BIO 101

Cellular Basis of Life

Instructor:

Dr. Sharvan Sehrawat

+Two tutors

(Swati and Aswathy)

Class timings:

Tuesday (Tutorial), Wednesday, and Thursday

10 am-10.55 am

Office : AB1-1F10

Suggested Text Books

BIOLOGY (8-10th Edition)

Campbell and Reece

(http://www.course-notes.org/biology/slides/campbells_biology_8th_edition)

Or,

LIFE: THE SCIENCE OF BIOLOGY (8th Edn.)

Sadava, Purves, Orians, and Heller

It is recommended that you should use **atleast** one textbook.

Slides of the lectures will be uploaded in the IISER Mohali Moodle Server

@

IISER Mohali Computer Center Webpage

(http://www.iisermohali.ac.in/compcentre/html/index.html)

Grading Scheme

1st Mid Sem	:	20
2nd Mid Sem	:	20
End Sem	:	50
Attendance and/or quizzes	:	10

100% attendance is expected

Grading

A	**(10)** Grasp all of the syllabus, can answer most questions without hints
B	**(8)** Good understanding of material, can answer most questions given a few hints
C	**(6)** Satisfactory/Passing performance, has shown the capacity to learn materials that are in the syllabus
D	**(4)** Marginal, student has failed to grasp most aspects of the syllabus
F	**(0)** Must repeat the course

Biology

Investigation about the life.

(We recognize life by what we do)

The central theme in biology -

Ask questions about the living world and try to **seek** scientific explanations.

!! Biologists' questions can be ambitious !!

- How a single cell develops into multicellular organism…
- Why and how do we fall sick….
- How to cure, treat or manage a disease……
- How our mind works…..
- How the different forms of life interact with each other…..

------- Biologist's ambition-

Describing the living systems----

Unraveling the mysteries of the living systems

With the help of our knowledge in physics, chemistry, and mathematics…….

SCOPE: Biologists' domains of investigation:

- **Cell Biology**
- **Biochemistry and Molecular Biology**
- **Genetics**
- **Developmental Biology**
- **Immunology**
- **Neurobiology**
- **Microbiology**
- **Plant Biology**
- **Ecology**
- **Evolutionary Biology**
- **Systems biology**
- **Computational and Theoretical Biology**

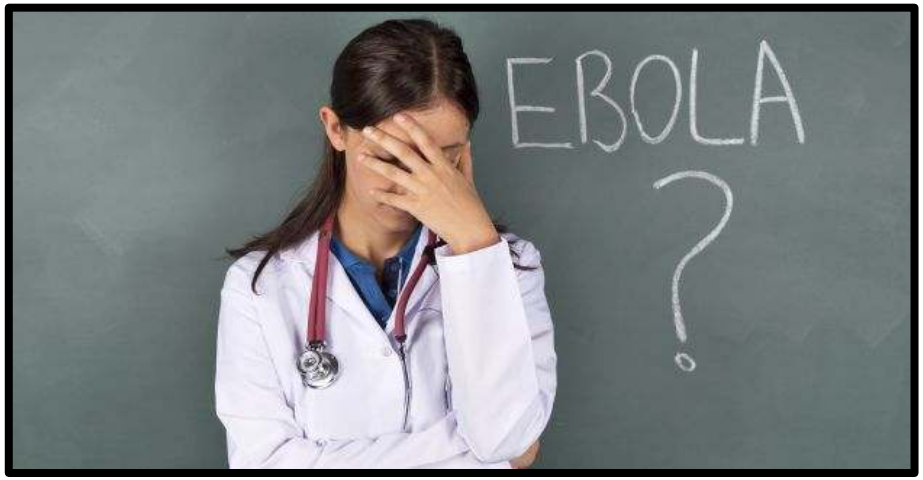
……

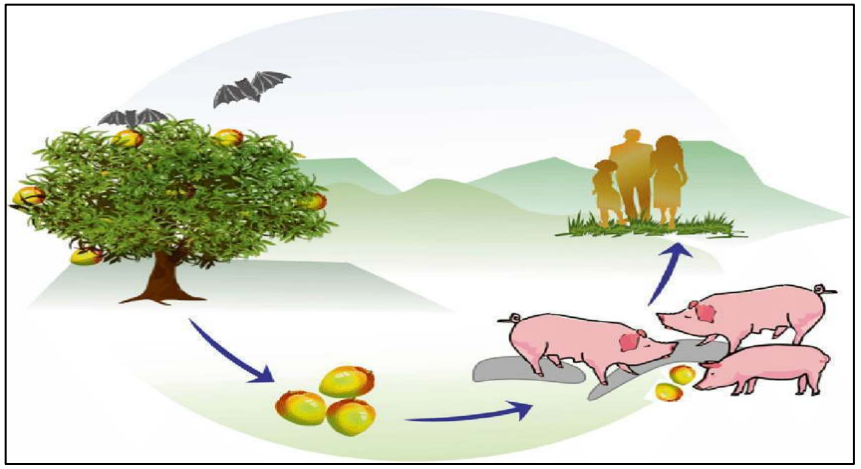
Most efforts in Biology and related disciplines

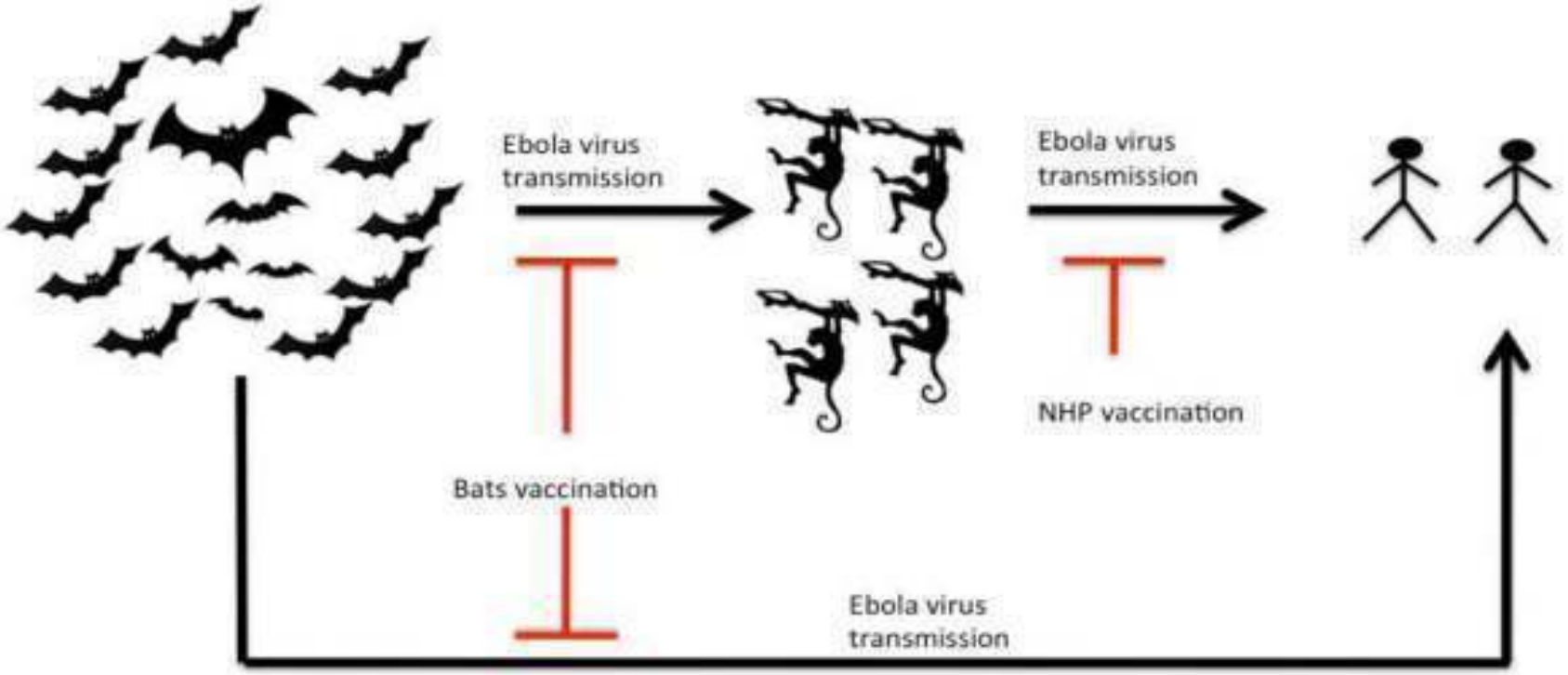
(to make life better)

- **Prevention and eradication of diseases….**
- **Drug discovery……..**
- **Improved production of better quality agriculture and dairy products……..**
- **Keeping environment safe**
- **Etc……..**

Intervention







How to investigate or study Biology ?

- ✓ Ask a question
- ✓ Do some research
- ✓ Draw a hypothesis
- ✓ Do experiments
- ✓ Draw a conclusion

How to design an experiment ?

- ✓ Control group
- ✓ Sufficiently large group size
- ✓ Blind experiment

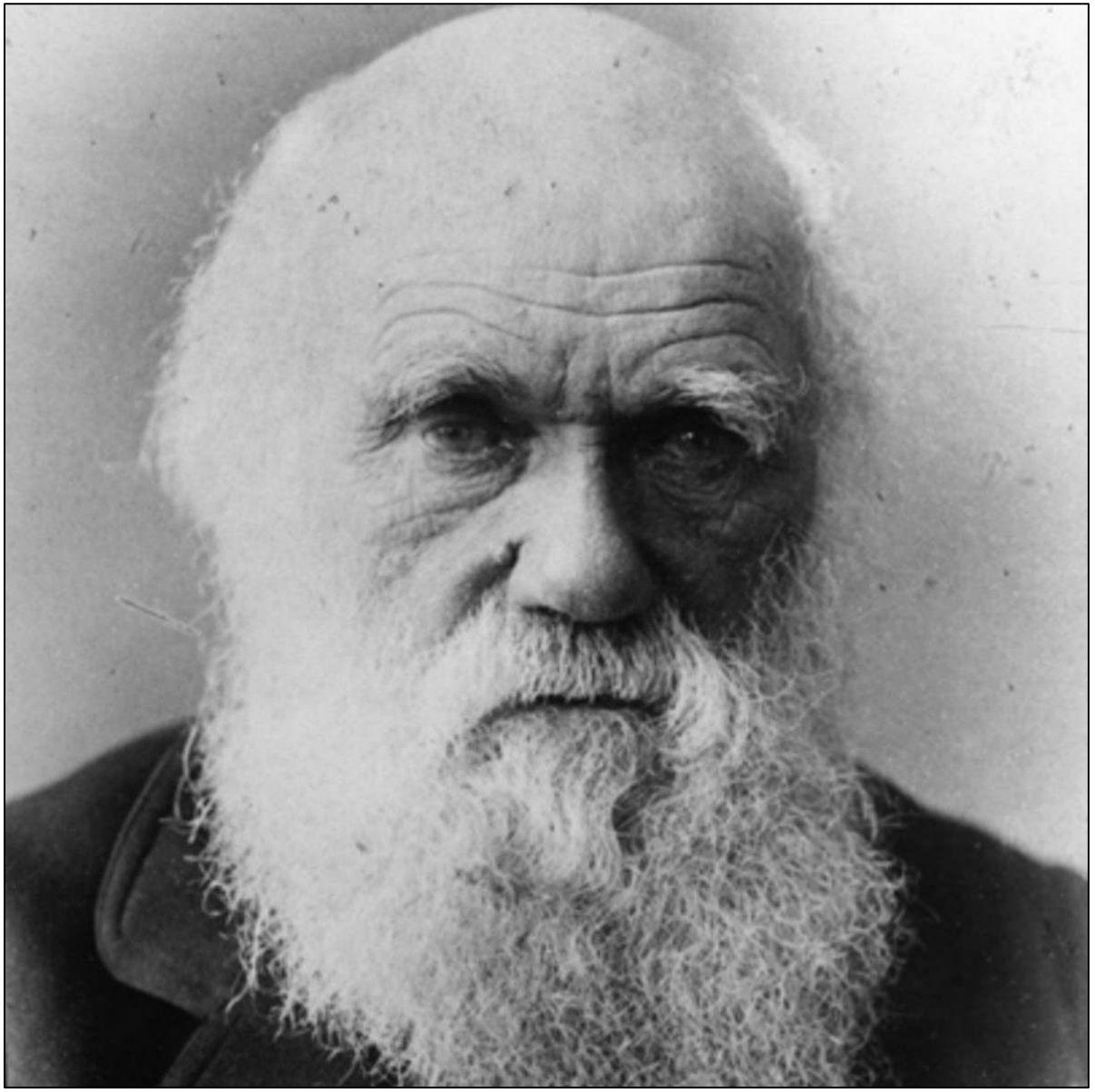
Characteristics of Life : What is it?

- Made of cell or cell products
- Consume energy and other materials
- Responsiveness
- Ability to maintain homeostasis
- Reproduce
- Species evolve in response to environmental changes

✓ Life is what we do

What is in the Tool Box of Biologists

- Curiosity and observations



Charles Darwin 1809-1882

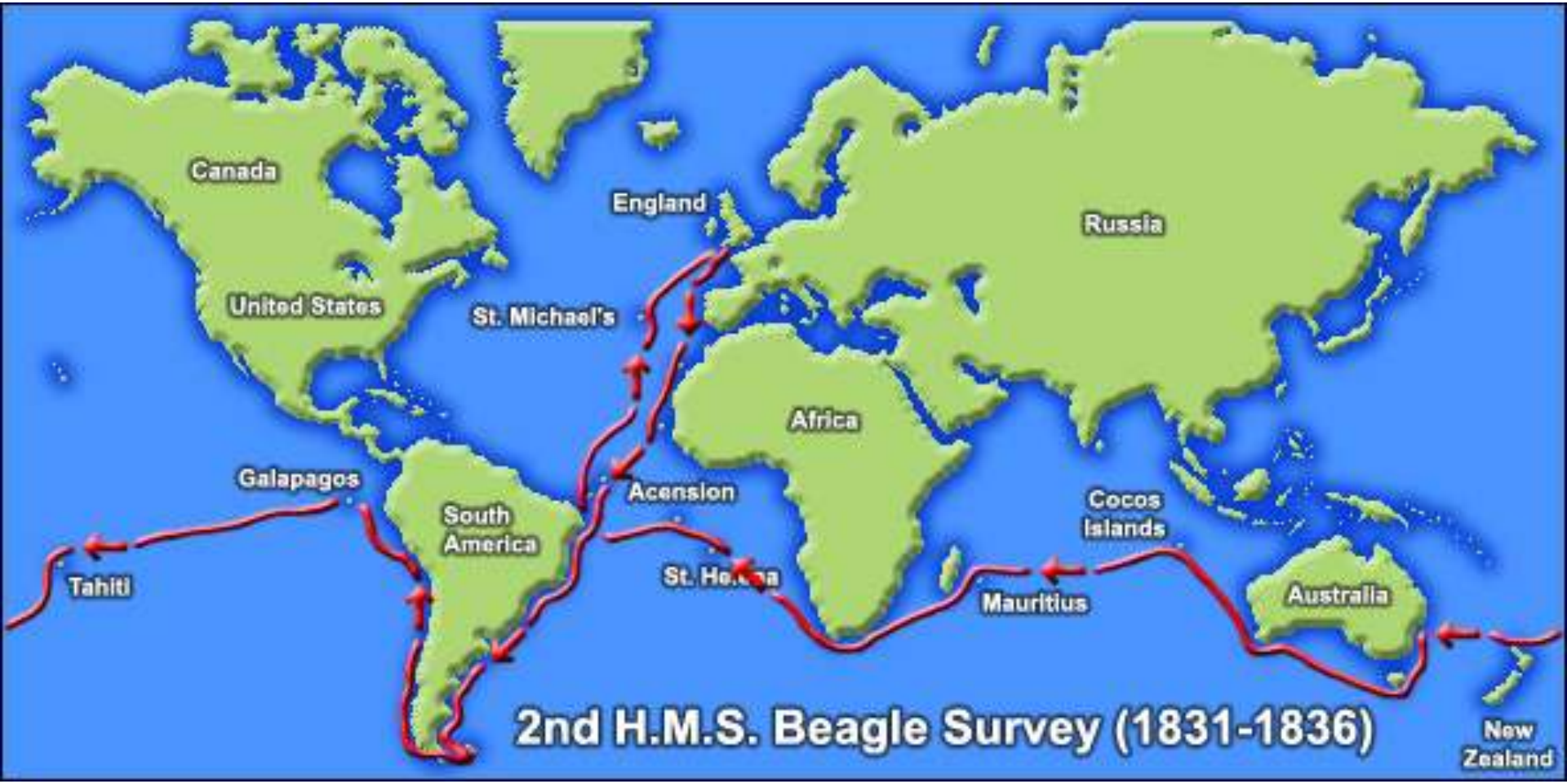
The importance of Darwin's voyage

- **Species vary globally,**
- **Species vary locally,**
- **Species evolve overtime**

"The voyage of the 'Beagle' has been by far the most important event in my life, and has determined my whole career;

I have always felt that I owe to the voyage the first real training or education of my mind; I was led to attend closely to several branches of natural history, and thus my powers of observation were improved, though they were always fairly developed."

– Autobiography



The Second Voyage of the HMS *Beagle*, 1831 – 1836

Importance of Darwin's voyage

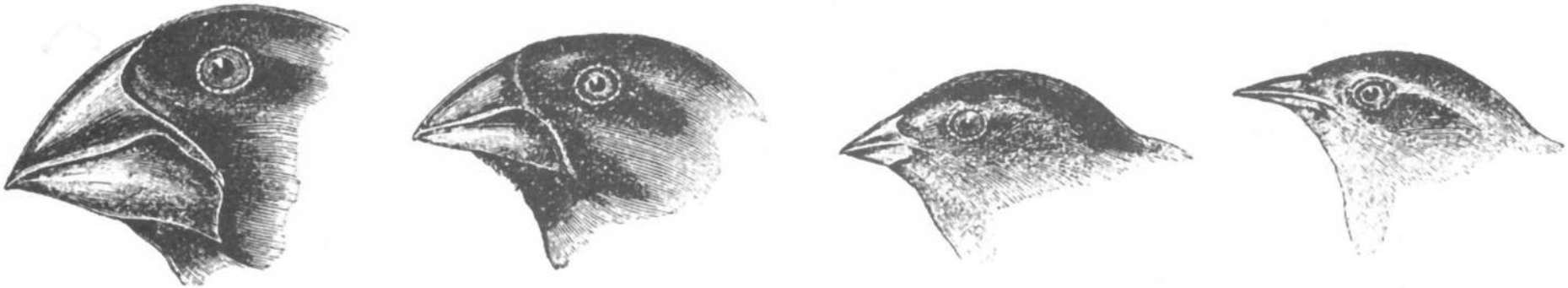
Darwin visited **Brazil's** Atlantic rainforest before logging began, and discovered the incredible diversity of its flora and fauna, which differed greatly from Great Britain's.

In Argentina he found fossils of extinct mammals and discovered that they were different from living species but often closely resembled them.

He discovered that animals in different parts of **South America** resembled each other, but not completely – they exhibited distinct differences.

In the **Galapágos Islands** he discovered that animals like birds and turtles differed slightly from one island to another.

Finches



Short: feeding on dead trees, **Long and sharp**: to hold nuts

Long neck and short neck of turtles

- **Species vary globally,**
- **Species vary locally,**
- **Species evolve overtime**

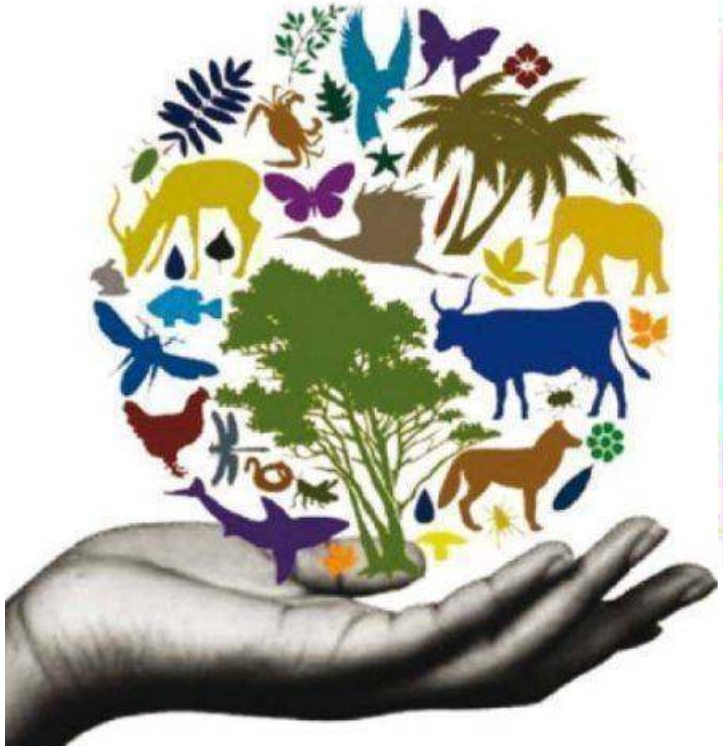
Theory of natural selection

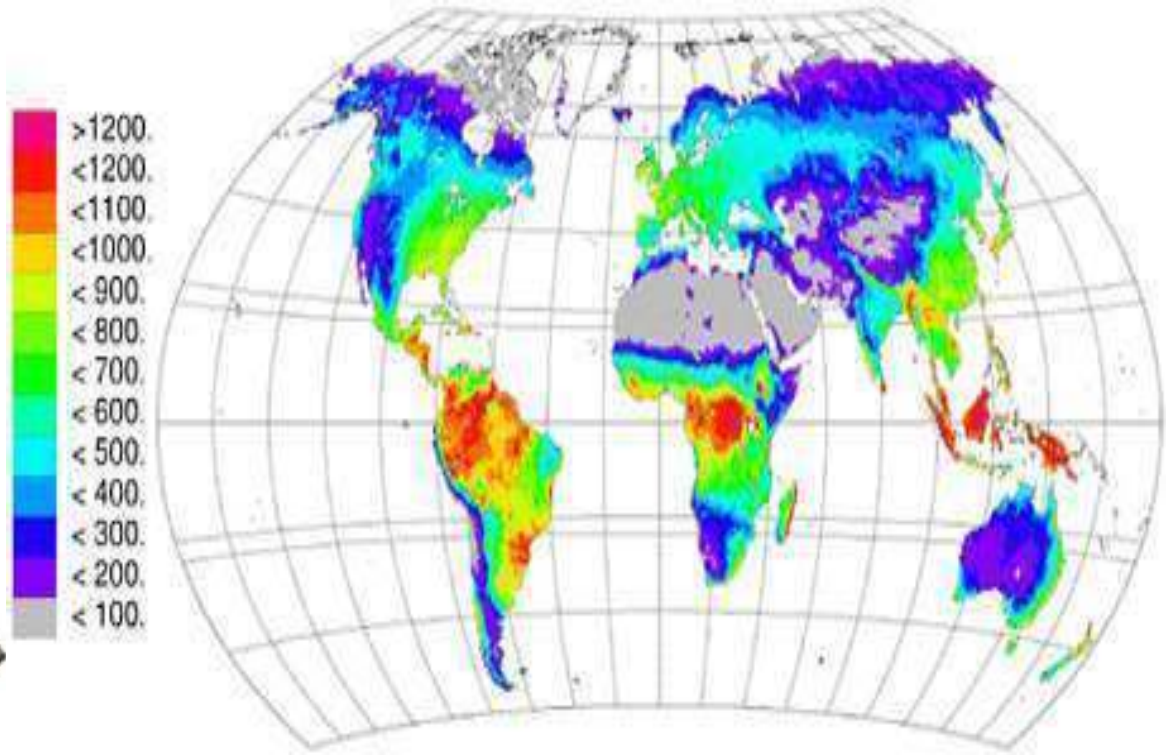
Natural selection is the "principle by which each slight variation [of a trait], if useful, is preserved or The process by which random evolutionary changes are selected by nature by consistent, orderly and non-random ways.

On the origin of species

Biodiversity

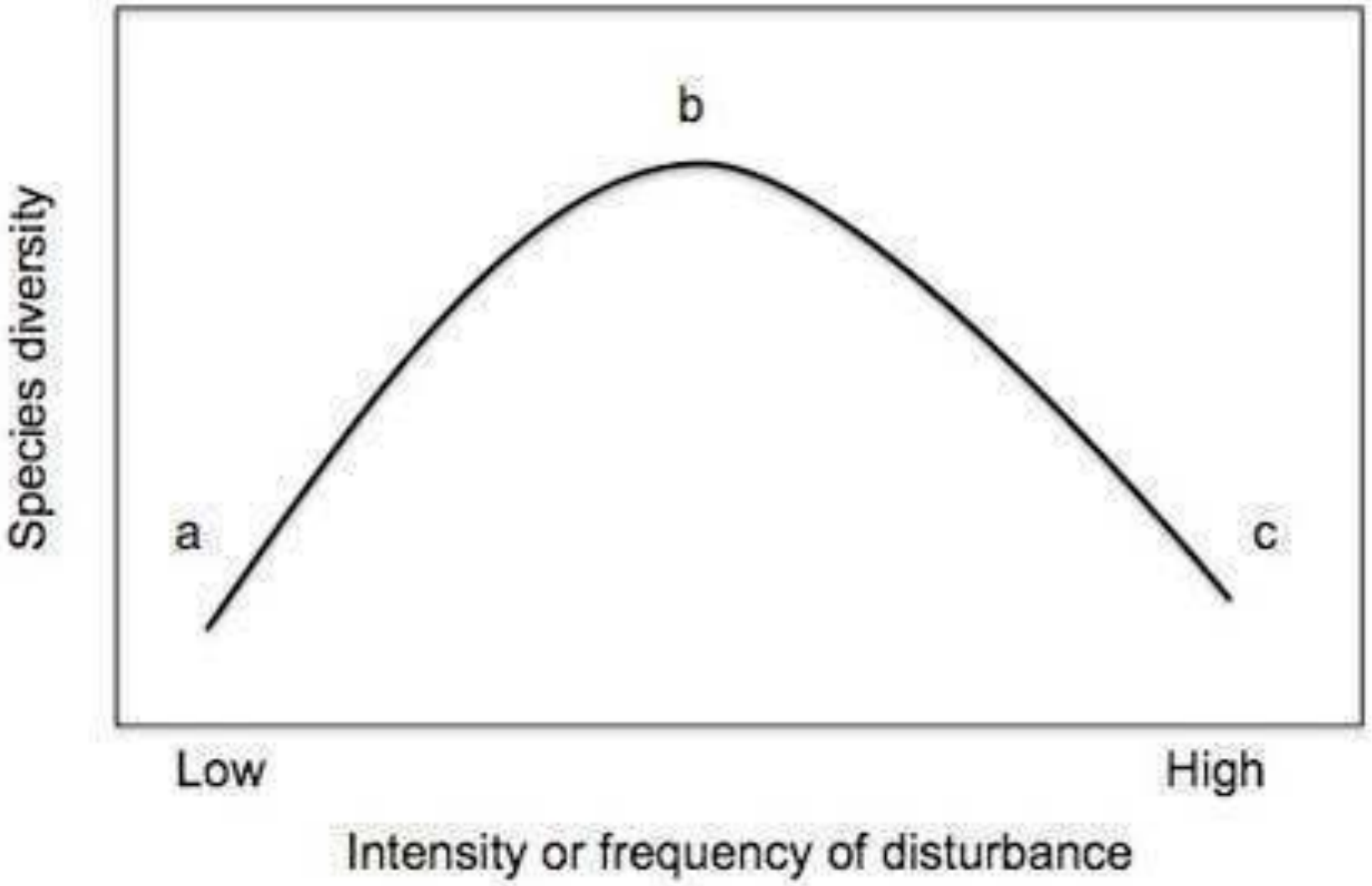
the variety of plant and animal life in the world or in a particular habitat





Genetic biodiversity, Species biodiversity, Ecosystem biodiversity

Disturbance vs Diversity



Importance

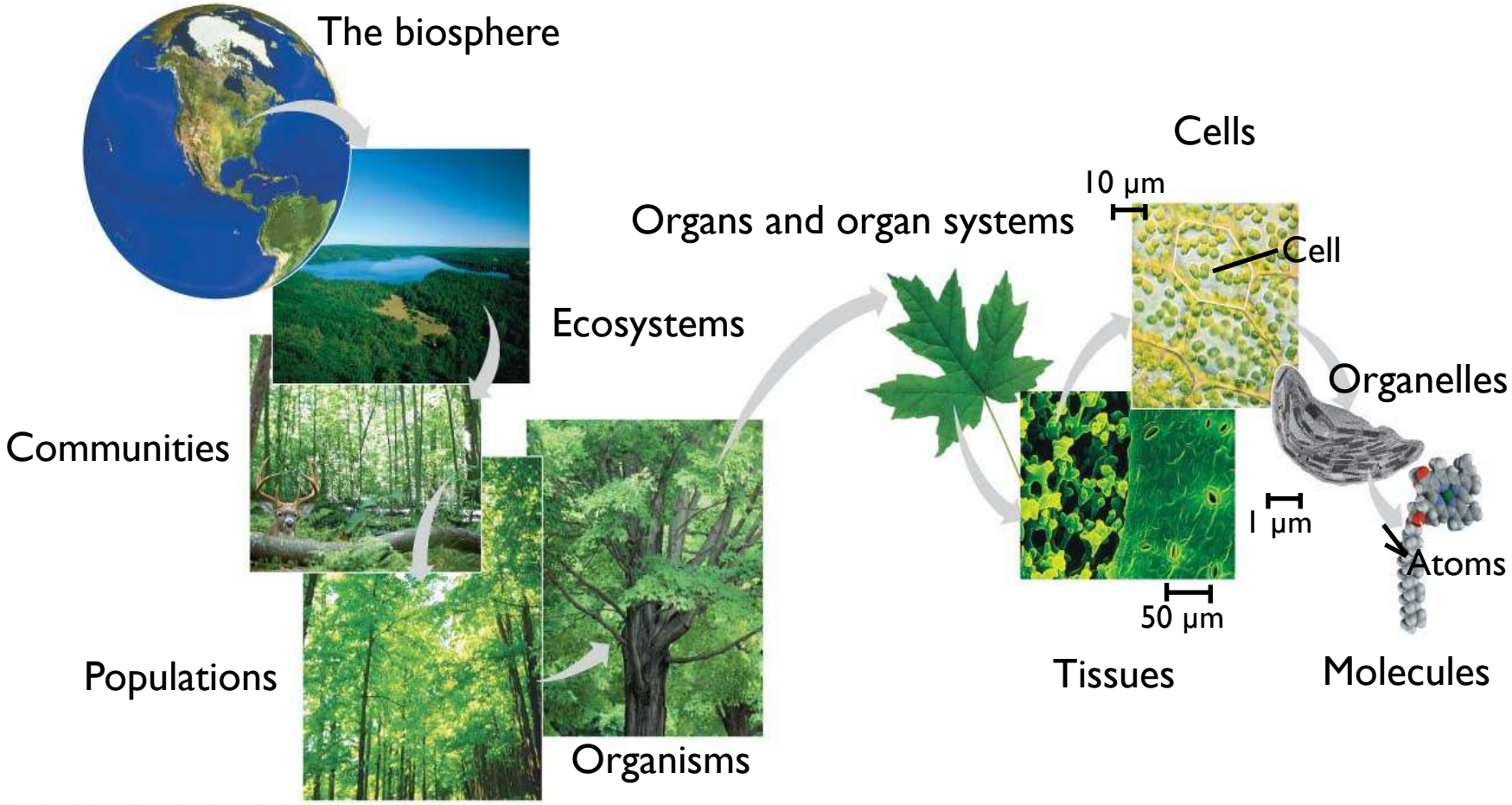
- Balance our ecosystem
- Aesthetic value
- Various food varieties
- Medical use

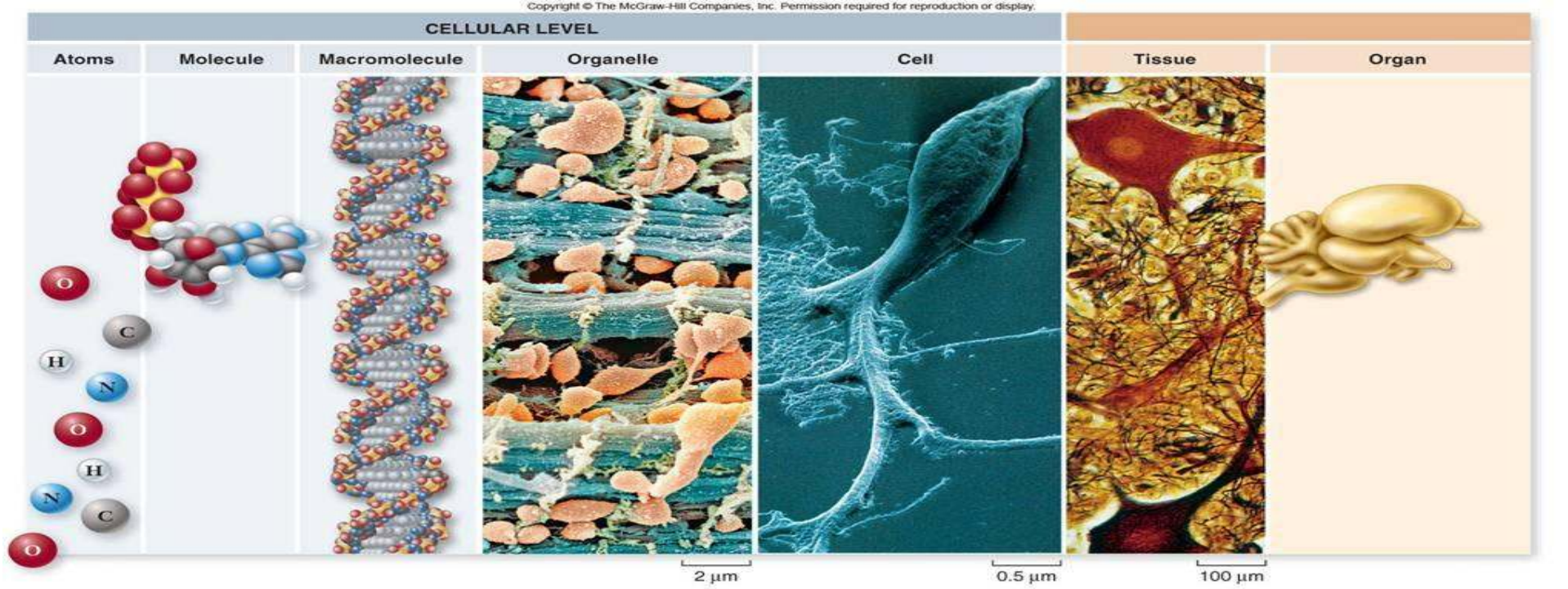
Loss of biodiversity

- High population rate
- Pollution
- Natural disaster
- Poaching
- Deforestation
- Exotic species
- Agriculture

Biological landscape

- Life can be studied at different levels
- From molecules to the entire living planet
- Different levels of **biological organization**





(organelle): © S. Gschmeissner/SPL/PUBLIPHOTO; (cell): © Lennart Nilsson/Albert Bonniers Förlag AB; (tissue): © Ed Reschke; (organism): © Russell Illig/Getty Images; (population): © Jeremy Woodhouse/Getty Images;

Biological landscape

Biosphere : Life on earth

Ecosystem : Living things + nonliving things? (Area)

Community : Arrays of organims

Population : Individuals of a spp (Area)

Organism : Individual living thing

Organ/s : Body part to perform function

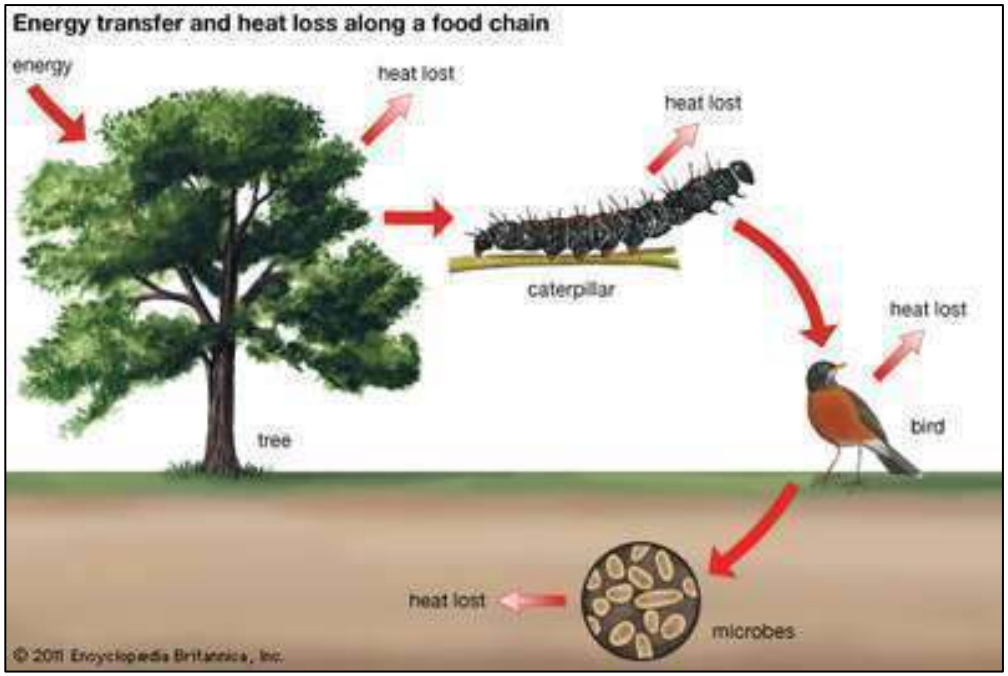
Tissues :Group of cells working together

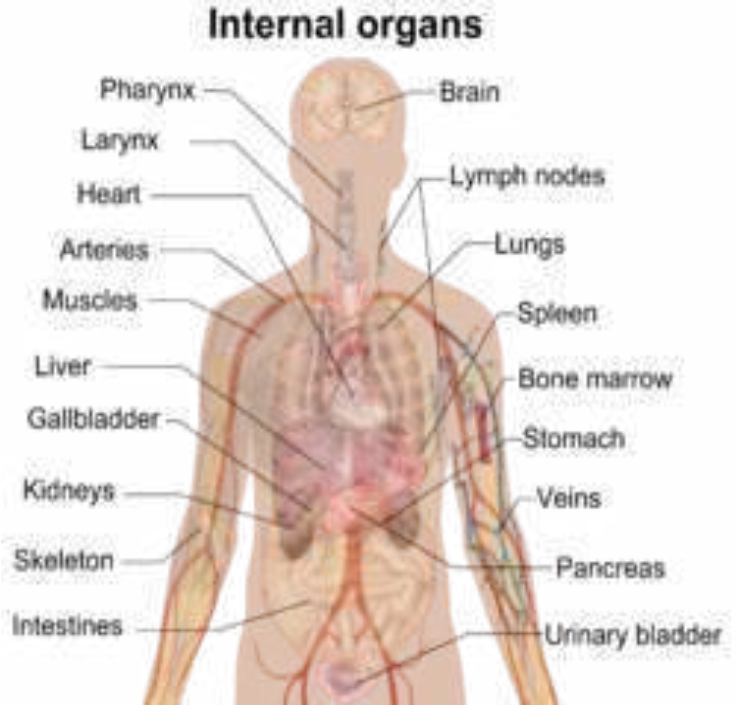
Cell : Life's fundamental unit with a structure and function

Organelles : Components of cell

Molecules : n (atoms)

Examples

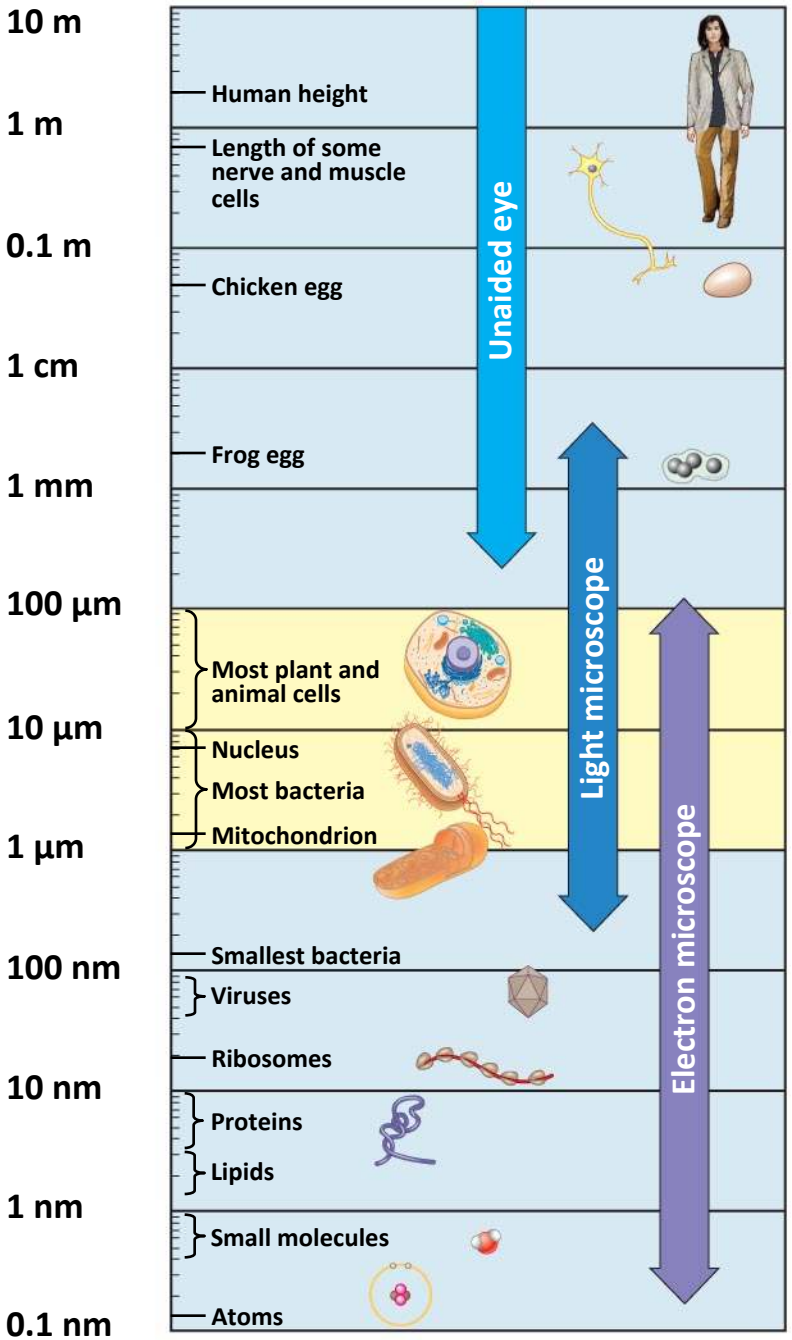




Community: Arrays of organims

Organs: an ensemble of similar cells and their extracellular matrix from the same origin that together carry out a specific function.

Fig. 6-2



What is in the Tool Box of Biologists

- Curiosity and observations
  - Retinal cells (Rods and Cone) are at work here
  - Rods for intensity –Cones for color
- Microscopy:

  -To magnify objects

  -Separate details

  -Render details visible to human eyes or camera

  Broad categories of microscopy
  - Light microscopy
  - Fluorescent microscopy
  - Electron microscopy

Fig. 6-3ab

TECHNIQUE

RESULTS

Brightfield (unstained specimen)

- Most elementary
- Sample illuminated from below and observed from above with white light,
- Contrast in the sample is caused by attenuation of the transmitted light in dense areas of the sample.

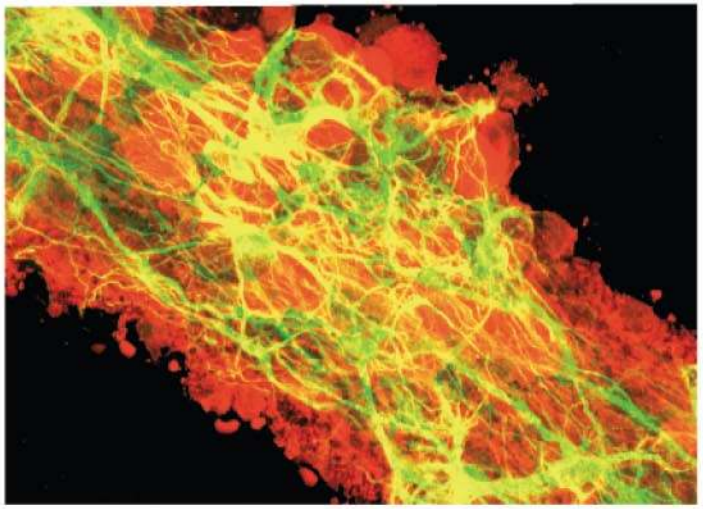
Brightfield (stained specimen)

Phase-contrast

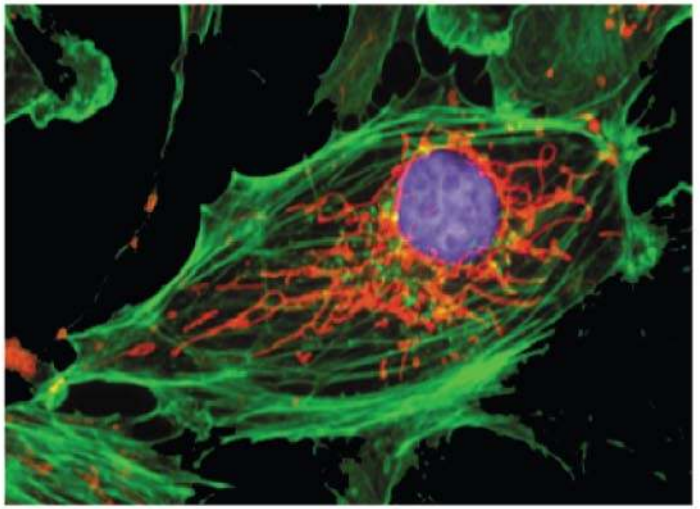
Utilizing two characteristics of light,
- Diffraction
- Interference

Observed without staining

Confocal



Fluorescence



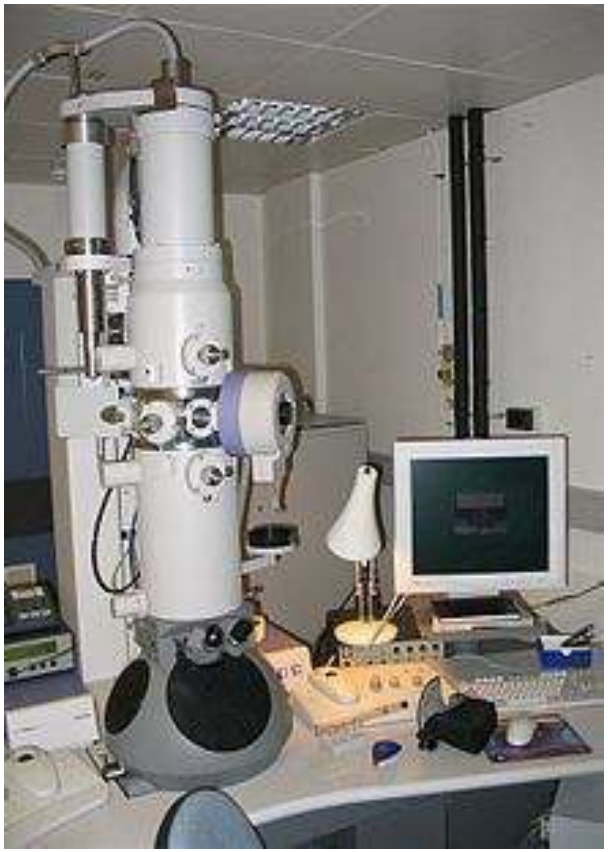
High contrast, High Specificity, Quantitative, Live cell Imaging

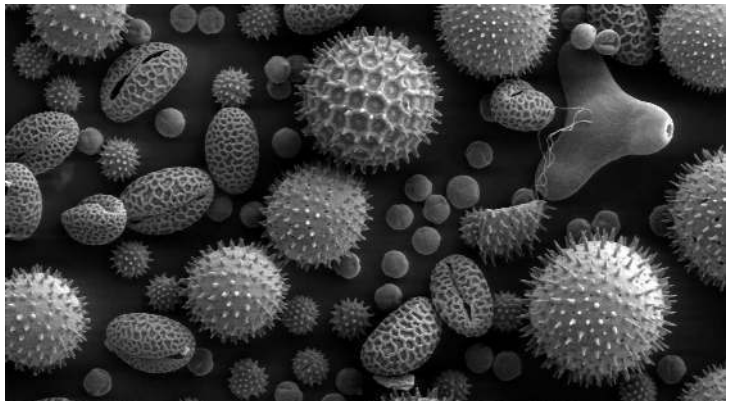
Electron micrscopy

- A beam of electron for illumination
- Wavelength 100,000x shorter than visible light

→High resolution

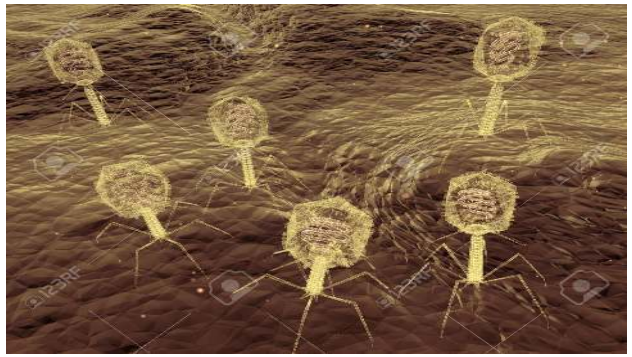
→10 x10^6 times amplification (Light microscope= 2000x)





Pollen grains

Virus



Studying Biology at Various levels

Molecules

Cells

Organisms

Biosphere

The Power of Reductionism

Reductionism is the reduction of complex systems to simpler components that are more manageable to study

For example,

the molecular structure of DNA

How a protein functions

How cells behave in a cell culture

The Limitations of Reductionism

- An understanding of biology balances reductionism with the study of emergent properties
  - For example, new understanding comes from studying the interactions of DNA with other molecules
  - How two different molecules of protein interact
  - How more than two cells talk to each other
  - Interaction of animals, plant and environment

Cells are an organisms' basic units of structure and function

- The cell is the lowest level of organization that can perform all activities required for life
- All cells:
  - Are enclosed by a membrane
  - Use DNA as their genetic information
- The ability of cells to divide is the basis of all reproduction, growth, and repair of multicellular organisms

What is in the Tool Box of Biologists

- Vision
  - Retinal cells (Rods and Cone) are at work here
  - Rods for intensity –Cones for color
- Microscopy:

  -To magnify objects

  -Separate details

  -Render details visible to human eyes or camera

  Broad categories of microscopy
  - Light microscopy
  - Electron microscopy
  - Fluorescent microscopy
- Procedure for performing cell culture

Microscopy to visualize cell and cell organelles

LMs can magnify effectively to about 1,000 times the size of the actual specimen

Various techniques enhance contrast and enable cell components to be stained or labeled

Most subcellular structures, including **organelles** (membrane-enclosed compartments), are too small to be resolved by an LM

Therefore electron microscopes are used:

Two basic types of **electron microscopes (EMs)** are used to study subcellular structures

Scanning electron microscopes (SEMs) focus a beam of electrons onto the surface of a specimen, providing images that look 3-D

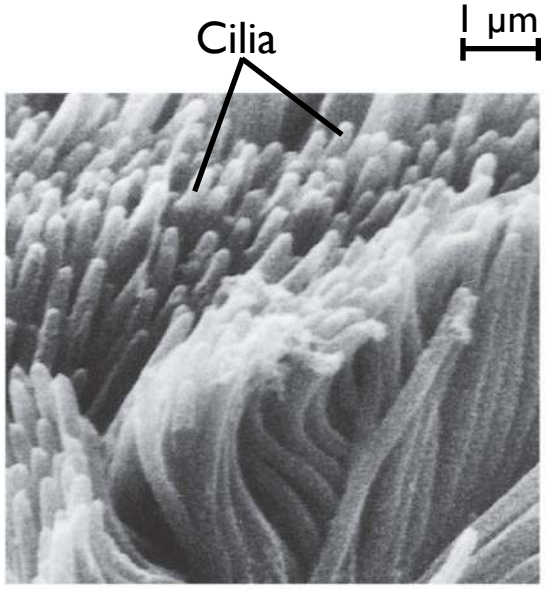
Transmission electron microscopes (TEMs) focus a beam of electrons through a specimen

TEMs are used mainly to study the internal structure of cells

TECHNIQUE

RESULTS

(a) Scanning electron microscopy (SEM)



(b) Transmission electron microscopy (TEM)

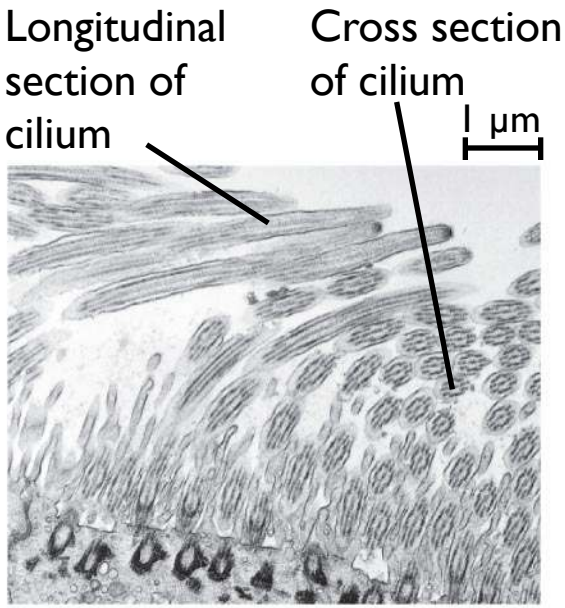


Fig. 6-4

Basics of Cell Culture

- **Cell culture is the process by which prokaryotic, eukaryotic or plant cells are grown under controlled conditions.**

- **Cell culture was first successfully undertaken by Ross Harrison in 1907**

- Roux in 1885 for the first time maintained embryonic chick cells in a cell culture

Major developments in cell culture technology

First development was the use of antibiotics which inhibits the growth of contaminants.

Second was the use of trypsin to remove adherent cells to subculture further from the culture vessel

Third was the use of chemically defined culture medium.

Types of cell culture

Primary culture

- Cells when surgically or enzymatically removed from an organism and placed in suitable culture environment will attach and grow

- Primary cells have a finite life span

Continuous cell lines:

- Most cell lines grow for a limited number of generations after which they cease to grow

Types of Cell Culture Media

	Media Type	Examples
Natural media	Biological Fluids	plasma, serum, lymph, human placental cord serum, amniotic fluid
	Tissue Extracts	Extract of liver, spleen, tumors, leucocytes and bone marrow, extract of bovine embryo and chick embryo
	Clots	coagulants or plasma clots
Artificial media	Balanced salt solutions	PBS, DPBS, HBSS, EBSS
	Basal media	MEM DMEM
	Complex media	RPMI-1640, IMDM

CELL CULTURE REQUIREMENTS

SOLID MEDIA

– Specially coated plastic dishes or flasks

– Agar as the medium

GROWTH MEDIA

Rich in nutrients- amino acids, vitamins, salts fatty acids, glucose, serum provides the different growth factors,

PRIMARY CULTURES

Undifferentiated cells

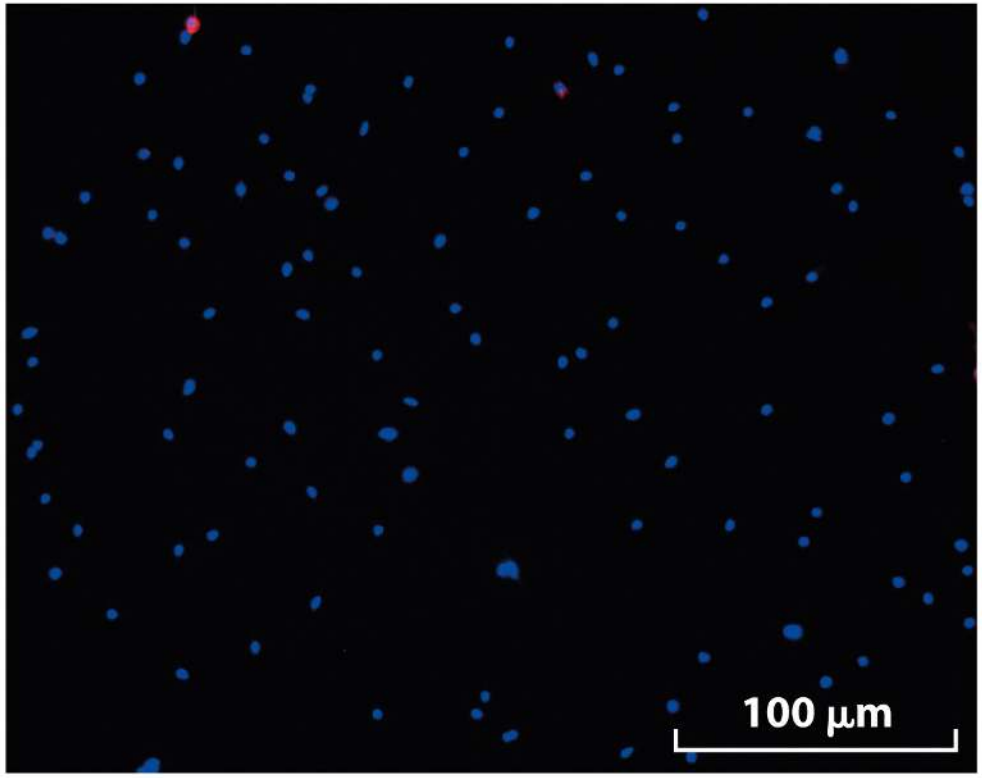
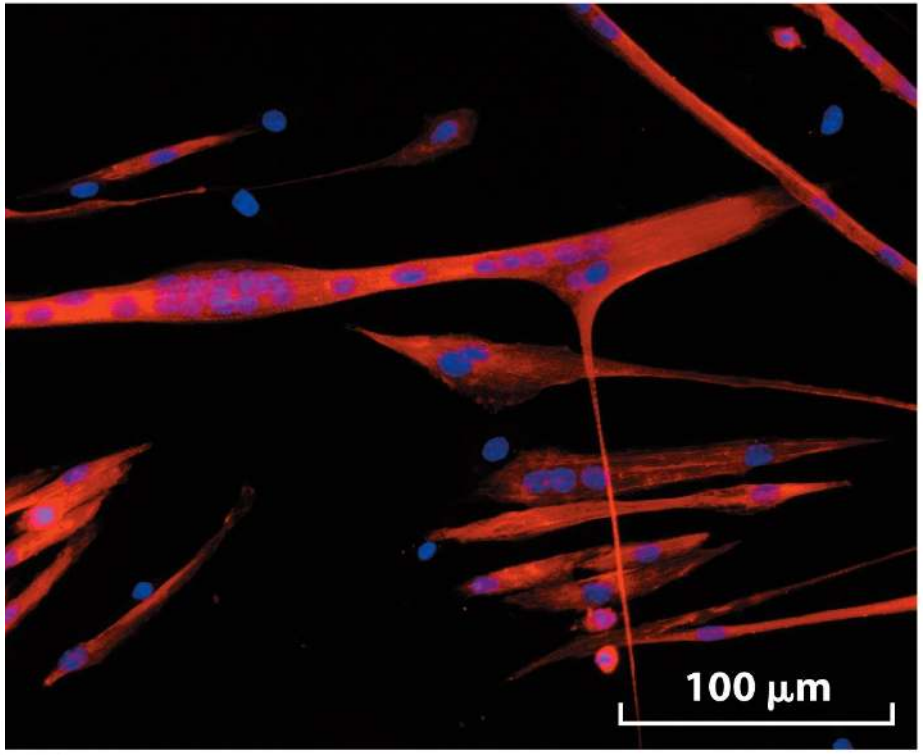


Figure 9-30c
Molecular Cell Biology, Sixth Edition

Differentiated cells



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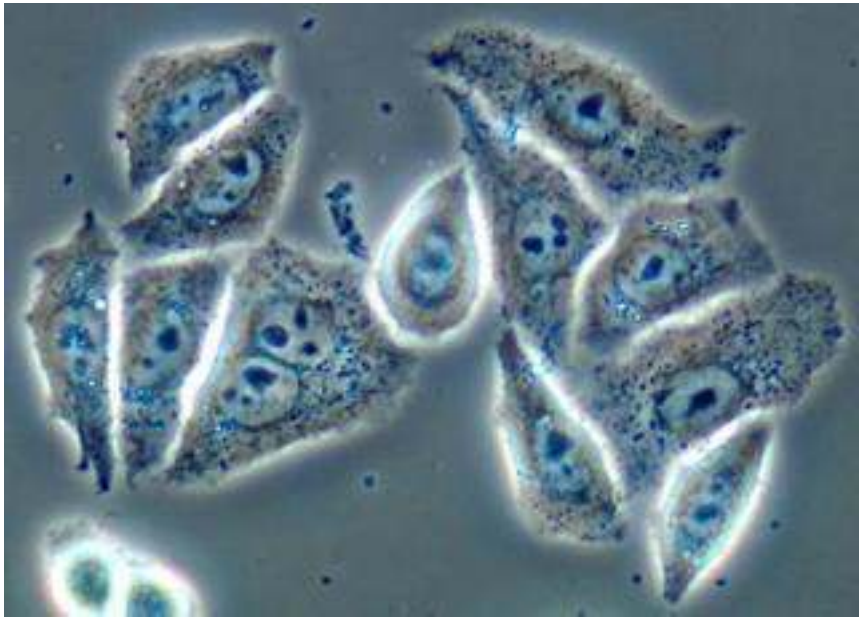
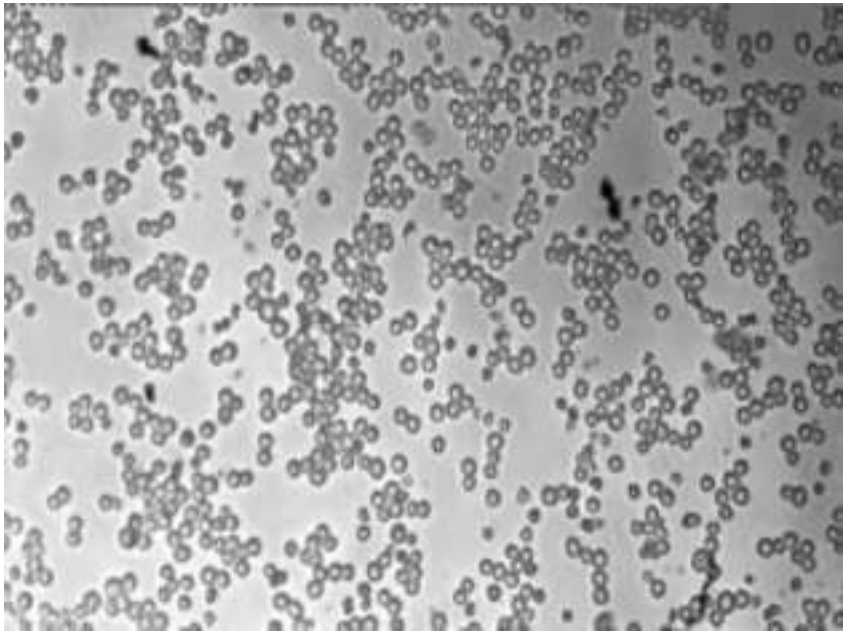
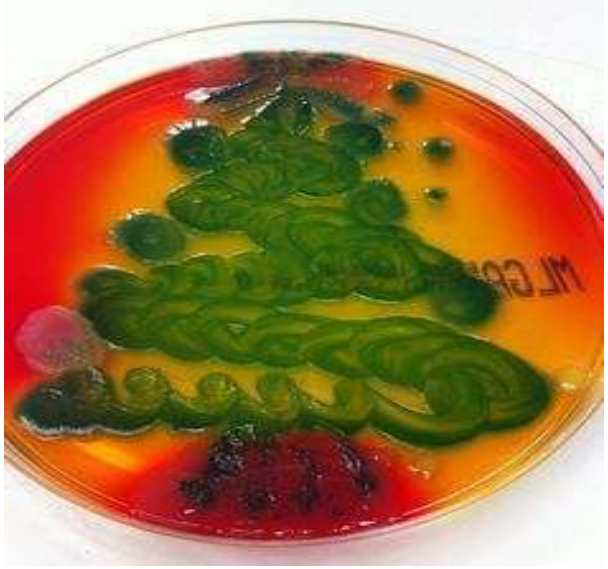
Adherent cells

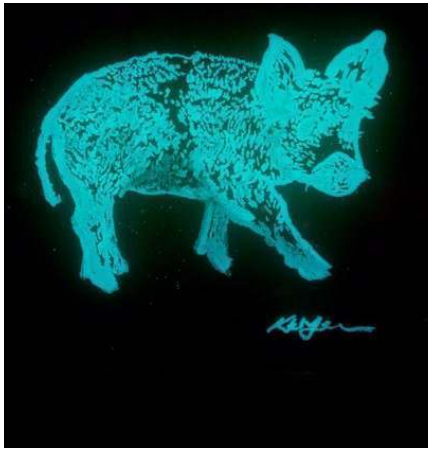


Non-adherent cells
Or
Suspension cells

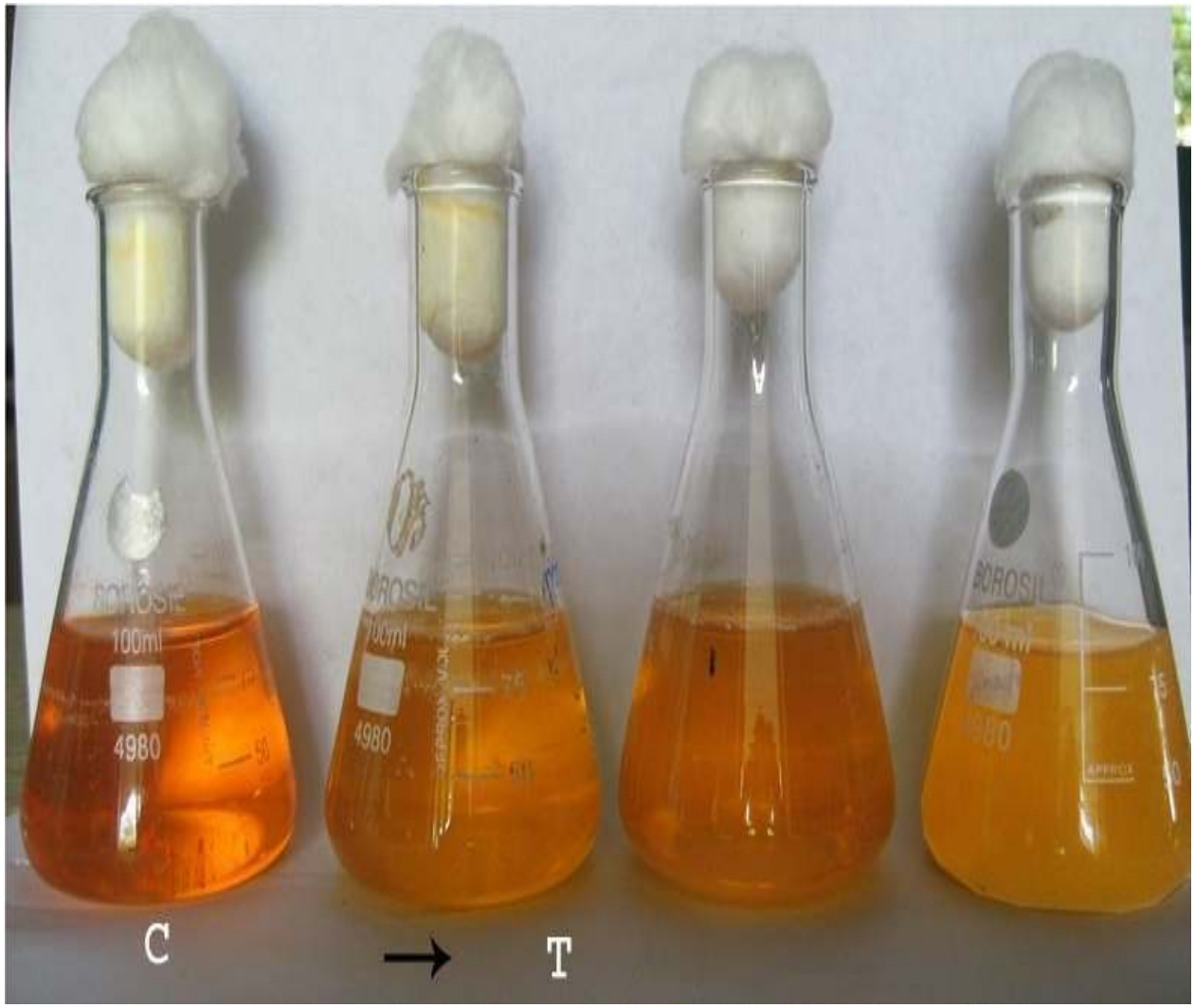


Artistic culture of bacteria





Large scale cultures



Growth can easily be measured by absorption (OD value) at 600nm

bioreactors

Cell viability

- Cell viability is determined by staining the cells with trypan blue

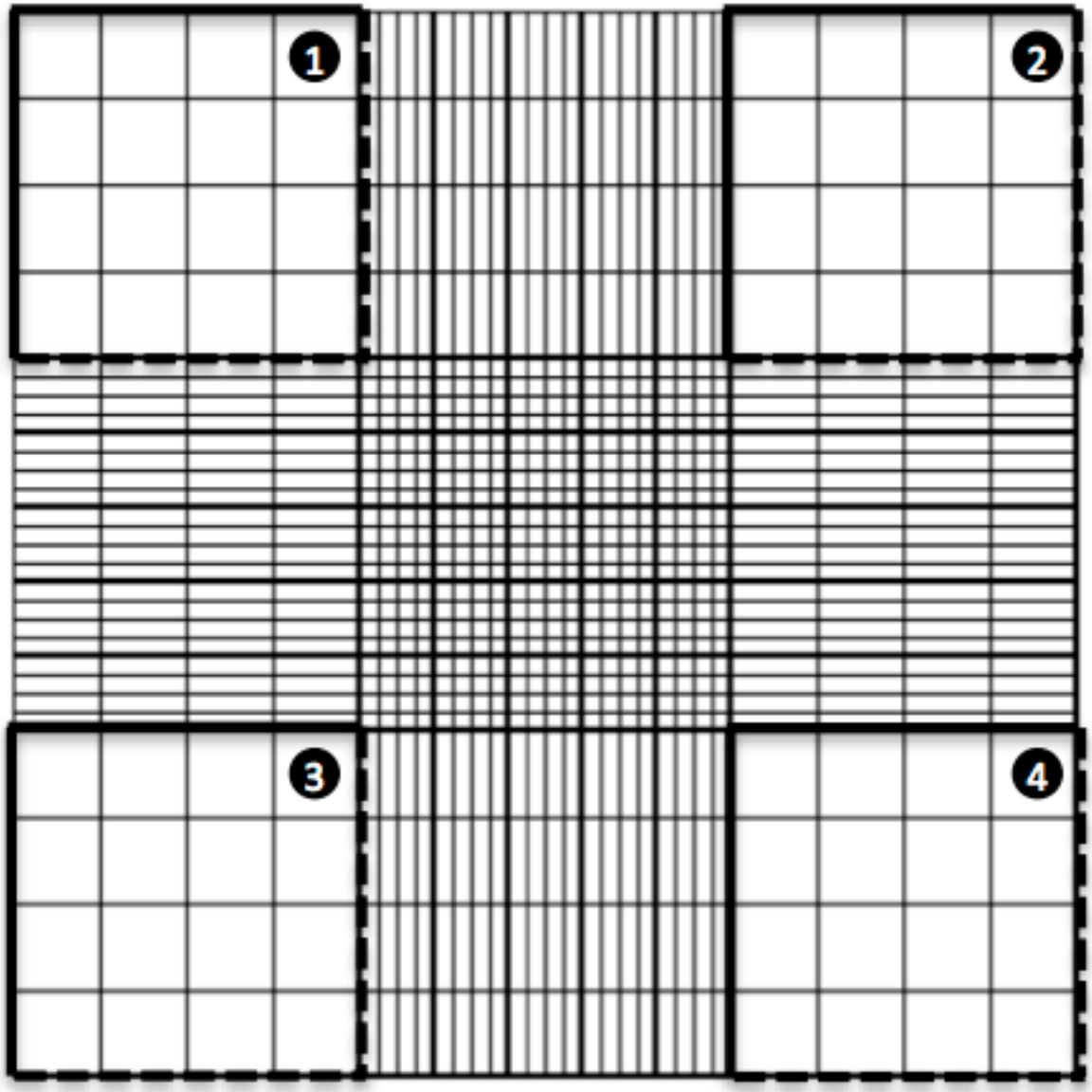
- As trypan blue dye is permeable to non-viable cells or dead cells whereas live cells impermeable to this dye

- Stain the cells with trypan dye and load to haemocytometer and calculate % of viable cells

  - % of viable cells= $\frac{\text{No of unstained cells}}{\text{total no. of cells}} \times 100$

count

don't count

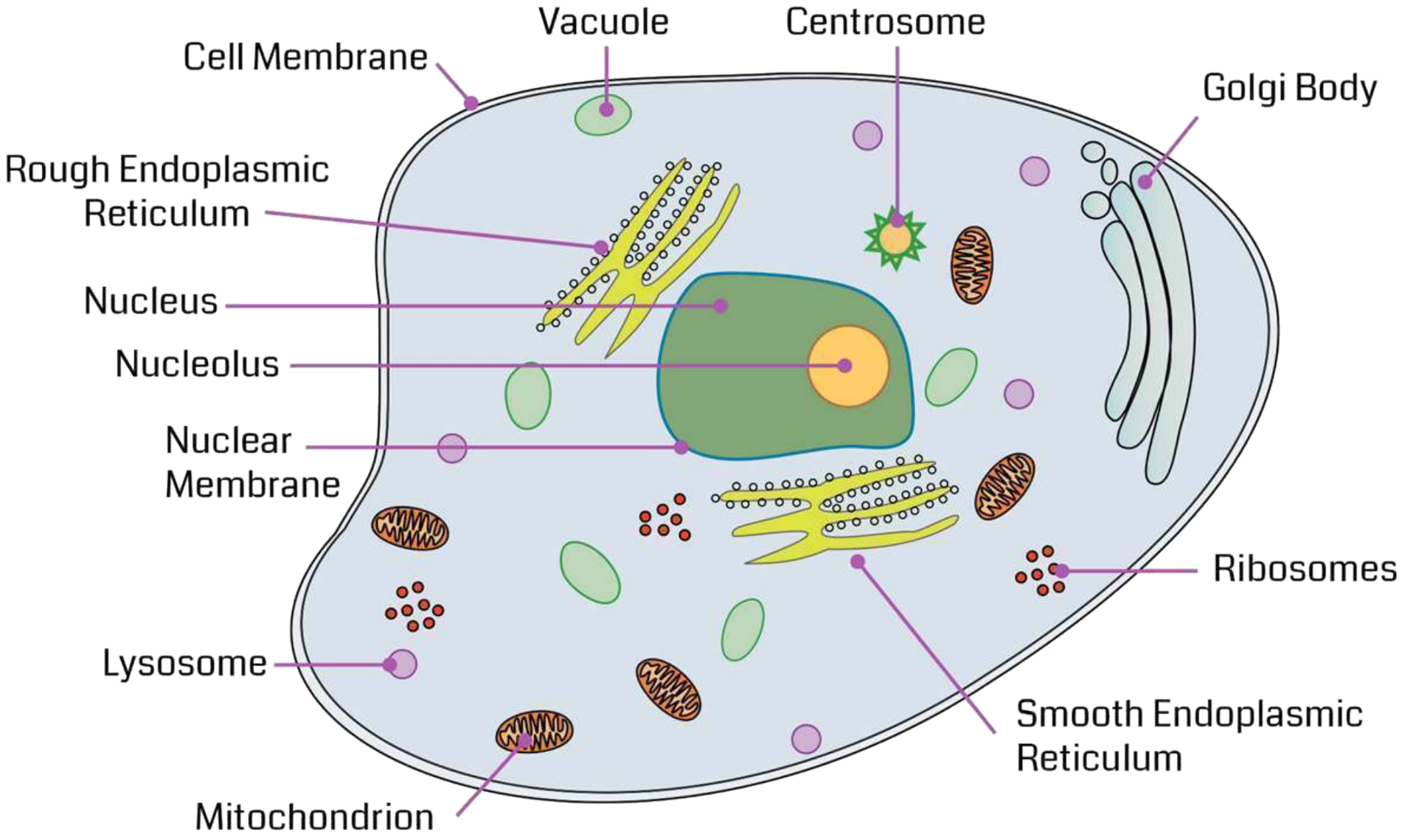


A haemocytometer for cell counting

Basic aseptic techniques

- Sterile media
- If working on the bench use a Bunsen flame to heat the air surrounding the Bunsen
- Swab all bottle tops & necks with 70% ethanol

Cell organelles



In Brief

Cell membrane: Separates and protects the inside of the cell from harmful agents around the cell and controls transport.
Lysosome: breaks down waste materials in an animal cell.
Nucleus: the information center of a cell , stores DNA.
Nucleolus: a round structure that is inside the nucleus of a cell; this structure makes ribosomes.
Nuclear membrane: separates the nucleus from the rest of the cell; regulates substances that move in and out of the nucleus.
Vacuole: stores food, water, and wastes.
Mitochondrion: converts food into usable energy.
Golgi body: processes, packs, and transports proteins to be sent outside a cell.
Ribosomes: make proteins for a cell.
Endoplasmic reticulum: processes and transports proteins from place to place inside a cell.
Cytoplasm: a jellylike substance that fills up the inside of a cell.
Centrosome: the region of a cell that is located next to the nucleus and contains the centrioles

Cell Fractionation

- **Cell fractionation** takes cells apart and separates the major organelles from one another
  - (CELL DISRUPTION)
- Ultracentrifuges fractionate cells into their component parts
- PREPARATION OF PURIFIED ORGANELLES USING SPECIFIC ANTIBODIES
- Cell fractionation enables scientists to determine the functions of organelles
- Biochemistry and cytology help correlate cell function with structure

BREAKING OPEN PLASMA MEMBRANES IN CELLS

- CELLS ARE SUSPENDED IN ISOTONIC SUCROSE
- SONICATION
- HOMOGENIZATION
- CELLS IN HYPOTONIC SOLUTION – RUPTURE OF CELL MEMBRANES
- SEPARATING ORGANELLES BY DIFFERENTIAL CENTRIFUGATION AND DENSITYGRADIENT CENTRIFUGATION

Fig. 6-5a

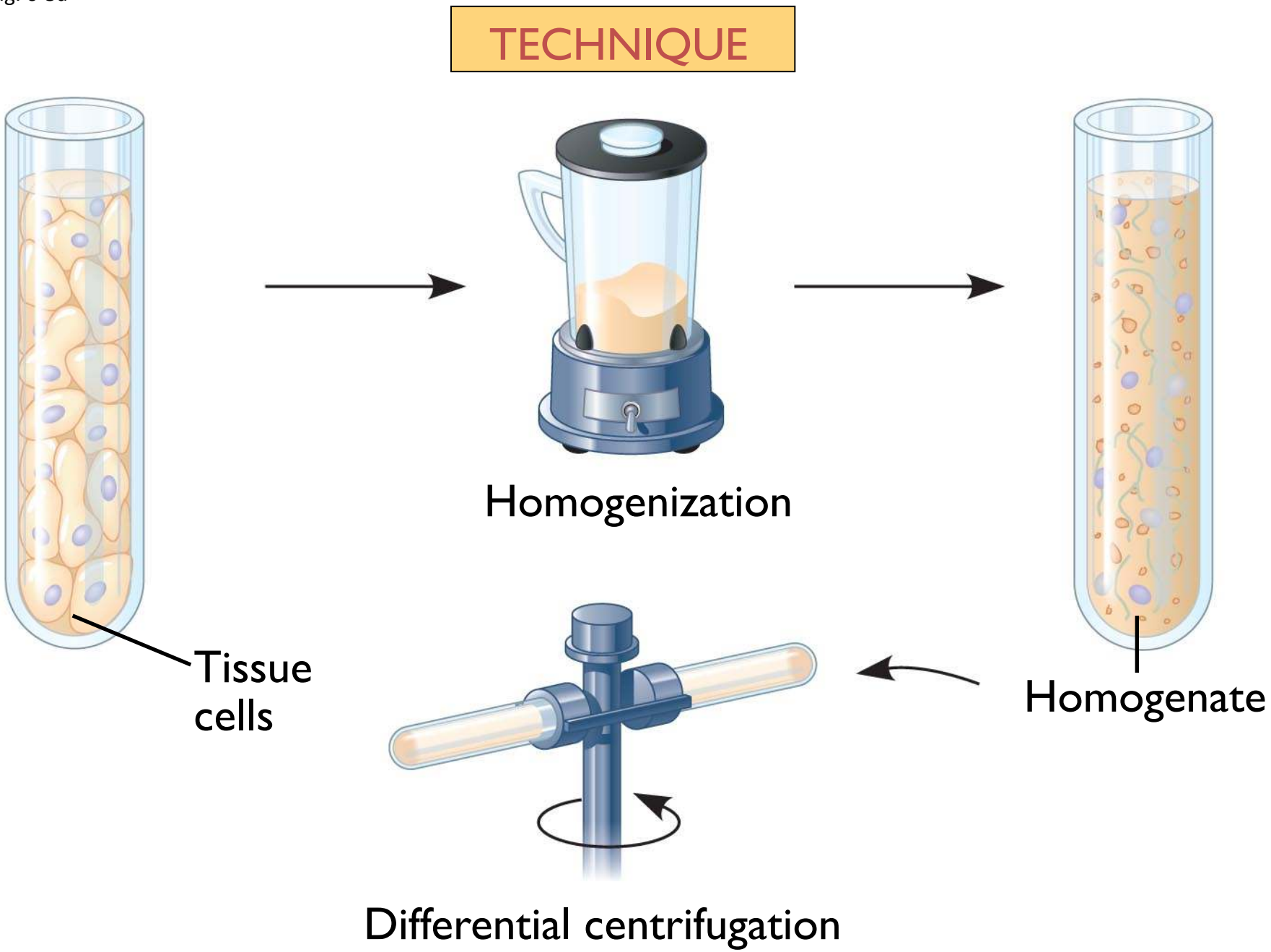
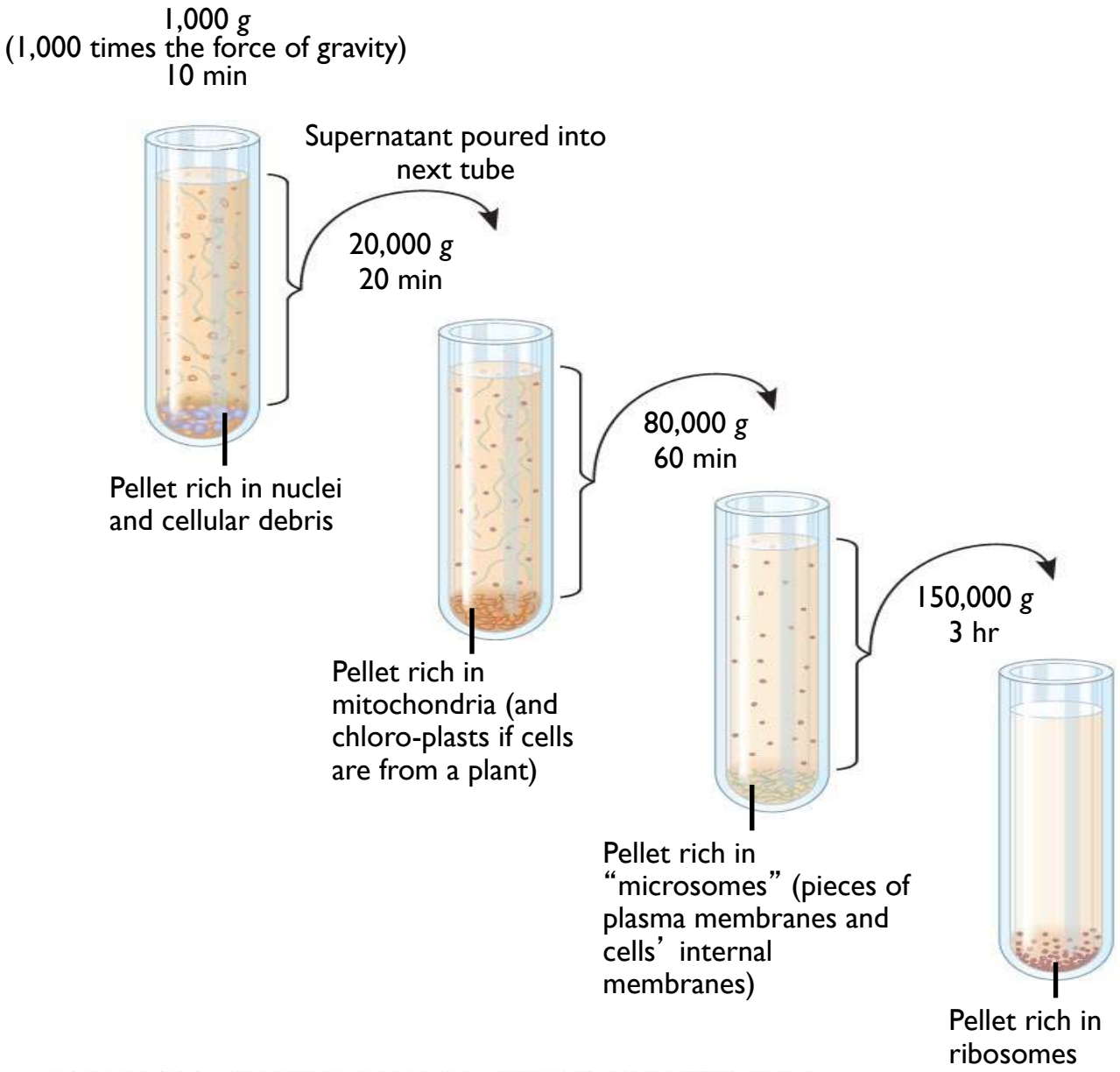


Fig. 6-5b

TECHNIQUE (cont.)



DENSITY GRADIENT CENTRIFUGATION

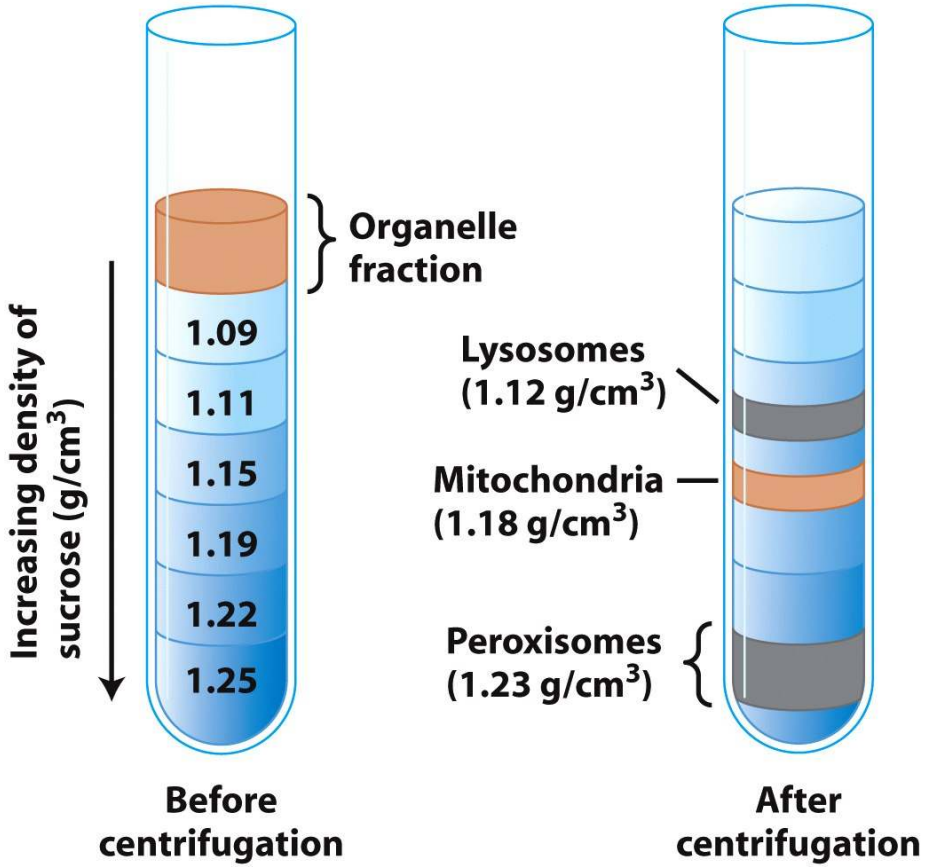


Figure 9-26
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ANTIBODIES ARE USED TO MAKE HIGHLY PURIFIED ORGANELLES

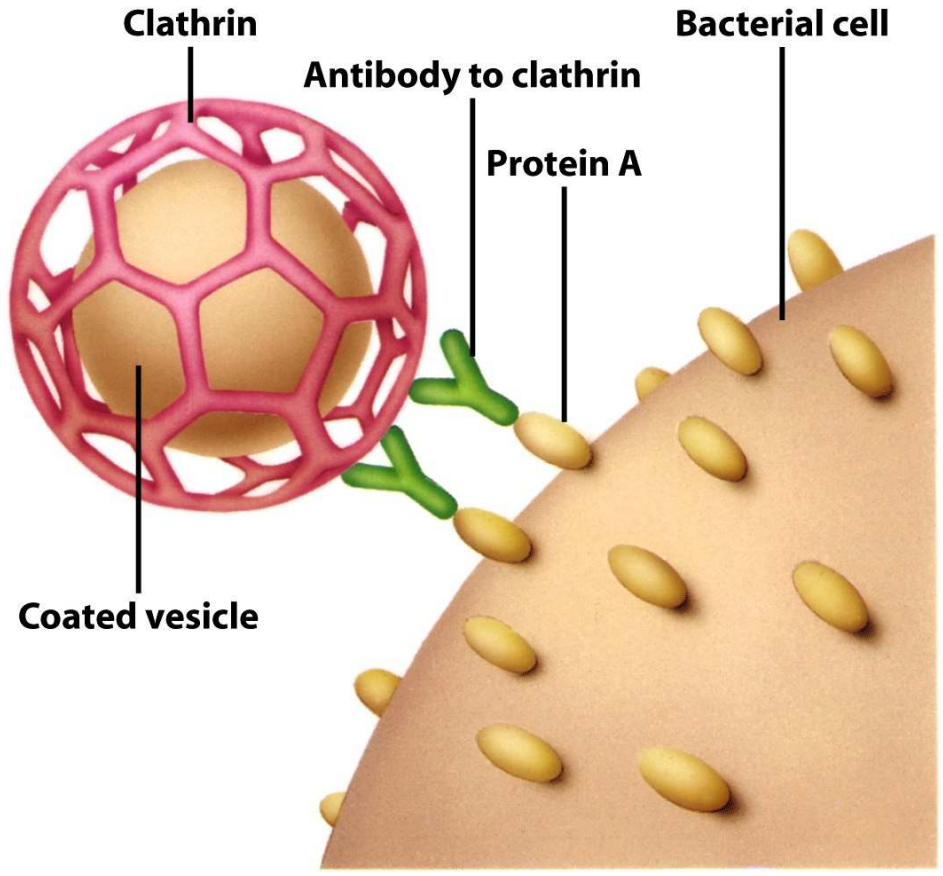


Figure 9-27a
Molecular Cell Biology, Sixth Edition

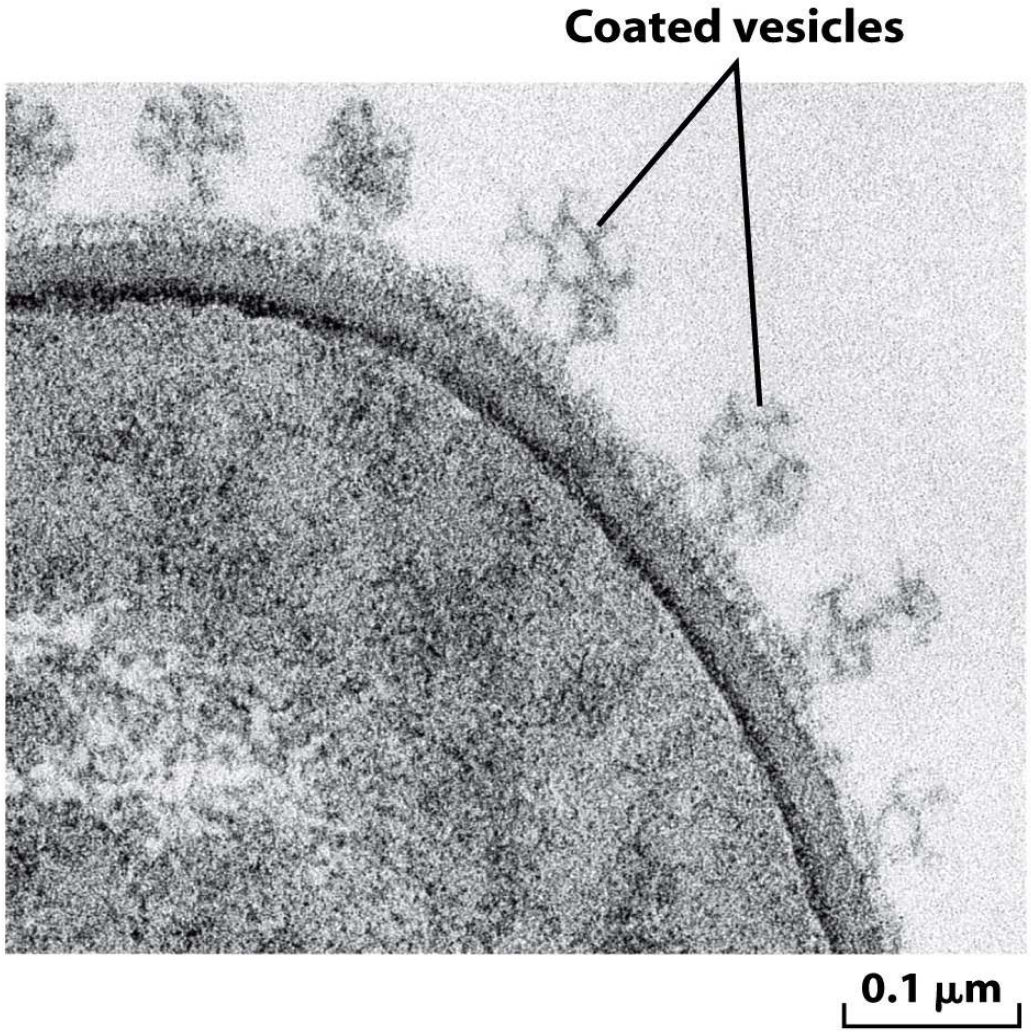


Figure 9-27b
Molecular Cell Biology, Sixth Edition

CELL SORTER – FLOW CYTOMETRY

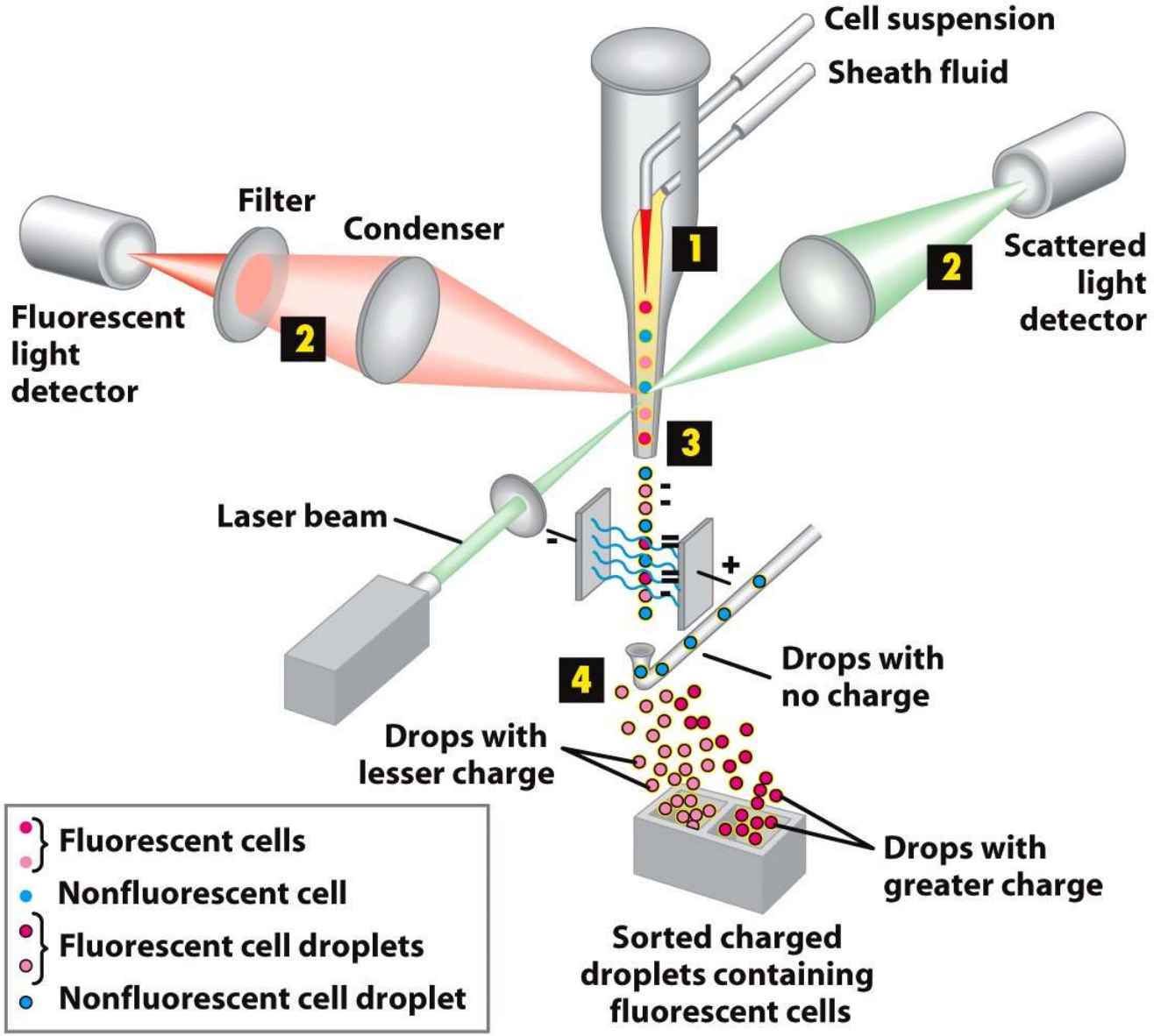
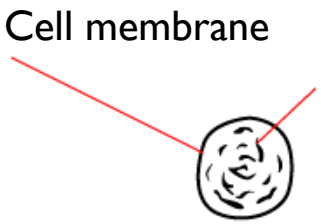


Figure 9-28
Molecular Cell Biology, Sixth Edition

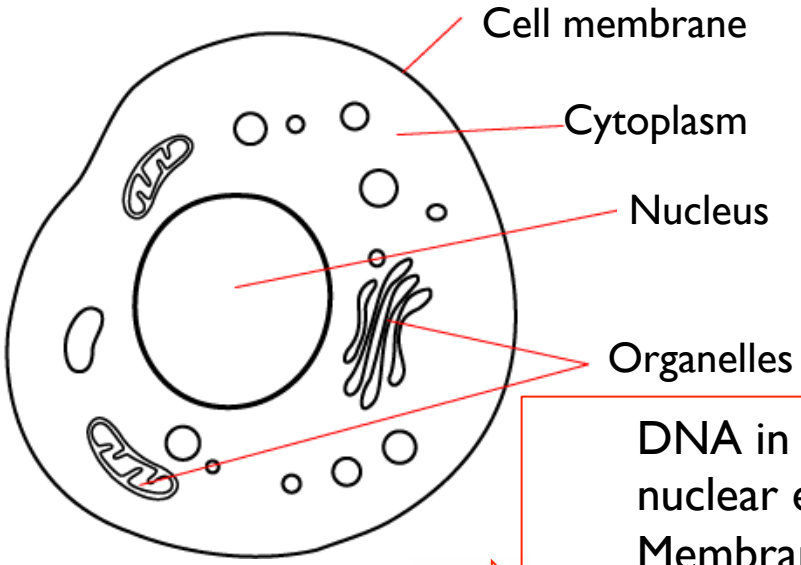
Eukaryotic vs Prokaryotic cells

Basic features of all cells: Plasma membrane, Semifluid substance called **cytosol**, Chromosomes (carry genes), Ribosomes (make proteins)

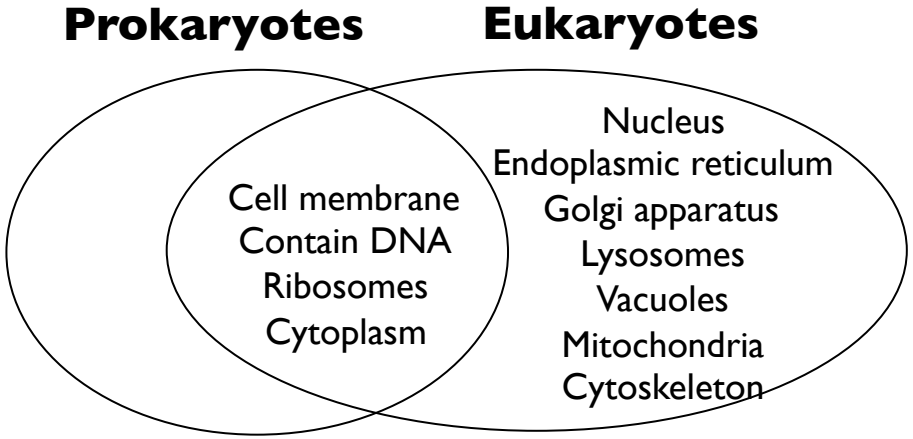


Prokaryotic Cell

No organized nucleus,
DNA in an unbound region called the **nucleoid**
No membrane-bound organelles
Cytoplasm bound by the plasma membrane

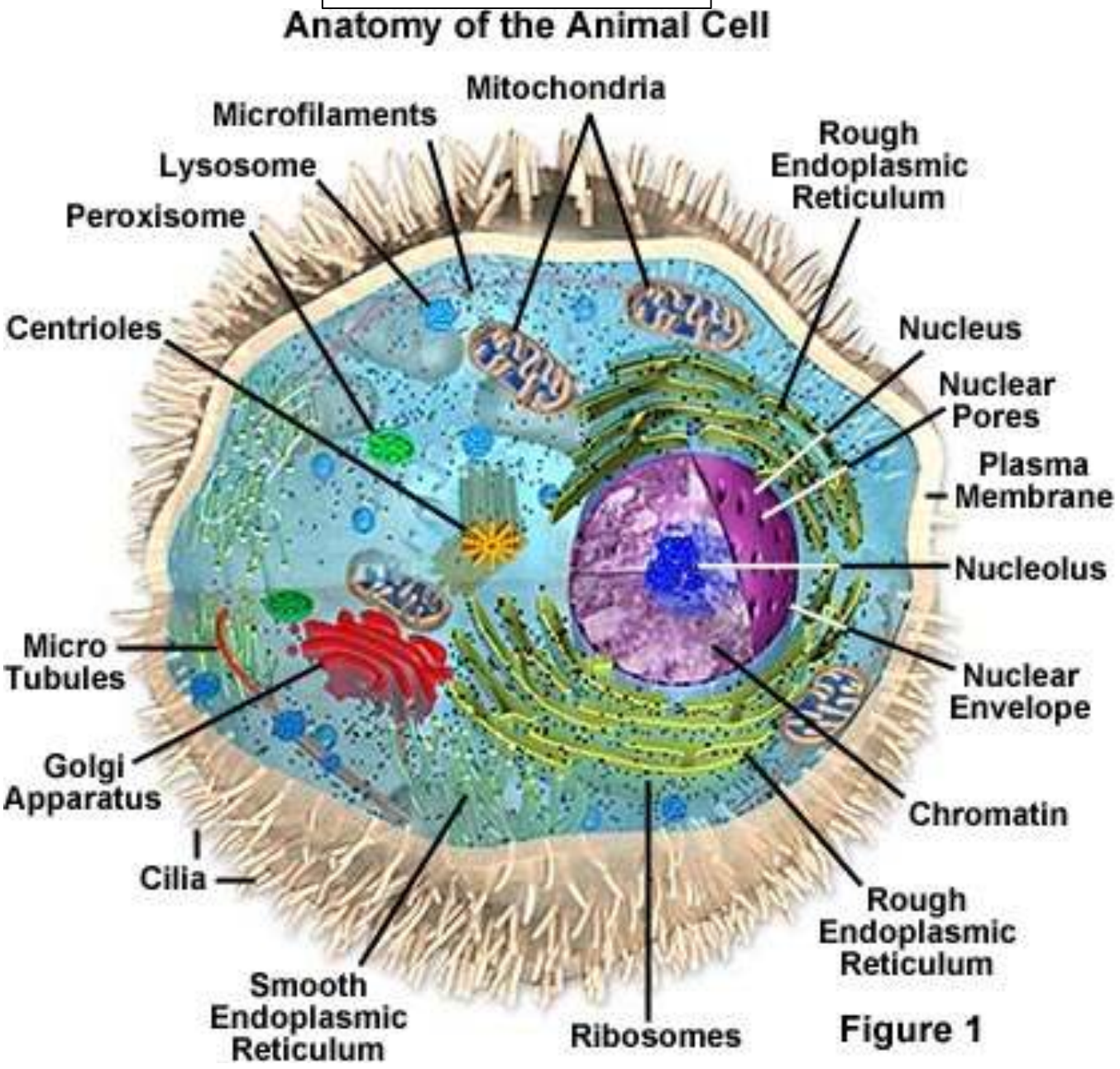


Eukaryotic Cell

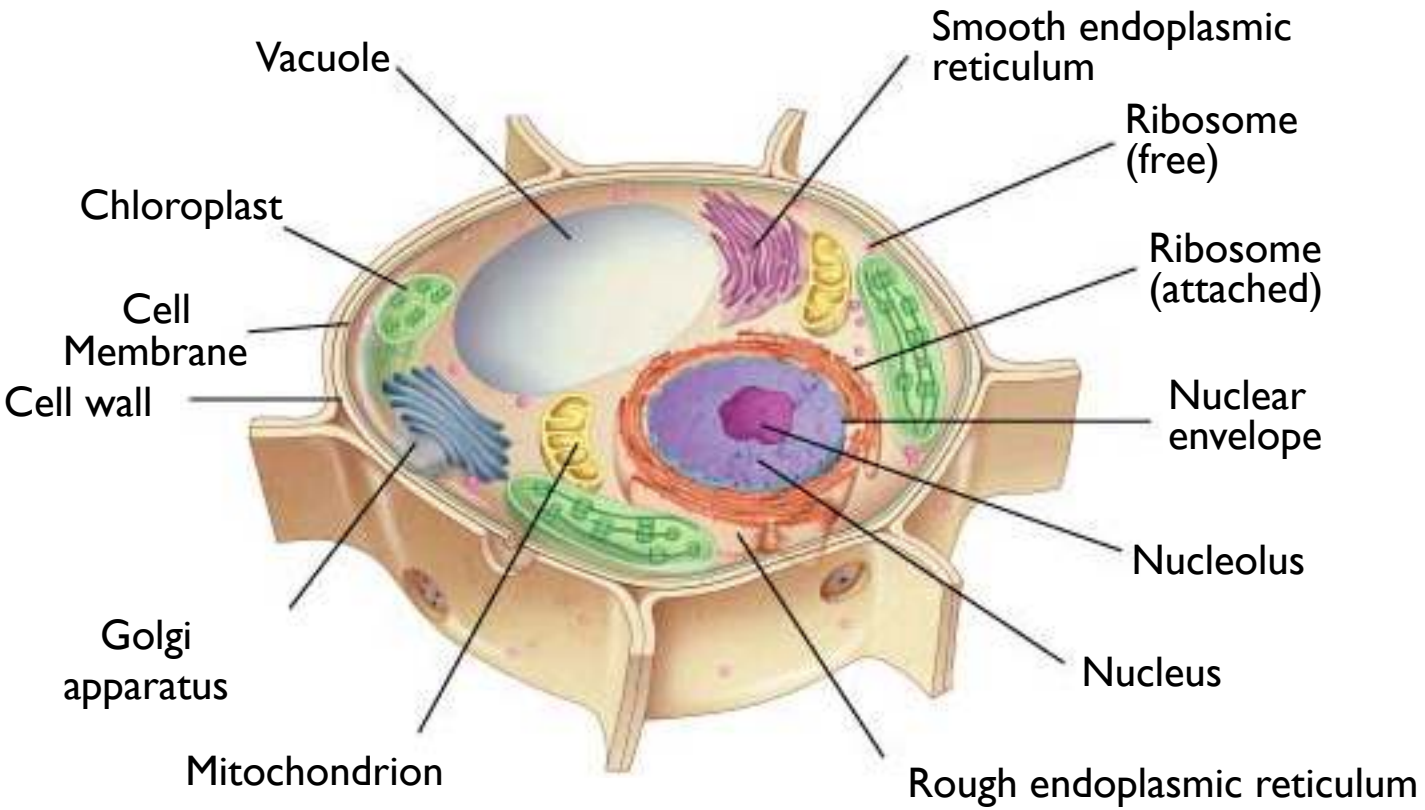


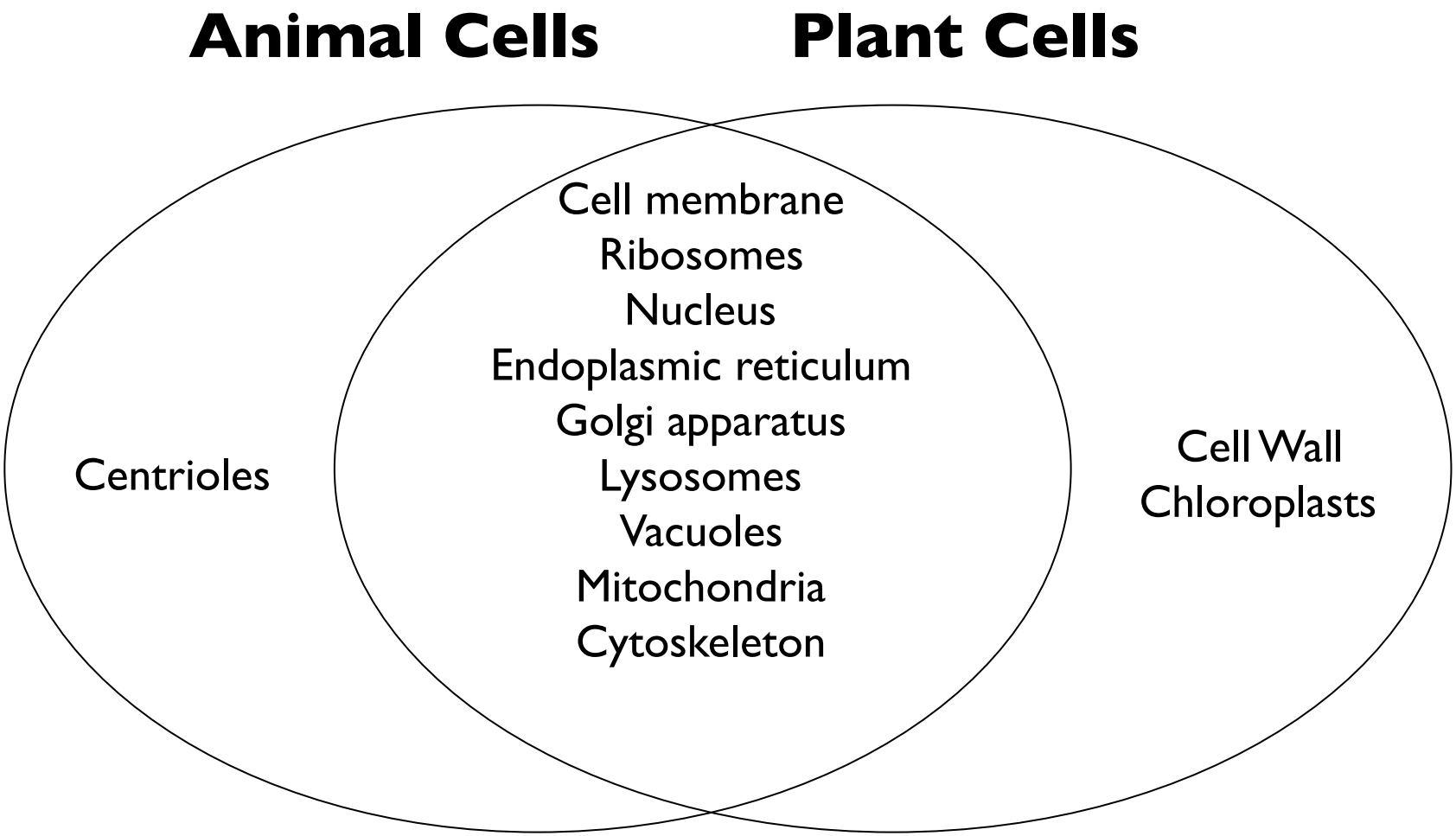
DNA in a nucleus that is bounded by a membranous nuclear envelope
Membrane-bound organelles
Cytoplasm in the region between the plasma membrane and nucleus

Animal cell


Anatomy of the Animal Cell
Mitochondria
Microfilaments
Lysosome
Peroxisome
Rough Endoplasmic Reticulum
Centrioles
Nucleus
Nuclear Pores
Plasma Membrane
Nucleolus
Micro Tubules
Nuclear Envelope
Golgi Apparatus
Chromatin
Cilia
Rough Endoplasmic Reticulum
Smooth Endoplasmic Reticulum
Ribosomes
Figure 1

Plant cell


Vacuole
Smooth endoplasmic reticulum
Ribosome (free)
Chloroplast
Ribosome (attached)
Cell Membrane
Cell wall
Nuclear envelope
Nucleolus
Golgi apparatus
Nucleus
Mitochondrion
Rough endoplasmic reticulum


Animal Cells
Plant Cells
Centrioles
Cell membrane
Ribosomes
Nucleus
Endoplasmic reticulum
Golgi apparatus
Lysosomes
Vacuoles
Mitochondria
Cytoskeleton
Cell Wall
Chloroplasts

The Nucleus: Information Central

- The **nucleus** contains most of the cell's genes and is usually the most conspicuous organelle
- The **nuclear envelope** encloses the nucleus, separating it from the cytoplasm
- The nuclear membrane is a double membrane; each membrane consists of a lipid bilayer
- Pores (120 nm) regulate the entry and exit of molecules from the nucleus → 3000-4000 in numbers
- In the nucleus, DNA wrapped around proteins forms the genetic material called **chromatin**
- Chromatin condenses to form discrete **chromosomes**
- The **nucleolus** is located within the nucleus and is the site of ribosomal RNA (rRNA) synthesis and protein gets in the nucleolus to form ribosomes

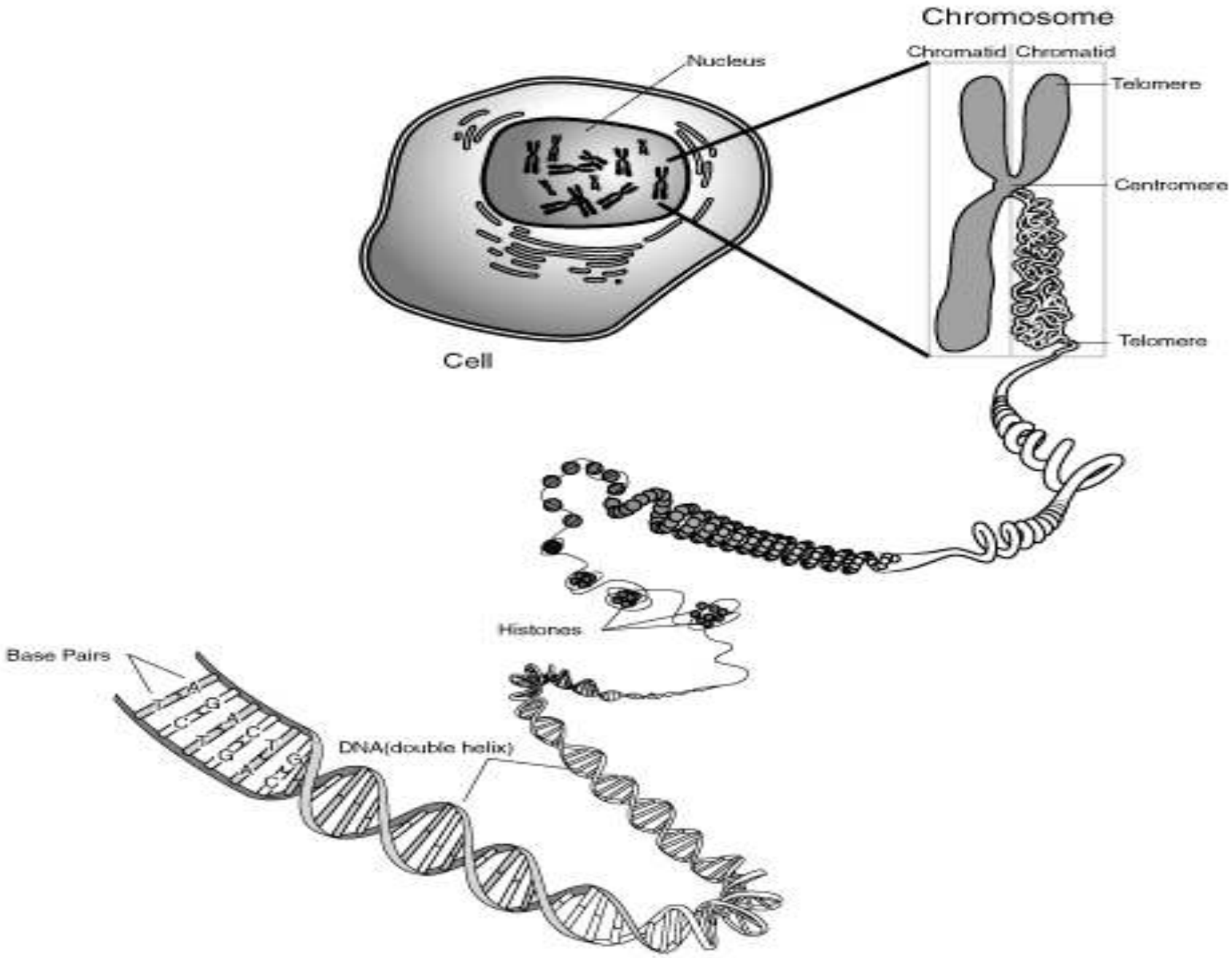
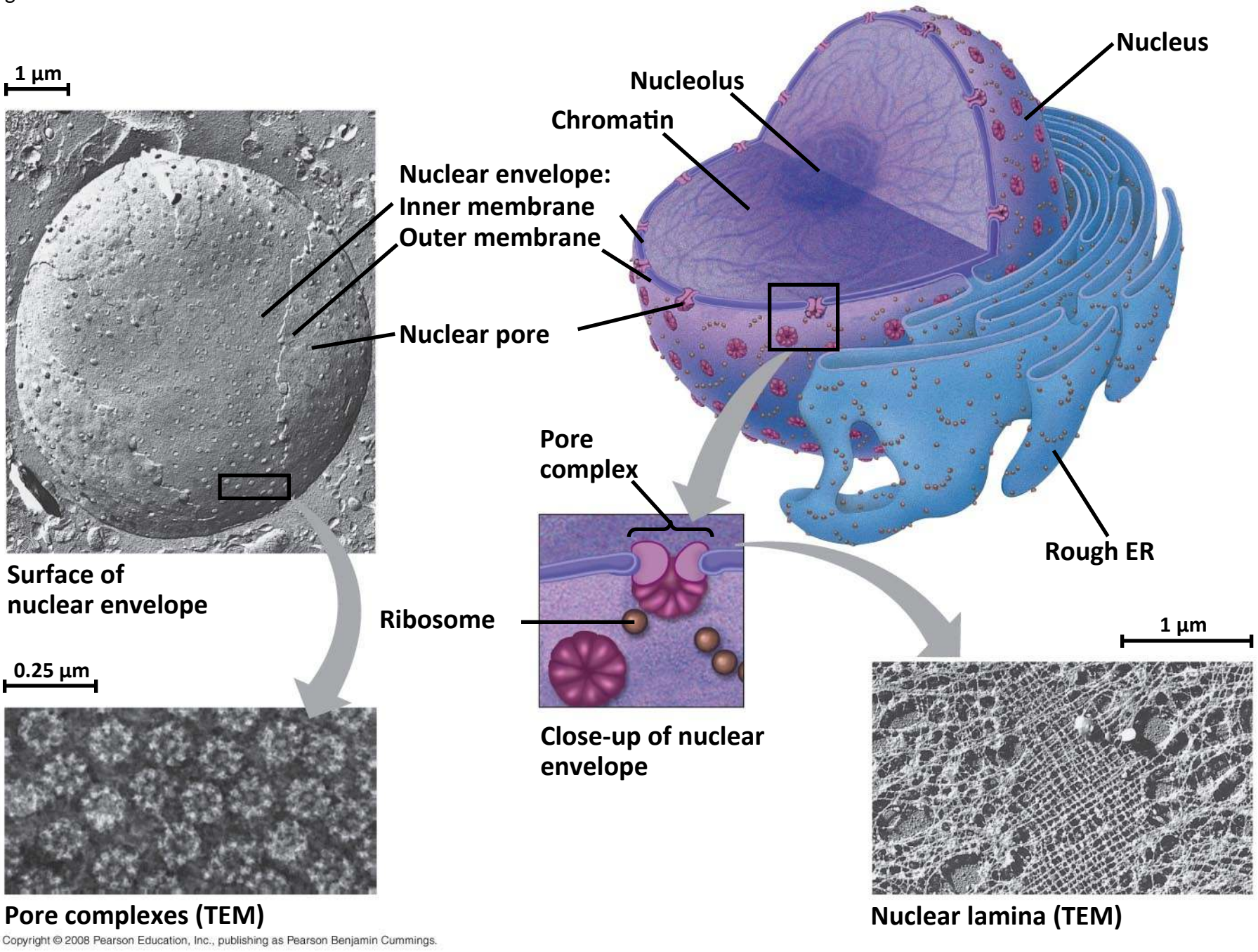

Chromosome
Chromatid
Chromatid
Nucleus
Telomere
Centromere
Telomere
Cell
Histones
Base Pairs
DNA(double helix)

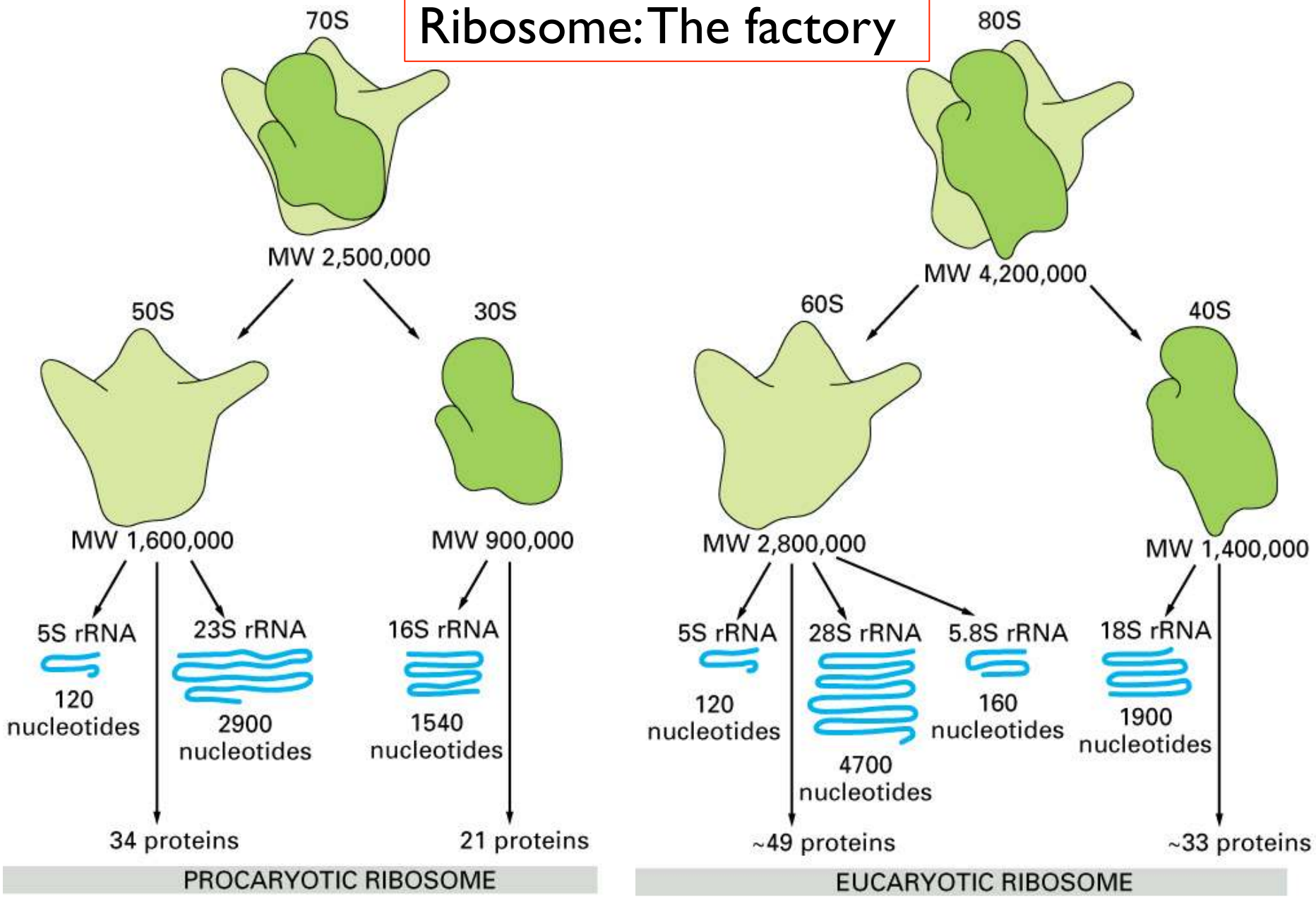
Fig. 6-10



Ribosomes: Protein Factories

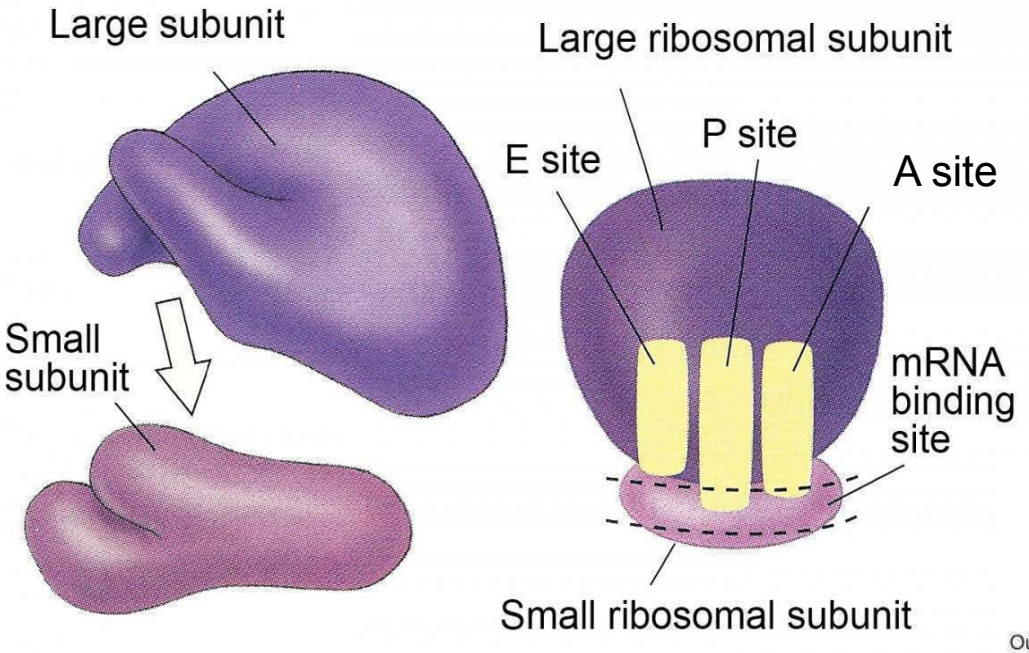
- **Ribosomes** are particles made of ribosomal RNA and protein
- Ribosomes carry out protein synthesis in two locations:
  - In the cytosol (free ribosomes)
  - On the outside of the endoplasmic reticulum or the nuclear envelope (bound ribosomes)

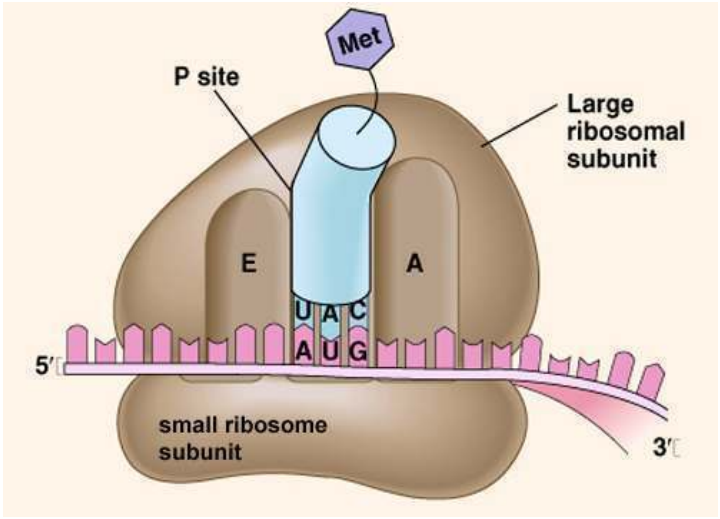
Ribosome: The factory

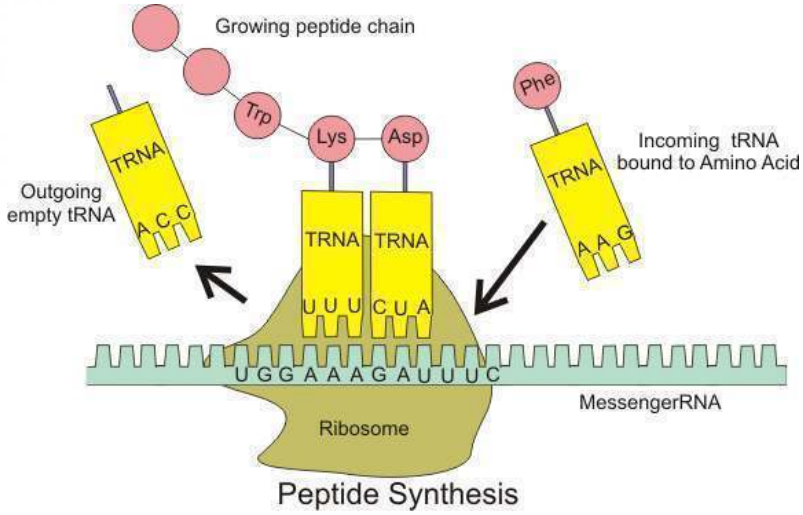


Large subunit: catalyze peptide bond formation Small subunit aligns codon with anticodon

Ribosome : a site for translation





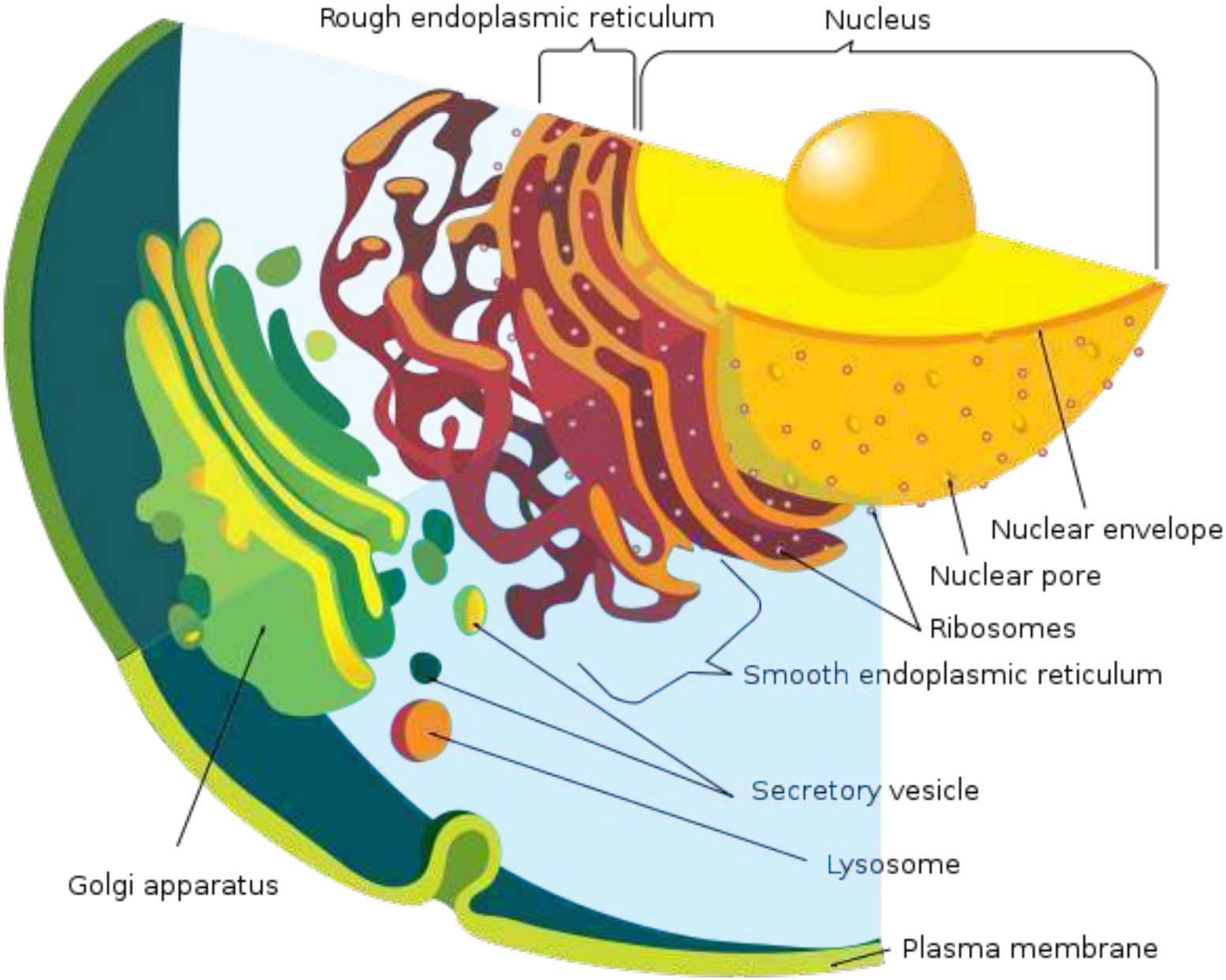


E site: Exit
P site: peptidyl-tRNA
A site: aminoacyl-tRNA

The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- Components of the **endomembrane system**:
  - Nuclear envelope
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosomes
  - Vacuoles
  - Plasma membrane
- These components are either continuous or connected via transfer by **vesicles**

Proposed by Morre and Mollenhauer 1974

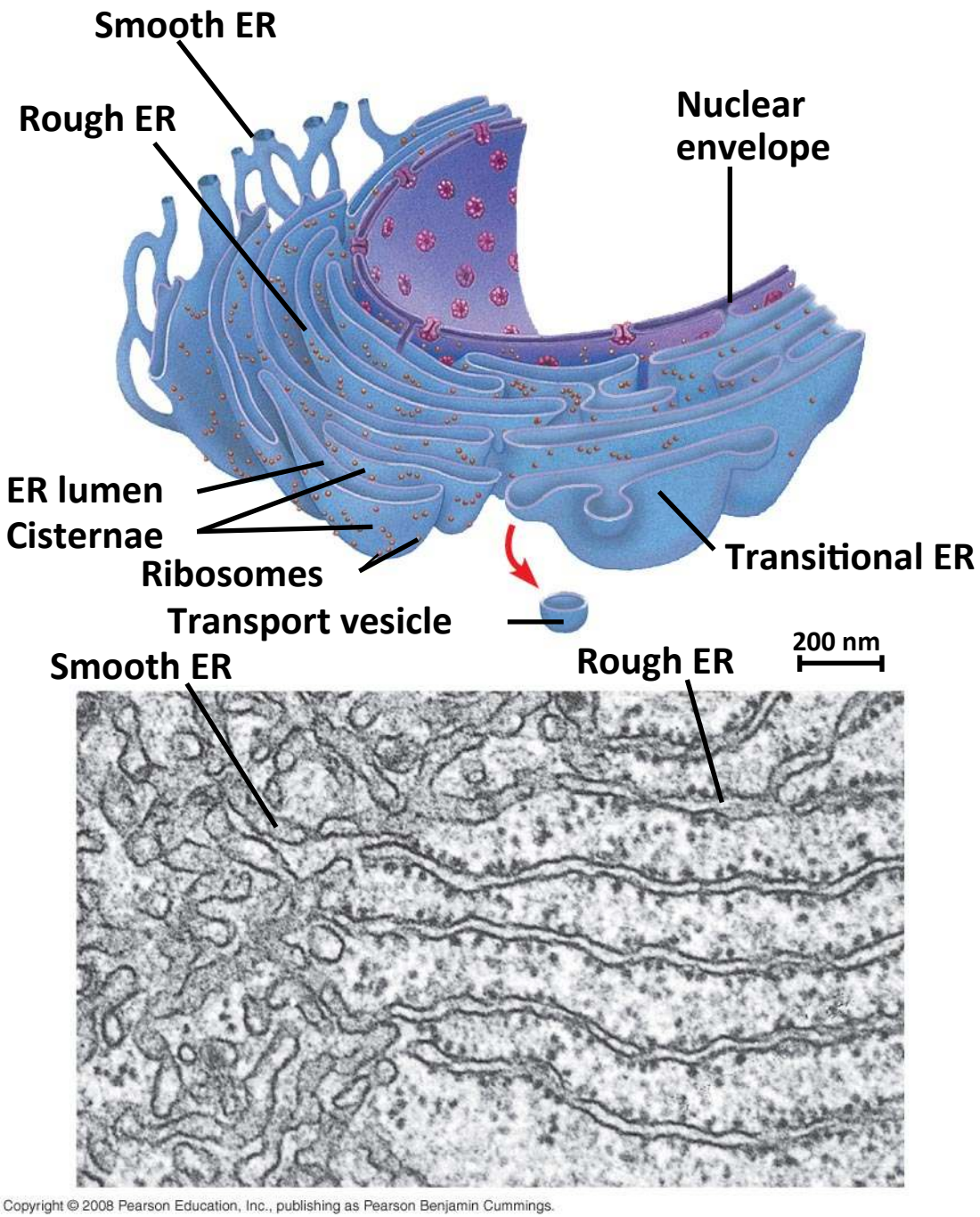


https://en.wikipedia.org/wiki/File:Endomembrane_system_diagram_en_(edit).svg

The Endoplasmic Reticulum: Biosynthetic Factory

- The **endoplasmic reticulum (ER)** accounts for more than half of the total membrane in many eukaryotic cells
- The ER membrane is continuous with the nuclear envelope
- There are two distinct regions of ER:
  - **Smooth ER**, which lacks ribosomes
  - **Rough ER**, with ribosomes studding its surface

Fig. 6-12



Functions of ER

The smooth ER

- Synthesizes lipids, oils, hormones
- Rich in gonads and liver cells
- Produces organelles such as Golgi apparatus, lysosomes and vacuoles
- Metabolizes carbohydrates
- Detoxifies poison and drugs such as alcohol and barbiturates
- Stores calcium

The rough ER

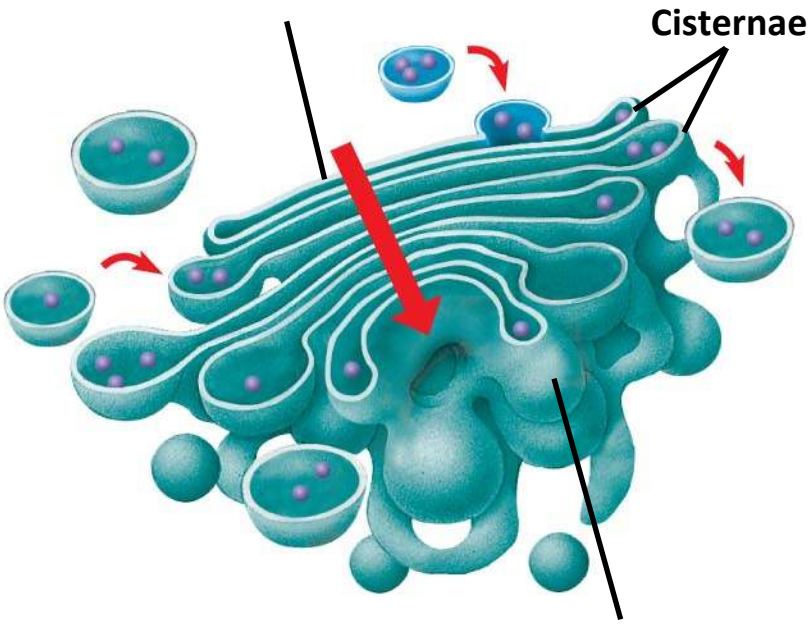
- Has bound ribosomes, which secrete **glycoproteins** (proteins covalently bonded to carbohydrates)
- Distributes **transport vesicles,** proteins surrounded by membranes
- Is a membrane factory for the cell

The Golgi Apparatus: Shipping and Receiving Center

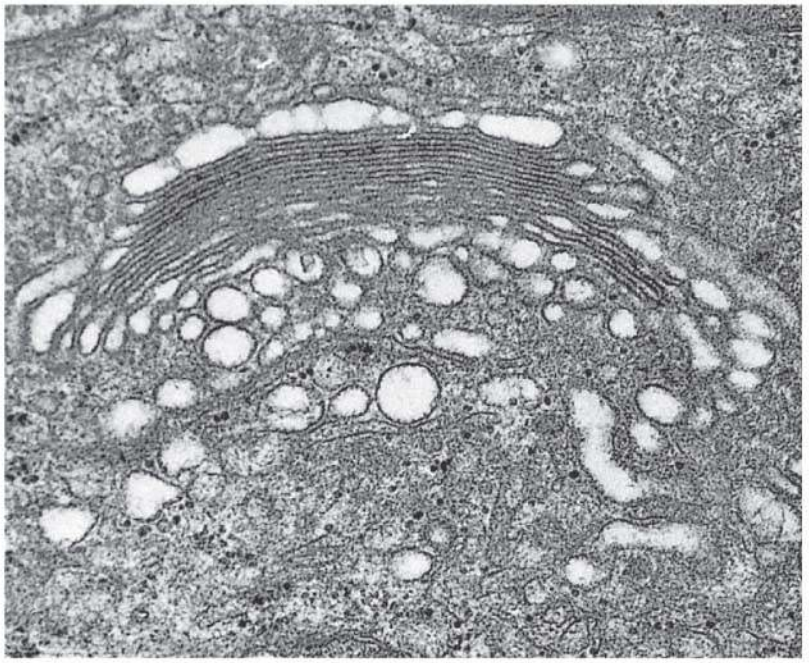
- The **Golgi apparatus** consists of flattened membranous sacs called cisternae
- Functions of the Golgi apparatus:
  - Modifies products of the ER
  - Manufactures certain macromolecule
    - Glycolipids and sphingomyelin
  - Sorts and packages materials into transport vesicles

Fig. 6-13

cis face
("receiving" side of Golgi apparatus)



trans face
("shipping" side of Golgi apparatus)

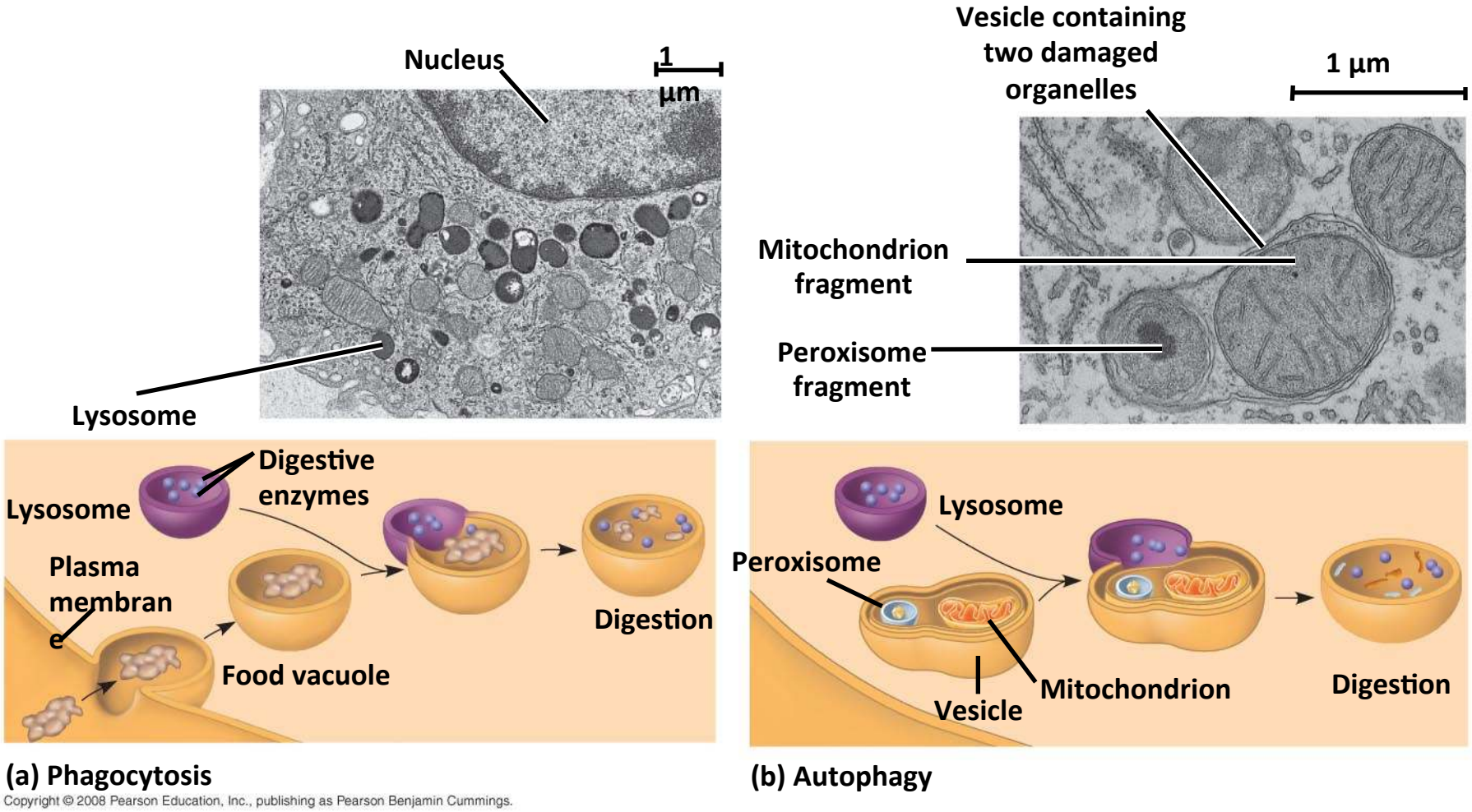


TEM of Golgi apparatus

Lysosomes: Digestive Compartments

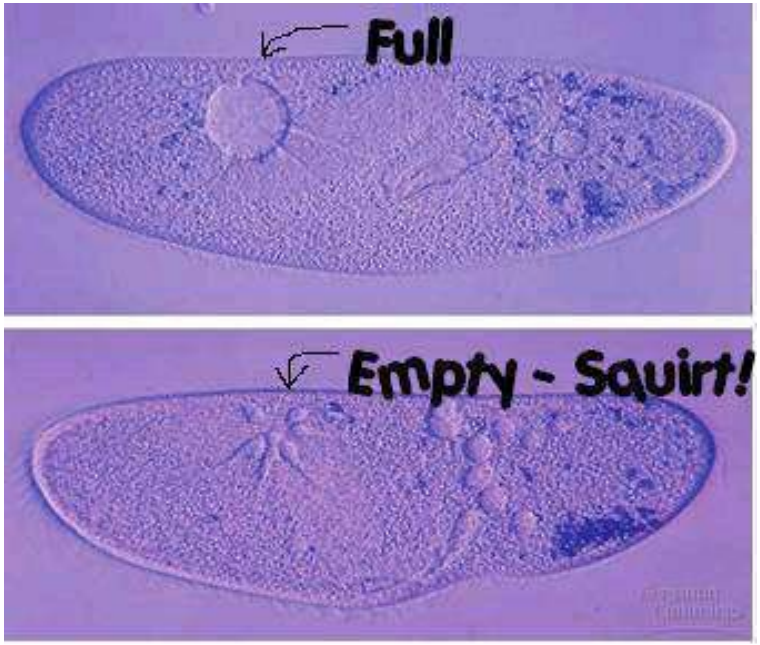
- A **lysosome** is a membranous sac of hydrolytic enzymes that can digest macromolecules
- Lysosomal enzymes can hydrolyze proteins, fats, polysaccharides, and nucleic acids
- Some types of cell can engulf another cell by **phagocytosis**; this forms a food vacuole
- A lysosome fuses with the food vacuole and digests the molecules
- Lysosomes also use enzymes to recycle the cell's own organelles and macromolecules, a process called **autophagy**

Fig. 6-14



Vacuoles: Diverse Maintenance Compartments

- A plant cell or fungal cell may have one or several vacuoles
- **Food vacuoles** are formed by phagocytosis
- **Contractile vacuoles**, found in many freshwater protists, pump excess water out of cells
- **Central vacuoles**, found in many mature plant cells, hold organic compounds and water, surrounded by tonoplast



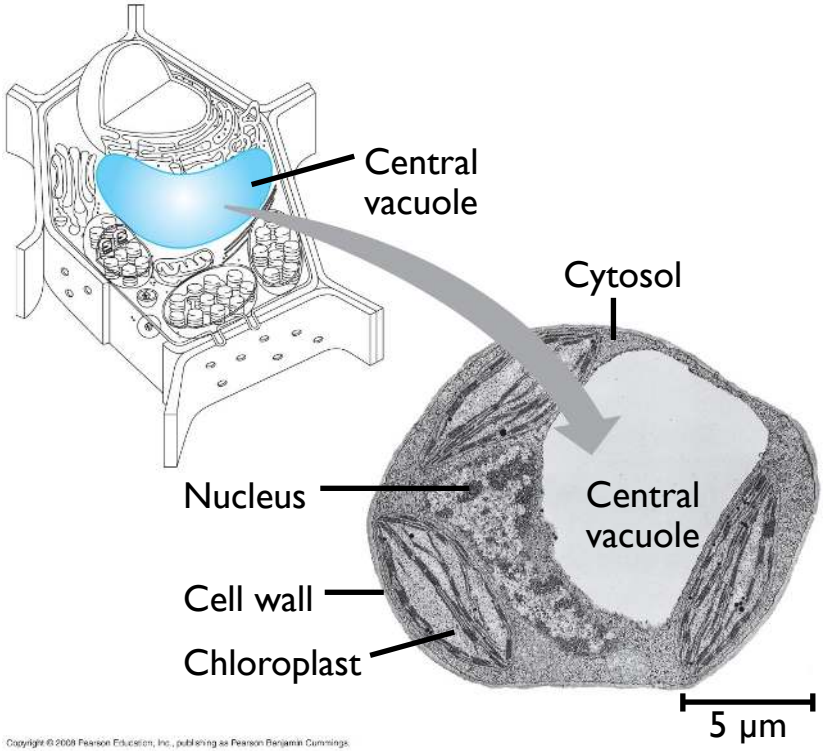
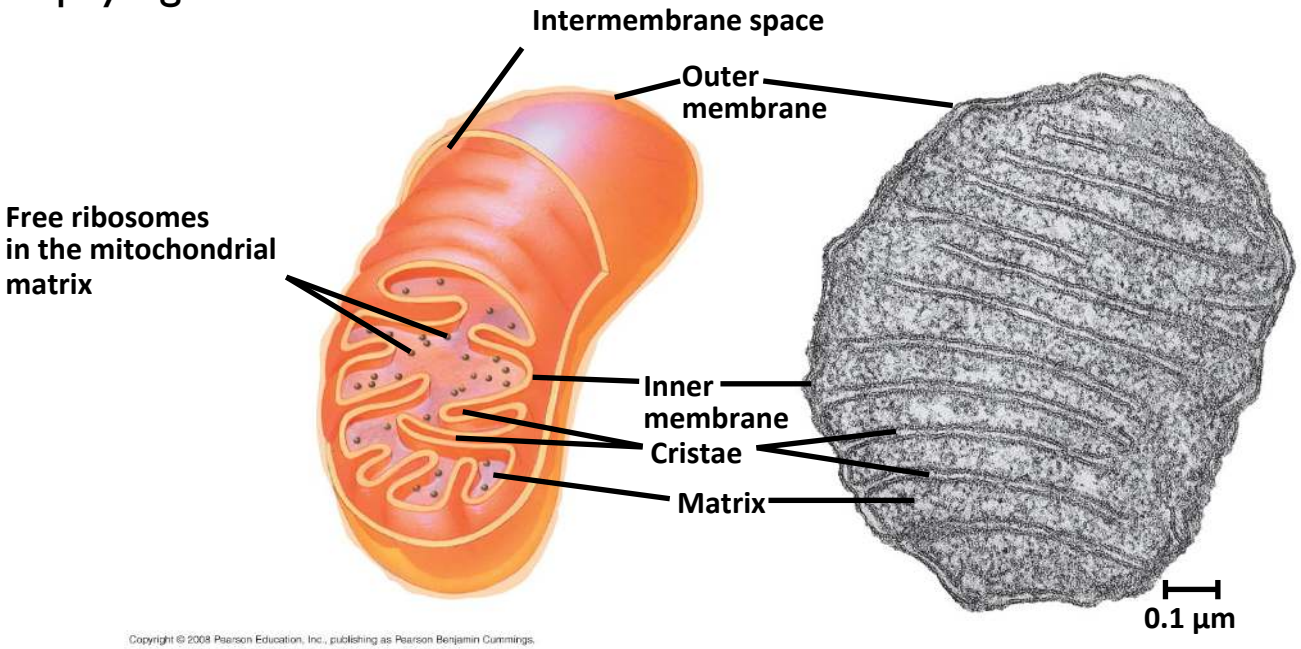


Fig. 6-15

Mitochondria (and chloroplasts in plants) change energy from one form to another

- **Mitochondria** are the sites of cellular respiration, a metabolic process that generates ATP
- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis
- Mitochondria and chloroplasts
  - Are not part of the endomembrane system
  - Have a double membrane
  - Have proteins made by free ribosomes
  - Contain their own DNA→ ~40genes encoded by mtDNA(~16.5K bp), For phylogenetic relatedness



Mitochondria: Chemical Energy Conversion

- Mitochondria are in nearly all eukaryotic cells
- They have a smooth outer membrane and an inner membrane folded into **cristae**
- The inner membrane creates two compartments: intermembrane space and **mitochondrial matrix**
- Some metabolic steps of cellular respiration are catalyzed in the mitochondrial matrix
- Cristae present a large surface area for enzymes that synthesize ATP

Chloroplasts: Capture of Light Energy

- The chloroplast is a member of a family of organelles called **plastids**
- Chloroplasts contain the green pigment chlorophyll, as well as enzymes and other molecules that function in photosynthesis
- Chloroplasts are found in leaves and other green organs of plants and in algae
- Chloroplast structure includes:
  - **Thylakoids**, membranous sacs, stacked to form a **granum**
  - **Stroma**, the internal fluid

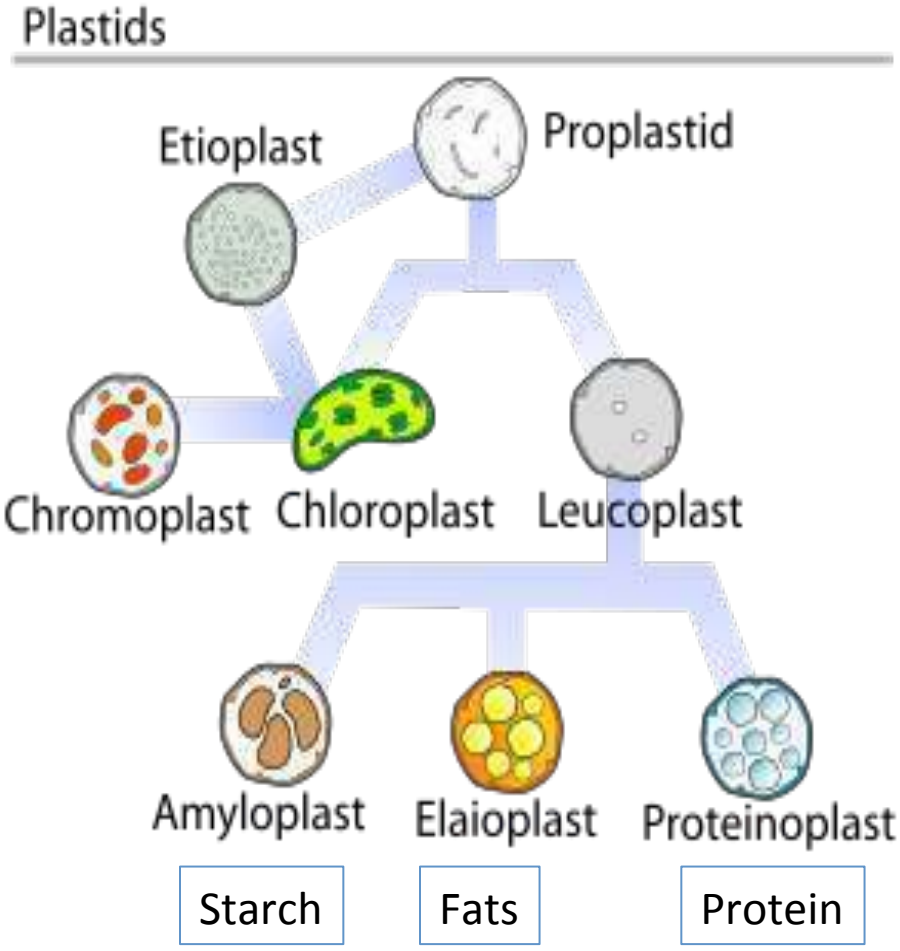
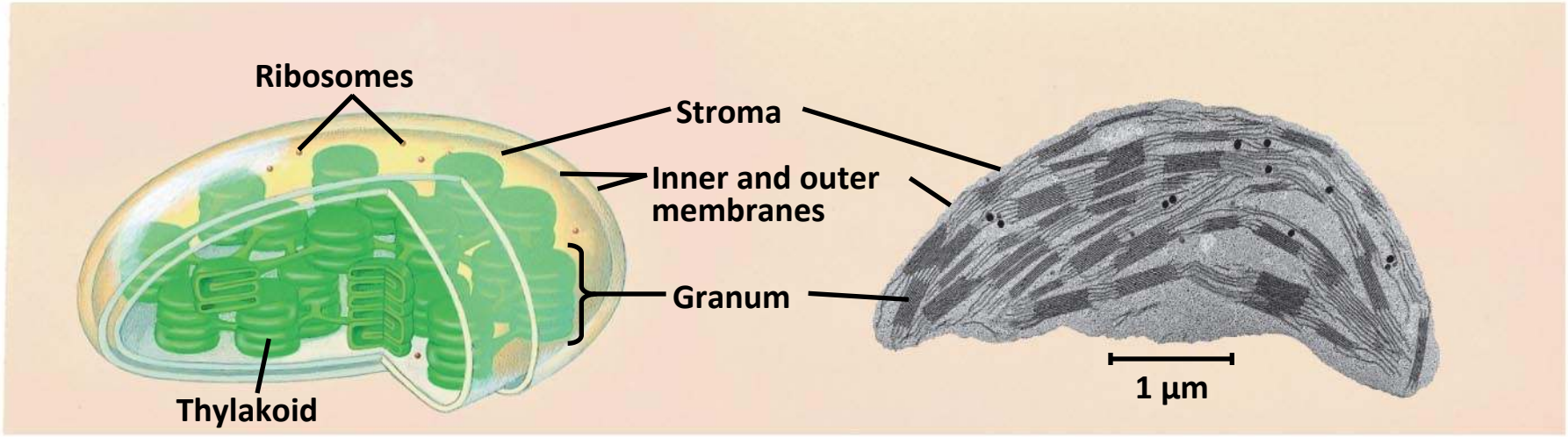


Fig. 6-18

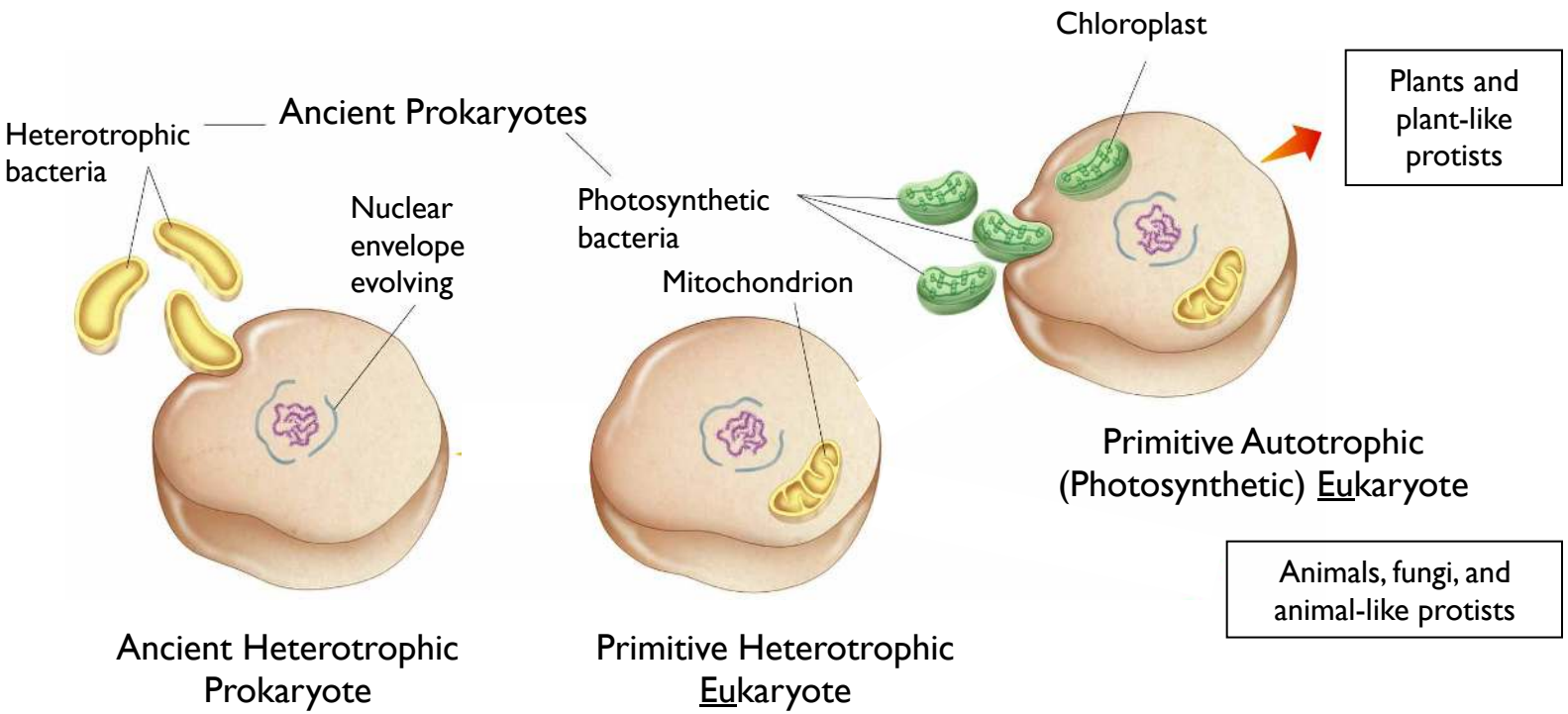


The Endosymbiotic Theory
(An attempt to explain genesis of Eukaryotic cells)

The endosymbiotic theory is the idea that a long time ago, prokaryotic cells engulfed other prokaryotic cells by endocytosis. This resulted in the first eukaryotic cells.

- First proposed by Lynn Margulis
- Explains the origin of eukaryotic cells
- Explains the origin of certain membrane-bound organelles

What Exactly Happened?



Evidence in support of the endosymbiotic theory:

Similarities between mitochondria, chloroplasts, & prokaryotes:

1. Circular DNA
2. Ribosomes
3. Binary fission

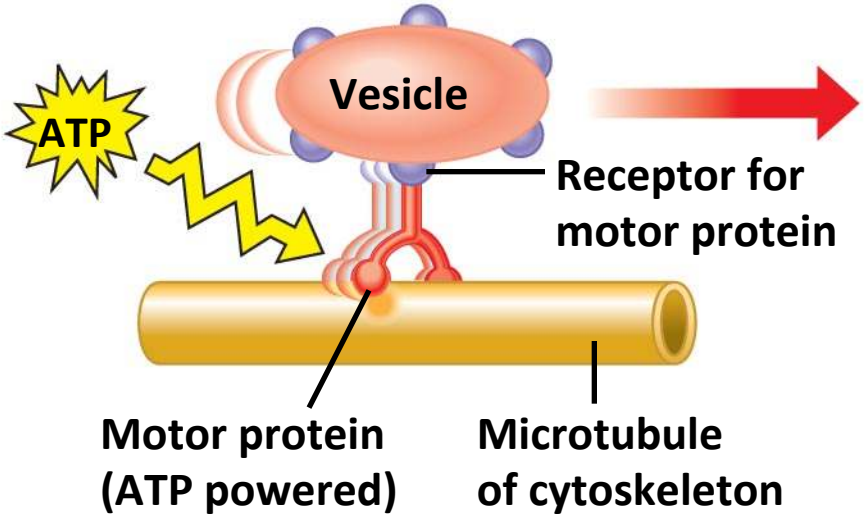
The cytoskeleton is a network of fibers that organizes structures and activities in the cell

- The **cytoskeleton** is a network of fibers extending throughout the cytoplasm
- It organizes the cell's structures and activities, anchoring many organelles
- It is composed of three types of molecular structures:
  - Microtubules ~25nm, thick (cillia and flagella: movement)
  - Microfilaments~ 7nm, thin (actin)
  - Intermediate filaments~10nm,

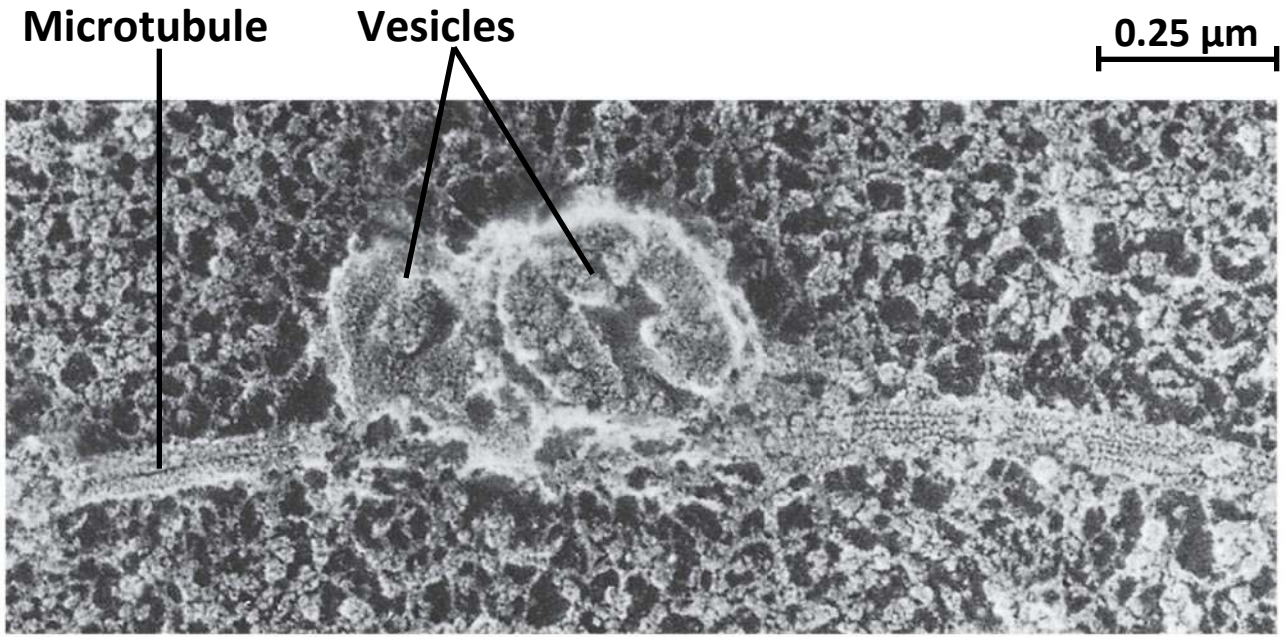
Roles of the Cytoskeleton: Support, Motility, and Regulation

- The cytoskeleton helps to support the cell and maintain its shape
- It interacts with **motor proteins** to produce motility
- Inside the cell, vesicles can travel along "monorails" provided by the cytoskeleton
- The cytoskeleton may help regulate biochemical activities

Fig. 6-21



(a)



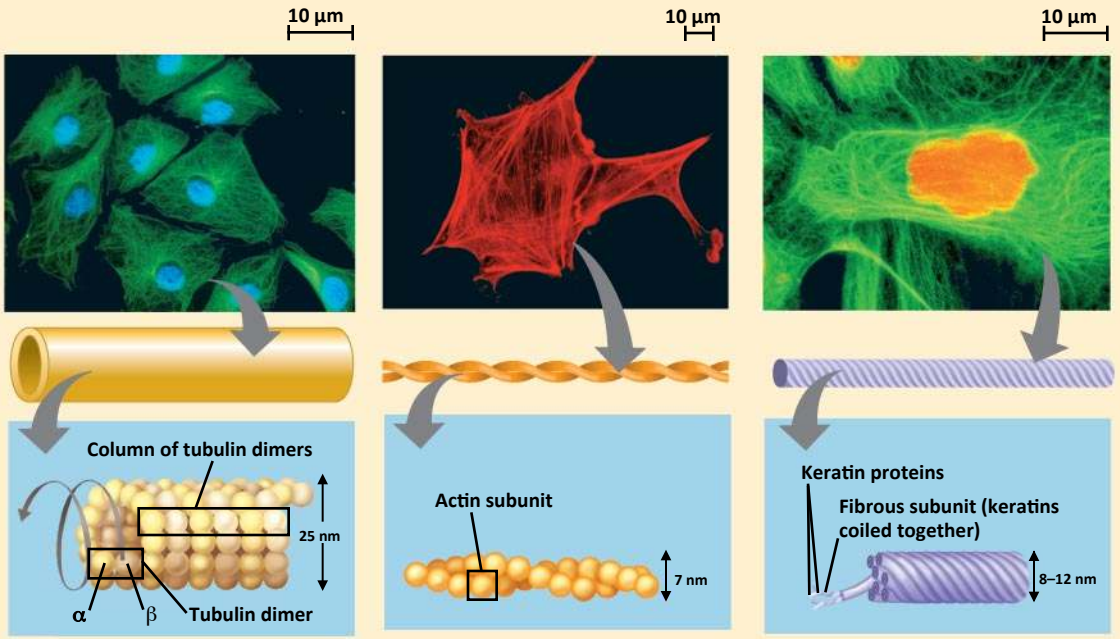
(b)

Table 6-1

Table 6.1 The Structure and Function of the Cytoskeleton

Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin, each a polymer of actin subunits	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins of the keratin family, depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina

Micrographs of fibroblasts, a favorite cell type for cell biology studies. Each has been experimentally treated to fluorescently tag the structure of interest.



Some characteristics of microtubules

- **Microtubules** are hollow rods about 25 nm in diameter and about 200 nm to 25 microns long
- Functions of microtubules:
  - Shaping the cell
  - Guiding movement of organelles
  - Separating chromosomes during cell division

Centrosomes and Centrioles

- In many cells, microtubules grow out from a **centrosome** near the nucleus
- The centrosome is a "microtubule-organizing center"
- In animal cells, the centrosome has a pair of **centrioles**, each with nine triplets of microtubules arranged in a ring

Microtubules control the beating of **cilia** and **flagella**

https://www.youtube.com/watch?v=YTv9ItGd050

Extracellular components and connections between cells help coordinate cellular activities

- Most cells synthesize and secrete materials that are external to the plasma membrane
- These extracellular structures include:
  - Cell walls of plants
  - The extracellular matrix (ECM) of animal cells
  - Intercellular junctions

The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by an elaborate **extracellular matrix (ECM)**
- The ECM is made up of glycoproteins such as **collagen**, **proteoglycans**, and **fibronectin**
- ECM proteins bind to receptor proteins in the plasma membrane called **integrins**
- Functions of the ECM:
  - Support
  - Adhesion
  - Movement
  - Regulation

Intercellular Junctions

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact
- Intercellular junctions facilitate this contact
- There are several types of intercellular junctions
  - Plasmodesmata: in plant cell walls for transport of solutes
  - Tight junctions
  - Desmosomes
  - Gap junctions

Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

- At **tight junctions**, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid
- **Desmosomes** (anchoring junctions) fasten cells together into strong sheets
- **Gap junctions** (communicating junctions) provide cytoplasmic channels between adjacent cells

Fig. 6-32

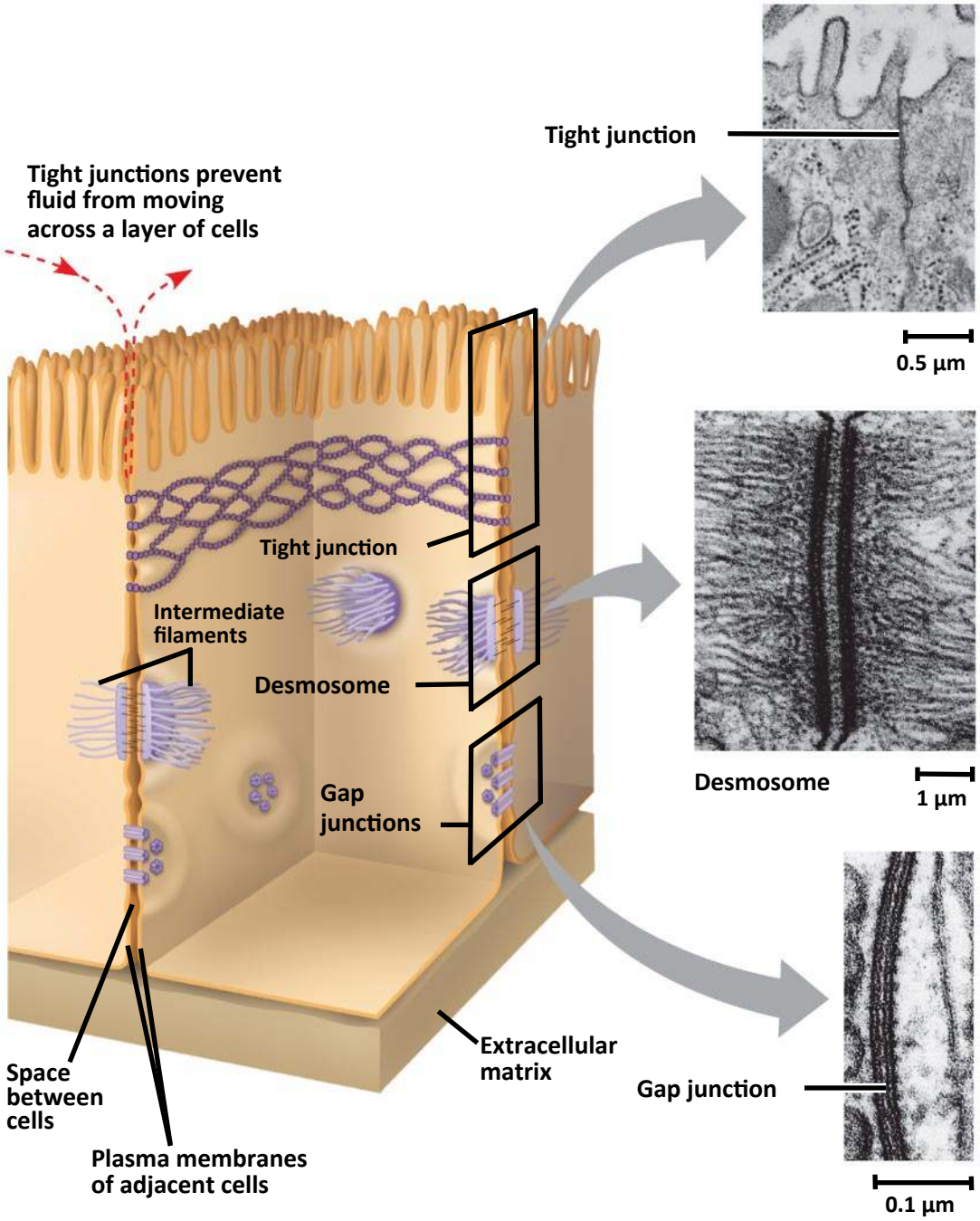
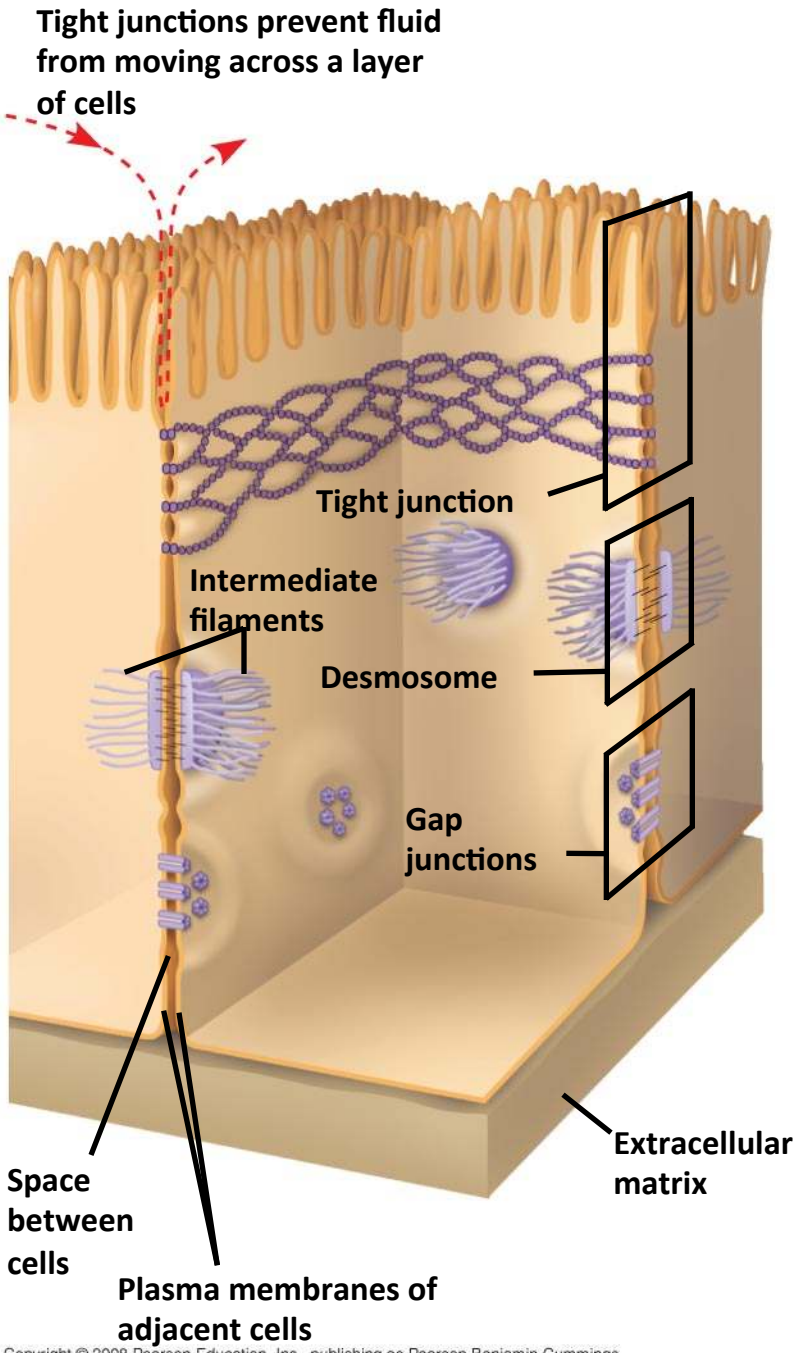


Fig. 6-32a

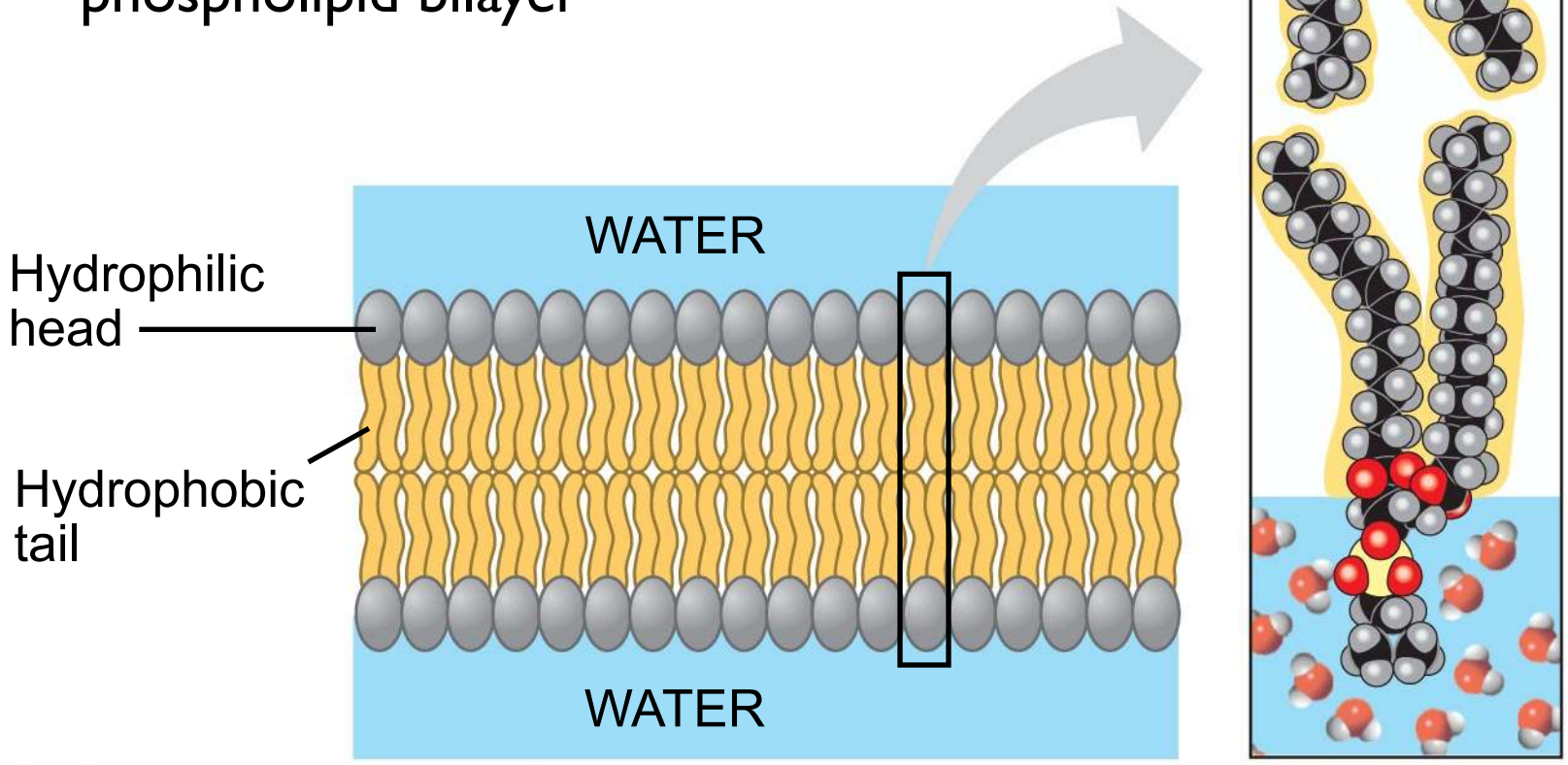


Membrane Structure and Function

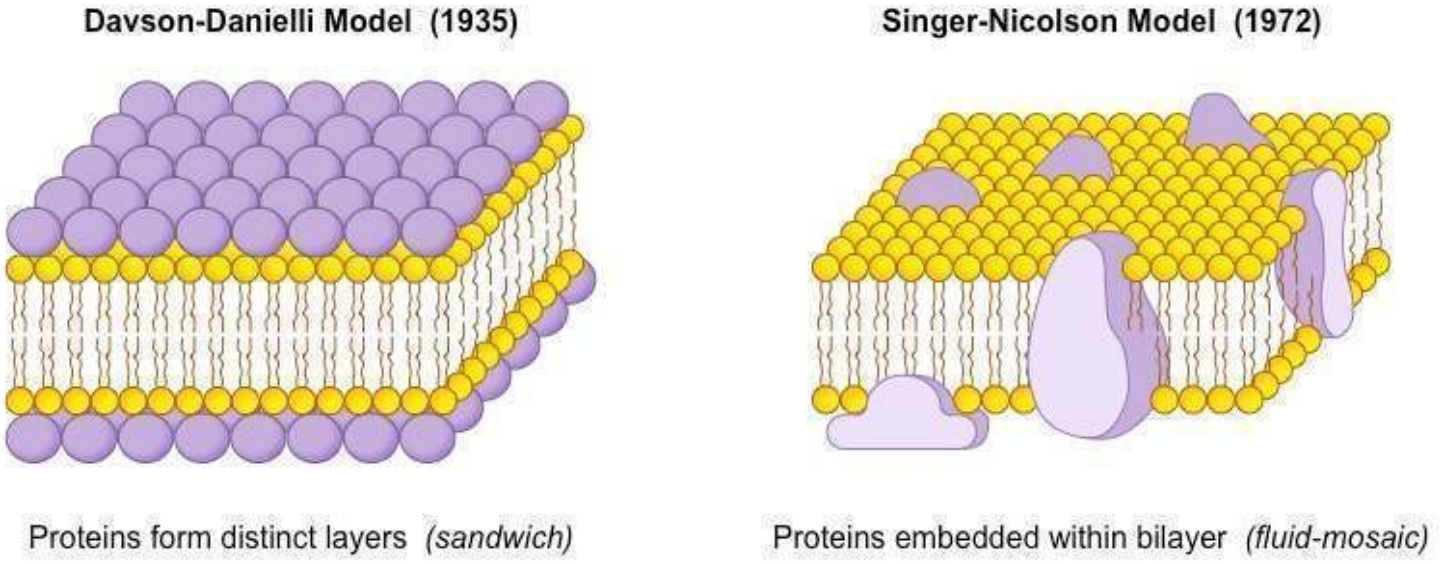
- The plasma membrane is the boundary that separates the living cell from its surroundings
- The plasma membrane exhibits **selective permeability**, allowing some substances to cross it more easily than others
- **Phospholipids** are the most abundant lipid in the plasma membrane
- Phospholipids are **amphipathic molecules**, containing hydrophobic and hydrophilic regions
- The **fluid mosaic model** states that a membrane is a fluid structure with a "mosaic" of various proteins embedded in it.

Fig. 7-2

- Membranes have been chemically analyzed and found to be made of proteins and lipids
- Scientists studying the plasma membrane reasoned that it must be a phospholipid bilayer

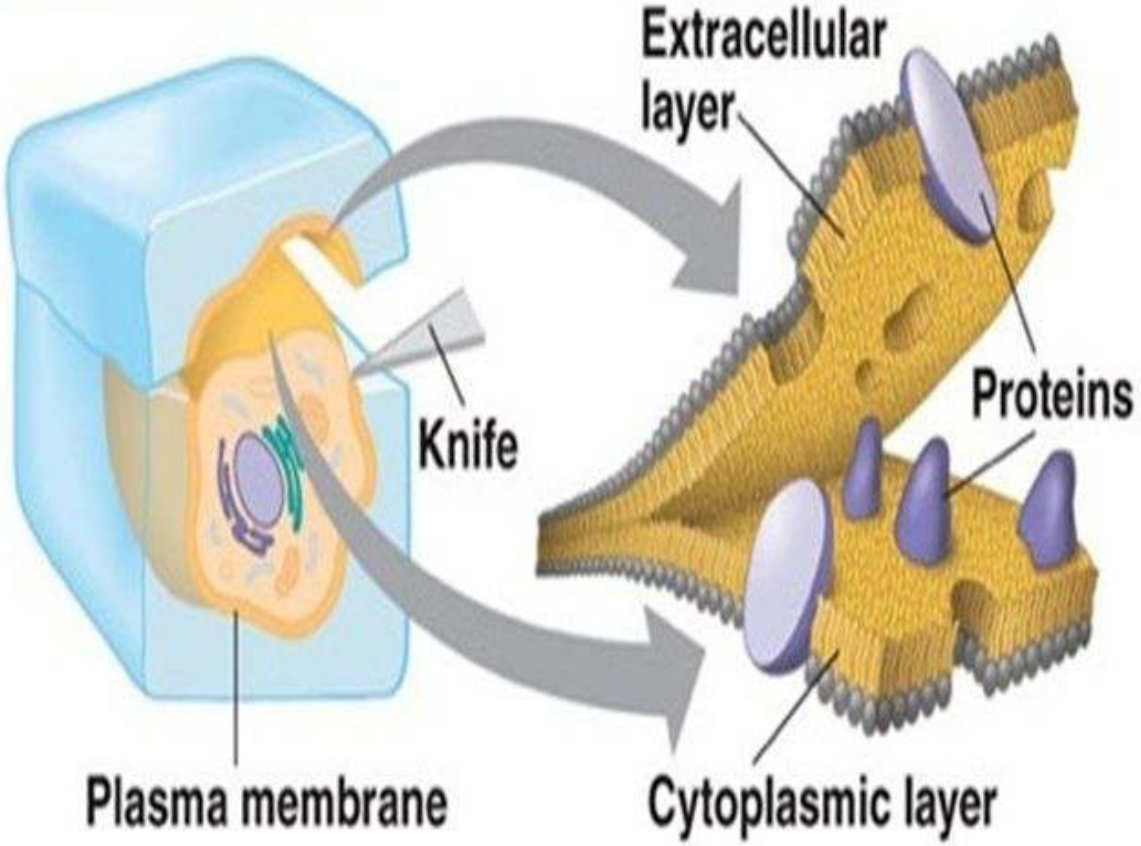


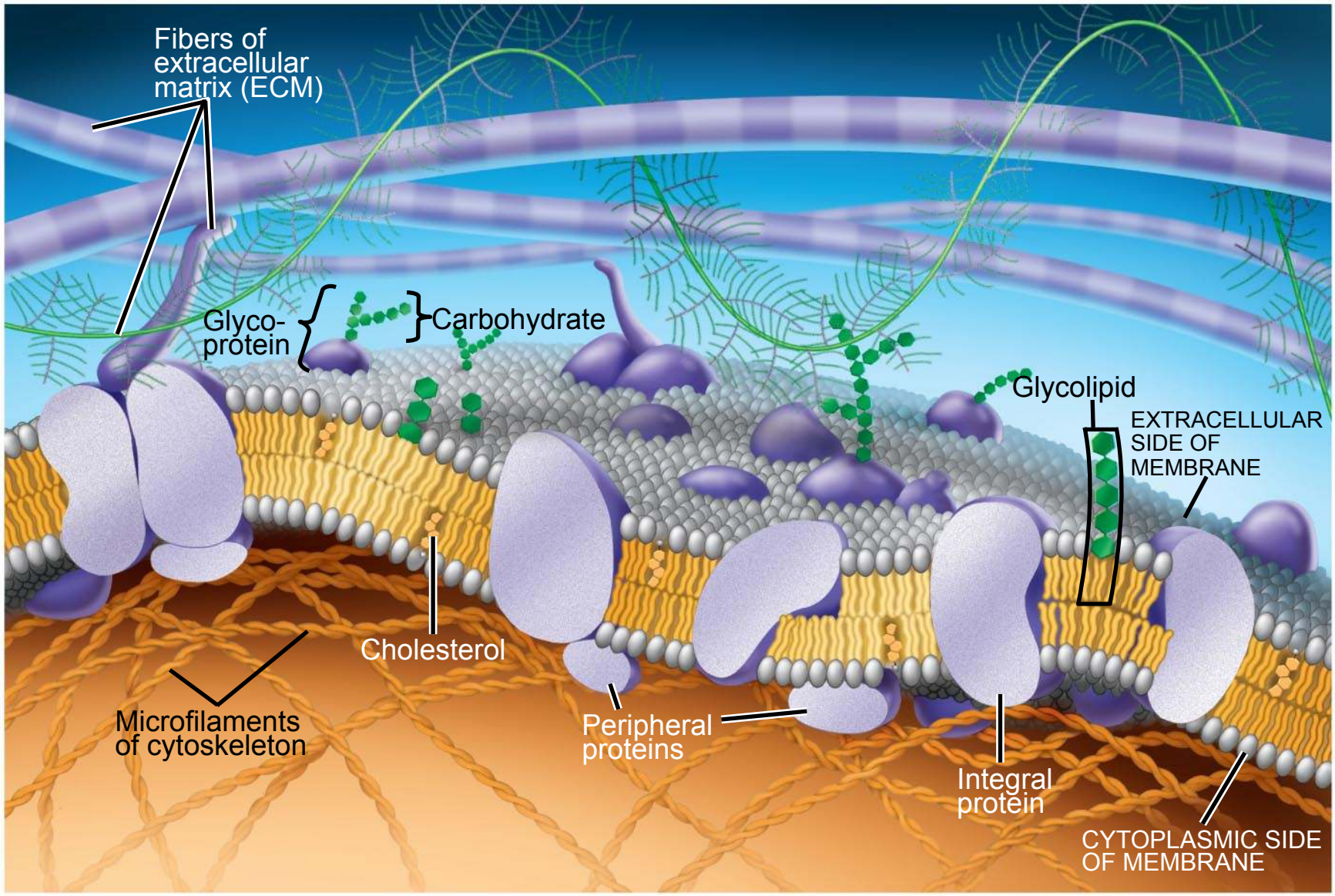
- In 1935, Hugh Davson and James Danielli proposed a **sandwich model** in which the phospholipid bilayer lies between two layers of globular proteins
- Later studies found problems with this model, particularly the placement of membrane proteins, which have hydrophilic and hydrophobic regions
- In 1972, J. Singer and G. Nicolson proposed that the **membrane is a mosaic of proteins dispersed within the bilayer**, with only the hydrophilic regions exposed to water



Freeze and Fracture

TECHNIQUE





Peripheral proteins are bound to the surface of the membrane

Integral proteins penetrate the hydrophobic core → Transmembrane