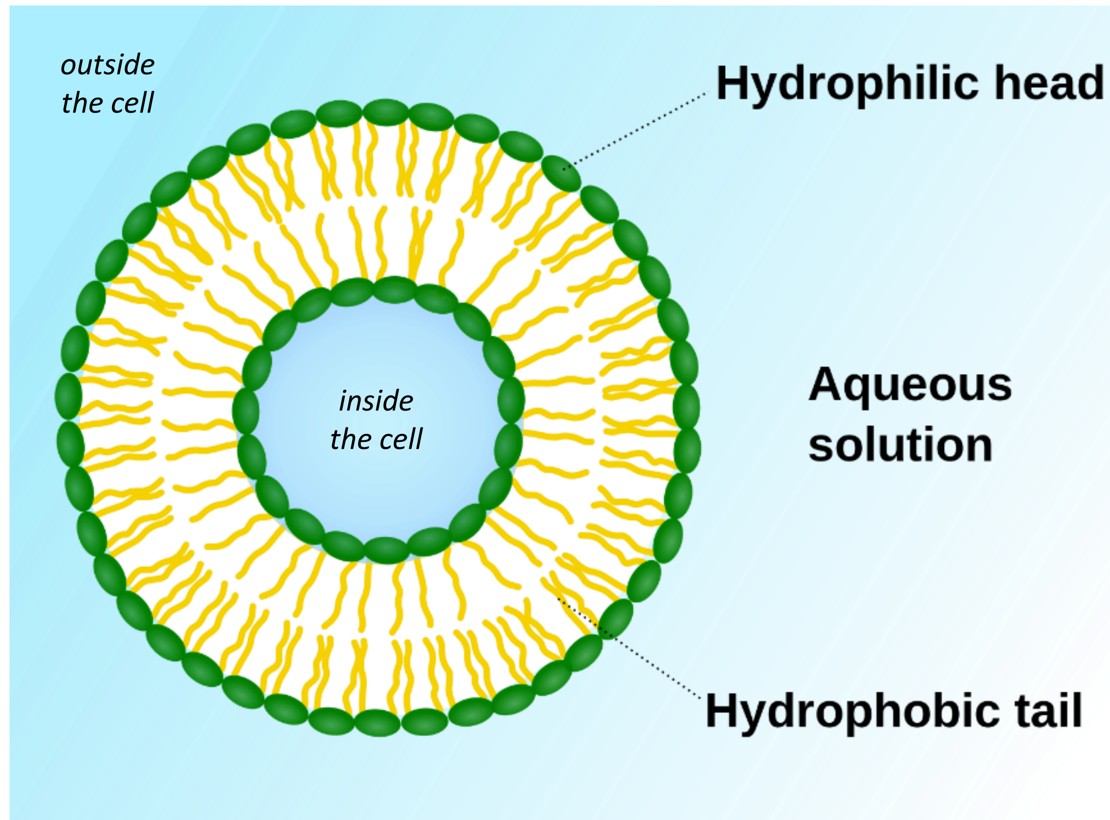
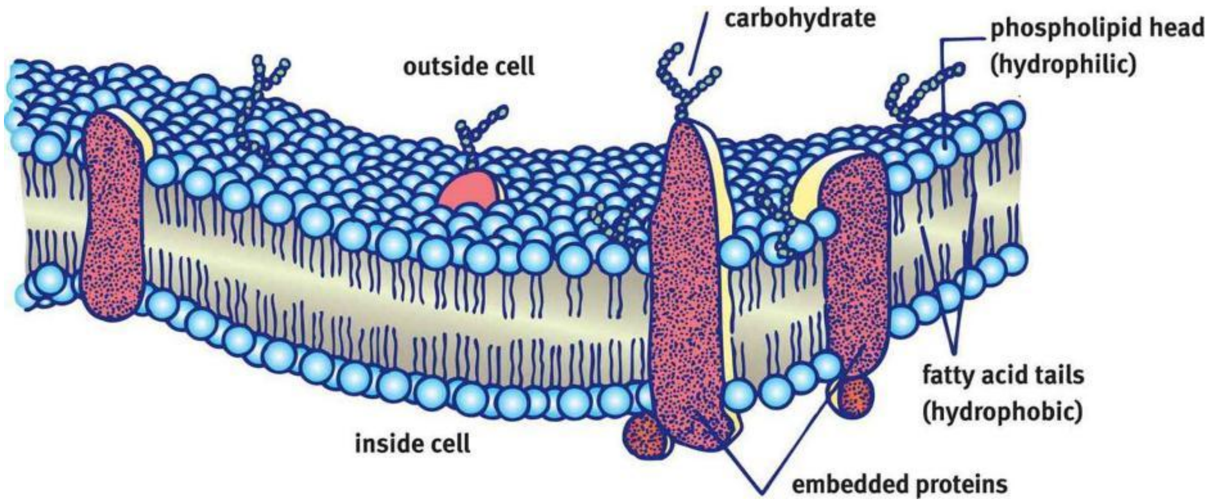


Figure: https://commons.wikimedia.org/wiki/File:Liposome_scheme-en.svg

- Because phospholipids are not bound together, the cell membrane is very flexible or “fluid” rather than a rigid, unmoving straight line



- The fatty acid tails of the phospholipids can alter how fluid or flexible the membrane is

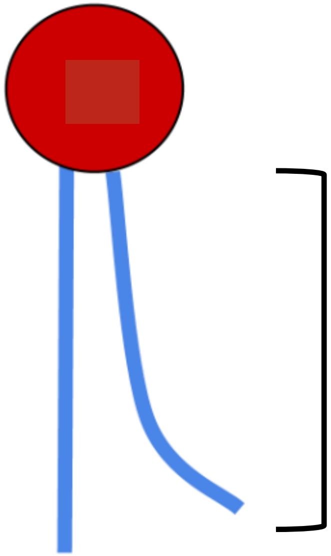


Figure: https://schoolbag.info/chemistry/mcat_biochemistry/47.html
Figure: https://commons.wikimedia.org/wiki/File:Phospholipid_Chemicalmakeup.png

Which of the following statements about phospholipids is true?

A Phospholipids are tightly bound together.

B Phospholipids form a rigid structure.

C Phospholipids form a bilayer that encloses the cell.

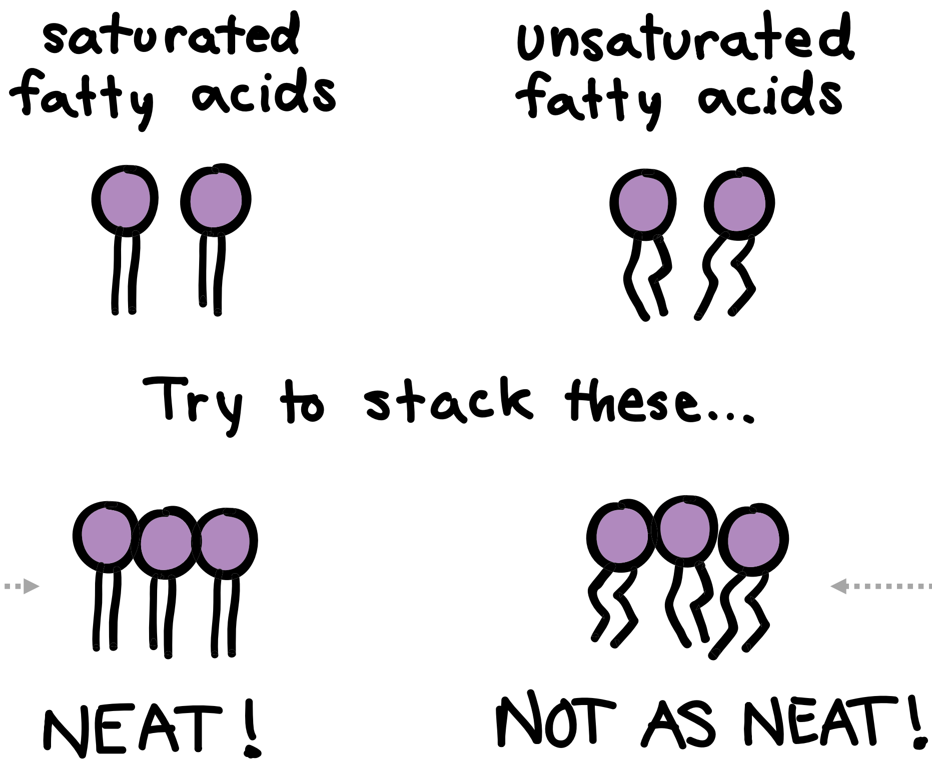
D Phospholipids do not affect the fluidity of the cell membrane.

提交

- Remember: **saturated** fatty acids stack well next to each other – this makes phospholipids <u>more stiff</u>

- Remember: **unsaturated** fatty acids don’t line up well – this makes phospholipids <u>more flexible/fluid</u>

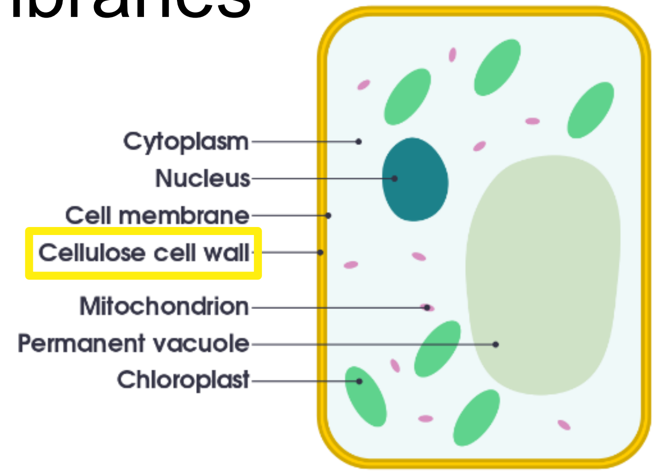
stiff/less fluid



flexible/more fluid

Figure: https://www.khanacademy.org/science/ap-biology/cell-structure-and-function/membrane-permeability/a/fluid-mosaic-model-cell-membranes-article

- Remember: plants make unsaturated fats
  - they have very flexible cell membranes
    - How do they stay rigid then?
      - Remember: they have <u>cell walls</u> for support



- Remember: animals don't have cell walls
  - How do they maintain structure then?
    - They make <u>saturated fats</u> to make their cell membranes more rigid & stiff
      - *Animals have 1 more thing that plants don't to help make their cell membranes more stiff…*

Figure: https://commons.wikimedia.org/wiki/File:Simple_diagram_of_plant_cell_(en).svg