4 Organization of the Cell

Lecture Outline

I. The cell is the basic unit of life
   A. The cell theory states that the cell is the fundamental unit of life
   B. Schleiden and Schwann were the first to set forth the cell theory
   C. Virchow stated that cells arise from previously existing cells
   D. Weismann described the common ancestry of all cells

II. Cell organization and size permit homeostasis
   A. Organization is basically similar in all cells
      1. All cells have a plasma membrane, which is a selective barrier
      2. Cells have internal organelles which are specialized for various functions
   B. Cell size is limited
      1. Cells are typically small because of the relationship between surface area and volume
      2. As a cell increases in size, the ratio of volume (cytoplasm) to surface area (plasma membrane) increases
      3. Microvilli increase the surface area of a cell without greatly increasing the volume

III. Cells are studied by a combination of methods
   A. Hooke is often credited with seeing the first cells; rather he first identified the cell walls of dead cells
   B. Light microscopes are used to study stained or living cells
      1. Organelles were first identified in the early 1900s, using different stains
      2. Phase contrast and interference microscopes allow unstained living cells to be observed
      3. Fluorescence microscopes can identify the location of molecules within cells
      4. Light microscopes are limited by resolving power
   C. Electron microscopes provide a high resolution image that can be greatly magnified
      1. Electron microscopes allow investigation of the ultrastructure of cells
      2. TEM allows visualization of structures within sections of tissues
      3. SEM allows visualization of entire specimens
   D. Cell fractionation procedures permit study of cell components
      1. This process involves centrifugation and allows investigation of the function of cellular organelles
      2. Differential centrifugation separates cellular components based on their varying sizes and densities
      3. Density gradient centrifugation allows further purification
IV. Prokaryotic cells are structurally simpler than eukaryotic cells
   A. Prokaryotes lack membrane-bound organelles and are typically smaller than eukaryotic cells
   B. Prokaryotes have a plasma membrane, and typically a cell wall

V. Eukaryotic cells are characterized by membrane-bounded organelles
   A. The term protoplasm is an old term which refers to the cellular contents
   B. Currently, biologists differentiate the cellular contents into the nucleoplasm and the cytoplasm
      1. The cytoplasm contains fluid (cytosol) and organelles

VI. Membranes divide the cell into compartments
   A. Biological membranes have no free ends, therefore they surround a compartment
   B. These compartments are the site of chemical reactions
      1. Membranes may also form barriers to substances, important in production of ATP
      2. Many enzymes are embedded in membranes
      3. In eukaryotes, many of the membranes are part of the endomembrane system
         a. The organelles of the endomembrane system connect directly or indirectly via vesicles
         b. The endomembrane system includes the ER, the nucleus, the Golgi, lysosomes and vacuoles, as well as the plasma membrane
      4. Vesicles are small membrane bounded transport sacs
   C. The cell nucleus contains DNA
      1. The nucleus is typically in the center of the cell
      2. Most cells have a single nucleus
      3. The nuclear envelope controls traffic between the nucleus and the cytoplasm
         a. Pores in the nuclear membrane allow materials to pass in and out of the nucleus
      4. Chromosomes consist of chromatin, a DNA/protein complex
         a. Nearly all of the DNA in a cell is in the nucleus
         b. DNA takes the form of chromosomes during cell division
         c. When not dividing, DNA is more loosely arranged, associated with proteins, collectively called chromatin
      5. Ribosomal subunits are assembled in the nucleolus
         a. Ribosomes are composed of two subunits
         b. Eukaryotic ribosomal subunits are assembled in the nucleolus
   D. Ribosomes manufacture proteins
      1. Ribosomes are composed of RNA and protein, and may be free or attached to the endoplasmic reticulum
   E. The endoplasmic reticulum is a major manufacturing center
      1. The ER extends from the nuclear membrane into the cytoplasm
      2. The space enclosed by the ER membranes is the lumen
      3. The lumen side of the membrane is a typical intracellular membrane
      4. The cytosolic side of the membrane may be studded with ribosomes
5. Rough ER is the site of protein synthesis
   a. Proteins formed may be transferred to other sites within the
      cell in transport vesicles
6. Smooth ER lacks ribosomes and functions in the production of
   various fats, as well as detoxifying chemicals

F. The Golgi complex processes and packages proteins
1. First described in 1898 by Camillo Golgi
2. Appears as a stack of flattened sacs with bulging ends
   a. The cis face functions in receiving materials
   b. The trans face is directed towards the plasma membrane
3. Functions in processing, sorting and modifying proteins
4. The processed product is then passed to other organelles or to the
   plasma membrane
5. The Golgi manufactures lysosomes

G. Lysosomes are compartments for digestion
1. Lysosomes are small sacs filled with hydrolytic enzymes
2. Primary lysosomes bud from the Golgi complex
3. Secondary lysosomes form by fusion of a primary lysosome with a
   vesicle containing ingested material
4. Lysosomes are involved in apoptosis (programmed cell death)
   a. Inappropriate apoptosis may be involved in cancer, AIDS, and
      Alzheimer’s disease
5. Lysosomal action is involved in the metamorphosis of amphibians
   and some human diseases, like rheumatoid arthritis and Tay-
   Sachs disease

H. Peroxisomes metabolize small organic compounds
1. Peroxisomes transfer hydrogen from various compounds to oxygen,
   forming hydrogen peroxide
2. Catalase splits hydrogen peroxide
3. These organelles are most common in cells that synthesize, store, or
   degrade lipids
4. Plant seeds have specialized peroxisomes called glyoxysomes

I. Vacuoles are large, fluid-filled sacs with a variety of functions
1. In plants and fungi, vacuoles carry out many of the functions of a
   lysosome
2. Vacuoles are bound by a membranous tonoplast
3. Vacuoles may store toxins or pigments
4. Plant vacuoles allow cells to increase in size
5. Protoplasts have various vacuoles involved in digestion and excretion

J. Mitochondria and chloroplasts are energy-converting organelles

K. Mitochondria make ATP through cellular respiration
1. Mitochondria are the site of aerobic cellular respiration
2. Mitochondria are double-membrane bound
   a. The matrix is inside of the inner membrane
   b. The intermembrane space is between the two membranes
   c. The inner membrane is a particularly selective barrier
   d. Cristae are the foldings of the inner membrane, providing a
      large surface area
3. Mitochondrial DNA has been linked to several genetic diseases
L. Chloroplasts convert light energy to chemical energy through photosynthesis
   1. Photosynthetic cells may have one or many chloroplasts
   2. Pigments like chlorophylls are specialized for photosynthesis
   3. Chloroplasts are also double-membrane bound
      a. The stroma is inside the inner membrane
      b. The inner membrane forms the thylakoids
         1). The thylakoids contain the photosynthetic pigments
         2). Thylakoids are formed in stacks called grana
      c. The thylakoid interior space is within the thylakoid membranes
   4. Chloroplasts and other plastids develop from proplastids
   5. Chromoplasts contain pigments and are common in petals and ripe fruit
   6. Leukoplasts lack pigments and may store starch

VII. Eukaryotic cells contain a cytoskeleton
   A. The cytoskeleton provides for cell shape and allows movement
      1. Microfilaments are very thin
      2. Microtubules are larger in diameter
      3. Intermediate filaments are of an intermediate diameter
   B. Microtubules are hollow cylinders
      1. Microtubules grow by the addition of alpha and beta tubulins more rapidly at the plus end
      2. Microtubules extend from the MTOC
         a. The most important part of the MTOC is the centrosome
         b. Centrioles are part of the the centrosome in animal cells
      3. Microtubules move chromosomes during cell division via a spindle
      4. Microtubules are also involved in movement of organelles or vesicles
      5. The proteins kinesin and dynein are motor proteins involved in the movement of materials
   C. Cilia and flagella are composed of microtubules
      1. Cilia are numerous and short; flagella are longer and fewer in number
      2. Cilia and flagella act to move cells, or move substances over a surface
      3. Both have a 9 + 2 arrangement of microtubules
      4. The basal body has a 9 x 3 arrangement, as do centrioles
   D. Microfilaments consist of intertwined strings of actin
      1. Actin and myosin are the contractile units of muscle cells
      2. Actin microfilaments form the structure of microvilli
      3. Microfilaments aid in the division of an animal cell after cell division
   E. Intermediate filaments help stabilize cell shape
      1. These filaments are the most stable and strengthen the cell
      2. Inside the nuclear membrane is the nuclear lamina formed by intermediate filaments
VIII. An extracellular matrix surrounds most cells
   A. Most eukaryotic cells have a cell coat, or glycocalyx, formed by molecules associated with the plasma membrane
      1. The glycocalyx may act as recognition sites
   B. Many animal cells also have extracellular proteins, including the fibronectins and integrins
   C. Plant, fungal, and bacterial cells are surrounded by cellulose-containing cell walls
      1. The primary cell wall can expand as the cell grows
      2. The secondary cell wall is formed between the primary cell wall and the cell membrane
      3. The middle lamella glues adjacent plant cells together