Biology

/ Lecture 1 /

-Visualization technique

- Cell and tissue definiton

Important notes:

Biology LECTURES – will be each week at 16:20. Only 28-9-2021 is state hliday (however the presentation „Mebranes and organelss“ will be sent to your email or IS.MUNI profile)

Biology LAB EXCERSISE – will be each second week, the protocols will e avaluated and you must have credits from each protocol. If somebody is ill in some week, the extra excersise will be prepared in December.

Today presentation (for day 21-9-2021) is focused to BASIC DEFINTION OF CELL BIOLOGY and BASIC OVERVIEW of Visualization technique in Medicine

What is visibility?

And what visibility is needed in medicine? :

Analogy:

If we fight against “forest disaster“, sometimes we need technique for macroscopic visibility, sometimes for detail (microscopic) visibility

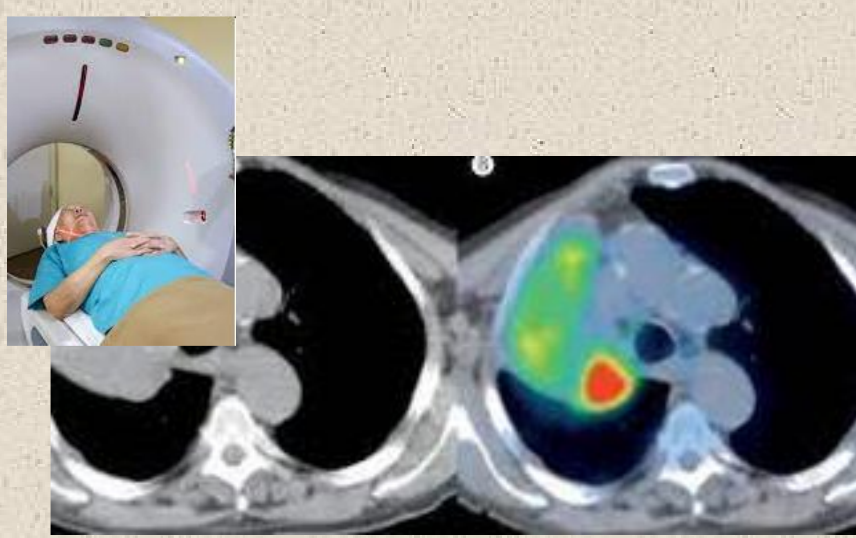
Good objective visualisation = key step for good fighting

What is visibility?

And what visibility is needed in medicine? :

Analogy:

If we fight against “medical disaster“, sometimes we need technique for macroscopic visibility, sometimes for detail (microscopic) visibility



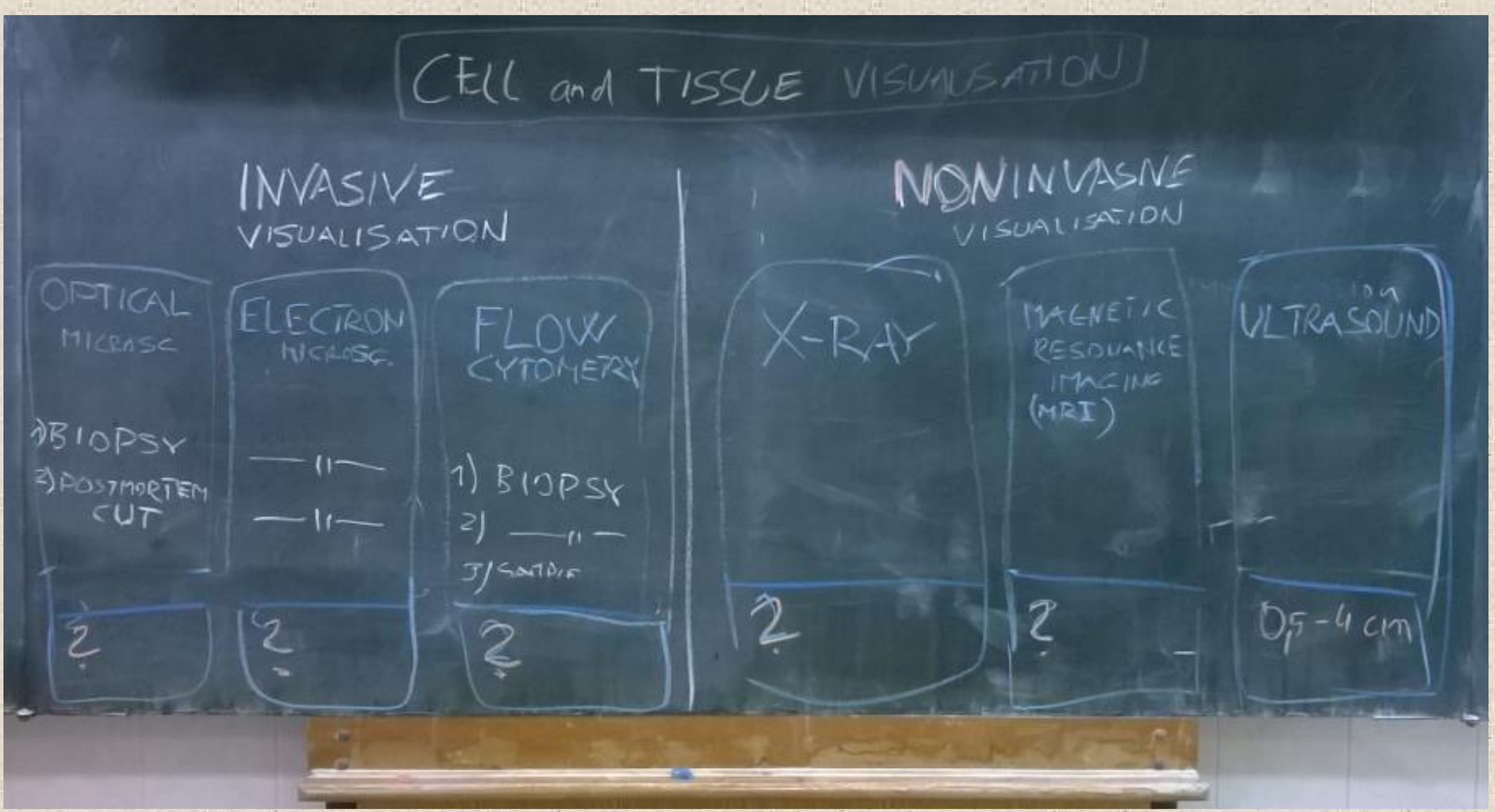
Good objective visualisation = key step for good fighting

The human and animal body is not o „bag of sugar water with smal soul inside", however exact description of body and tissue structure had to wait to first „science-man" ***Aristotle*** *(384–322 BC). Before Aristotle, many Greek philosophers had speculated copartments of body and live organims but their theorizing was unsupported by empirical investigation.*

TABLE 1–1 HISTORICAL LANDMARKS IN DETERMINING CELL STRUCTURE

1665	Hooke uses a primitive microscope to describe small chambers in sections of cork that he calls "cells."
1674	Leeuwenhoek reports his discovery of protozoa. Nine years later, he sees bacteria for the first time.
1833	Brown publishes his microscopic observations of orchids, clearly describing the cell nucleus.
1839	Schleiden and Schwann propose the cell theory, stating that the nucleated cell is the universal building block of plant and animal tissues.
1857	Kölliker describes mitochondria in muscle cells.
1879	Flemming describes with great clarity chromosome behavior during mitosis in animal cells.
1881	Cajal and other histologists develop staining methods that reveal the structure of nerve cells and the organization of neural tissue.
1898	Golgi first sees and describes the Golgi apparatus by staining cells with silver nitrate.
1902	Boveri links chromosomes and heredity by observing chromosome behavior during sexual reproduction.
1952	Palade, Porter, and Sjöstrand develop methods of electron microscopy that enable many intracellular structures to be seen for the first time. In one of the first applications of these techniques, Huxley shows that muscle contains arrays of protein filaments—the first evidence of a cytoskeleton.
1957	Robertson describes the bilayer structure of the cell membrane, seen for the first time in the electron microscope.
1960	Kendrew describes the first detailed protein structure (sperm whale myoglobin) to a resolution of 0.2 nm using X-ray crystallography. Perutz proposes a lower-resolution structure for hemoglobin.
1965	Christian de Duve and his colleagues use a cell-fractionation technique to separate peroxisomes, mitochondria, and lysosomes from a preparation of rat liver.
1968	Petran and collaborators make the first confocal microscope.
1970	Frye and Edidin use fluorescent antibodies to show that plasma membrane molecules can diffuse in the plane of the membrane, indicating that cell membranes are fluid.
1974	Lazarides and Weber use fluorescent antibodies to stain the cytoskeleton.
1994	Chalfie and collaborators introduce green fluorescent protein (GFP) as a marker to follow the behavior of proteins in living cells.

We can divide the technique via the invasivity or the non-invasivity:



Homework: 1) ad resolution to your exercisebook (information are on folloving pages)
2) describe basic components of optical microscopy.

Each technique have some advantages and disadvantages:

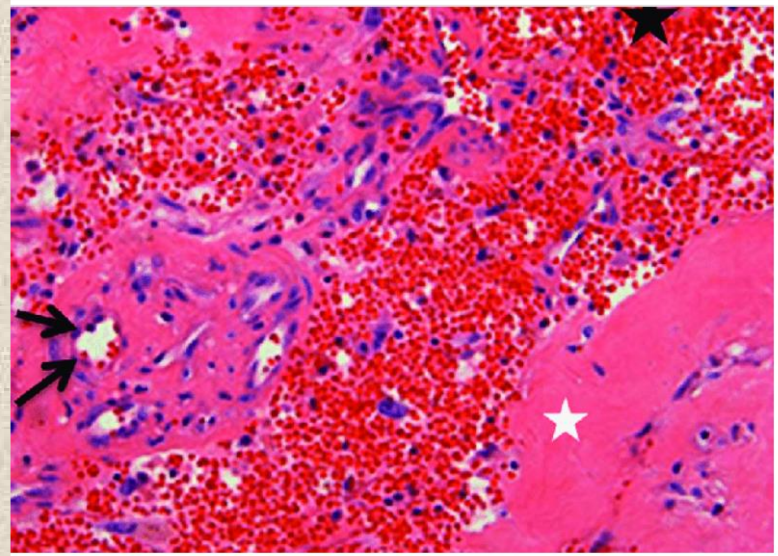
For example Hematoma of leg

Hematoma by microscopy (focused inside the muscle)

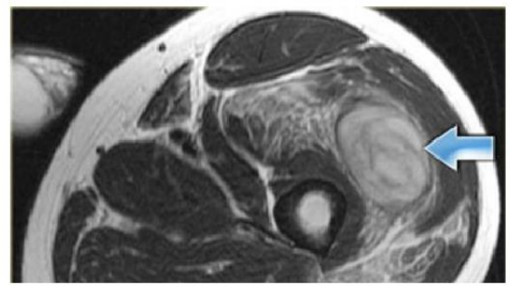
Hematoma by X-RAY CT

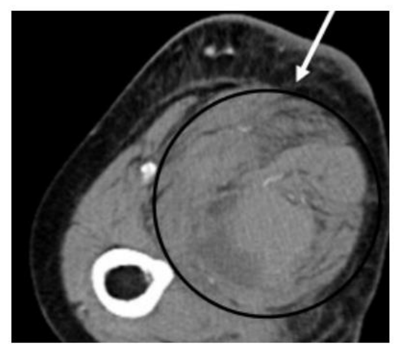
Hematoma by NMRi

Hematoma by Ultra Sound



Microscopic view of organized hematoma showing angiogenesis (arrows), fibrosis (white asterisk) and extravasated red blood cells (black asterisk) (hematoxylin and eosin staining, original magnification, × 400).

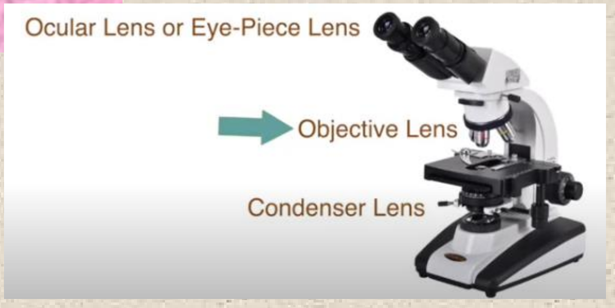




For medical and pharmacologica curative strategy we need mostly combination of all these technique.

Ad. Optical and Electron MICROSCOPY

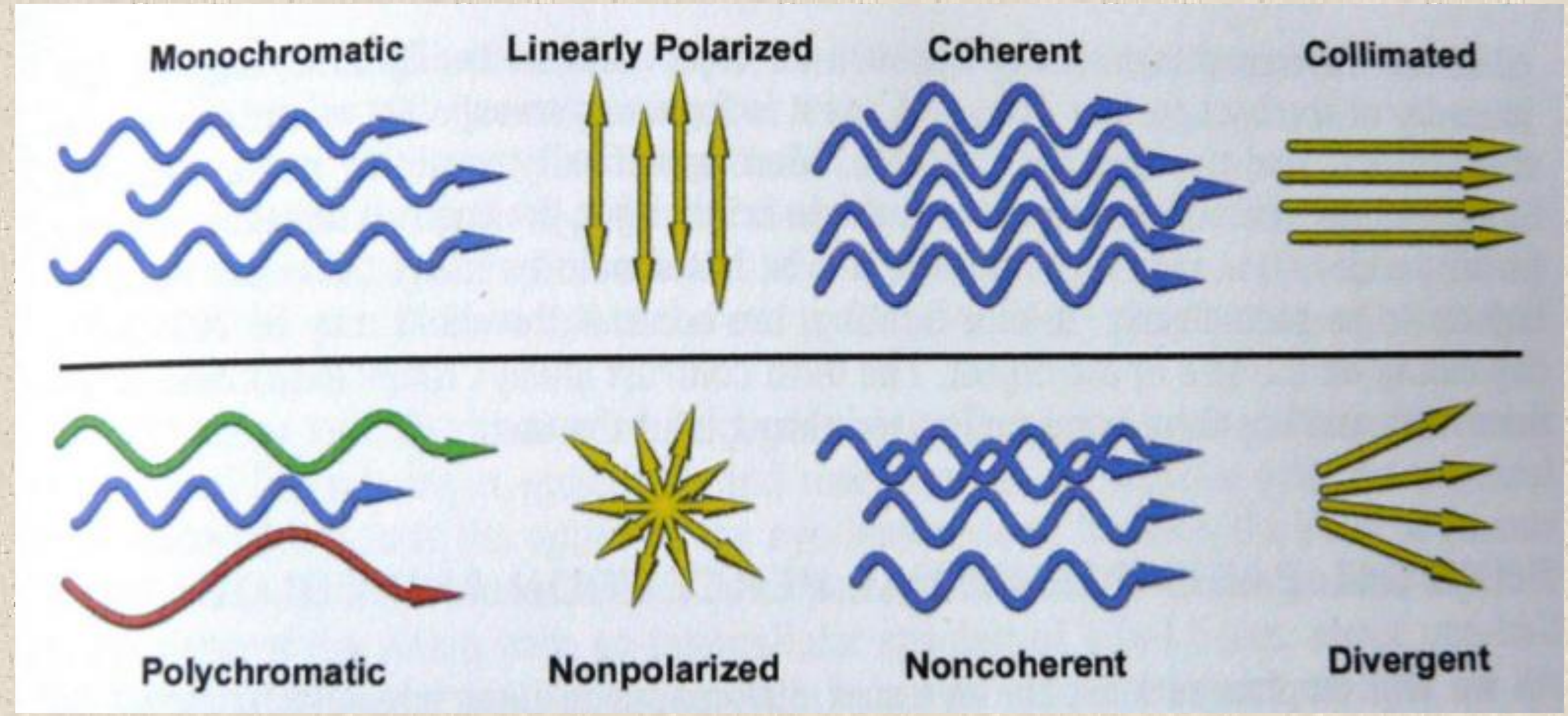
Looking to the tissue structure by microscopy is the similar problem like “visualisation“ of paving stone by blind man



We need identify where is the border of paving stone or cells (or another biological entities)

Basic tools for visualisation = fotons (light) and electron (particle)

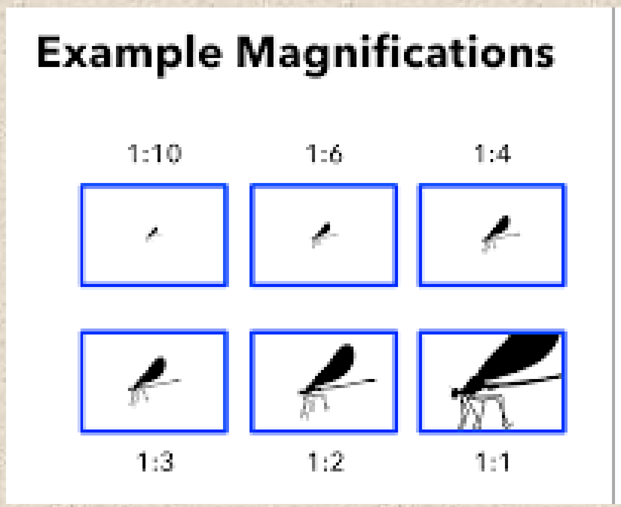
Basic definition for diferent form of light, which are important for scinceman in microscopy:

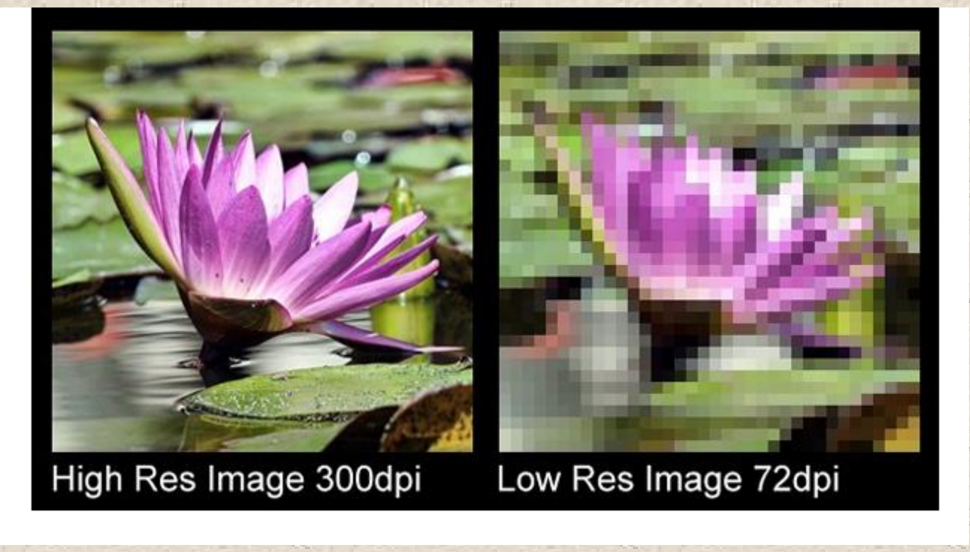


Two important aspect of microscopy visualisation:

MAGNIFICATION and RESOLUTION

May be you know the theory from high school. Who not. There is very clear definiton: https://www.youtube.com/watch?v=CVusz4wHaic



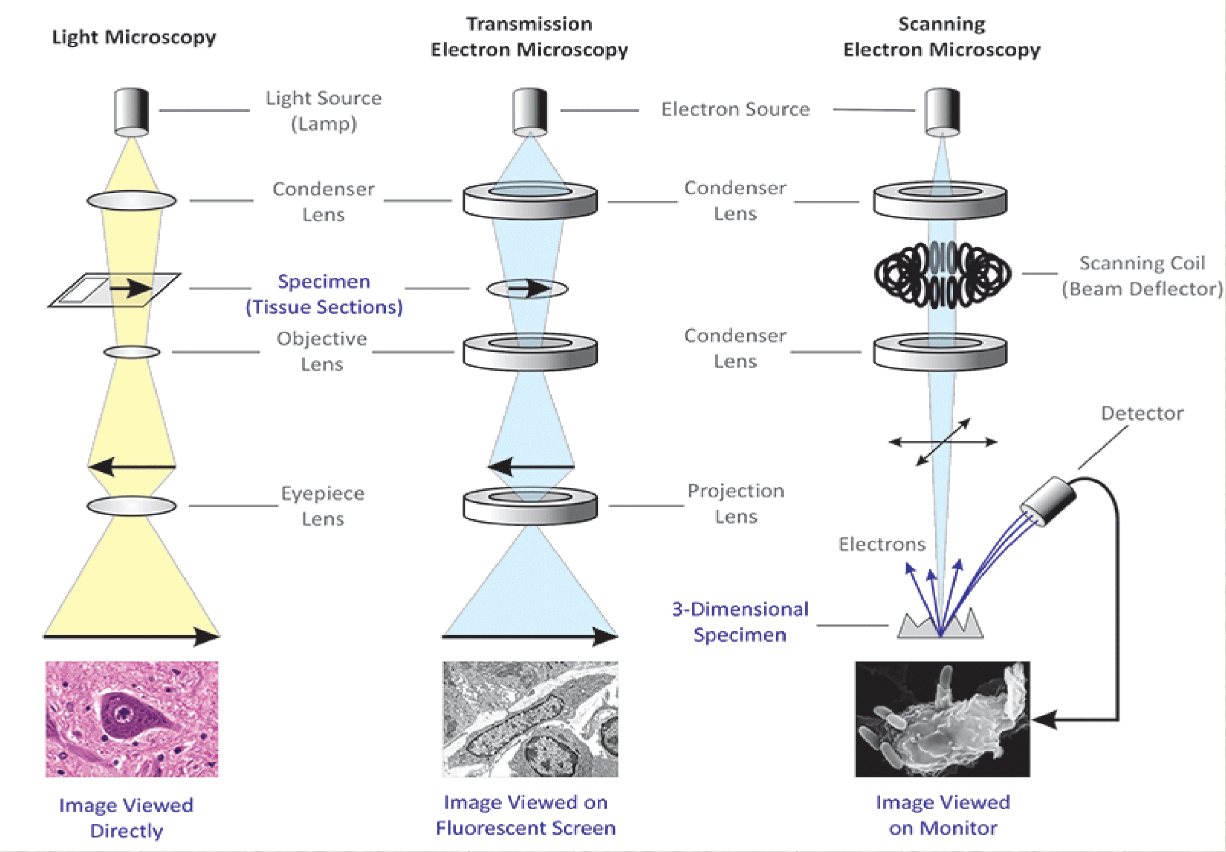


High resolution = ther is visibility of two leaflet

Low resolution = there is not, two leaflet seems like one violet flag

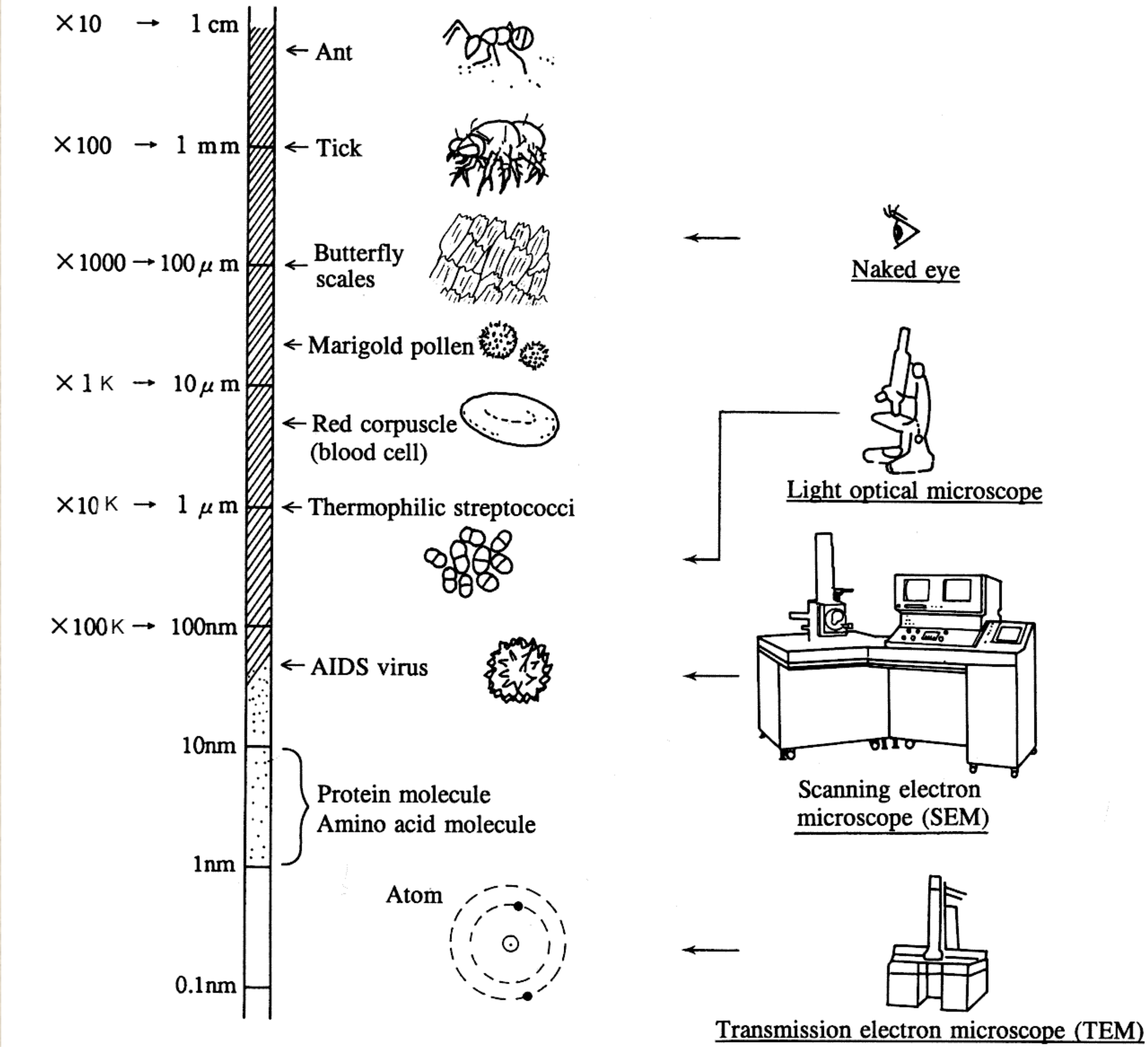
Basic construction of microscopies:

OPTICAL and ELECTRON



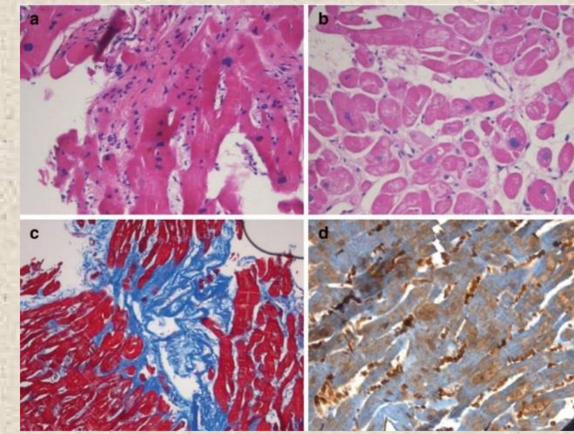
	Optical	TEM	SEM
Resolution	200nm	0.1nm	0.5nm
Magnific.	~×2000	×50~×1,500,000	×10~×1,000,000

MAGNIFICATION Object RESOLUTION

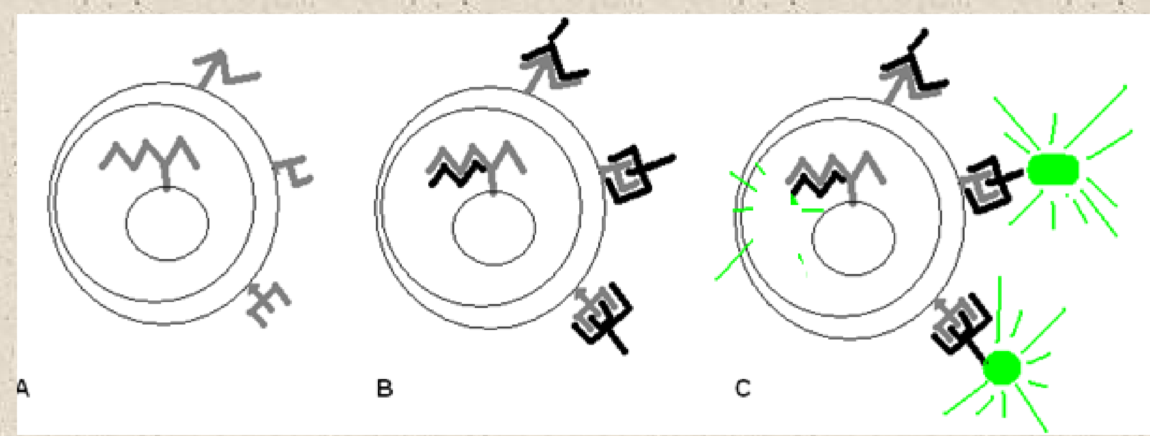


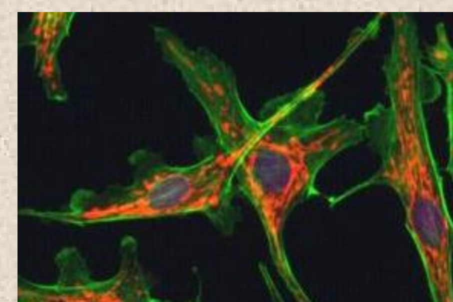
How we can upgrade some structure of cells for better contrast ?
Use staining.

1) Traditional Histochemistry Staining (used chemicals which have specific afinity to some part of cell or tissue, for example DNA, collagen etc.

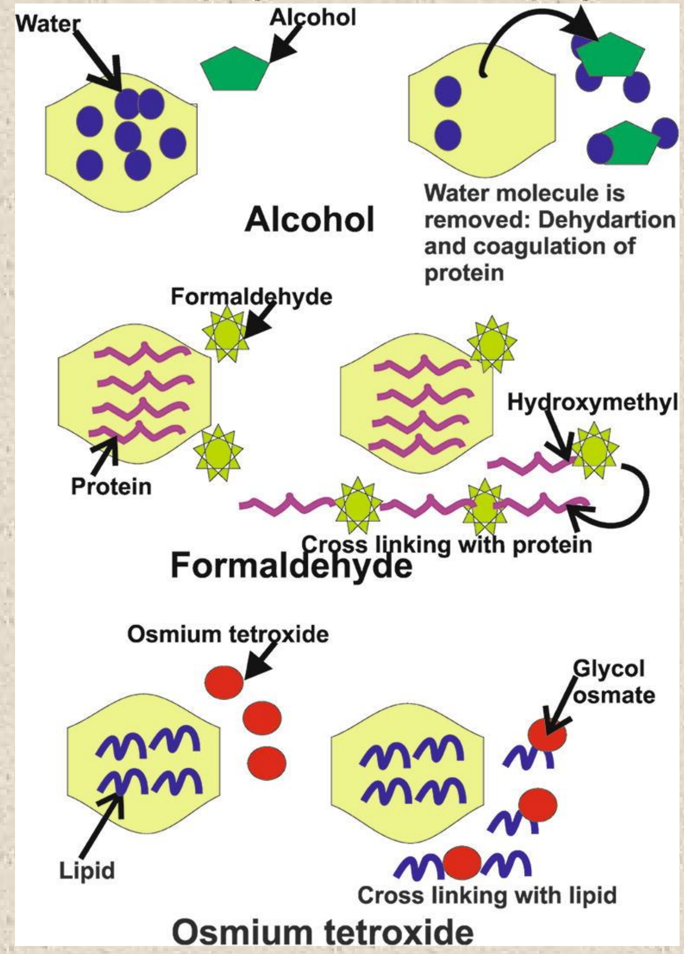


2) **Anitibody staining** (best way: rimary and secondar antibody which makes some structure fluorescent)

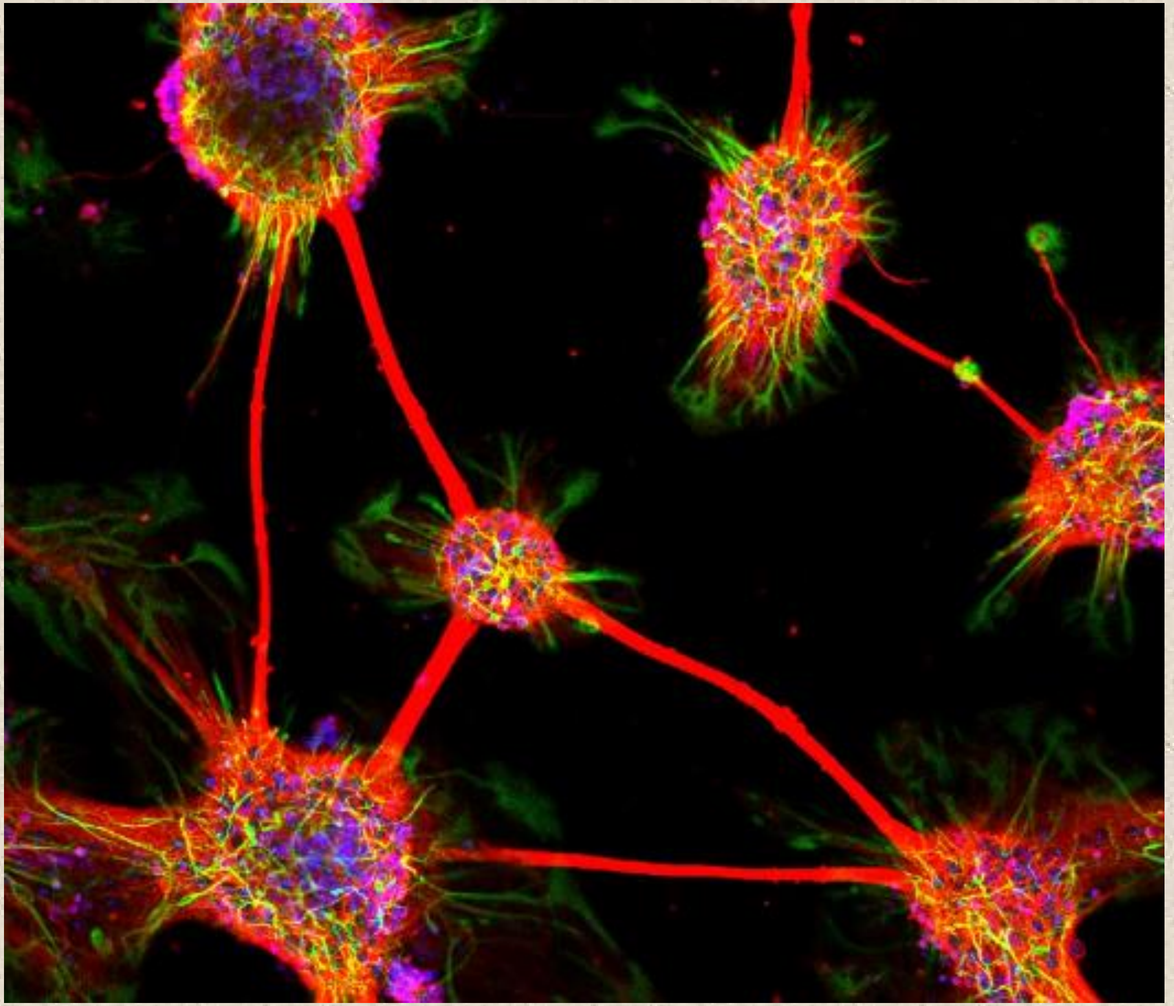




3) Variety of staining for Electron microscopy (mostly heavy metal like Osmium)



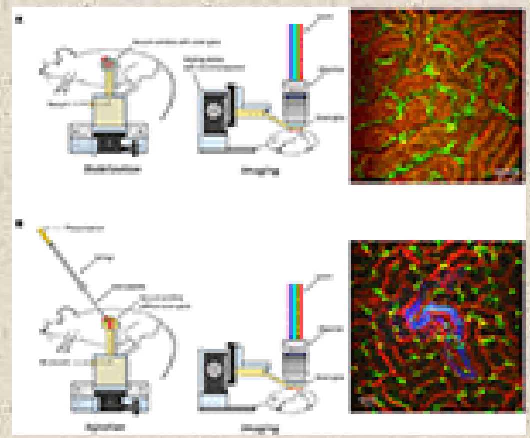
Exmple of final photo by optical microscope. Multicolor image (fluorescence microscopy of fluorsent probe adhered to specific part of neuron cells)

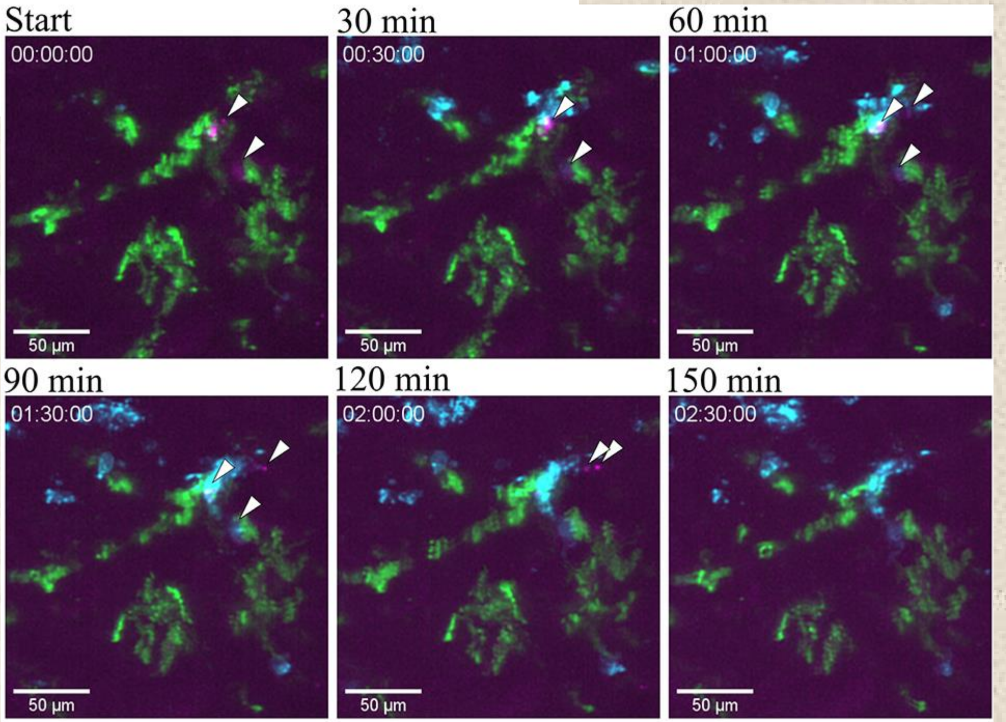


Most of the microscopy scan needs separation of sample from live body. However thera are also futuristic and very modern machine , for example INTRAVITAL MICROSCOPY:

High Resolution Intravital Imaging of the Renal Immune Response to Injury and Infection in Mice

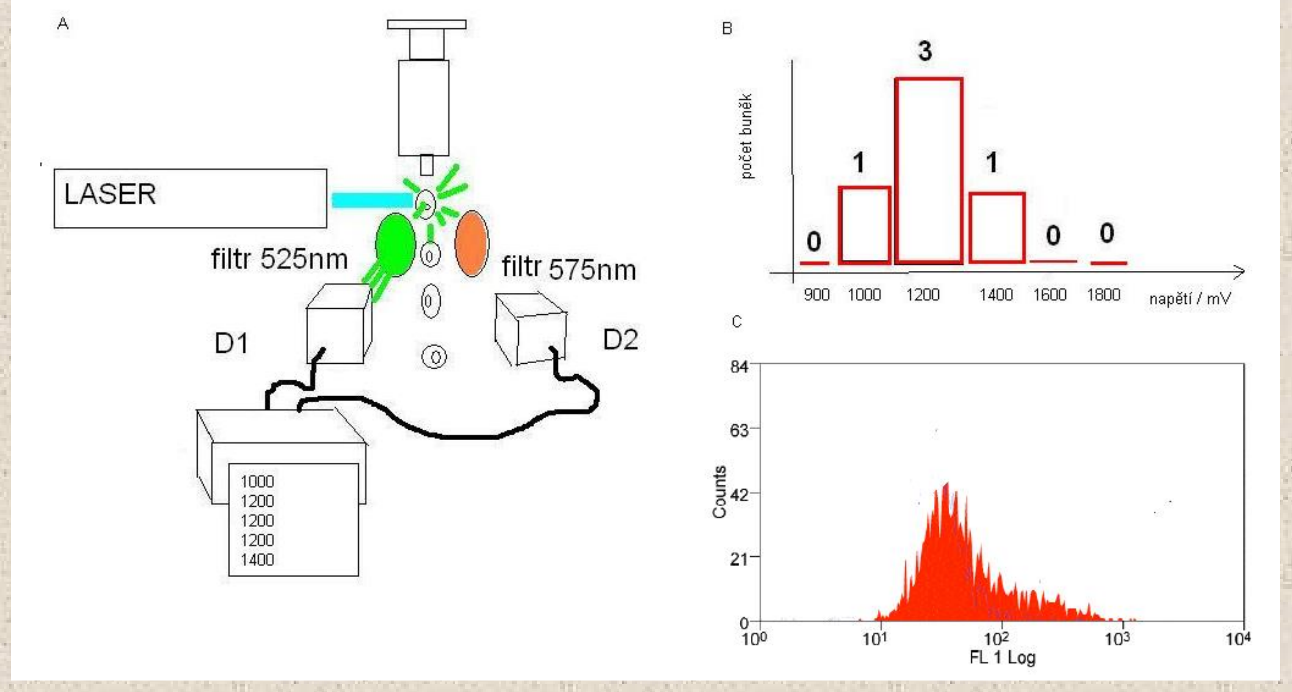
John Sedin





Ad. FLOW-CYTOMETRY

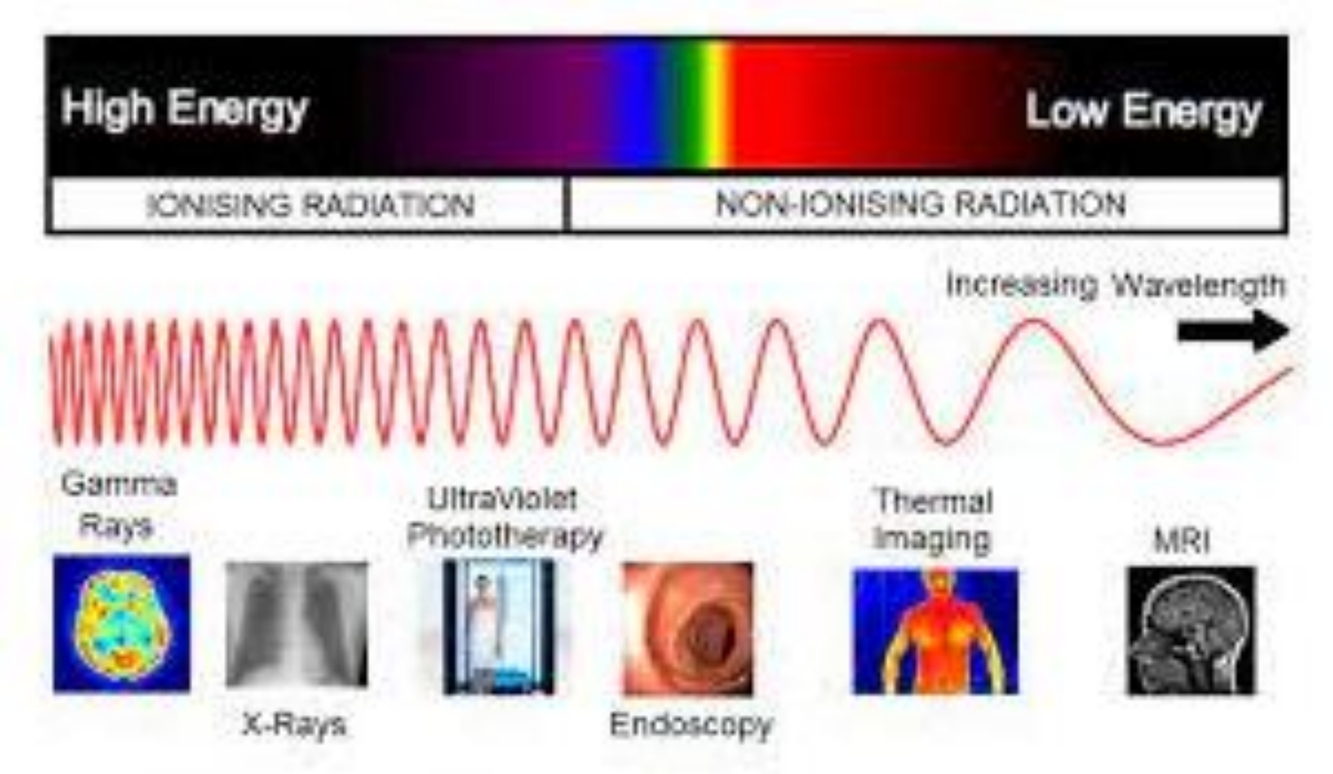
Flow cytometry is a technology that **provides rapid multi-parametric analysis of single cells in solution**. Flow cytometers have started be used in hematology to speed analysis of blood cells and analysis of surface protein on these cells



Good ilustrative video: https://www.youtube.com/watch?v=B2zreF2dnWk

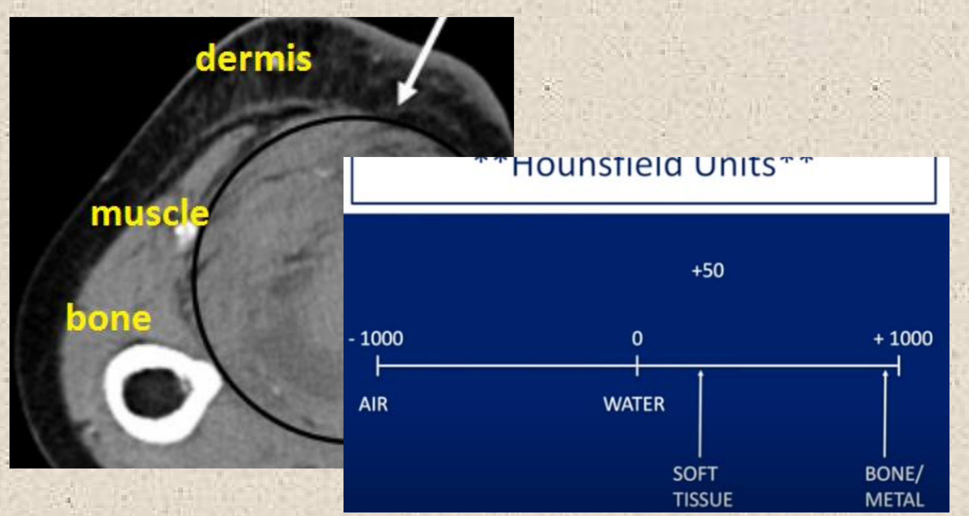
Ad. X-RAY and MRI TOMOGRAPHY

People have only one visibility detector – eye. Half a century ago, the light was only detecting tool for all doctors and biology spcialist. However visualisation of some animal and some machine is based on another electromagnetic :

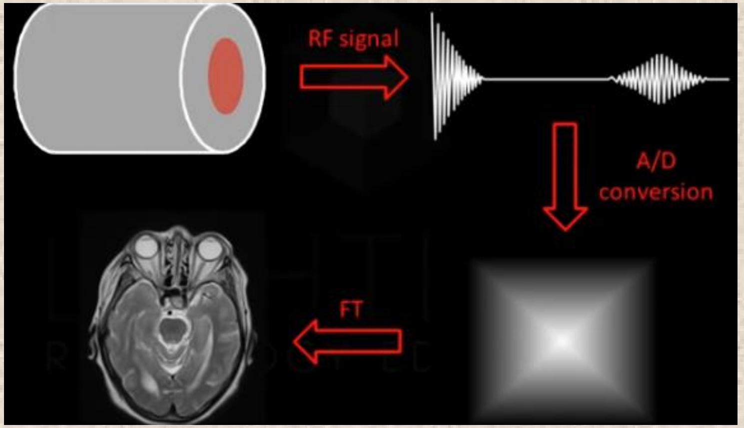


X-RAY CT and also MRI have only grey scale output. We can say that each milimeter of tissue is precomputed to one pixel (whit, grey or black). So microscopy has variety of color and resolution of cells ant biological entities could be higher thanks to specific staining, on the oposite the CT has contrast which correlates to „DENSITY OF MATERIAL“ (bones – the highest density, air – the lowest), MRI has contrast which correlates to H2O concentration in the tissue (bone – low concentration, soft tissue – higher concentration). For aditive contrast we use for example stining of intestine or blood by metal nanoparticles.

X-RAY CT



MRI



CT and MRI are very sofistic technical aparature, where geat physical theoretic backround is neded from quantm physics and nuclear physics theory. Very ilustrative videos for medical and biological worker is here:

CT image quality and

https://www.youtube.com/watch?v=qsHTrQ0lb2s

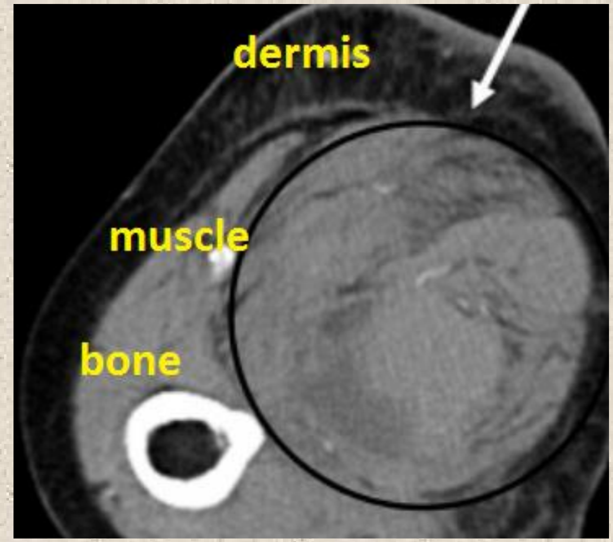
MRI basic principles and resolution

https://www.youtube.com/watch?v=Ok9ILIYzmaY

https://www.youtube.com/watch?v=aQZ8tTZnQ8A

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

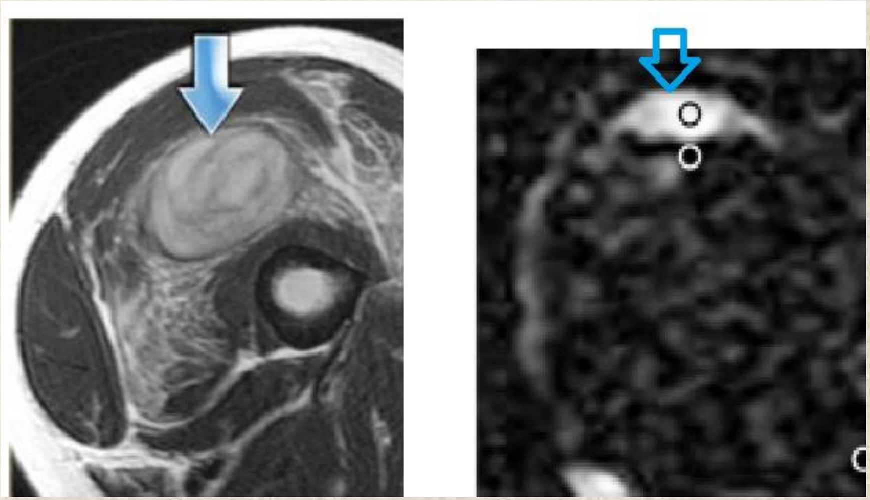
X-RAY CT



The spatial resolution of CT is excellent and the primary strength of the modality. Current CT scanners have a spatial resolution of **0.5–0.625 mm in the z-axis**, and approximately 0.5 mm in the x- to y-axes

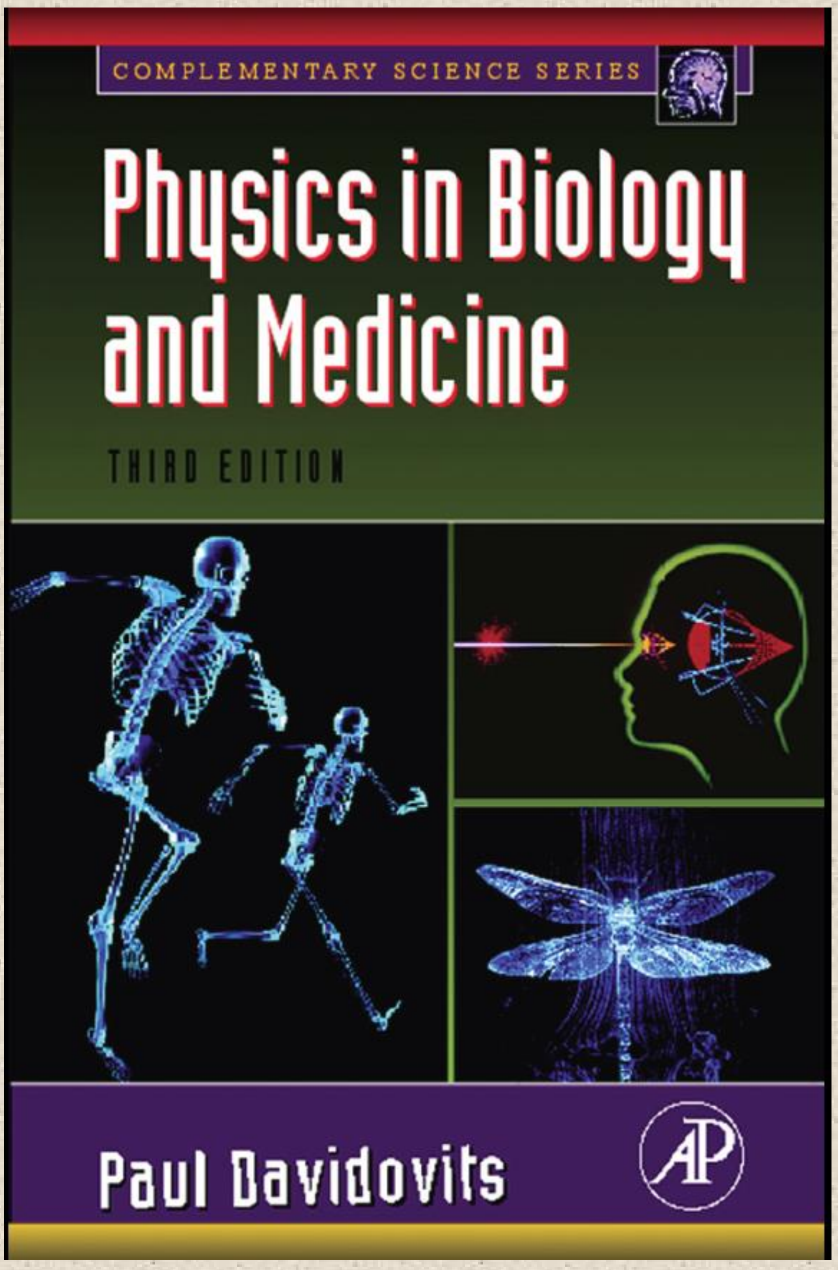
MRI

High resolution vs. Bad resolution



Nowadays, most MRI scanners used for medical purposes have B0 values of 1.5 or 3 T and can reach typical resolutions of around **1.5×1.5×4 mm**. In parallel, ultra-high magnetic field MRI scanners with B0 = 11.7 T are developed for research pur- pose and resolutions of 80 × 80 × 200 μm

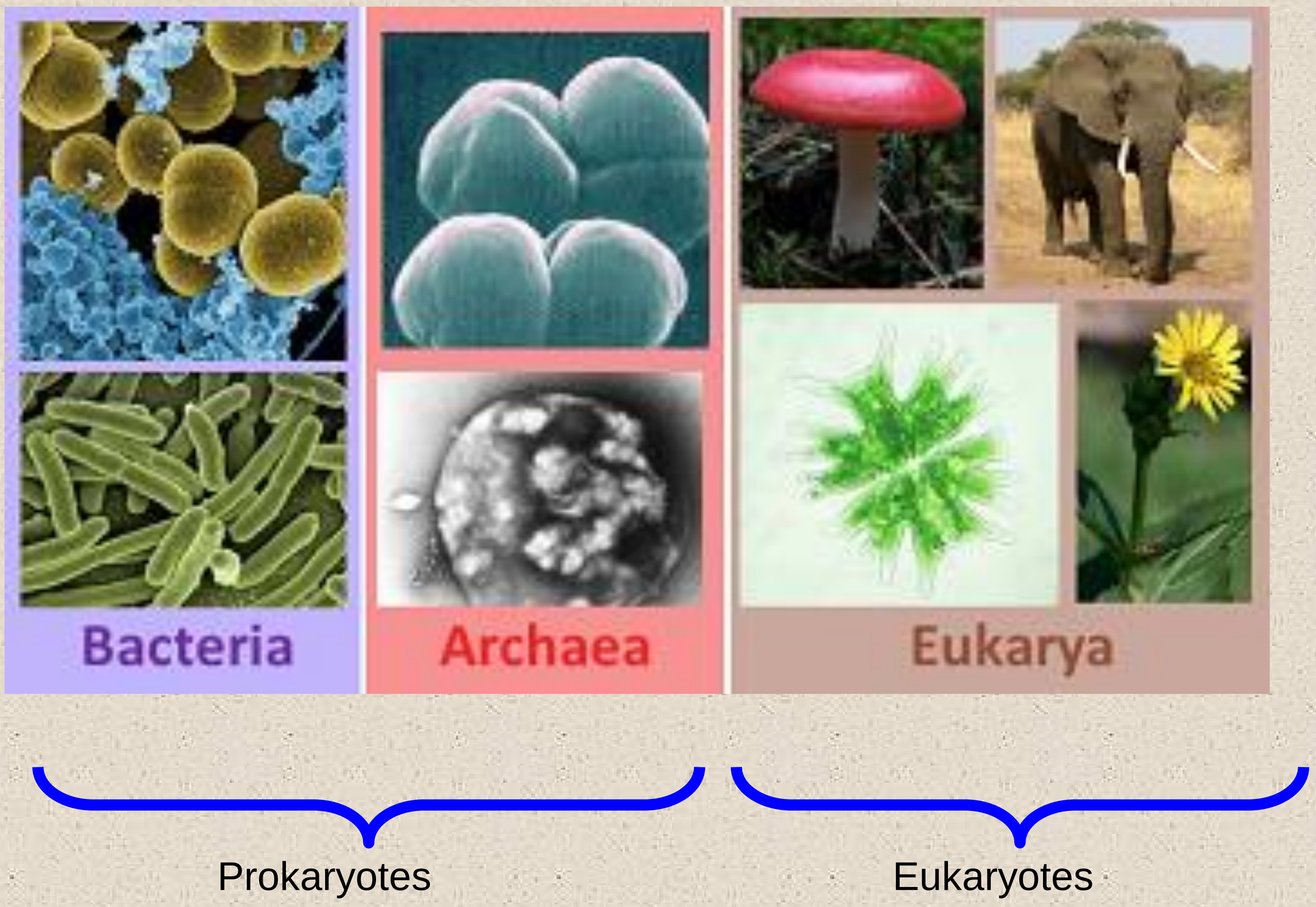
Detail literature:



CELLS and CELL BIOLOGY

Cells are the fundamental units of life. Thus it is to *cell biology*—the study of cells and their structure, function, and behavior—that we must look for an answer to the question of what life is and how it Works.

Medicinal experts should have good overview not only about human cells, but alo about another historical cells and viruses, becouse their interaction with human body is cccritical development of many pathologies (flu, diabetic wound, pathology of intestine micro-organism, …aerobic or anearobic environment could induce different bacterial aktivity etc)


Bacteria
Archaea
Eukarya
Prokaryotes
Eukaryotes

The Prokaryotic Cell

Of all the types of cells revealed by the microscope, *bacteria* have the simplest structure and come closest to showing us life stripped down to its essentials. Indeed, a bacterium contains essentially no organelles—not even a nucleus to hold its DNA. This property—the presence or absence of a nucleus—is used as the basis for a simple but fundamental classification of all living things. Organisms whose cells have a nucleus are called eukaryotes (from the Greek words *eu*, meaning "well" or "truly," and *karyon*, a "kernel" or "nucleus"). Organisms whose cells do not have a nucleus are called prokaryotes (from *pro*, meaning "before").

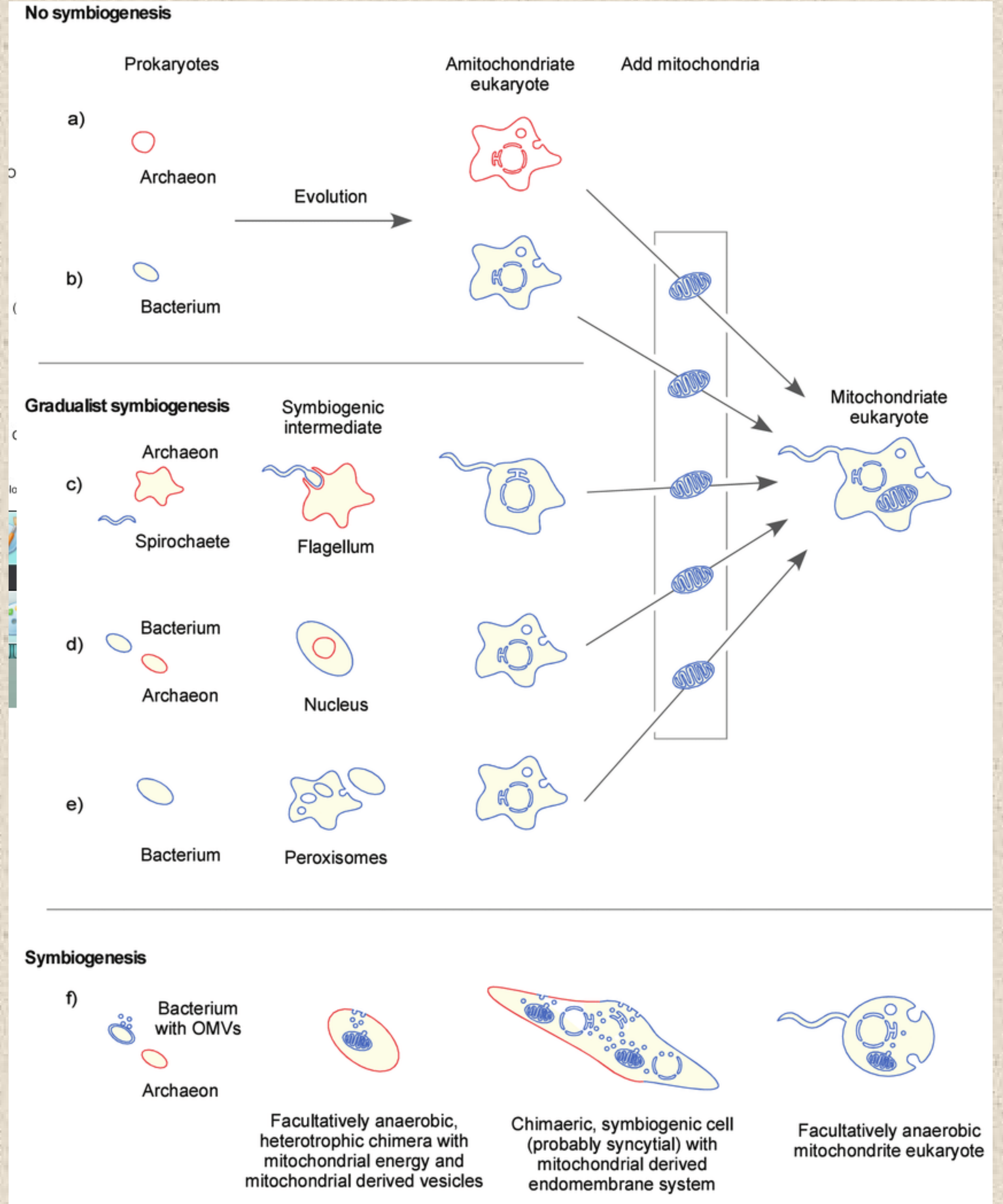
The Eukaryotic Cell

Eukaryotic cells, in general, are bigger and more elaborate than bacteria and archaea. Some live independent lives as single-celled organisms, such as amoebae and yeasts (Figure 1–13); others live in multicellular assemblies. All of the more complex multicellular organisms—including plants, animals, and fungi—are formed from eukaryotic cells.

By definition, all eukaryotic cells have a nucleus. But possession of a nucleus goes hand-in-hand with possession of a variety of other organelles,

Notes to relationship of Prokaryotic and Eukaryotic ….Schematic comparison of selected theories for eukaryote origin.

Details in
Symbiogenesis, gradualism, and mitochondrial energy in eukaryote origin
September 2017
Periodicum Biologorum 119(3)



Date (million years ago)	Organisms	Events	Atmospheric oxygen (~%)
3800	Prokaryote chemoautotrophs	Origin of life	0
3500–3000	Prokaryote heterotrophs; precursors of cyanobacteria. Stromatolites. Sulfur bacteria	Beginning of photosynthesis	Traces
2100	Filamentous spirally curled organisms, (Grypania)	Major land masses; shallow seas, Iron deposits, BIFs	0.1%
2000	Cyanobacteria tolerant to O_2	Sterols in bitumen (fossil organisms)	0.2%
1700	Spheromorph Acritarchs, primitive unicellular eukaryotes	Atmosphere oxidising Endosymbiosis. Aerobic respiration	0.3%
1200	Red algae and metaphytes	Large cells. Endosymbiosis. Aerobic respiration. Meiosis. Genetic recombination	0.5%
1000–550	Various primitive multi-cellular eukaryotes in precambrian fossils, some mineralized. Green algae dominant. Early land plants	Fossils and tracks. Oxygen and ozone accumulating	1–4%
450–present	Full flourishing multicellular eukaryotes; land living organisms	Ozone layer completed. Crust movements more pronounced. Super continents formed. Ocean basins altered	10–21%

Cells vary enormously in appearance and Function

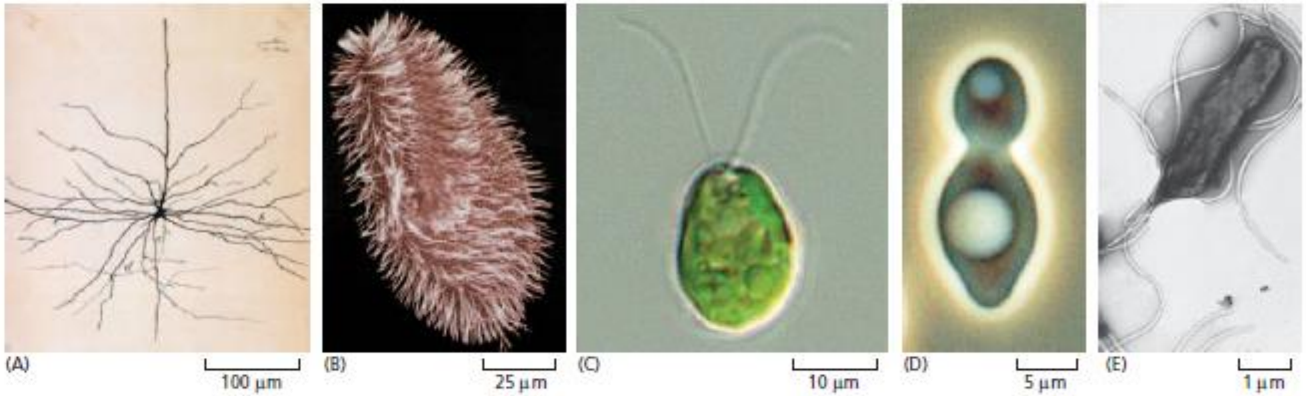
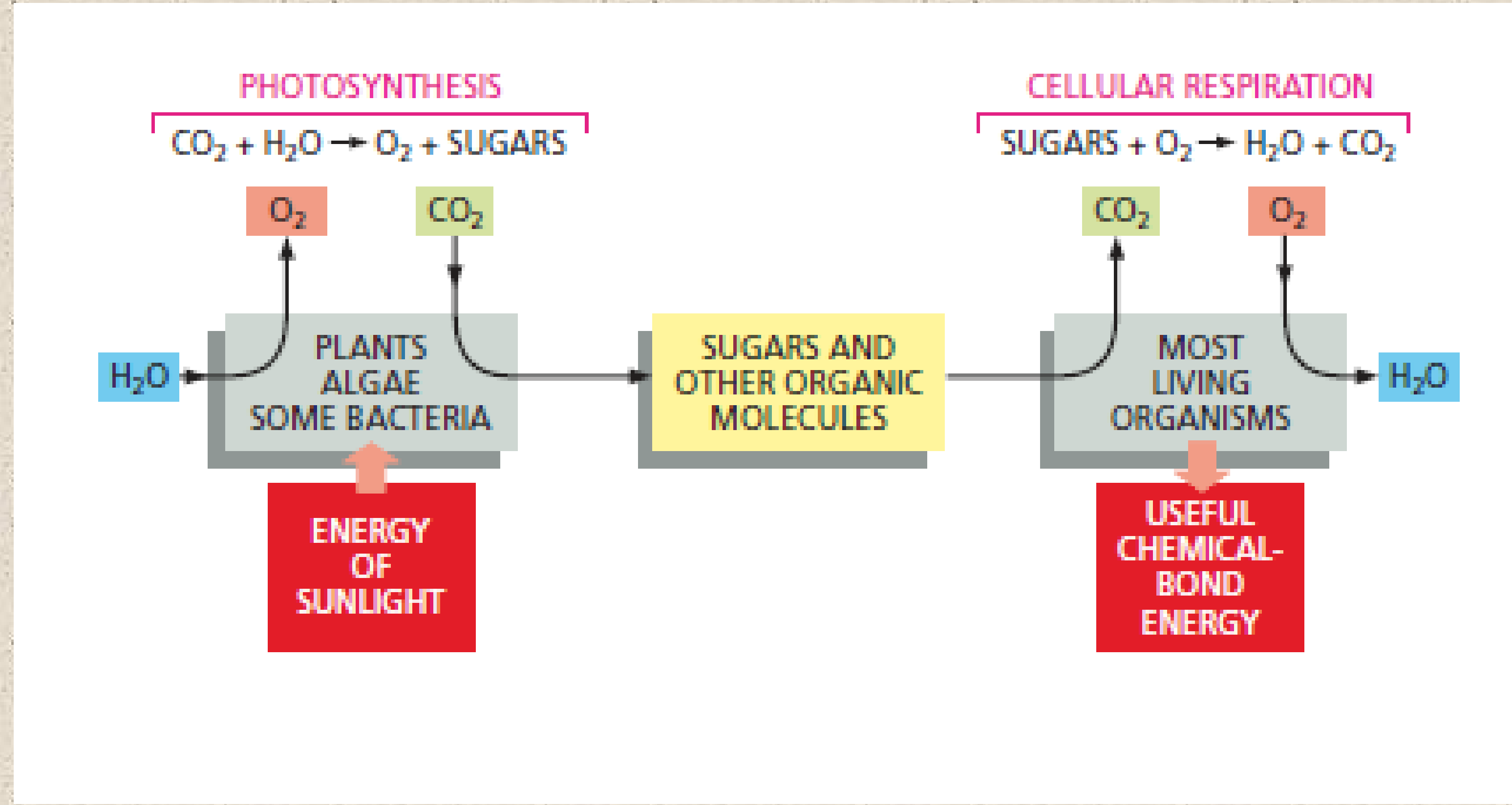


Figure 1–1 Cells come in a variety of shapes and sizes. Note the very different scales of these micrographs. (A) Drawing of a single nerve cell from a mammalian brain. This cell has a huge branching tree of processes, through which it receives signals from as many as 100,000 other nerve cells. (B) *Paramecium*. This protozoan—a single giant cell—swims by means of the beating cilia that cover its surface. (C) *Chlamydomonas*. This type of single-celled green algae is found all over the world—in soil, fresh water, oceans, and even in the snow at the top of mountains. The cell makes its food like plants do—via photosynthesis—and it pulls itself through the water using its paired flagella to do the breaststroke. (D) *Saccharomyces cerevisiae*. This yeast cell, used in baking bread, reproduces itself by a process called budding. (E) *Helicobacter pylori*. This bacterium—a causative agent of stomach ulcers—uses a handful of whiplike flagella to propel itself through the stomach lining. (A, copyright Herederos de Santiago Ramón y Cajal, 1899; B, courtesy of Anne

However biologist during centruries of modern science made basic identification of basal cell principles:

Fundamental principles of all known cells are:
(A) CEHMICAL MACROMOLECULES and STRUCTURE
(B) BIOENERGETIC



Essential Concepts

• Cells are the fundamental units of life. All present-day cells are believed to have evolved from an ancestral cell that existed more than 3 billion years ago.
• All cells are enclosed by a plasma membrane, which separates the inside of the cell from its environment.
• All cells contain DNA as a store of genetic information and use it to guide the synthesis of RNA molecules and proteins.
• Cells in a multicellular organism, though they all contain the same DNA, can be very different. They turn on different sets of genes according to their developmental history and to signals they receive from their environment.
• Animal and plant cells are typically 5–20 μm in diameter and can be seen with a light microscope, which also reveals some of their internal components, including the larger organelles.c

The electron microscope reveals even the smallest organelles, but specimens require elaborate preparation and cannot be viewed whilealive.

- Specific large molecules can be located in fixed or living cells with a fluorescence microscope.
- The simplest of present-day living cells are prokaryotes: although they contain DNA, they lack a nucleus and other organelles and probably
resemble most closely the ancestral cell.
- Different species of prokaryotes are diverse in their chemical capabilities and inhabit an amazingly wide range of habitats. Two fundamental evolutionary subdivisions are recognized: bacteria and archaea.
- Eukaryotic cells possess a nucleus and other organelles not found in prokaryotes. They probably evolved in a series of stages, including the acquisition of mitochondria by engulfment of aerobic bacteria and (for plant cells) the acquisition of chloroplasts by engulfment of photosynthetic bacteria.
- The nucleus contains the genetic information of the eukaryotic organism, stored in DNA molecules.

- The cytoplasm includes all of the cell's contents outside the nucleus and contains a variety of membrane-enclosed organelles with specialized functions: mitochondria carry out the final oxidation of food molecules; in plant cells, chloroplasts perform photosynthesis; the endoplasmic reticulum and the Golgi apparatus synthesize complex molecules for export from the cell and for insertion in cell membranes; lysosomes digest large molecules.
- Outside the membrane-enclosed organelles in the cytoplasm is the cytosol, a very concentrated mixture of large and small molecules that carry out many essential biochemical processes.
- The cytoskeleton is composed of protein filaments that extend throughout the cytoplasm and are responsible for cell shape and movement and for the transport of organelles and other large molecular complexes from one location to another.
- Free-living, single-celled eukaryotic microorganisms are complex cells that can swim, mate, hunt, and devour other microorganisms.
- Animals, plants, and some fungi consist of diverse eukaryotic cell types, all derived from a single fertilized egg cell; the number of such cells cooperating to form a large multicellular organism such as a human runs into thousands of billions.
- Biologists have chosen a small number of model

Conclusion:

Cell definition

The cell is the structural and functional elementary unit of all living organisms,

conserving the features of the organism,

having the ability of self-control, self-regulation, and self-reproduction,

being the result of a long time of evolution

Key terms, which everybody had to understand from actual lection of Biology

KEY TERMS

- archaeon
- bacterium
- cell
- chloroplast
- chromosome
- cytoplasm
- cytoskeleton
- cytosol
- DNA
- electron microscope
- eukaryote
- evolution
- fluorescence microscope
- genome
- homologous
- micrometer
- microscope
- mitochondrion
- model organism
- nucleus
- organelle
- photosynthesis
- plasma membrane
- prokaryote
- protein
- protozoan
- ribosome
- RNA