Cell Structure

Bio 103 Lecture
GMU
Dr. Largen

The cell
✓ The cell
  – is as fundamental to biology as atom is to chemistry
  – is basic unit of life
    • simplest collection of matter that can live

Outline
✓ Introduction to the world of the cell
✓ Eukaryotic versus prokaryotic cells
✓ Nucleus and ribosomes
✓ Organelles of the endomembrane system
✓ Energy-converting organelles
✓ Cytoskeleton & related structures
✓ Eukaryotic cell surfaces & junctions

Introduction to world of the cell
Microscopes provide windows to world of cell
✓ Before microscopes (first used in 17th century), no one knew living organisms were composed on cells

Introduction to world of the cell
Microscopes provide windows to world of cell
✓ Two main types of microscopes
  – light microscope
  – electron microscope

Introduction to world of the cell
Microscopes provide windows to world of cell
✓ microscopes used to study cells
  – light microscope
    • illumination source =
    • image magnification by =
    • lower limit of resolution =
    • types
      – compound light
      – stereomicroscope (dissection)

Introduction to world of the cell
Microscopes provide windows to world of cell
✓ microscopes used to study cells
  – light microscope
    • compound light
      – light passes through specimen
      – creates 2 dimensional image
    • dissection or stereomicroscope
      – light reflected off surface of specimen
      – creates 3-D image

Table 7.1 Different Types of Light Microscopy: A Comparison, Campbell & Reece

Introduction to world of the cell
Microscopes provide windows to world of cell
✓ microscopes used to study cells
  – electron microscope
    • illumination source =
    • image magnification by =
    • lower limit of resolution =
    • types
      – transmission electron microscope
      – scanning electron microscope

Introduction to world of the cell
Microscopes provide windows to world of cell
✓ microscopes used to study cells
  – electron microscope
    • transmission electron microscope
      – electron beam passes through specimen
      – creates 2 dimensional image
    • scanning electron microscope
      – electron beam is reflected off surface of specimen
      – creates 3-D image

Figure 7.1 The size range of cells, Campbell & Reece

Cell sizes vary with their function
✓ Cell size and shape related to function
  – smallest cells
  – largest cells

Figure 7.2 Electron micrographs, Campbell & Reece
Introduction to world of the cell
Natural laws limit cell size

- Cell size has lower and upper limits
  - reasons for limits of the size of a cell
    - “smallness”
    - “largeness”

Cells are small
- advantages of small cell size

Surface area-to-volume ratio imposes limits on cell size
- as cell’s size increases, its volume increases more rapidly than surface area
  - surface area of sphere = \(4\pi r^2\)
  - volume of sphere = \(\frac{4}{3}\pi r^3\)
- for example
  - cell radius: 1 cm 10 cm
  - surface area: 12.57 cm\(^2\) 1257 cm\(^2\)
  - volume: 4.189 cm\(^3\) 4189 cm\(^3\)

Prokaryotic cells are small and structurally simple
- Two kinds of structurally different cells have evolved over time
  - prokaryotic cells
    - Archaeabacteria
    - Eubacteria
Prokaryotic cells are small and structurally simple

- small
- lacks nucleus
  - nucleoid region
- surrounded by plasma membrane
- most have bacterial cell wall
- some have capsule
- some have pilus (sticky)
- some propelled by a flagellum

Eukaryotic cells are partitioned into functional compartments

- fundamentally similar to each other
  - profoundly different from prokaryotic cells
- in general
- comparing animal and plant cell

Eukaryotic cells are partitioned into functional compartments

- presence vs. absence of cell walls
  - animal cells lack cell walls
  - some protists lack cell walls
  - plants, fungi and some protists have cell walls

Eukaryotic cells are partitioned into functional compartments

- complex interior organization
  - extensive compartmentalization
  - many membrane-bound organelles
• true, membrane-bound nucleus
• complex DNA molecule
• vesicles and vacuoles

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Introduction to world of the cell
Eukaryotic cells are partitioned into functional compartments

✔ Eukaryotic cells
– membranes partition cytoplasm into compartments called membranous organelles
• many of chemical activities known as cellular metabolism
– occur in membranous organelles
–

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Eukaryotic cells, animal vs. plant

✔ animal cells
• cell wall absent
• chloroplasts absent
• central vacuole absent
• mitochondria present
• centrioles present
• lysosome present
• flagella may be present
Introduction to world of the cell
Eukaryotic cells are partitioned into functional compartments

✔ Eukaryotic cells, plant vs. animal
  – plant cells
    • cell wall present
    • chloroplasts present
    • mitochondria present
    • central vacuole present
    • flagella absent (except in some sperm)
    • lysosome absent
    • centrioles absent

Introduction to the Cell
Membranes organize the activities of cells
✔ For all types of cells
  – plasma membrane is edge of life
    • boundary between living cell and its surroundings
✔ For most eukaryotic cells
  – membranes form
    • most organelles
    • compartments within cells

Introduction to the Cell
Membranes organize the activities of cells
✔ Plasma membrane (cell membrane)
– very thin
  • too small to be seen by light microscope
  • can be seen by electron microscope
    – shows up as three zones

**Plasma membrane** composed mainly of phospholipids
  – phospholipid molecule
    • two parts
    • “head”
      – glycerol and phosphate group
      – polar = hydrophilic
    • “tail”
      – two fatty acid tails
      – non-polar = hydrophobic

Membranes organize the activities of cells

**Phospholipid structure suited to role in membranes**
  – spontaneously form a stable two-layer sheet in water, a **phospholipid bilayer**

Eukaryotic cells are partitioned into functional compartments

**membranous organelles**
  – nucleus
  – endoplasmic reticulum
  – Golgi apparatus
  – mitochondria
  – lysosome
  – peroxisome
  – chloroplast
  – central vacuole

**non-membranous structures**
  – centriole
  – flagellum
  – ribosome
  – microtubule
  – microfilament
  – cell wall
**Organelles of the endomembrane**

Nucleus is cell’s genetic control center

**Nucleus**
- genetic control center
- contains **DNA**
  - hereditary blueprint
  - attached to proteins
    - forms long fibers called **chromatin**
      - each fiber constitutes a **chromosome**

**Organelles of the endomembrane**

Nucleus is cell’s genetic control center

**Nucleus** bounded by phospholipid bilayer
- **nuclear envelope (membrane)**
  - perforated with **pores**
    - outer membrane is continuous with cytoplasm’s interior membrane system
      - endoplasmic reticulum

**Organelles of the endomembrane**

Nucleus is cell’s genetic control center

**Nucleus**
- contains **nucleolus**
  - mass of fibers and granules adjoining chromatin
  - consists of
    - location where **ribosomes** are made

**Organelles of the endomembrane**

Nucleus is cell’s genetic control center

**N**OT enclosed in membrane
- **Ribosomes**
  - particles made of ribosomal RNA and protein
  - carry out protein synthesis
  - composed of two subunits
    - small subunit, large subunit
  - can be
    - free in cytoplasmic fluid
    - bound to endoplasmic reticulum

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Figure 7.10 Ribosomes, Campbell & Reece
Figure 7.9 The nucleus and its envelope, Campbell & Reece
Figure 7.x1 Nuclei and F-actin in BPAEC cells, Campbell & Reece

**Organelles of the endomembrane**
Many organelles related through endomembrane system

- **endomembrane system**
  - collection of membranous organelles
  - some membranes are physically connected and some are not

- Rough endoplasmic reticulum (RER)
  - network of interconnected flattened sacs
    - made of membrane
    - studded with **ribosomes**
  - two main functions
    - make more membrane
    - make proteins secreted by cell

**Figure 7.11 Endoplasmic reticulum (ER), Campbell & Reece**

- Smooth endoplasmic reticulum has a variety of functions
  - **Smooth endoplasmic reticulum (SER)**
    - network of interconnected tubules
      - made of membrane
      - continuous with RER
      - lacks ribosomes
      - thus “smooth” ER
Smooth endoplasmic reticulum (SER) has three functions:

- Lipid synthesis
- Destruction of toxic substances
- Regulation of muscle contraction

Lipid synthesis is one of the most important functions of SER. The type of lipid varies with cell type and includes:

- Fatty acids
- Phospholipids
- Steroids

Destruction of toxic substances occurs in liver cells, where SER contains enzymes that break down drugs and harmful substances.

Regulation of muscle contraction is necessary for muscle contraction in muscle cells, where SER stores calcium ions.
Organelles of the endomembrane
Golgi apparatus finishes, sorts and transports cell products

✓ Golgi apparatus
  – consists of series of flattened sacs
    • made of membrane
    • **not** interconnected
    – cell may have few or hundreds
  – serves as warehouse & finishing factory

Organelles of the endomembrane
Golgi apparatus finishes, sorts and transports cell products

✓ Golgi apparatus
  – “receiving” side of Golgi apparatus
  .
  – **interior**
  .
  – “shipping” side of Golgi apparatus
    .

Figure 7.12 The Golgi apparatus, Campbell & Reece

Organelles of the endomembrane
Lysosomes digest the cell’s food and wastes

✓ Lysosome
  – consists of
    • digestive (hydrolytic) enzymes enclosed in a membrane sac
  – a **compartment** where digestive enzymes are safely stored and isolated from rest of cytoplasm
    .

Organelles of the endomembrane
Lysosomes digest the cell’s food and wastes

✓ Lysosome
  – produced cooperatively by RER and Golgi
    • RER puts enzymes and membranes together
    • Golgi apparatus chemically refines enzymes and releases mature lysosome

Organelles of the endomembrane
Lysosomes digest the cell’s food and wastes

✓ Lysosome
  – several types of digestive functions
    • **engulf and digest nutrients**
      –
      –
      –
Organelles of the endomembrane

Lysosomes digest the cell’s food and wastes

- Lysosome
  - have several types of digestive functions
    - destroy harmful bacteria

- recycle damaged organelles

- play roles in embryonic development
  - providing enzymes that breakdown intermediate structures

Vacuoles function in the general maintenance of the cell

- membranous sacs
- shapes, sizes, functions vary
  - storage
    - plant cell’s central vacuole
• contractile
  – *Paramecium* sp.
  » collects and expels excess water

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93 Organelles of the endomembrane
Review of the endomembrane system
  ✔ organelles of endomembrane system are related structurally & functionally
    – structural
      • direct connections
        – btwn nuclear envelope, RER & SER
    – functional
      • transport vesicles
        – move from ER to Golgi to other destinations
      • some vesicles develop into lysosomes

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95 Energy converting organelles
Chloroplasts convert solar energy to chemical energy
  ✔ Chloroplasts
    – photosynthesizing organelles
    – internal membranes create 3 compartments
      • space
        – btwn inner and outer membranes
        – enclosed by inner membrane
        – inside tubules and disks

96 Energy converting organelles
Chloroplasts convert solar energy to chemical energy
  ✔ Chloroplasts
    – intermembrane space
      •
      – stroma
        •
      – grana
        •

97 Figure 7.18 The chloroplast, site of photosynthesis, Campbell & Reece

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100 Figure 7.19 Peroxisomes Campbell & Reece

101 Energy converting organelles
Mitochondria harvest chemical energy from food
Mitochondria
– convert chemical energy from one form to another
– carryout cellular respiration
  • chemical energy of foods converted to chemical energy of a molecule such as ATP (adenosine triphosphate)

Energy converting organelles
Mitochondria harvest chemical energy from food

Mitochondria
– enclosed by 2 membranes
– has 2 compartments
  • intermembrane space
  • mitochondrial matrix

Energy converting organelles
Mitochondria harvest chemical energy from food

Mitochondria
– mitochondrial matrix
  • has cristae

Cell's cytoskeleton helps organize structures and activities

Cytoskeleton
– supportive meshwork of fine fibers
– provides structural support
– involved in cell movement
– helps regulate cellular activities
  • made up of 3 main types of fibers
    • microfilaments, intermediate filaments, microtubules
Cytoskeleton & Related Structures

Cell's cytoskeleton helps organize structures and activities

✓ **microfilaments**
  - solid helical rods
  - made of a globular protein called **actin**
  - thinnest fiber
  - helps cell move and change shape
  - interacts with other protein fibers to make cells contract

Table 7.2  The structure and function of the cytoskeleton, Campbell & Reece

Cytoskeleton & Related Structures

Cell's cytoskeleton helps organize structures and activities

✓ **Intermediate fibers**
  - varied group
  - intermediate thickness
  - made up of fibrous proteins
  - rope-like structure
  - serve as reinforcing rods for bearing tension
  - help anchor certain organelles

Table 7.2  The structure and function of the cytoskeleton, Campbell & Reece

Cytoskeleton & Related Structures

Cell's cytoskeleton helps organize structures and activities

✓ **Microtubules**
  - thickest fiber
  - straight hollow tubes
  - composed of globular proteins (tubulins)
  - length changed by adding/removing subunits called **tubulin pairs**
  - provide rigidity & shape, anchorage for organelles
  - guide chromosomes during cell division
  - provide basis for ciliary & flagellar movement

Table 7.2  The structure and function of the cytoskeleton, Campbell & Reece
Some eukaryotic cells have locomotor appendages

- cilia & flagella
  - have common structure and mechanism of movement
    - cilia are short, numerous appendages
    - flagella are longer and usually less numerous

Cilia & flagella move when microtubules bend

- core of microtubules
  - wrapped in extension of plasma membrane
- arrangement of microtubules
  - central pair of microtubules surrounded by a ring of 9 microtubule doublets
    - called the 9+2 pattern
  - same throughout length of organelle
  - different at base

9 doublets extend into anchoring structure called a basal body

- has pattern of 9 microtubule triplets
- pair of central microtubules terminates above the basal body

Microtubules provide support and locomotor mechanism for whipping action

- bending involves knobs of protein called dynein arms attached to each doublet
• 10-100 times as thick as plasma membrane
• protects cell, is very strong
• collectively provide skeletal support that keeps plants upright
• consists of fibers of cellulose embedded in a matrix of other polysaccharides and proteins

134 Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells
✓ Plant cell surfaces
  – plant cell wall
    • doesn’t isolate cells from one another
  – plasmodesmata
    • type of cell junction
      – channels between adjacent plant cells

135 Figure 7.28  Plant cell walls, Campbell & Reece
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137 Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells
✓ Animal cell surfaces
  – animal cells lack cell walls
  – most secrete & are embedded in a sticky layer of glycoproteins
  • extracellular matrix
    – helps hold cells together in tissues
    – protective & supportive functions
    – helps regulate cell behavior

138 Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells
✓ cell junctions
  – connect adjacent animal cells in many tissues
  – three types
    • tight junctions
    • anchoring junctions
    • communicating junctions

139 Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells
✓ tight junctions
  – bind cells together forming leakproof sheet
  – found lining digestive tract, prevents contents from leaking into surrounding tissue

140 Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells
✓ Anchoring junctions
  – attach adjacent cells to each other or to the extracellular matrix
rivet cells together together with cytoskeletal fibers
allows materials to pass along spaces between cells

Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells

✓ Communicating junctions
– channels between adjacent cells
• allows water and other small molecules to flow between neighboring cells
– numerous in animal embryos

Figure 7.30  Intercellular junctions in animal tissues, Campbell & Reece

Figure 7.29  Extracellular matrix (ECM) of an animal cell, Campbell & Reece

Functional Categories of Organelles Eukaryotic organelles comprise four functional categories

✓ Eukaryotic cell organelles can be grouped into
– four categories based on function
  • manufacture
  • breakdown
  • energy processing
  • support, movement & communication

Manufacture
– function
  • synthesis of molecules
  • transport of molecules within the cell
– structure
  • network of metabolically active membranes is basis for function
  • includes
    • nucleus, ribosomes, RER, SER, Golgi apparatus

Breakdown
– function
  • breakdown & recycle materials that are harmful or no longer needed
– structure
  • single membranous sacs, inside which materials can be broken down
  • includes
    • lysosomes, peroxisomes, vacuoles

Energy processing
– function
  • conversion of light & chemical energy
– structure
  • expansive metabolically active membrane surfaces for energy conversion reactions
  – includes
    • chloroplasts, mitochondria

Functional Categories of Organelles

Eukaryotic organelles comprise four functional categories

- Support, movement, communication
  – function
    • movement requires support, which involves external cell boundaries, which are involved in communication
  – structure
    • various fibers
  – includes
    • cytoskeleton, cell walls, extracellular matrix, cell junctions

All life forms share fundamental features

- Major features common to all cells
  – plasma membrane
  – DNA
  – cytoplasm
  – carry out metabolism

- Plasma membrane
  • encloses a cell
  • separates its contents from its surroundings

- DNA – the hereditary molecule
  • prokaryotes
    – nucleoid
  • eukaryotes
    – nucleus

- Cytoplasm
  • semi-fluid matrix
  • fills interior of cell, exclusive of nucleoid or nucleus
• contains chemical wealth of cell
  – sugars
  – amino acids
  – proteins
• contains organelles in eukaryotes

155  Functional Categories of Organelles All life forms share fundamental features
  ✓ Major features common to all cells
    – carry out metabolism
      • interconversion of different forms of energy and of chemical materials

156  Functional Categories of Organelles All life forms share fundamental features
  ✓ primary tenants of the Cell Theory
    – all organisms are composed of 1 or 1+cells
    •
    – cell is smallest (basic) unit of life
      • smallest living thing
    – cells arise only by the division of a previously existing cell
    •

157  Figure 7.31 The emergence of cellular functions from the cooperation of many organelles, Campbell & Reece