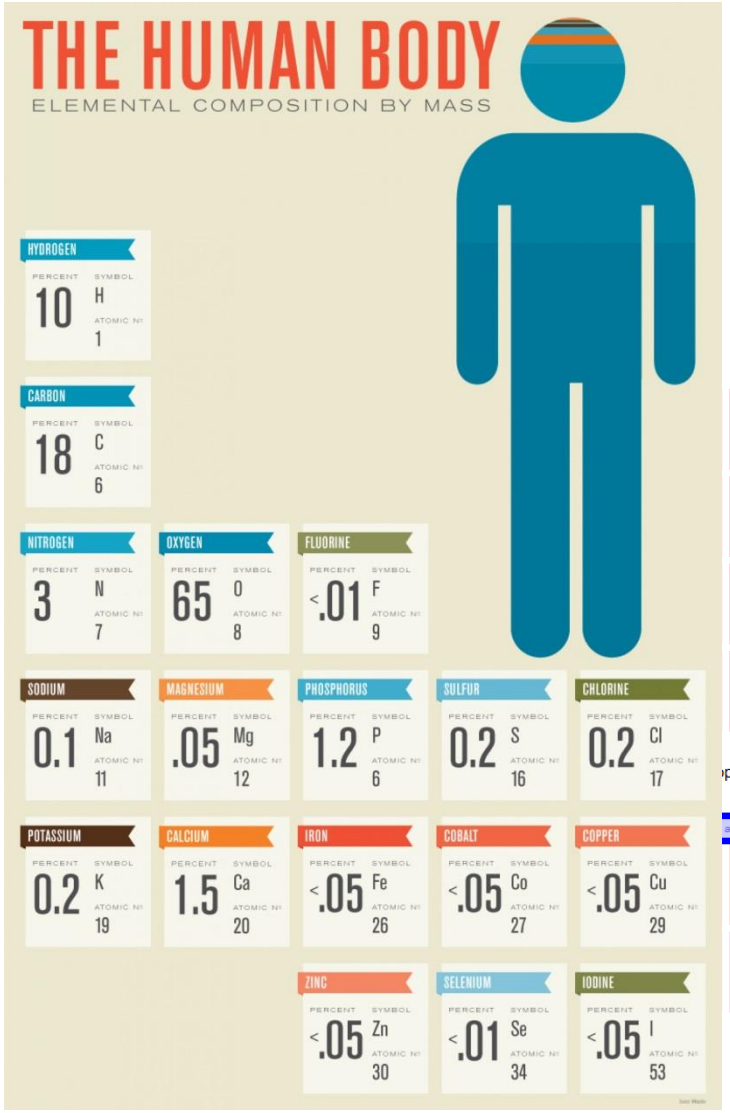
From atoms to molecules... Organelles and beyond!

Andrei Leitão

Atoms

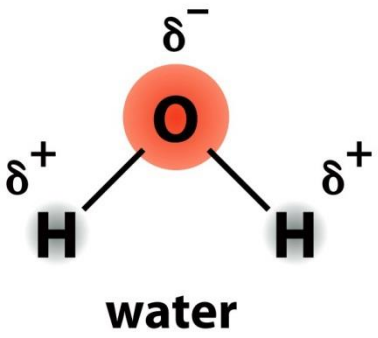
- Our primary set of atoms is composed by non metal due to the huge variety of organic molecules in our body



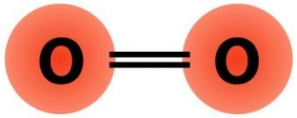
http://visual.ly/human-body-composition

Brownian motion

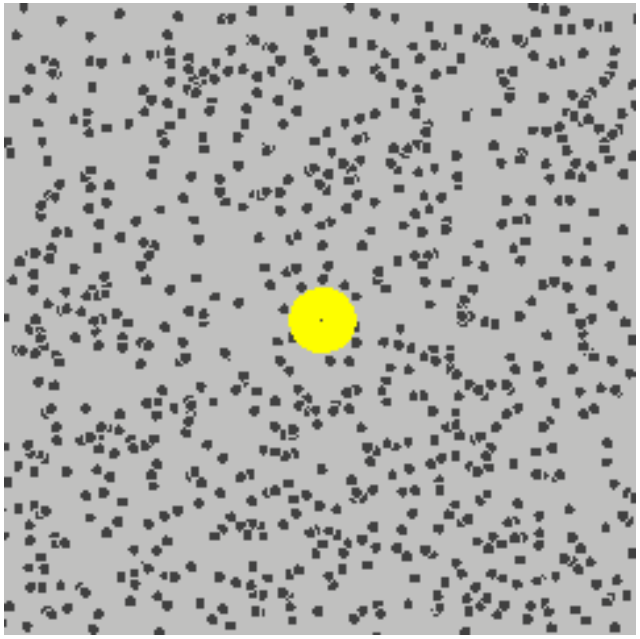
- The movement of inanimate particles (molecules/atoms) depends on the environment that they are interacting with;
- It could be, for example, charge-charge interactions, hydrogen bonding, or interactions that are not so energetic, like dispersion forces.
- Brownian movement depends on the resultant forces that are not equal to all sides of a particle that is being hit by another one.



water



oxygen

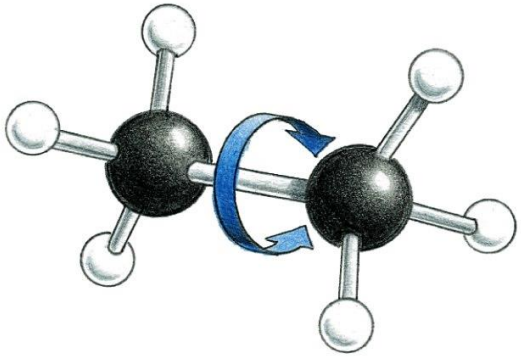


Molecular Motion in Water.mp4

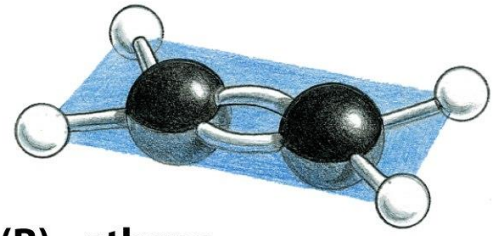
https://www.youtube.com/watch?v=t5ZFoU0S5iE

Molecules

- A compound can undergo a set of movements according to the flexibility of the chemical bonds and, of course, the atom properties;
- This is of utmost importance for the dynamic aspect of the chemicals inside a cell, including diffusion, intermolecular recognition and chemical reactions.
- The presence of double or triple bonds decrease the mobility of the compound, reducing the degrees of freedom.



(A) ethane



(B) ethene

Figure 2-9 *Molecular Biology of the Cell* (© Garland Science 2008)

http://youtube.com/watch?v=W5gimZlFY6I

Molecules

Table 2–2 The Approximate Chemical Composition of a Bacterial Cell

	PERCENT OF TOTAL CELL WEIGHT	NUMBER OF TYPES OF EACH MOLECULE
Water	70	1
Inorganic ions	1	20
Sugars and precursors	1	250
Amino acids and precursors	0.4	100
Nucleotides and precursors	0.4	100
Fatty acids and precursors	1	50
Other small molecules	0.2	~300
Macromolecules (proteins, nucleic acids, and polysaccharides)	26	~3000

Table 2-2 *Molecular Biology of the Cell* (© Garland Science 2008)

Molecules

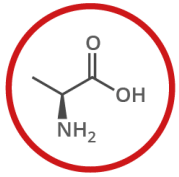
A GUIDE TO THE TWENTY COMMON AMINO ACIDS

AMINO ACIDS ARE THE BUILDING BLOCKS OF PROTEINS IN LIVING ORGANISMS. THERE ARE OVER 500 AMINO ACIDS FOUND IN NATURE - HOWEVER, THE HUMAN GENETIC CODE ONLY DIRECTLY ENCODES 20. 'ESSENTIAL' AMINO ACIDS MUST BE OBTAINED FROM THE DIET, WHILST NON-ESSENTIAL AMINO ACIDS CAN BE SYNTHESISED IN THE BODY.

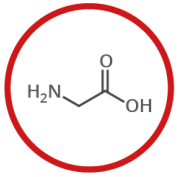
Chart Key: ALIPHATIC · AROMATIC · ACIDIC · BASIC · HYDROXYLIC · SULFUR-CONTAINING · AMIDIC · NON-ESSENTIAL · ESSENTIAL

Chemical Structure — single letter code

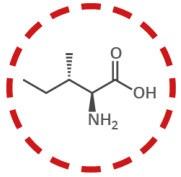
NAME A — three letter code



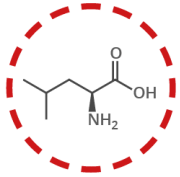
ALANINE A — *ala*



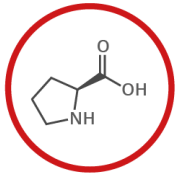
GLYCINE G — *gly*



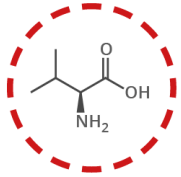
ISOLEUCINE I — *ile*



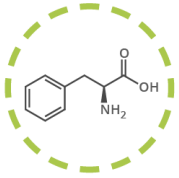
LEUCINE L — *leu*



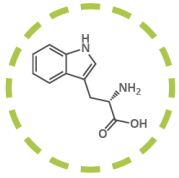
PROLINE P — *pro*



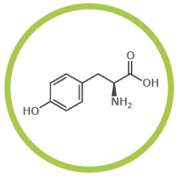
VALINE V — *val*



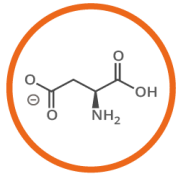
PHENYLALANINE F — *phe*



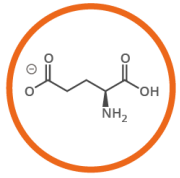
TRYPTOPHAN W — *trp*



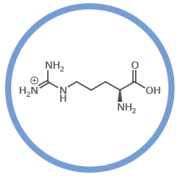
TYROSINE Y — *tyr*



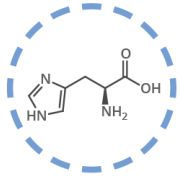
ASPARTIC ACID D — *asp*



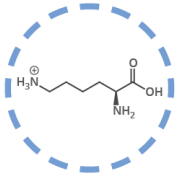
GLUTAMIC ACID E — *glu*



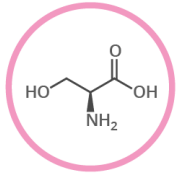
ARGININE R — *arg*



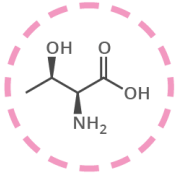
HISTIDINE H — *his*



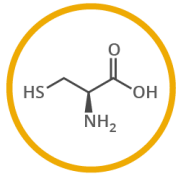
LYSINE K — *lys*



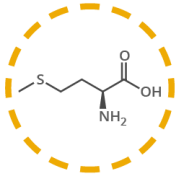
SERINE S — *ser*



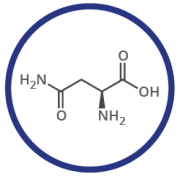
THREONINE T — *thr*



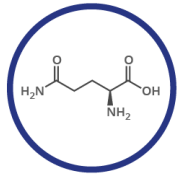
CYSTEINE C — *cys*



METHIONINE M — *met*



ASPARAGINE N — *asn*



GLUTAMINE Q — *gln*

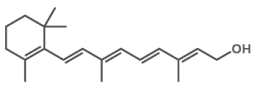
Note: This chart only shows those amino acids for which the human genetic code directly codes for. Selenocysteine is often referred to as the 21st amino acid, but is encoded in a special manner. In some cases, distinguishing between asparagine/aspartic acid and glutamine/glutamic acid is difficult. In these cases, the codes asx (B) and glx (Z) are respectively used.

Molecules

THE CHEMICAL STRUCTURES OF VITAMINS

Vitamins are the essential nutrients that our body needs in small amounts. More specifically, a compound is defined as a vitamin when it is required by an organism, but not synthesised by that organism in the required amounts (or at all). There are thirteen recognised vitamins.

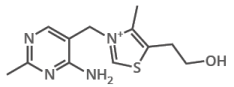
VITAMIN A



RETINOL
active form in mammalian tissues

Important for eyesight. Also strengthens immune system and keeps skin and linings of parts of the body healthy.

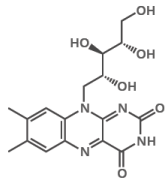
VITAMIN B1



THIAMIN
can also occur in pyrophosphate ester form

Used to keep nerves & muscle tissue healthy. Also important for processing of carbohydrates and some proteins.

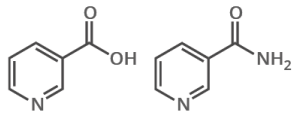
VITAMIN B2



RIBOFLAVIN
excess turns urine bright yellow

Important for body growth, red blood cell production, and keeping the eyes healthy. Also helps processing of carbohydrates.

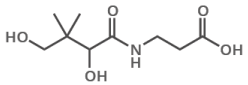
VITAMIN B3



NICOTINIC ACID **NICOTINEAMIDE**
niacin is collective name for these compounds

Helps with digestion and digestive system health. Also helps with the processing of carbohydrates.

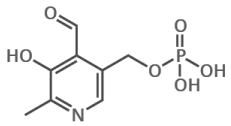
VITAMIN B5



PANTOTHENIC ACID
can also occur in pyrophosphate ester

Important for manufacturing red blood cells and maintaining a healthy digestive system. Also helps process carbohydrates.

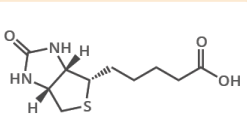
VITAMIN B6



PYRIDOXAL PHOSPHATE
active form in mammalian tissues

Helps make some brain chemicals; needed for normal brain function. Also helps make red blood cells and immune system cells.

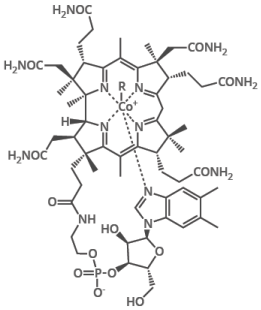
VITAMIN B7



BIOTIN
produced by intestinal bacteria

Needed for metabolism of various compounds. Often recommended for strengthening hair, but evidence is variable.

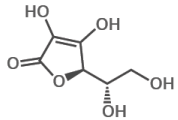
VITAMIN B12



COBALAMIN
usually contains CN as the R group

Important for the nervous system, for making red blood cells, and helps in the production of DNA and RNA.

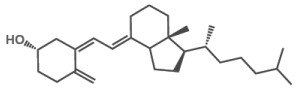
VITAMIN C



ASCORBIC ACID
deficiency can cause scurvy

Important for a healthy immune system; helps produce collagen, used to make skin and other tissues. Also helps wound healing.

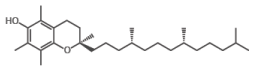
VITAMIN D



CHOLECALCIFEROL
natural form; different form used in supplements

Important for bone health and maintaining the immune system function. May also have a preventative role in cancers.

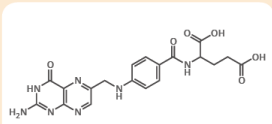
VITAMIN E



ALPHA-TOCOPHEROL
other tocopherols included in this group

An antioxidant that helps prevent damage to cells and may have a preventative role in cancer. Also helps make red blood cells.

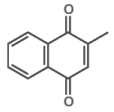
VITAMIN B9



FOLIC ACID
synthetic form; found as folate in food

Important for brain function & mental health. Aids production of DNA & RNA. Important when tissues are growing quickly.

VITAMIN K



MENADIONE
all K vitamins are menadione or derivatives

Helps blood clot properly, & plays a key role in bone health. Newborns recieve vitamin K injections to prevent bleeding.

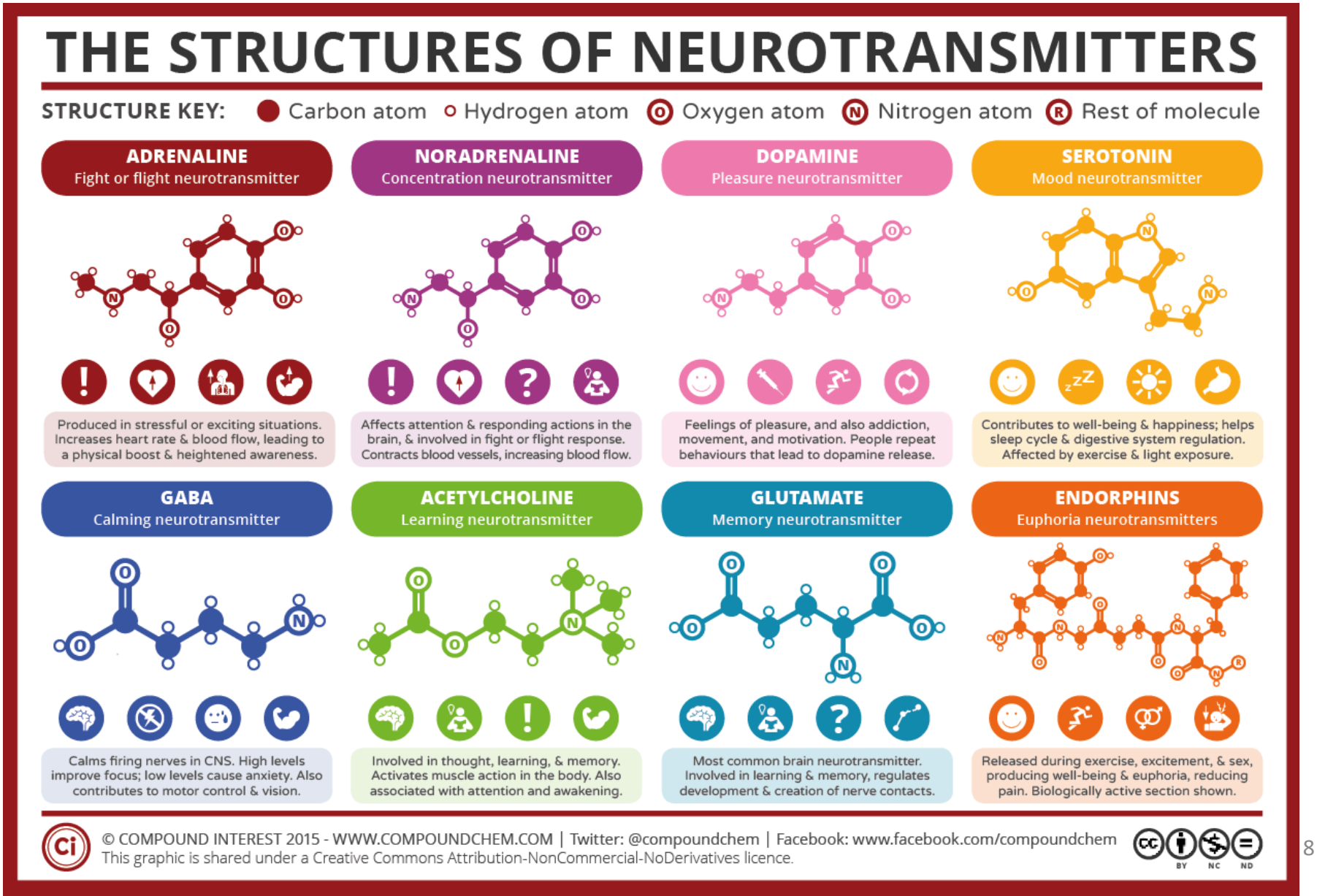
Key

Vitamins can be divided broadly into two classes.

WATER SOLUBLE VITAMINS
These vitamins are not stored in the body. As such, generally, they are required more frequently than the fat soluble vitamins.

FAT SOLUBLE VITAMINS
These vitamins are stored in the liver and fatty tissues until required. As such, they can be harmful if too much is taken in.

Molecules


THE STRUCTURES OF NEUROTRANSMITTERS
STRUCTURE KEY: Carbon atom Hydrogen atom Oxygen atom Nitrogen atom Rest of molecule
ADRENALINE
Fight or flight neurotransmitter
Produced in stressful or exciting situations. Increases heart rate & blood flow, leading to a physical boost & heightened awareness.
NORADRENALINE
Concentration neurotransmitter
Affects attention & responding actions in the brain, & involved in fight or flight response. Contracts blood vessels, increasing blood flow.
DOPAMINE
Pleasure neurotransmitter
Feelings of pleasure, and also addiction, movement, and motivation. People repeat behaviours that lead to dopamine release.
SEROTONIN
Mood neurotransmitter
Contributes to well-being & happiness; helps sleep cycle & digestive system regulation. Affected by exercise & light exposure.
GABA
Calming neurotransmitter
Calms firing nerves in CNS. High levels improve focus; low levels cause anxiety. Also contributes to motor control & vision.
ACETYLCHOLINE
Learning neurotransmitter
Involved in thought, learning, & memory. Activates muscle action in the body. Also associated with attention and awakening.
GLUTAMATE
Memory neurotransmitter
Most common brain neurotransmitter. Involved in learning & memory, regulates development & creation of nerve contacts.
ENDORPHINS
Euphoria neurotransmitters
Released during exercise, excitement, & sex, producing well-being & euphoria, reducing pain. Biologically active section shown.
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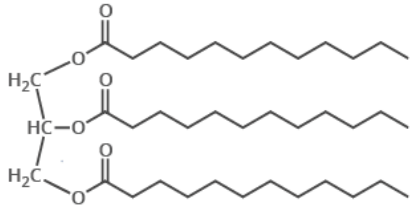
Molecules

A GUIDE TO THE DIFFERENT TYPES OF FAT

Fat is an essential part of our diets, and has a number of important roles in the body. However, there are different types, and there are health concerns surrounding eating too much of some types of fat. Here, we look at what distinguishes different types of fat, and their effects on the body.

TRIGLYCERIDES & FATTY ACIDS

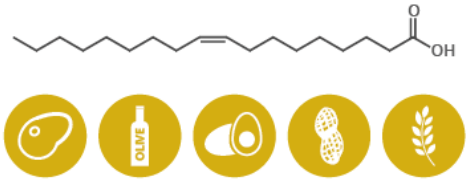


Triglycerides account for around 95% of the fat in our diet, and are formed from the combination of glycerol and three fatty acid molecules. The three fatty acids are often different, and the chemical structures of these fatty acids defines the type of fat. Cholesterol is made in the liver, and transported around the body by low density lipoproteins (LDL) and high density lipoproteins (HDL). Different fats affect LDL and HDL differently.

SATURATED FATS

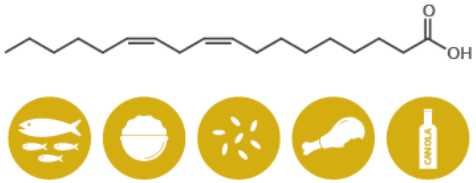
Contain no carbon-carbon double bonds. Saturated fats are solids at room temperature. They increase levels of LDL in the bloodstream. They have previously been associated with heart disease, though more recent studies and reviews have called this association into question.

MONOUNSATURATED FATS



Contain one carbon-carbon double bond. They are liquids at room temperature, but solidify when chilled. They reduce levels of LDL in the bloodstream, thereby decreasing the total cholesterol to HDL ratio (HDL helps take cholesterol back to the liver where it can be disposed of).

POLYUNSATURATED FATS

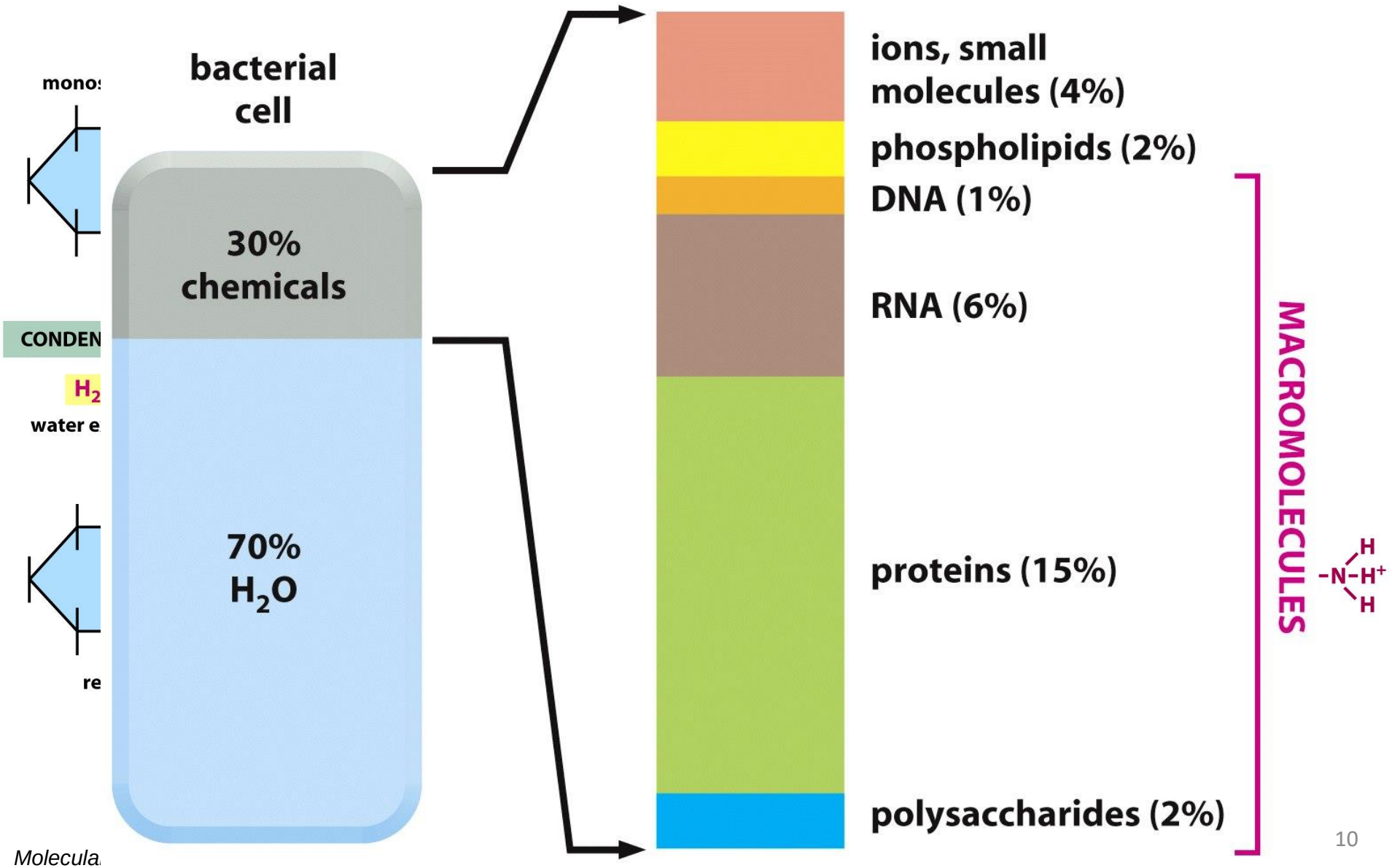


Contain two or more carbon-carbon double bonds. They are liquids at room temperature, but they start to solidify when chilled. They are split into omega-3 and omega-6 fatty acids. Polyunsaturated fats help reduce LDL levels, decreasing the total cholesterol to HDL ratio.

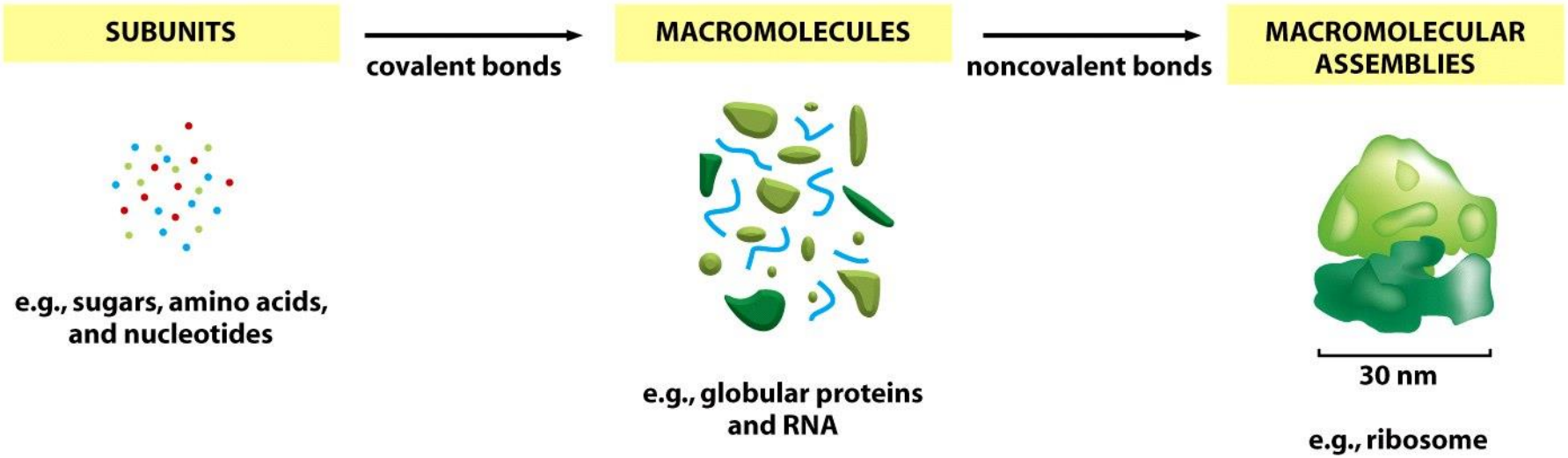
TRANS FATS

Contain carbon-carbon double bonds in a *trans* rather than *cis* configuration. Formed artificially, via a process called hydrogenation; also found naturally in small amounts in meat and dairy products. They raise LDL, and are associated with heart disease. Many countries are phasing them out.

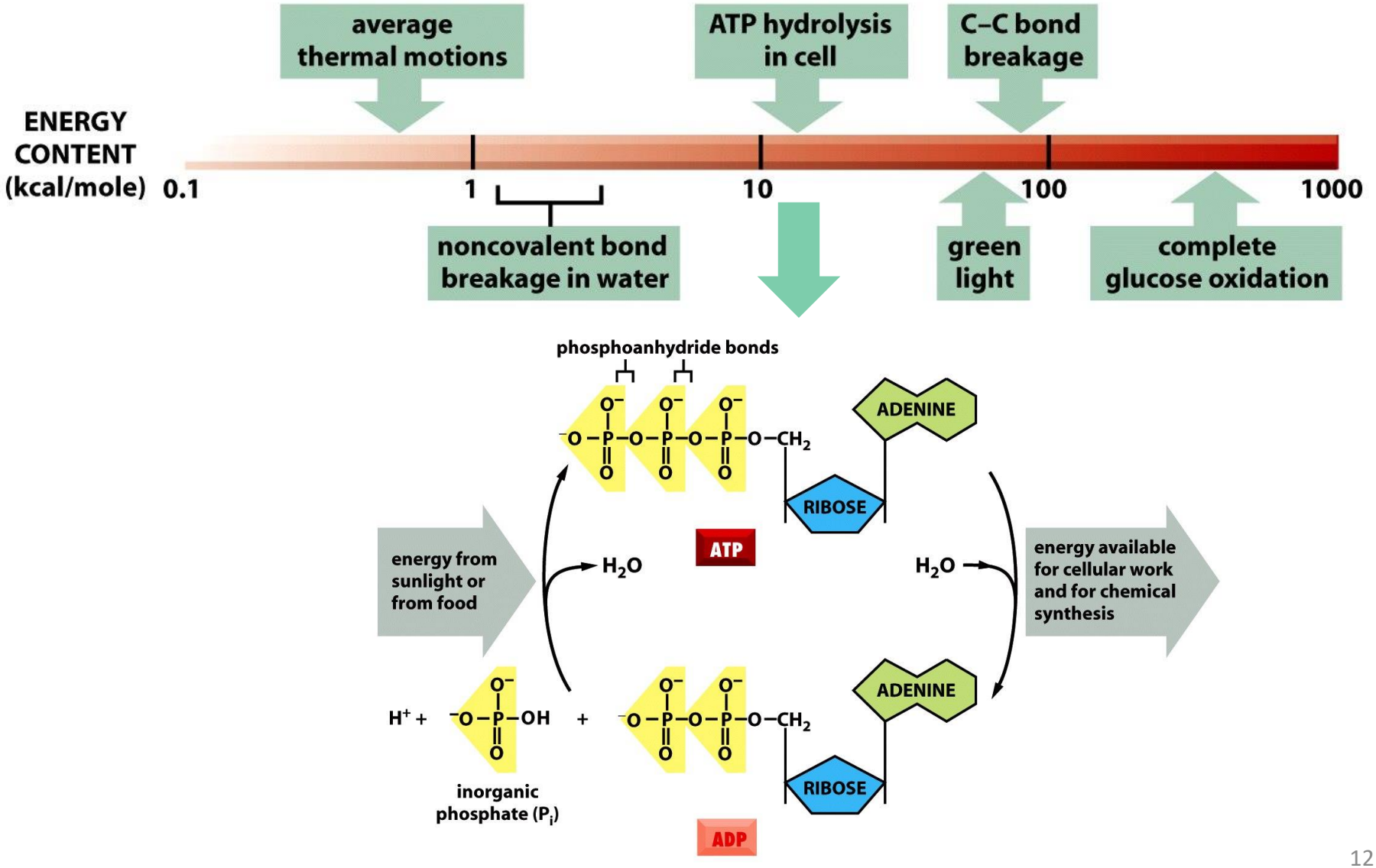
Macromolecules



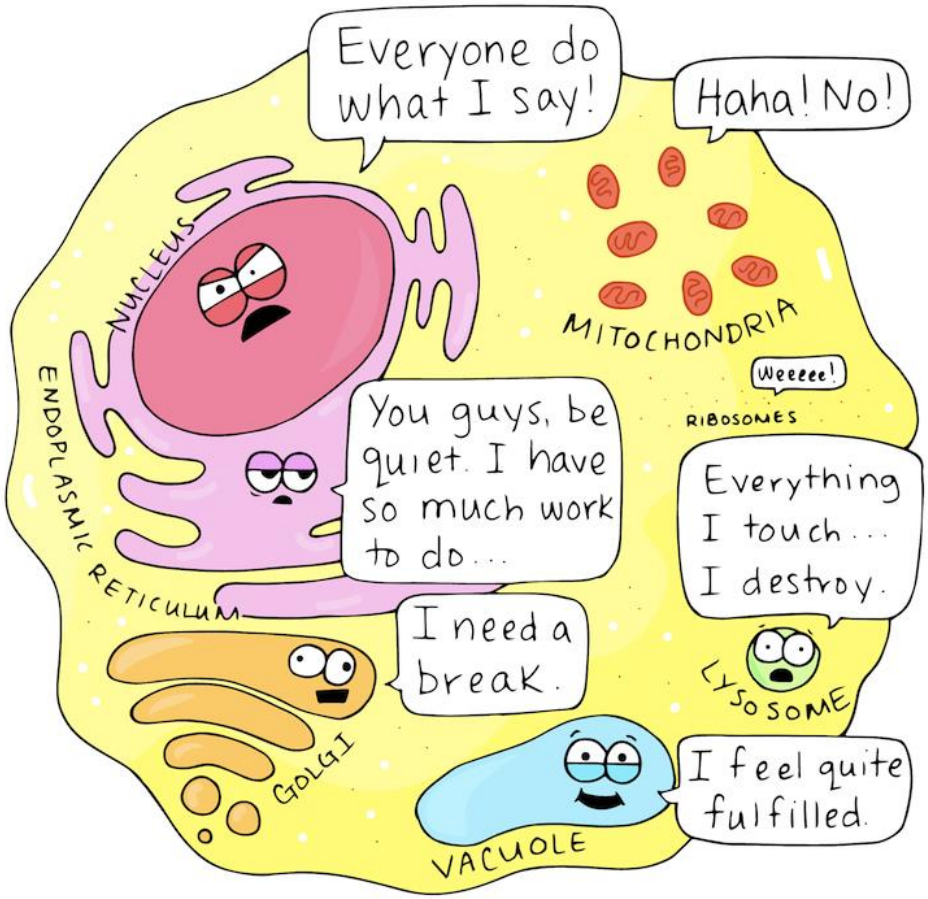
Macromolecules



Energy scale



Organelles

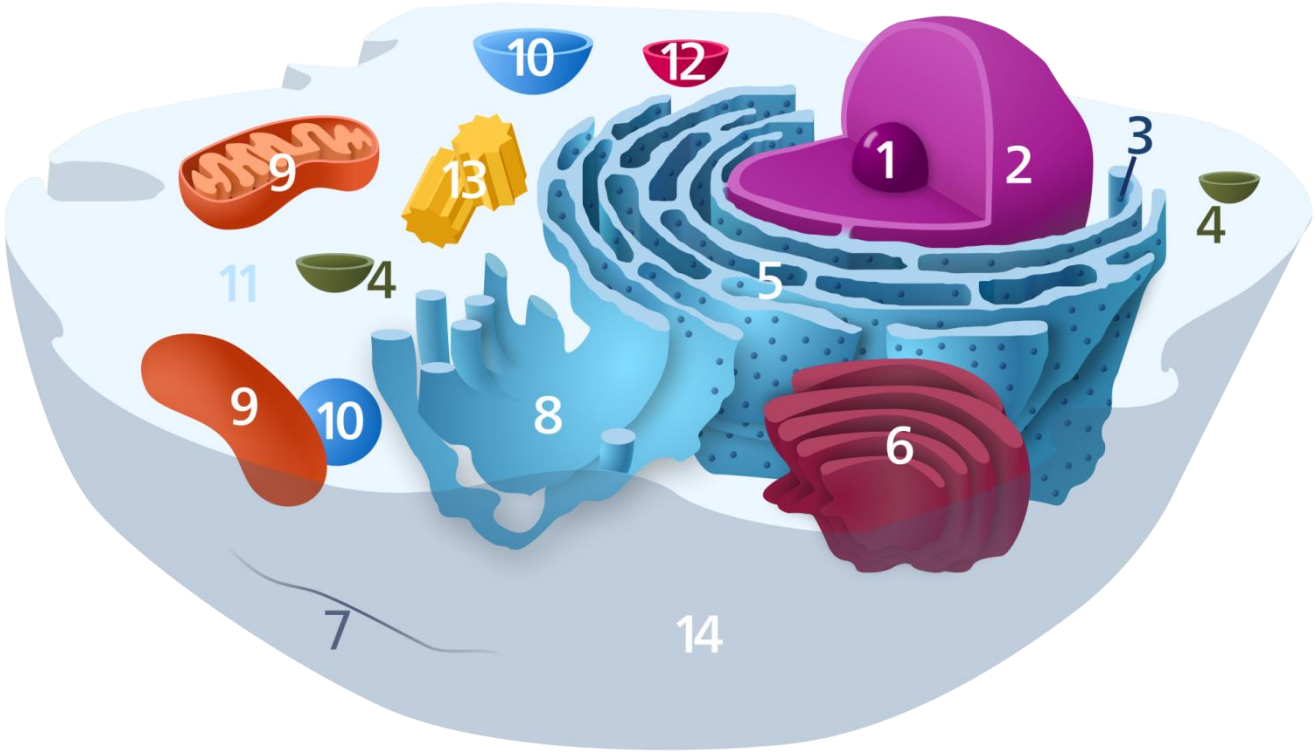


http://www.beatricebiologist.com/2014/03/if-organelles-could-talk/

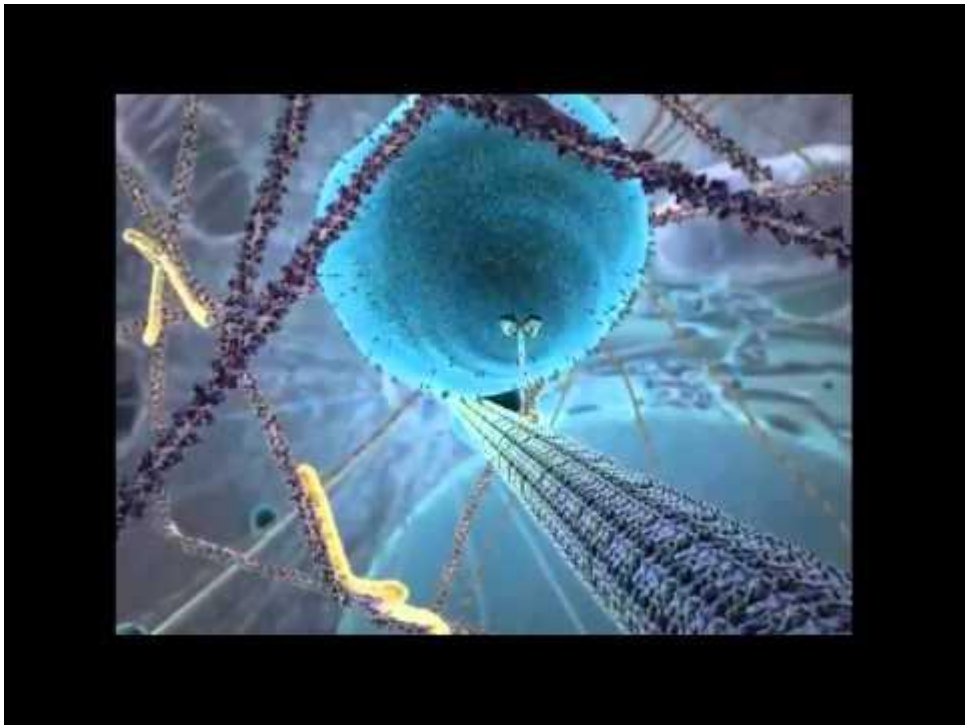
Whole cells

Components of a typical animal cell:

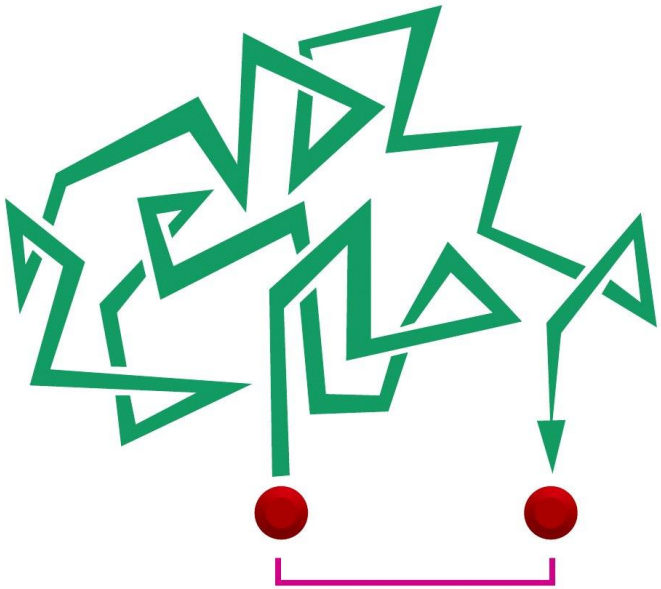
1. Nucleolus
2. Nucleus
3. Ribosome (little dots)
4. Vesicle
5. Rough endoplasmic reticulum
6. Golgi apparatus
7. Cytoskeleton
8. Smooth endoplasmic reticulum
9. Mitochondrion
10. Vacuole
11. Cytosol
12. Lysosome
13. Centrosome
14. Cell membrane



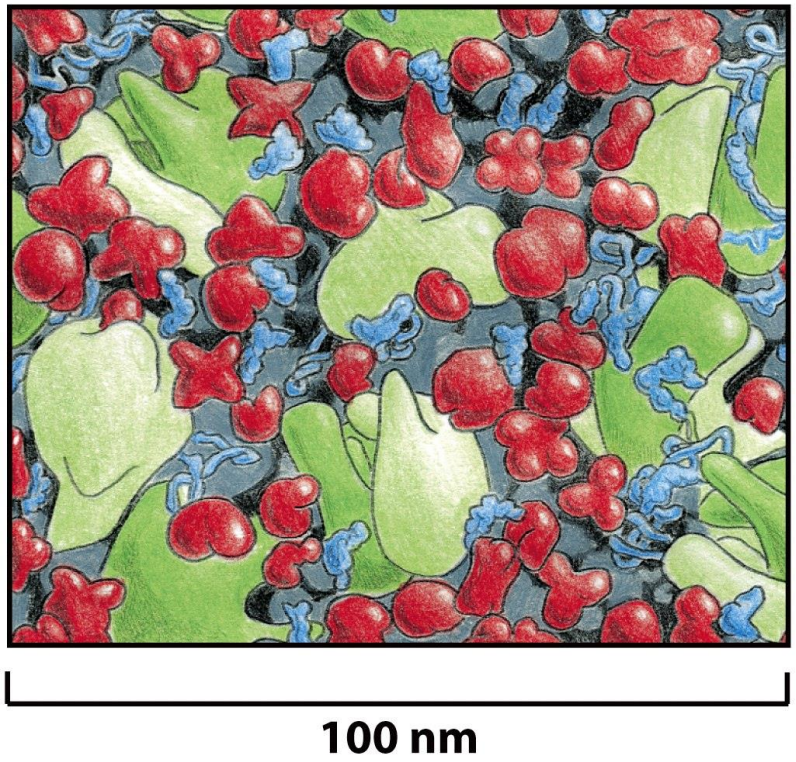
Whole cells



Cells are crowded places...

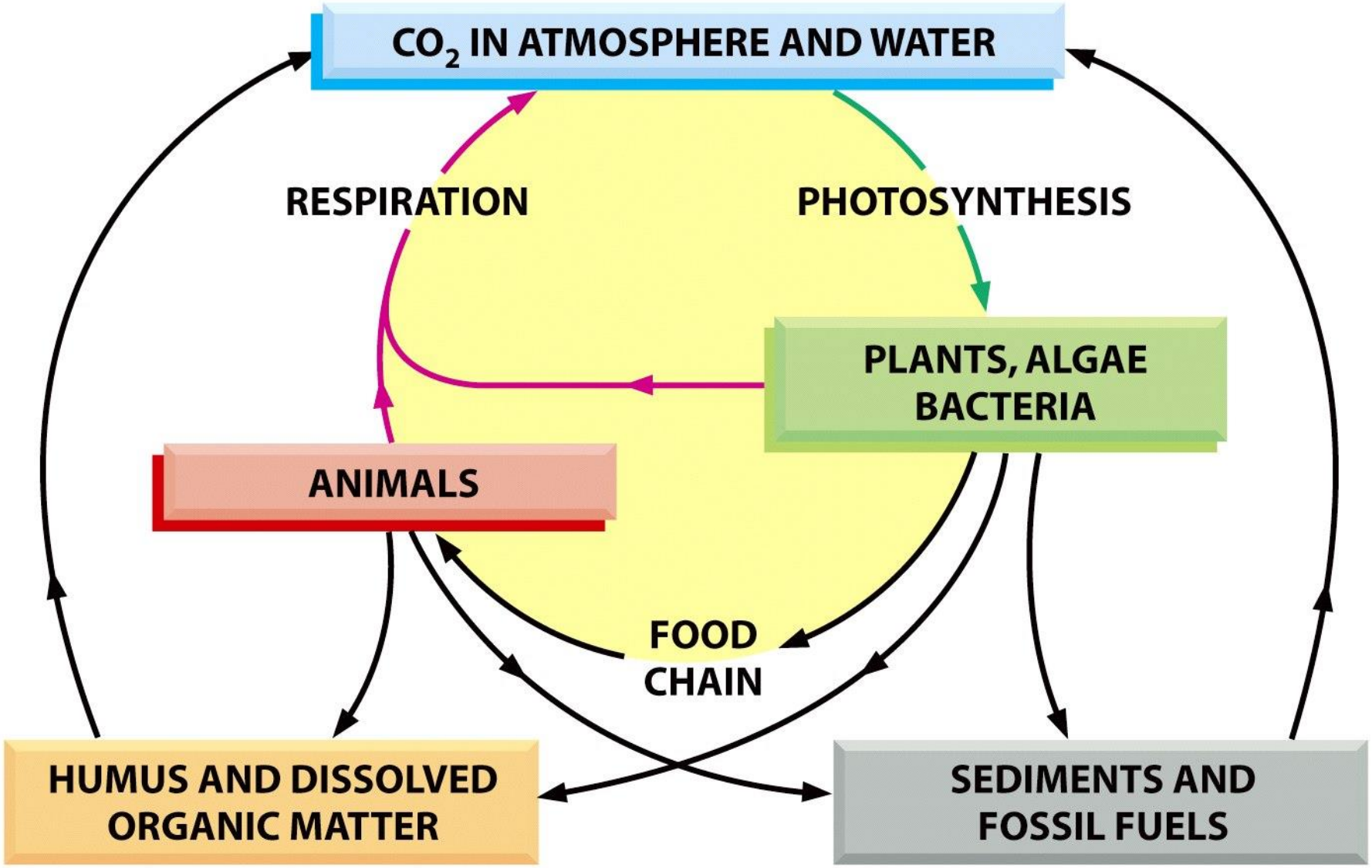


Diffusion in a liquid:
1 µm/s
(organic molecule)



Diffusion in a cell:
1-2 µm/s
(organic molecule)

Reactions inside cells



Heat flow of cells

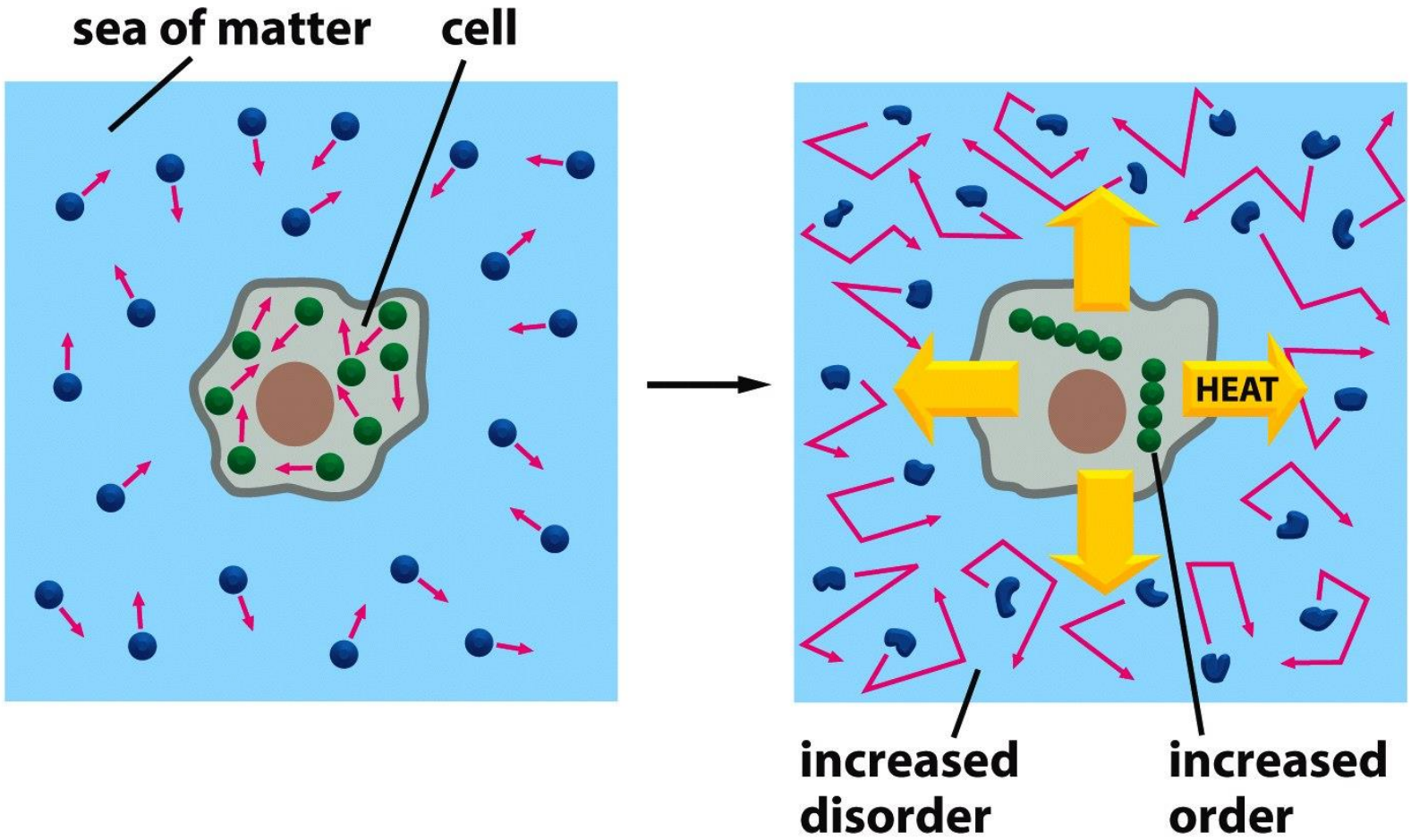
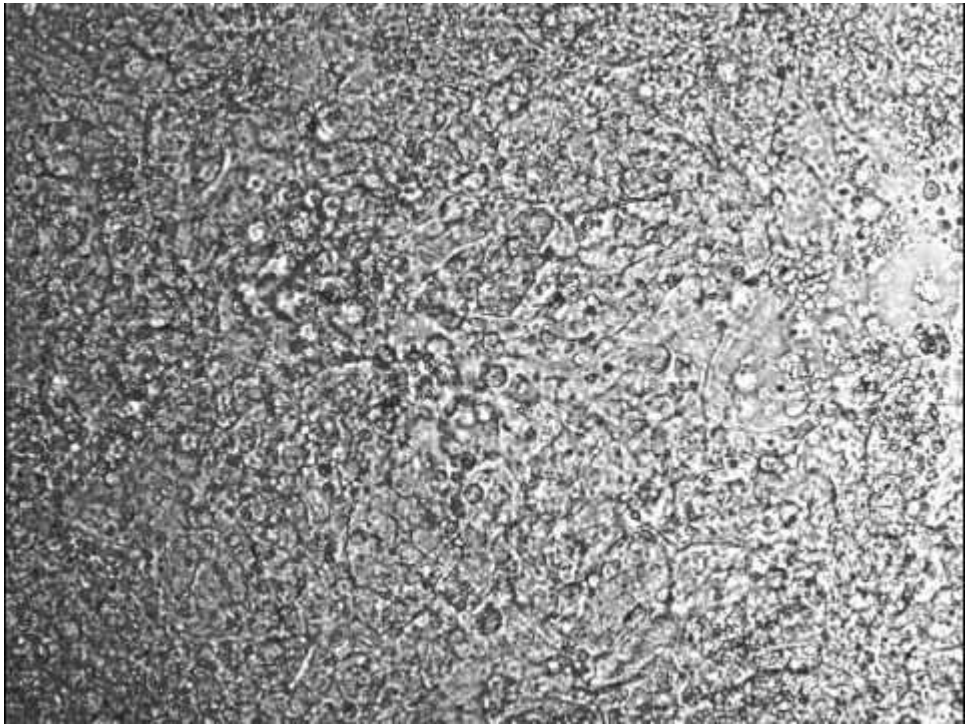


Figure 2-38 *Molecular Biology of the Cell* (© Garland Science 2008)

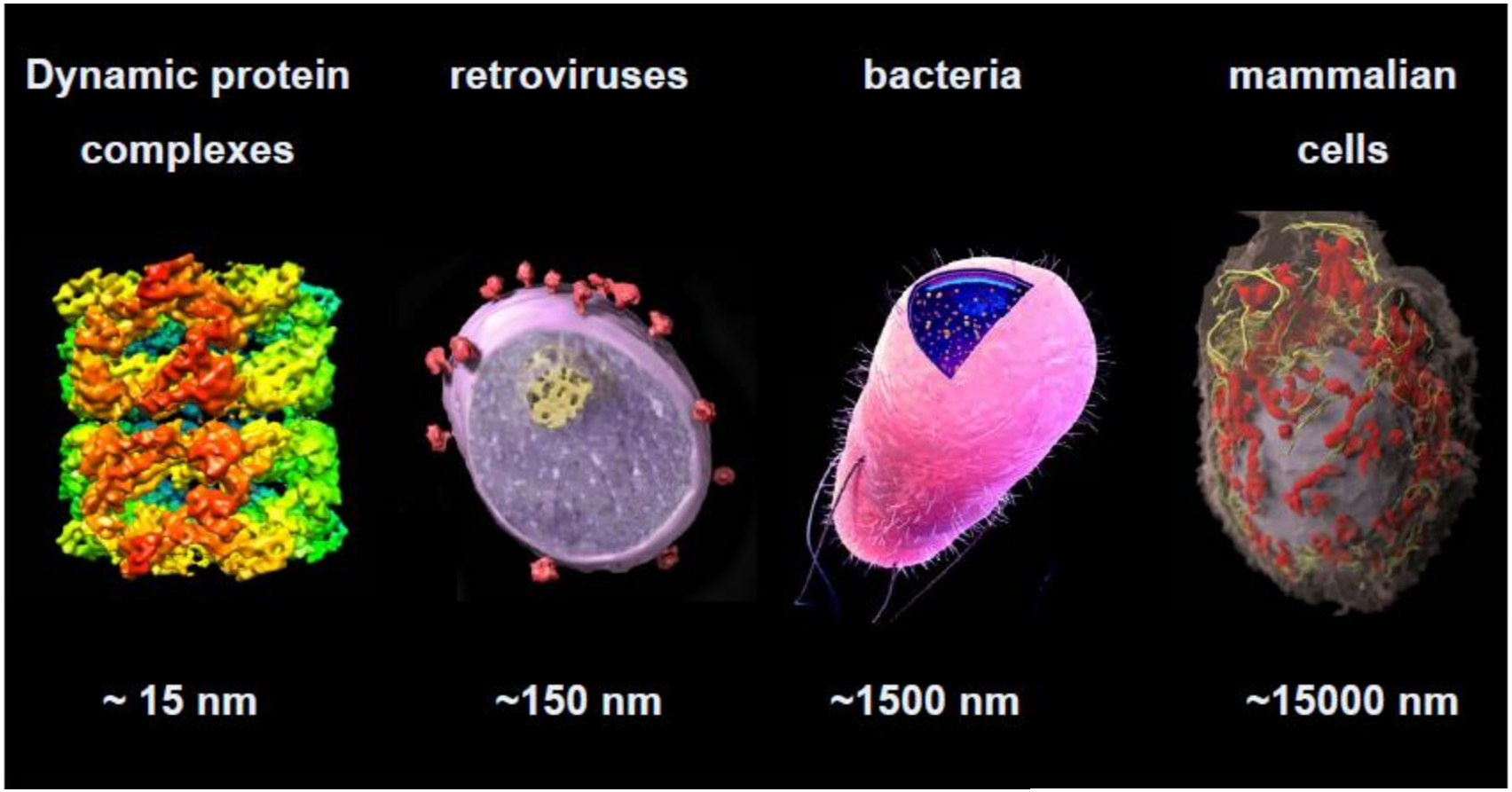
In vitro cell function

Cardiomyocytes from human induced pluripotent stem cells



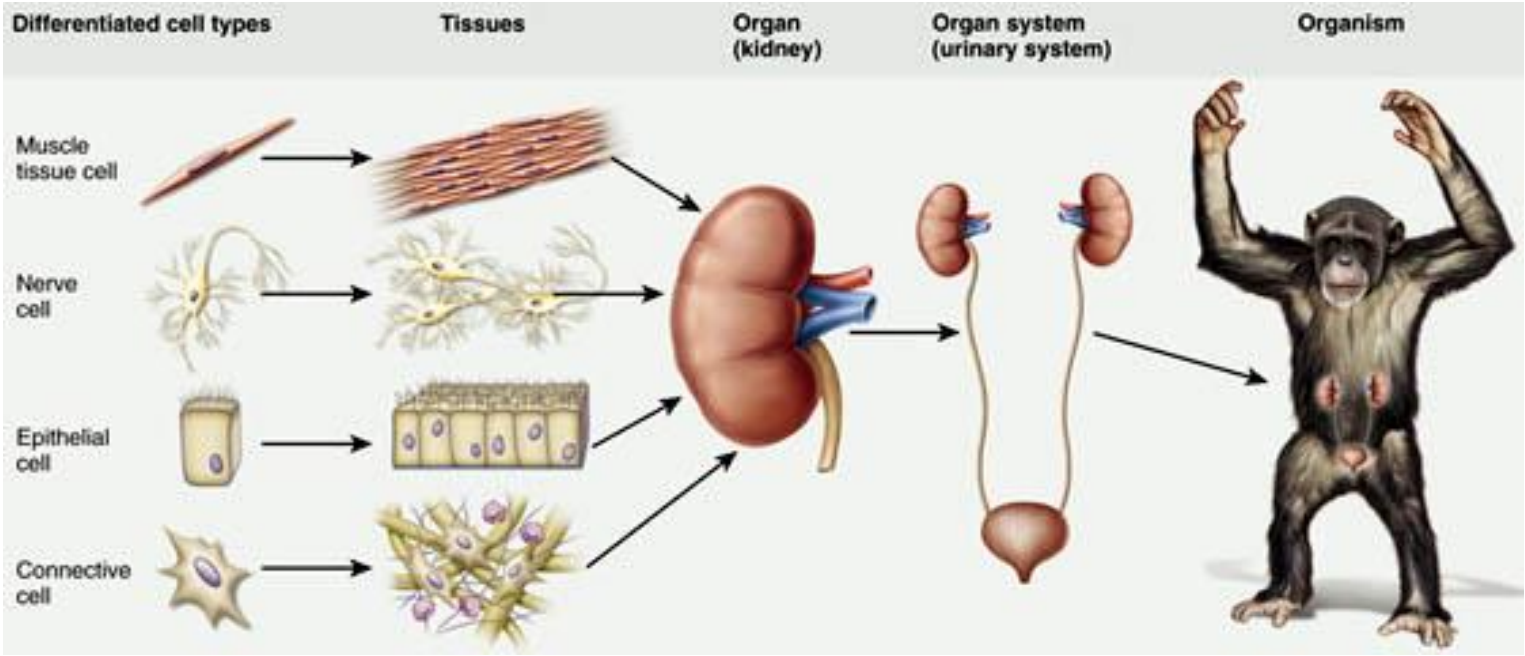
http://youtube.com/watch?v=PFeAhLJ1vL0

From proteins to cells



Sriram Subramaniam, Ph.D.
National Cancer Institute, NIH
Bethesda, MD

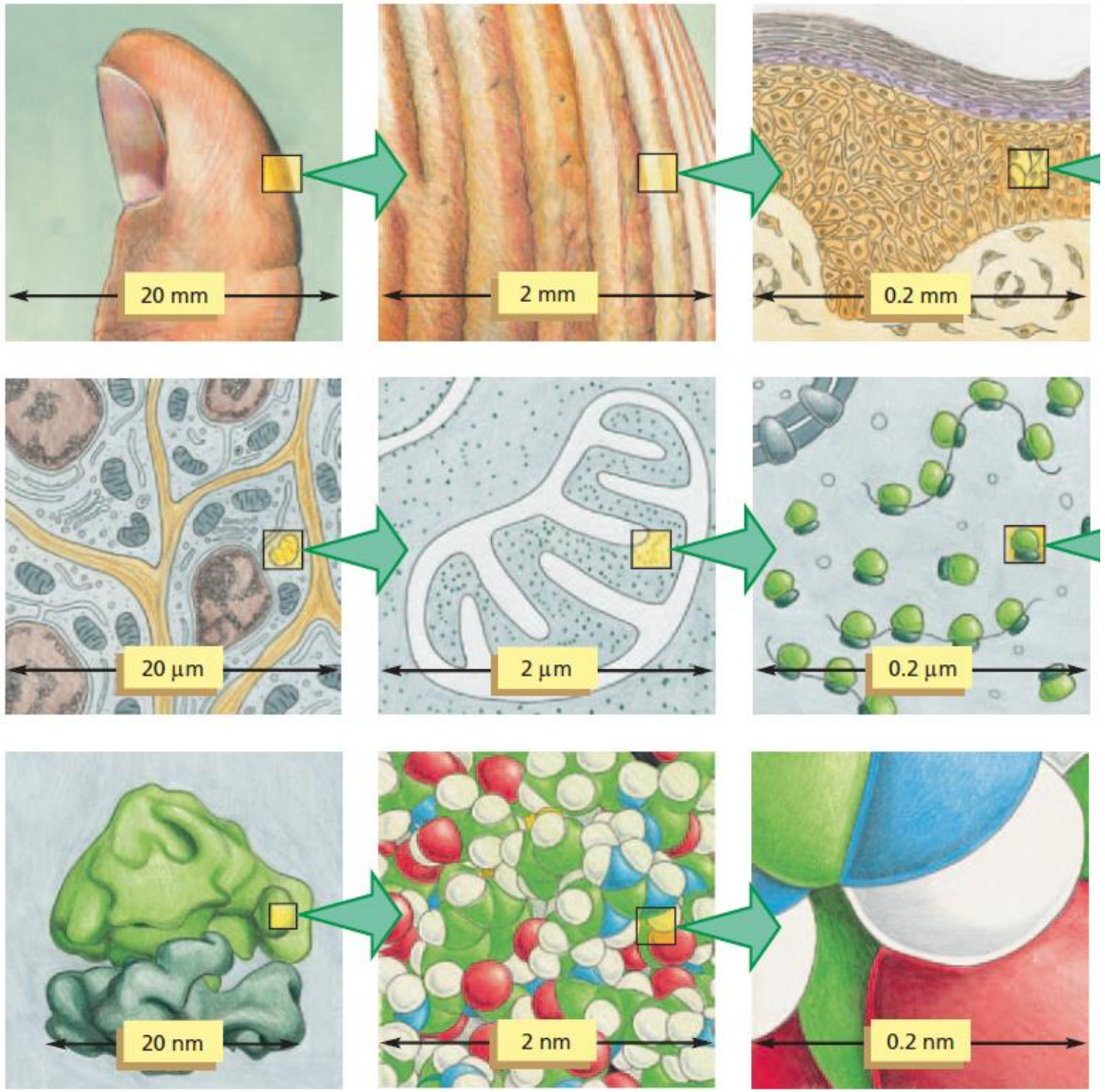
Tissues/Organs

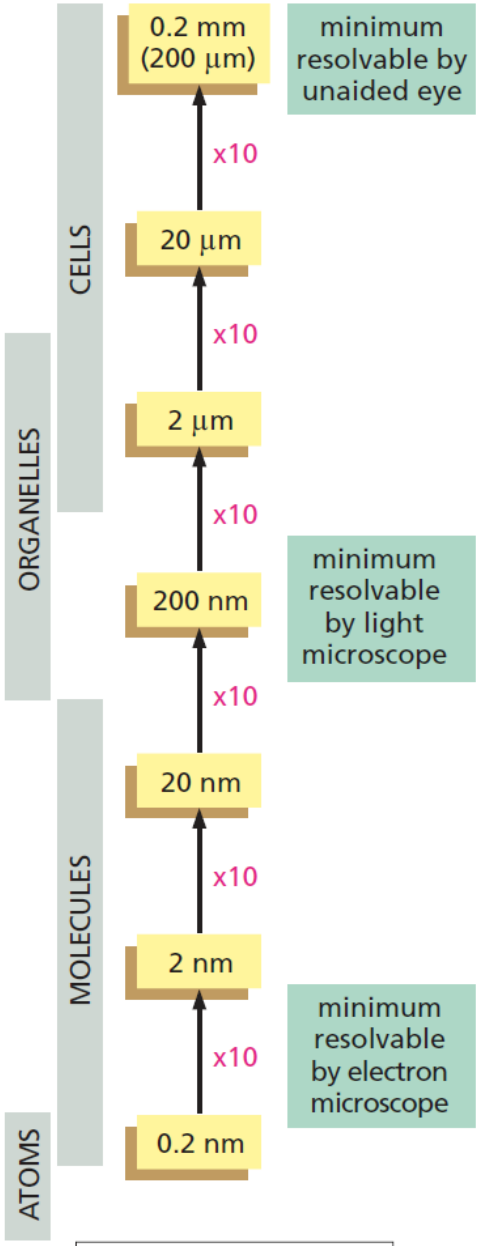


http://bio8.wikispaces.com/file/view/tissues-organs.jpg/312401076/615x263/tissues-organs.jpg

Multicelullar organisms

Size and detection





$1\ m = 10^3\ mm = 10^6\ \mu m = 10^9\ nm$

Alberts – Essential Cell Biology 4th Edition - Fig. 1.8