# Johns Hopkins Engineering

## Molecular Biology

Cell Vesicles, Structural Components, and Examples of Cellular Invaders

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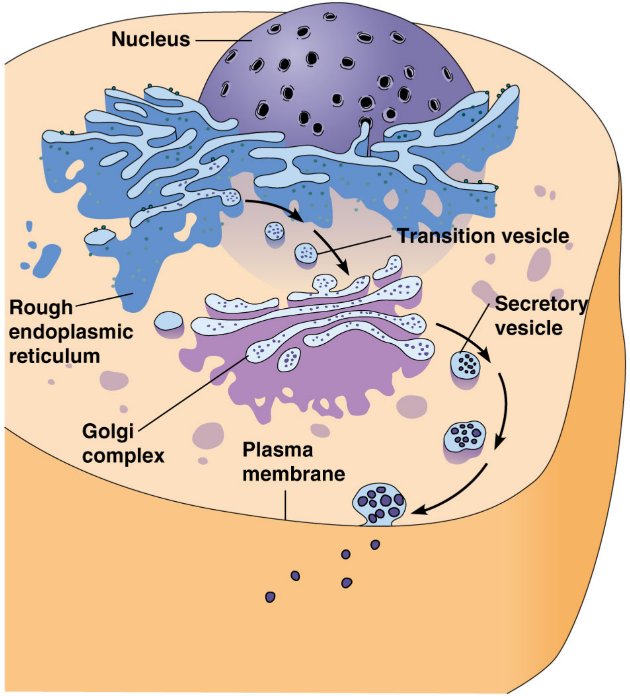
# Outline

- Cell vesicles
- Organelles (continued)
- Ribosomes
- Cytoskeleton
- Extracellular matrix
- Cellular invaders

# Secretory Vesicles

- Once processed by the Golgi complex, materials to be exported from the cell are packaged into **secretory vesicles**
- These move to the plasma membrane and fuse with it, releasing their contents outside the cell
- The  ER, Golgi, secretory vesicles and lysosomes make up the *endomembrane system* of the cell, responsible for *trafficking* substances through the cell



# The Lysosome

- **Lysosomes** are single membrane organelles that store *hydrolases*, enzymes that can digest any kind of biological molecule (proteins, nucleic acids, carbohydrates, lipids)
- These enzymes (~50) are sequestered to prevent them from digesting the contents of the cell
- A special carbohydrate coating on the inner lysosome membrane protects it from digestion
- All of the lysosomal enzymes are *acid hydrolases*, and become active at low pH (5), but not at neutral pH (7.2)

# Vacuoles

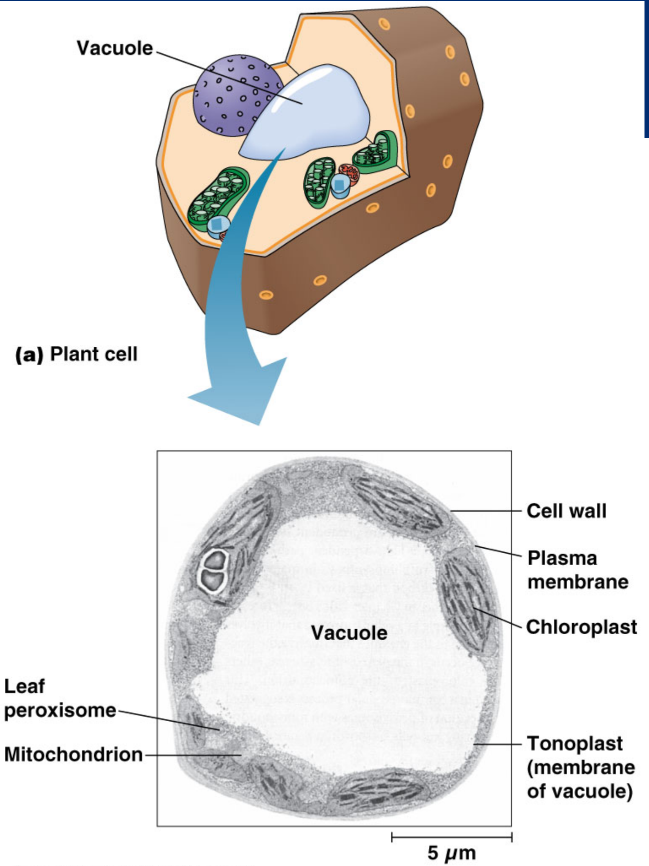
- Some cells contain a membrane-bounded vacuole
- In animal and yeast cells they are used to temporary storage or transport
- In phagocytosis, specialized cells take up and degrade large particles (bacteria, cell debris, and aged cells) from outside of the cell into phagocytic vacuoles (phagosomes).
- When this type of vacuole fuses with a lysosome, the contents are hydrolyzed to provide nutrients to a cell

# Plant vacuoles

- Most mature plant cells contain a single large vacuole called a **central vacuole**

- The main function of the central vacuole is to maintain the *turgor pressure* that keeps the plant from wilting

- Tissues wilt when the central vacuole no longer presses against the cell contents (fails to provide adequate pressure)

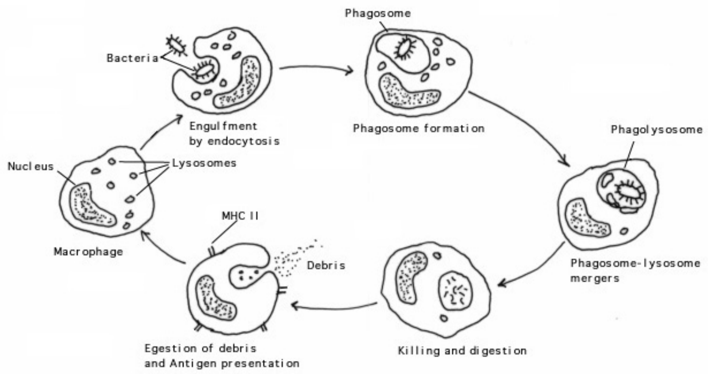


(b) Large central vacuole

# The Phagolysosome

- **Phagolysosomes** are formed when phagosomes merge with lysosomes to destroy ingested materials such as bacterial pathogens
- *Mycobacterium tuberculosis* is a well-studied intracellular parasite that survives in macrophages by arresting phagosomal maturation


Credit: starklab.slu.edu



Credit: http://textbookofbacteriology.net

https://www.youtube.com/watch?v=BDr44vLNnPY

# The Peroxisome

- **Peroxisomes** resemble lysosomes in size and appearance
- They are surrounded by a single membrane and perform several functions depending on cell type
- Peroxisomes are especially prominent in the liver and kidney cells of animals
- Peroxisomes detoxify other harmful compounds, and catabolize unusual substances
- In animals, they play roles in oxidative breakdown of fatty acids, especially longer chain fatty acids (up to 22 carbon atoms)

# Hydrogen Peroxide

- $H_2O_2$ is highly toxic to cells but can be formed into water and oxygen by the enzyme *catalase*
- Eukaryotic cells have metabolic processes that produce $H_2O_2$
- These reactions are confined to peroxisomes that contain catalase, so that cells are protected from the harmful effects of peroxide
- Peroxide production is increased during cellular stress (infection, disease, UV exposure) and can serve as a useful biomarker for early infections.

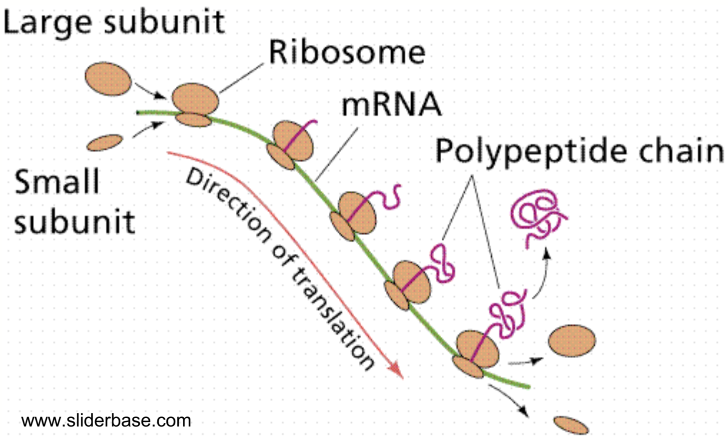
# Ribosomes

- ***Ribosomes** are the sites of protein synthesis in all cells*
  - They are not really organelles because they are not enclosed by a membrane
  - They are found in all cells but differ slightly in bacteria, archaea and eukarya in their size and composition
- Ribosomes are very small
- They can only be seen under the electron microscope
- They have sedimentation coefficients in keeping with their small size, values of 80S (eukaryotes) or 70S (bacteria and archaea)
- Sedimentation coefficient: a measure of how rapidly a particle sediments in an ultracentrifuge, expressed in Svedberg units (S)

# Ribosome are numerous and ubiquitous

- Ribosomes are much more numerous than most other cellular structures (prokaryote cells contain thousands, eukaryote cells may contain millions)
- Ribosomes in mitochondria and chloroplasts are similar size and composition to those of bacteria
- This is particularly true of the nucleotide sequences of their rRNAs

**Ribosomes read or "translate" mRNA, to link amino acids together and form proteins**

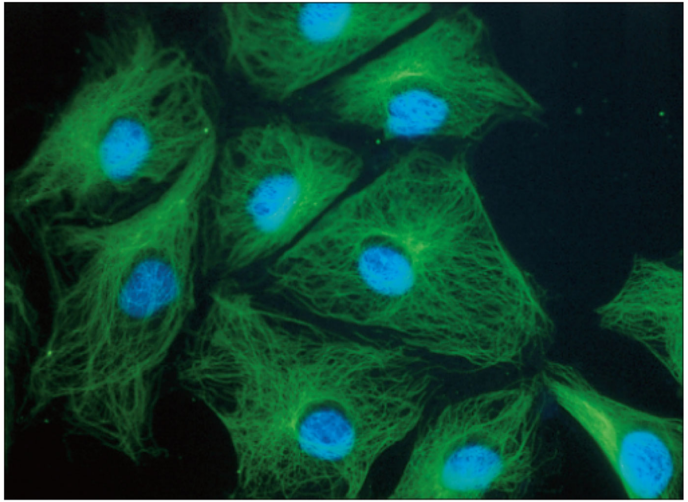


# The Cytoplasm of Eukaryotic Cells Contains the Cytosol and Cytoskeleton

- The **cytoplasm** of a eukaryotic cell is the interior of the cell not occupied by the nucleus
- The **cytosol** is the semifluid substance in which the organelles are suspended
- The synthesis of fats and proteins and the initial steps in releasing energy from sugars takes place in the cytosol
- The cytosol is permeated by the **cytoskeleton**

# The Cytoskeleton

- The cytoskeleton is a three-dimensional array of interconnected **microfilaments, microtubules, and intermediate filaments**
- It gives a cell its distinctive shape and internal organization
- It also plays a role in cell movement and cell division
- The cytoskeleton serves as a framework for positioning and moving organelles and macromolecules within the cell



# Microtubules

- **Microtubules** are the largest structural elements of the cytoskeleton

- Microtubules also form the *mitotic spindle fibers* that separate chromosomes prior to cell division

- Microtubules play a role in the organization of the cytoplasm:
    - Overall shape of the cell, distribution of organelles
    - Movement of macromolecules and other substances within the cell
    - Distribution of microfilaments and intermediate filaments

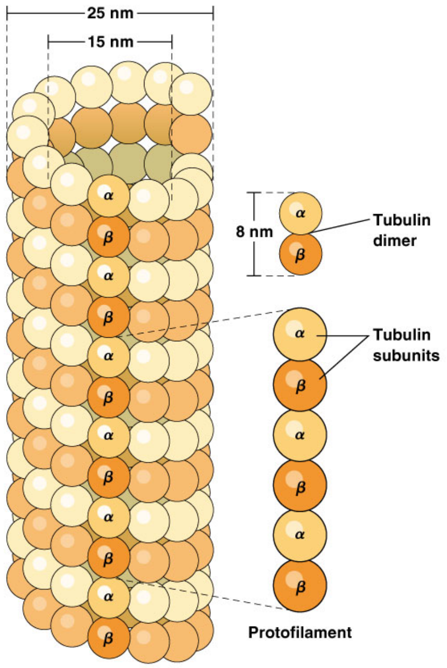
# Structure of microtubules

- Microtubules are cylinders of longitudinal arrays of *protofilaments* with a hollow center called a *lumen*

- Each protofilament is a linear polymer of *tubulin* with inherent *polarity*

- Tubulin is a dimeric protein consisting of $\alpha$-*tubulin* and $\beta$-*tubulin*

**(a) A microtubule.** A diagram of a microtubule, showing 13 protofilaments forming a hollow cylinder. Each protofilament is a polymer of tubulin dimers. All the tubulin dimers are oriented in the same direction, giving polarity to the protofilament and hence to the entire microtubule.



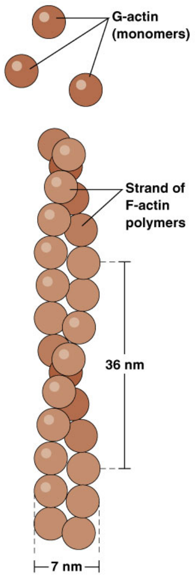
# Microfilaments

- Microfilaments are the smallest components of the cytoskeleton
- They can form connections with the plasma membrane to affect movement
- They produce the cleavage furrow in cell division
- They contribute to cell shape

# The Structure of Microfilaments

- Microfilaments are polymers of the protein *actin*
- Actin is synthesized as a monomer called *G-actin* (globular)
- These subunits are polymerized into *F-actin* (filamentous), with a helical appearance
- Microfilaments have polarity

**(b) A microfilament.** A diagram of a microfilament, showing a strand of F-actin twisted into a helical structure. The F-actin polymer consists of monomers of G-actin, all oriented in the same direction to give the microfilament its inherent polarity.



# The Extracellular Matrix and the Cell Wall Are "Outside" the Cell

- Most cells are characterized by extracellular structures
- For many animal cells these structures are called the **extracellular matrix** (**ECM**) and consist mainly of collagen fibers and proteoglycans
- For plant and fungal cells, these are **cell walls**, consisting mainly of *cellulose microfibrils*

# Bacterial Cell Walls

- Bacterial cell walls are composed of *peptidoglycans*, long chains of GlcNAc and MurNAc

- These are held together by peptide bonds between a small number of amino acids, forming a netlike structure

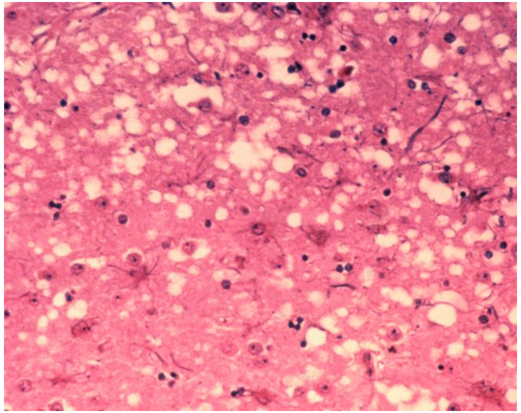
- There are additional substances specific to cell walls of major groups of bacteria

# The ECM

- The primary function of the ECM is support but the types of materials and patterns in which they are deposited regulate a variety of processes
- In animal cells, a network of proteoglyans  surrounds the collagen fibers
- In vertebrates, **collagen** is the most abundant protein in the animal body, as it is also found in tendons, cartilage and bone
- Processes regulated by the ECM may include:
    - Cell motility and migration
    - Cell division
    - Cell recognition and adhesion
    - Cell differentiation during embryonic development

# Cellular Invaders

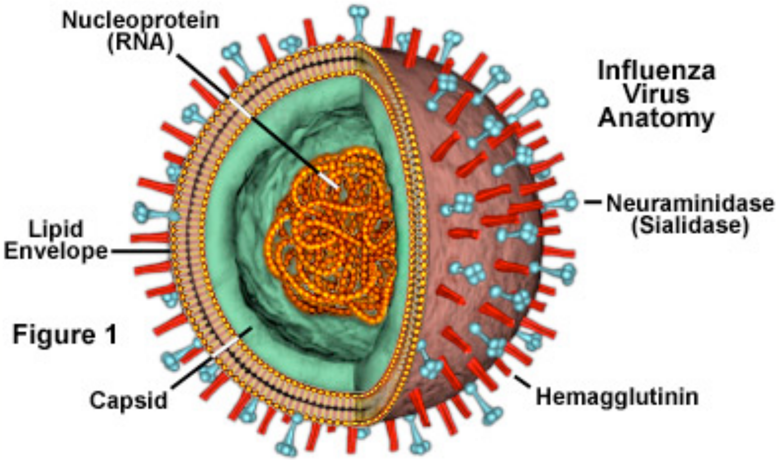
- **Prions** are *proteinaceous infective particles* which are simply abnormally folded versions of normal cellular proteins
- They induce existing, properly folded proteins to convert into the disease-associated prion form (like a template that guides misfolding)
- All know prions induce amyloid plaques

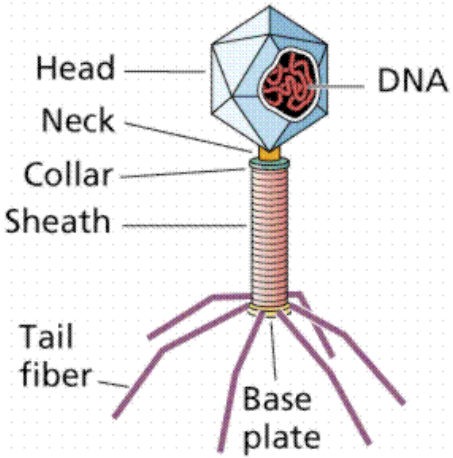


**Brain tissue showing characteristic “spongy” architecture from prion disease**

# Viruses

- There are several types of agents that invade cells, disrupt cell function and even kill the host cell
- These include the *viruses* and the less well understood *viroids* and *prions*



# A Virus Consists of a DNA or RNA Core Surrounded by a Protein Coat

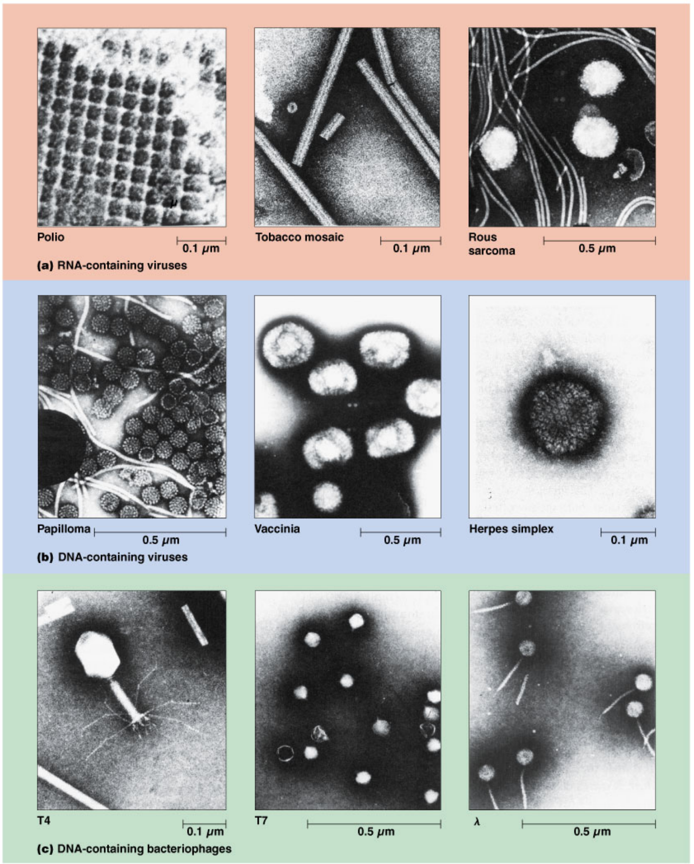
- **Viruses** are noncellular parasitic particles incapable of a free-living existence
- They have no cytoplasm, organelles or ribosomes, and consist of only a few different molecules of nucleic acid and protein
- They invade and infect cells, using the synthetic machinery to produce more virus particles

# Viruses

- Viruses are responsible for many diseases in humans, animals and plants
- They are also important as research tools for cell and molecular biologists
- Viruses are chemically quite simple, consisting of a *coat* (*capsid*) of protein surrounding a *core*, containing DNA or RNA, depending on the type of virus
- Viruses are small; the smallest are about the size of a ribosome, while the largest are about one quarter the size of a bacterial cell
- Viruses that infect bacteria are *bacteriophages* or *phages*

# Structure of viruses

- Each virus has a characteristic shape, defined by its protein capsid
- Some viral capsids consist of a single type of protein, while more complex viruses have capsids with a number of different proteins
- Some viruses are surrounded by a membrane, and are called *enveloped viruses*; HIV (Human immunodeficiency virus) is an example

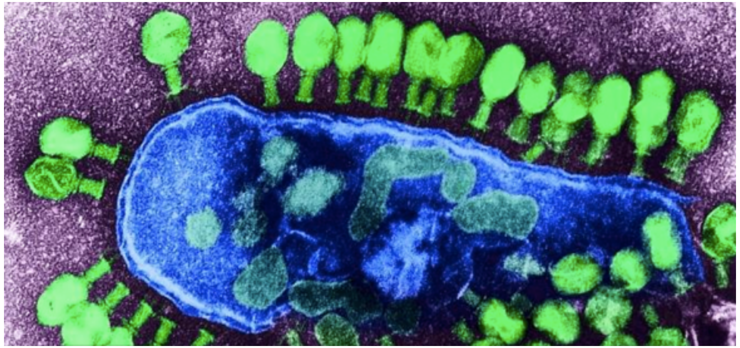


# Are viruses living?

- Living things have the fundamental properties of:
    - *Metabolism*, (cellular reactions, in pathways)
    - *Irritability* (ability to perceive and respond to external stimuli)
    - *Ability to reproduce*
- Viruses do not satisfy the first two and though they reproduce, can only do so via the machinery of a living cell

# Bacteriophage

- In theory, bacteriophage exist for every type of bacterium
- They are present in every ecosystem
- They can be highly specific for their hosts
- Bacteriophage discovered through metagenomic sequencing have been shown to reside in the mucus of many mammals.  As a part of our microbiome, they seem to provide “non-host-derived immunity.”



# Summary

- Ribosomes – protein synthesis
- Cytoskeleton
- Cell vesicles and vacuoles
- Viruses and bacteriophages

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