1

# Cell Structure

**Bio 103 Lecture**
**GMU**
**Dr. Largen**

2 ## 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

3 

Figure 7.0 Fluorescent stain of cell, Campbell & Reece

4 ## 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

5 ## 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

6 ## Introduction to world of the cell

Microscopes provide windows to world of cell

- ✓ Two main types of microscopes
  - – **light microscope**
  - – **electron microscope**

7 ## 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)**

8 ## 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

9 

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

10 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**

11 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

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

13 Figure 7.2 Electron micrographs, Campbell & Reece

14 Introduction to world of the cell

Cell sizes vary with their function

✓Cell size and shape related to function

– smallest cells

•

– largest cells

•

15 Figure 7.1 The size range of cells, Campbell & Reece

16

17 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”
–
–

18 Introduction to world of the cell
Natural laws limit cell size
✓Cells are small
– advantages of **small cell size**
•
•
•

19 Introduction to world of the cell
Natural laws limit 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 = $4/3\pi r^3$
• for example
– cell radius: 1cm 10cm
– surface area: $12.57 cm^2$ $1257 cm^2$
– volume: $4.189 cm^3$ $4189 cm^3$

20

21

22 Figure 7.5 Geometric relationships explain why most cells are microscopic, Campbell & Reece)

23 Introduction to world of the cell
Natural laws limit cell size
✓**surface area-to-volume ratio** imposes limits on cell size
– most cells are not large for practical reasons
• communication
•
•

24 Introduction to world of the cell
Prokaryotic cells are small and structurally simple
✓Two kinds of structurally different cells have evolved over time
– prokaryotic cells
– Archaebacteria
– Eubacteria

- eukaryotic cells
  - Protista
  - Fungi
  - Plantae
  - Animalia

25 Introduction to world of the cell
Prokaryotic cells are small and structurally simple

✓ Prokaryotic cell characteristics
- small
- lacks nucleus
  - **nucleoid region**
    -
- surrounded by **plasma membrane**
- most have **bacterial cell wall**
- some have **capsule**
- some have **pili** (sticky)
- some propelled by a **flagellum**

26 
Figure 7.4 A prokaryotic cell, Campbell & Reece

27 

28 
Figure 7.4x1 *Bacillus polymyxa*, *Campbell & Reece*

29 
Figure 7.4x2 *E. coli*, *Campbell & Reece*

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

✓ **Eukaryotic cells**
-
- fundamentally similar to each other
  - profoundly different from prokaryotic cells

✓ characteristics of eukaryotic cells
- in general
- comparing animal and plant cell

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

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

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

✓ **Eukaryotic cells**
- **complex interior organization**
  - extensive compartmentalization
  - many membrane-bound organelles

- true, membrane-bound nucleus
- complex DNA molecule
- vesicles and vacuoles
  –

33

34 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
  –

  –

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

✓ **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

36  Figure 7.7 Overview of an animal cell, Campbell & Reece

37 

38 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

39  Figure 7.8 Overview of a plant cell, Campbell & Reece

40 

41 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

42 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

43 
Figure 7.6 The plasma membrane, Campbell & Reece

44 Introduction to the Cell
Membranes organize the activities of cells
✓ **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

45 

46 Introduction to the Cell
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**
  •
  •
–

47 

48 Introduction to world of the cell
Eukaryotic cells are partitioned into functional compartments
✓ **membranous organelles**
– nucleus
– endoplasmic reticulum
– Golgi apparatus
– mitochondria
– lysosome
– peroxisome
– chloroplast
– central vacuole

49 Introduction to world of the cell
Eukaryotic cells are partitioned into functional compartments
✓ **non-membranous structures**
– centriole
– flagellum
– ribosome
– microtubule
– microfilament
– cell wall

50 **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**
»

51 **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

52

53 **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

54

55 **Organelles of the endomembrane**
Nucleus is cell's genetic control center
✓**NOT** 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

56 Figure 7.10 Ribosomes, Campbell & Reece
57 Figure 7.9 The nucleus and its envelope , Campbell & Reece
58 Figure 7.x1 Nuclei and F-actin in BPAEC cells, Campbell & Reece
59 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

–

–

60 Organelles of the endomembrane

Rough endoplasmic reticulum makes membrane and proteins

✓**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

61

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

63 Organelles of the endomembrane

Rough endoplasmic reticulum makes membrane and proteins

✓**Rough endoplasmic reticulum (RER)**

– makes more membrane

- RER membrane enlarges as
  - some of the proteins and phospholipids made by RER enzymes are inserted into it
-

64 Organelles of the endomembrane

Rough endoplasmic reticulum makes membrane and proteins

✓**Rough endoplasmic reticulum (RER)**

– makes **secretory proteins**

-

– ribosomes synthesize polypeptides

  – which pass passes into RER

  – modified

  – packaged into **transport vesicle**

  –

65

66 Organelles of the endomembrane

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

–

67

68 
Figure 7.11 Endoplasmic reticulum (ER), Campbell & Reece

69 Organelles of the endomembrane
Smooth endoplasmic reticulum has a variety of functions
✓**Smooth endoplasmic reticulum (SER)**
– has three functions
• **lipid synthesis**
• **destruction of toxic substances**
• **regulation of muscle contraction**

70 Organelles of the endomembrane
Smooth endoplasmic reticulum has a variety of functions
✓**Smooth endoplasmic reticulum (SER)**
– **lipid synthesis**
• one of most important functions
• type of lipid varies w/ cell type
– **fatty acids**
– **phospholipids**
– **steroids**
»

71 Organelles of the endomembrane
Smooth endoplasmic reticulum has a variety of functions
✓**Smooth endoplasmic reticulum (SER)**
– **destruction of toxic substances**
• liver cell SER contains enzymes
– breakdown drugs & harmful substances

–

–

72 Organelles of the endomembrane
Smooth endoplasmic reticulum has a variety of functions
✓**Smooth endoplasmic reticulum (SER)**
– **regulation of muscle contraction**
• in muscle cells, SER stores calcium ions
– necessary for muscle contraction

–

–

73 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
•

74 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
•

75

76 
Figure 7.12 The Golgi apparatus, Campbell & Reece

77 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
•

78 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

79 Organelles of the endomembrane
Lysosomes digest the cell's food and wastes
✓**Lysosome**
– several types of digestive functions
• **engulf and digest nutrients**
–

–

–

80 Organelles of the endomembrane
Lysosomes digest the cell's food and wastes
✓**Lysosome**
– have several types of digestive functions
• **destroy harmful bacteria**
–
–
–

81 Organelles of the endomembrane
Lysosomes digest the cell's food and wastes
✓**Lysosome**
– have several types of digestive functions
• **recycle damaged organelles**
–
–
–

82 Organelles of the endomembrane
Lysosomes digest the cell's food and wastes
✓**Lysosome**
– have several types of digestive functions
• **play roles in embryonic development**
– providing enzymes that breakdown intermediate structures
»

83
84 Figure 7.13 Lysosomes, Campbell & Reece
85 Figure 7.14 The formation and functions of lysosomes (Layer 1), Campbell & Reece
86 Figure 7.14 The formation and functions of lysosomes (Layer 2), Campbell & Reece
87 Figure 7.14 The formation and functions of lysosomes (Layer 3), Campbell & Reece
88
89 Figure 7.15 The plant cell vacuole , Campbell & Reece
90 Figure 7.16 Review: relationships among organelles of the endomembrane system , Campbell & Reece

91 Organelles of the endomembrane
Vacuoles function in the general maintenance of the cell
✓**Vacuoles**
– membranous sacs
– shapes, sizes, functions vary
• storage
– plant cell's **central vacuole**
»

- contractile
  - *Paramecium* sp.
    - » collects and expels excess water

92

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

94

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

98

99

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)
    -

102 Energy converting organelles
Mitochondria harvest chemical energy from food

✓ **Mitochondria**
- enclosed by 2 membranes
- has 2 compartments
  - **intermembrane space**
    -
    -
  - **mitochondrial matrix**
    -
    -

103 Energy converting organelles
Mitochondria harvest chemical energy from food

✓ **Mitochondria**
- **mitochondrial matrix**
  - has **cristae**
    »

    »

    »

104

105 Figure 7.17 The mitochondrion, site of cellular respiration, Campbell & Reece

106 Figure 7.19 Peroxisomes, Campbell & Reece

107 Cytoskeleton & Related Structures
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

108

109

110 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

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

112

113 Figure 7.x4 Actin and keratin, Campbell & Reece

114 Figure 7.x2 Actin, Campbell & Reece

115 Figure 7.x3 Actin, Campbell & Reece

116 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
  - 

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

118

119 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 cilliary & flagellar movement

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

121

122 Figure 7.20 The cytoskeleton, Campbell & Reece

123 Figure 7.22 Centrosome containing a pair of centrioles, Campbell & Reece

124 Figure 7.27 Microfilaments and motility, Campbell & Reece

125 Cytoskeleton & Related Structures
Cilia & flagella move when microtubules bend
✓ 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

126 Cytoskeleton & Related Structures
Cilia & flagella move when microtubules bend
✓ **cilia** & **flagella**
– 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

127 Cytoskeleton & Related Structures
Cilia & flagella move when microtubules bend
✓ **cilia** & **flagella**
– arrangement of microtubules
• 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

128

129 Cytoskeleton & Related Structures
Cilia & flagella move when microtubules bend
✓ **cilia** & **flagella**
– microtubules provide support and locomotor mechanism for whipping action
• bending involves knobs of protein called **dynein arms** attached to each doublet
–

–

130 Figure 7.21 Motor molecules and the cytoskeleton, Campbell & Reece

131

132 Figure 7.23 A comparison of the beating of flagella and cilia, Campbell & Reece

133 Eukaryotic Cell Surfaces & Junctions
Cell surfaces protect, support & join cells
✓ **Plant cell surfaces**
– plant cell wall

- 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 polysacchraides 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

136

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

141 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
•

142 Figure 7.30 Intercellular junctions in animal tissues, Campbell & Reece

143

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

145 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**

146 Functional Categories of Organelles Eukaryotic organelles comprise four functional categories

✓**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

147 Functional Categories of Organelles Eukaryotic organelles comprise four functional categories

✓**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

148 Functional Categories of Organelles Eukaryotic organelles comprise four functional categories

✓**Energy processing**

- function
  - conversion of light & chemical energy
- structure
  - expansive metabolically active membrane surfaces for energy conversion reactions
- includes
  - chloroplasts, mitochondria

149 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

150

151 Functional Categories of Organelles All life forms share fundamental features

✓ Major features common to all cells

- **plasma membrane**
- **DNA**
- **cytoplasm**
- **carry out metabolism**

152 Functional Categories of Organelles All life forms share fundamental features

✓ Major features common to all cells

- **plasma membrane**
  - encloses a cell
  - separates its contents from its surroundings
  -
  -

153 Functional Categories of Organelles All life forms share fundamental features

✓ Major features common to all cells

- **DNA – the hereditary molecule**
  - **prokaryotes**
    - **nucleoid**
      »
  - **eukaryotes**
    - **nucleus**
      »

154 Functional Categories of Organelles All life forms share fundamental features

✓ Major features common to all cells

- **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