INTRODUCTORY BIOLOGY AND MICROBIOLOGY

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Introduction

- Biology is the science of life while Microbiology is from Greek words mīkros, meaning "small"; bios, meaning "life"; and –logia meaning study.
- Therefore microbiology is the study of microorganisms, those being:
  - Unicellular (single cell),
  - multicellular (cell colony), or
  - acellular (lacking cells).

- Modern biology is divided into 2 categories based on primary level of focus:
  - Organismic biology , which emphasize on biodiversity, evolutionary relationships, adaptations, and ecology of plants and animals.
  - Molecular and cellular biology, which is concerned with interactions between the various systems of a cell, including the interrelationship of DNA, RNA, and protein synthesis and how these interactions are regulated.

- Cell biology studies the physiological properties of cells, as well as their behaviors, interactions, and environment.
- Cell biology involve interweaving of 3 historically distinct disciplines:
  - Cytology (the study of cells)
    - Microscopic study of cell structure organization
  - Biochemistry
    - concerned with chemistry of biological structure and their functions/cellular function
  - Genetics
    - Information flow

The Cell

- The cell is life's fundamental unit of structure and function.
- Some organisms such as amoebas and most bacteria, are single cells. Other organisms including plants and animals, are multicellular.
- Instead of a single cell performing all the functions of life, a multicellular organism has a division of labour among specialized cells.

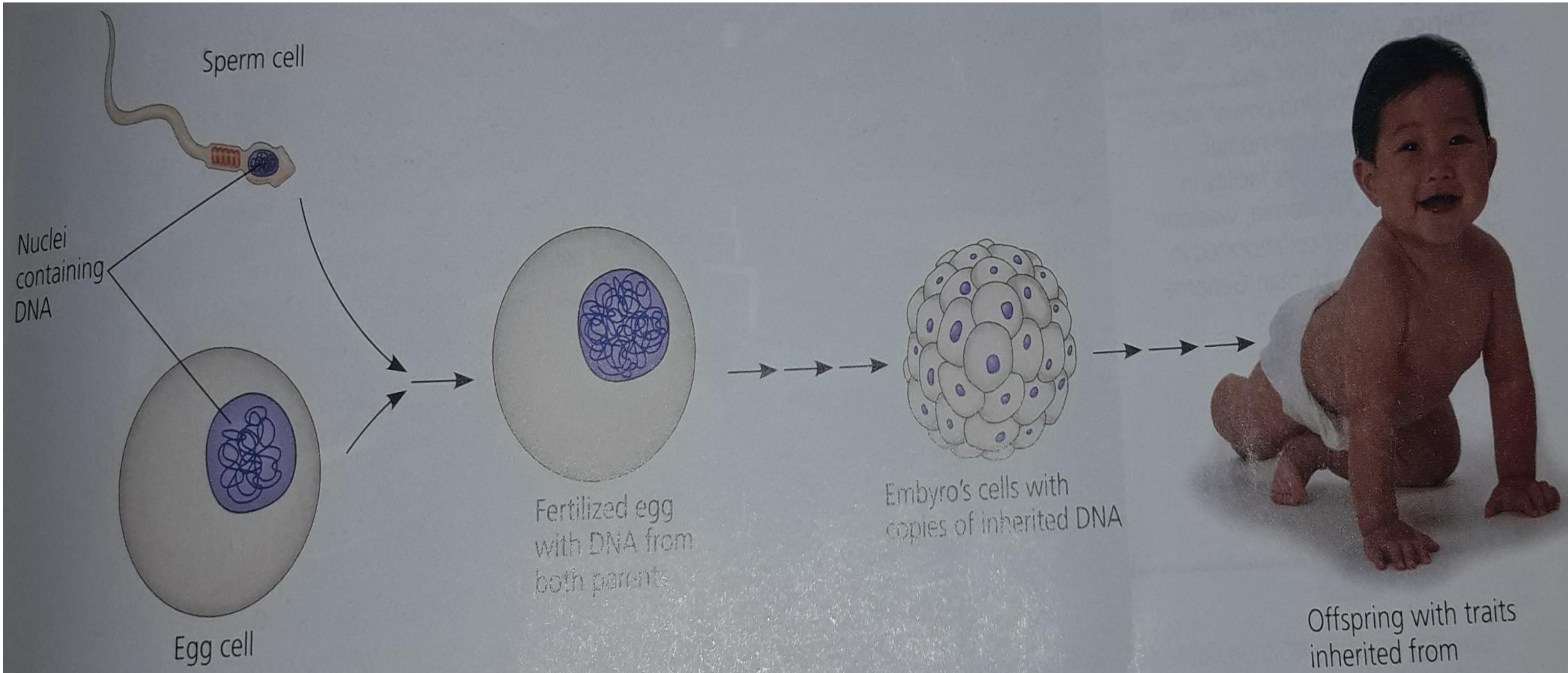


Figure 1.9 Inherited DNA directs development of an organism.

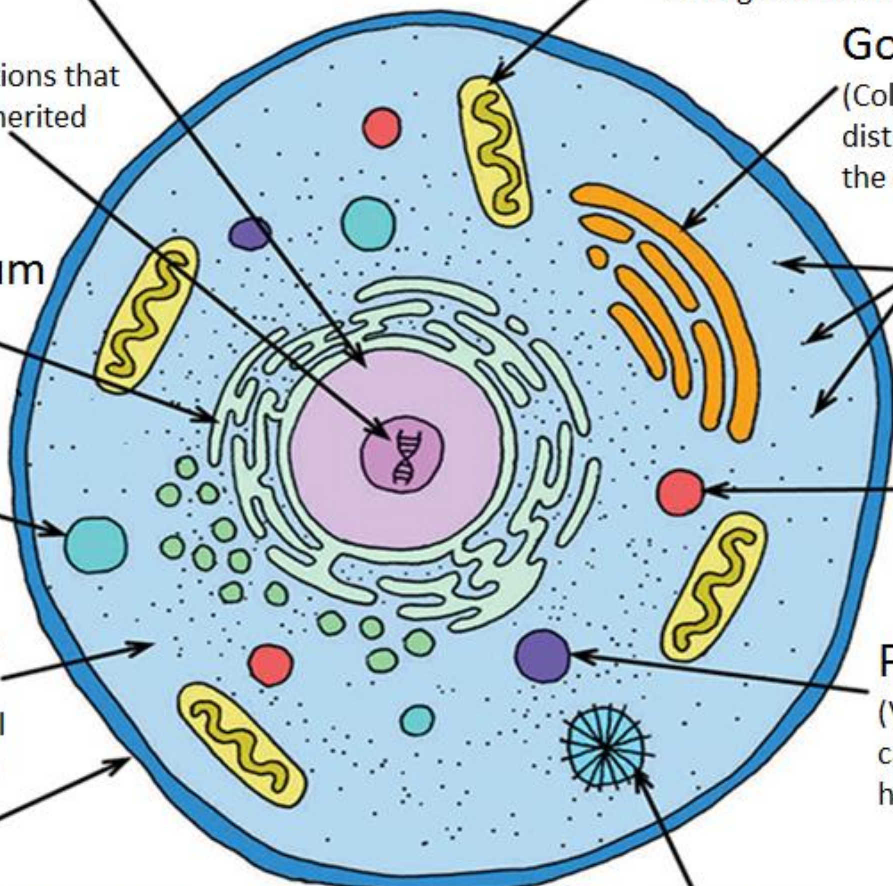
- A human body consists of trillions of microscopic cells of many different kinds such as muscle cells and nerve cells, which are organized into the various specialized tissues.
- In life's structural hierarchy, the cell has a special place as the lowest level of organization that can perform all activities required for life.
- The activities of organisms are all based on the activities of the cells.
- For instance, the division of cells to form a new cell is the basis for all reproduction and for the growth and repair of multicellular organisms.

- There are two main forms of cells namely:
  - Prokaryotic cells
    - Bacteria and Archea. The word prokaryotoic is from the Greek word *Pro*, meaning before and *karyon*, which means kernel.
  - Eukaryotic cells
    - All other forms of life including plants and animals. The word eukaryotic is from the Greek word *eu*, which means true and *karyon* - he nucleus of a cell.
- A eukaryotic cell is subdivided by internal membranes into various membrane-enclosed organelles. Organelles are the various functional components that make up the cell.

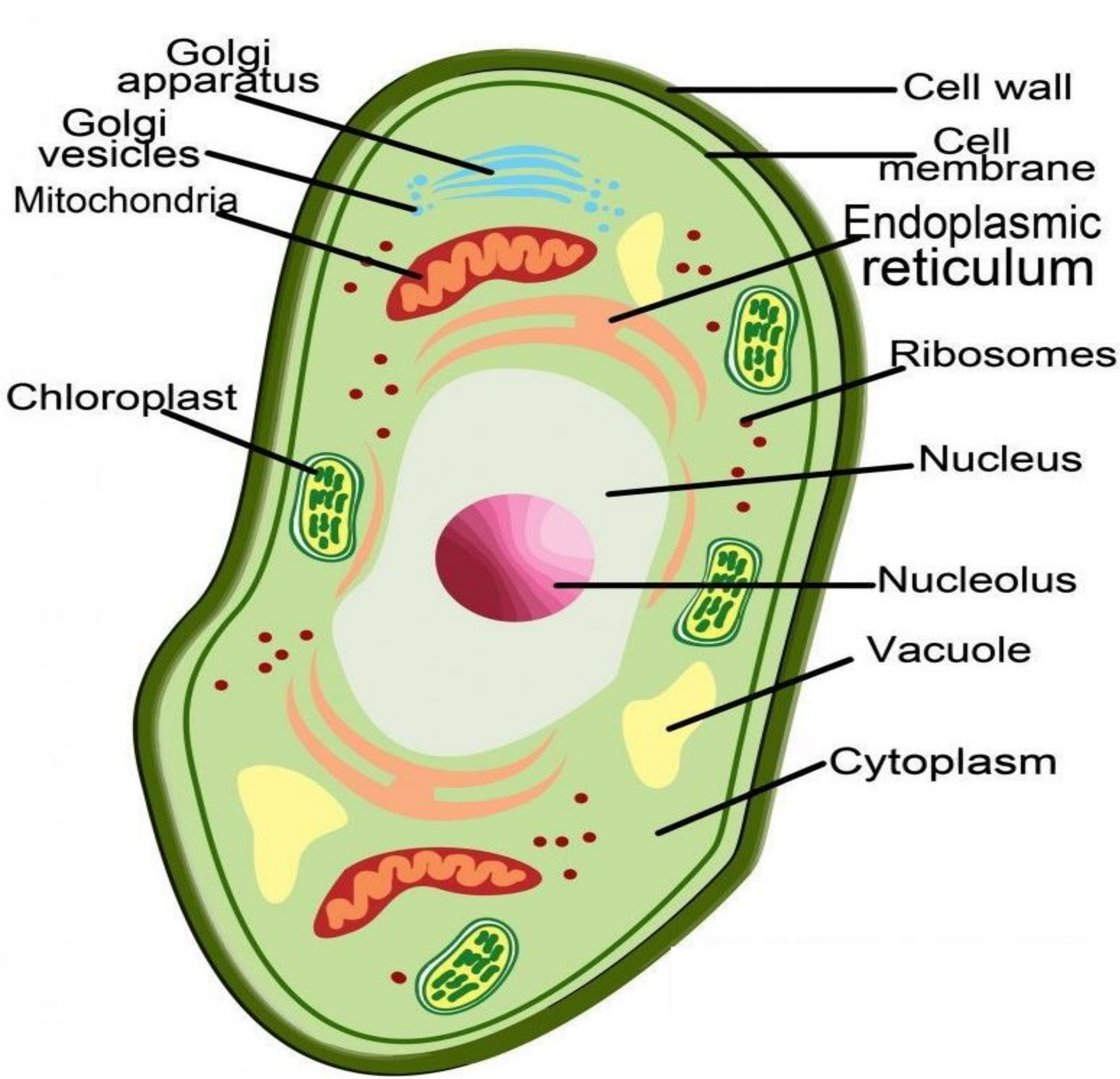
- Examples of organelles include nucleus, the mitochondrion, the chloroplast, the Golgi apparatus, the lysosome, and the endoplasmic reticulum.
- Other organelles are located within the cytoplasm of the cell which is simply the entire region between the nucleus and the outer membrane of the cell.
- Prokaryotic cells are much smaller and simpler than eukaryotic cells.

- In prokaryotic cells the DNA (genetic material), which is contained within the nucleus in eukaryotic cells, is not enclosed in the nucleus and so not separated from the rest of the cell i.e. not enclosed in a membrane bound nucleus.
- Some organelles, such as mitochondria and chloroplasts, have their own genome (genetic material) separate from that found in the nucleus of the cell
- Prokaryotic cells also lack other membrane bound organelles as is the case in eukaryotic cells.

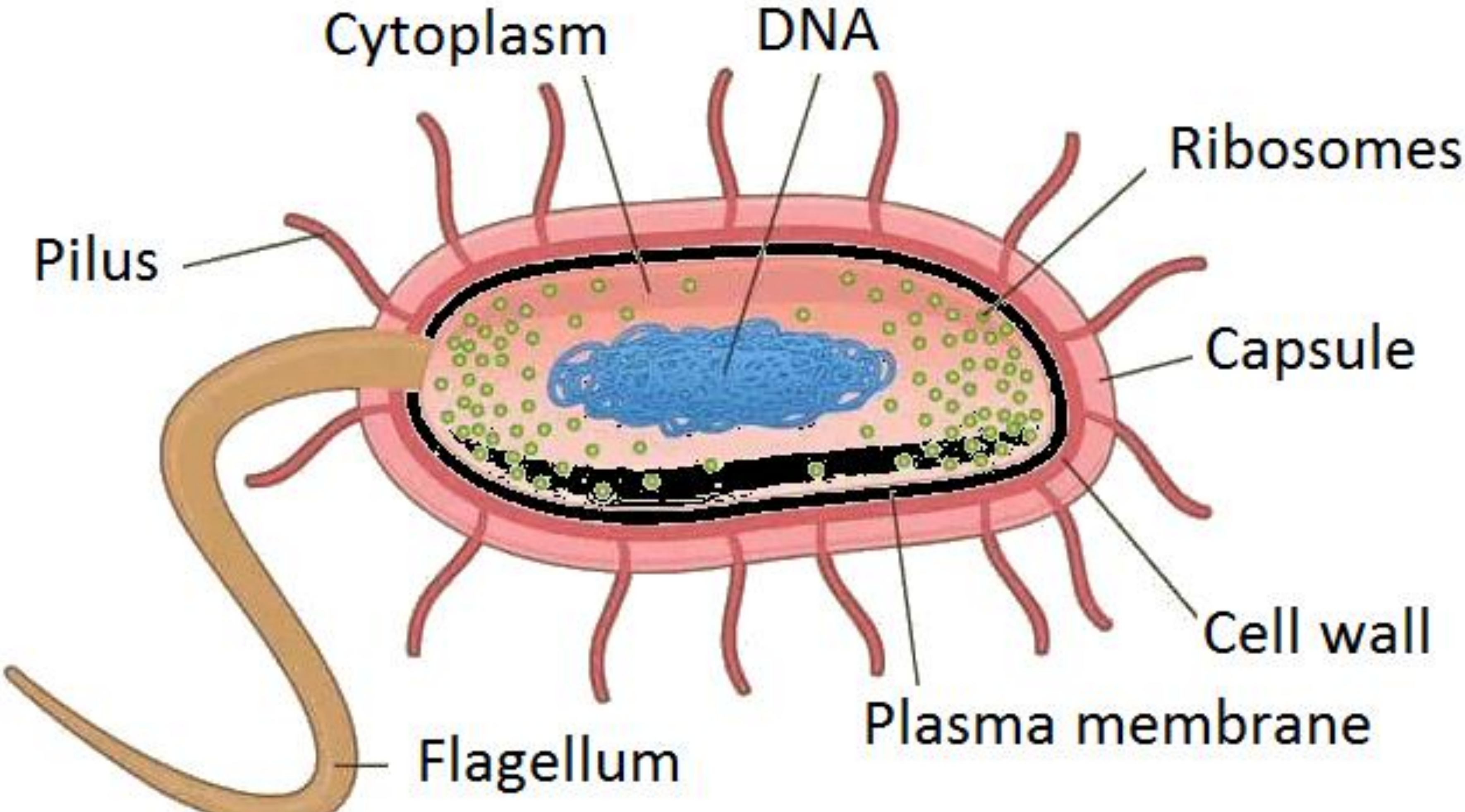
Animal Cell


Nucleus
(Cell's controll center)
DNA
(Contains coded informations that passes on every single inherited characteristic)
Endoplasmic reticulum
(SER and RER move and store materials made by the cell)
Lysosome
(Where digestion of cell nutrients takes place)
Cytoplasm
(Jelly-like fkuid between cell membrane and the nucleus) This is where all the organells are found)
Cell membrane
Made up of a double layer of fatty materials. It allows some materials to pass into and out of the cell. It allows foods to pass into the cell and waste to pass out of the cell)
Mitochondria
(Produces energy for cells to use by breaking down susbstances during metabolisms)
Golgi complex
(Collects, packages and distributes molecules made in the cell)
Ribosomes
(Tiny protein producing factories. The proteins produce chemical messages that run a cell)
Vacuole
(Storage area for fats and other substances)
Peroxisome
(Vesicles that contains enzymes that carry out reactions such as detoxifying harmful molecules)
Centriole
(Tiny organs that help the cell to divide)

Plant cell


Golgi apparatus
Golgi vesicles
Mitochondria
Chloroplast
Cell wall
Cell membrane
Endoplasmic reticulum
Ribosomes
Nucleus
Nucleolus
Vacuole
Cytoplasm

Bacterial cell



Comparing Prokaryotic and Eukaryotic Cells

- **Similarities:**
  - All cells, whether prokaryotic or eukaryotic are bounded by a selective barrier, called the plasma membrane.
  - Enclosed by the plasma membrane is a semi-fluid, jellylike substance called the cytosol, in which organelles and other compartments are found.
  - All cells contain chromosomes, which carry genes in the form of DNA.
  - All cells also have ribosomes, which are tinny complexes that make proteins as instructed by the genes.

- **Differences:**
  - In eukaryotic cells most of the DNA is in an organelle called the nucleus whereas in prokaryotic cell the DNA is concentrated in a region that is not membranous enclosed called the nucleoid.
  - Within the cytoplasm of a eukaryotic cell, suspended in the cytosol, are organelles of specialized form and functions. However, these organelles are lacking in a prokaryotic cell.
  - Eukaryotic cells have true nucleus whereas prokaryotic cells do not have true nucleus.

- Eukaryotic cells are generally much larger than prokaryotic cells with eukaryotic cell measuring between 10 and 100 µm in diameter while prokaryotes measure between 0.1 and 5 µm.

Differences Between Prokaryotic and Eukaryotic Cells

	Prokaryotes	Eukaryotes
Size	Usually 1 – 2 μm	5 – 100 μm
Nucleus	Absent	Present, bounded by nuclear envelope
DNA	Usually single or circular molecule (chromosome)	Multiple molecules, linear associated with proteins
Cell division	Simple fission	Mitosis and meiosis
Internal membranes	Rare	Complex (nuclear envelope, golgi apparatus, endoplasmic reticulum)
Ribosome	70S	80S (70S in mitochondria and chloroplasts)
Cytoskeleton	Absent	Present (Microtubules, microfilaments, intermediate filaments)
Motility	Rotary motor (drives bacterium flagellum)	Dynein (Drives cilia and eukaryote flagellum), kinesin, myosin.

The Discovery of Cells

- The cell theory
  - The term cell was first used by the English scientist Robert Hooke (1635-1703), who, in the mid-seventeenth century, used the term to describe the structure of bark cork.
  - The Dutch scientist Anton van Leeuwenhoek (1632-1723) made the first recorded observations of bacterial cells (termed “animalcules”) from pond water and tooth scrapings.

- 1830s – importance of cells was realized.
  - 1838 - German botanist Matthias Schleiden (1804-1881) observed that despite differences in tissue structure, all plants tissues were made of cells.
- In 1839 - German zoologist Theodor Schwann (1810-1882) realized that animals were also composed of fundamental cellular units or cells.

- Schwann then proposed the first 2 principles of Cell Theory:

    1. All organisms consist of 1 or more cells

    2. The cell is the structural unit of life

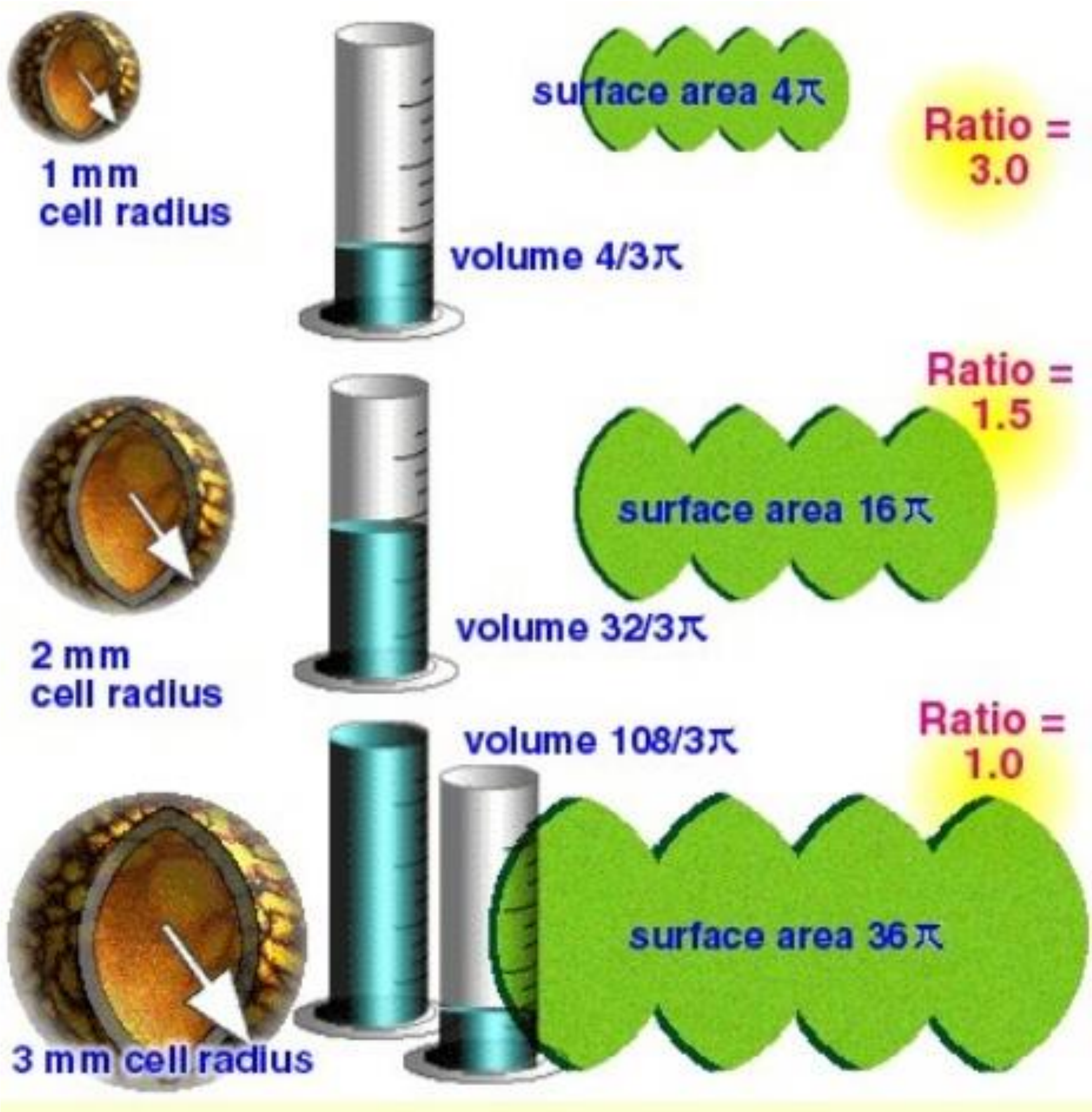
- Schleiden-Schwann's view of cell origin was less insightful – i.e. cells could arise from noncellular materials.

- German physician Rudolph Virchow (1821-1902) demonstrated that living cells could arise only from other living cells (biogenesis), and not from inanimate matter (abiogenesis).

Principles of Microscopy

- Size of cells pose challenge to understand cellular structure and organization.
- Most cells and their organelles cannot be seen by unaided eye.
- Cell size is usually measured in micrometers (µm, where 1000 µm = 1 mm), nanometers (1 nm = 10^{-9} m).
- Cells are mostly microscopic in size. Most eukaryotic cells have single nucleus with only 2 copies of most genes.

- As a cell increases in size, the surface area to volume ratio decreases.
  - Ability of a cell to exchange substances with its environment is proportional to its surface area.
- Cells depend to a larger degree on random movement of molecules (diffusion).


1 mm
cell radius
surface area 4π
volume 4/3π
Ratio =
3.0
2 mm
cell radius
surface area 16π
volume 32/3π
Ratio =
1.5
3 mm cell radius
volume 108/3π
surface area 36π
Ratio =
1.0

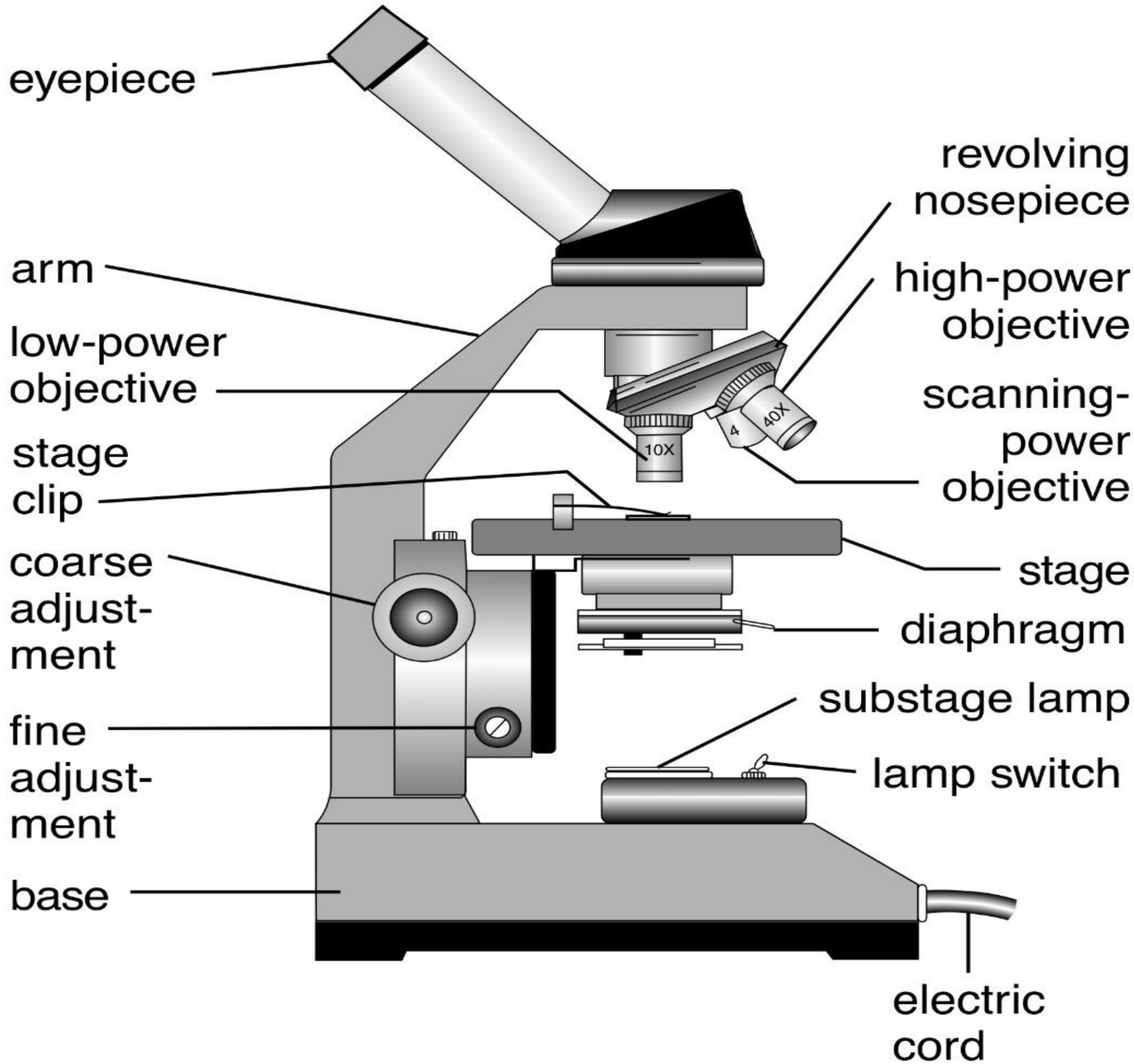
Microscopy

- The discovery and early study of cells progressed with the invention of microscopes in 1590 and their refinement during the 1600s.
- Microscopes make small objects appear bigger to the human eye.
- Magnification is only better when more details are revealed.
- There are different types of microscopes
  - Light microscope
  - Electron microscope

Light Microscope

- In Light Microscope (LM), visible light is passed through the specimen and then through glass lenses.
- The lenses refract (bend) the light in such a way that the image of the specimen is magnified as it is projected into the eye, onto photographic film or a digital sensor or onto a video screen.
- It has a series of lenses and uses light as its source of illumination.
  - To be able to do this it has the:
    - Condenser lenses
    - Objective lens and
    - Projector lens/eyepiece

Electric compound microscope



Parts of the Microscope

- **Ocular lens or eyepiece:** The upper part of the arm holds the eyepiece. The microscopes to be used in our practicals are binocular (two eye pieces). Each eye piece may have a magnification of 10; 6; or 5.
- **Body tube:** contains mirrors and prisms that direct the image to the ocular lens.
- **Nosepiece:** Found on lower part of the arm and holds the objective lenses of differing magnifying power.
- Objective lenses: There are 3 or 4 objective lenses on the microscope, 3.5; or 4 (low power); 10x (medium power); 40x or 45x (high power) and 100x (oil immersion).

- **The objective lenses are color coded:** red band is low power; yellow is medium power; blue band is high power and white band is oil immersion.
- **Stage:** Platform on which slides are mounted for viewing; the control knobs on the mechanical stage allow the operator to move the slide easily during the viewing.
- **Sub-stage condenser:** is mounted within or below the stage. It focuses a cone of light on the slide.
- **Diaphragm or Iris:** Many microscopes have a rotating disk under the stage. The diaphragm has different sized holes and is used to vary the intensity and size of light that is projected upward into the slide.

- **Focusing knobs:** located on the side of the microscope; outer (small) is the fine focus and inner (large) is the course focus.
- **Light source:** The have built-in light source (this could be electrical source or a mirror). The brightness control knob for electrical source is located on the base and has a brightness range of 0-9.
- **Par focal:** Microscopes are par focal, meaning that the image remains in focus when the objectives are changed, requiring only a slight change in fine adjustment for sharp image.

- **Field of vision:** The area you can see at a given level of magnification.
- **Numerical aperture (NA):** The different objective lenses show different details of an object. This is the property of a microscope lens that determines how much light can enter it and how great a resolution it can provide.
- The NA number is directly related to the cone of light from the specimen at its vertex (base) which is brought into the lens.
- When light from the condenser, under the stage, hits the specimen on the slide, the ligh is scattered (difffracted). However, the objective lens gathers the light in order to form an image. This is dependent on the resolution power of the lens.

- The bigger the cone of light that can be brought into the lens, the higher its numerical aperture is and this will give a good resolution.
- Usually some light is lost as the cone of light passes through the condenser, however, oil immersion is used to minimize the loss. One or two drops of oil is usually placed on the cover slip and the 100x objective lens is brought into position so that it touches the oil and creates a “bridge” between the slide and the objective lens.

- This allows for very little diffraction of light rays as it go through the slide, specimen, coverslip, oil and through the glass objective lens of the microscope.

Parameters in Microscopy

- There are three important parameters in microscopy namely:
  - Resolution: Resolving power
  - Magnification and
  - Contrast or visibility

1. Resolution: Resolving power

- Resolution is a measure of the clarity of the image; it is the minimum distance two points can be separated and still be distinguished as two points.
- For instance, what appears to an unaided eye as one star in the sky may be resolved as twin stars with a telescope.
- The resolving power of a lens or microscope is the smallest distance separating two objects that allows the objects to be seen as two distinct objects rather than a single entity.

- The image produced should not only be magnified but must show details. Hence the resolution of a microscope is extremely important.
- Limitations of resolution imposed by the wavelengths of illumination source e.g. visible light (400 – 700 nm).
- Shorter wavelengths provides better resolution Resolution (r) = $\lambda \div 2NA$.
  - Where by:
    - r = the resolution
    - λ = imaging wavelength and
    - NA = Numerical aperture (object and condenser)

2. Magnification

– Magnification is the ratio of an object's image size to its real size. It is the ability of the lens to enlarge the object being viewed.

– Objective lenses form an enlarged real image within the microscope.

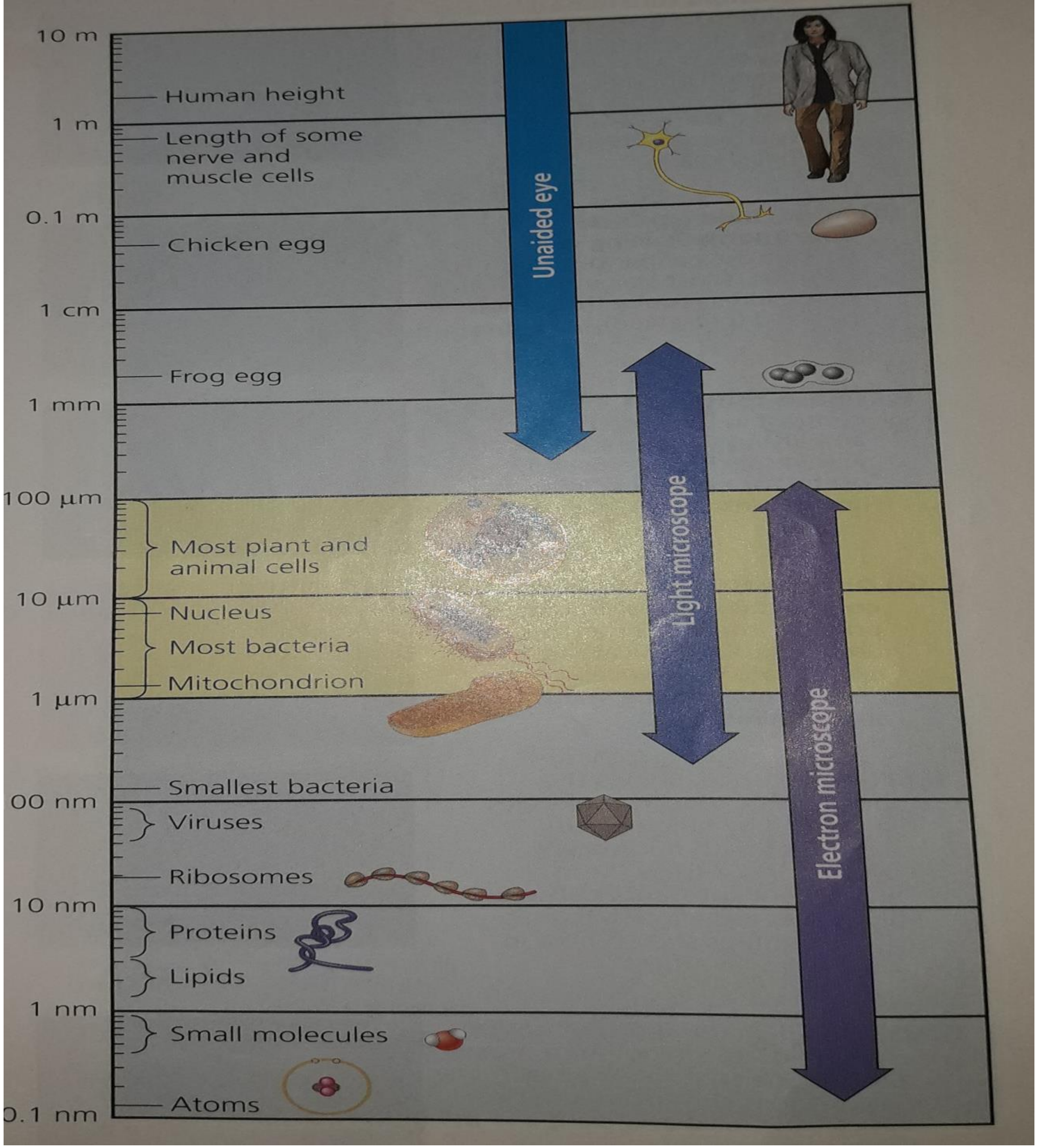
– The eyepiece further magnifies the image. The total magnification is obtained by multiplying the objective and eyepiece magnifications.

  - **Total magnification = magnification of the objective lens × magnification of the ocular (eyepiece) lens**.

- To achieve high magnification with good resolution an immersion oil lens is usually used by introducing a drop of oil between the slide and the objective les.
  - This reduces loss of light rays after it passes through the specimen.
  - Immersion oil has same refractive index as glass with same effect as increasing the diameter of objective lens.

3. Contrast or Visibility

- Contrast emphasizes the differences in parts of the sample.
- In fact, most improvements in light microscopy has enhanced contrast such as staining or labeling cell components to stand out visually.
- Staining will make objects to appear colored. The disadvantage is that staining cannot be used with living cells because it kills the cell and cannot allow movement of cells to be seen.



The size range of cells

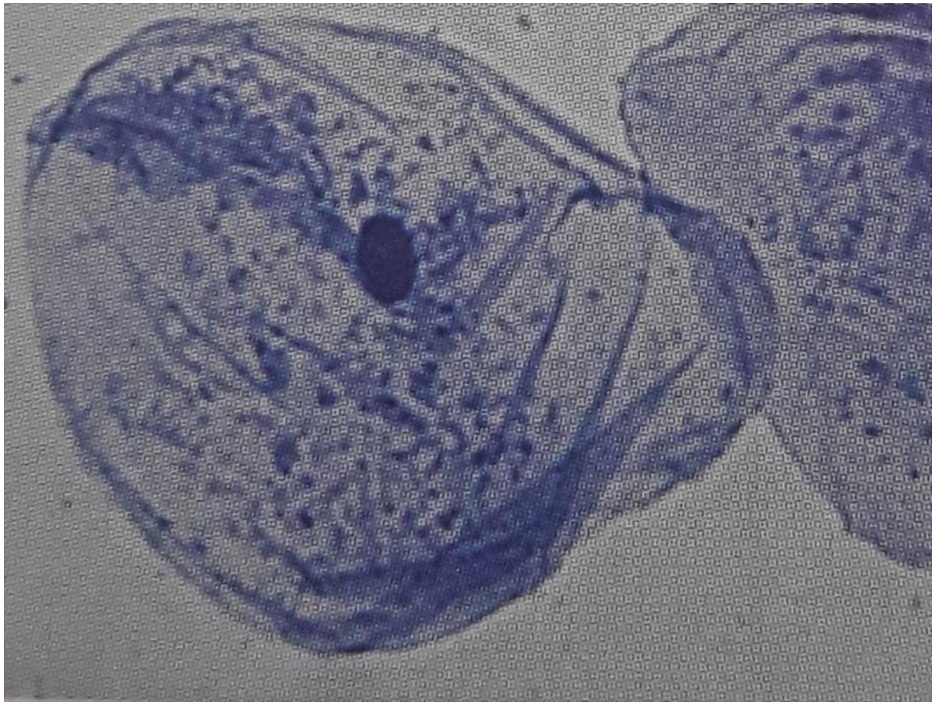
Light Microscopy Techniques

- There are different types of light microscopy namely:
  - Brightfield
  - Phase contrast
  - Differential interference contrast
  - Fluorescense and
  - Confocal

- **Brightfield (Unstained specimen)**
  - Passes light directly through the specimen. Unless cell is naturally pigmented or artificially stained, images has little contrast.

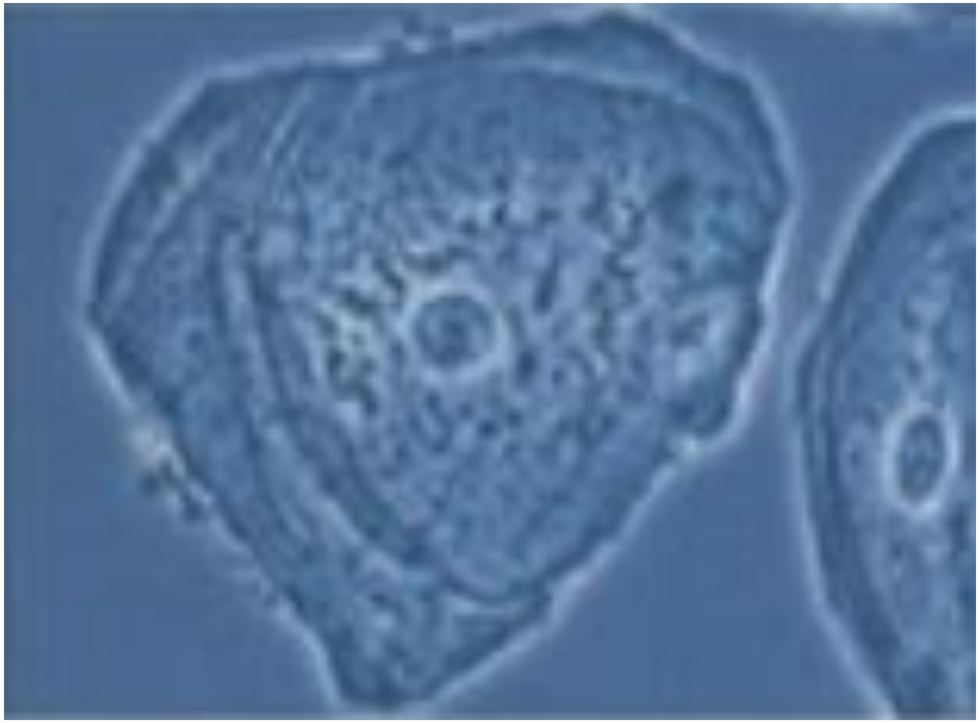
Human cheek epithelium through Brightfield (unstained specimen)

- **Brightfield (Stained specimen)**
  - Staining with various dyes enhances contrast. Most staining procedures require that cells be fixed (preserved). Practical 2 part b on page 21 of the practical manual.



Human cheek epithelium through Brightfield (stained specimen)

- **Phase contrast**
  - Enhances contrast in unstained cells by amplifying variations in density within specimen; especially useful for examining living unpigmented cells.

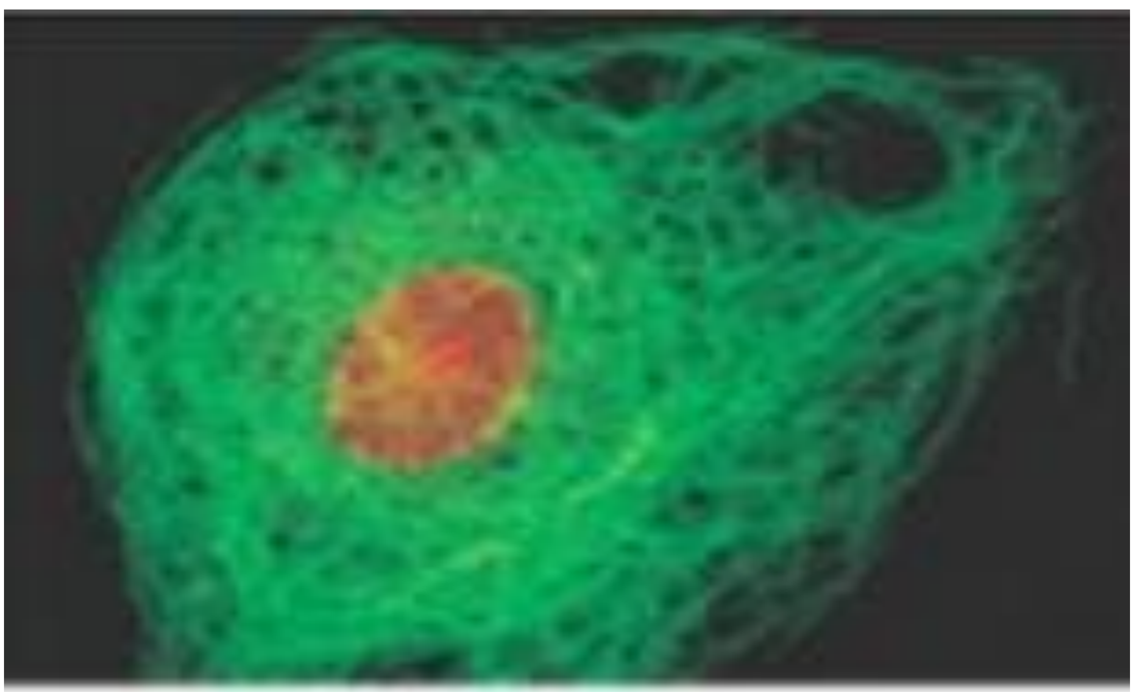


Human cheek epithelium through phase contrast microscopy

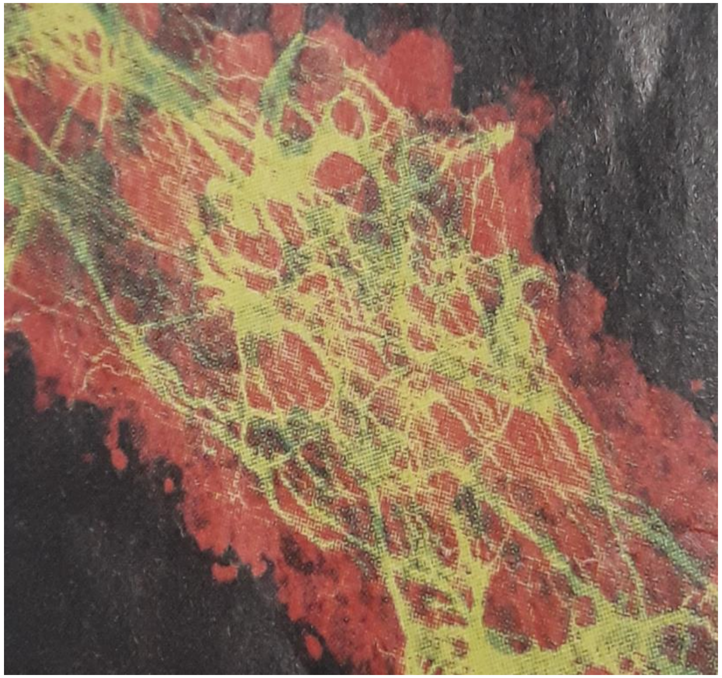
- **Differential interference contrast**
  - Like phase contrast microscopy, uses optical modifications to exaggerate differences in density, making the image appear almost 3-D.

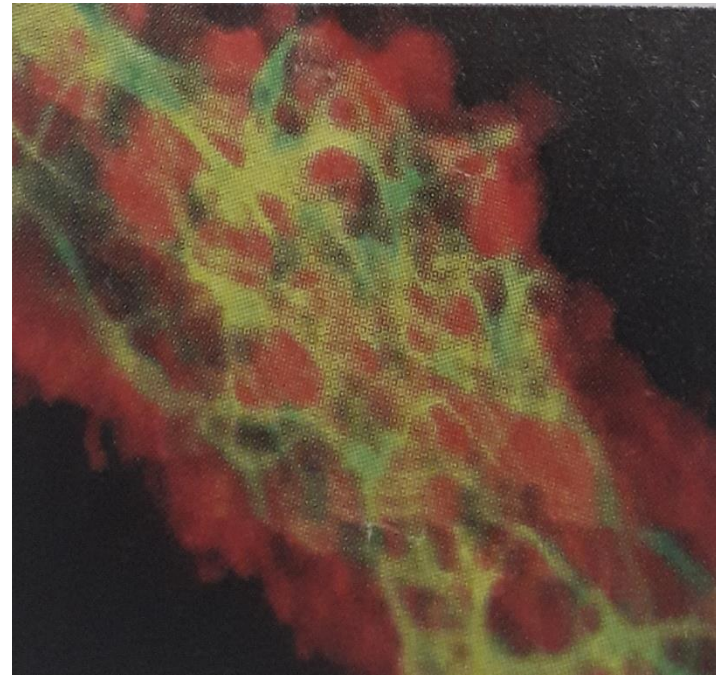
Human cheek epithelium through Differential interference contrast microscopy

- **Fluorescense**
  - Shows the locations of specific molecules in the cell by tagging the molecules with fluorescent dyes or antibodies.
  - These fluorescent substances absorb ultra-violet radiation and emit visible light.

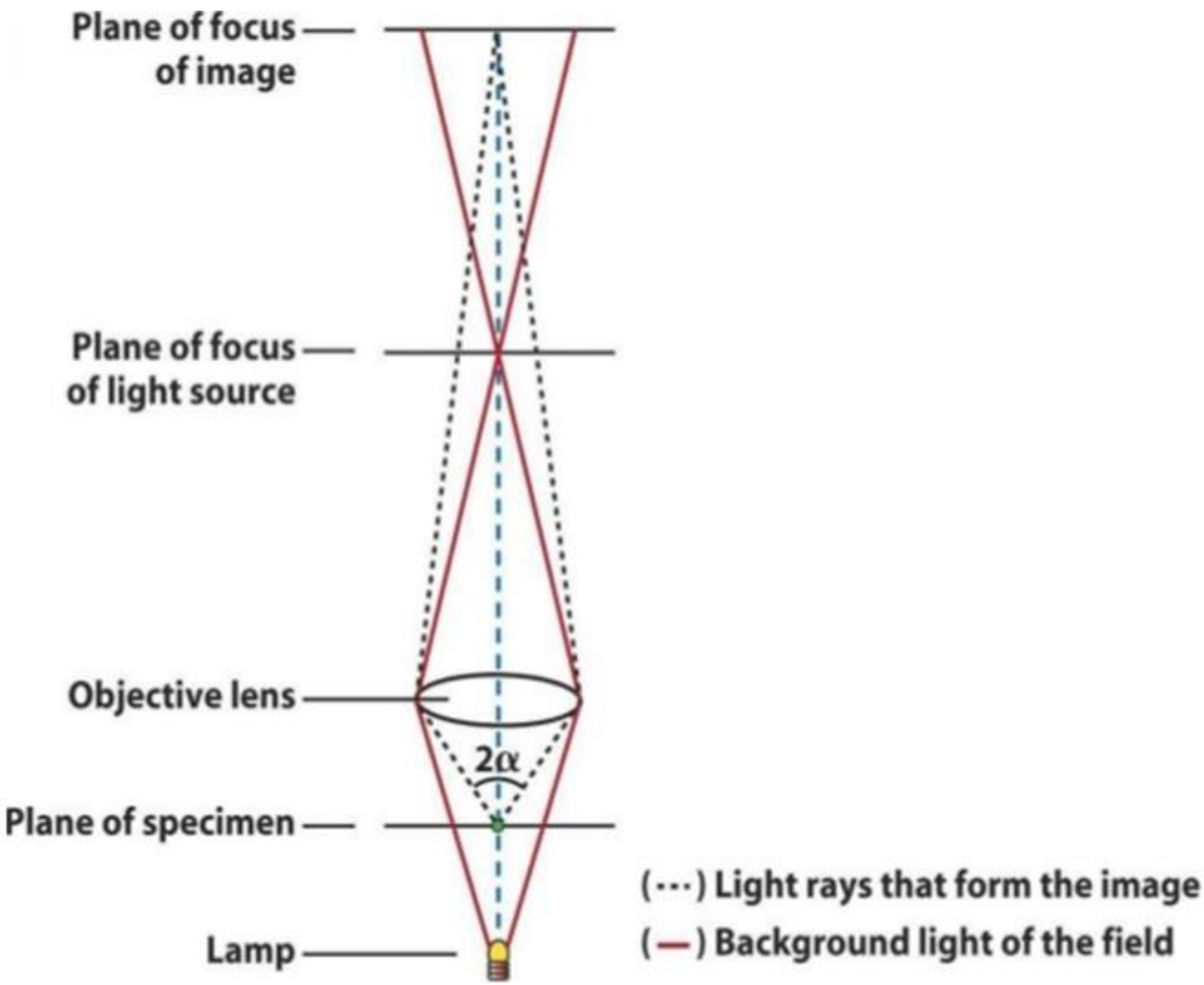


- **Confocal**
  - This a fluorescent “optical sectioning technique that uses a pinhole aperture to eliminate out-of-focus light from a thick sample, creating a single plane of fluorescence in the image.
  - By capturing sharp images at many different planes, a 3-D reconstruction can be created.

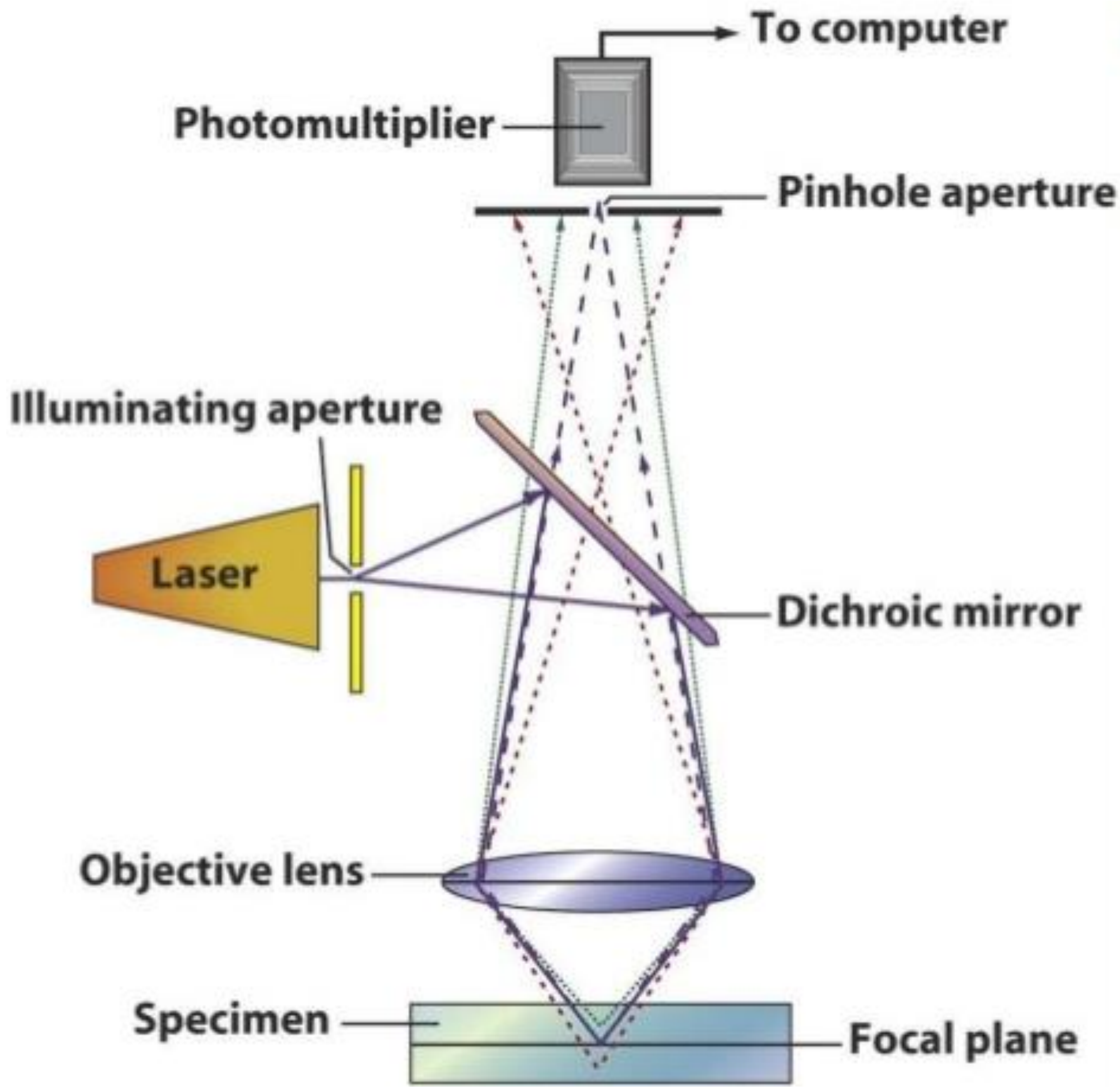
a) 

b) 

a) Confocal fluorescent micrograph of stained nervous tissues ;b) Standard fluorescent micrograph of stained nervous tissues. Adopted from Campbell 2008.



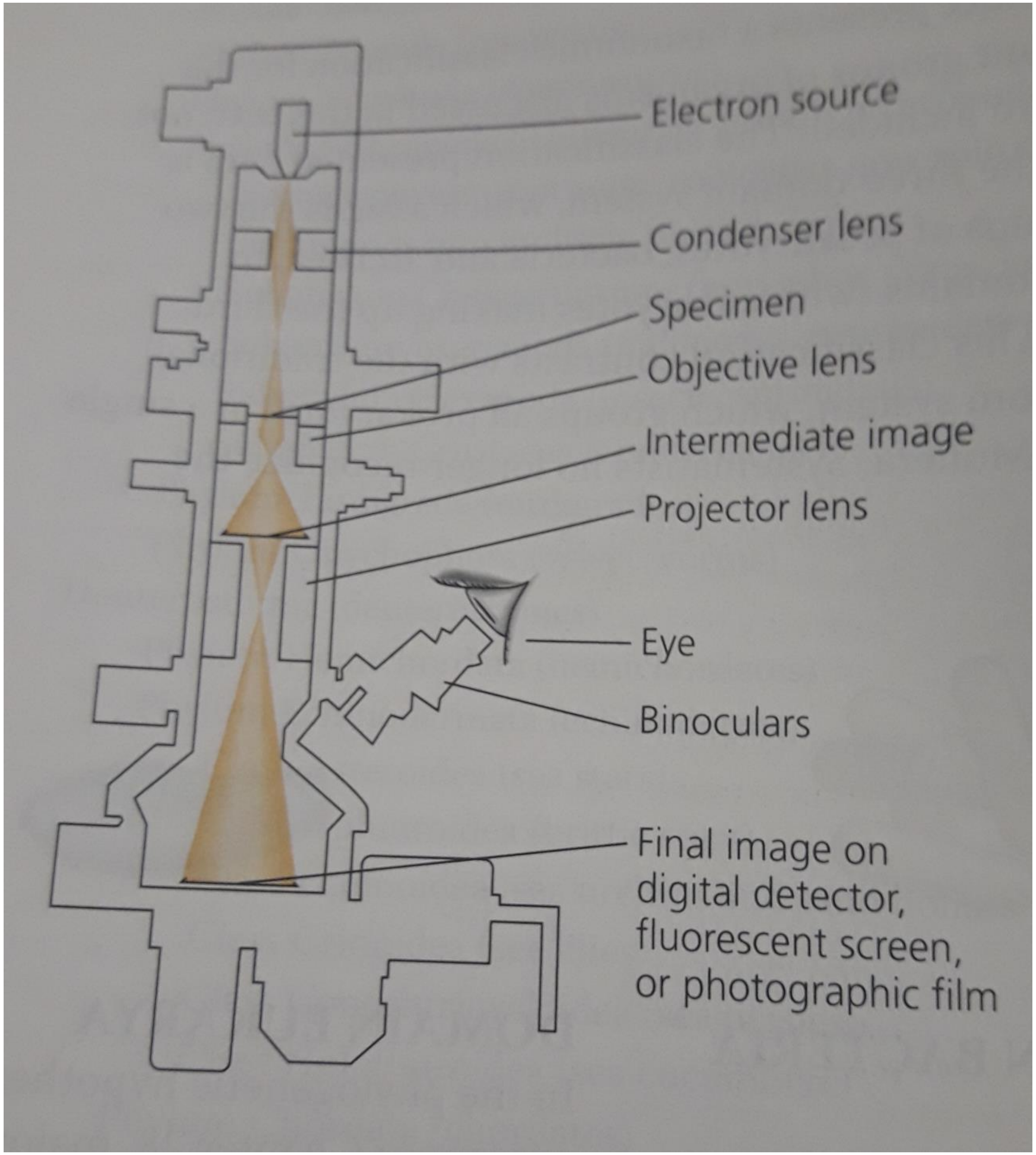
The paths taken by light rays that form the image of the Specimen and those that form the background light of the field.



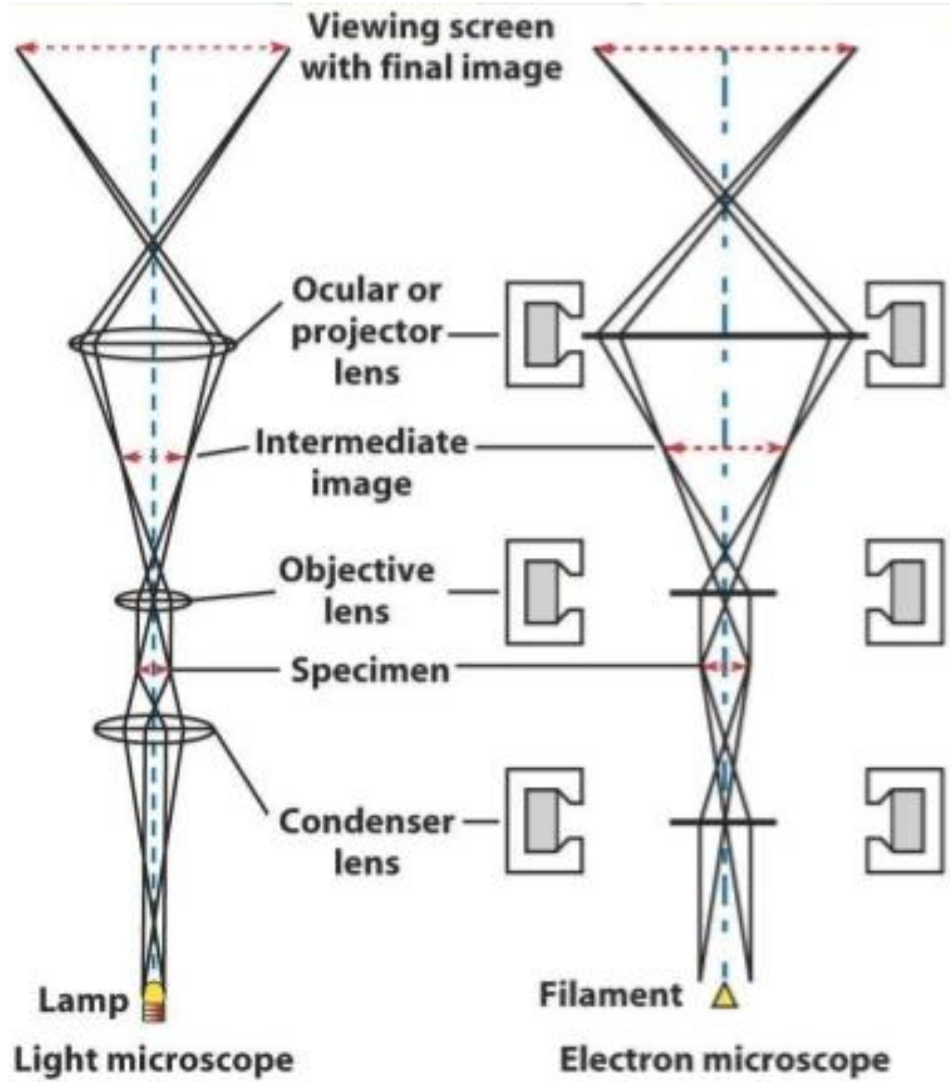
The light paths in a fluorescense confocal scanning light microscope.

Electron Microscopy

- Cell biology advanced rapidly in 1950s with the introduction of the electron microscope (EM).
- The electron microscope focuses a beam of electrons through the specimen or onto its surface.



Electron microscope



A comparison of the les system of a light and electron microscope

Types of Electron Microscopes

- There are two types of electron microscopes namely:
  - Scanning Electron Microscope (SEM)
  - Transmission Electron Microscope (TEM)

- Scanning Electron Microscope (SEM)
  - The scanning electron microscope is especially useful for studying surface of specimens.
  - The electron beam scans the surface of the sample which is usually coated with a thin film of gold.
  - The beam excites electrons on the surface and these secondary electrons are detected by a device that translates the pattern of electrons into an electronic signal to a video screen.

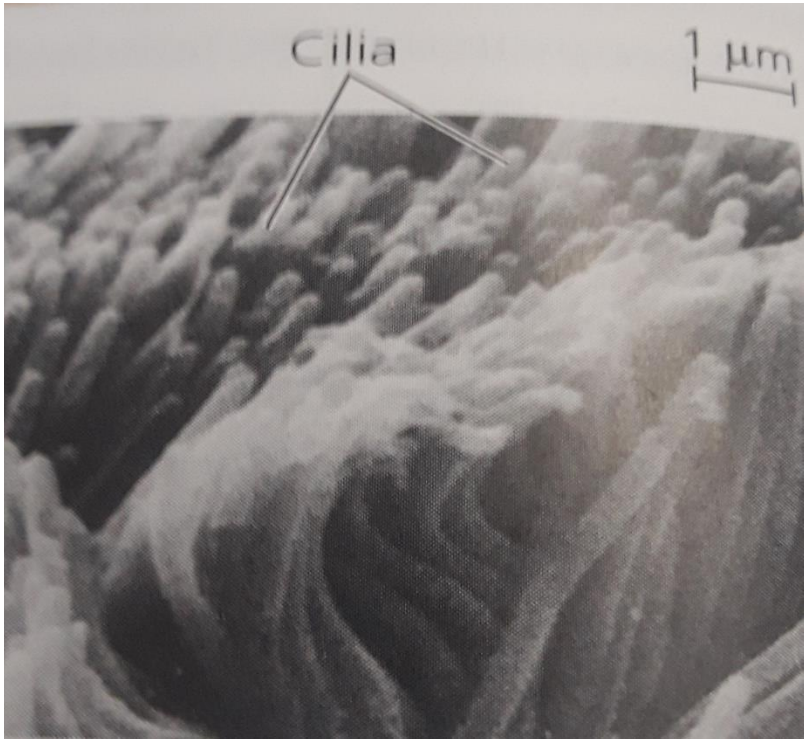
  - The result is an image of the specimens topography, which is 3-dimensional.

- **Transmission Electron Microscope (TEM)**
  - Transmission Electron Microscope (TEM) is used to study the internal ultrastructure of the cell.
  - The term *ultrastructure* refers to the cellular anatomy revealed by electron microscope.
  - The TEM aims an electron beam through a very thin section of the specimen.

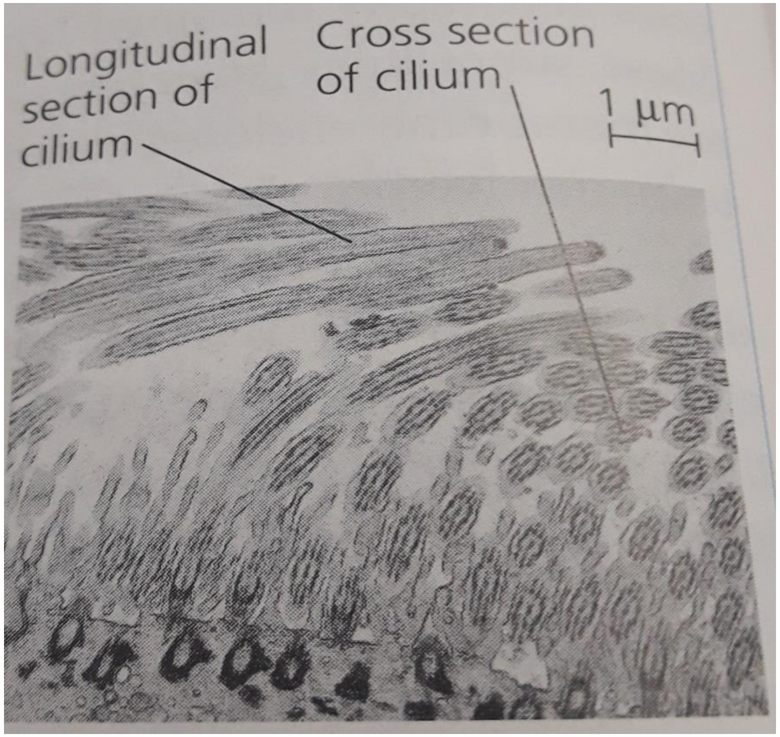
- The specimen is stained with atoms of heavy metals, which attach to certain cellular structure, thus enhancing the electron density of some parts of the cell more than others.
- The electrons passing through the specimen are scattered more in the dense regions so that few are transmitted.
- The image displays the pattern of the transmitted electrons.
- TEM uses electromagnetic lenses instead of glass lens to bend the paths of the electrons and focusing on a screen for viewing or onto a photographic film.

- Some microscopes are fitted with a digital camera which can be used to photograph the image or detector in the place of both screen and camera.

a)



b)



a) Micrograph taken with SEM showing a 3-D image of the surface of specimen. B) Micrograph taken with TEM showing a cross-section of cilium. This is a 3-D image of a rabbit trachea showing cilia

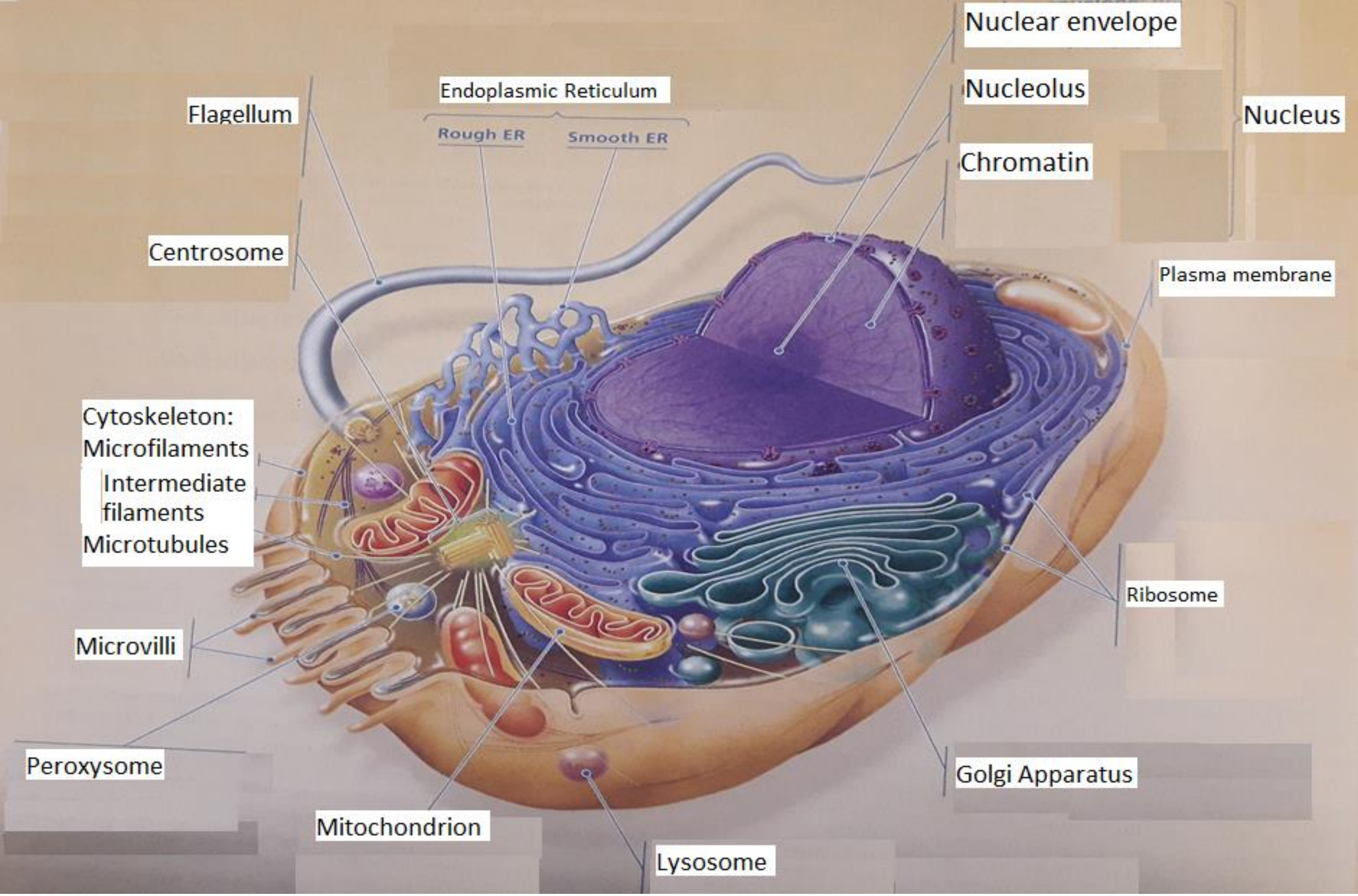
A View of the Eukaryotic Cell

- Eukaryotic cell has extensive and elaborately arranged internal membranes in addition to the plasma membrane.
- These internal membranes divide the cell into compartments or what are called organelles.
- The cells organelles are responsible for different functions.
- The membranes consist of a double layer of phospholipids and other lipids. Embedded in the lipid bilayer or attached on its surface are diverse proteins.

- The two extensively studied eukaryotic cells are animal and plant cells.

The Animal Cell

- The most prominent organelle in an animal cell is usually the nucleus.
- Most of the cell’s metabolic activities occur in the cytoplasm, which is the entire region between the nucleus and the plasma membrane. The cytoplasm contains many organelles and other cell components suspended in a semifluid medium the cytosol.
- Pervading much of the cytoplasm is a series of membranes called the endoplasmic reticulum (ER).

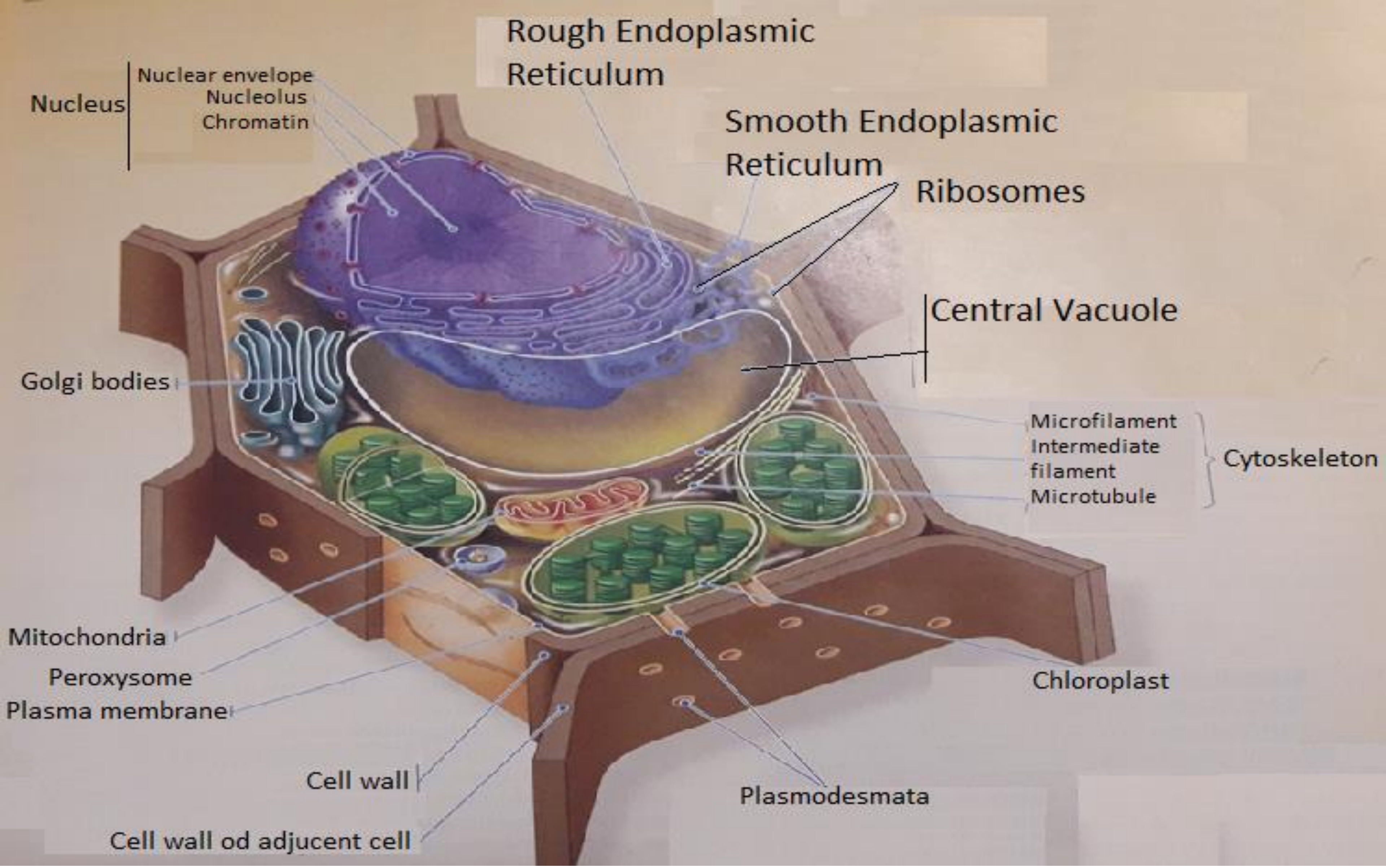


A diagram of the animal cell. Adopted from Campbell 2008. Relabeled for clarity.

- The following organelles are present in animal cells but absent in plant cells.
  - Lysosomes
  - Centrosomes, with centrioles
  - Flagella (but present in some plant sperm).

The Plant Cell.

- In addition to the same organelles found in the animal cell, plant cell has membrane enclosed organelles called the plastids.
- The most important type of plastid is the chloroplast, which carries out photosynthesis.
- Many plant cells have a large central vacuole, however, some may have one or more smaller vacuoles



A diagram of the plant cell. Adopted from Campbell 2008. Relabeled for clarity.

- The following organelles are present in plant cells but absent in animal cells.
  - Chloroplast
  - Central vacuole
  - Cell wall
  - Plasmodesmata

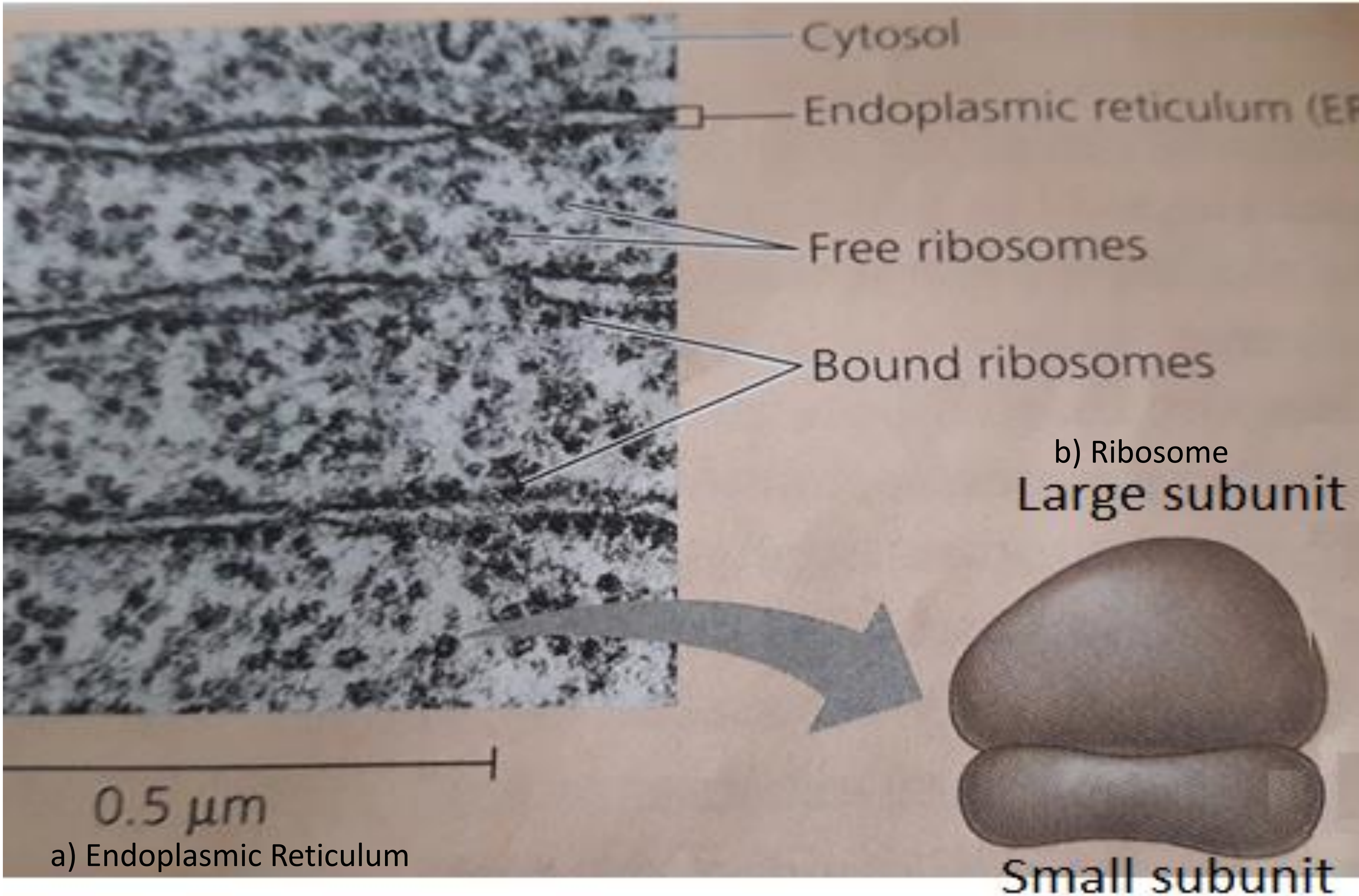
Functions of Different Cell Organelles

- **The nucleus**
  - Contains most of the genes. It is covered by the nuclear envelope, which separates it from the cytoplasm.
  - The nuclear envelop is a double membrane organelle.
  - The bilayer membrane is made of lipids with associated proteins and is separated by a space of 20 – 40 nm.
  - The nuclear envelope is perforated by pores and a protein structure called pore complex lines each pore and functions to regulate the entry and exit of proteins, RNA and other macromolecules.

- The nuclear side of the envelope is lined with a nuclear lamina that maintains the shape of the nucleus by supporting the nuclear envelope.
- There is also a nuclear matrix that extends throughout the nuclear exterior.
- Within the nucleus are the DNA that are organized into units called chromosomes, structures that carry the genetic material.
- Chromosomes are made of chromatins which are a complex of proteins and DNA. Chromatins when stained appear as a diffuse mass throughout the light and electron microscope.

- Each eukaryotic species has a characteristic number of chromosomes. For example human cell has 46 chromosomes in it nucleus, the exception are the sex cells (eggs and sperm), which have only 23 chromosomes in humans.
- A fruit fly
- has 8 chromosomes in each cell with 4 in the sex cells.
- An important structure in a nondividing nucleus is the nucleolus (plural: *nucleoli*), which appears through the electron microscope as a mass of densely stained granules and fibers adjoining part of the chromatin.
- Inside the nucleolus, a type of protein called ribosomal RNA (rRNA) are synthesized from instructions in the DNA.

- Ribosomes
  - Ribosomes are complexes made of ribosomal RNA and protein. Their function is to carry out protein sythesis (protein factories).
  - Ribosomes build proteins in two cytoplasmic locales. At any given time *free ribosomes* are suspended in the cytosol, while bound ribosomes are attached to the outside of the endoplasmic reticulum or nuclear envelope.



a) Endoplasmic Reticulum

b) Ribosome

- Ribosomes in the cytoplasm translate the genetic message carried from the DNA in the nucleus by mRNA into a polypeptide chain.
- Proteins made on free ribosomes function within the cytosol. Examples include enzymes that catalyze the first step of sugar breakdown during metabolism.
- Bound ribosomes make proteins that are meant for insertion into membranes, for packaging within certain organelles such as lysosomes, or for export from the cell (secretion).

Endoplasmic Reticulum (ER)

- ER is an extensive network of membranes within the cell that it accounts for more than half the total membranes in many eukaryotic cells.
- The word endoplasmic means within the cytoplasm and reticulum is a Latin word for “little” net.
- The ER is made of tubules and sacs known as citernae (from Latin word Cisterna, a reserve for liquid.
- There are two distinct though connected regions of the ER that differ in structure and functions.

- These are the smooth ER (SER) and rough ER (TER).
- The smooth ER is named so because it outer surface lacks ribosomes. The RER has ribosomes on its outer surface of the membrane and so appears rough through electron microscope.

Functions of SER

- The functions of SER varies with cell type. The functions include synthesis of lipids, metabolism of carbohydrates and detoxification of drugs and poisons.
- Enzymes of SER are important in the synthesis of lipids including oils, phospholipids and steroids.
- The steroids synthesized by SER in animals cells include but not limited to sex hormones and steroid hormones secreted by the adrenal glands.

- Other enzymes of SER help to detoxify drugs and poisons, especially in the liver.
- Detoxification of drugs involves the addition of hydroxyl group making them more soluble and easier to flush out of the body.
- SER also stores calcium ions and releases it when need arises.

Functions of RER

- Many types of cells secrete proteins produced by ribosomes attached to RER.
- For instance certain pancreatic cells synthesize the protein insulin on the ER and release this hormone to the bloodstream.
- It also synthesizes secretory proteins such as glycoproteins and keep them separate from proteins produced by free ribosomes.
- Brain twister: Describe how transport vesicles integrate the endomembrane system.

- The secretory proteins are also transported using transport vesicles.
- RER is also a membranous factory for the cell that grows in place by adding membrane proteins and phospholipids to its own membrane.

- **Golgi apparatus**
  - In the Golgi apparatus the proteins synthesized in ER are modified and stored and then sent to other destinations.
  - Golgi apparatus consists of flattened membranous sacs – cisternae-looking like a stack of bread.
  - There are vesicles lining the vicinity of the Golgi apparatus and they are involved in the transfer of materials between parts of the Golgi and other apparatus.

- **Lysosomes**
  - A lysosome is a membranous sac of hydrolytic enzymes that an animal cell uses to digest macromolecules.
  - Lysosomal enzymes work best in acidic environment found in lysosomes.
  - If a lysosome breaks open and releases its content the content does not act on the cytosol as cytosol has a neutral pH.

- Lysosomes also carry digestion of food, for instance, when amoeba engulf food through phagocytosis. The digestion products then pass into the cytosol and become nutrients to the cell.
- Lysosomes also use their hydrolytic enzymes to recycle the cells own organic materials a process called autophagy.

Question: Briefly describe the process of autophagy.

- **Vacuoles**
  - Function of vacuoles vary in different kinds of cells.
  - Food vacuoles are made by phagocytosis. Fresh water protists have contractile vacuoles that pump excess water out of the cell thereby maintaining a suitable concentration of ions and molecules inside the cell.
  - In plant and fungi, which lack lysosome, vacuoles carry out hydrolysis in addition to other functions.
  - Plant cells have the central vacuole, which hold reserves of important organic compounds such as proteins.

- It also serves as the plants repository of inorganic ions such as potassium and chloride.
- Plant cells also use the central vacuole as a disposal site for metabolic by-products that would endanger the cell if allowed to accumulate in the cytosol.
- Some vacuoles contain pigments that color the cell, such as the red and blue pigments of petals that help attract pollinating insects to flowers.
- Vacuoles may also help to protect the plant against predators by containing compounds that are poisonous or unpalatable to animals.

– Vacuoles of plants help plants to grow by absorbing water enabling the cell to become larger.

- Mitochondria
  – Mitochondria are found in all eukaryotic cells including those of plants, animals, fungi and most protists (protozoans, most algae, and often some fungi {such as slime molds})
  – Its in the mitochondria where cellular respiration.
  – Some cells have a single large mitochondria but more often a cell has hundreds or even thousands of mitochondria.

- Mitochondria is enclosed by a phospholipid membrane bilayer with a collection of embedded proteins.
- The outer membrane is smooth but the inner membrane is folded into cristae.
- The inner membrane divides the mitochondria into 2 compartments namely:
  - Intermembrane space
  - Mitochondrial matrix
- The matrix contain different enzymes, mitochondria DNA and ribosomes.

- Enzymes in the matrix catalyze respiration.
- The cristae is highly folded giving the inner mitochondrial membrane a large surface area for enhanced cellular respiration.

- **Chloroplast**
  - Chloroplast is a specialized member of closely related plant organelles called plastids.
  - Chloroplast contain chlorophyll, along with enzymes and other molecules that function in photosynthesis.
  - Inside the chloroplast is a membranous system in the form of flattened, interconnected sacs called thylakoids.

- In some regions the thylakoid are stacked on each other to give a structure called the *granum* (plural, grana).
- The fluid outside the thylakoids is the stroma, which contains the chloroplast DNA and ribosomes as well as many enzymes.
- The membranes of the chloroplast divide the chloroplast divide chloroplast space into three compartments:
  - The intermediate space
  - The stroma
  - The thylakoid space.

- Peroxisomes
  - The peroxisome is a specialized metabolic compartment that is bounded by a single membrane.
  - Peroxisomes contain enzymes that transfer hydrogen from various substrates to oxygen, producing hydrogen peroxide (H_2O_2) as a by-product, from which the organelle derives its name.
  - Some peroxisomes use oxygen to break fatty acids down into smaller molecules that can then be transported to mitochondria, where they are used as fuel for cellular respiration.

– Peroxisomes in the liver detoxify alcohol and other harmful compounds by transferring hydrogen from the poisons to oxygen.

– Specialized peroxisomes called *glyoxysomes* are found in the fat-storing tissues of plant seeds. The organelles contain enzymes that convert fatty acids to sugar, which the emerging seedling uses as a source of energy and carbon until it can produce its own sugar by photosynthesis.

Assignment

- Discuss the role of cytoskeletons.
- Discuss the structure of the plant cell wall.

-END-