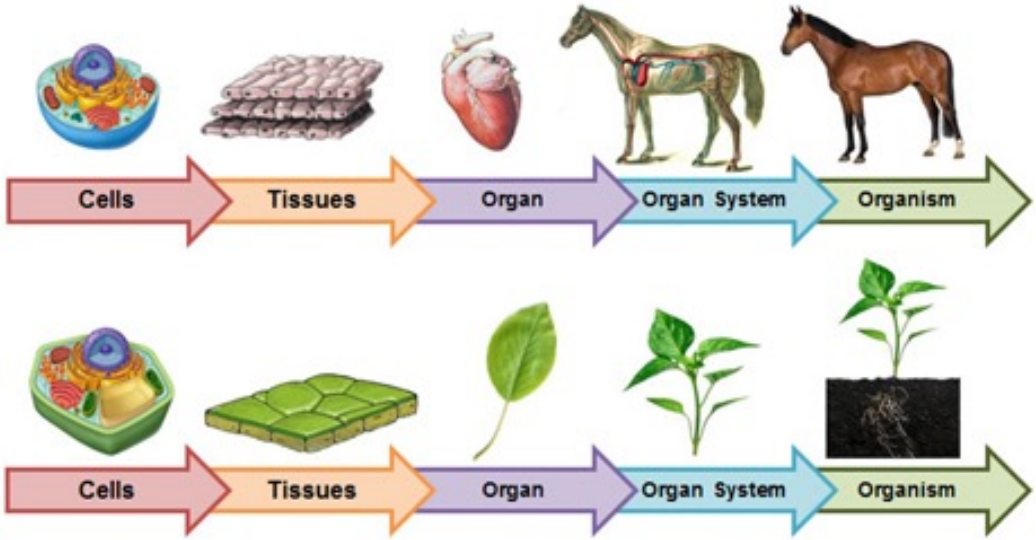
LSM1301

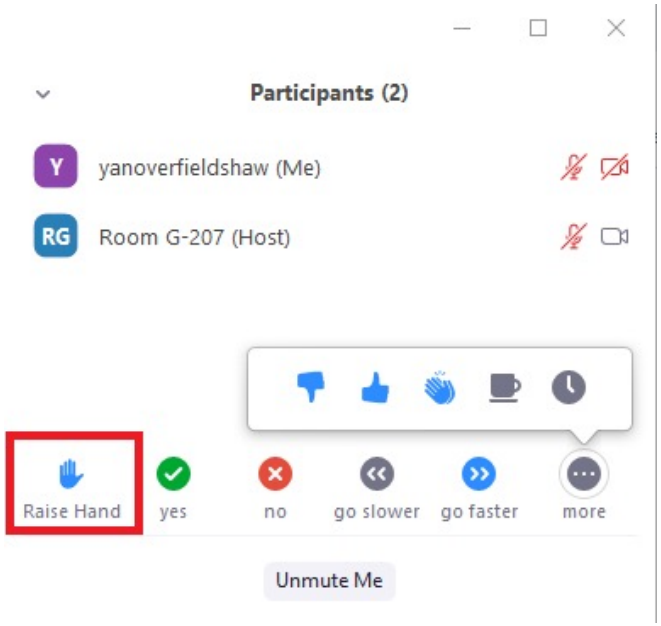


Cell structure and function

Maxine Mowe
Office at S2-04
dbsmadm@nus.edu.sg
Tel: 65161614

Lecture participation/ asking questions

- Press the raise hand function
- Type your question in the chat
  - I will only see this when I pause to ask for questions
  - Keep your questions until I ask for questions
- Please remain muted during the lecture to minimize disruptions
- Longer questions should be put into Forum on Luminus



Lecture Topics and Assignments

- **Introduction (1 Lecture Session)**

- **Dr. NP Lectures/labs/Museum (5 Lects, 2 Labs, 1 Museum, 3 Tutorials)**

- **Chemistry of Life (1 Lect session)**
- **Cell Structure and Function (1 Lect)** (Today)
- **Energy and Life (1 Lect)**
- **DNA and Gene Expression (2)**
- **Biotechnology (1 Lect)**
- **Summary & Tutorial (1 Session)**
  - **Total Assignments = 4 lab assignments (30%)**

Learning Plan (Cell/Unit of Life)

Topic	Learning outcomes: Students are able to	Activities for online session	Activities for face-to-face session	Assignments/Assessments
Cell Structure, Function, and Division	•*Explain how cells are demonstrated as the basic unit of life using scientific inquiry* •*compare structures of prokaryotic and eukaryotic cells* •*Build up connection of the cellular structure and function* •*Build up a systematic understanding of different organelles using protein synthesis as an example* •*Relate cellular structure to some diseases*	•*Read lecture notes to have an overall idea on the cell structure, and function* •*Watch video: Cell Structure and Function http://www.youtube.com/watch?v=g4L_QO4WKtM (10 min)* •*Raise questions on LumiNUS forum* •*Participate discussion on LumiNUS forum* •*Try Track-Learning MCQs (pre-class quizzes)*	•*Demonstrate cell structure with models and a chicken egg* •*Application of knowledge of cell membrane (e.g. aquaporin, kidney disease, New-water regeneration and membrane technology)* •*Organelle malfunction and disease* •*Play student-made videos to elaborate structure and function* •*Try application-based MCQs via PollEverywhere* •*Observe cell shape and structure in the lab*	•Enhance understanding with Track-learning MCQs (post-class quizzes) •Complete assignments related to lab sessions

Intended Learning Outcomes

At the end of this topic, the student should be able

- To relate the surface area to volume ratio to the size of a cell
- To describe the structure of biological membranes, and to relate the components of a membrane to the selective permeability feature of a biological membrane
- To describe the structures of a prokaryotic cell and a eukaryotic cell, and to relate the structures to their specific functions
- To explain why a eukaryotic cell can survive despite being larger than a prokaryotic cell

Outline

- Cells
  - Cell theory
  - Cell size
  - Structure
- Cell Membranes
  - Membrane structure
  - Movement across membranes
  - Cell walls
- Prokaryotic Cells
- Eukaryotic Cells
  - Nucleus
  - Endomembrane system
  - Energy-related organelles
  - Cytoskeleton

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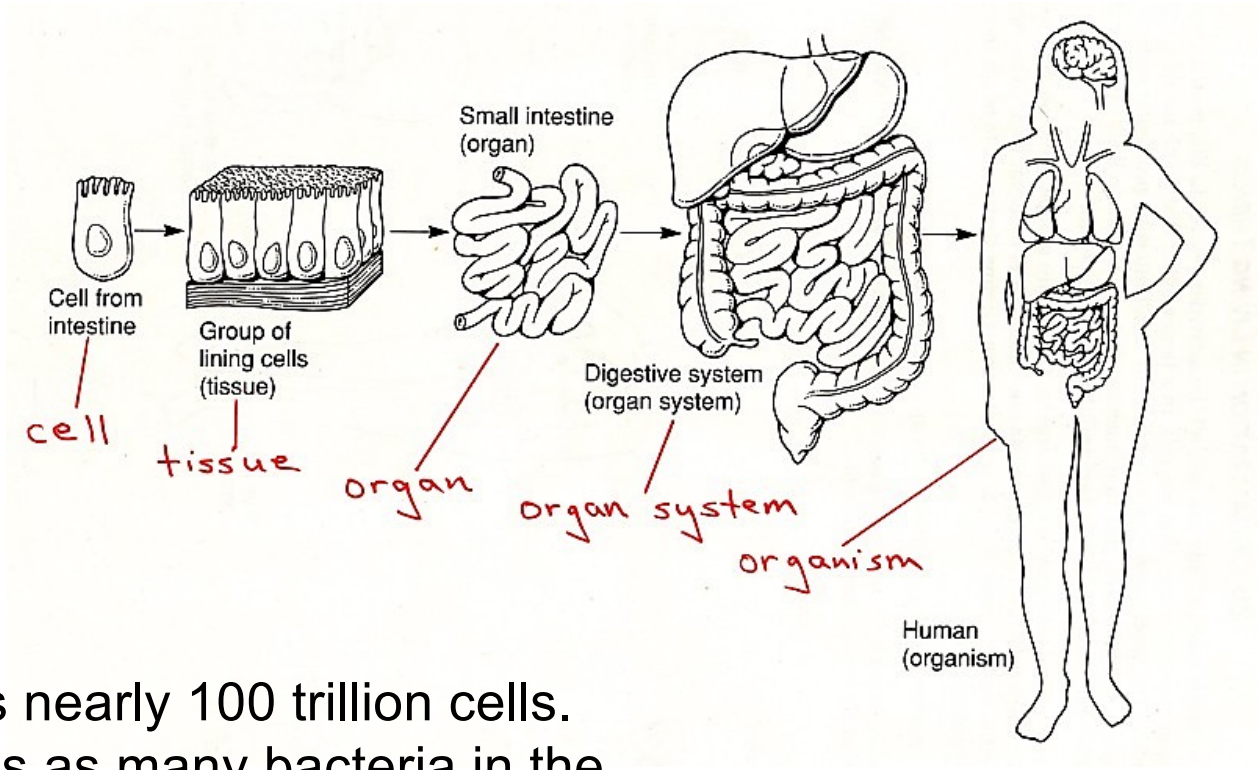
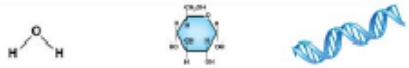
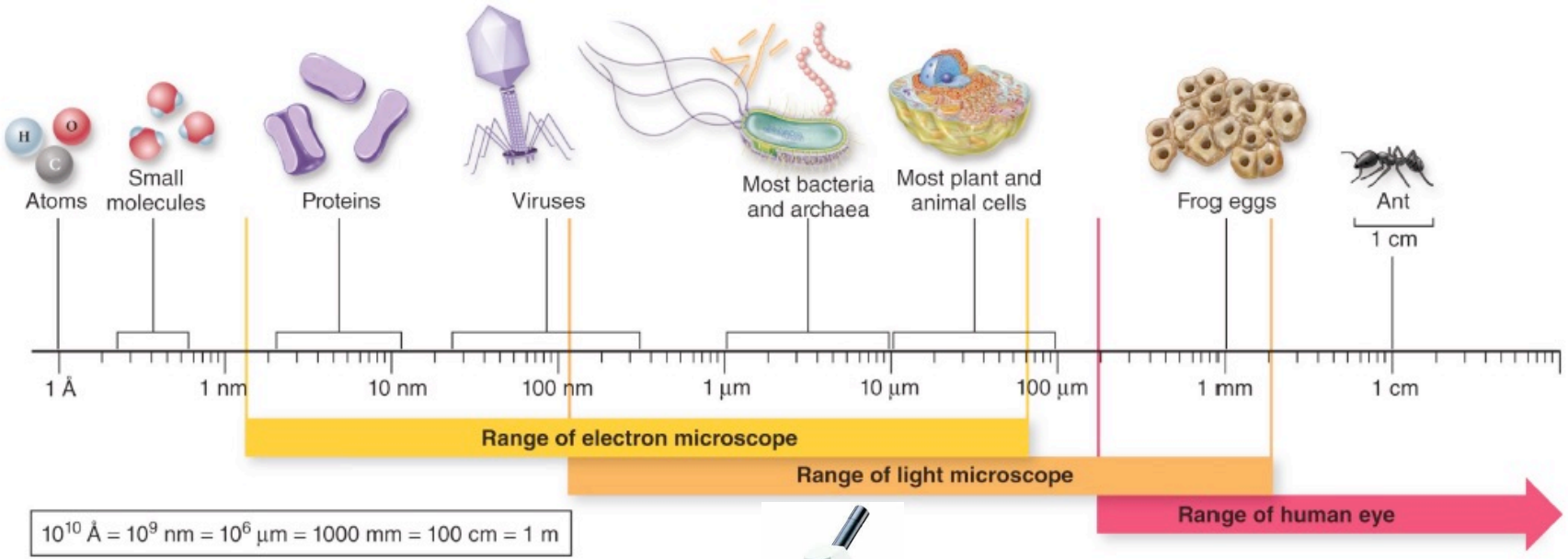
How is life organized around cells?



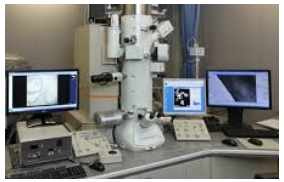
- Unicellular organisms
- Multicellular organisms

- The human body contains nearly 100 trillion cells.
- There are at least 10 times as many bacteria in the human body as cells.

Biosphere	**All life on Earth and the nonliving portions of Earth that support life**	 Earth's surface
Ecosystem	**A community together with its nonliving surroundings**	 snake, antelope, hawk, bushes, grass, rocks, stream
Community	**Populations of different species that live in the same area and interact with one another**	 snake, antelope, hawk, bushes, grass
Species	**All organisms that are similar enough to interbreed**	 herd of pronghorn antelope
Population	**All the members of a species living in the same area**	
Multicellular organism	**An individual living thing composed of many cells**	 pronghorn antelope
Organ system	**Two or more organs working together in the execution of a specific bodily function**	 the digestive system
Organ	**A structure usually composed of several tissue types that form a functional unit**	 the stomach
Tissue	**A group of similar cells that perform a specific function**	 epithelial tissue
Cell	**The smallest unit of life**	 red blood cell epithelial cell nerve cell
Molecule	**A combination of atoms**	 water glucose DNA
Atom	**The smallest particle of an element that retains the properties of that element**	 hydrogen carbon nitrogen oxygen



10^{10} Å = 10^{9} nm = 10^{6} µm = 1000 mm = 100 cm = 1 m



Cell size

- Most cells are small
  - Diameters range from 1 to 100 μm
- Large surface area needed
  - To allow for adequate rate of exchange nutrients and wastes with environment
- Surface-area-to-volume ratio
  - Larger cells – surface area relative to volume smaller
  - Smaller cells – surface area relative to volume larger

	One 4-cm cube	Eight 2-cm cubes	Sixty-four 1-cm cubes
Total surface area (height × width × number of sides × number of cubes)	96 cm^2	192 cm^2	384 cm^2
Total volume (height × width × length × number of cubes)	64 cm^3	64 cm^3	64 cm^3
Surface area: **Volume per cube** (surface area ÷ volume)	1.5:1	3:1	6:1

Who discovered the cell?

Robert Hooke
(1635-1703)
England

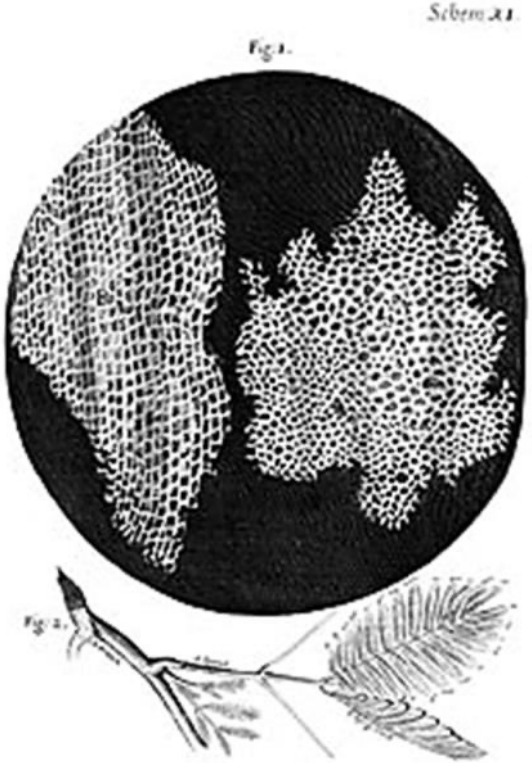
- Observed small boxes, they resembled the tiny rooms, or “cells” occupied by monks
- He coined the word **'cell'** to describe the tiny compartment, later, we know it is the basic unit of life

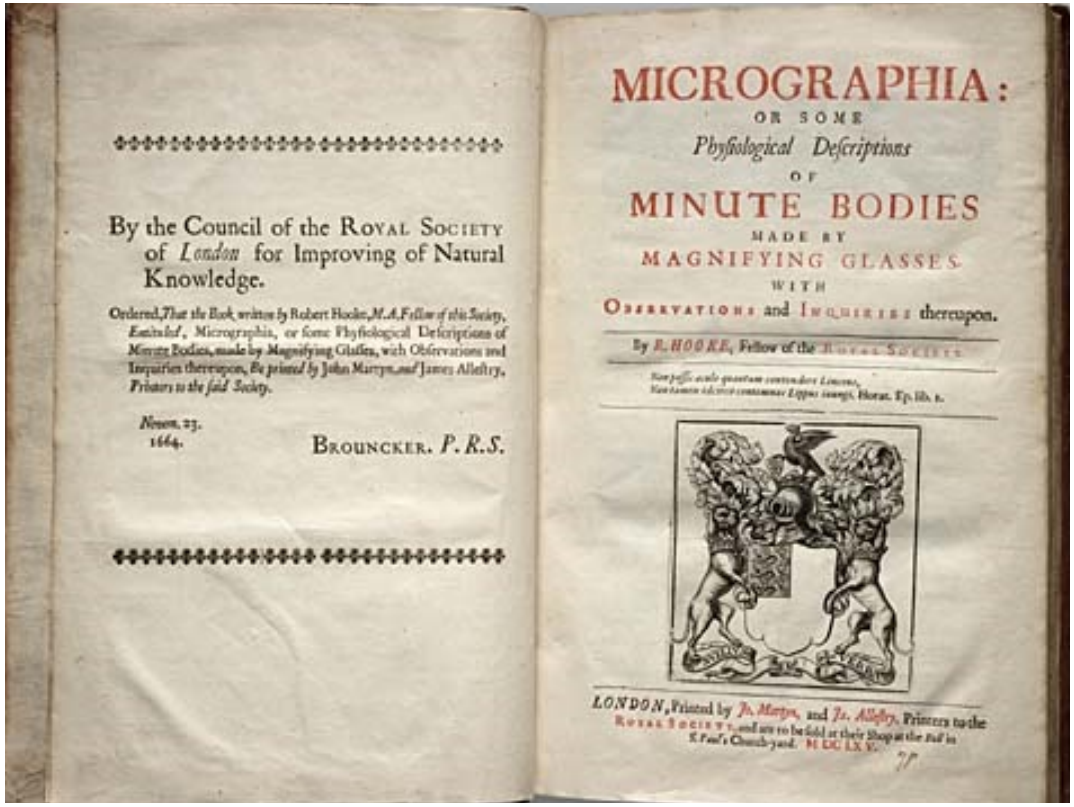
Peel off dry outer bark of the cork oak, then **thinly slice** a piece of cork

Robert Hooke's Cork Cells

January 01, 1653

First published in 1665





By the Council of the Royal Society of *London* for Improving of Natural Knowledge.

Ordered, That the Book, written by Robert Hooke, *M.A. Fellow of this Society*, Entituled, Micrographia, or some Physiological Descriptions of Minute Bodies, made by Magnifying Glasses, with Observations and Inquiries thereupon, *Be printed by* John Martyn, *and* James Allestry, *Printers to the said Society.*

Novem. 23. 1664. BROUNCKER. *P. R. S.*

MICROGRAPHIA:
OR SOME
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OF
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WITH
OBSERVATIONS and INQUIRIES thereupon.

By R. HOOKE, Fellow of the Royal Society.

LONDON, Printed by Jo. Martyn, and Ja. Allestry, Printers to the Royal Society, and are to be sold at their Shop at the Bell in S. Paul's Church-yard. MDCLXV.

"Exceeding thin, piece of cork, a great many little box"

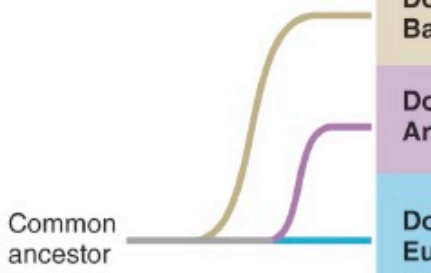
Cell Theory

Three principles comprise cell theory

- All living things or organisms are made of cells and their products
- Cells are the basic building units of life
- Cells come from pre-existing cells

Structure

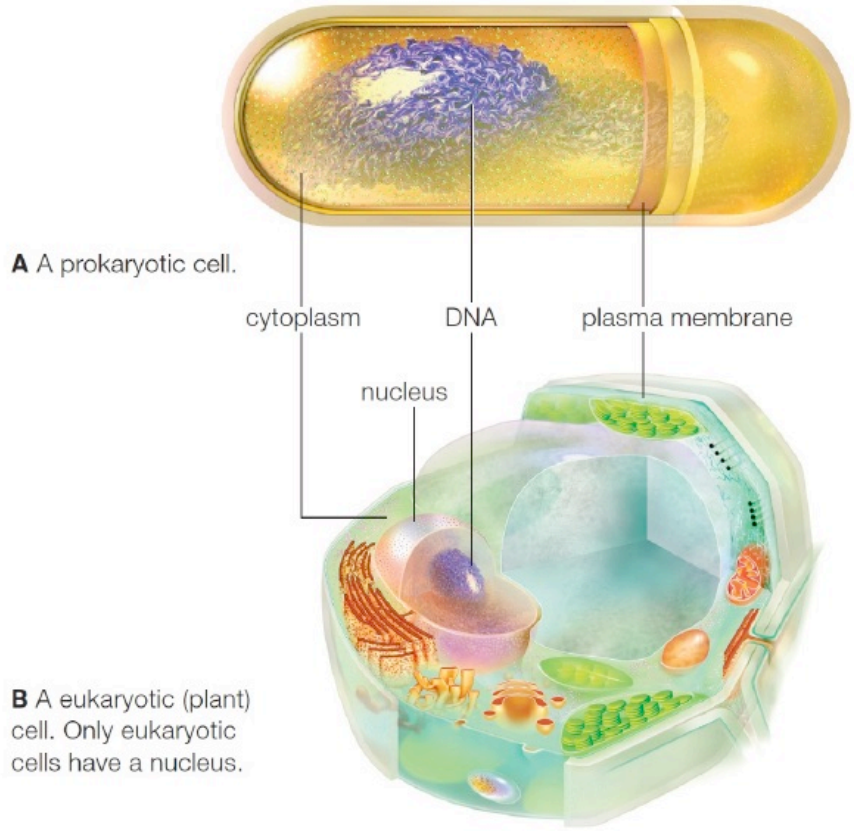
- Types of cells
  - Prokaryotic (*before nucleus* in Greek)
  - Eukaryotic (*true nucleus* in Greek)



	Cell Type	Nucleus	Membrane-bounded Organelles	Membrane Chemistry	Cell Wall Chemistry	Typical Size
Domain Bacteria	Prokaryotic	Absent	Absent	Fatty acids	Peptidoglycan (if present)	1-10 µm
Domain Archaea	Prokaryotic	Absent	Absent	Nonfatty acid lipids	Pseudopeptidoglycan or protein	1-10 µm
Domain Eukarya	Eukaryotic	Present	Present	Fatty acids	Usually cellulose or chitin (if present)	1-100 µm

Structure

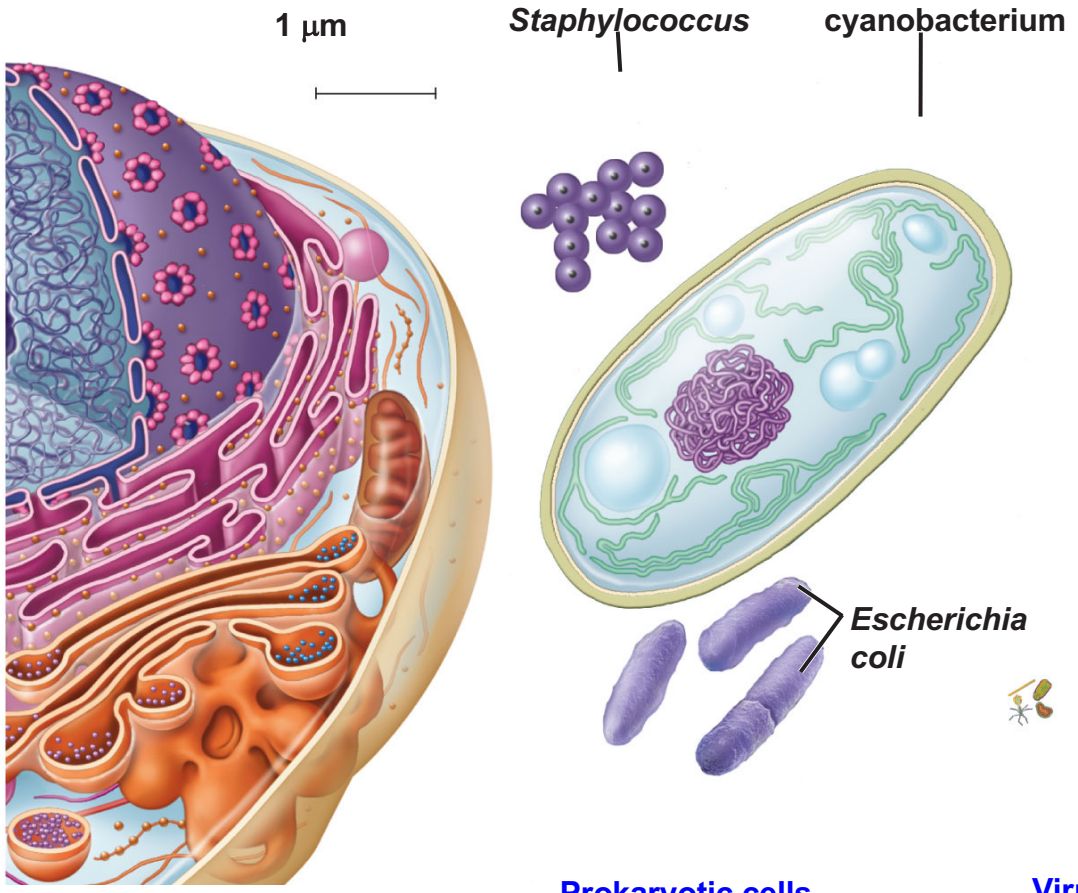
- Structural features of all cells
  - Plasma membrane
  - DNA-containing region
  - Cytoplasm



Structure

- Plasma membrane
  - Encloses cell and keeps cell as distinct entity from environment
  - Boundary that controls passage of substances in and out of cell
- DNA-containing region
  - Nucleus – in eukaryotes
  - Nucleoid region – in prokaryotes
- Cytoplasm
  - Fluid portion and structures between plasma membrane and DNA-containing region
  - Fluid portion contains water, salts and organic molecules – cytosol
  - Structures with specific functions – organelles

The Sizes of Microorganisms



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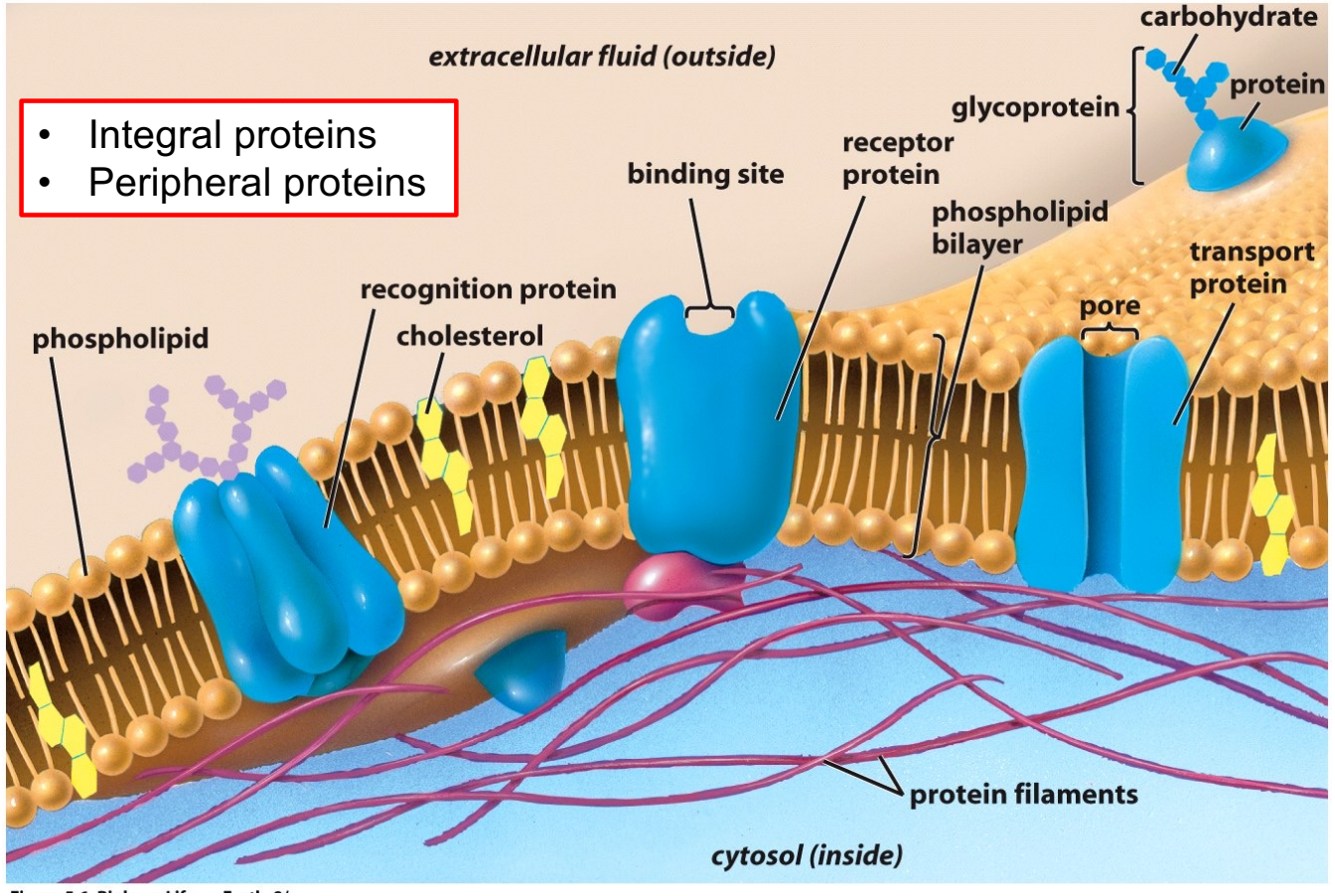
Cell Membranes

- Plasma membrane
  - Common to all cells
  - Separates cell's internal cytoplasm from external environment
  - Controls traffic of substances in and out of cell
  - Regulates biochemical reactions
  - Communicates with other cells
  - Creates attachments within and between cells
- Basic structure of all membranes in cells – similar
  - Bilayer of phospholipids with embedded and attached proteins

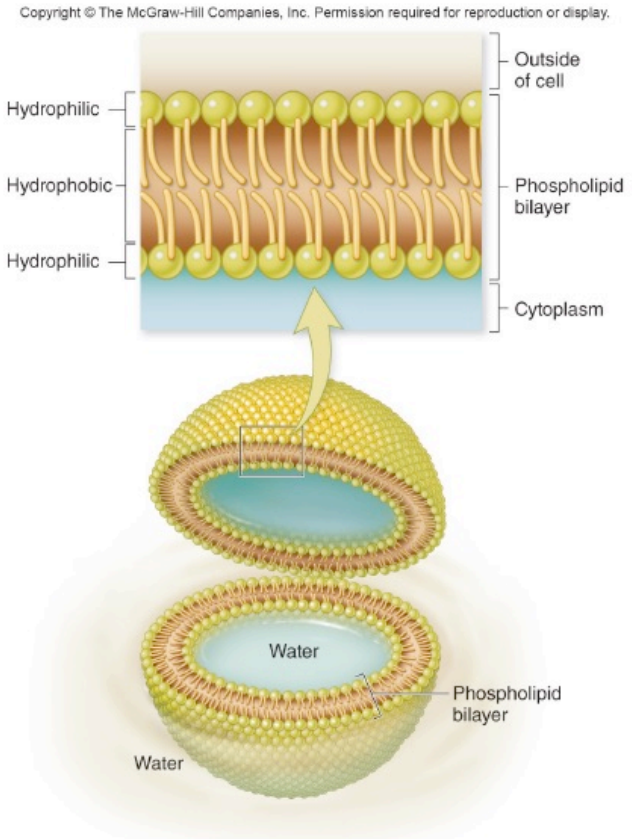
Plasma Membrane Structure



- Integral proteins
- Peripheral proteins

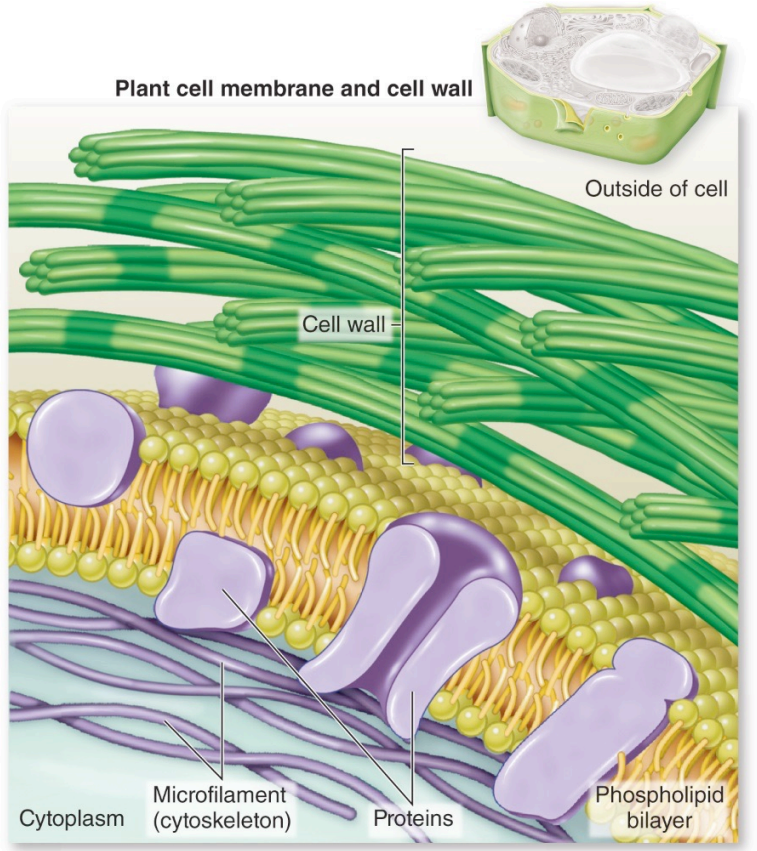
Membrane Structure

- Fluid mosaic model
  - Mosaic mixture of phospholipids, steroids and proteins
  - Constantly drifting and moving within viscous fluid of phospholipid bilayer
- Phospholipid bilayer
  - Forms selectively permeable barrier
  - Some are glycolipids, with attached carbohydrate chains



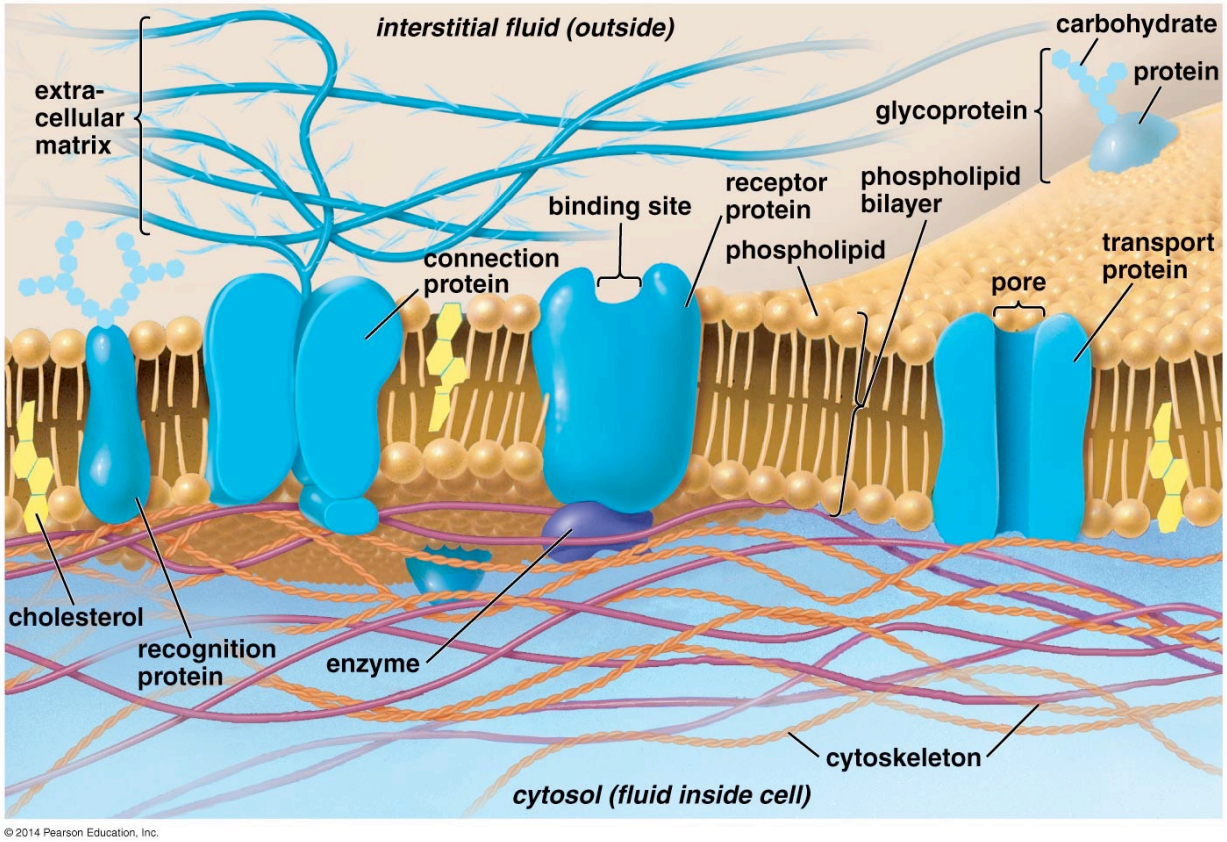
Membrane Structure

- Associated proteins
  - Float around like icebergs on sea
  - Some anchored by protein filaments in cytoplasm
  - Some are glycoproteins, with attached carbohydrate chains
  - Some are partially or wholly embedded in bilayer
  - Some are temporarily attached to surface of bilayer



Membrane Structure

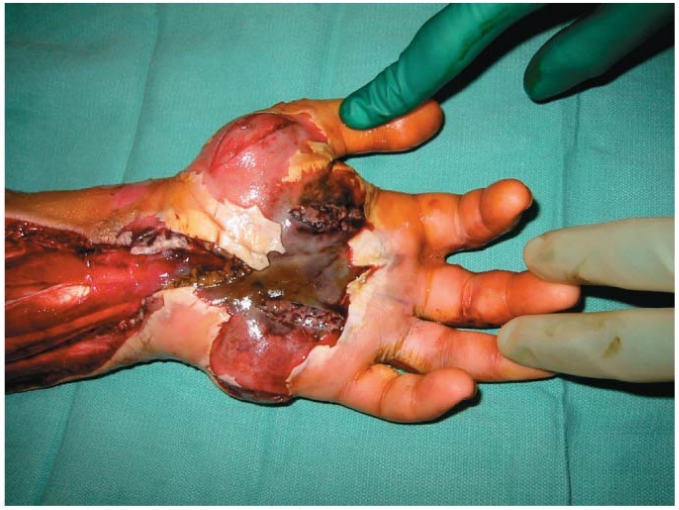
- Associated proteins
  - Responsible for variety of membrane functions –adhesion, enzymes,receptors, recognition, transport
- Steroids – cholesterol
  - Affects fluidity of membrane
  - Membranes of animal cells



Plasma Membrane Function

- Common to **all cells**
- Functions
  - It isolates the cell's contents from the external environment
  - It regulates the exchange of essential substances
  - It allows communication between cells
  - It creates attachments within and between cells
  - It regulates biochemical reactions

Case Study: Bites from rattlesnakes and spiders



(a) Justin's rattlesnake bite

(b) Brown recluse spider bite

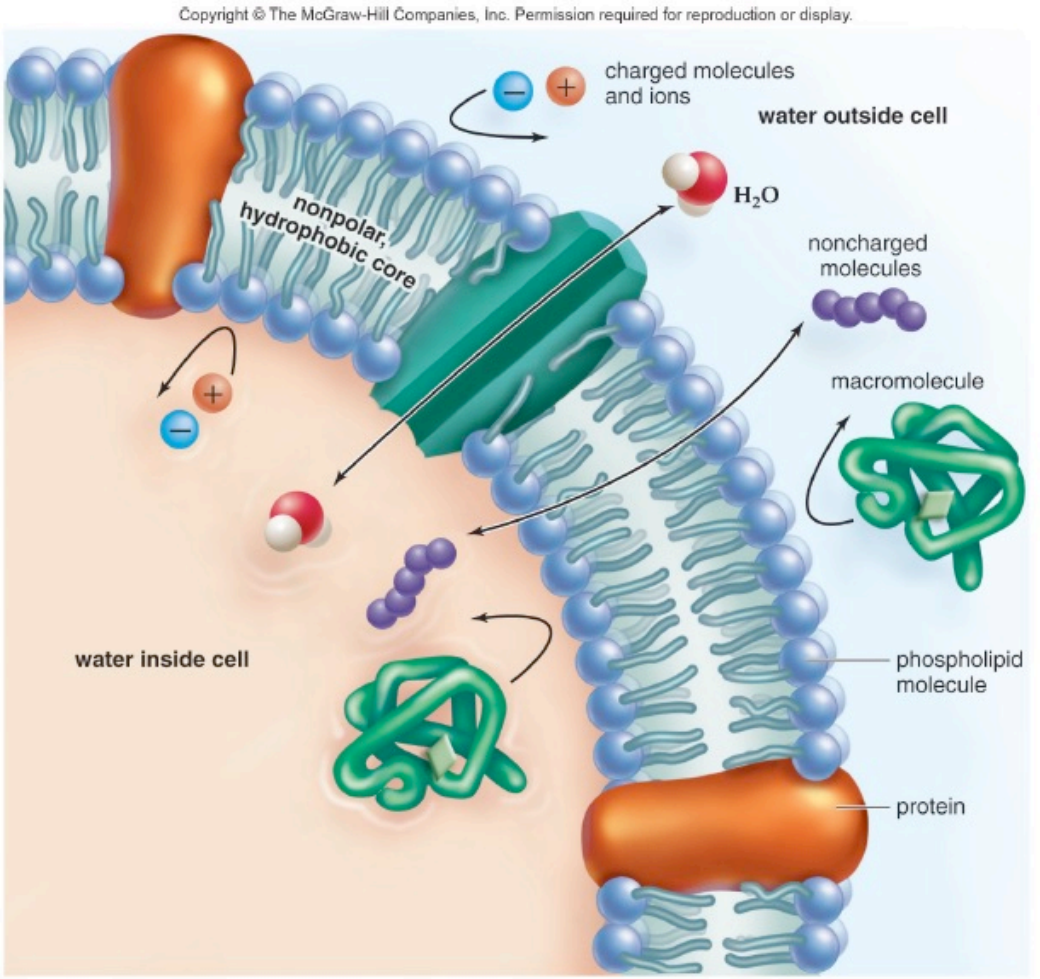
Transport of Substance Across Membranes

I. Passive transport: no energy required

Diffusion (simple diffusion; facilitated diffusion)

II. Active transport: energy-requiring transport

Such as Sodium-potassium carrier proteins

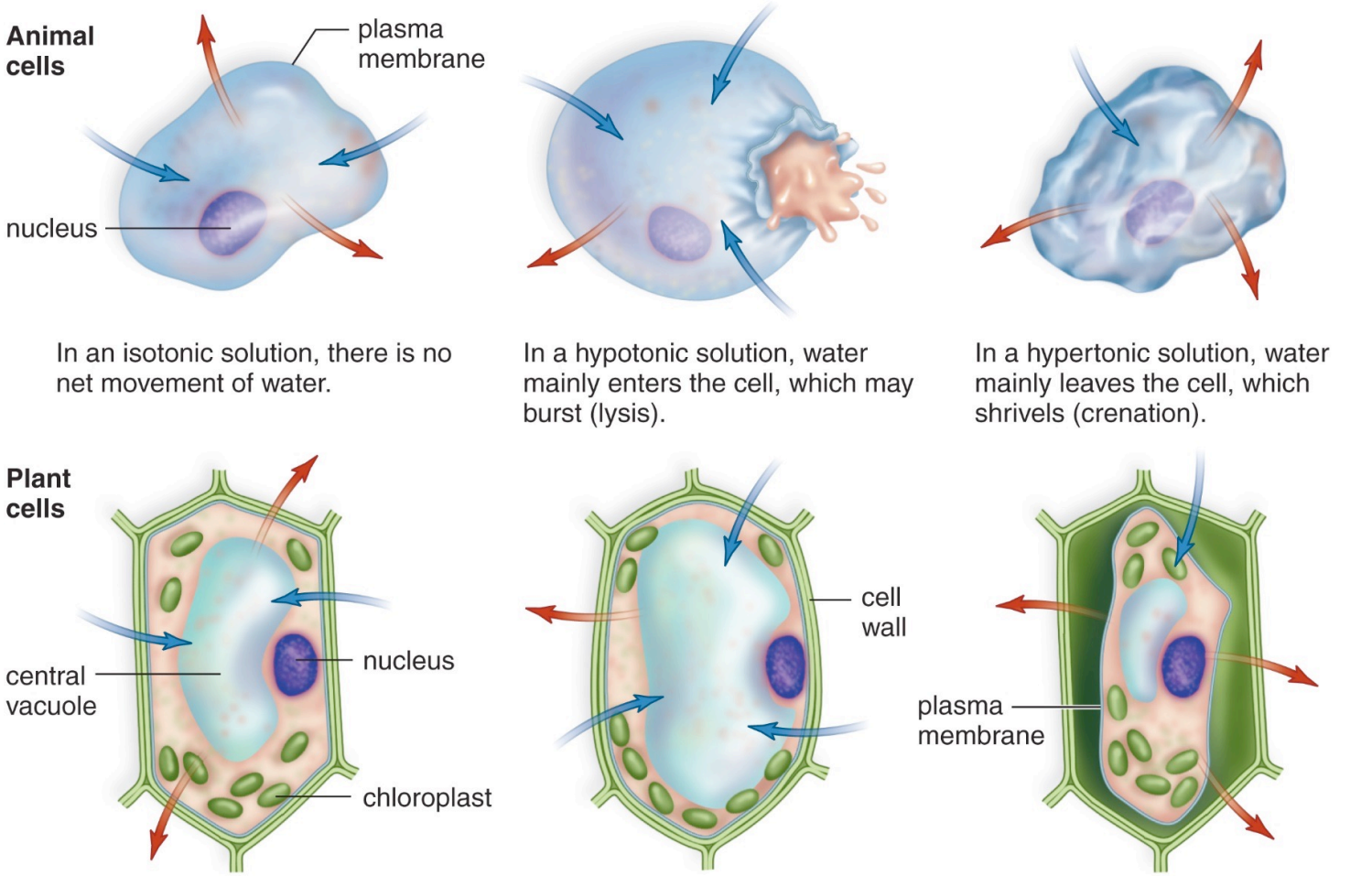


I. Passive Transport: Diffusion

- Diffusion
  - Net movement of molecules down a concentration gradient (high to low concentration)
- Osmosis – special case of diffusion
  - Diffusion of water across a selectively permeable membrane down its own concentration gradient
  - From high water (low solute) concentration to low water (high solute) concentration

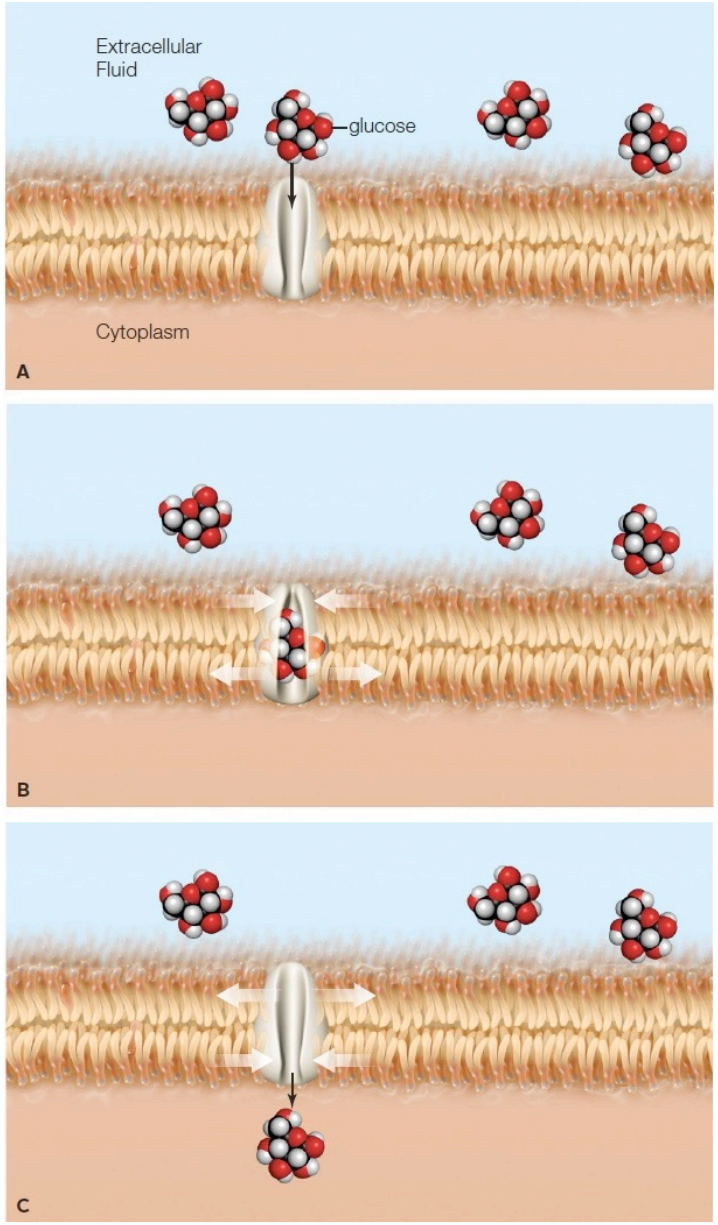
Movement across membranes

- Isotonic solution
  - Solute concentration equal on both sides of membrane
- Hypotonic solution
  - Solute concentration lower than on other side of membrane
- Hypertonic solution
  - Solute concentration higher than on other side of membrane



Movement across membranes

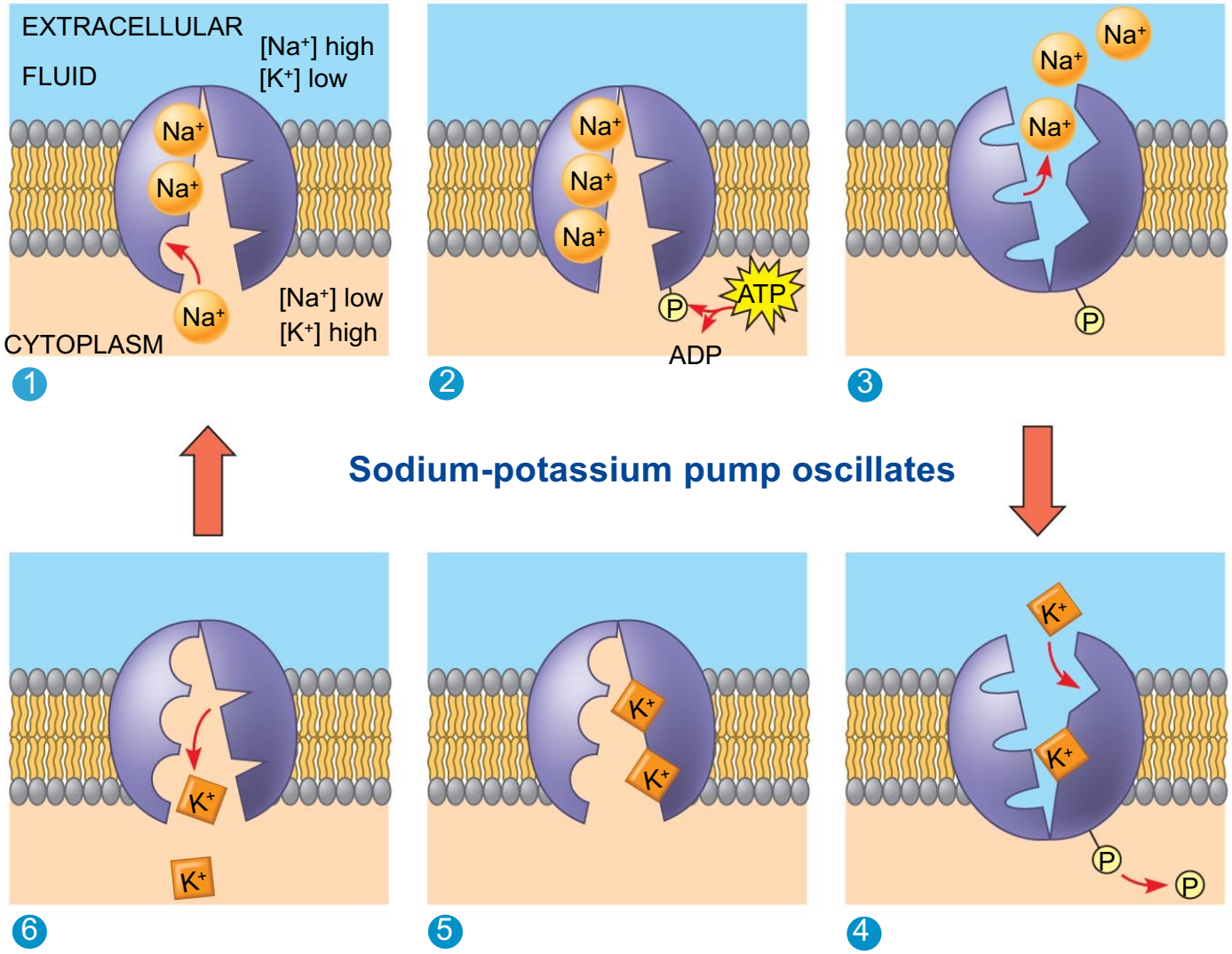
- Facilitated diffusion (facilitated transport)
  - Movement of molecules that cannot diffuse directly through phospholipid bilayer
  - Ions and polar molecules
  - Follow their concentration gradients
  - Transport proteins required
  - Specialised water-channel proteins, aquaporins, enhance water transport



II. Active Transport

The movement of materials across a membrane through the use of cellular energy, normally against a concentration gradient

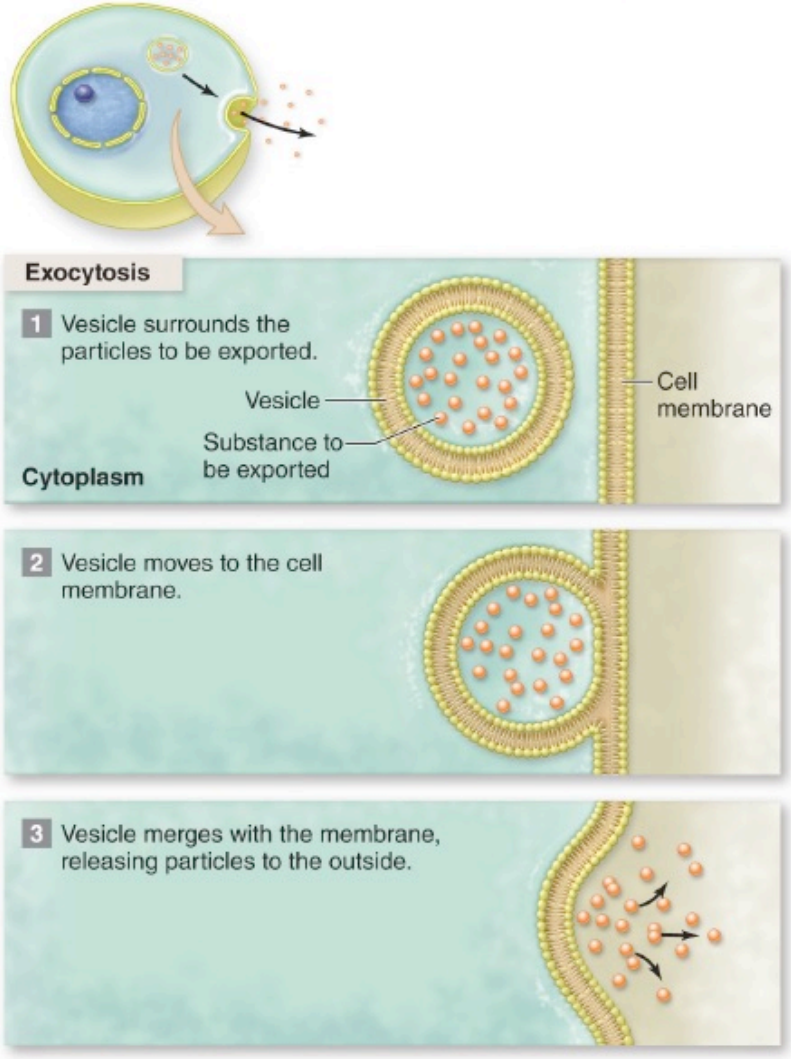
- Active transport is performed by specific proteins embedded in the membranes
- Active transport allows cells to maintain concentration gradients that differ from their surroundings

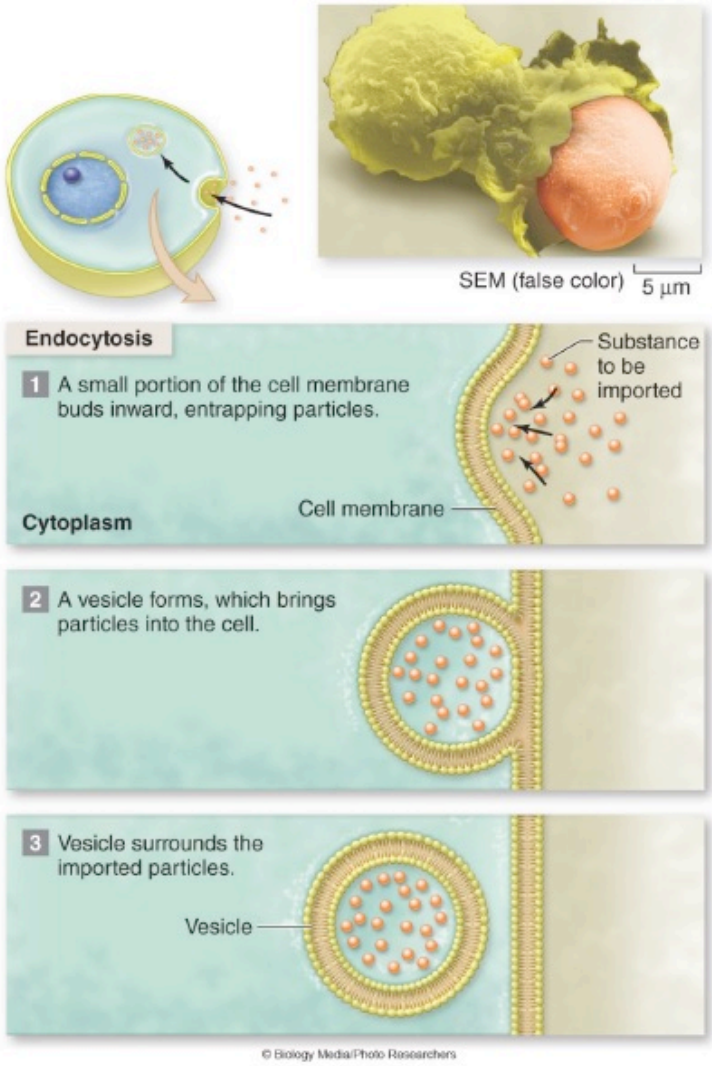


Animation of membrane transport (video)

Movement Across Membranes

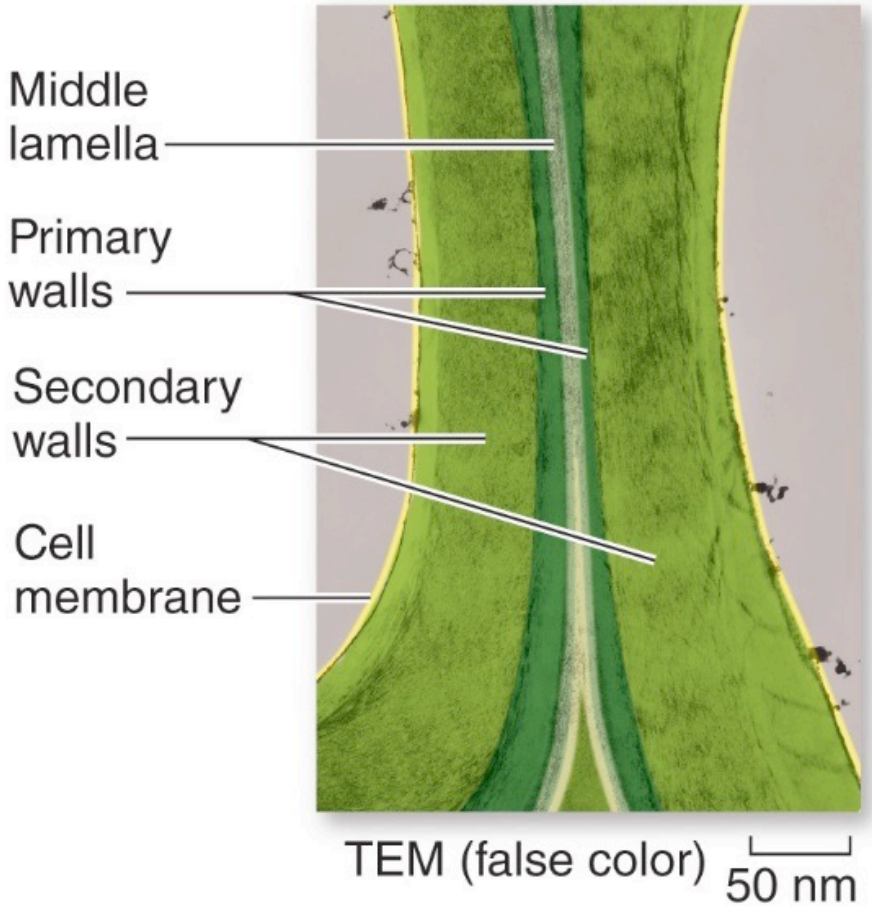
- Large substances are transported into or out of cell inside membrane enclosed pouches (vesicles)
  - Macromolecules and particles too large for transport proteins
  - Formation and movement of vesicles involve motor proteins and ATP
- Exocytosis
  - Vesicle fuses with plasma membrane, releasing contents outside cell
- Endocytosis
  - Small patch of plasma membrane pinched off, forming vesicle, engulfing substances near cell surface, bringing them into cell





Cell Walls

- Relatively stiff structural coating that surround plasma membranes
  - Strong, flexible and porous
  - Support and protect fragile cell
- Found in nearly all
  - Bacteria
  - Archaea
  - Protists
  - Fungi – chitin
  - Plants – cellulose



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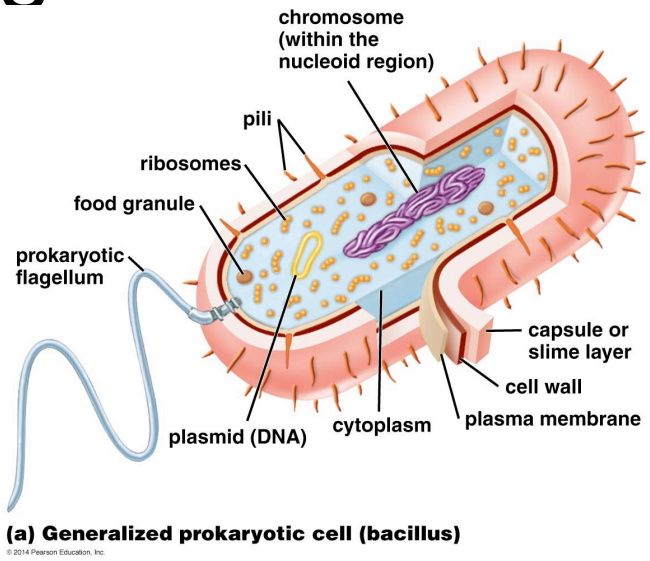
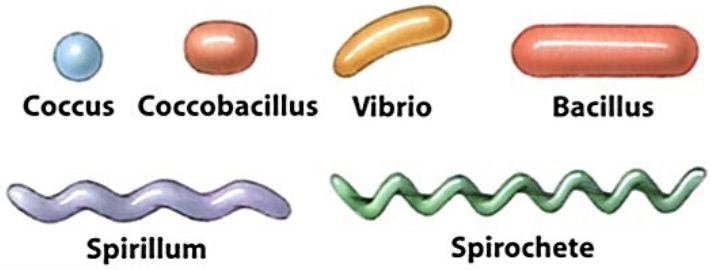
Prokaryotic Cells

- Extremely small
  - 1 to 1.5 μm wide
  - 2 to 6 μm long
- Specialised surface features
  - Cell envelope
  - Appendages
- Prokaryotic cells can take several shapes:
  - Rod-shaped
  - Spiral-shaped
  - Spherical

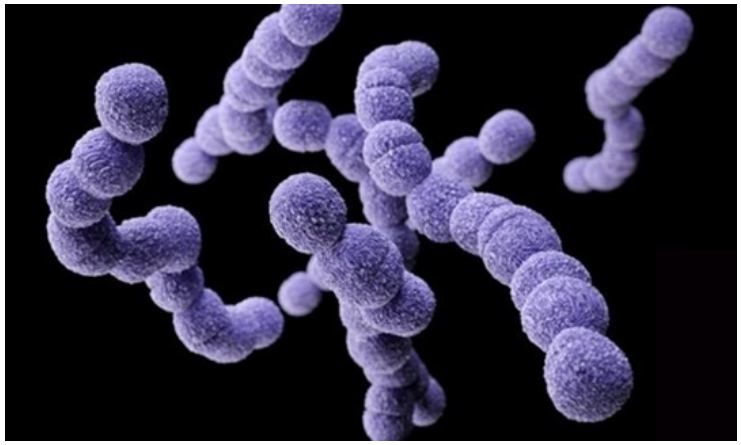


(a) Generalized prokaryotic cell (bacillus)



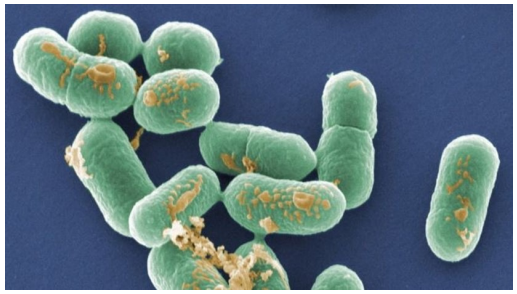
Case Study: The National Environment Agency (NEA) has banned the use of all freshwater fish in ready-to-eat raw fish dishes (Yusheng) with immediate effect on Dec 5 2015.

Group B streptococcus (GBS); Sequence Type 283, ST283

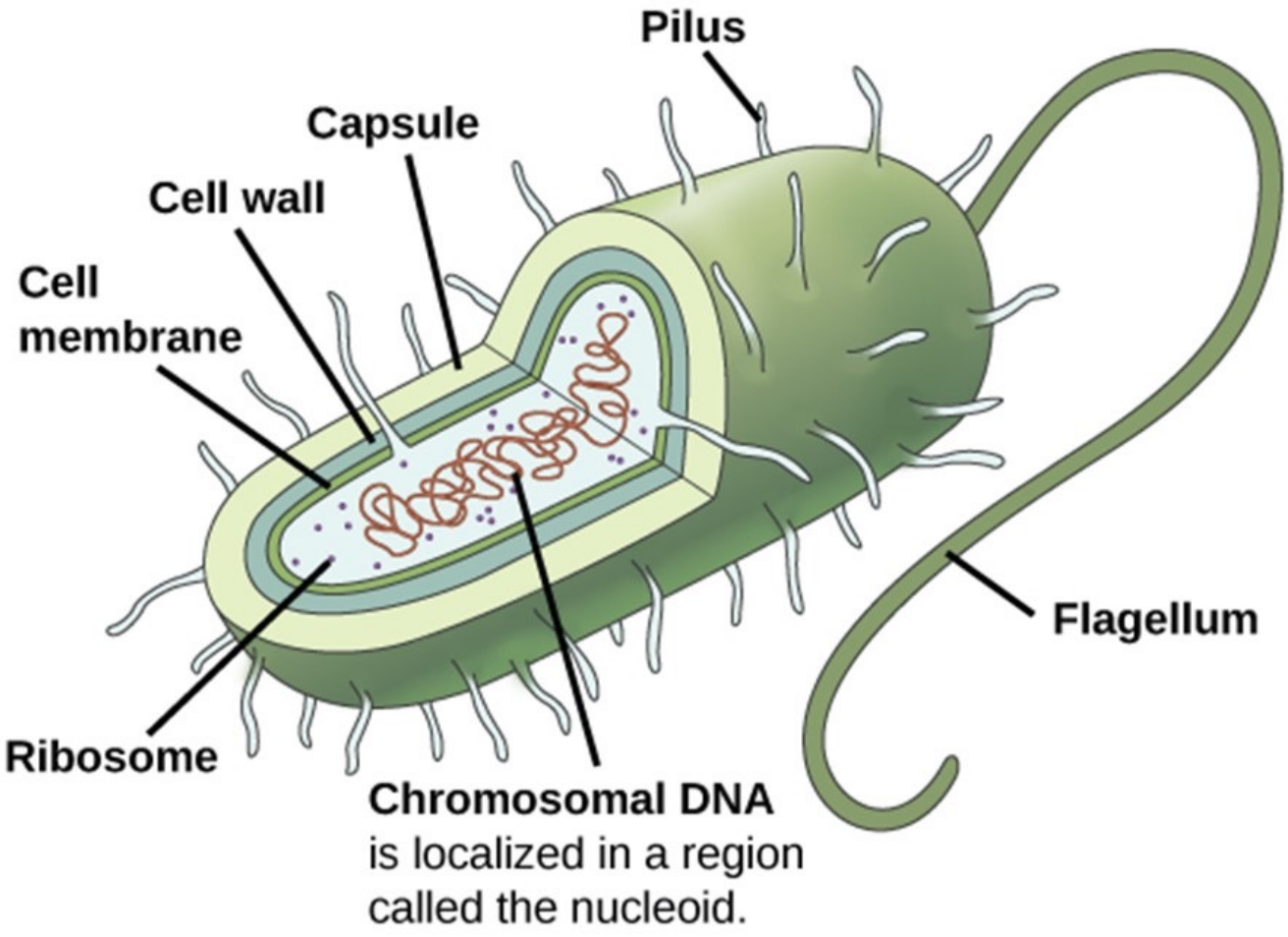


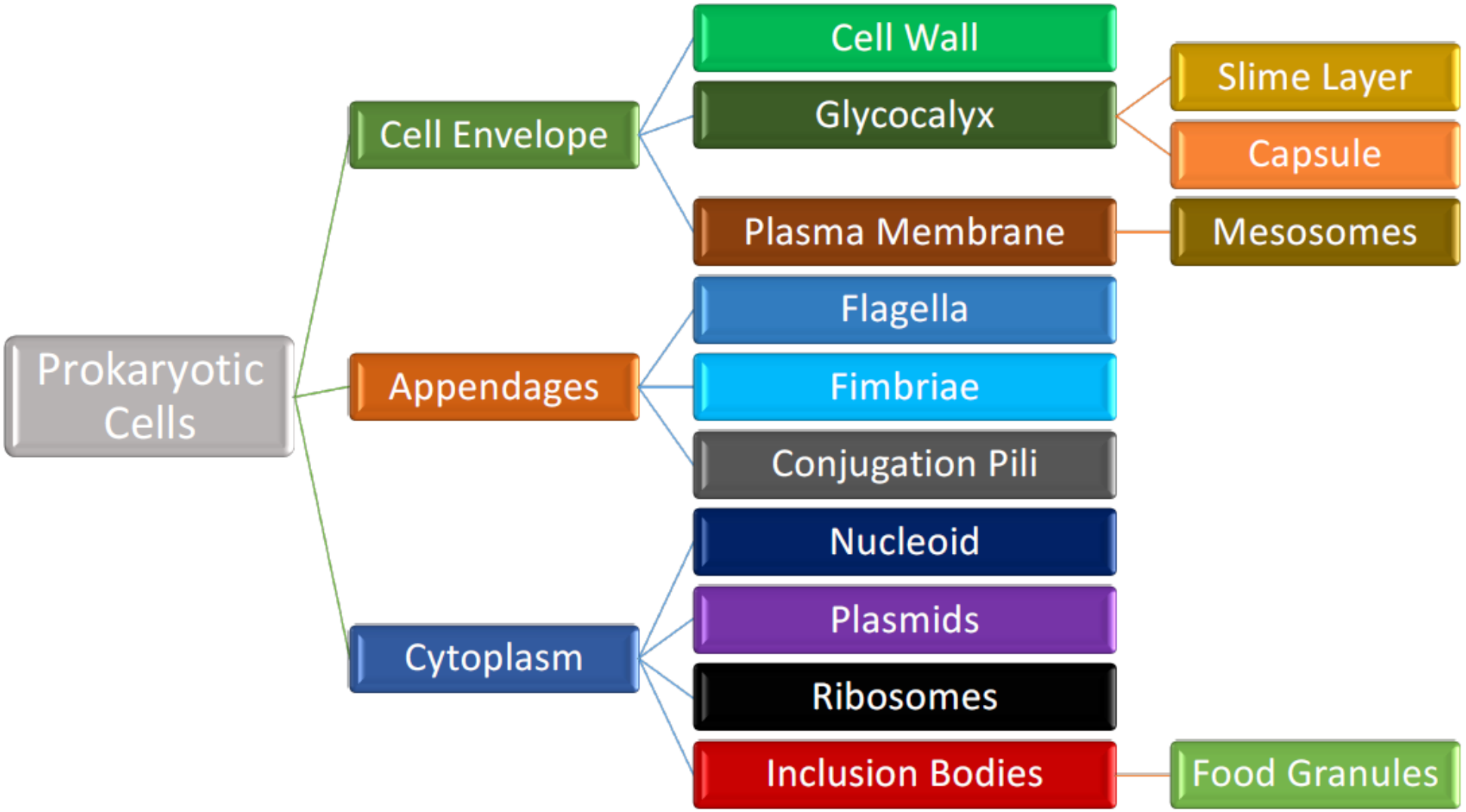
A dish of yusheng sold at a hawker stall. PHOTO: THE NEW PAPER

Fourth person dies in Australia from contaminated rock melon (The Straits Times, 7 Mar 2018)



Prokaryotic Cells Are Simpler Than Eukaryotic Cells




Prokaryotic Cells
Cell Envelope
Cell Wall
Glycocalyx
Slime Layer
Capsule
Plasma Membrane
Mesosomes
Appendages
Flagella
Fimbriae
Conjugation Pili
Cytoplasm
Nucleoid
Plasmids
Ribosomes
Inclusion Bodies
Food Granules

Prokaryotic cells

- Cell envelope
  - Cell wall – polysaccharides in bacteria, proteins in archaea
  - Glycocalyx – polysaccharide coating outside cell wall – slime layer and capsule (harder to remove)
  - Plasma membrane – forms internal pouches – mesosomes

- Appendages
  - Flagella – in some bacteria for motility
  - Fimbriae (attachment pili) – bristle-like, short and abundant, for adhesion to surfaces
  - Conjugation pili (sex pili) – tubular, long and fewer, for DNA transfer from cell to cell

Prokaryotic Cells

- Cytoplasm
  - Fewer specialised cytoplasmic structures
  - Nucleoid – irregularly shaped region of single, circular chromosome of DNA molecule
  - Plasmids – small rings of DNA with few genes that may be advantageous, e.g. resistance to antibiotics
  - Ribosomes – organelles on which proteins are synthesized
  - May contain inclusion bodies, e.g. food granules

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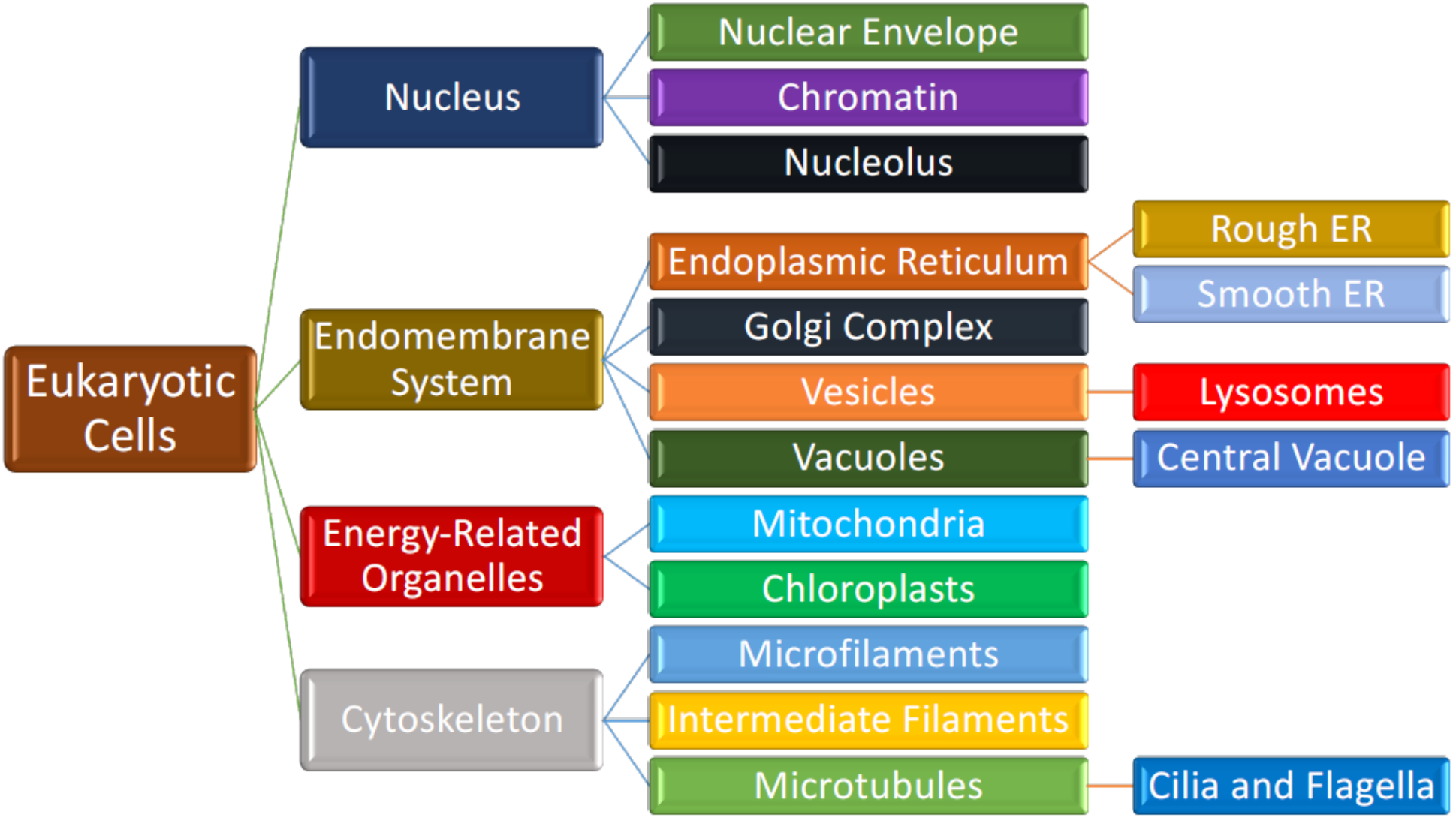
Eukaryotic Cells

- Much larger than prokaryotic cells
- Membrane-enclosed organelles result in compartmentalisation
  - Specialised organelles for specific functions
  - Types and amounts of substances that enter and exit organelles regulated
  - Maintains special internal environments
  - Metabolic reactions isolated from others

Table 4.2 Components of Eukaryotic Cells

Name	Main Function
Organelles with membranes	
Nucleus	Protecting, controlling access to DNA
Endoplasmic reticulum (ER)	Routing, modifying new polypeptide chains; synthesizing lipids
Golgi body	Modifying new polypeptide chains; sorting, shipping proteins and lipids
Vesicles	Transporting, storing, or digesting substances in a cell
Mitochondrion	Making ATP by glucose breakdown
Chloroplast	Photosynthesis in plants, some protists
Lysosome	Intracellular digestion
Peroxisome	Inactivating toxins
Vacuole	Storage
Organelles without membranes	
Ribosomes	Assembling polypeptide chains
Centriole	Anchor for cytoskeleton
Other components	
Cytoskeleton	Contributes to cell shape, internal organization, movement

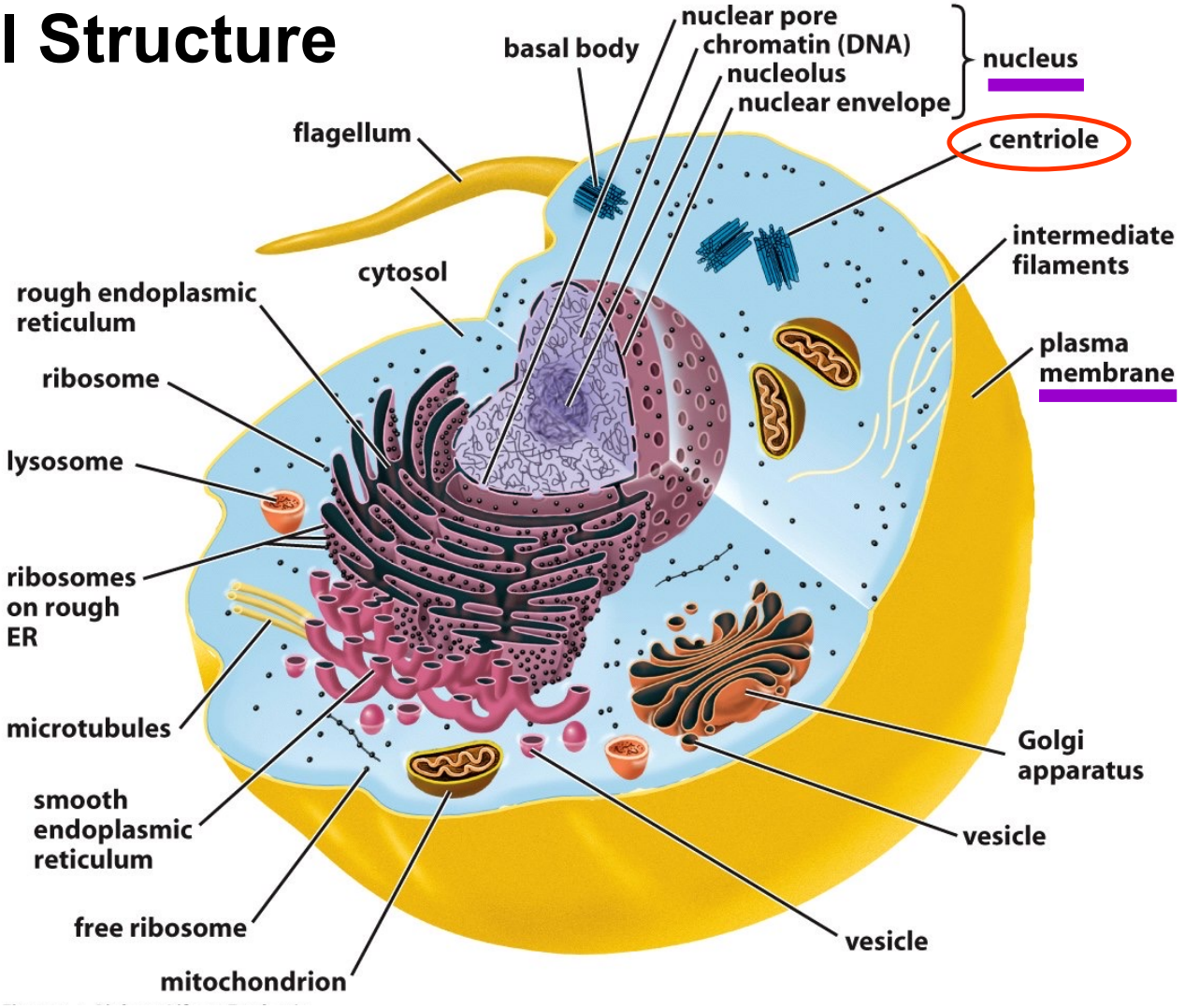

Eukaryotic Cells
Nucleus
Nuclear Envelope
Chromatin
Nucleolus
Endomembrane System
Endoplasmic Reticulum
Rough ER
Smooth ER
Golgi Complex
Vesicles
Lysosomes
Vacuoles
Central Vacuole
Energy-Related Organelles
Mitochondria
Chloroplasts
Cytoskeleton
Microfilaments
Intermediate Filaments
Microtubules
Cilia and Flagella

Eukaryotic Cell Structure

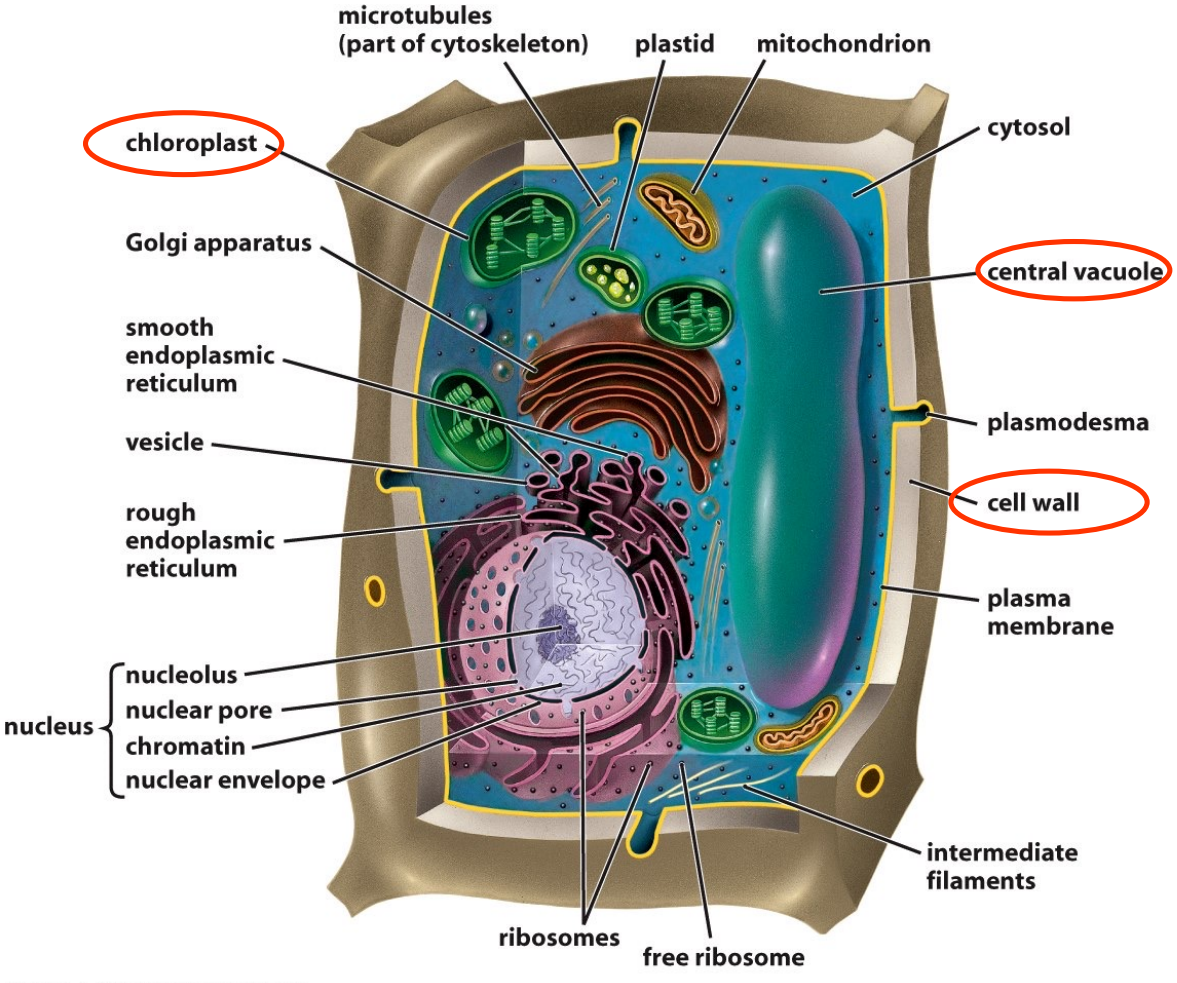
- **Eukaryotic cells** are characterized by having
  - DNA in a nucleus that is bounded by a membranous nuclear envelope
  - Membrane-bound organelles

- Eukaryotic cells are generally much larger than prokaryotic cells
- The cytoplasmic structures

Animal Cell Structure

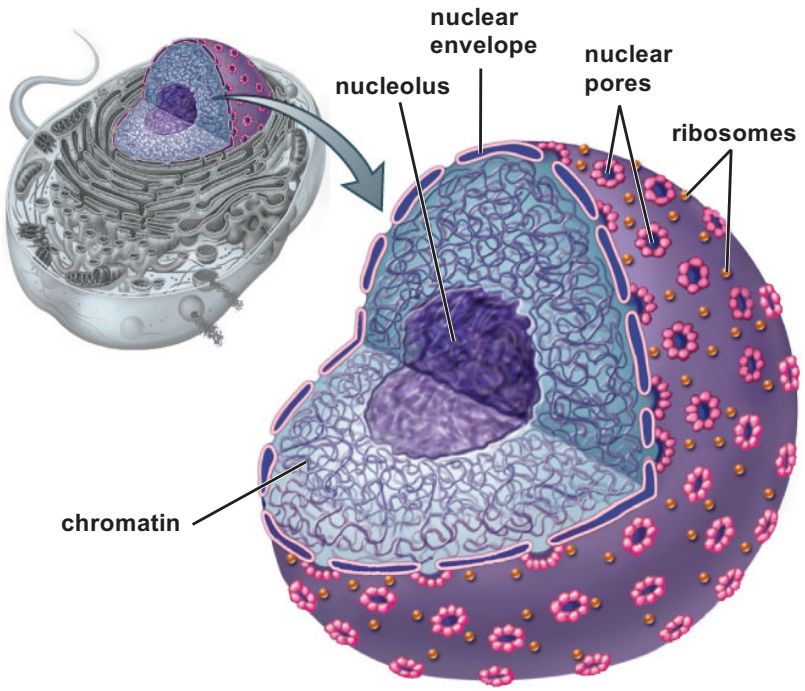


Plant cell Structure



Nucleus

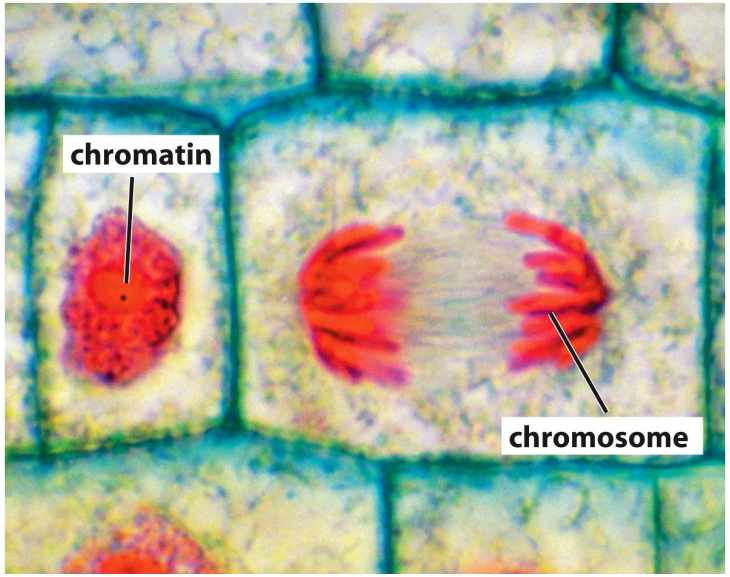
- Control center of the eukaryotic cell (stores DNA)
- Three major components
  - Nuclear envelope (double membrane)
  - Chromatin
  - Nucleolus (where ribosomes are made)



The nucleus

Chromatin and Chromosome

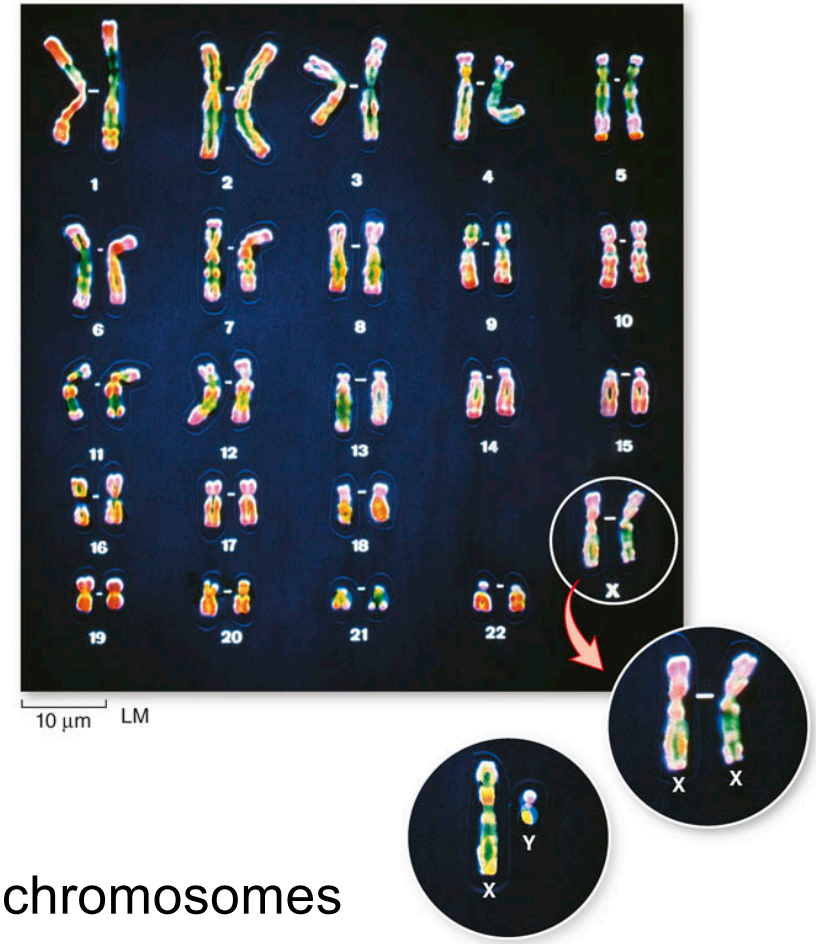
- Consists of DNA and proteins
- Chromatin Condenses to form chromosomes during cell division
- Chromatin are long thin fibres, but chromosomes are compacted, thick and ribbon-like.
- They contain genes that provide a blueprint for a huge variety of proteins



To do this, genetic information in DNA is copied into messenger RNA (mRNA), which travels through the nuclear pores to the cytoplasm, where it directs protein synthesis

Chromosomes

- Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus
- **Somatic cells** (non-reproductive cells) have two sets of chromosomes, one from the father and one from the mother.
- **Gametes** (Gametic cells, reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells



Each of human body cells has 23 pairs of chromosomes

TABLE 4-1 Functions and Distribution of Cell Structures

Structure	Function	Prokaryotes	Eukaryotes: Plants	Eukaryotes: Animals
Cell Surface				
Extracellular matrix	Surrounds cells, providing biochemical and structural support	Absent	Present	Present
Cilia	Move the cell through fluid or move fluid past the cell surface	Absent	Absent (in most)	Present
Flagella	Move the cell through fluid	Present[1]	Absent (in most)	Present
Plasma membrane	Isolates the cell contents from the environment; regulates movement of materials into and out of the cell; allows communication with other cells	Present	Present	Present
Organization of Genetic Material				
Genetic material	Encodes the information needed to construct the cell and to control cellular activity	DNA	DNA	DNA
Chromosomes	Contain and control the use of DNA	Single, circular	Many, linear	Many, linear
Nucleus[2]	Contains chromosomes and nucleoli	Absent	Present	Present
Nuclear envelope	Encloses the nucleus; regulates movement of materials into and out of the nucleus	Absent	Present	Present
Nucleolus	Synthesizes ribosomes	Absent	Present	Present
Cytoplasmic Structures				
Ribosomes	Provide sites for protein synthesis	Present	Present	Present
Mitochondria[2]	Produce energy by aerobic metabolism	Absent	Present	Present
Chloroplasts[2]	Perform photosynthesis	Absent	Present	Absent
Endoplasmic reticulum[2]	Synthesizes membrane components, proteins, and lipids	Absent	Present	Present
Golgi apparatus[2]	Modifies, sorts, and packages proteins and lipids	Absent	Present	Present
Lysosomes[2]	Contain digestive enzymes; digest food and worn-out organelles	Absent	Absent (in most)	Present
Plastids[2]	Store food, pigments	Absent	Present	Absent
Central vacuole[2]	Contains water and wastes; provides turgor pressure to support the cell	Absent	Present	Absent
Other vesicles and vacuoles[2]	Transport secretory products; contain food obtained through phagocytosis	Absent	Present	Present
Cytoskeleton	Gives shape and support to the cell; positions and moves cell parts	Present	Present	Present
Centrioles	Produce the basal bodies of cilia and flagella	Absent	Absent (in most)	Present

[1]Some prokaryotes have structures called flagella, which lack microtubules and move in a fundamentally different way than do eukaryotic flagella.
[2]Indicates organelles, which are surrounded by membranes and found only in eukaryotic cells.

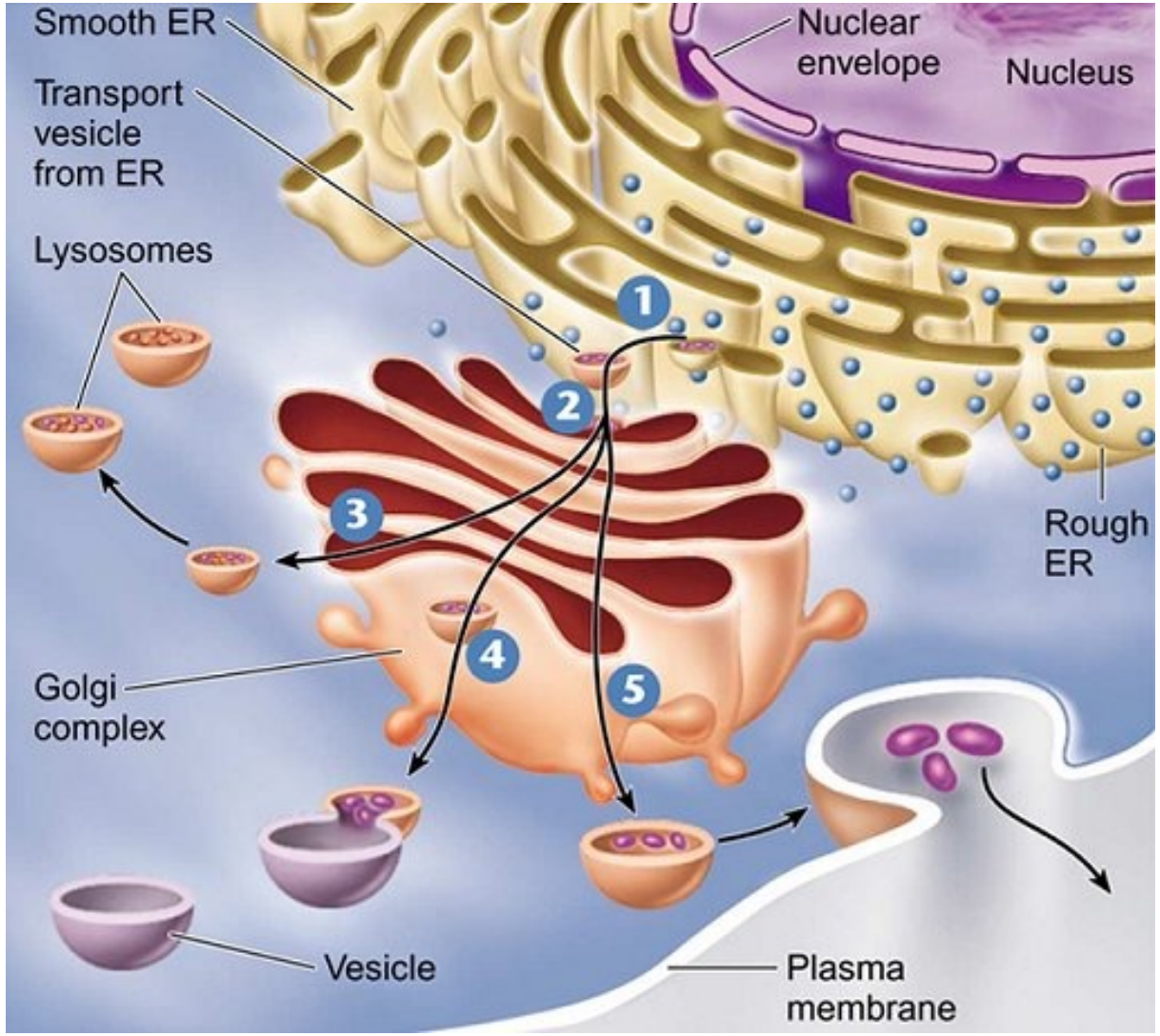
4.3 Endomembrane System (Cell's Membrane System)

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

Endomembrane System

Functions:

- Synthesizes, modifies, and transports proteins
- Synthesizes lipids
- Detoxifies the cell of certain toxins



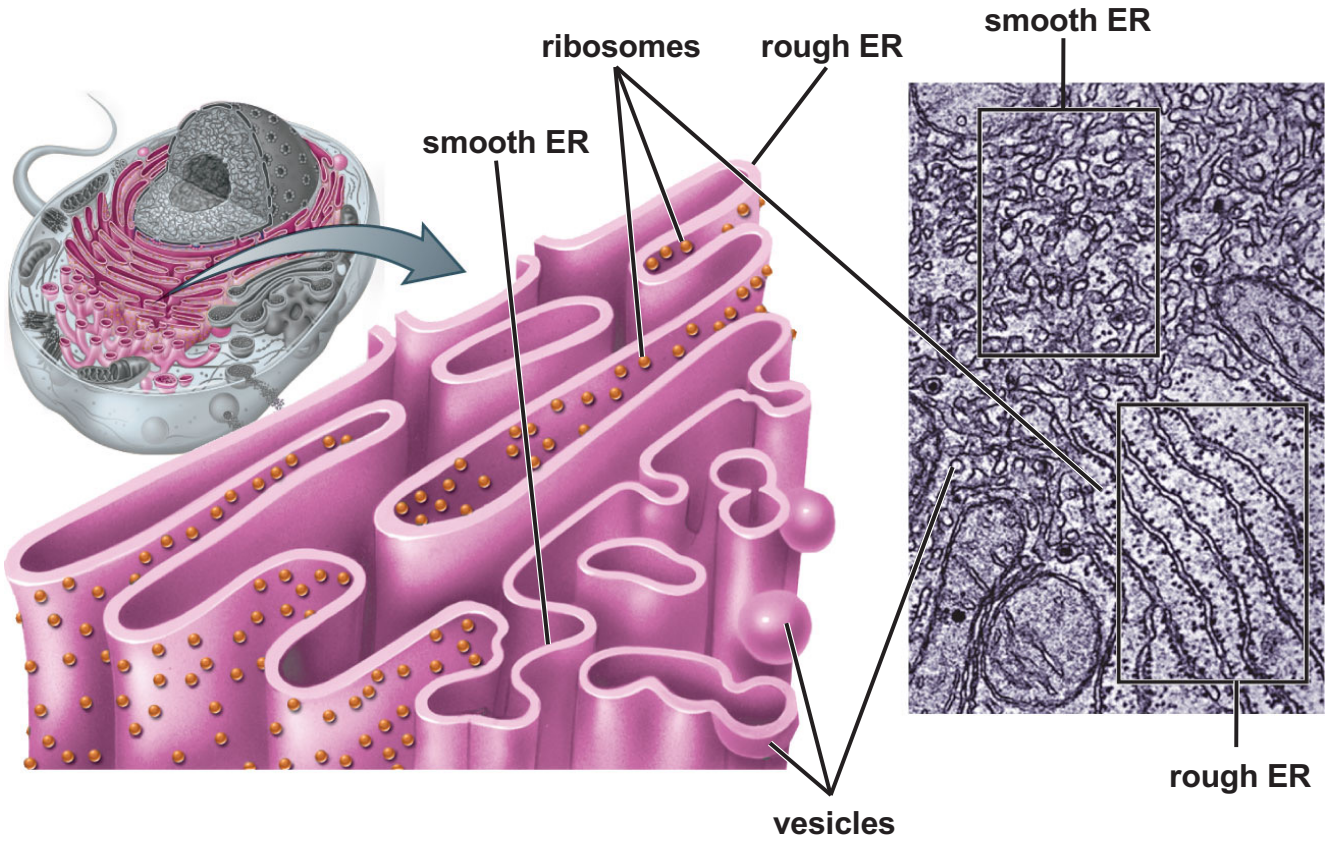
Endoplasmic Reticulum (ER)

- A network of sacs and tubules composed of membranes. This complex organelle originates at the nuclear envelope and winds throughout the cell.

(Endoplasmic means “within the cytoplasm” and reticulum means “network”)

- Two forms
  - Rough ER
  - Smooth ER

Endoplasmic Reticulum



(a) Endoplasmic reticulum may be rough or smooth (b) Smooth and rough ER

I. Rough **ER**

- Flattened sacs
- Studded with ribosomes on outer surface
- **Synthesises, modifies and folds proteins**

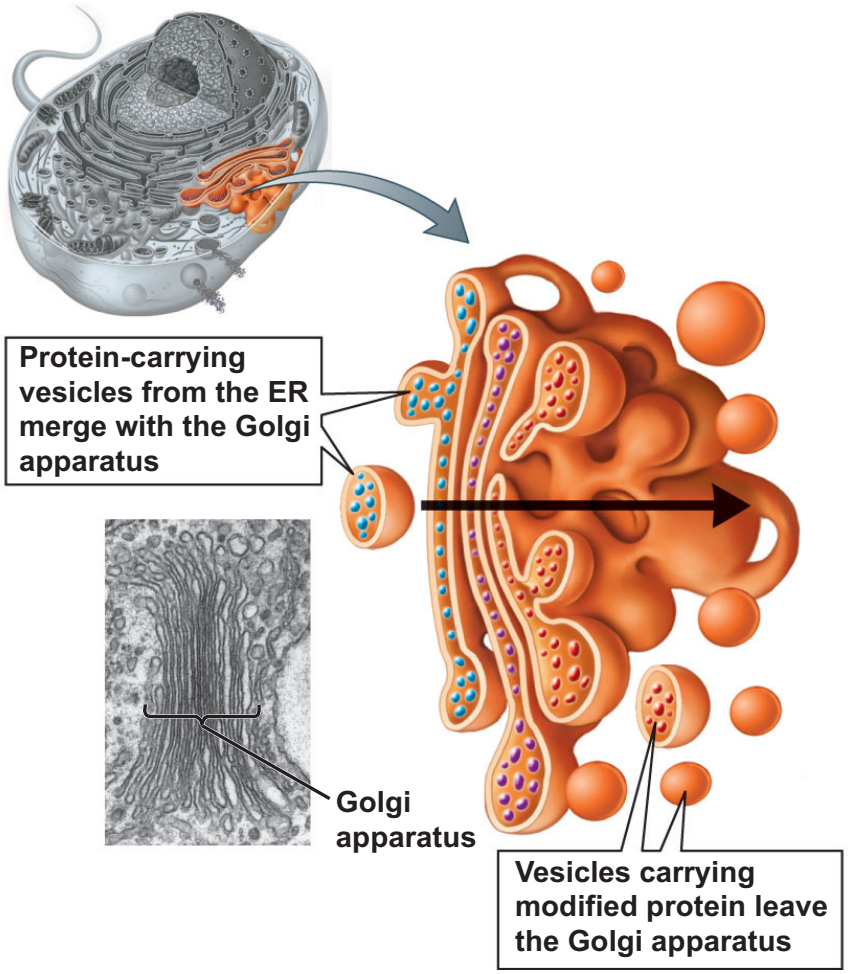
II. Smooth **ER**

- Series of inter-connected tubules
- No ribosomes
- **Synthesises lipids (**like steroid hormones made from cholesterol)
- **Detoxify harmful chemical drugs**

Golgi Complex/Apparatus

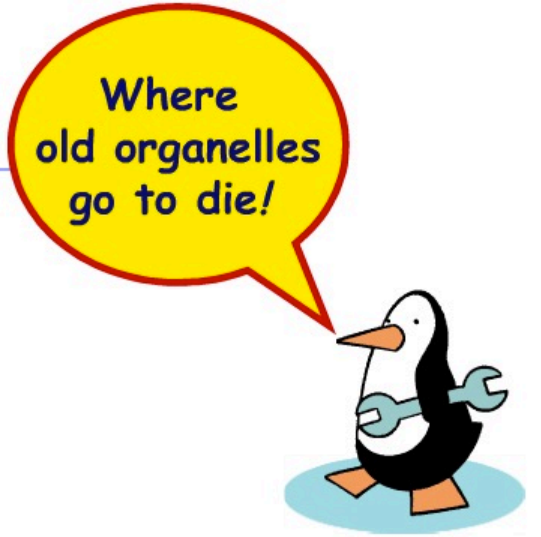
- Set of stacked flattened, curved sacs
- Receives material from ER in vesicles
- Modifies some molecules, such as adding a carbohydrate group to proteins, and making glycoproteins; it breaks some proteins into smaller peptides
- Synthesizes some polysaccharides used in plant cell walls, such as cellulose and pectin
- Sort and Packages finished material in vesicles for shipment to final destinations
  - Some within cell
  - Some exported from cell via exocytosis

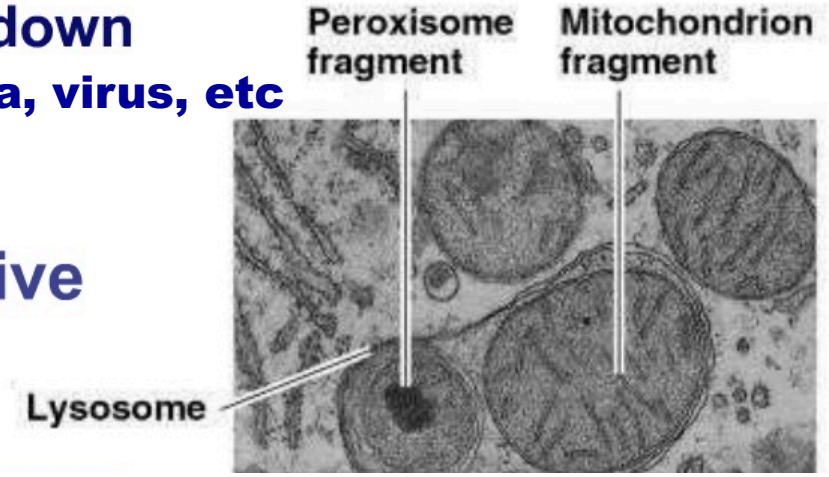
The Golgi Apparatus



Lysosomes

- **Function**
  - little "stomach" of the cell
    - digests macromolecules
  - "clean up crew" of the cell
    - cleans up broken down organelles, **bacteria, virus, etc**
- **Structure**
  - vesicles of digestive enzymes

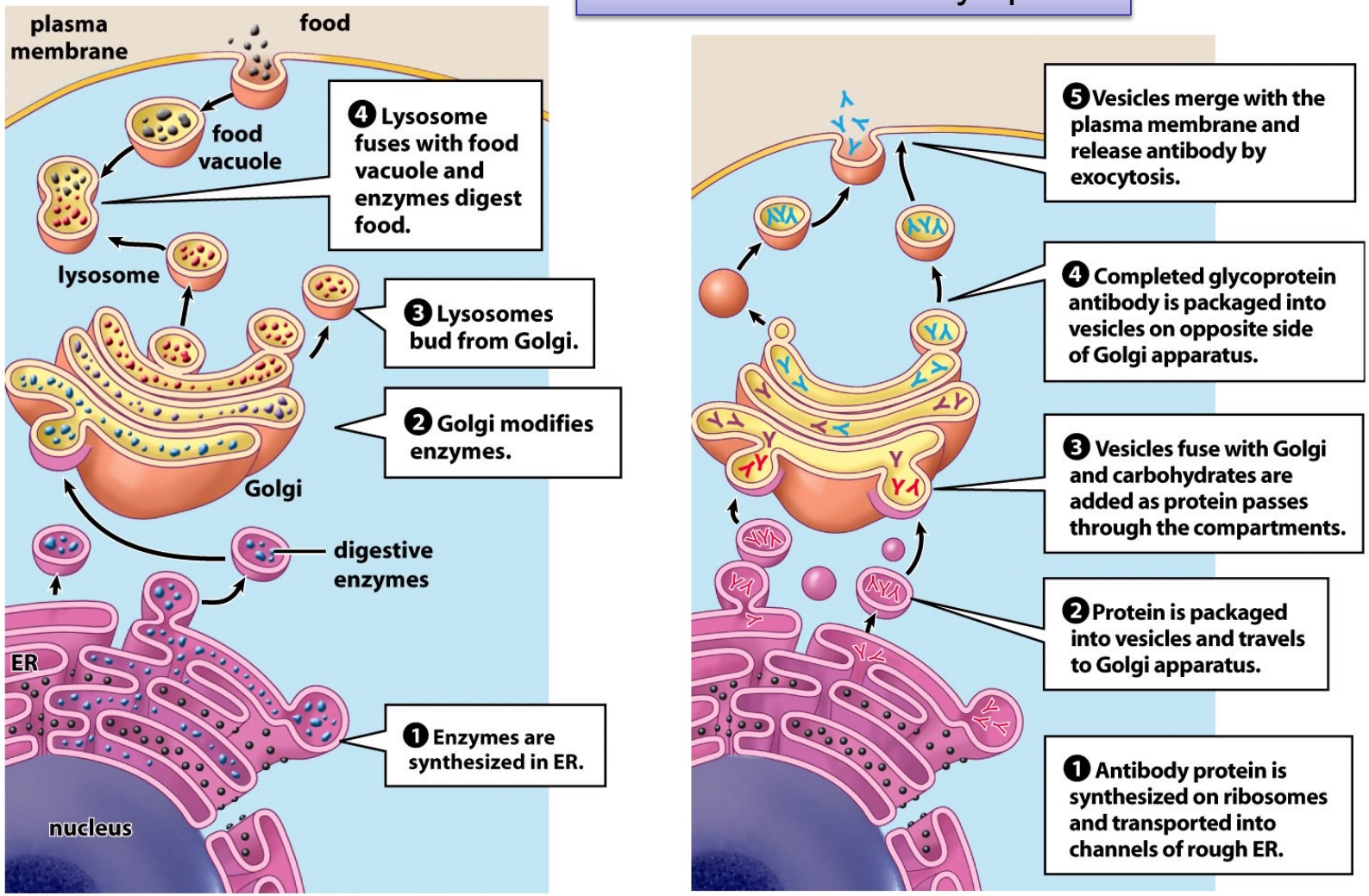




Lysosomes serve as the cell's digestive system

Endomembrane System: A Review

Vesicle traffic in the cytoplasm



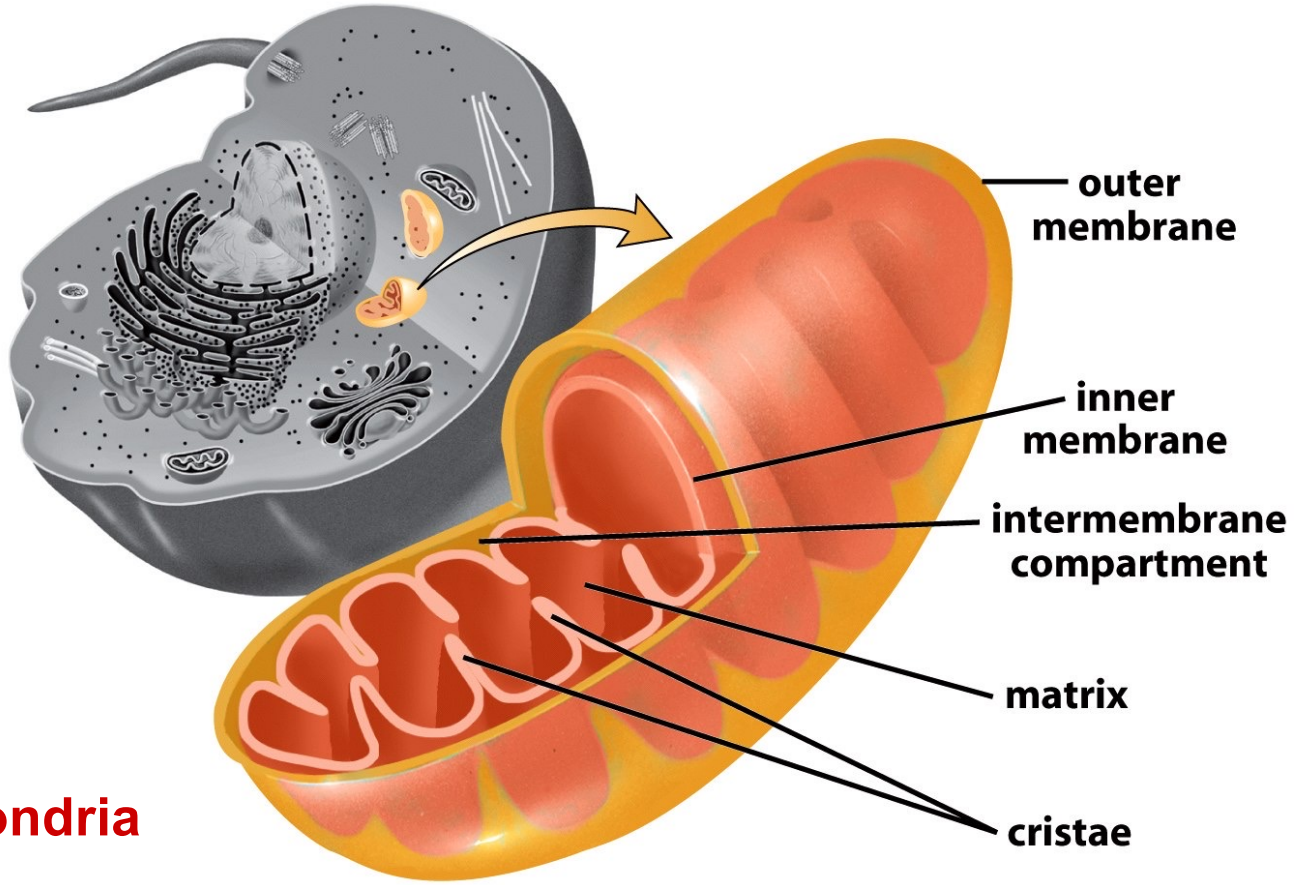
Energy-Related Organelles

- **Mitochondria** are the sites of cellular respiration, a metabolic process that generates ATP, function as the “powerhouses of the cell”

- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis

- Both organelles have their own DNA

Mitochondria: Chemical Energy Conversion



Mitochondria

Figure 4-17 part 1 Biology: Life on Earth, 8/e

Mitochondria

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

Case study: Correcting human mitochondrial mutations

Correcting Human Mitochondrial Mutations

ScienceDaily (Mar. 12, 2012) — Researchers at the UCLA stem cell center and the departments of chemistry and biochemistry and pathology and laboratory medicine have identified, for the first time, a generic way to correct mutations in human mitochondrial DNA by targeting corrective RNAs, a finding with implications for treating a host of mitochondrial diseases.

See Also:

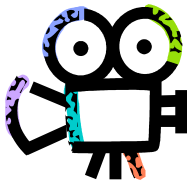
Health & Medicine

- Genes
- Human Biology
- Stem Cells
- Diseases and Conditions

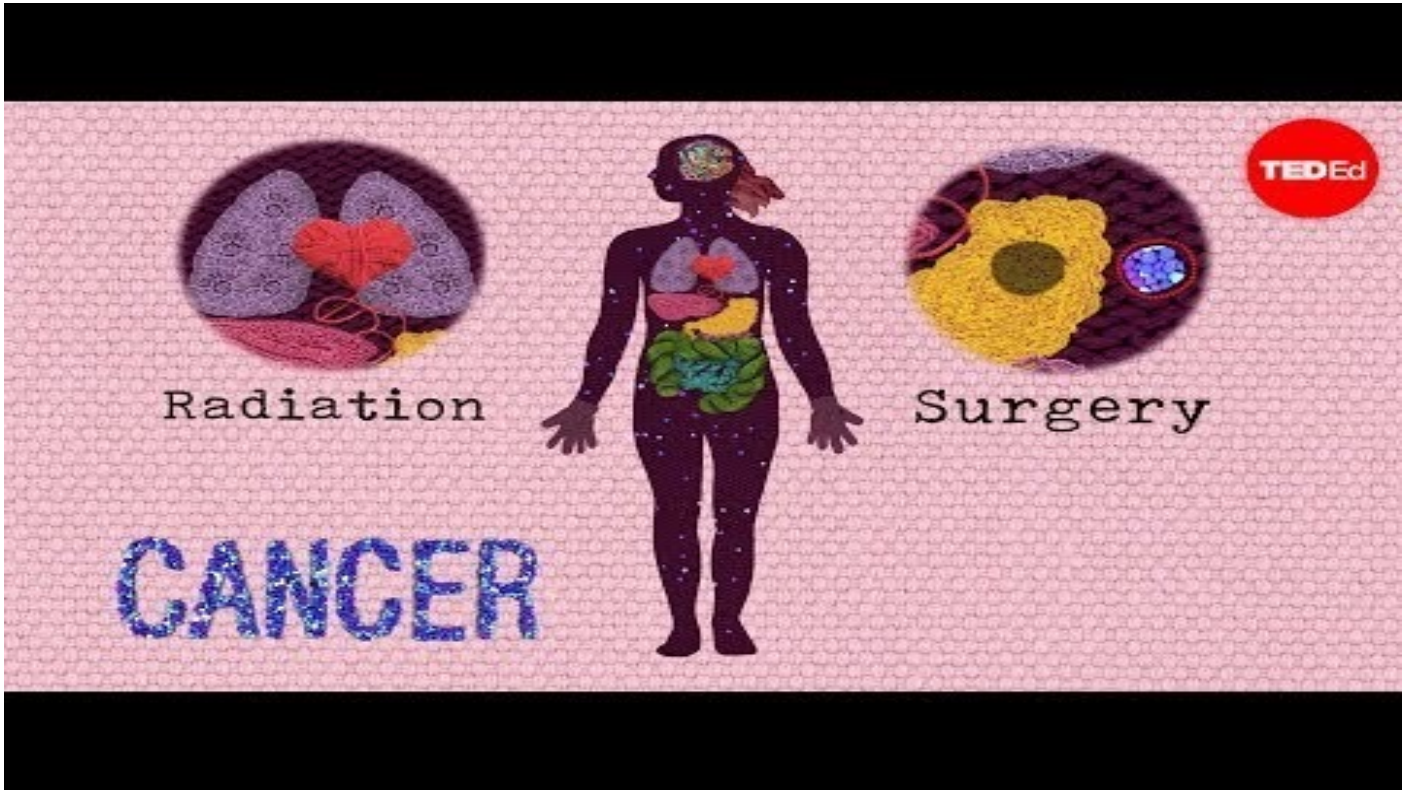
Mutations in the human mitochondrial genome are implicated in neuromuscular diseases, metabolic defects and aging. There currently are no methods to successfully repair or compensate for these mutations, said study co-senior author Dr. Michael Teitell, a professor of pathology and

In adults, many diseases of aging have been associated with defects of mitochondrial function, including diabetes, Parkinson's disease, heart disease, stroke, Alzheimer's disease and cancer. (Credit: © Yuri Arcurs / Fotolia)

Case study: How do cancer cells behave differently from healthy ones?



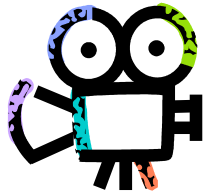
https://www.youtube.com/watch?v=BmFEoCFDi-w



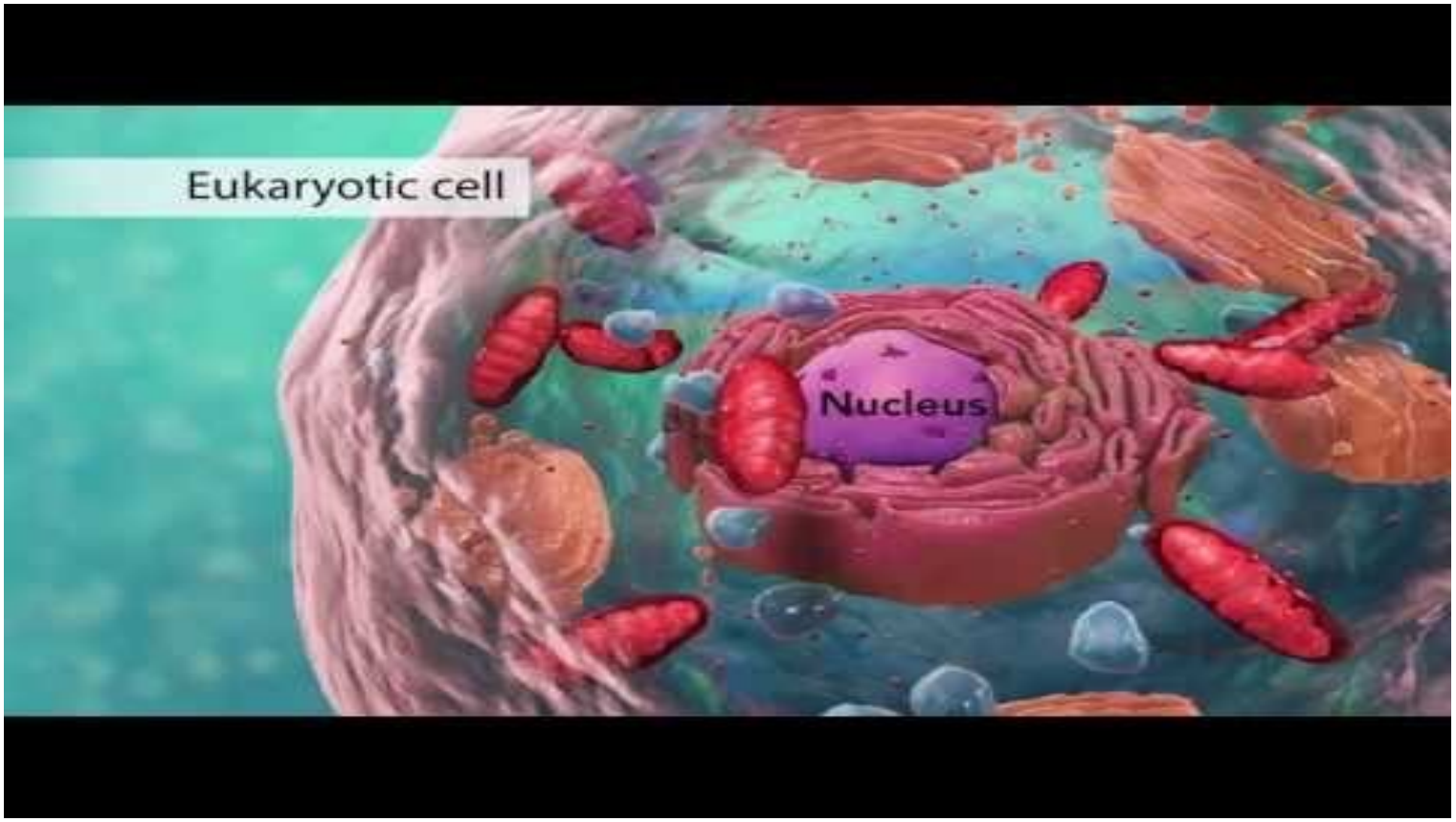
Outline

- Cells
  - Cell theory
  - Cell size
  - Structure
- Cell Membranes
  - Membrane structure
  - Movement across membranes
  - Cell walls
- Prokaryotic Cells
- Eukaryotic Cells
  - Nucleus
  - Endomembrane system
  - Energy-related organelles
  - Cytoskeleton

Summary



Biology: Cell Structure I Nucleus Medical Media



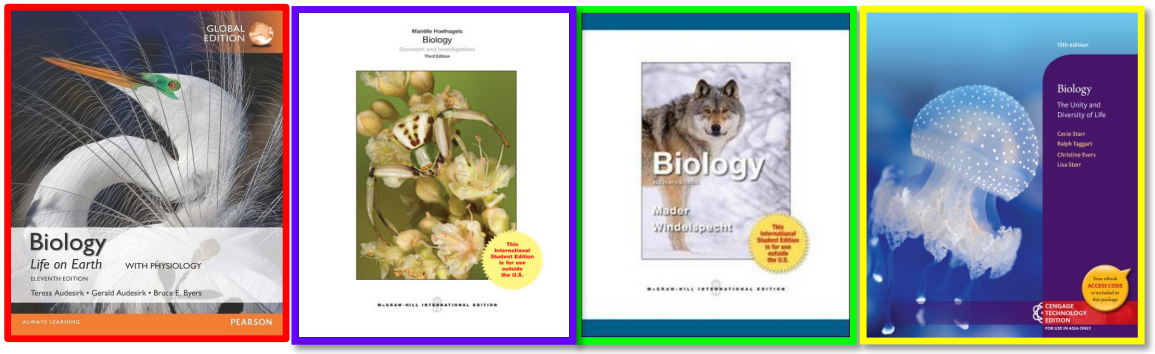
https://www.youtube.com/watch?v=URUJD5NEXC8

Further questions

- If samples of muscle tissue were taken from the legs of a world-class marathon runner and a sedentary individual, which would you expect to have a higher density of mitochondria? Why?

- If a cell is treated with Brefeldin A, a drug that interferes with the functions of the Golgi apparatus and the secretory pathway, what would be the result? Can such a drug be useful in killing diseased or harmful cells?

Text Books/References



Today's Lecture

Chapters 4,5 Chapter 3 Chapters 4,5 Chapter 4

Next Lecture

Chapter 6, 8 Chapters 8,9 Chapters 9, 10 Chapters 11, 12

Reminders

- Practical 3 is this Thursday (10th March)
  - Please read through practical handout before coming to lab
  - Can be found under “Handouts for tutorials/practicals” in “Lab 3 Macromolecules and Food” folder

- Be punctual and properly attired
  - No shorts, slippers, sandals
  - Not allowed to enter lab if not properly attired