

<b>B-2 The student will demonstrate an understanding of the structure and function of cells and their organelles.</b>
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**B-2.1 Recall the three major tenets of cell theory (all living things are composed of one or more cells; cells are the basic units of structure and function in living things; and all presently existing cells arose from previously existing cells).**

**Taxonomy Level:** 1.2-B Remember Conceptual Knowledge

**Key Concepts:**

Cell theory

Unicellular organism, multicellular organism

**Previous knowledge:** In 5<sup>th</sup> grade (5-2.1), students recalled the cell as the smallest unit of life and identified its major structures (including cell membrane, cytoplasm, nucleus, and vacuole). In 7<sup>th</sup> grade, students summarized the structures and functions of the major components of plant and animal cells (including the cell wall, the cell membrane, the nucleus, chloroplasts, mitochondria, and vacuoles) (7-2.1), compared the major components of plant and animal cells (7-2.2), and explained how cellular processes (including respiration, photosynthesis in plants, mitosis, and waste elimination) are essential to the survival of the organism (7-2.4).

**It is essential for students to know** the three major tenets of the *cell theory*:

- All living things are composed of one or more cells.
- Cells are the basic unit of structure of all living things.
  - The lowest level of structure capable of performing all the activities of life is the cell.
  - A *unicellular organism* is composed of one cell and all of life's activities occur within that single cell.
  - In a *multicellular organism*, each cell carries on most of the major functions of life.
- All presently existing cells arose from previously existing cells.
  - The ability of cells to divide to form new cells is the basis for all reproduction (both sexual and asexual) and for the growth and repair of all multicellular organisms.

**It is not essential for students to recall** the history of cell theory, although the development of cell theory highlights its significance to the study of biology and would serve as an aide in helping students comprehend the value and relevance of this concept.

**Assessment Guidelines:**

The objective of this indicator is to *recall* the three major tenets of cell theory; therefore, the primary focus of assessment should be to remember the three principles as outlined in the indicator.

In addition to *recall*, assessment may require students to

- *identify* that unicellular and multicellular organisms must carry out all basic cell processes;
- *recall* reasons that new cells must be formed.

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**B-2.2 Summarize the structures and functions of organelles found in a eukaryotic cell (including the nucleus, mitochondria, chloroplasts, lysosomes, vacuoles, ribosomes, endoplasmic reticulum [ER], Golgi apparatus, cilia, flagella, cell membrane, nuclear membrane, cell wall, and cytoplasm).**

**Taxonomy Level:** 2.4-B Understand Conceptual Knowledge

**Key Concepts:**

Organelles (*as stated in the indicator*)

Chlorophyll

Enzymes

**Previous knowledge:** In 5<sup>th</sup> grade (5-2.1), students recalled the cell as the smallest unit of life and identified its major structures (including cell membrane, cytoplasm, nucleus, and vacuole). In 7<sup>th</sup> grade, students summarized the structures and functions of the major components of plant and animal cells (including the cell wall, the cell membrane, the nucleus, chloroplasts, mitochondria, and vacuoles) (7-2.1), compared the major components of plant and animal cells (7-2.2), and explained how cellular processes (including respiration, photosynthesis in plants, mitosis, and waste elimination) are essential to the survival of the organism (7-2.4).

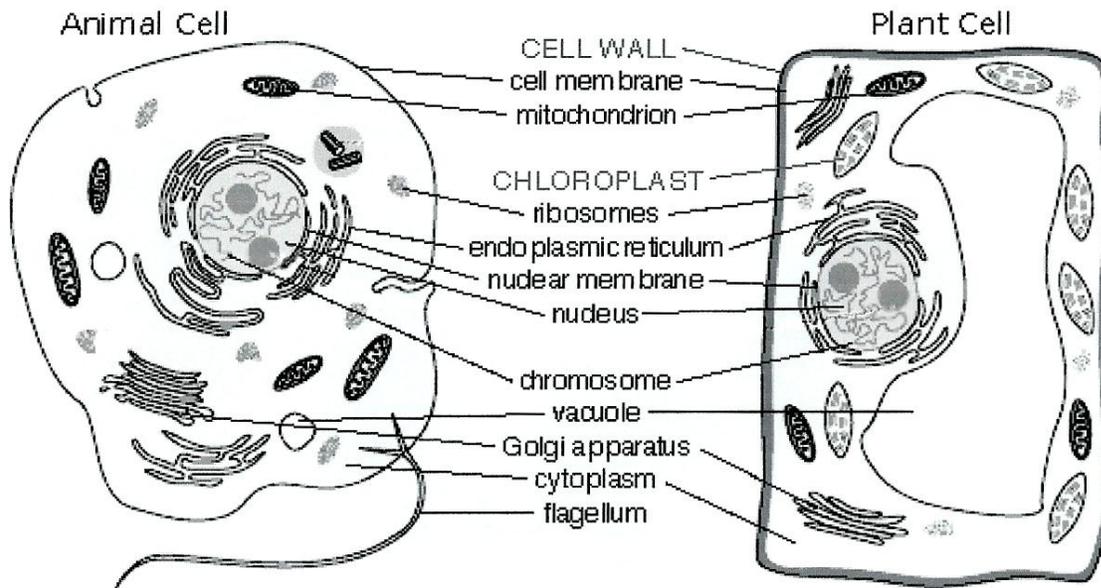
**It is essential for students to understand** that an *organelle* is a cell structure that performs a specialized function within a eukaryotic cell. Organelles found in a eukaryotic cell include:

- *Nucleus* contains the chromosomes which are composed of DNA (a chemical compound called deoxyribonucleic acid); functions in the genetic control of the cell.
- *Mitochondria* are the sites of cellular respiration, a process which supplies the cell with energy. TEACHER NOTE: Students will be responsible for understanding the process of cellular respiration in the context of standard B-3.
- *Chloroplasts* are found only in plant cells, contain the green pigment, *chlorophyll*, which absorbs energy from the Sun to convert carbon dioxide and water into sugar through the process of photosynthesis. TEACHER NOTE: Students will be responsible for understanding the process of photosynthesis in the context of standard B-3.
- *Lysosomes* contain chemicals called *enzymes* necessary for digesting certain materials in the cell. TEACHER NOTE: Students will be responsible for understanding the function of enzymes in the context of indicator B-2.8.
- *Vacuoles* store materials such as water, salts, proteins, and carbohydrates; vacuoles in animal cells (if they are present) are much smaller than those in plant cells.
- *Ribosomes* are the sites of protein synthesis; some are located on the ER, others are found in the cytoplasm.
- *Endoplasmic reticulum (ER)* is a complex, extensive network that transports materials throughout the inside of a cell.
  - Rough ER has ribosomes attached to the surface is ribosome-studded.
  - Smooth ER has no attached ribosomes.
- *Golgi apparatus* modifies, collects, packages, and distributes molecules within the cell or outside the cell.
- *Cilia* are short hair-like projections responsible for the movement of animal cells or protists.

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- *Flagella* are long whip-like projections responsible for the movement of some animal cells, bacteria, or protists.
- *Cell membrane* (sometimes called the plasma membrane) is the cell structure that encloses the cell and regulates the passage of materials between the cell and its environment; the cell membrane also aids in protection and support of the cell.
- *Nuclear membrane* (sometimes called nuclear envelope) is the membrane that surrounds the nucleus of the cell and regulates the passage of materials between the nucleus and the cytoplasm.
- *Cell wall* is the cell structure that surrounds the cell membrane for protection and support in plant cells, bacteria, fungi, and some protists, and allows for specific substances to pass in and out of the cell.
- *Cytoplasm* is the semi-fluid material inside the cell containing molecules and the organelles, exclusive of the nucleus; is bound by the cell membrane.

**It is also essential for students to locate and identify** each of the above organelles when presented with a scientific drawing, diagram, or model of a eukaryotic cell. For example:



**It is not essential for students to**

- understand any additional functions of various organelles stated in the indicator;
- have any deeper comprehension of the structure of various organelles than what is depicted in the diagram above (such as the parts of the endoplasmic reticulum, the structure of the nucleus, or the structure of the cell membrane);
- understand the structure or function of any additional organelles.

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**Assessment Guidelines:**

The objective of this indicator is to *summarize* the structures and functions of organelles found in a eukaryotic cell; therefore, the primary focus of assessment should be to generalize the functions of the organelles listed in the indicator.

In addition to *summarize* assessment may require students to

- *identify* organelles in a diagram or model;
- *recall* the functions of given organelles;
- *illustrate* appropriate organelles found in plant and animal cells;
- *classify* a cell as a plant or an animal cell based on a description of the organelles, a diagram, or a model;
- *compare* plant cells to animal cells.

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**B-2.3 Compare the structures and organelles of prokaryotic and eukaryotic cells.**

**Taxonomy Level:** 2.6-B Understand Conceptual Knowledge

**Key Concepts:**

Prokaryotic cells: DNA

Eukaryotic cells

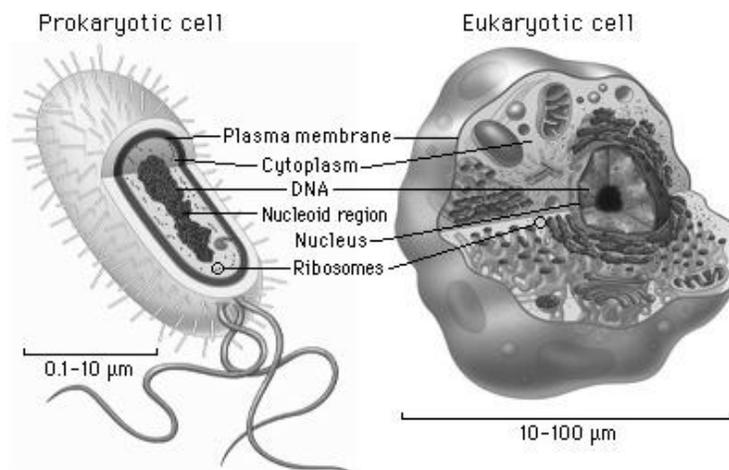
**Previous knowledge:** In 5<sup>th</sup> grade (5-2.1), students recalled the cell as the smallest unit of life and identified its major structures (including cell membrane, cytoplasm, nucleus, and vacuole). In 7<sup>th</sup> grade, students summarized the structures and functions of the major components of plant and animal cells (including the cell wall, the cell membrane, the nucleus, chloroplasts, mitochondria, and vacuoles) (7-2.1) and compared the major components of plant and animal cells (7-2.2).

**It is essential for students to understand** that the major difference between prokaryotic cells and eukaryotic cells is the presence of a nucleus.

- *Prokaryotic cells* do not have a true nucleus; the DNA in prokaryotic cells is not completely separated from the rest of the cell by a nuclear membrane (envelope) and is not arranged in strands called chromosomes.
  - *DNA (deoxyribonucleic acid)* is a chemical compound that stores and transmits genetic information
- In *eukaryotic cells*, the DNA is organized into structures called chromosomes and the chromosomes are separated from the cytoplasm by a nuclear membrane.  
TEACHER NOTE: Students will be responsible for understanding the structure and function of chromosomes and DNA in the context of standard B-4.

Prokaryotic cells differ from eukaryotic cells in other ways:

- Prokaryotic cells lack most of the other organelles which are present in the cytoplasm of eukaryotic cells.
- Prokaryotic cells do not contain mitochondria but they can obtain energy from either sunlight or from chemicals in their environment.
- Prokaryotic cells, however, do contain ribosomes, the site of protein synthesis.
- Most prokaryotes are unicellular organisms, such as bacteria.



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**Assessment Guidelines:**

The major focus of assessment is to *compare* the structure and organelles of prokaryotic and eukaryotic cells; therefore, the primary focus of assessment should be to detect similarities and differences between the two types of cells.

In addition to *compare*, assessment may require students to

- *recognize* a prokaryotic or eukaryotic cell based on a diagram showing the cell structure and the organelles are present;
- *recall* bacteria as examples of prokaryotic cells;
- *illustrate* the organelles that are found in prokaryotic and eukaryotic cells;
- *classify* a cell as prokaryotic or eukaryotic based on a diagram or a written description which includes the form and organelles present in the cell.

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**B-2.4 Explain the process of cell differentiation as the basis for the hierarchical organization of organisms (including cells, tissues, organs, and organ systems).**

**Taxonomy Level:** 2.7-B Understand Conceptual Knowledge

**Key Concepts:**

Cell division: differentiation

Stem cells

**Previous knowledge:** In 7<sup>th</sup> grade, students summarized the levels of structural organization within the human body, including cells, tissues, organs, systems (7-3.1), and explained how cellular processes (including respiration, photosynthesis in plants, mitosis, and waste elimination) are essential to the survival of the organism (7-2.4).

**It is essential for students to understand**

- In the development of most multicellular organisms, a single cell (fertilized egg) gives rise to many different types of cells, each with a different structure and corresponding function.
  - The fertilized egg gives rise to a large number of cells through *cell division*, but the process of cell division alone could only lead to increasing numbers of identical cells.
  - As cell division proceeds, the cells not only increase in number but also undergo *differentiation* becoming specialized in structure and function. (Cell division is covered in B-2.6.)
  - The various types of cells (such as blood, muscle, or epithelial cells) arrange into tissues which are organized into organs, and, ultimately, into organ systems.
- Nearly all of the cells of a multicellular organism have exactly the same chromosomes and DNA.
  - During the process of differentiation, only specific parts of the DNA are activated; the parts of the DNA that are activated determine the function and specialized structure of a cell.
  - Because all cells contain the same DNA, all cells initially have the potential to become any type of cell.
  - Once a cell differentiates, the process can not be reversed.
- *Stem cells* are unspecialized cells that continually reproduce themselves and have, under appropriate conditions, the ability to differentiate into one or more types of specialized cells.
  - Embryonic cells, which have not yet differentiated into various cell types, are called embryonic stem cells.
  - Stem cells found in adult organisms, for instance in bone marrow, are called adult stem cells.
  - Scientists have recently demonstrated that stem cells, both embryonic and adult, with the right laboratory culture conditions, differentiate into specialized cells.

TEACHER NOTE: The process of cloning will be addressed in standard B-4.

**It is not essential for students to understand** how the process of transcriptional regulation in a cell produces specific proteins which results in cell differentiation.

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**Assessment Guidelines:**

The objective of this indicator is to *explain* the process of cell differentiation; therefore, the primary focus of assessment should be to construct a cause-and-effect model showing how cell differentiation results in the hierarchical organization of an organism (including cells, tissues, organs, and organ systems). Assessments should ensure that students can model how the processes of cell division and cell differentiation result in identical cells specializing to become unique cells with specific functions which will form the organism's tissues and organs.

In addition to *explain*, assessments may require students to

- *recall* that all of the cells of a particular organism contain all of the genetic code for the organism;
- *summarize* the unique characteristics of embryonic and adult stem cells;
- *compare* the results of cell division and cell differentiation.

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**B-2.5 Explain how active, passive, and facilitated transport serve to maintain the homeostasis of the cell.**

**Taxonomy Level:** 2.7-B Understand Conceptual Knowledge

**Key Concepts:**

Homeostasis: semipermeable membrane (selectively permeable)

Passive transport: diffusion, concentration gradient, osmosis, lyse, facilitated transport (diffusion), transport proteins

Active transport: endocytosis, ectocytosis

**Previous knowledge:** In 7<sup>th</sup> grade, students summarized the structures and functions of the major components of plant and animal cells (diffusion and osmosis across the cell membrane) (7-2.1) and explained how cellular processes (including respiration and waste elimination) are essential to the survival of the organism (7-2.4). The dynamics of homeostasis and active or passive transport of substances is new material in this course.

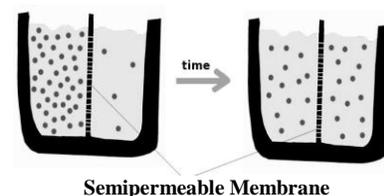
**It is essential for students to understand** that *homeostasis* refers to the necessity of an organism to maintain constant or stable conditions. In order to maintain homeostasis, all organisms have processes and structures which respond to stimuli in ways that keep conditions in their bodies conducive for life. Homeostasis depends in part on appropriate movement of materials across the cell membrane.

- Materials needed for cellular processes must pass into cells so they can be utilized. For example, oxygen and glucose are continuously needed for the process of cellular respiration.
- Waste materials from cellular processes must pass out of cells as they are produced. For example, carbon dioxide is continuously produced within the cell during the process of cellular respiration.
- The cell membrane regulates the passage of material into and out of the cell. Depending on the needs of the cell, excess substances must move out of the cell and needed substances must move into the cell.
- Each individual cell exists in a fluid environment, and the cytoplasm within the cell also has a fluid environment. The presence of a liquid makes it possible for substances (such as nutrients, oxygen, and waste products) to move into and out of the cell.
- A cell membrane is *semipermeable (selectively permeable)*, meaning that some substances can pass directly through the cell membrane while other substances can not.
- Materials can enter or exit through the cell membrane by passive transport or active transport.

*Passive transport* is a process by which substances move across a cell membrane but do not require energy from the cell. Types of passive transport are diffusion, osmosis, and facilitated diffusion.

- *Diffusion* is the spreading out of molecules across a cell membrane until they are equally concentrated. It results from the random motion of molecules and occurs along a *concentration gradient* (molecules move from an area of higher concentration to an area of lower concentration); substances that are able to pass directly across the cell membrane can diffuse either into a cell or out of a cell.

**Diffusion across a semipermeable membrane**



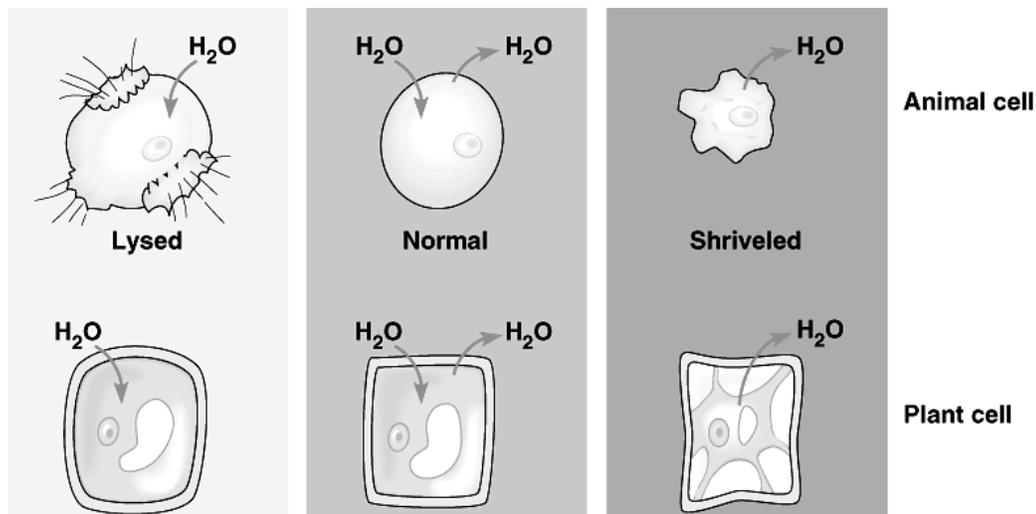
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- *Osmosis* is the diffusion of water molecules through a selectively permeable membrane from an area of greater concentration of water to an area of lesser concentration of water.
  - If two solutions with the same solute concentration are separated by a selectively permeable membrane, water molecules will pass through the membrane in both directions at the same rate so the concentration of the solutions will remain constant.
  - The diffusion of water molecules is a passive transport process because it does not require the cell to expend energy.
  - If cells are placed in solutions that are very different in concentration from that of the cell, the cells may be damaged and even shrivel or burst (*lyse*).

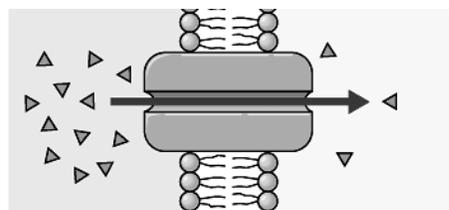
Water concentration greater outside the cell than inside so water moves into the cell

Water concentration the same inside and outside the cell so there is no net movement of water

Water concentration greater inside the cell than outside so water moves out of the cell



- *Facilitated diffusion (transport)* is the process by which some substances that are not able to pass directly through a cell membrane are able to enter the cell with the aid of *transport proteins*. Facilitated diffusion occurs along a concentration gradient and does not require energy from the cell.
  - Some substances have chemical structures that prevent them from passing directly through a cell membrane. The cell membrane is not permeable to these substances.
  - Transport proteins provide access across the cell membrane.
  - Glucose is an example of a substance that passes through the cellular membrane using facilitated diffusion.



Facilitated Diffusion

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*Active transport* is another one way that substances can move through a cell membrane. However, molecules move against the concentration gradient (from an area of low concentration to an area of high concentration) and require the cell to expend energy.

- One process of active transport happens when cells pump molecules through the cell membrane.
  - Unlike the process of facilitated diffusion, in active transport, molecules are “pumped” across the cell membrane by transport proteins. This pumping process requires an expenditure of chemical energy.
  - Because this process does not depend on diffusion, cells can use this process to concentrate molecules within the cell, or to remove waste from a cell.
  - Calcium, potassium, and sodium ions are examples of materials that must be forced across the cell membrane using active transport.
- Another process of active transport happens when molecules are too large to pass through a cell membrane even with the aid of transport proteins. These molecules require the use of *vesicles* to help them through the membrane.
  - If the large molecule is passing into the cell, the process is called *endocytosis*.
  - If the large molecule is passing out of the cell, the process is called *exocytosis*.

**It is not essential for students to**

- understand the structure of the cell membrane;
- understand how the specific mechanisms of active transport function (i.e., sodium-potassium pump, proton pump);
- calculate osmotic pressure.

**Assessment Guidelines:**

The objective of the indicator is to *explain* how active, passive, and facilitated transport serves to maintain the homeostasis of the cell; therefore, the primary focus of assessment should be to construct a cause-and-effect model showing how the various methods by which molecules are transported across a cell membrane to maintain balance in the cell.

In addition to *explain*, assessments may require students to:

- *illustrate* the ways that each type of cellular transport helps the cell maintain homeostasis;
- *classify* a specific description of cellular transport;
- *summarize* the ways that each method of cellular transport helps the cell to maintain homeostasis;
- *infer* which type of cellular transport would be best suited to transport a given type of substance into or out of a cell;
- *compare* the unique functions of each type of cellular transport.

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**B-2.6 Summarize the characteristics of the cell cycle: interphase (called G1, S, G2); the phases of mitosis (called prophase, metaphase, anaphase, and telophase); and plant and animal cytokinesis.**

**Taxonomy Level:** 2.4-B Understand Conceptual Knowledge

**Key Concepts:**

Cell cycle

Interphase: gap 1 phase (G1); synthesis phase (S), chromatid, centromere; gap 2 phase (G2)

Mitosis: prophase, metaphase, anaphase, telophase

Cytokinesis: cleavage furrow, cell plate

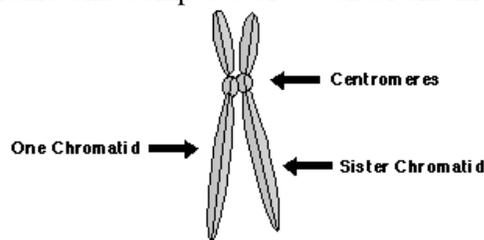
**Previous knowledge:** In 7<sup>th</sup> grade (7-2.4), students explained how cellular processes (including respiration, photosynthesis in plants, mitosis, and waste elimination) are essential to the survival of the organism.

**It is essential for students to understand** that the *cell cycle* is a repeated pattern of growth and division that occurs in eukaryotic cells. This cycle consists of three phases. The first phase represents cell growth while the last two phases represent cell division.

**Interphase**

- Cells spend the majority of their cell cycle in interphase. The purpose of interphase is for cell growth. By the end of interphase a cell has two full sets of DNA (chromosomes) and is large enough to begin the division process.
- Interphase is divided into three phases. Each phase is characterized by specific processes involving different structures.
  - During the *G1 (gap 1) phase*, the cell grows and synthesizes proteins.
  - During the *S (synthesis) phase*, chromosomes replicate and divide to form identical *sister chromatids* held together by a *centromere*.
  - During the *G2 (gap 2) phase*, cells continue to grow and produce the proteins necessary for cell division.

Chromosome composed of two sister chromatids



**Mitosis**

- The purpose of mitosis is cell division: making two cells out of one. Each cell has to have its own cytoplasm and DNA. The DNA that replicated in Interphase when two chromosome strands became four strands (two strands per chromatid). In mitosis the four strands (two sister chromatids) have to break apart so that each new cell only has one double-stranded chromosome.
- Mitosis, which follows Interphase, is divided into four phases. Each phase is characterized by specific processes involving different structures.
  - *Prophase* is characterized by four events:
    - ◆ Chromosomes condense and are more visible.
    - ◆ The nuclear membrane (envelope) disappears.

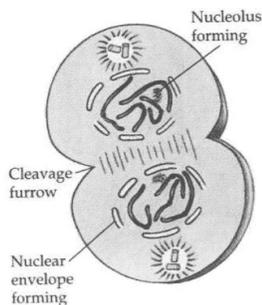
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- ◆ By the end of prophase the centrioles (cell organelles that produce spindle fibers) have separated and taken positions on the opposite poles of the cell.
- ◆ Spindle fibers form and radiate toward the center of the cell.
- *Metaphase* (the shortest phase of mitosis) is characterized by two events:
  - ◆ Chromosomes line up across the middle of the cell.
  - ◆ Spindle fibers connect the centromere of each sister chromatid to the poles of the cell.
- *Anaphase* is characterized by three events:
  - ◆ Centromeres that join the sister chromatids split.
  - ◆ Sister chromatids separate becoming individual chromosomes.
  - ◆ Separated chromatids move to opposite poles of the cell.
- *Telophase* (the last phase of mitosis) consists of four events:
  - ◆ Chromosomes (each consisting of a single chromatid) uncoil.
  - ◆ A nuclear envelope forms around the chromosomes at each pole of the cell.
  - ◆ Spindle fibers break down and dissolve.
  - ◆ Cytokinesis begins.

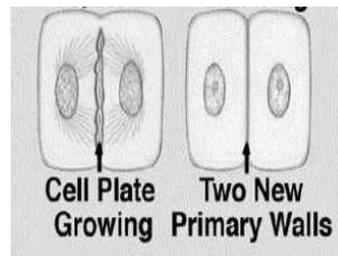
***Cytokinesis***

*Cytokinesis* is the division of the cytoplasm into two individual cells. The process of cytokinesis differs somewhat in plant and animal cells.

- In animal cells the cell membrane forms a *cleavage furrow* that eventually pinches the cell into two nearly equal parts, each part containing its own nucleus and cytoplasmic organelles.
- In plant cells a structure known as a *cell plate* forms midway between the divided nuclei, which gradually develops into a separating membrane. The cell wall forms in the cell plate.



Animal Cell Telophase/Cytokinesis



Plant Cell Telophase/Cytokinesis

TEACHER NOTE: The replication of DNA, the formation of RNA, or protein synthesis will be addressed in indicator B-4.3 and B-4.4.

**It is not essential for students to**

- recognize any structures other than those listed in the essential content;
- understand cell division in prokaryotic cells.

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**Assessment Guidelines:**

The objective of this indicator is to *summarize* the characteristics of the cell cycle; therefore the major focus of assessment should be to give major points about the events in each phase of the cell cycle. Assessments must also show that students understand the relevance of interphase, mitosis and cytokinesis to the survival of the organism.

In addition to *summarize*, assessments may require students to

- *identify* the phases of the cell cycle;
- *recall* the events that occur in each phase of the cell cycle;
- *illustrate* the phases of the cell cycle with pictures, diagrams, models, or words;
- *classify* a specific description or diagram as a particular phase of the cell cycle;
- *compare* the phases of the cell cycle;
- *explain* the purpose of each event in each phases of the cell cycle to the survival of the cell or organism.

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**B-2.7 Summarize how cell regulation controls and coordinates cell growth and division and allows cells to respond to the environment, and recognize the consequences of uncontrolled cell division.**

**Taxonomy Level:** 2.4-B Understand Conceptual Knowledge  
1.1-B Remember Conceptual Knowledge

**Key Concepts:**

Chemical control system: internal signal, external signal, checkpoint  
Cancer cells: malignant tumor, benign tumor

**Previous knowledge:** This concept has not been addressed in earlier grades

**It is essential for students to understand** that the cell cycle is driven by a *chemical control system* that both triggers and coordinates key events in the cell cycle. The cell cycle control system is regulated at certain checkpoints.

- Signals from inside the cell (internal signals) and from outside the cell (external signals) are involved in turning the process of cell division off and on.
  - An *internal signal* involves the cell sensing the presence of chemicals, called enzymes, which are produced inside the cell
  - An *external signal* involves the cell sensing the presence of a chemical (such as a growth factor) which was produced in other specialized cells.
- Cells can also respond to physical signals from their environment.
  - Cells sense when they are too closely packed and cell division is turned off.
  - Cells sense when they are not in contact with a surface and cell division is turned on.
- A *checkpoint* in the cell cycle is a critical control point where stop and go signals can regulate the cycle. The cell division mechanism in most animal cells is in the “off” position when there is no stimulus present. Specific stimuli are required to start the processes.

**It is also essential for students to recognize** consequences of uncontrolled cell division. Sometimes cells do not respond normally to the body’s control mechanisms and divide excessively.

- *Cancer cells* are an example of cells that do not heed the normal signals which shut down the cell division process; they continue to divide even when they are very densely packed and/or there is no growth factor present.
- Cancer begins when a single cell is transformed into a cancer cell, one that does not heed the regulation mechanism.
  - Normally the body’s immune system will recognize that the cell is damaged and destroy it, but if it evades destruction, it will continue to divide and each daughter cell will be a cancer cell.
  - A mass of these cells that invades and impairs the functions of one or more organs is called a *malignant tumor*.
  - A *benign tumor* is a mass of abnormal cells that remains at the original site.
- Cancer cells may also separate from the original tumor, enter the blood and lymph vessels of the circulatory system, and invade other parts of the body, where they grow to form new tumors.

**It is not essential for students to understand** the chemical mechanism of cell regulation.

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**Assessment Guidelines:**

The first objective of this indicator is to *summarize* how cell regulation controls and coordinates cell growth and division and allows cells to respond to the environment; therefore, the primary focus of assessment should be to give major points about the ways that inside and outside stimuli can regulate and control cell growth.

Another objective of this indicator is to *recognize* the consequences of uncontrolled cell division, therefore, the primary focus of assessment should be to remember that uncontrolled cell division can result in cancer cells forming tumors and possibly spreading throughout the body.

In addition to *summarize* and *recognize*, assessments may require students to

- *exemplify* internal signals (enzymes) and the external signals (cell density) that activate the process of cellular growth and division;
- *classify* a signal as an internal signal or an external signal;
- *recall* that a breakdown in the cellular regulatory process can result in growth of tumors.

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**B-2.8 Explain the factors that affect the rates of biochemical reactions (including pH, temperature, and the role of enzymes as catalysts).**

**Taxonomy Level:** 2.7-B Understand Conceptual Knowledge

**Key Concepts:**

Biochemical reactions: activation energy

pH: buffers

Catalyst: enzyme

**Previous knowledge:** In 7<sup>th</sup> grade (7-5.6), students distinguished between acids and bases and used indicators (including litmus paper, pH paper, and phenolphthalein) to determine their relative pH. In physical science, students classified various solutions as acids or bases according to their physical properties, chemical properties, generalized formulas, and pH (using pH meters, pH paper, and litmus paper) (PS 3.8) and explained the effects of temperature, concentration, surface area, and the presence of a catalyst on reaction rates (PS 4-1.1).

**It is essential for students to understand** that *biochemical reactions* allow organisms to grow, develop, reproduce, and adapt. A chemical reaction breaks down some substances and forms other substances. There are several factors that affect the rates of biochemical reactions.

- Chemical reactions (including biochemical reactions) can occur when reactants collide with sufficient energy to react. The amount of energy that is sufficient for a particular chemical reaction to occur is called the *activation energy*.
  - Sometimes a chemical reaction must absorb energy for the reaction to start; often, but not always, this energy is in the form of heat.
  - Energy, as heat or light, can also be given off as a result of biochemical reactions, such as with cellular respiration or bioluminescence.
- Changes in temperature (gaining or losing heat energy) can affect a chemical reaction.
- *pH* (a measure of the acidity of a solution) in most organisms needs to be kept within a very narrow range. *Buffers* within an organism are used to regulate pH so that pH homeostasis can be maintained. A small change in pH can disrupt cell processes.
- A *catalyst* is a substance that changes the rate of a chemical reaction or allows a chemical reaction to occur (activate) at a lower than normal temperature. Catalysts work by lowering the activation energy of a chemical reaction. A catalyst is not consumed or altered during a chemical reaction, so, it can be used over and over again. *Enzymes* are proteins which serve as catalysts in living organisms.
  - Enzymes are very specific. Each particular enzyme can catalyze only one chemical reaction by working on one particular reactant (substrate).
  - Enzymes are involved in many of the chemical reactions necessary for organisms to live, reproduce, and grow, such as digestion, respiration, reproduction, movement and cell regulation.
  - The structure of enzymes can be altered by temperature and pH; therefore, each catalyst works best at a specific temperature and pH.

**It is not essential for students to understand** the

- specific mechanisms by which a catalyst lowers activation energy;
- mechanism of chemical reactions (i.e. atoms, ions, bonding);
- role of cofactors or coenzymes;
- role of enzyme inhibitors.

**B-2 The student will demonstrate an understanding of the structure and function of cells and their organelles.**

**Assessment Guidelines:**

The objective of this indicator is to *explain* the factors that affect the rates of biochemical reactions; therefore, the primary focus of assessment should be to construct a cause-and-effect model showing how temperature, pH, and enzymes are used to control chemical reactions in living systems.

In addition to *explain*, assessments may require students to

- *interpret* diagrams, charts, and graphs of biochemical reactions;
- *summarize* factors that affect the rate of biochemical reactions;
- *recall* the purpose of a catalyst.