Section 1.4 The Cell Cycle (Student textbook pages 40 to 45)

In this section, students will develop an understanding of the cell cycle and the three main checkpoints for continued growth and division. They will investigate the consequences when a cell does not respond to those checkpoints due to mutation. The causes of cancer and its impact on the cells, tissues, organs and organisms will be presented. Cell death, programmed cell suicide, and the signals that control these processes will be linked to cancer to help students better understand the complexity of the cell cycle.

Common Misconceptions

- Students may interpret the length of arrows in the cell cycle diagram as representing the time the cell spends in the phases. Explain that it represents only the sequence and names, not length of time.
- Life span is sometimes thought of as the birth-to-death span of a cell's existence. Since cells reproduce by splitting, life span is defined as the average amount of time a cell spends in interphase before it divides. Cell death is defined when the cell exits the cycle.
- Interphase is sometimes explained as a "resting" phase. Emphasize that during interphase the cell is carrying out all the life-sustaining functions of the cell, growing larger, and producing new organelles.

Background Knowledge

As long as DNA is free of errors, omissions, insertions, etc., the proteins produced will be functional and the cell can live and reproduce successfully. Mutations can arise through transcription and/or translation errors caused by mistakes during protein synthesis (in replication) or because of mutagens/carcinogens in the environment.

Cells produce housekeeping proteins that are constantly required by the cell. Any mutations in these proteins may be fatal to the cell. If a mutation occurs in the DNA code that does not ever get translated into a functioning protein (i.e., in non-coding DNA), and the mutation did not cause a new protein to be created, then the mutation can be considered silent. These errors occur all the time.

There is a wide range of cell division rates in different types of human cells; this is related to the function of each type. For example, some cells, such as red blood cells, muscle cells, and nerve cells, lose the capacity to divide as they differentiate and mature. In the case of mammalian red blood cells only, once they have matured they extrude their nuclei and thus have no instructions for cell division. From this moment they have 100 to 120 days to function as oxygen (and carbon dioxide) transporters.

Literacy Support

Using the Text

- Have students predict which statements in **BLM 1-4 Chapter 1 Anticipation Guide** will be covered in this section.

Before Reading

- Brainstorm all the jobs that could be done by the 30 000+ human genes or proteins (that this section will explore). Guide students to categories such as housekeeping/maintenance, cell division, energy transformation, cell transport, cell death, disease penetration, communication, and growth.
- Tell students that they will explore these categories. Ask probing questions, such as: What conditions must be met before cells divide? What might cause a cell to die? How do cells die? What happens to all cell parts? What might happen to a cell when it has an error in a gene(s) that controls the decision of when to divide?

Specific Expectations

- **B2.1** use appropriate terminology related to cells, tissues, organs, and systems of living things, including, but not limited to: *absorption, anaphase, capillaries, concentration, differentiation, diffusion,meristematic, mesophyll, phloem, prophase, red blood cells, regeneration, stomate,* and *xylem*
- **B2.5** investigate the rate of cell division in cancerous and non-cancerous cells, using pictures, videos, or images, and predict the impact of this rate of cell division on an organism
- **B3.1** describe the cell cycle in plants and animals, and explain the importance of mitosis for the growth of cells and repair of tissues
- **B3.2** explain the importance of cell division and cell specialization in generating new tissues and organs

During Reading

- Have students quiz each other on the Key Terms. Once they have defined each term, students can challenge each other to use the terms in a sentence.
- Ask students to create a short summary (or graphic organizer or chart) of the narrative on page 40 of the student textbook. This should address all the ways mutations in different genes can result in cancerous cell growth.
- A cycle flow chart is one of the best static tools to use to illustrate a dynamic process. It allows students to view previous and future steps while exploring steps in the middle. Animations are strong exemplars of dynamic processes, but serve a different purpose because they can suggest the length of each step. Direct students to the use and value of the cycles presented in Figures 1.27 and 1.28. Focus on these cycles to help students, especially struggling readers, develop a basic understanding of the cell cycle.

After Reading

- Students may be drawn in by the heading Cell Suicide. Ask them to read the text, then as a class, come up with alternative terms for *cell suicide* (e.g., cell recycling). The caption for Figure 1.30 shows how *programmed death* can have very positive outcomes (i.e., differentiating fingers and toes). Remind students that the majority of cells are going through rapid growth and division, not cell suicide.

Using the Images

- Figure 1.29 uses the non-threatening format of a cartoon to connect the complex theory to familiar forms of conceptualization. Explain the value in being able to restate something complex in a new format that connects with the audience. This cartoon representation of the cell cycle checkpoints is based on laborious scientific studies that confirmed these as authentic checkpoints. Guide students to observe that there are two "Stop!" commands at each checkpoint.
- Help students see that there are two separate processes illustrated in Figure 1.31: the top images show normal cell division, replacing a dead cell; the bottom images show the development of a tumour and the difference between a tumour and cancer.

Assessment FOR Learning

Tool	Evidence of Student Understanding	Supporting Learners
Section Review question 2, page 45	Students differentiate between cell death and cell life span (average time between cell divisions).	Have students re-evaluate Activity 1-1 Did You Get the Message? to show how it mimics the cell cycle, with each person in the chain representing a new cell and the time it takes to relay the message representing life span. Students who get a garbled message (inaccurate DNA copy) exit the cycle. When a player gets tired of the game, they exit the cycle. Similarly, when making copies on a photocopier, any scrunched, faded, worn out, or smudged copy exits the cycle. Like paper, the cell parts could get recycled (cell suicide), or the cell could be ejected (go to the landfill).
Section Review question 6, page 45	Students explain that the number of cancer cells undergoing cell division is significantly higher than in a sample of non-cancer cells.	Have students examine Table 1.3 to get a sense of typical life span of cells. Explain that if liver cells reproduce every 200 days, then most of the cells in the liver would not be dividing at any one time. On the other hand, 75 percent of cancer cells are reproducing at any one time. The drug will kill the few liver cells that are reproducing, but it will kill 75 percent of the cancer.
Section Review question 7, page 45	Students point out key characteristics of rapid growth, inaccurate DNA, not performing tissue functions, travelling, and disobeying stop signals.	Provide students with **BLM G-46 T-chart** and **BLM G-47 Venn Diagram** to compare and contrast normal cells and cancer cells.

Instructional Strategies

- Ask students, "How do cells decide what to do next? How do they decide when to divide? What conditions must be met before cells can divide? What causes cell death? What happens when a cell dies? What happens when a cell has a poor DNA copy?
- Ask students to brainstorm examples of checkpoints (e.g., ticket taker at a theatre, border crossing).
- Explain that the times for each period of interphase and mitosis varies for every species, cell type, and age of organism. Therefore these details are omitted from diagrams of the cell cycle. For example, bacteria such as *E. coli,* and embryonic cells of most animals and plants can divide every 15 to 20 minutes.
- Preface any conversation about cancer by establishing sensitivity to students' personal connection to the illness. For example, survey the class for personal connections, respecting students' right not to share. Establish that this section shares what is known about the disease, and that a lot more is left to learn. Have students make private notes about what they already know and wish to know about cancer.
- Show students two micrographs: healthy and cancerous cells from the same tissue. Note that the difference is not visible beyond perhaps the cancer cells being more numerous and closer together.
- To consolidate learning, have the class create a board game based on the cell cycle. The board should progress through the stages of mitosis and interphase, with checkpoints written on appropriate landings. (Examples: "Your DNA is damaged, go back to the start"; "A neighbouring cell is damaged, divide and take another turn.")
- When assigning Section 1.4 Review questions, clarify that the pictures show: A) healthy skin, B) damaged skin, C) brain, and D) muscle.

Section 1.4 Review Answers (Student textbook pages 45)

Please also see **BLM 1-14 Section 1.4 Review (Alternative Format).**

1. **a.** anaphase
   b. whether more of that type of cell are required
2. Example: A cell is born from another cell through division, then grows and carries out the job it is assigned. The cell replicates its DNA and continues to grow until it is large enough to divide through mitosis into two daughter cells. Along the way, the cell may be stopped at many points if various conditions are not met. When the cell is too old or unrepairable, it dies.
3. Skin and digestive system cells have short lives because they are exposed to chemicals (e.g., stomach acids) and physical damage (e.g., burns).
4. injured skin, normal skin, muscle, brain
5. Example: when there are not enough nutrients to support cell growth; when DNA has not replicated; and when DNA is damaged
6. Yes, because cancer cells are rapidly dividing; much more rapidly than healthy cells
7. Wanted posters should describe cancer cells as having mutations and dividing rapidly. The crime(s) might be described as: disobeying stop signs, reproducing or travelling without permission, pushing other cells out of the way, taking an unfair share of resources, and refusal to function like surrounding cells, and travelling without permission.
8. Example: Yes, because cities (cancer cells) that grow without considering whether there is sufficient space, energy, or nutrients to supply the people in them (cells) eventually deplete and damage the environment (organism) on which they rely.

Inquiry Investigation 1-A Examining Cell Structures

(Student textbook pages 46 and 47)

Pedagogical Purpose

The importance of microscopy as a discipline within biology cannot be overstated. An important aspect of being a modern biologist is the ability to perform certain technical or manual skills such as pipetting, performing tissue culturing, and microscopy analyses. When assessing laboratory skills, most tools involve self-confidence surveys, self-reported skills checklists, videotaping performance, portfolios and concept maps, and rubrics to measure accuracy and success.

Planning		
Materials	Compound microscope Prepared slide of human skin cells Prepared slide of tomato (optional) **BLM G-14 Using a Microscope** (optional)	Prepared slide of *Elodea* (or similar) leaf cells Prepared slide of onion (optional) Electron microscope micrographs of a human skin cell (optional)
Time	20 min prep 60 min in class	
Safety	Be sure your hands are dry when you plug in or disconnect the cord of the microscope. The glass or plastic slides and cover slips used to mount specimens are fragile and can break easily. Ensure students handle them carefully to avoid getting a cut. Have a broken glass receptacle on hand.	

Background

The light or optical microscope is the most commonly used microscope, using glass lenses to focus beams of visible light for viewing and image capture. Typical resolution is 0.2 mm (micrometers), making this a great tool for cell study at this level.

In 2008, the most powerful electron microscope on Earth was installed at McMaster University in Hamilton. The Titan 80-300 Cubed allows researchers to peer into molecules and atoms on a scale never before possible. It is so sensitive that the building is isolated from sound and vibration, and the operator cannot be in the room with it when it is capturing images.

Activity Notes and Troubleshooting

- Spirogyra or banana cells may be used in place of *Elodea* leaf cells.
- Review proper and effective use of the microscope using either **BLM G-14 Using a Microscope,** or Science Skills Toolkit 8 (pages 546 and 547 of the student textbook). Link the parts of the microscope to each step in the procedure. Use **BLM A-48 Using Tools, Equipment, and Materials Rubric** to assess students use of the microscope.
- Review how to make diagrams using either **BLM G-11 Scientific Drawing** or Science Skills Toolkit 6 (pages 543 and 544 of the student textbook).
- Have students work individually or in pairs.
- Prepare one set of slides for each student or pair to view at the same time.
- Coach students to focus the microscope by first placing the specimen in the middle of the field of view.

- Students may find that **BLM A-7 Scientific Drawing Checklist** provides a starting point or useful check for their drawings.
- Have supplies on hand for students who to wish to pursue the Extend Your Inquiry and Research Skills question (e.g., onion and tomato samples; iodine for staining). **BLM G-33 Experimental Design Worksheet** and Science Skills Toolkit 2 (pages 532 to 535 of the student textbook) may help students begin.
- Have electron microscope micrographs of a human skin cell available to help students with question 7.
- Direct students to the Microscopy Society of Canada for information on new microscopic findings and micrographs. Go to **www.scienceontario.ca** for more information and links.
- Use **BLM A-40 Scientific Drawing Rubric** to assess students' drawings.

Additional Support

- DI This is an excellent investigation for visual and spatial learners.
- Enrichment—Have students look at other cells, such as protozoa. Students may wish to explore all kingdoms and compare cell size and organelles in each cell.
- Project a slide onto a screen or monitor, and work as a class to identify the structures.

Answers

1. Example: The high power lens lets me see enough detail to distinguish the features.

2. – 3. Example:

Elodea Cell		Human Cheek Cell	
What is the large space in the middle?	It does not appear to be the nucleus, likely a large vacuole for water storage to support cell structure	What is surrounding the cell?	I could not see a definite outline of a cell/plasma membrane, so it must be thin.
Why is the nucleus not in the middle?	The large vacuole could be pushing it to the side. The nucleus does not have to be in the middle.	What does the shape of these cells tell me?	These cells are flat and used to be beside each other in the cheek. They act like a skin cell barrier as one continuous layer.
What is surrounding the cell?	There is a very strong, dark line around the cell. It could be the cell wall.		
What are all those spots inside cells?	They could be storage vacuoles, or chloroplasts.		

4. Example: I could see nuclei clearly (and the cell wall and chloroplasts in the *Elodea*) but the vacuoles, cell membranes, and endoplasmic reticulum were unclear.

5. Example: Greater magnification and more control of the light in the microscope as well as in the classroom would improve the view of the cell. Also, a different type of microscope would help to see the contents better, such as an electron microscope.

6. Example: Cell structures of other plants would be similar.

7. a. endoplasmic reticulum, Golgi body, vacuole, mitochondrion, ribosome,

b. See the endoplasmic reticulum in Figure 1.5 (student textbook page 12) or the mitochondrion in Figure 1.6 (student textbook page 13).

Inquiry Investigation 1-B Mitosis in Plant and Animal Cells

(Student textbook pages 48 and 49)

Pedagogical Purpose

Today, students have access to a variety of visual examples of mitosis; micrographs, illustrations, real-time videos, animations and simulations. However, it is important for students to use the microscope to view previously made microslides to practise their microscopy skills, understand the magnification and scale of these cells, and to observe the static capture of mitosis in action for themselves.

Planning		
Materials	Compound microscope Prepared slide of onion root tip The day before, prepare slides.	Prepared slide of whitefish embryo **BLM G-14 Using a Microscope** (optional)
Time	20 min prep 80 min in class	
Safety	Be sure your hands are dry when you plug in or disconnect the cord of the microscope. The glass or plastic slides and cover slips used to mount specimens are fragile and can break easily. Ensure students handle them carefully to avoid getting a cut. Have a broken glass receptacle available.	

Background

The cells in onion root tips are meristematic (undifferentiated) and constantly divide as the tip grows. Whitefish embryo cells have become the standard for viewing mitosis in animal cells, as it has proven too difficult to find other animal specimens that have concentrated areas of mitotic growth. It is more difficult to find a concentrated area of active division in animal cells.

Activity Notes and Troubleshooting

- Review proper and effective use of the microscope using either **BLM G-14 Using a Microscope** or Science Skills Toolkit 8 (pages 546 and 547 of the student textbook). Link the parts of the microscope to each step in the procedure. Use **BLM A-48 Using Tools, Equipment, and Materials Rubric** to assess students' use of the microscope.
- Review how to make diagrams using either **BLM G-11 Scientific Drawing** or Science Skills Toolkit 6 (pages 543 and 544 of the student textbook).
- Have students work individually or in pairs.
- Prepare one set of slides for each student or pair to view at the same time.
- Coach students to focus the microscope by first placing the specimen in the middle of the field of view.
- If students have difficulty locating cells captured in mitosis, ensure they are viewing the tip of the onion root specimen, where the most active meristem is located.
- Students often believe that they are looking at a few cells under low power, when in reality they are viewing hundreds. Remind them to use a higher power lense to focus on a few cells to accurately observe any phases.
- To facilitate comparisons and organize drawings, have students fold their papers in half twice to produce two columns of four squares. Use one column for plant cells and the other for animal cells.

- Students may find that **BLM A-7 Scientific Drawing Checklist** provides a starting point or useful check for their drawings.
- Use **BLM A-40 Scientific Drawing Rubric** to assess students drawings.

Additional Support

- DI This is an excellent investigation for visual and spatial learners.
- Remind students that an embryo is a group of actively dividing cells, initially begun by sexual reproduction.
- Enrichment—Students can look at other cells available, such as protozoa. Students may wish to explore all kingdoms and compare cell size and organelles in each cell.
- Project a slide onto a screen or monitor, and work as a class to identify the structures.
- Have models of plant and animal mitosis available for students to observe.
- Have micrographs available for comparison to what students observe.
- Have students with artistic skill support those students struggling to produce scale drawings.
- If available, attach a camera to the microscope.
- Allow students to describe what they see before drawing it.

Answers

1. The cells near the root tip are smaller and more numerous than those farther from the root tip. More of these cells are reproducing (in mitosis), and most are in metaphase, then prophase, telophase, and anaphase (by quantity).
2. The onion root tip cells have a cell plate forming across the middle, while the whitefish embryo cells are getting pinched inwards along the equator.
3. Example: Human bone or plant leaf cells do not undergo mitosis often enough to ensure many samples. Embryo and root tip cells are growing rapidly, so have the most number of cells undergoing mitosis.
4. Example: Place as thin a slice as possible onto a microslide then add stain to make the structures stand out.
5. Cytoskeleton is viewed using phalloiden (attached to a fluorescent dye). Mitochondria are viewed using MitoTracker, Mitofluor, Rhodamine 123, or MitoLight. Lysosomes are viewed using LysoTracker or LysoSensor. Endoplasmic Reticulum is viewed using DiOC6(3) (a fluorescent lipid), Nissl stain, or ER-Tracker. DNA (nucleus) is viewed using DAPI (a fluorescent dye). None of these dyes are considered significantly hazardous to health. However, some of the solvents in which they are dissolved should not come into contact with skin or eyes. First aid involves flushing the area with water for 10 minutes, moving the person to fresh air, and seeking medical advice. All stains should be disposed of in a waste container, not poured down the drain.

Data Analysis Investigation 1-C Does the Patient Have Cancer? (Student textbook page 50)

Pedagogical Purpose

Data analysis and reporting are two critical skills in medicine, often completed by laboratory technicians. In this investigation, students are asked to infer a medical diagnosis of health or cancer from a given data set, consolidating both an understanding of the norms of cell reproduction and interpreting data through graphing.

Planning		
Materials	Graph paper or graphing software Cell growth data set from student textbook	Coloured pencils (optional)
Time	60 min	

Background

There are a number of methods that identify cancer cells. Initially, doctors conduct screening tests such as this one when the patient is not yet sick. If abnormal growth is detected, diagnostic tests follow. Some screening tests happen on the sub-cellular level; counting nuclei, total protein, or DNA synthesis rate.

Samples are usually obtained by fluid collection (e.g., blood) or by biopsy (excised tissue). This investigation does not specify the type of cells under investigation. If this sample was deemed cancerous, it would be named by the tissue from which it came (e.g., cancer in breast cells are named breast cancer).

The proportion of cells growing and dividing varies from tumour to tumour. For example, if more than 6 percent to 10 percent of the cells are dividing, the rate of growth is considered "unfavourably high." Identifying the type of cancer is more challenging.

It is important that students understand there is a multi-step process for all cancer investigations. Later, a pathologist may look at other characteristics including the "grade" of cell growth, and the number of dead cells within the tumour (more dead cells means a high rate of growth).

Continuing the study of cancer in this investigation following the narrative's focus on cancer may provoke questions and pre-conceptions students have about cancer and the causes of cancer. A comprehensive list of myths (e.g., anti-perspirants cause breast cancer) can be found on the Canadian Cancer Society website. In addition, the information is presented in multiple languages to better inform all Canadians. Go to **www.scienceontario.ca** for more information and links.

Activity Notes and Troubleshooting

- Ask students if they think this investigation models a screening test or a diagnosis test, and why. (Answer: Screening, since diagnosis would require examination of the cells themselves, not just their rate of growth.)
- Focus students on their specific role in this investigation and the voice they should use in the written conclusions. They represent the laboratory pathologists who communicates with the family doctor. Their tone and medical sophistication can and should be at a higher level. They should directly reference their data analysis (i.e., graphs), note the length of the study (i.e., 90 days) and the dependent variable (i.e., number of cells in culture).
- This activity may be completed in class or as homework.
- For guidance and support in making the graphs, refer students to **BLM A-19 Graph from Data Checklist** or Math Skills Toolkit 3 (student textbook page 556).

- Just after students have analyzed their graphs, ask them to reflect on the data they were provided. Does it appear to be enough data? On the other hand, is 90 days too long to wait for information about a tissue sample and the possibility that it is a cancerous tissue sample? Are there faster methods of diagnosis for real patients?

Additional Support

- DI This is an excellent activity for logical-mathematical learners. Encourage them to write mathematical expressions to represent the growth of the normal and patient sample cells, then predict the population at 180 days and so forth.
- ELL Read the introductory paragraph aloud, having English language learners flag unfamiliar terms such as physician, culture, and abnormalities. Explain that "to culture cells" means to grow a population of cells from a sample. Have them write definitions on the flags.
- ELL Direct English language learners to the Canadian Cancer Society for information in their first language.
- Visual learners may benefit from seeing (either in photos or a video) a cultured sample with a grid overlay to understand how the rate of population growth can be determined.
- Allow students to use graphing calculators or software.
- Model part of the process on the board.
- Demonstrate how to use colours or shapes to represent different data sets on the graph.

Answers

1. Example: The sample cells divide (increase in number) at two or three times the rate of the normal cells.

2. The patient's sample cells divided (increased in number) at a much faster rate than the normal cells over the 90-day test period. These cells are performing at a cancer-growth rate.

3. a. On day 90, normal cells will use 128 units of energy to divide and the patient's sample will use 360 units.

b. Example: The patient is likely tired and either more hungry or losing fat because the cancer is using so much energy.