Cell Physiology

Cell Physiology

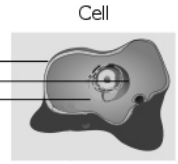
- The “Inner Life of a Cell”
- Components and their functions
- Cell to Cell Junctions - Forming Tissues
- How it’s Integrated

Part 1

The “Inner Life of a Cell”

Cell Components

- What are the basic components of a cell?
  - cell membrane
  - nucleus
  - cytoplasm
    - cytosol
    - organelles

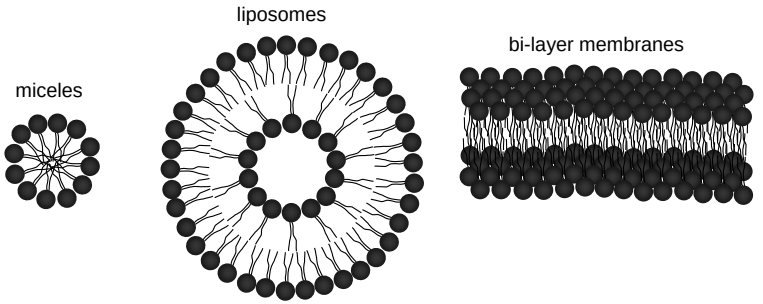


Cell Components — The Cell Membrane

- What does the cell membrane do?
  - – Creates separation between ECF vs. ICF
    - Creates fluid compartments
  - – Regulates ECF – ICF exchange
  - – Allows for communication
  - – Provides structural support for cell and tissues

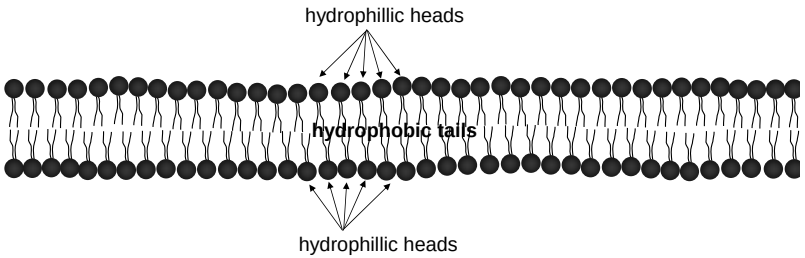
Cell Components — The Cell Membrane

- The physical barrier
  - – Formed by the tail to tail arrangement of the phospholipid molecules
    - Self assembles into



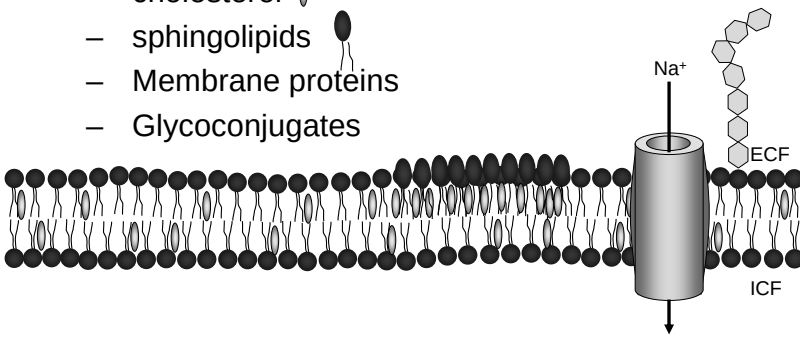
Cell Components — The Cell Membrane

- How does a barrier become a regulator?
  1. By being having a polar surface
  2. By specialized membrane components



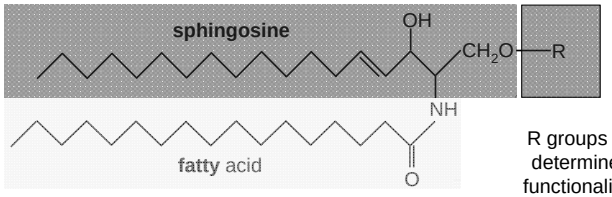
Cell Components — The Cell Membrane

- Other phospholipid bilayer membrane components
  - – cholesterol
  - – sphingolipids
  - – Membrane proteins
  - – Glycoconjugates



Cell Components — The Cell Membrane

- Sphingolipids
  - Group of membrane lipids with larger “heads”
  - Involved in
    - cell signal transduction by forming caveolae
    - cell-cell communication
    - Endocytosis & uptake of viruses and bacteria
  - Form “lipid rafts” – more cholesterol



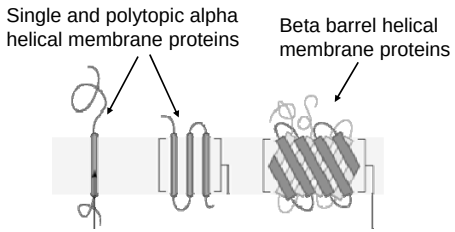
R groups – determine functionality

Cell Components — The Cell Membrane

- Membrane Proteins
  - 3 categories
    - transmembrane proteins
    - peripheral proteins
    - lipid anchored (amphitropic) proteins

Cell Components — The Cell Membrane

- Transmembrane Proteins
  - Types:
    - Most common type in mammalian cells are alpha helical proteins
    - Also beta barrels in mitochondria

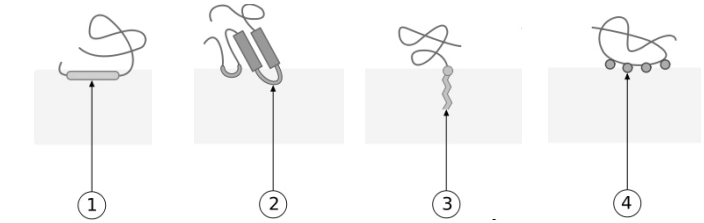


Cell Components — The Cell Membrane

- Functions of transmembrane proteins
  - Transport function
  - Enzyme function
  - Gated Ion channel formation
  - Receptor function/signal transduction

Cell Components — The Cell Membrane

- Peripheral Proteins –
  - attachments to the phospholipid bi-layer



Cell Components — The Cell Membrane

- Peripheral Protein Functions
  - Enzyme function
    - Mediate chemical reactions
  - Structural
    - Mediate attachment
  - Transporters
    - Between/among cell membrane proteins
  - Electron carriers
    - In electron transport chain
  - Regulators
    - Such as apoptosis

Cell Components — The Cell Membrane

- Glycoconjugates
  - Includes glycolipids & glycoproteins
  - Form a glycocalyx on the exoplasmic surface
  - Many functions
    - Integrated with other membrane molecules/structures such as sphingolipids

Cell Components — The Cell Membrane

- Functions of glycocalyx:
  - Protection
    - Cushions the plasma membrane and protects it from chemical injury
  - Immunity to infection
    - Enables the immune system to recognize and selectively attack foreign organisms
  - Defense against cancer
    - Changes in the glycocalyx of cancerous cells enable the immune system to recognize and destroy them
  - Transplant compatibility
    - Forms the basis for compatibility of blood transfusions, tissue grafts, and organ transplants
  - Cell adhesion
    - Binds cells together so that tissues do not fall apart
  - Inflammation regulation
    - Glycocalyx coating on endothelial walls in blood vessels prevents leukocytes from rolling/binding in healthy states
  - Fertilization
    - Enables sperm to recognize and bind to eggs
  - Embryonic development
    - Guides embryonic cells to their destinations in the body

Cell Components — The Nucleus

- Contains
  - DNA
  - Nucleolus
    - DNA that regulates the synthesis of ribosomal RNA
  - Double phospholipid bilayer for a nuclear membrane
- Functions
  - Nuclear membrane compartmentalizes the nuclear material from the rest of the cell allowing control on both sides
    - Outer membrane is in contact with the endoplasmic reticulum membrane
    - Material enters and exits through nuclear pores
  - Gene Expression
    - Can only happen if material is allowed in & out of the nucleus
  - Processing of pre-mRNA
    - Introns are removed, exons remain

Cell Components — The Cytoplasm

- Cytoplasm is divided functionally into
  - Cytosol
    - Site of many chemical reactions
  - Inclusions
  - Membranous Organelles
    - Functional units of the cell

Cell Components — The Cytoplasm

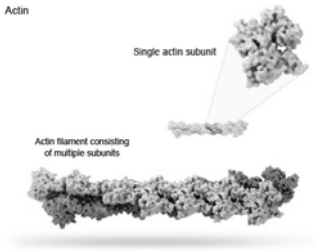
- Cytosol functions (many in conjunction with other processes)
  - Cell signaling
  - Cytokinesis
  - Protein synthesis
  - Glycolysis
  - gluconeogenesis

Cell Components — The Cytoplasm

- The Inclusions
  - Direct contact on the cytosol
    - Ribosomes
      - Involved in synthesis of proteins
    - Proteasomes
      - Involved in protein degradation
    - Vaults
      - Functional aspect TBD definitively
        - » Found associated with lipid rafts
        - » May play a role in transport into and out of the nucleus
    - Protein fibers
      - Provide structure and movement within the cell
        - » Actin
        - » Intermediate filaments
        - » microtubules

Cell Components — The Cytoplasm

- Actin
  - Smallest cytoskeletal filament (aka microfilament)
  - Fiber composed of actin molecules
  - Associated with myosin for muscle contraction
    - Contains binding sites for myosin



Cell Components — The Cytoplasm

- Intermediate Filaments
  - Provide structure for
    - Type I & II Intermediate filaments
      - Hair/nails – keratin fibers
    - Type III Intermediate filaments
      - Desmin
        - » Involved in structural support of sarcomeres
        - » Connects z discs to subsarcolemmal cytoskeleton!
        - » Involved in migration of cells during embryogenesis
      - Vimentin
        - » Support cell membranes
        - » Cytoskeltal component that anchors some organelles
      - Peripherins & GFAP's (glial fibrillary acidic protein)
        - » Intermediate filaments in nerves and glial cells

Cell Components — The Cytoplasm

- Intermediate filaments cont…
  - Type IV Intermediate filaments
    - Filament group that has types in neural tissue as well as muscle tissue
  - Type V Intermediate filaments
    - These are nuclear filaments, providing support for the nuclear membrane
  - Type VI Intermediate filaments
    - Aids in growth of axons

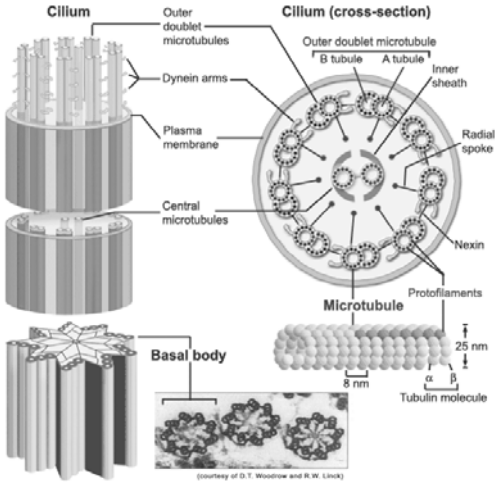
Cell Components — The Cytoplasm

- Microtubles
  - Assembled from monomers of tubulin (α & β)
    - (α & β) monomers combine to form dimers
    - these assemble to create protofilaments (single tubes) which then assemble into the larger structures of
      - Centrioles
        - » Direct microtubule formation during the M phase of the cell cycle
        - » Form basal bodies for flagella and cilia
      - flagella and cilia – provide motility
        - » Using dyenin "motors"

Cell Components

The Cytoplasm

Assembly of a cilium



Cell Components

The Cytoplasm

- The cytoskeletal components help to
  - Maintain cell shape
  - Organize the internal compartment of the cell
  - Provide transport routes within cells
  - Aid in creation of tissues from cells
  - Create movement
    - Along with motor proteins such as

      Myosins – Actin motor protein

      Dyenins, Kinesins } Microtubule motor proteins

      Other cellular motors proteins include:

      ATP synthase, DNA & RNA polymerase

Cell Components

The Cytoplasm

- The Membrane Bound Organelles
  - Provide additional specific functionality to cells
    - Protein production
    - Lipid, phospholipid, steroid manufacture
    - ATP generation
    - Defense/Protection
    - Storage

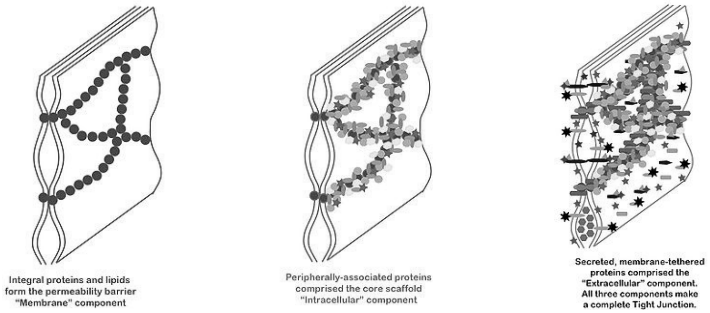
Cell to Cell Junctions

- The formation of tissues requires
  - Ability to attach cells to neighboring cells
    - Very important in epithelial cells & muscle cells
  - Production of extracellular materials
    - Very important in connective tissues
  - Communication between cells
  - Cell migration during development and repair

Cell to Cell Junctions

- Junctions between cells
  - Zonula occludens
  - Zonula adherens
  - Macula adherens
  - Gap junctions
  - Synapses
- Junctions between cells and the extracellular material
  - Hemidesmosomes
  - Focal adhesions

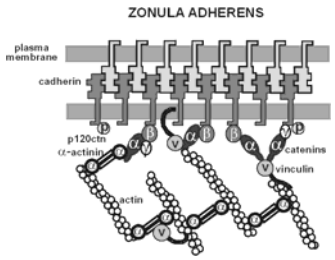
Cell to Cell Junctions — Tight Junctions



- Why all this complexity in tight junctions?
  - Prevents integral protein migration
    - Maintains polarity of cells that utilize them
  - Prevents passage of substance between cell membranes

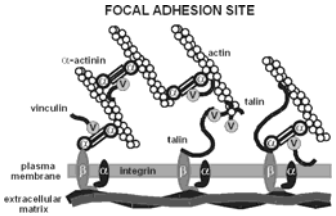
Cell to Cell Junctions — Desmosomes

- zonula adherens & macula adherens
  - Function in providing strong attachemnts between adjacent lateral membranes
  - Difference is in continuity
    - Zonula (zone) is around the apical region of tightly packed cells (epithelial)
    - Macula (spot) occurs in spots on the lateral membranes of adjacent cells



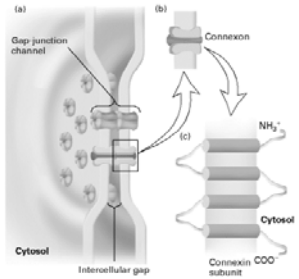
Cell to Cell Junctions — cell-matrix junctions

- Focal Adhesions & Hemidesmosomes
  - Attach to underlying extracellular matrix
    - Focal Adhesions
      - Transmembrane protein integrin interacts with fibers such as collagen to anchor the membrane
      - Cytoplasmic fibers (actin) interact with the integrin to provide intracellular stability
    - Hemidesmosomes
      - Attach epithelials to underlying basement membrane
      - Similar to "regular" desmosomes, but only ½ and use integrins instead of cadherins



Cell to Cell Junctions — gap junctions

- Gap Junction Structure
  - Transmembrane proteins called connexons form “channels” between adjacent cells
- Function
  - Communication by allowing ions to flow from cell to cell very quickly
  - Form electrical synapses in neural tissue



Cell to Cell Junctions — Synapses

- Specialized junctions between neurons and
  - Other neurons
  - Muscle (neuromuscular junction)
  - Glands (neuroglandular junction)
- Specialized for
  - Communication via neurotransmitters!
- More on these later…

Integrative Physiology

- How do cells “fit in” the big picture?

Tissues

- What tissues are formed?
  - Epithelial
  - Connective
  - Muscular
  - Nervous

Tissues

- Epithelial Tissues
  - Form sheets of single or multiple layers of cells and glands
  - form barriers due to zonula adherens, zonula occludens and high cellularity
  - Functions in
    - Filtration
    - Absorption & Secretion
    - Protection & defense
    - Communication

Tissue

- Connective
  - Many different types
  - Many different functions
    - Defense & Protection
    - Transportation
    - Structure
    - Storage
    - Shock absorption
    - Production

Tissues

- Muscle
  - Functions
    - Movement
    - Heat generation
    - Protection
  - Types of muscle
    - Skeletal
    - Cardiac
    - Smooth

Tissues

- Nervous Tissue
  - Functions
    - COMMUNICATION!