



Biological Physics

FYS4715 2020

Some questions

Write, 5 min, read aloud the parts you want, publish anonymously, helpful for me

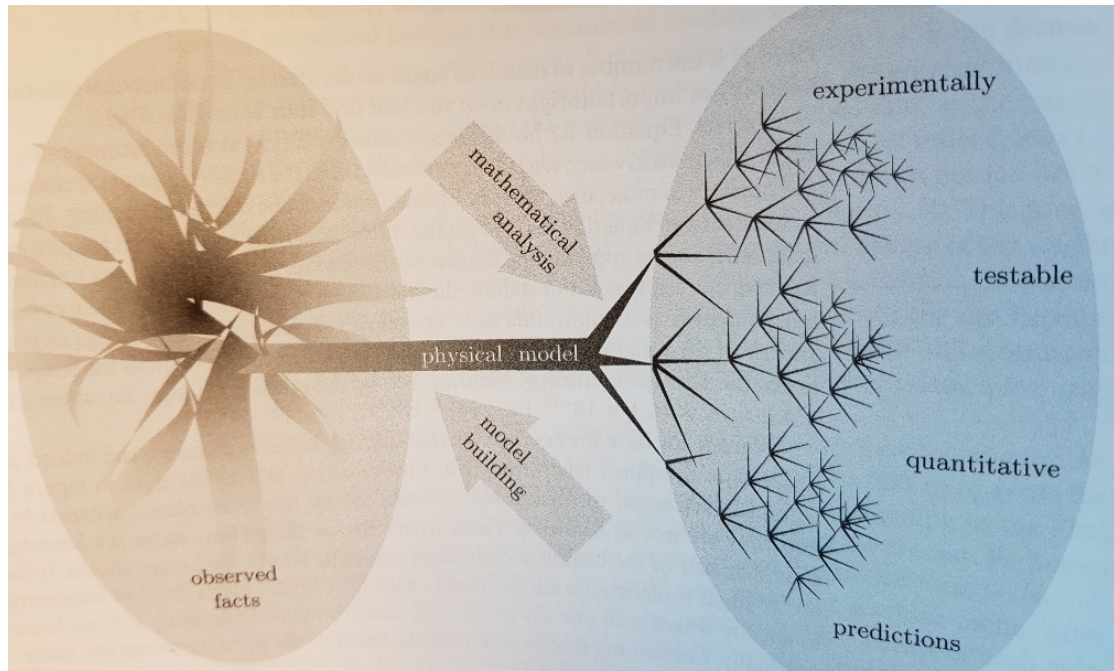
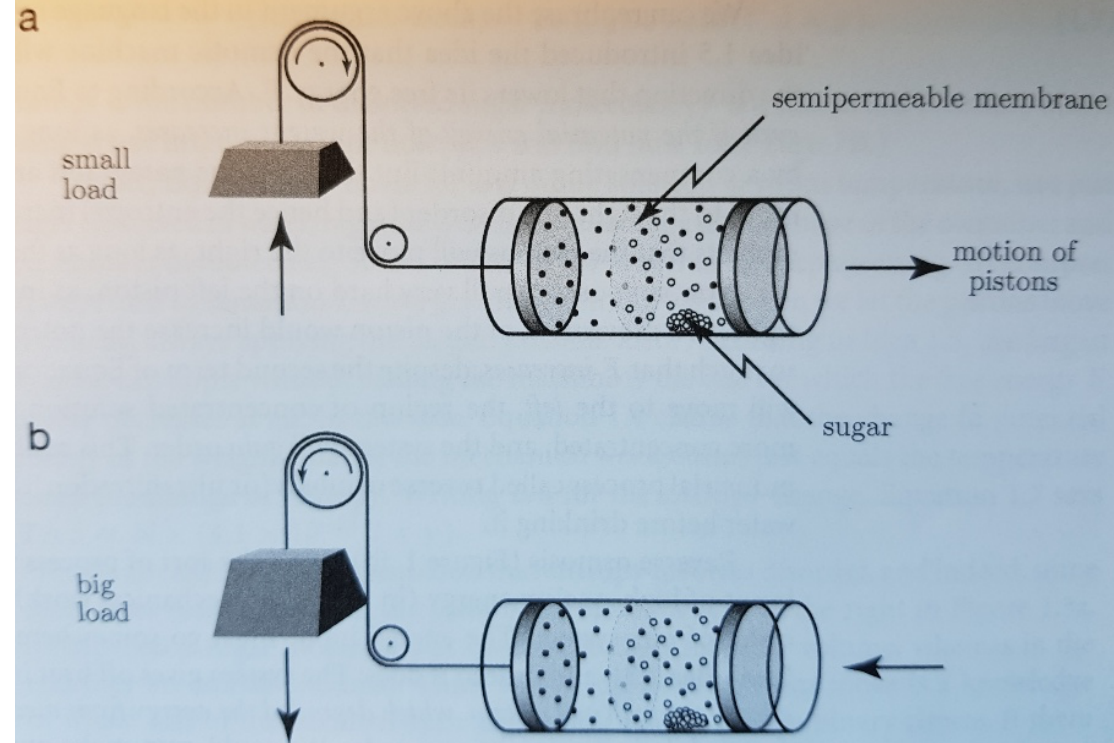
- Why did you choose to follow FYS4715?
- What do you expect to get out of the course?
- What have you learnt previously that is relevant for the course?
- What education background do you have?

Themes this year

- General: Processes on cellular and molecular scale
 - 1nm – 100 μm
 - from atomic to macroscopic: stat mech
 - small scale: atomic forces, velocities, charges
 - large scale: surface tension, stress-strain, diffusion, osmosis, electrochemistry
- Nelson ch 1-8, 12 + chosen topics
- Projects:
 - Passive and active swimmers
 - Cellular Potts model (?)
 - [Mechanobiology](#), effects of ultrasound on cells
 - Bioimpedance
 - Nerve impulses

Chapter 1

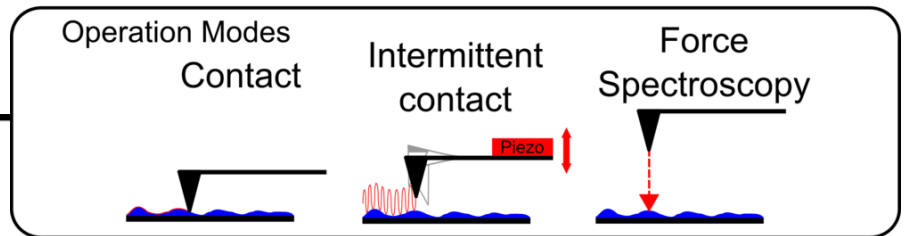
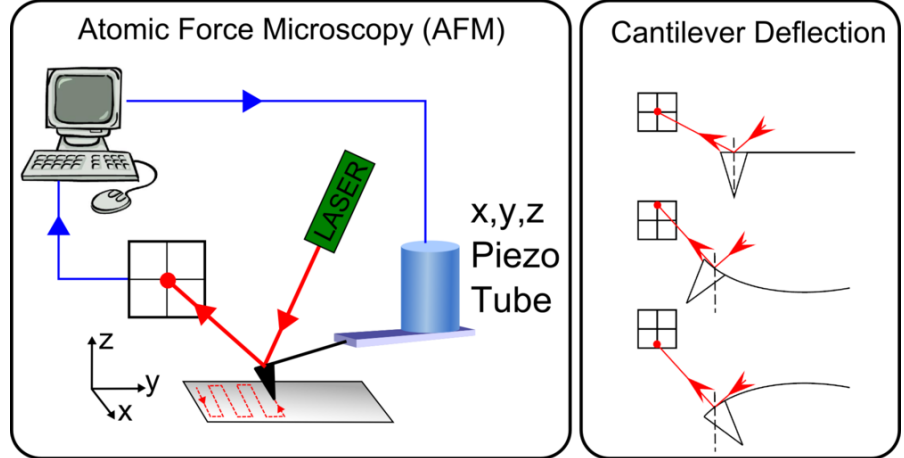
- What is heat?
- Entropy
- 2nd law vs. order
- Free energy
- Osmosis
- Physical models
 - For biologists:
<https://www.nature.com/articles/d41586-019-03960-z>



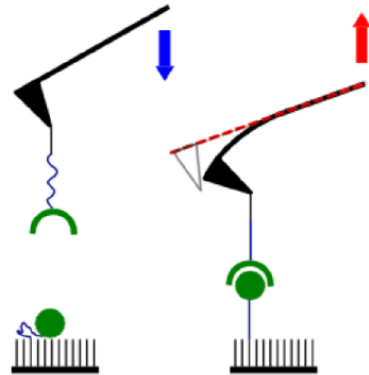
Biological **Physics**

- In physics we make mathematical models and calculate stuff
- What is the volume of one molecule of water?
- Most famous model: ideal gas
 - equation of state: $PV = nk_B T$
 - What is PV ?
 - How much is $k_B T$?

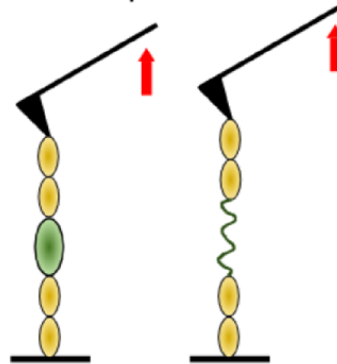
pN forces
nm distances



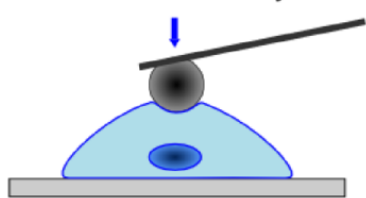
AFS - Single molecule ligand-receptor unbinding



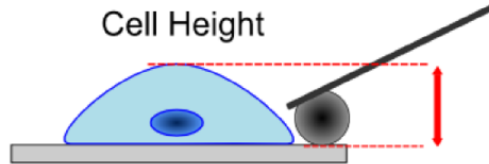
AFS - Unfolding of proteins



Cell Elasticity

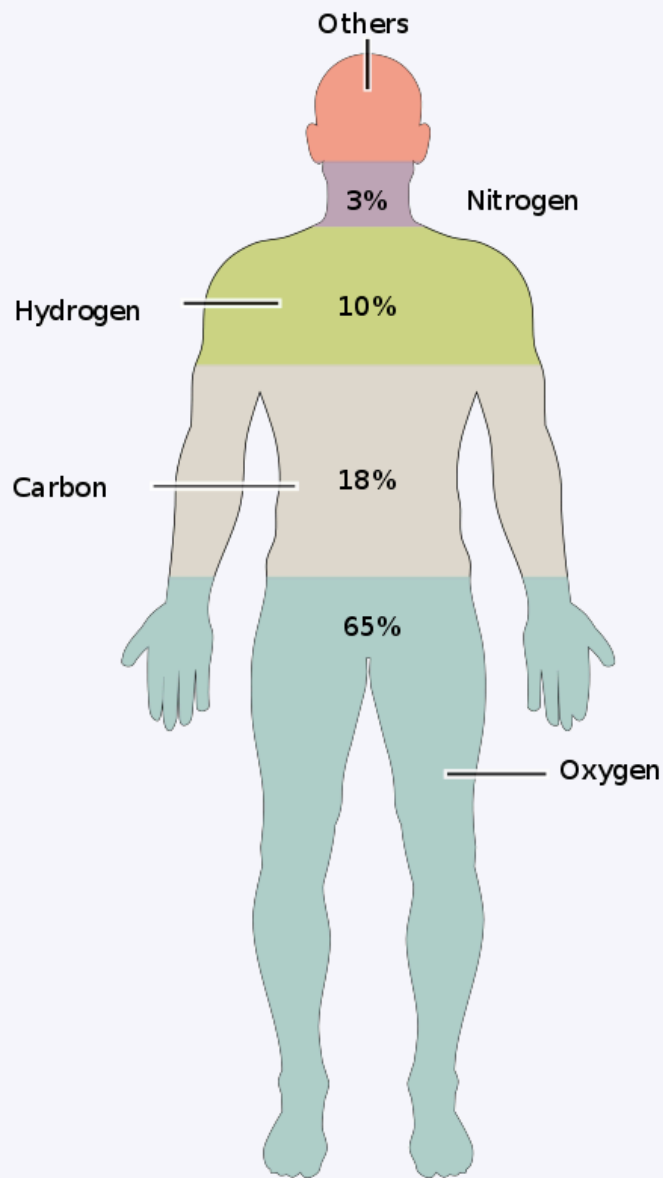


Cell Height



Chapter 2: What's inside cells

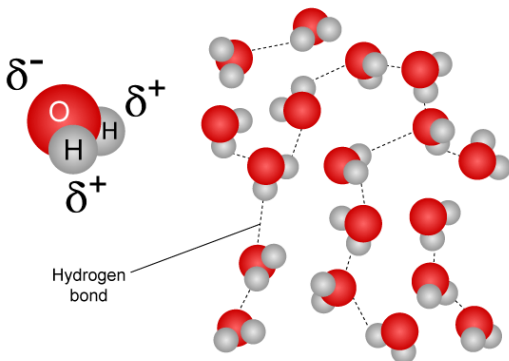
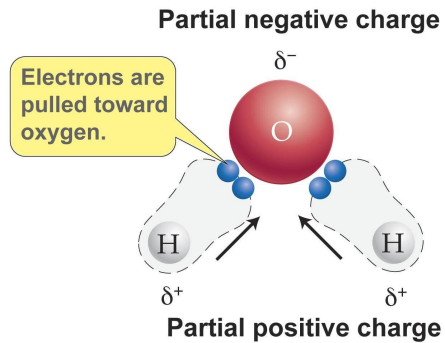
- Biological question: How do organisms organize all the chemical processes?
- Physical ideas
 - Compartmentalization
 - Active transport
 - Specific processes
 - Non-linearity -> switching in networks



Element	Symbol	% 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	0.2
Others		< 1.0

The main elements that compose the human body are shown from most abundant (by mass, not by fraction of atoms) to least abundant.

Polar – hydrophilic – water soluble

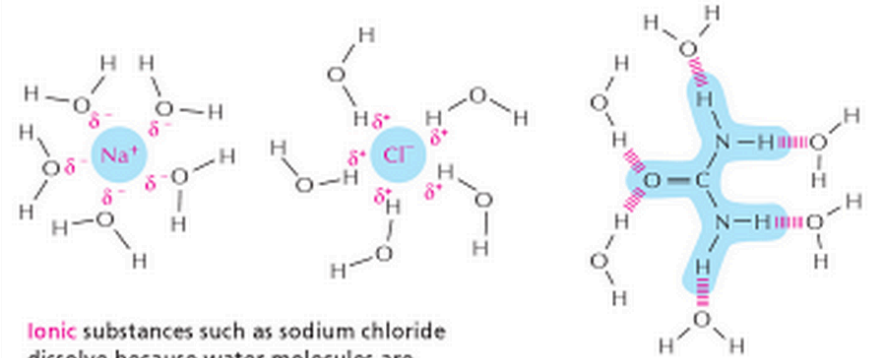


(length appears different for perspective (3D))

Dept. Biol. Penn State ©2002

HYDROPHILIC MOLECULES

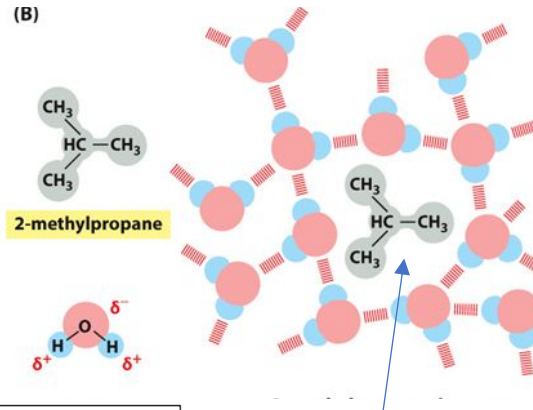
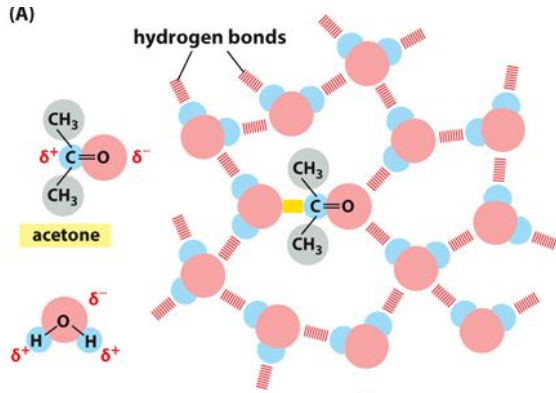
Substances that dissolve readily in water are termed **hydrophilic**. They include ions and polar molecules that attract water molecules through electrical charge effects. Water molecules surround each ion or polar molecule and carry it into solution.



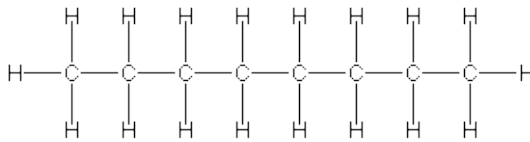
Ionic substances such as sodium chloride dissolve because water molecules are attracted to the positive (Na^+) or negative (Cl^-) charge of each ion.

Polar substances such as urea dissolve because their molecules form hydrogen bonds with the surrounding water molecules.

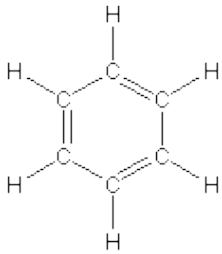
Hydrophobe & amphiphile



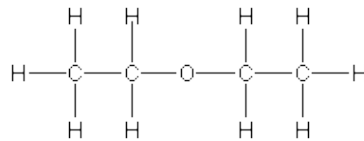
Some hydrophobic molecules



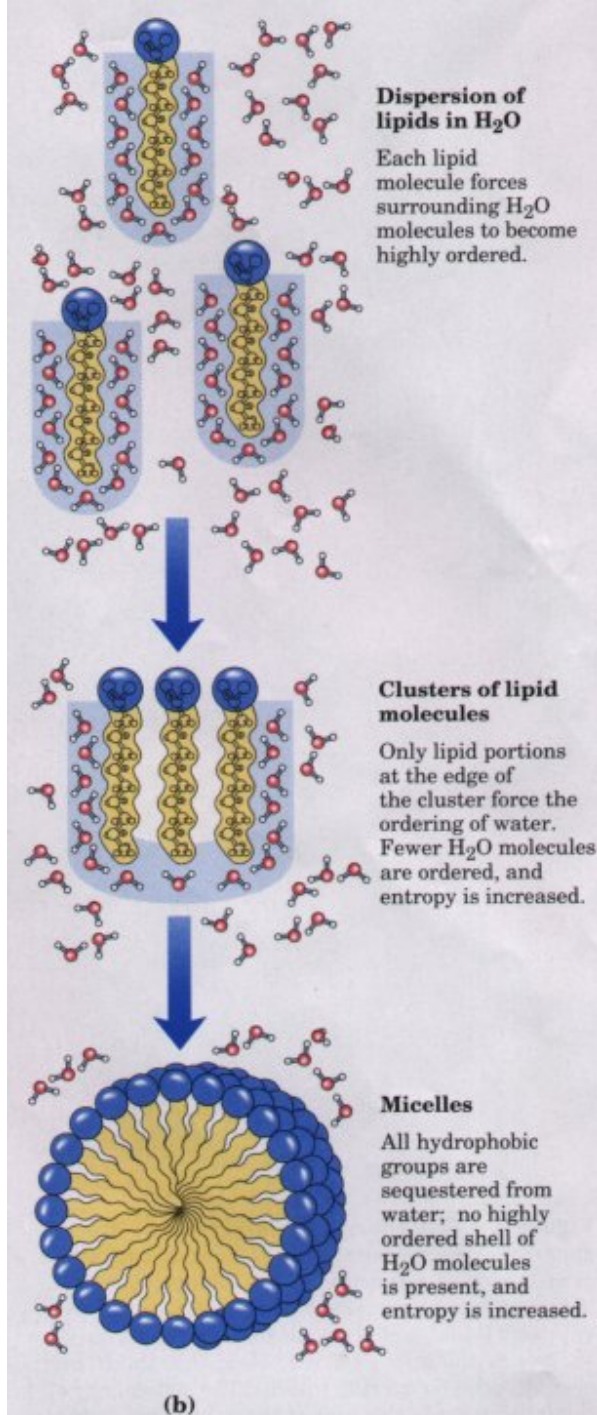
octane



benzene

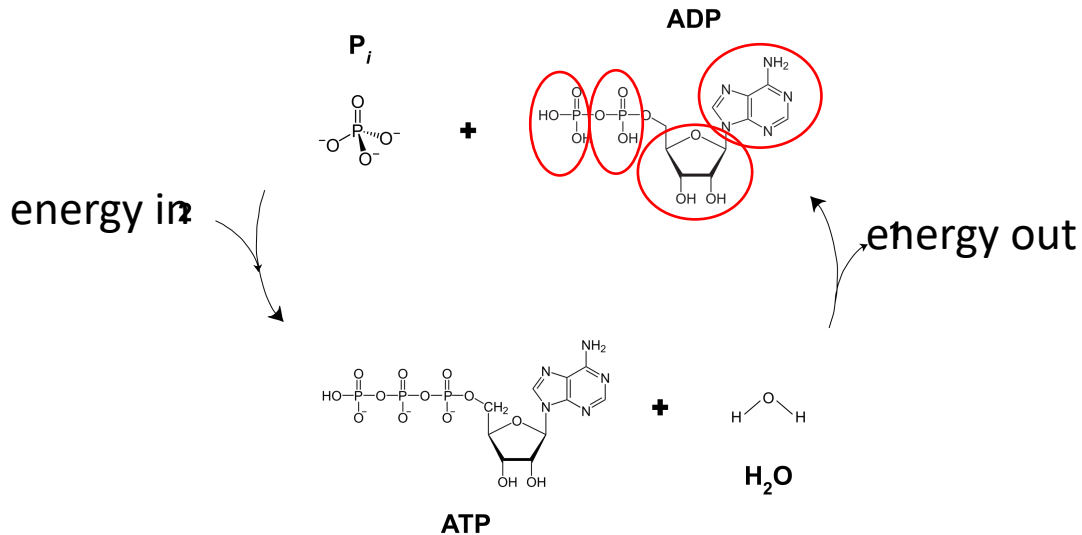
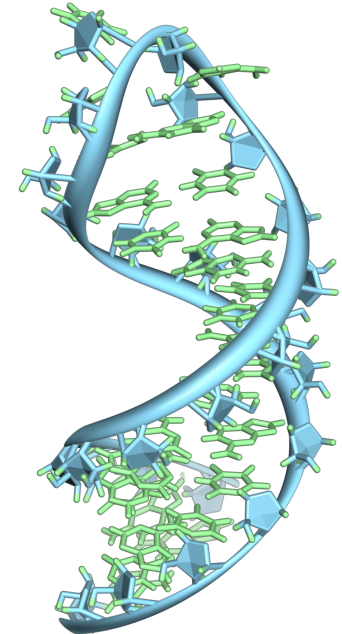
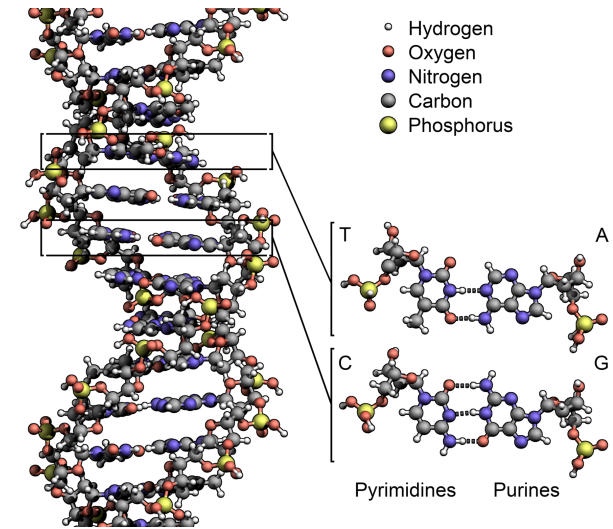


ether



Important molecules

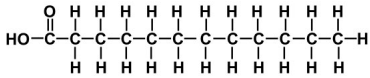
- Important nitrogenous bases: Adenine, Thymine, Guanine, Cytosine, Uracil
- Nucleic acids
 - DNA (DeoxyriboNucleic Acid): base **pairs** T-A, C-G
 - RNA (RiboNucleic Acid): single strands of G,U,A,C
- Nucleotide = (nitrogenous) base + sugar + phosphate
 - Adenine (base) + ribose (sugar) = Adenosine
 - ATP (Adenosine TriPhosphate)
 - ADP (Adenosine DiPhosphate)



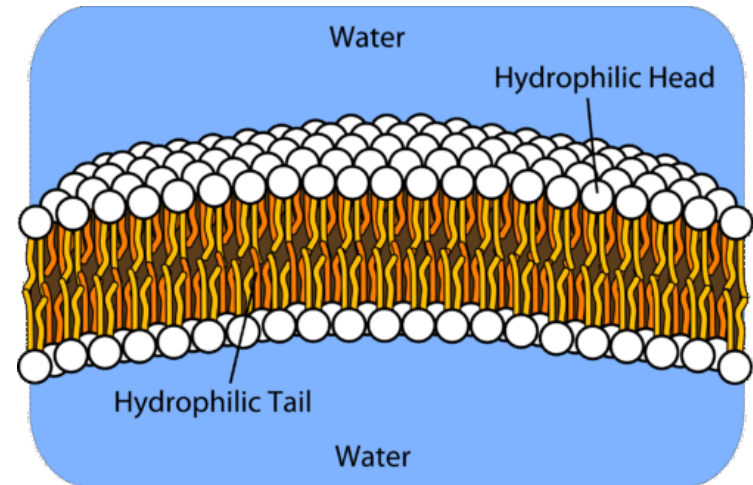
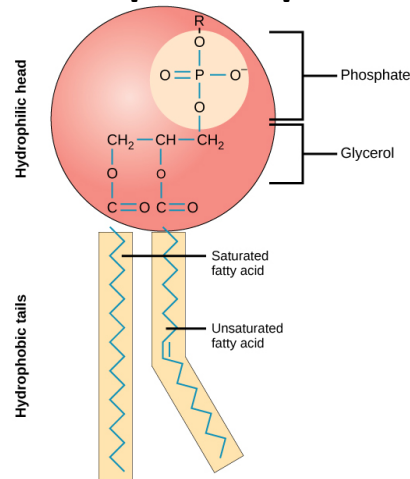
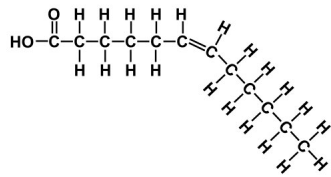
Important molecules

- fatty acids -> phospholipid -> membranes

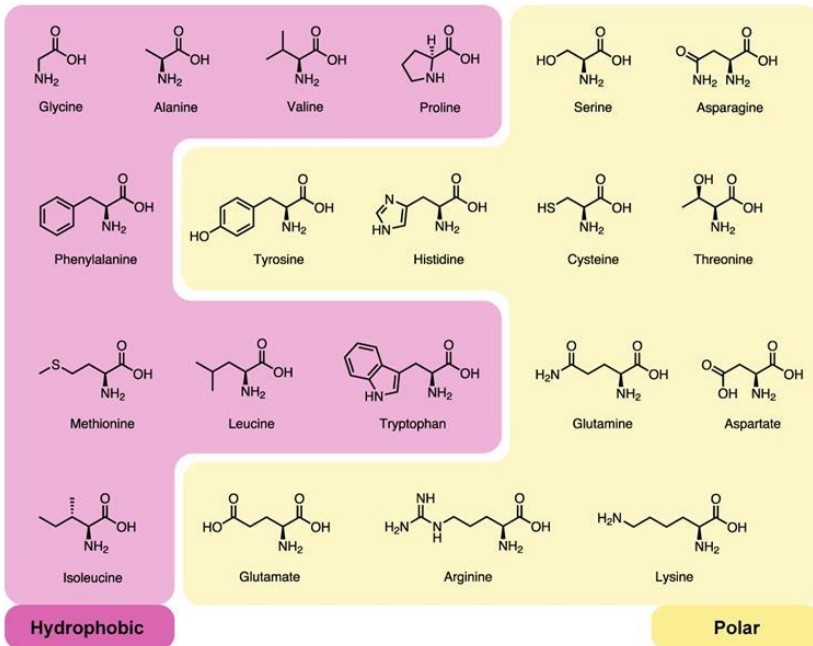
Saturated Fatty Acid



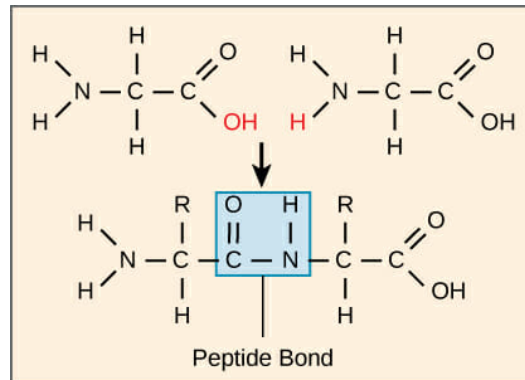
Unsaturated Fatty Acid



- amino acids -> polypeptides - proteins



Amino: NH₂, Acid: OOH



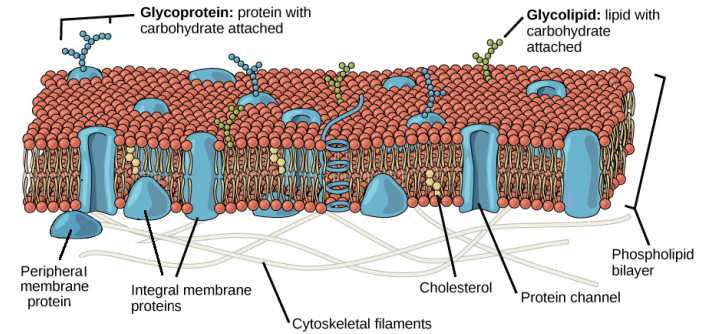
Peptides: 2-50 amino acids
Proteins: >50 amino acids

Molecule databases

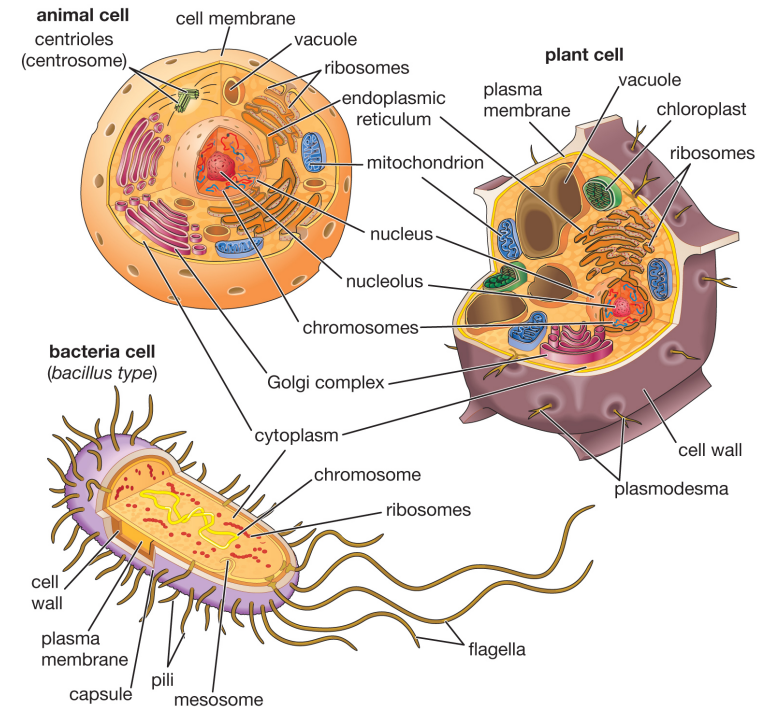
- <https://www.rcsb.org> protein data bank
 - 1aoi
 - 1tau
 - 1mbn
- Proteins are folded
- info on different scales
- <https://www.ucalgary.ca/tieleman/>
- atomify

Cells – fundamental functional units of life

- enclosed by **plasma membrane**
- interior «soup» called **cytoplasm**
- organized in **organelles** = specialized compartments surrounded by membrane
 - **nucleus**: contains the genetic information necessary for cell growth and reproduction
 - **mitochondria**: responsible for the energy transactions necessary for cell survival
 - **lysosomes**: digest unwanted materials within the cell
 - **endoplasmic reticulum & Golgi apparatus**: organization of the cell by synthesizing selected molecules and then processing, sorting, and directing them to their proper locations

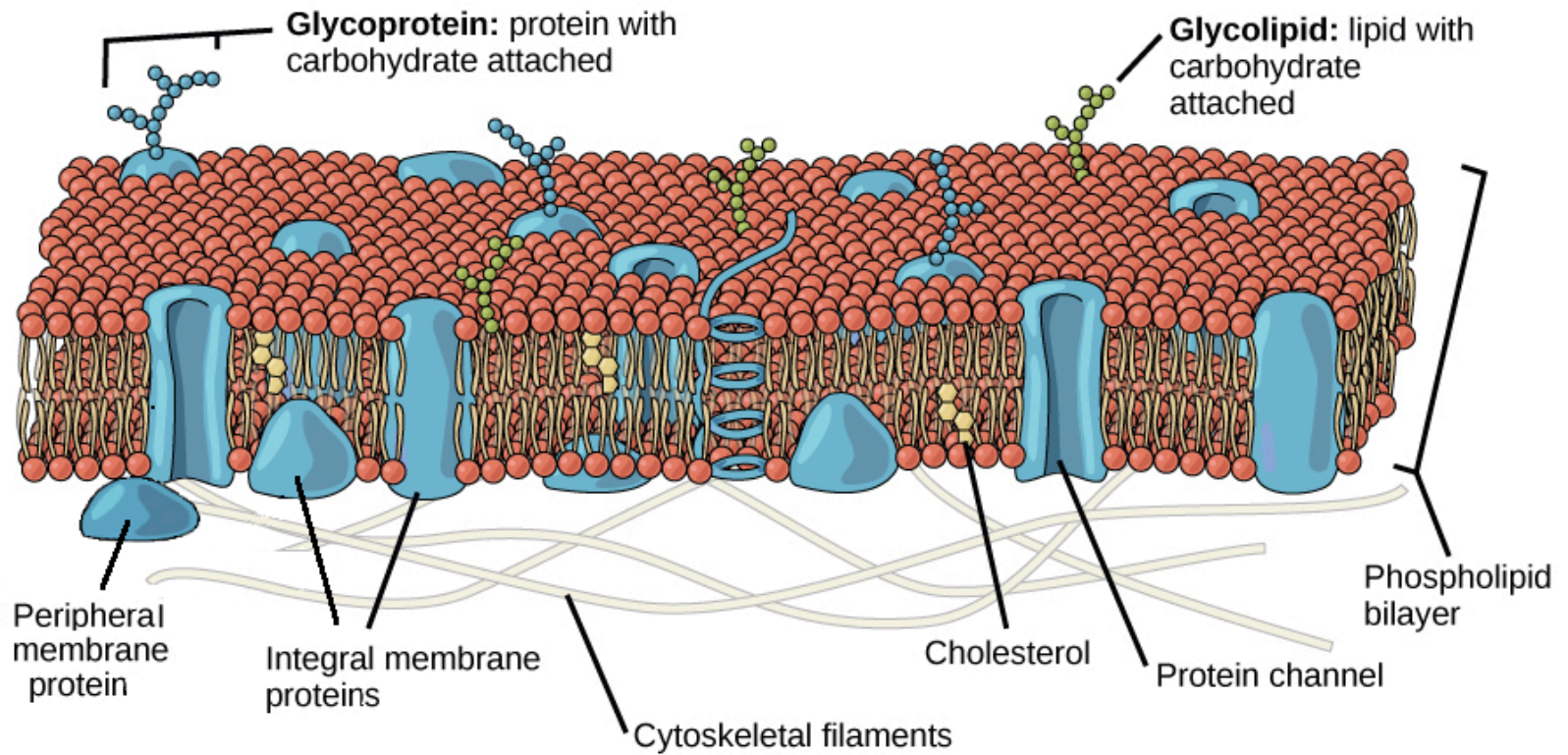


Some typical cells



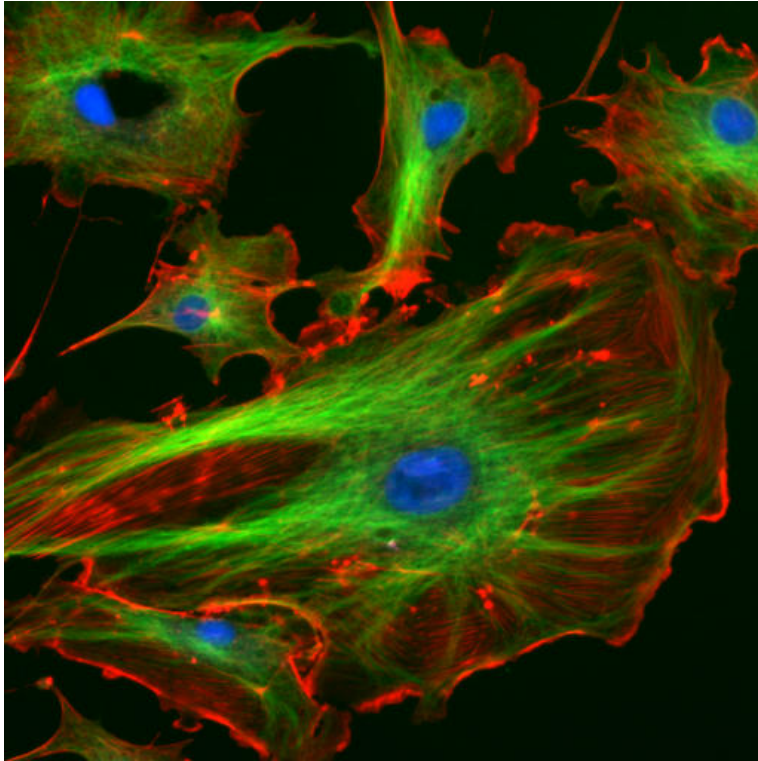
cyto- = cell

Plasma membrane

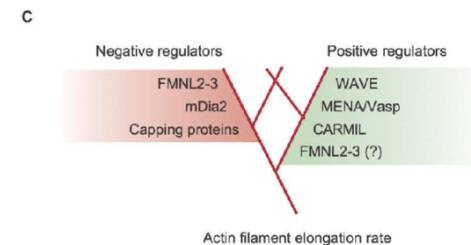
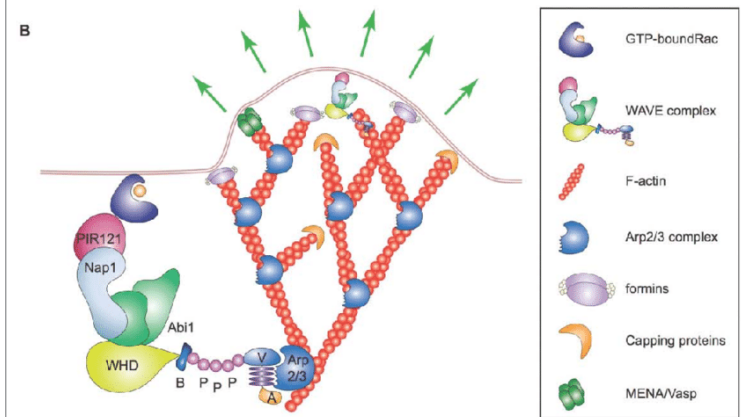
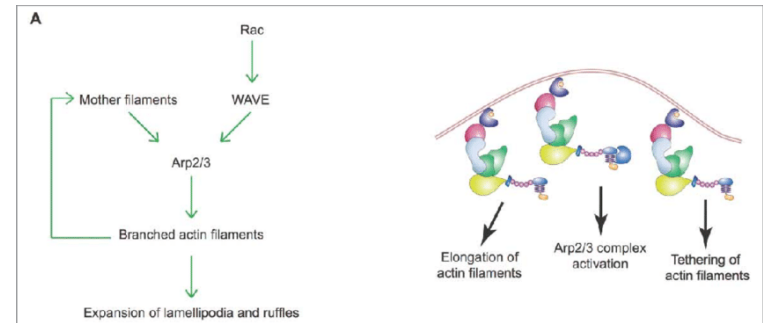
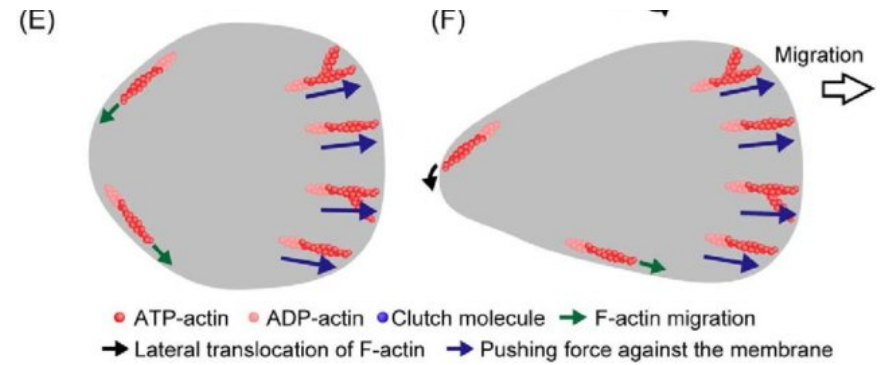


Cytoskeleton

- actin filaments (7 nm \varnothing)
- microtubules (25 nm \varnothing)
- intermediate filaments (10 \varnothing)



The eukaryotic cytoskeleton. Actin filaments are shown in red, and microtubules composed of beta tubulin are in green.



physics questions:

- polarization
- force

G-actin monomer
F-actin polymer

Crash course in greek and latin:

Angio-		Vessel	
-atomy, -otomy		cutting	Angiogenesis
Auto-	self		=production
Brachy		short	of vessels
Cata- (katalysis)		dissolving	
Carcino-		tumor (crab-like)	
Centro-, -centric		centre	Carcinogenesis
-ceptor, ceptive		capere, to take	=
Chromo-		color	Production
Chrono-		time	(development)o
-cyte, cyto-	hollow		f cancer
Diplo	double		
e-, ec-		out of	
Endo-	within, inside		
Exo-	outside		
Extra-	beyond		
Erythro-		red	
-gen, genous	descent		
-genic, -genous		birth, descent, origin	
-genic, -genous		to produce	

Crash course in greek and latin:

Glia-	glue
Haem-	blood
Histo-	tissue
Homeo-	alike
Homo-	the same
Hyper-	above
Hypo-	under
Infero-	beneath
Infra-	below
Inter-	between
Intra-	within
Iso-	equal
-kinesis, -kinetic	kinesis=movement
Leuko-	white
Lipo-	fat
-lysis, -lysin	dissolving
Macro-	large
Medi-	middle

Crash course in greek and latin:

-mere, mero-	a part	
Meta-	after	
Metabolism	change	Centromere=
Micro-	small	middle part
Mito- (mitosis)	a tread	
Mono-	single	
Muta-	mutare=to change	telomere=
Necro-	dead	end part
Neuro-	nerve	
-nomics	law	
Oligo-	few	
Onco-	bulk, mass	
Ortho-	straight	
Para-	beside	
Per-	through	
Peri-	around	
-phage, -phagous	phagein=to eat	
-phil	to love	

Crash course in greek and latin:

-phobe	to fear
Photo-	light
Plasma-, -plasm	form
-plicate	to fold
Post-	after
Pre-	before
Pro-	before
Proto-	first
Re-	back
Retro-	backwards
Serum	whey (myse)
-some, soma-	body
Stereo-, -steric	solid
Sub-	under
Super-	over
Supra-	above
Sym-, syn-	with

Crash course in greek and latin:

-synthesis	composition
Tauto-	the same
Tele-	far
Teleo-	complete
Telo-, telio-	end
Trans-	across
Ultra-	beyond

Statistical mechanics

- Model: MD (Atomify)
- micro $x_i, m_i, v_i, f_{ij}, 10^{23} \rightarrow$ macro $\rho, \langle v \rangle, \langle v^2 \rangle, E_k,$
- thermodynamics: P, T, c_p, H_v, \dots (stat + conservation laws)
- distributions: uniform, Gaussian, Poisson

$$P(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-x_0)^2}{2\sigma^2}}$$

- $x \rightarrow vx, x_0 \rightarrow 0, s$
- $\langle v \rangle, \langle v^2 \rangle$
- Model: ideal gas