1 Tour of the Cell

Chapter 7

2 1. Microscopes provide windows to the world of the cell

- The discovery and early study of cells progressed with the invention and improvement of microscopes in the 17th century.
- In a **light microscope (LMs)** visible light passes through the specimen and then through glass lenses.
  - The lenses refract light such that the image is magnified into the eye or a video screen.

3 How we see cells

- Microscopes vary in magnification and resolving power.
- Magnification is the ratio of an object’s image to its real size.
- **Resolving power** is a measure of image clarity.
  - It is the minimum distance two points can be separated and still viewed as two separate points.
  - Resolution is limited by the shortest wavelength of the source, in this case light.

4 Resolution

- The minimum resolution of a light microscope is about 2 microns, the size of a small bacterium
- Light microscopes can magnify effectively to about 1,000 times the size of the actual specimen.
  - At higher magnifications, the image blurs.

5 Comparison of size

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- Techniques developed in the 20th century have enhanced contrast and enabled particular cell components to be labeled so that they stand out.

7 Functions of light and electron microscopes

- While a light microscope can resolve individual cells, it cannot resolve much of the internal anatomy, especially the **organelles**.
- To resolve smaller structures we use an **electron microscope** (**EM**), which focuses a beam of electrons through the specimen or onto its surface.

8 Electron Microscope

  - Because resolution is inversely related to wavelength used, electron microscopes with shorter wavelengths than visible light have finer resolution.
  - Theoretically, the resolution of a modern EM could reach 0.1 nanometer (nm), but the practical limit is closer to about 2 nm.

9 Transmission electron microscopes (TEM)

- are used mainly to study the internal ultrastructure of cells.

  - A TEM aims an electron beam through a thin section of the specimen.
  - The image is focused and magnified by electromagnets.
  - To enhance contrast, the thin sections are stained with atoms of heavy metals.

10 Scanning electron microscopes (SEM)

- are useful for studying surface structures.
  - The sample surface is covered with a thin film of gold.
  - The beam excites electrons on the surface.
  - These secondary electrons are collected and focused on a screen.
- The SEM has great depth of field, resulting in an image that seems three-dimensional.

11 Live or Dead?

- Electron microscopes reveal organelles, but they can only be used on dead cells and they may introduce some artifacts.
- Light microscopes do not have as high a resolution, but they can be used to study live cells.

12 Cytology

- Microscopes are a major tool in *cytology*, the study of cell structures.
- Cytology coupled with *biochemistry*, the study of molecules and chemical processes in metabolism, developed modern cell biology.

13 Cell biologists can isolate organelles to study their functions

- The goal of **cell fractionation** is to separate the major organelles of the cells so that their individual functions can be studied.

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- This process is driven by a **ultracentrifuge,** a machine that can spin at up to 130,000 revolutions per minute and apply forces more than 1 million times gravity (1,000,000 *g*).
- Fractionation begins with homogenization, gently disrupting the cell.
- Then, the homogenate is spun in a centrifuge to separate heavier pieces into the pellet while lighter particles remain in the supernatant.
  - As the process is repeated at higher speeds and longer durations, smaller and smaller organelles can be collected in subsequent pellets.

15 Cell fractionation

- Cell fractionation prepares quantities of specific cell components.
- This enables the functions of these organelles to be isolated, especially by the

reactions or processes catalyzed by their proteins.

  - For example, one cellular fraction is enriched in enzymes that function in cellular respiration.
  - Electron microscopy reveals that this fraction is rich in the organelles called mitochondria.

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Science as a process

- Cytology and biochemistry complement each other in connecting cellular structure and function.

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Prokaryotic and eukaryotic cells differ in size and complexity

- All cells are surrounded by a *plasma membrane*.
- The semifluid substance within the membrane is the **cytosol**, containing the organelles.
- All cells contain chromosomes which have genes in the form of DNA.
- All cells also have *ribosomes,* tiny organelles that make proteins using the instructions contained in genes.

18

Nuclear regions

- A major difference between prokaryotic and eukaryotic cells is the location of chromosomes.
- In an eukaryotic cell, chromosomes are contained in a membrane-enclosed organelle, the *nucleus*.
- In a prokaryotic cell, the DNA is concentrated in the **nucleoid** without a membrane separating it from the rest of the cell.

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Cytoplasm

- The region between the nucleus and the plasma membrane is the **cytoplasm**.
  - All the material within the plasma membrane of a prokaryotic cell is cytoplasm.
- Within the cytoplasm of a eukaryotic cell is a variety of membrane-bounded organelles of specialized form and function.
  - These membrane-bounded organelles are absent in prokaryotes.

21

Cell Size

- Eukaryotic cells are generally much bigger than prokaryotic cells.
- The logistics of carrying out metabolism set limits on cell size.
  - At the lower limit, the smallest bacteria, mycoplasmas, are between 0.1 to 1.0 micron.
  - Most bacteria are 1-10 microns in diameter.
  - Eukaryotic cells are typically 10-100 microns in diameter.

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Cell Size Limitations

- Metabolic requirements also set an upper limit to the size of a single cell.
- As a cell increases in size its volume increases faster than its surface area.
  - Smaller objects have a greater ratio of surface area to volume.

23 Surface area to volume ratios

24 Plasma membrane

- functions as a selective barrier that allows passage of oxygen, nutrients, and wastes for the whole volume of the cell.

25 Significance of Cell Volume

- The volume of cytoplasm determines the need for this exchange.
- Rates of chemical exchange may be inadequate to maintain a cell with a very large cytoplasm.
- The need for a surface sufficiently large to accommodate the volume explains the microscopic size of most cells.
- Larger organisms do not generally have *larger* cells than smaller organisms - simply *more* cells.

26 Internal membranes compartmentalize the functions of a eukaryotic cell

- A eukaryotic cell has extensive and elaborate internal membranes, which partition the cell into compartments.
- These membranes also participate in metabolism as many enzymes are built into membranes.
- The barriers created by membranes provide different local environments that facilitate specific metabolic functions.

27 Phospholipid membrane

- The general structure of a biological membrane is a double layer of phospholipids with other lipids and diverse proteins.
- Each type of membrane has a unique combination of lipids and proteins for its specific functions.
  - For example, those in the membranes of mitochondria function in cellular respiration.

28 Generic Animal Cell

29 Generic Plant Cell

30 The nucleus contains a eukaryotic cell's genetic library

- The nucleus contains most of the genes in a eukaryotic cell.
  - Some genes are located in mitochondria and chloroplasts.
- The nucleus averages about 5 microns in diameter.
- The nucleus is separated from the cytoplasm by a double membrane.
  - These are separated by 20-40 nm.
- Where the double membranes are fused, a pore allows large macromolecules and particles to pass through.

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- The nuclear side of the envelope is lined by the **nuclear lamina**, a network of intermediate filaments that maintain the shape of the nucleus.

32 Chromatin

- Within the nucleus, the DNA and associated proteins are organized into fibrous material, **chromatin**.
- In a normal cell they appear as diffuse mass.
- However when the cell prepares to divide, the chromatin fibers coil up to be seen as separate structures, **chromosomes**.

33 Number of Chromosomes species specific

- Each eukaryotic species has a characteristic number of chromosomes.
  - A typical human cell has 46 chromosomes, but sex cells (eggs and sperm) have only 23 chromosomes.

34 Nucleolus

- In the nucleus is a region of densely stained fibers and granules adjoining chromatin, the **nucleolus.**
  - In the nucleolus, ribosomal RNA (rRNA) is synthesized and assembled with proteins from the cytoplasm to form ribosomal subunits.
  - The subunits pass from the nuclear pores to the cytoplasm where they combine to form ribosomes.

35 mRNA

- The nucleus directs protein synthesis by synthesizing messenger RNA (mRNA).
  - The mRNA travels to the cytoplasm and combines with ribosomes to translate its genetic message into the primary structure of a specific polypeptide.

36 Ribosomes build a cell's proteins

- Ribosomes contain rRNA and protein.
- A ribosome is composed of two subunits that combine to carry out protein synthesis.

37 Ribosomal Locations

- Some ribosomes, *free* ribosomes, are suspended in the cytosol and synthesize proteins that function within the cytosol.
- Other ribosomes, *bound* ribosomes, are attached to the outside of the endoplasmic reticulum.
  - These synthesize proteins that are either included into membranes or for export from the cell.

38 Ribosomal Role

- Cell types that synthesize large quantities of proteins (e.g., pancreas) have large numbers of ribosomes and prominent nuclei.
- Ribosomes can shift between roles depending on the polypeptides they are synthesizing.

39 Endomembranes

- Many of the internal membranes in a eukaryotic cell are part of the **endomembrane system**.
- These membranes are either in direct contact or connected via transfer of **vesicles**, sacs of membrane.
- In spite of these links, these membranes have diverse functions and structures.
  - In fact, the membranes are even modified during life.

40 Endomembrane System

- The endomembrane system includes the nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, and the plasma membrane.

41 The endoplasmic reticulum manufacturers membranes and performs many other biosynthetic functions

- The **endoplasmic reticulum** (**ER**) accounts for half the membranes in a eukaryotic cell.
- The ER includes membranous tubules and internal, fluid-filled spaces, the cisternae.
- The ER membrane is continuous with the nuclear envelope and the cisternal space of the ER is continuous with the space between the two membranes of the nuclear envelope.

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- There are two, albeit connected, regions of ER that differ in structure and function.
  - **Smooth ER** looks smooth because it lacks ribosomes.
  - **Rough ER** looks rough because ribosomes (bound ribosomes) are attached to the outside, including the outside of the nuclear envelope.

43 smooth ER

- is rich in enzymes and plays a role in a variety of metabolic processes.
- Enzymes of smooth ER synthesize lipids, including oils, phospholipids, and steroids.
  - These includes the sex hormones of vertebrates and adrenal steroids.
- The smooth ER also catalyzes a key step in the mobilization of glucose from stored glycogen in the liver.
  - An enzyme removes the phosphate group from glucose phosphate, a product of glycogen hydrolysis, permitting glucose to exit the cell.

44 Specific ER functions

- Other enzymes in the smooth ER of the liver help detoxify drugs and poisons.
  - These include alcohol and barbiturates.
  - Frequent exposure leads to proliferation of smooth ER, increasing tolerance to the target and other drugs.

45 Other ER functions

- Muscle cells are rich in enzymes that pump calcium ions from the cytosol to the cisternae.
  - When nerve impulse stimulates a muscle cell, calcium rushes from the ER into the cytosol, triggering contraction.
  - These enzymes then pump the calcium back, readying the cell for the next stimulation.

46 Rough ER

- is especially abundant in those cells that secrete proteins.
  - As a polypeptide is synthesized by the ribosome, it is threaded into the cisternal space through a pore formed by a protein in the ER membrane.
  - Many of these polypeptides are **glycoproteins**, a polypeptide to which an oligosaccharide is attached.
- These secretory proteins are packaged in **transport vesicles** that carry them to their next stage.

47 Other Rough ER functions

- Rough ER is also a membrane factory.
  - Membrane bound proteins are synthesized directly into the membrane.
  - Enzymes in the rough ER also synthesize phospholipids from precursors in the cytosol.
  - As the ER membrane expands, parts can be transferred as transport vesicles to other components of the endomembrane system.

48 The Golgi apparatus finishes, sorts, and ships cell products

- Many transport vesicles from the ER travel to the **Golgi apparatus** for modification of their contents.
- The Golgi is a center of manufacturing, warehousing, sorting, and shipping.
- The Golgi apparatus is especially extensive in cells specialized for secretion.

49 Morphology of Golgi Appartus

- The Golgi apparatus consists of flattened membranous sacs - cisternae - looking like a sac of pita bread.
  - The membrane of each cisterna separates its internal space from the cytosol
  - One side of the Golgi, the *cis* side, receives material by fusing with vesicles, while the other side, the *trans* side, buds off vesicles that travel to other sites.

50 Golgi Appartus

51 Function of Golgi Appartus

- During their transit from the cis to trans pole, products from the ER are modified to reach their final state.
  - This includes modifications of the oligosaccharide portion of glycoproteins.
- During processing material is moved from cisterna to cisterna, each with its own set of enzymes.
- Finally, the Golgi tags, sorts, and packages materials into transport vesicles.

52 Other Golgi functions

- The Golgi can also manufacture its own macromolecules, including pectin and other noncellulose polysaccharides.

53 Lysosomes are digestive components

- The **lysosome** is a membrane-bounded sac of hydrolytic enzymes that digests macromolecules.

54 Lysosomes

- Lysosomal enzymes can hydrolyze proteins, fats, polysaccharides, and nucleic acids.
- These enzymes work best at pH 5.
  - Proteins in the lysosomal membrane pump hydrogen ions from the cytosol to the lumen of the lysosomes.
- While rupturing one or a few lysosomes has little impact on a cell, but massive leakage from lysosomes can destroy an cell by autodigestion.
- The lysosomes creates a space where the cell can digest macromolecules safely.

55 Lysosomal enzymes and membrane

- are synthesized by rough ER and then transferred to the Golgi.
- At least some lysosomes bud from the trans face of the Golgi.

56 How lysosomes work

- Lysosomes can fuse with food vacuoles, formed when a food item is brought into the cell by **phagocytosis**.
  - As the polymers are digested, their monomers pass out to the cytosol to become nutrients of the cell.

57 Autophagy

- Lysosomes can also fuse with another organelle or part of the cytosol.
  - This recycling, this process of *autophagy* renews the cell.

58 Developmental Role of lysosomes

- The lysosomes play a critical role in the programmed destruction of cells in multicellular organisms.
  - This process allows reconstruction during the developmental process.

59 Diseases that affect lysosomal functioning

- Several inherited diseases affect lysosomal metabolism.
  - These individuals lack a functioning version of a normal hydrolytic enzyme.
  - Lysosomes are engorged with indigestable substrates.

- These diseases include Pompe’s disease in the liver and Tay-Sachs disease in the brain.

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Vacuoles have diverse functions in cell maintenance

- Vesicles and vacuoles (larger versions) are membrane-bound sacs with varied functions.
  - **Food vacuoles**, from phagocytosis, fuse with lysosomes.
  - **Contractile vacuoles**, found in freshwater protists, pump excess water out of the cell.
  - **Central vacuoles** are found in many mature plant cells.

61

Functions of the Central Vacuole

- The membrane surrounding the central vacuole, the **tonoplast**, is selective in its transport of solutes into the central vacuole.
- The functions of the central vacuole include stockpiling proteins or inorganic ions, depositing metabolic byproducts, storing pigments, and storing defensive compounds against herbivores.
- It also increases surface to volume ratio for the whole cell.

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Synthesis of Macromolecules

- The endomembrane system plays a key role in the synthesis (and hydrolysis) of macromolecules in the cell.
- The various components modify macromolecules for their various functions.

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Mitochondria and chloroplasts are the main energy transformers of cells

- Mitochondria and chloroplasts are the organelles that convert energy to forms that cells can use for work.
- **Mitochondria** are the sites of cellular respiration, generating ATP from the catabolism of sugars, fats, and other fuels in the presence of oxygen.
- **Chloroplasts**, found in plants and eukaryotic algae, are the site of photosynthesis.
  - They convert solar energy to chemical energy and synthesize new organic compounds from CO_2 and H_2O.

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Semiautonomous Organelles

- Mitochondria and chloroplasts are not part of the endomembrane system.
- Their proteins come primarily from free ribosomes in the cytosol and a few from their own ribosomes.
- Both organelles have small quantities of DNA that direct the synthesis of the polypeptides produced by these internal ribosomes.
- Mitochondria and chloroplasts grow and reproduce as semiautonomous

organelles.

66 **Almost all eukaryotic cells have mitochondria.**

- There may be one very large mitochondrion or hundreds to thousands in individual mitochondria.
- The number of mitochondria is correlated with aerobic metabolic activity.
- A typical mitochondrion is 1-10 microns long.
- Mitochondria are quite dynamic: moving, changing shape, and dividing.

67

Parts of the mitochondrion

- Mitochondria have a smooth outer membrane and a highly folded inner membrane, the **cristae**.
  - This creates a fluid-filled space between them.
  - The cristae present ample surface area for the enzymes that synthesize ATP.
- The inner membrane encloses the **mitochondrial matrix**, a fluid-filled space with DNA, ribosomes, and enzymes.

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Chloroplasts

- The chloroplast is one of several members of a generalized class of plant structures called **plastids**.
  - Amyloplasts store starch in roots and tubers.
  - Chromoplasts store pigments for fruits and flowers.
- The chloroplast produces sugar via photosynthesis.
  - Chloroplasts gain their color from high levels of the green pigment chlorophyll.

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Chloroplast size

- Chloroplasts measure about 2 microns x 5 microns and are found in leaves and other green structures of plants and in eukaryotic algae.

71

Structure of Chloroplasts

- The processes in the chloroplast are separated from the cytosol by two membranes.
- Inside the innermost membrane is a fluid-filled space, the **stroma**, in which float membranous sacs, the **thylakoids**.
  - The stroma contains DNA, ribosomes, and enzymes for part of photosynthesis.
  - The thylakoids, flattened sacs, are stacked into **grana** and are critical for converting light to chemical energy.

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Mitochondria and Chloroplasts are mobile!

- Like mitochondria, chloroplasts are dynamic structures.
  - Their shape is plastic and they can reproduce themselves by pinching in two.
- Mitochondria and chloroplasts are mobile and move around the cell along tracks in the cytoskeleton.

74 Peroxisomes generate and degrade H_2O_2 in performing various metabolic functions

- **Peroxisomes** contain enzymes that transfer hydrogen from various substrates to oxygen
  - An intermediate product of this process is hydrogen peroxide (H_2O_2), a poison, but the peroxisome has another enzyme that converts H_2O_2 to water.

75 Perioxisome functions

- Some peroxisomes break fatty acids down to smaller molecules that are transported to mitochondria for fuel.
- Others detoxify alcohol and other harmful compounds.
- Specialized peroxisomes, glyoxysomes, convert the fatty acids in seeds to sugars, an easier energy and carbon source to transport.

76 Formation of peroxisomes

- Peroxisomes are bounded by a single membrane.
- They form not from the endomembrane system, but by incorporation of proteins and lipids from the cytosol.
- They split in two when they reach a certain size.

77 Providing structural support to the cell, the cytoskeleton also functions in cell motility and regulation

- The **cytoskeleton** provides mechanical support and maintains shape of the cell.
- The fibers act like a geodesic dome to stabilize a balance between opposing forces.
- The cytoskeleton provides anchorage for many organelles and cytosolic enzymes.
- The cytoskeleton is dynamic, dismantling in one part and reassembling in another to change cell shape.

78 Cytoskeleton contributes to cell motility.

  - This involves both changes in cell location and limited movements of parts of the cell.
- The cytoskeleton interacts with motor proteins.
  - In cilia and flagella motor proteins pull components of the cytoskeleton past each other.
  - This is also true in muscle cells.

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- Motor molecules also carry vesicles or organelles to various destinations along “monorails’ provided by the cytoskeleton.

- Interactions of motor proteins and the cytoskeleton circulates materials within a cell via streaming.
- Recently, evidence is accumulating that the cytoskeleton may
transmit mechanical
signals that rearrange
the nucleoli and
other structures.

80 Fiber types of cytoskeleton

- There are three main types of fibers in the cytoskeleton: **microtubules**, **microfilaments**, and **intermediate filaments**.

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- Microtubules, the thickest fibers, are hollow rods about 25 microns in diameter.
  - Microtubule fibers are constructed of the globular protein, tubulin, and they grow or shrink as more tubulin molecules are added or removed.
- They move chromosomes during cell division.
- Another function is
as tracks that guide
motor proteins
carrying organelles
to their destination.

83 Centrosomes

- In many cells, microtubules grow out from a **centrosome** near the nucleus.
  - These microtubules resist compression to the cell.
- In animal cells, the centrosome has a pair of **centrioles**, each with nine triplets of microtubules arranged in a ring.

84 During cell division the centrioles replicate

85 **Microtubules are the central structural supports in** cilia **and** flagella**.**

  - Both can move unicellular and small multicellular organisms by propelling water past the organism.
  - If these structures are anchored in a large structure, they move fluid over a surface.
    - **For example, cilia sweep mucus carrying trapped debris from the lungs.**

86 Cilia and Flagella

- Cilia usually occur in large numbers on the cell surface.
  - They are about 0.25 microns in diameter and 2-20 microns long.
- There are usually just one or a few flagella per cell.
  - Flagella are the same width as cilia, but 10-200 microns long.

87 Flagellar movement

- A flagellum has an undulatory movement.
  - Force is generated parallel to the flagellum’s axis.

88 Ciliar movement

- Cilia move more like oars with alternating power and recovery strokes.
  - They generate force perpendicular to the cilia’s axis.

89 Cilia and flagella have the same ultrastructure

- Both have a core of microtubules sheathed by the plasma membrane.
- Nine doublets of microtubules arranged around a pair at the center, the “9 + 2” pattern.
- Flexible “wheels” of proteins connect outer doublets to each other and to the core.
- The outer doublets are also connected by motor proteins.
- The cilium or flagellum is anchored in the cell by a **basal body,** whose structure is identical to a centriole.

90 9 + 2 arrangement

91

- The bending of cilia and flagella is driven by the arms of a motor protein, **dynein**.
  - Addition to dynein of a phosphate group from ATP and its removal causes conformation changes in the protein.
  - Dynein arms alternately grab, move, and release the outer microtubules.
  - Protein cross-links limit sliding and the force is expressed as bending.

92 Actin

- Microfilaments, the thinnest class of the cytoskeletal fibers, are solid rods of the globular protein **actin.**
  - An actin microfilament consists of a twisted double chain of actin subunits.
- Microfilaments are designed to resist tension.
- With other proteins, they form a three-dimensional network just inside the plasma membrane.

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- In muscle cells, thousands of actin filaments are arranged parallel to one another.
- Thicker filaments, composed of a motor protein, **myosin**, interdigitate with the thinner actin fibers.
  - Myosin molecules walk along the actin filament, pulling stacks of actin fibers together and shortening the cell.

95 Other contractile fiber arrangements

- In other cells, these actin-myosin aggregates are less organized but still cause localized contraction.

  - A contracting belt of microfilaments divides the cytoplasm of animals cells during cell division.
  - Localized contraction also drives amoeboid movement.

96 Pseudopodia

- **Pseudopodia**, cellular extensions, extend and contract through the reversible assembly and contraction of actin subunits into microfilaments.

97 Cytoplasmic streaming

- In plant cells (and others), actin-myosin interactions and sol-gel transformations drive.
  - This creates a circular flow of cytoplasm in the cell.
  - This speeds the distribution of materials within the cell.

98 Intermediate filaments

- Intermediate filaments, intermediate in size at 8 - 12 nanometers, are specialized for bearing tension.
  - Intermediate filaments are built from a diverse class of subunits from a family of proteins called keratins.

99 Intermediate filament function

- Intermediate filaments are more permanent fixtures of the cytoskeleton than are the other two classes.
- They reinforce cell shape and fix organelle location.

100 Plant cells are encased by cell walls

- The **cell wall**, found in prokaryotes, fungi, and some protists, has multiple functions.
- In plants, the cell wall protects the cell, maintains its shape, and prevents excessive uptake of water.
- It also supports the plant against the force of gravity.
- The thickness and chemical composition of cell walls differs from species to species and among cell types.

101 Construction of Plant Cell Walls

- The basic design consists of microfibrils of cellulose embedded in a matrix of proteins and other polysaccharides.
  - This is like steel-reinforced concrete or fiberglass.
- A mature cell wall consists of a **primary cell wall,** a **middle lamella** with sticky polysaccharides that holds cell together, and layers of **secondary cell wall.**

102 Plant cell walls

103 The extracellular matrix (ECM) of animal cells functions in support, adhesion, movement, and regulation

- Lacking cell walls, animals cells do have an elaborate **extracellular matrix**

(**ECM**).

- The primary constituents of the extracellular matrix are glycoproteins, especially **collagen** fibers, embedded in a network of **proteoglycans**.
- .

104 Connections of Extracellular matrix

- In many cells, **fibronectins** in the ECM connect to **integrins**, intrinsic membrane proteins.
- The integrins connect the ECM to the cytoskeleton

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- The interconnections from the ECM to the cytoskeleton via the fibronectin-integrin link permit the interaction of changes inside and outside the cell.

106 Regulatory functions of the ECM

- The ECM can regulate cell behavior.
  - Embryonic cells migrate along specific pathways by matching the orientation of their microfilaments to the “grain” of fibers in the extracellular matrix.
  - The extracellular matrix can influence the activity of genes in the nucleus via a combination of chemical and mechanical signaling pathways.
    - This may coordinate all the cells within a tissue.

107 Intracellular junctions help integrate cells into higher levels of structure and function

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact.
- Plant cells are perforated with **plasmodesmata**, channels allowing cysotol to pass between cells.

108 Plasmdesma

109 Animal intercellular connections

- Animal have 3 main types of intercellular links: tight junctions, desmosomes, and gap junctions.
- In **tight junctions**, membranes of adjacent cells are fused, forming continuous belts around cells.
  - This prevents leakage of extracellular fluid.

110 Intracellular junctions

111 Desmosomes

- **Desmosomes** (or anchoring junctions) fasten cells together into strong sheets, much like rivets.
  - Intermediate filaments of keratin reinforce desmosomes.

112 Gap junctions

- **Gap junctions** (or communicating junctions) provide cytoplasmic channels between adjacent cells.
  - Special membrane proteins surround these pores.

  - Salt ions, sugar, amino acids, and other small molecules can pass.
  - In embryos, gap junctions facilitate chemical communication during development.

113 A cell is a living unit greater than the sum of its parts

- While the cell has many structures that have specific functions, they must work together.
  - For example, macrophages use actin filaments to move and extend pseudopodia, capturing their prey, bacteria.
  - Food vacuoles are digested by lysosomes, a product of the endomembrane system of ER and Golgi.

114 **Organelle processes are fueled by ATP**

- The enzymes of the lysosomes and proteins of the cytoskeleton are synthesized at the ribosomes.
- The information for these proteins comes from genetic messages sent by DNA in the nucleus.
- All of these processes require energy in the form of ATP, most of which is supplied by the mitochondria.

115 **A cell is a living unit greater than the sum of its parts.**