Topic 2.1-2.2

Subcellular Components and Their Functions

Learning Objectives

- Learn the structure and function of the ribosome, endoplasmic reticulum, Golgi complex, mitochondrion, lysosome, vacuole, and chloroplast

Topic Questions

- How does the structure of each subcellular component contribute to its function in the cell?

2.1-2.2.01 Ribosome Structure and Function

[SYI-1.D.1 SYI-1.D.2]

The **cell** is the structural and functional unit of life. All cells can be classified as either eukaryotic or prokaryotic, and all cells have certain basic features such as:

- Genetic material in the form of **DNA**
- A **cell membrane**, which separates the cell from the outside environment
- **Cytoplasm**, which is found inside of the cell (the fluid portion of the cytoplasm is called the **cytosol**)
- **Ribosomes**, which are used to translate genetic information into a protein (described in more detail in Topic 6.4)

A functional ribosome is made up of two parts: a large subunit and a small subunit (Figure 2.1). Each ribosomal subunit is made from a combination of **ribosomal RNA (rRNA)** and **proteins**. The protein synthesis function of ribosomes is mainly carried out by the rRNA portion of the ribosome.

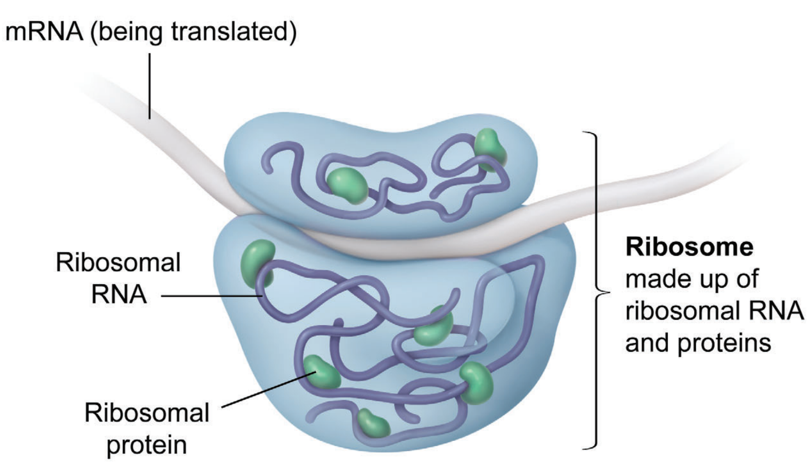
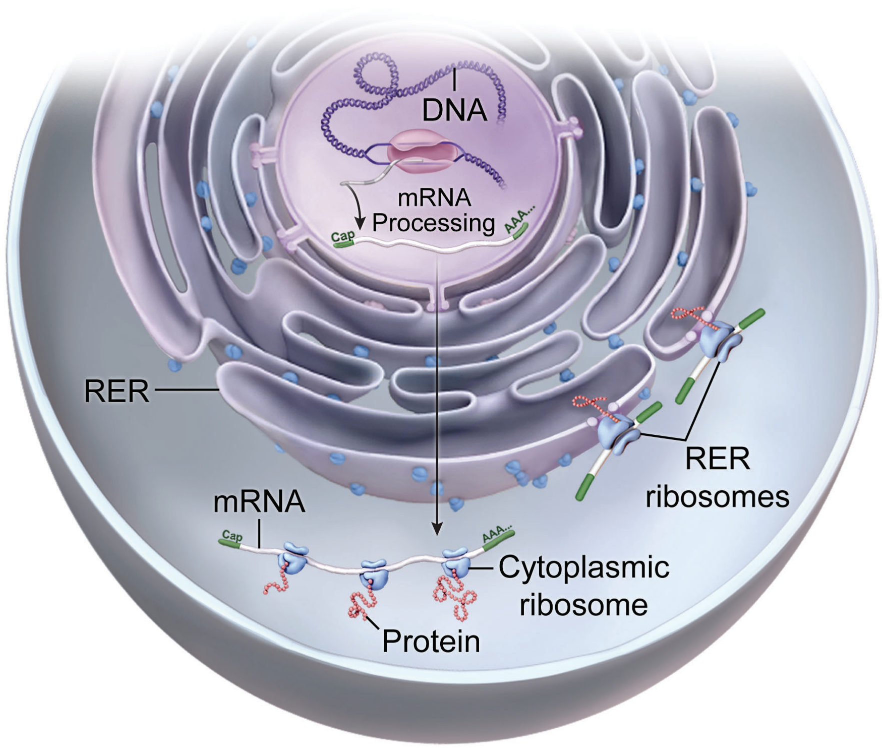


Figure 2.1 Structure of a ribosome.

During protein synthesis, translation of mRNA to make proteins in the cell's cytosol is carried out by **free ribosomes**, which are not attached to a membrane (Figure 2.2). In contrast, proteins that are meant to be trafficked (ie, transported) to other locations are made by **bound ribosomes**. Bound ribosomes become attached to a structure known as the rough endoplasmic reticulum during protein synthesis (discussed further in Sub-Topic 2.1-2.2.02).



RER = rough endoplasmic reticulum.

Figure 2.2 Translation of proteins by free and bound ribosomes.

Shared characteristics among different types of organisms are often used as evidence that these organisms may have had a common ancestor. Ribosomes synthesize proteins in all known life forms, providing evidence that *all* organisms likely evolved from an ancient common ancestor that also had ribosomes (Figure 2.3).

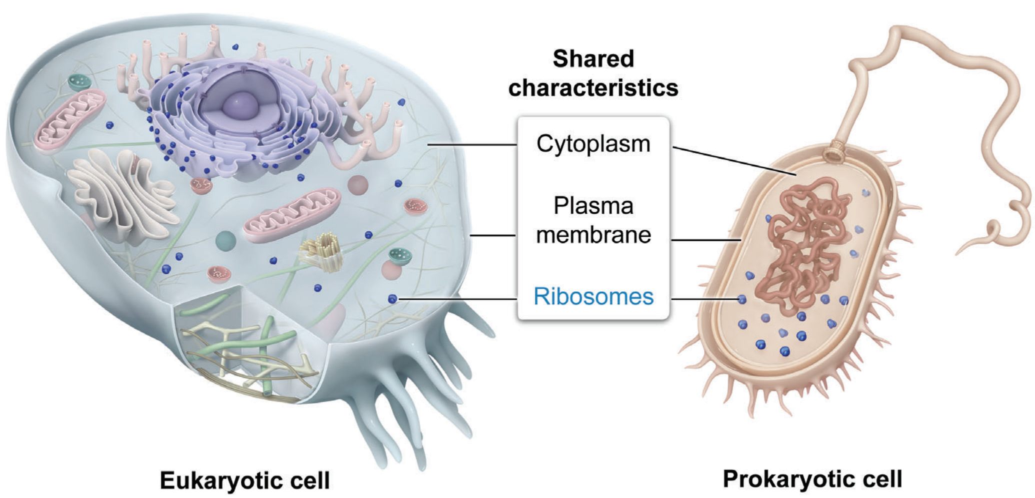


Figure 2.3 Ribosomes are present in all life forms.

In addition to eukaryotic cells being larger in size than prokaryotic cells, a major difference between eukaryotic and prokaryotic cells is that eukaryotes have membrane-bound compartments, or **organelles**, but prokaryotes do not. The largest eukaryotic organelle is the nucleus, which contains the cell's genetic material (ie, DNA). The nucleus is surrounded by a double membrane called the **nuclear envelope**, which is connected to the endoplasmic reticulum.

2.1-2.2.02 Endoplasmic Reticulum Structure and Function

[SYI-1.D.3 SYI-1.E.1]

Eukaryotic membrane-bound organelles are specialized to carry out particular functions in the cell (discussed further in Topics 2.10 and 2.11). The **endoplasmic reticulum (ER)** is one such organelle and participates in many cellular functions. Some functions of the ER include protein and lipid synthesis, intracellular transport, and mechanical support to help the cell keep its shape. As shown in Figure 2.4, the ER is divided into two parts with different functions:

- The **rough ER (RER)** has many ribosomes attached to its surface. These ribosomes produce proteins and deposit them inside the RER. Proteins deposited into the RER are most often transported to the Golgi complex by small membrane-bound compartments known as **vesicles**.
- The **smooth ER (SER)** makes lipids (including membrane lipids such as phospholipids and cholesterol) and detoxifies harmful substances. *Note: The SER has other, more specialized functions in certain cells, but these functions are beyond the scope of the exam.*

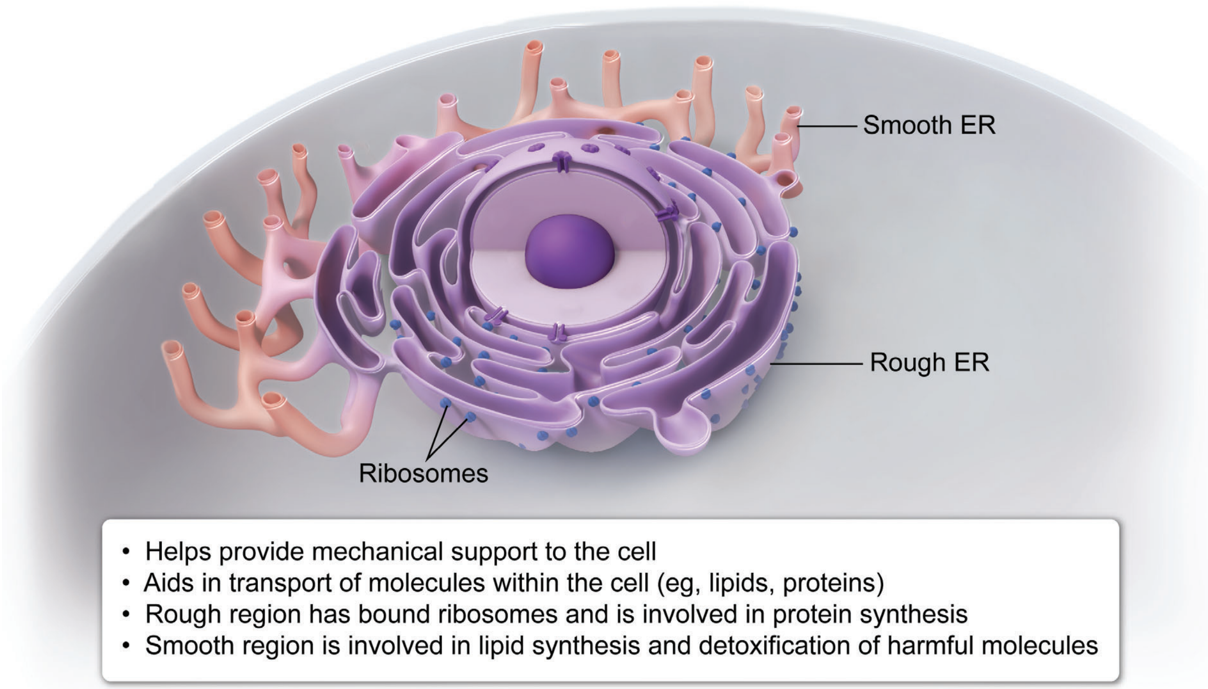


Figure 2.4 Endoplasmic reticulum components.

2.1-2.2.03 Golgi Complex Structure and Function

[SYI-1.D.4]

The **Golgi complex** (or **Golgi apparatus**) is a stack of flattened membrane-bound compartments called **cisternae** (singular: **cisterna**). The Golgi complex is usually found next to the rough endoplasmic reticulum (RER). Proteins received from the RER are modified, sorted, and packaged in the Golgi complex. Modified and sorted proteins are then transported to other cellular locations (eg, membranes, lysosomes) or secreted from the cell by vesicles, as shown in Figure 2.5.

Protein modifications help some proteins to fold correctly and can be used as a signal for the cell to send a protein to a specific location. One of the most common protein modifications is **glycosylation**, or the attachment of carbohydrates to proteins. Proteins with carbohydrates attached to them are called glycoproteins. *Note: Knowledge of Golgi complex function in phospholipid creation and in the packaging of enzymes for specific cellular compartments (eg, lysosomes, peroxisomes, secretory vesicles) is not required for the exam.*

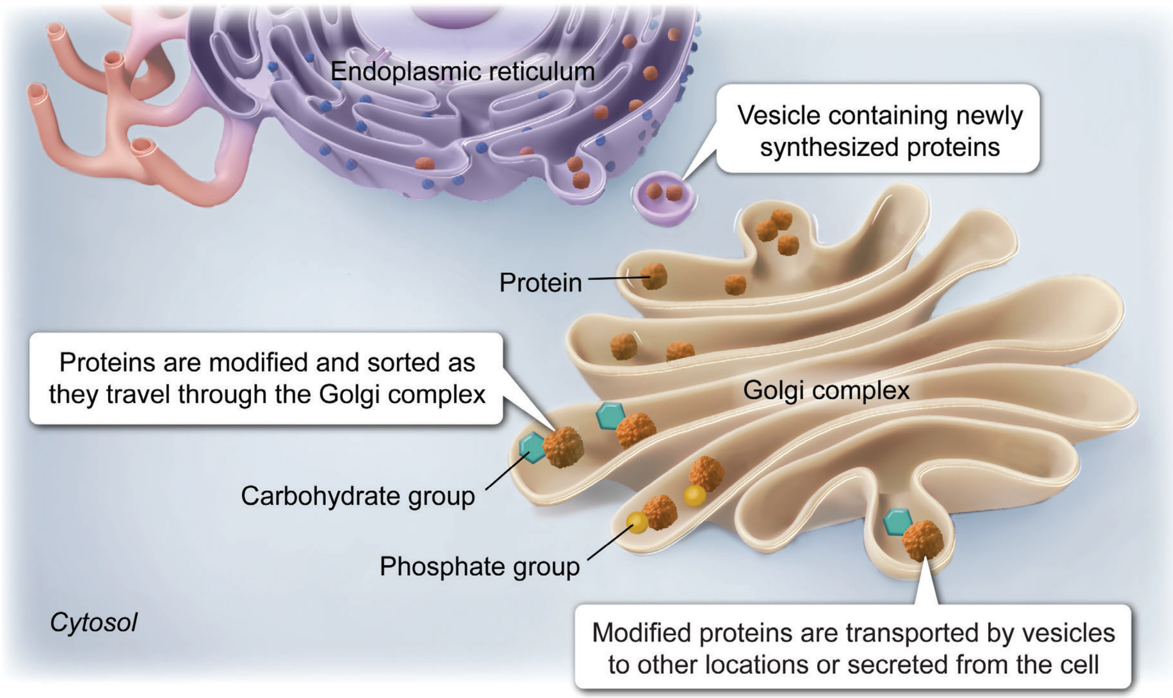


Figure 2.5 Proteins are modified and sorted in the Golgi complex.

2.1-2.2.04 Mitochondrial Structure, Function, and Biochemical Processes

[SYI-1.D.5 SYI-1.E.1 SYI-1.F.1 SYI-1.F.8 SYI-1.F.9]

Mitochondria (singular: **mitochondrion**) are called the *powerhouses of the cell* for their role in energy production. In eukaryotic cells, mitochondria are the major location of cellular respiration, in which energy from biological macromolecules (eg, glucose) is used to make ATP, the energy form used by the cell.

Mitochondria have a double membrane structure made up of an inner and outer membrane separated by an **intermembrane space**, as shown in Figure 2.6. The **outer mitochondrial membrane** is relatively smooth, but the **inner mitochondrial membrane** is convoluted (ie, highly folded), which greatly increases its surface area. The innermost space of the mitochondrion is called the **mitochondrial matrix**.

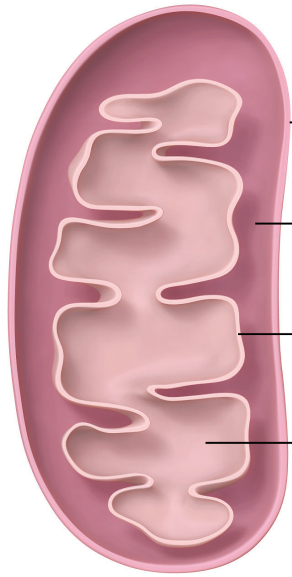


Figure 2.6 Mitochondrial compartments.

Each mitochondrial compartment has its own role during cellular respiration (Figure 2.7). For example, the Krebs cycle is a series of biochemical reactions that occur in the mitochondrial matrix, and the proteins of the **electron transport chain (ETC)** are found within the inner mitochondrial membrane. The ETC is a series of biochemical reactions that function in cellular respiration and also during photosynthesis. The highly folded inner membrane provides a greater surface area for ETC proteins, resulting in more ATP production. The function of mitochondria in cellular respiration is discussed in more detail in Topic 3.6.

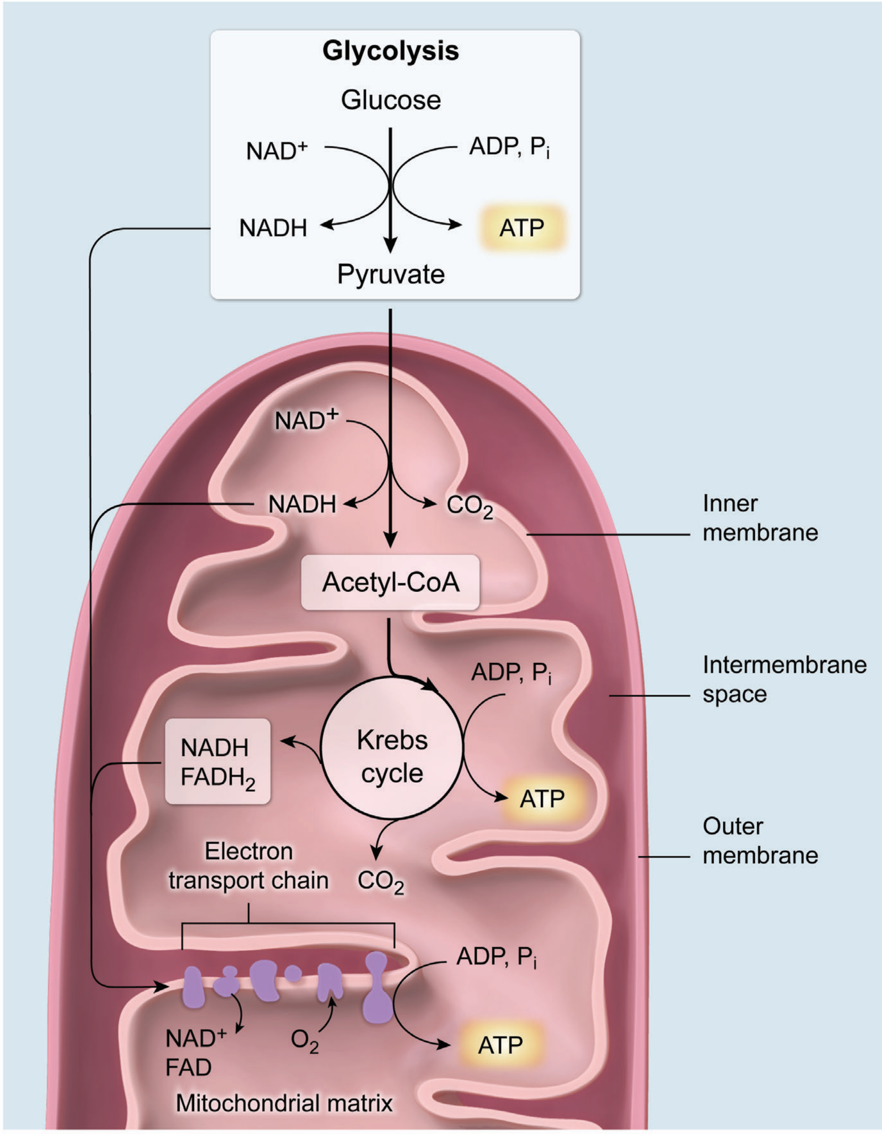


Figure 2.7 The reactions of cellular respiration occur in specific mitochondrial compartments.

2.1-2.2.05 Lysosome Structure and Function

[SYI-1.D.6 SYI-1.E.1]

Lysosomes are membrane-bound compartments formed by the Golgi complex. Because they contain hydrolytic (ie, digestive) enzymes, lysosomes are able to digest (ie, break down) macromolecules and other materials (eg, microbes) brought into the cell by endocytosis, and they help recycle damaged cellular components.

When a cell is damaged, it may undergo **apoptosis** (ie, **programmed cell death**), during which lysosomes may leak their contents into the cytosol to help break down intracellular structures. The functions of lysosomes are summarized in Figure 2.8.

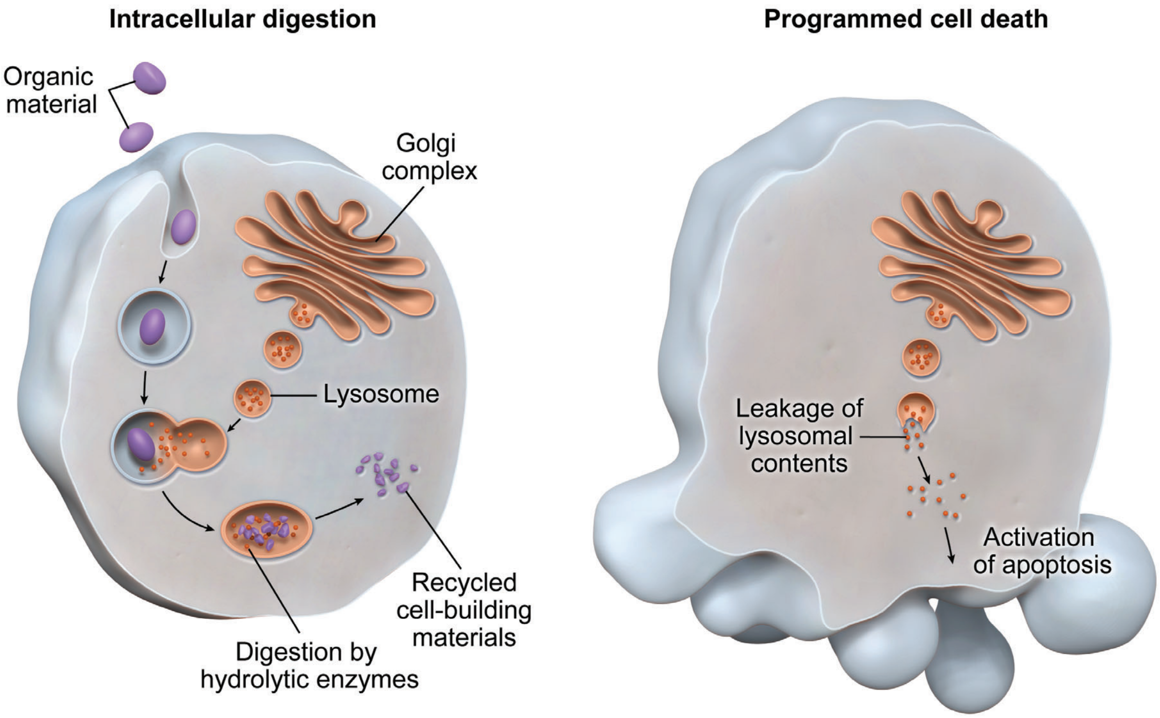


Figure 2.8 Lysosome function.

2.1-2.2.06 Vacuole Structure and Function

[SYI-1.D.7 SYI-1.E.1]

Vacuole is a general term for a large membrane-bound compartment in the cell. Vacuoles play different roles in different cell types. **Food vacuoles** are formed when organic matter is brought into the cell by a type of endocytosis called phagocytosis. Single-celled organisms (ie, protists) living in fresh water may have **contractile vacuoles**, which pump water out of the cell to help keep the correct solute balance inside the cell.

Plant cells contain a specialized vacuole called a **central vacuole** (shown in Figure 2.9), which carries out the following functions:

- Storage and release of macromolecules (eg, proteins or carbohydrates), ions, pigments, and waste products
- Transfer of water into and out of the cytosol, helping to regulate cell growth and shape
- Support of plant structure by keeping osmotic balance and creating turgor pressure

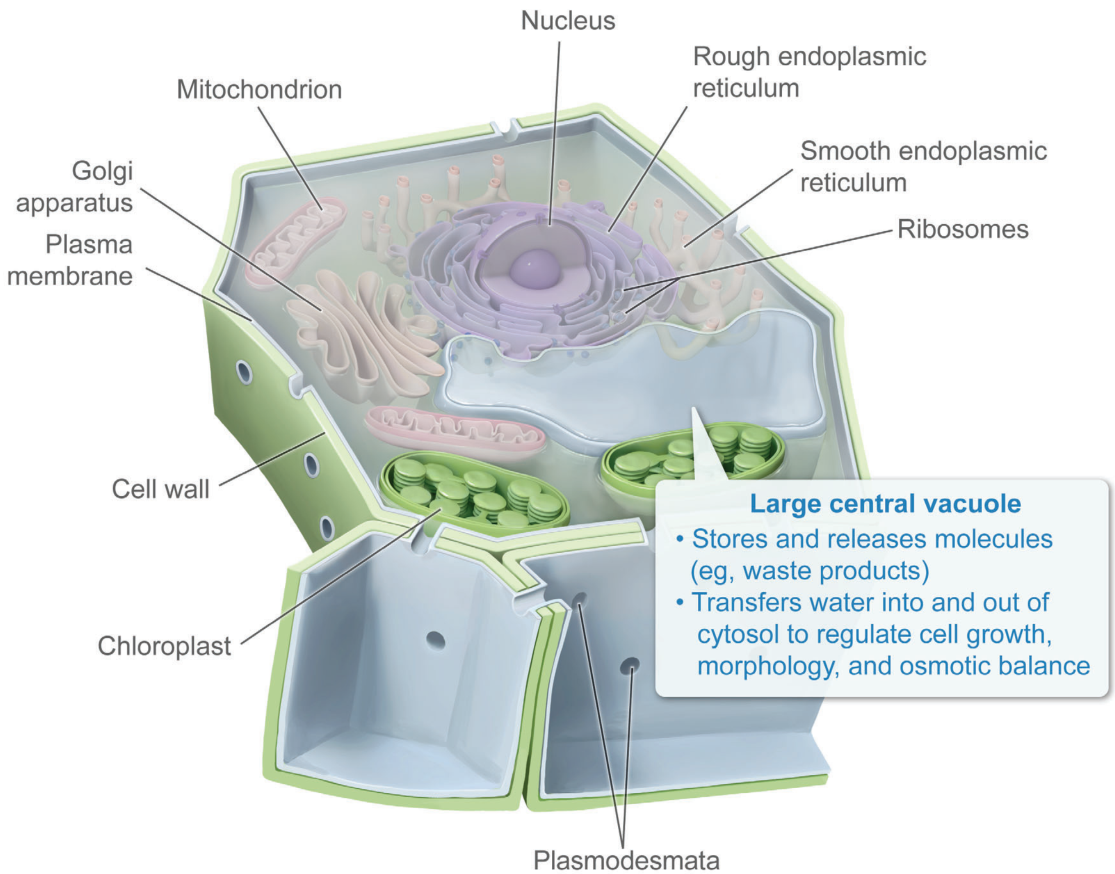


Figure 2.9 Central vacuole in a plant cell.

Turgor pressure develops in a plant cell when water enters the central vacuole by osmosis. During osmosis, water moves across a membrane from a region of lower solute concentration into a region of higher solute concentration. This process causes the central vacuole to fill with water, creating turgor pressure. When a plant cell is in a solution with a higher solute concentration (ie, a hypertonic solution), water leaves the central vacuole, decreasing turgor pressure. Osmosis is covered in further detail in Topic 2.8.

2.1-2.2.07 Chloroplast Structure and Function

[SYI-1.D.8 SYI-1.F.2 SYI-1.F.3 SYI-1.F.4 SYI-1.F.5 SYI-1.F.6 SYI-1.F.7]

In **photosynthesis**, organisms capture light energy and convert it into chemical energy (eg, glucose or starch). Photosynthetic organisms are called photoautotrophs because they obtain energy from light. In plants and algae, photosynthesis takes place in membrane-bound organelles called **chloroplasts**.

Each chloroplast is surrounded by a double membrane, and the fluid interior of the chloroplast is called the **stroma**. The stroma contains membrane-bound compartments called **thylakoids**, which are stacked into connected columns known as **grana** (singular: **granum**), as shown in Figure 2.10.

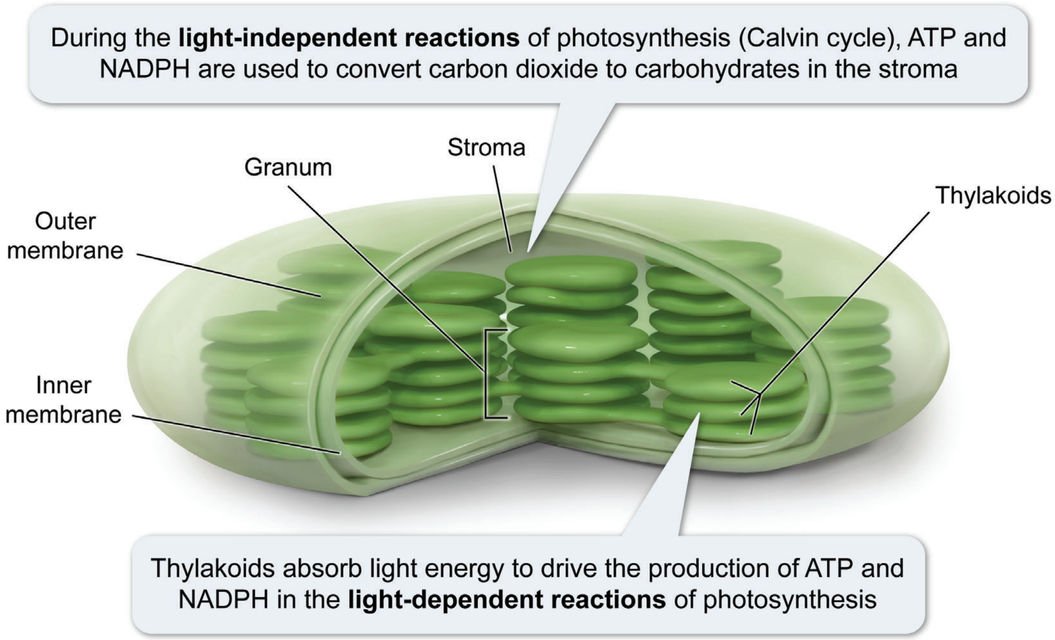


Figure 2.10 Structure of a chloroplast.

Two types of reactions take place within the chloroplast:

- **Light-dependent reactions** occur when light is trapped and absorbed by green pigment molecules (ie, **chlorophylls**) found in thylakoid membranes. Electrons in chlorophylls absorb light energy and are transferred to electron transport chain proteins within thylakoid membranes. The major products of the light-dependent reactions are ATP, NADPH, and oxygen.
- **Light-independent reactions** (**Calvin cycle**) occur within the stroma of the chloroplast. During the Calvin cycle, products of the light-dependent reactions (ATP, NADPH) are used to convert carbon dioxide to carbohydrates.

The process of photosynthesis is covered in greater detail in Topic 3.5.

Topic 2.1-2.2 Subcellular Components and Their Functions
Check for Understanding Quiz

1. Which of the following best explains how the Golgi complex contributes to cellular functions?
   A. The Golgi complex modifies, sorts, and packages proteins.
   B. The Golgi complex is the major location of cellular respiration.
   C. The Golgi complex translates genetic information into proteins.
   D. The Golgi complex makes lipids and detoxifies harmful substances.

2. Which of the following best describes a feature of mitochondria?
   A. The intermembrane space refers to the cytoplasmic side of the outer membrane.
   B. The space between the inner and outer membranes is known as the matrix.
   C. The proteins of the electron transport chain are found within the inner membrane.
   D. The outer membrane is highly folded, while the inner membrane is relatively smooth.

3. The organelle that supports plant structure by keeping osmotic balance and creating turgor pressure is which of the following?
   A. Chloroplast
   B. Lysosome
   C. Rough endoplasmic reticulum
   D. Central vacuole

4. Which of the following statements concerning ribosomes is true?
   A. Ribosomes are made up of messenger RNA and proteins.
   B. Ribosomes break down intracellular structures during apoptosis.
   C. Ribosomes not attached to a membrane synthesize cytosolic proteins.
   D. Ribosomes are formed when organic matter is brought into the cell by phagocytosis.

Note: Answers to this quiz are in the back of the book (appendix).