Chapter 3 Microscopy and Cell Structure

Summary Outline

3.1 Microscopic Techniques: The Instruments
- A. Light Microscopes
  1. The **bright-field microscope**: Visible light passes through the specimen
  2. **Phase contrast microscope**: Amplifies differences in refraction
  3. **Dark-field microscope**: Directs light toward a specimen at an angle
  4. The **fluorescent microscope**: used to observe cells that have been stained with fluorescent dyes
  5. The **confocal scanning laser microscope**: Used to construct a three-dimensional image of a thick structure and to provide detailed sectional views of the interior of an intact cell
- B. **Electron Microscopes**
  1. Use electromagnetic lenses, electrons, and phosphorus screens to produce a magnified image
     a) **Transmission electron microscopes** (TEM) transmit electrons through a specimen that has been prepared by thin-sectioning, freeze-fracturing, or freeze-etching
     b) **Scanning electron microscopes** scan a beam of electrons back and forth over the surface of a specimen, producing a three-dimensional effect
  1. **Scanning probe microscopes**: Maps the bumps and valleys of a surface on an atomic scale

3.2 Microscopic Techniques: Dyes and Staining
- A. Differential stains
  1. The Gram Stain
     a. **Gram-positive bacteria stain purple**
     b. **Gram-negative bacteria stain pink**
  2. The **acid-fast stain**: Stains organisms such as **mycobacteria**, which do not take up stains readily; acid-fast organisms stain pink and all other organisms stain blue
- B. Special stains to observe cell structures
  1. **Capsule stain** colors the background, allowing the capsule to stand out as a halo around an organism
  2. **Spore stain** stains endospores
  3. **Flagella stain** stains flagella
- C. **Fluorescent dyes and tags**: Some fluorescent dyes bind compounds that characterize all cells, others bind to compounds specific to only certain cell types

3.3 Morphology of prokaryotic cells
- A. Shapes
  1. **Cocci**
  2. **Rods**
  3. **Coccobacilli**
  4. **Vibrios**
  5. **Spirilla**
  6. **Spirochetes**
  7. **Pleomorphic** bacteria have variable shapes
- B. Groupings: Cells adhering to one another following division form a characteristic arrangement that depends on the plane in which the bacteria divide

C. Multicellular associations
    1. Associations containing multiple cells, such as myxobacteria
    2. **Biofilms** often alter their activities when a critical number of cells are present

3.4 The Prokaryotic Cell: The cytoplasmic membrane

A. Structure and chemistry of the cytoplasmic membrane
    1. **Phospholipid bilayer** embedded with a variety of different **proteins**
    2. **Differential barrier** between the cell and the surrounding environment
    3. Membrane **proteins function in transport** or provide a mechanism by which cells can **sense** and **adjust** to their surroundings

B. Permeability of the cytoplasmic membrane
    1. **Selectively permeable**
    2. Inflow of water into the cell exerts more osmotic pressure on the cytoplasmic membrane than it can generally withstand

C. The role of the cytoplasmic membrane is involved in **energy generation**: Electron transport chain within the membrane expels protons, generating an electrochemical gradient, which contains a form of energy called proton motive force

3.5 The Prokaryotic Cell: Directed movement of materials across the cytoplasmic membrane

A. **Transport systems**
    1. **Facilitated diffusion**: Moves impermeable compounds from one side of the membrane to the other by exploiting the concentration gradient
    2. **Active transport** mechanisms use energy to accumulate compounds against a concentration gradient
    3. Members of the major facilitator superfamily use **proton motive force** for energy
    4. **ABC transport** systems require ATP for energy
    5. **Group translocation** chemically modifies a molecule during its passage through the cytoplasmic membrane

B. **Secretion**: The general secretory pathway is the primary mechanism used to secrete proteins

3.6 The Prokaryotic Cell: Cell Wall

A. **Peptidoglycan**
    1. Found only in the bacteria and provides rigidity to the cell wall
    2. Composed of peptidoglycan which contains alternating subunits of ***N*-acetylmuramic acid (NAM)** and ***N*-acetylglucosamine (NAG)** interconnected via the tetrapeptide chains on NAM

B. The **Gram-positive cell wall**
    1. Relatively **thick layer of peptidoglycan**
    2. **Teichoic acids** and **lipoteichoic acids** stick out of the peptidoglycan molecule

C. The Gram-negative cell wall
    1. **Thin layer of peptidoglycan** sandwiched between the cytoplasmic membrane and an outer membrane
    2. **Periplasm** contains a variety of proteins
    3. The outer membrane contains lipopolysaccharides. **The Lipid A portion** of the lipopolysaccharide molecule is toxic, which is why LPS is called **endotoxin**
    4. **Porins** form small channels that permit small molecules to pass through the outer membrane

D. Antibacterial compounds that target peptidoglycan
    1. Penicillin binds to proteins involved in cell wall synthesis
    2. Lysozyme breaks the bond that links alternating NAG and NAM molecules

E. Characteristics of bacteria that lack a cell wall
    1. Because **mycoplasmas** do not have a cell wall, they are extremely variable in shape and are not effected by lysozyme or penicillin

F. Cell walls of the Domain Archaea have a greater variety than those of the Domain Bacteria

3.7 The Prokaryotic Cell: Surface layers external to the cell wall

1. **Glycocalyx**: Enable bacteria to adhere to surfaces; some capsules allow disease-causing microorganisms to thwart the innate defense system
   a) **Capsule**: A distinct and gelatinous layer made of polysaccharide
   b) **Slime layer**: Diffuse and irregular layer of polysaccharide

3.8. The Prokaryotic Cell: Filamentous protein appendages

1. **Flagella**
   a) Long protein structures responsible for most types of bacterial motility
   b) **Chemotaxis** is the directed movement toward an attractant or away from a repellant
2. Pili
   a) Many types of **pili (fimbriae)** enable attachment of cells to specific surfaces
   b) Some pili play a role in specific types of motility
   c) **Sex pili** are involved in conjugation, which enables DNA to be transferred from one cell to another

3.9. The Prokaryotic Cell: Internal structures

A. **Chromosome**
   1. The chromosome of prokaryotes resides in the nucleoid
   2. The typical chromosome is a **single, double-stranded DNA molecule** that contains all the genetic information required by a cell

B. **Plasmids**
   1. Plasmids are **circular, double-stranded DNA** molecules that typically encode genetic information that may be advantageous, but not required by the cell
   2. Populations of cells can gain and lose plasmids, depending on the relative advantages

C. **Ribosomes**
   1. Ribosomes facilitate the joining of amino acids
   2. The **70S bacterial ribosome** is composed of a 50S and a 30S subunit

D. **Storage granules**: Dense accumulations of high molecular weight polymers, which are synthesized from a nutrient that a cell has in relative excess

E. **Gas vesicles** are gas-permeable, water-impermeable rigid structures that provide buoyancy to aquatic cells

F. **Endospores**
   1. Dormant stage produced by members of the **genera *Bacillus*** and ***Clostridium***; they can germinate to become a vegetative cell
   2. **Resistant** to conditions such as heat, desiccation, toxic chemicals, and UV irradiation
   3. **Sporulation** is an eight-hour process initiated when cells are grown under nutrient-limiting conditions
   4. **Germination** is the process by which an endospore leaves its dormant state

3.10 The Eukaryotic Cell: The **plasma membrane**

A. **Phospholipid bilayer** embedded with **proteins**

B. Proteins are involved in **transport, structural integrity** and **signaling**

3.11 The Eukaryotic Cell: Transfer of molecules across the plasma membrane

A. **Transport proteins**
   1. **Channels** are pores in the membrane so small that only specific ions can pass. These channels are gated
   2. Cells of multicellular organisms often take up nutrients by facilitated diffusion because the nutrient concentration of their surrounding environment can be controlled

3. **Carriers** involved in active transport include members of the major facilitator superfamily and ABC transporters

B. **Endocytosis** and **exocytosis**
1. **Receptor-mediated endocytosis**
2. Protozoa and phagocytes take up bacteria and debris through the process of **phagocytosis**
3. **Exocytosis** expels products and it the reverse of endocytosis

C. **Secretion**
1. Proteins are made by ribosomes bound to the endoplasmic reticulum
2. The proteins are threaded through the membrane and into the lumen of the endoplasmic reticulum

3.12 The Eukaryotic Cell: Protein structures within the cytoplasm

A. **Ribosomes**: The 80S eukaryotic ribosome is composed of 60S and 40S subunits

B. **Cytoskeleton**
1. **Microtubules** are the thickest of the cytoskeleton structures and are long hollow cylinders
2. **Microfilaments** allow the cytoplasm to move and are composed of actin
3. **Intermediate filaments** strengthen the cell mechanically

C. Flagella and cilia
1. **Flagella** and **cilia** are composed of microtubules in a 9+2 arrangement
2. Flagella propel a cell or pull the cell forward
3. Cilia often cover the surface of a cell and move in synchrony to either propel a cell or move material along a stationary cell

3.13 The Eukaryotic Cell: Membrane-bound organelles

A. The **nucleus**
1. The nucleus **contains DNA** and is the predominant distinguishing feature of eukaryotes
2. Two membranes compose the **nuclear envelope**
3. **Nuclear pores** allow large molecules to be transported in and out of the nucleus
4. The **nucleolus** is where ribosomal RNAs are synthesized and, along with ribosomal proteins, are assembled into ribosomal subunits

B. Mitochondria and chloroplasts
1. Contained within the inner membrane of mitochondria and chloroplasts are the proteins of the electron transport chain and proteins that use proton motive force to generate ATP
2. **Mitochondria** use the energy released during the degradation of organic compound to generate ATP
3. **Chloroplasts** contain chlorophyll, which captures the energy of sunlight; this is then used to synthesize ATP

C. **Endoplasmic reticulum**
1. **Rough** endoplasmic reticulum
   a) Lined with ribosomes
   b) Serves as the site where proteins that are not located in the cytoplasm are synthesized
2. **Smooth** endoplasmic reticulum
   a) Lipids are synthesized and degraded, and calcium is stored

D. **Golgi apparatus**: Modifies and sorts molecules synthesized in the ER

E. **Lysosomes**: Structures within which digestion takes place

F. **Peroxisomes**: Organelles in which oxygen is used to oxidize certain substances