The Cell Cycle and Mitosis

Strand		Life at the Molecular and Cellular Level
Topic		Investigating mitosis and the cell cycle
Primary SOL	BIO.5	The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include a) cell growth and division.
Related SOL	BIO.3	The student will investigate and understand relationships between cell structure and function. Key concepts include b) characteristics of prokaryotic and eukaryotic cells.

Background Information

In eukaryotic cells, the cell cycle is an ordered set of events involving phases of cell growth, DNA replication, and division into two identical daughter cells. Nondividing cells are not considered to be in the cell cycle. The phases of the cell cycle, in order, are

- interphase, which includes
  - first gap (G_1) phase (cell growth)
  - synthesis (S) phase (cell growth and DNA/chromosome replication)
  - second gap (G_2) phase (cell growth)
- mitosis (M) (chromosome separation and nuclear division), which includes
  - prophase
  - metaphase
  - anaphase
  - telophase
- **cytokinesis (cytoplasmic division of cell).**

In prokaryotes, the process that provides for equal and identical replication of DNA in the daughter cells is called “binary fission.” DNA is not organized into chromosomes in bacteria.

Because of surface-area-to-volume limitations, and to replace lost or damaged cells, tissues and single-celled organisms must have a way of reproducing. The most efficient way is mitosis. For unicellular organisms like prokaryotes, mitosis is also the method of asexual reproduction.

Most instructional resources contain diagrams, descriptions, and photographs of the cell cycle in animal and plant cells to show and explain what is happening in interphase, prophase, metaphase, anaphase, telophase, and, finally, cytokinesis. Some resources also give information about what is happening in the “early, middle, and late” stages of the phases, alluding to the fact that this is a continuous process and that views are most often “midphase” to show an “average” or “effective” view of what is happening in this dynamic cycle.

The time the cell cycle takes in multicellular organisms depends on a number of factors, not the least of which is the type of tissue involved: cells exposed to the outside of the organism (usually epidermis) or located in meristematic growth regions undergo mitosis and cytokinesis more rapidly than the more persistent cells in nervous tissue, which in a mature vertebrate organism may not reproduce at all.

Materials

- Copies of the four attached handouts
- Prepared slides of onion root tip cells in the various phases of the cell cycle
- Prepared slides of animal cells in the various phases of the cell cycle
- Microscopes
- Drawing materials or microphotographic hardware and photo-editing software

Optional lab

- Latex gloves
- Apron or lab coat
- Safety glasses
- Fresh onion root tips
- Water
- Knife
- Plastic bag
- Hydrochloric acid, 18%
- Carnoy fluid with chloroform
- Slides
- Toluidine blue, 2%
- Eyedropper
- Coverslips
- Compound microscope

Vocabulary

anaphase, cell plate, chromatid, chromatin, chromosome, cytokinesis, equatorial plate, G_1 phase, G_2 phase, interphase, metaphase, mitosis, nuclear membrane, prophase, S phase, spindle fiber, telophase

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

Having students observe prepared slides is the most timesaving and resource-efficient way to perform this lesson. Alternatively, you may have them use the squash-and-smear technique with hydrochloric acid and toluidine stain-to-stain fresh preparations, which is a rewarding but time-consuming and somewhat unpredictable process. Students can use either of these processes to document observations of the phases of nuclear division and cytokinesis.

1. Introduce the basic organization and terminology of the cell cycle by having students complete the attached handout The Cell Cycle Pie. (This will prepare students to use that terminology in the main activity.)
2. Have students observe and document the appearance of cells in all phases of the cell cycle, using either prepared slides or freshly made ones. Have them draw and label the parts of the cell as appropriate, showing at least the
   - cell wall
   - cytoplasm
   - nucleus
   - nuclear membrane
   - spindle fiber
   - chromosomes

- chromatin
- cell plate.

If students are to use fresh material, have them follow the procedure on the attached Preparing an Onion Root Tip Squash Mount Slide handout or use a procedure found in a standard reference.

3. Have students document their observations of the phases of mitosis and cytokinesis by preparing either labeled drawings or, if microphotography and photo-editing tools are available, labeled photomicrographs of the phases of the cell cycle.
4. Have students infer and then calculate the time a dividing cell spends in each phase of the cell cycle. Direct them to observe a total of 200 cells, using either prepared or freshly made slides, and record which phase each cell is in. Inform them that among the 200 cells, the percentage of cells found in each phase is directly proportional to the percentage of time a cell stays in that phase.
5. Have students present their observations and findings, labeled drawings or photomicrographs, and time calculations.

Assessment

- **Questions**
  - Does a cell in a rapidly growing part of an organism go through mitosis continually? Explain.
  - How does the time mitosis takes compare to the time taken by the cell to fulfill its main function?
  - Explain in terms of mitosis why you look different than you did five years ago.
  - What would happen if your cells would spend the majority of the time in mitosis? What kinds of diseases in which this happens can you name?
  - What is apoptosis? Why is it necessary?
- **Journal/Writing Prompts**
  - Write a story about a person who does each of these things *in order* in his/her own way: Grow, copy, prepare, break down, face/confront/meet, pull apart/separate, build something new, start over. (You might have students do this as a pre- or post-learning activity.)
- **Other**
  - Have students prepare a slide show or narrated Claymation of the cell cycle with explanations of what is happening in each phase.
  - Have students prepare an animated hyperstack (thumb flipbook) to show the dynamic nature of the process of mitosis.
  - Have students complete the attached Cell Cycle Cookies activity to illustrate the major phases of the cell cycle.

Extensions and Connections (for all students)

- Have students investigate the G_0 phase of interphase, including which cells in their bodies that are in that phase most of their lives.
- Discuss the role of checkpoints, oncogenes, and tumor suppressor genes in the onset of cancer.

- Have students locate information on diseases that result from defects in the process of mitosis. Then, have them describe the changes that cause each disease.
- Have students locate information on the times various tissues in the vertebrate body need to complete the process of mitosis. Then, have them prepare charts comparing these times.
- Have students locate information on environmental factors that alter the process of mitosis or its rate. Then, have them provide plausible reasons why this happens.
- Have students compare the process of mitosis in animal and plant cells, noting any differences (phragmoplasts, centrioles, cleavage furrows).
- Have students explain how we can use juvenile hormones to influence the process to mitosis to our advantage.

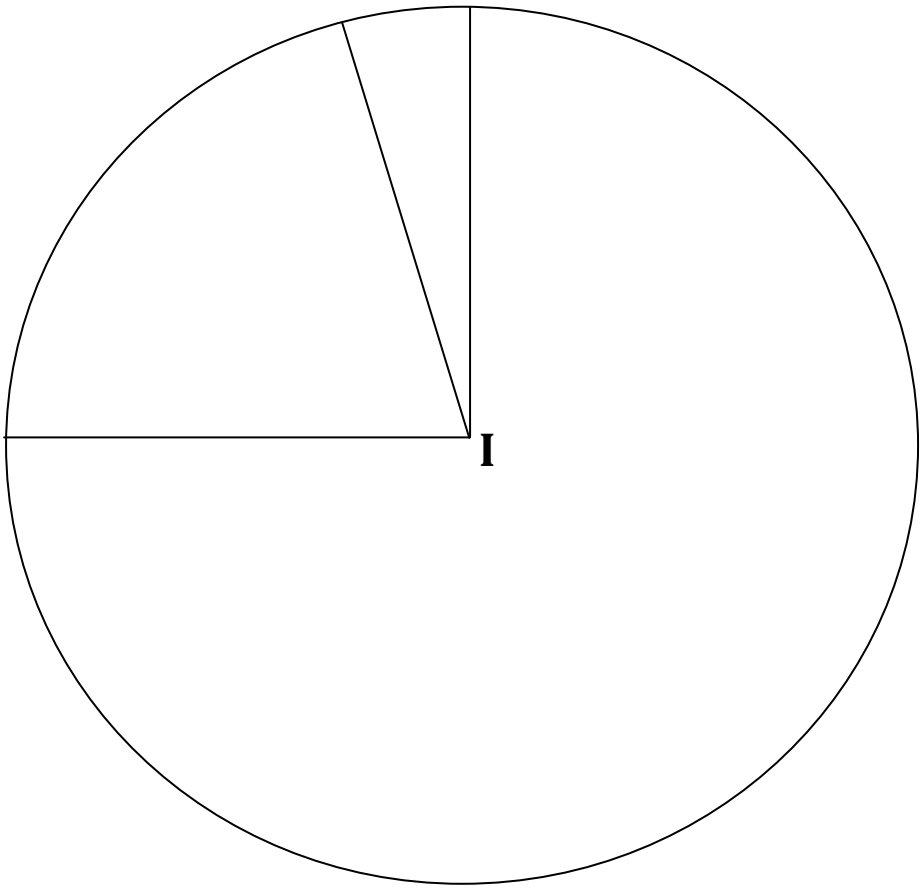
Strategies for Differentiation

- Have students complete the attached Cell Cycle Vocabulary Pyramid.
- Employ flexible groupings of students by grouping them according to common readiness levels, shared interests, or diverse strengths.

The Cell Cycle Pie

Procedure

1. Divide the interphase section of the pie, labeled "I," into three equal slices. Label them "G1," "S," and "G2."
2. Write one keyword in each of the interphase slices to identify what occurs during each part of interphase.
3. Color the interphase section of the pie green.
4. Divide the mitosis section of the pie, labeled "M," into four equal slices. Label them "prophase," "metaphase," "anaphase," and "telophase."
5. Write one keyword in each of the mitosis slices to identify what occurs during each phase of mitosis.
6. Color the mitosis section of the pie yellow.
7. Write one keyword in the cytokinesis slice, labeled "C," to identify what occurs during cytokinesis.
8. Color the cytokinesis section of the pie blue.
9. Write a phrase to help you remember the order of the cell cycle steps—interphase, prophase, metaphase, anaphase, telophase, and cytokinesis. Use the first letter of the name of each step to come up with the phrase (e.g., "**I** **p**aid **m**y **a**unt **t**o **c**ook.").



Preparing an Onion Root Tip Squash Mount Slide[1]

Materials

- Latex gloves
- Apron or lab coat
- Safety glasses
- Fresh onion root tips
- Water
- Knife
- Plastic bag
- Hydrochloric acid, 18%
- Carnoy fluid with chloroform
- Slides
- Toluidine blue, 2%
- Eyedropper
- Coverslips
- Compound microscope

Procedure

1. Put on a pair of latex gloves, safety glasses, and an apron or lab coat.
2. Wash an onion set (seedling), peel off the outer layers, trim away the old root tips, and place it in a plastic bag for several days to allow its roots to grow.
3. Remove the set from the bag, and cut off its root tips. Place them in 18% hydrochloric acid for 4 minutes.
4. Transfer them to carnoy fluid with chloroform, and let them sit for 4 minutes.
5. Place one of the root tips on a slide, and trim away all but 1 to 2 mm of the tip.
6. Cover the tip with 2 to 3 drops of 2% toluidine blue for 2 minutes.
7. Blot away the stain, add a drop of water, cover with a coverslip, and apply pressure to the coverslip with a pencil eraser until the cells in the tip spread out in a single layer.
8. Mount the slide on your microscope.
9. Use the low-power objective on your microscope to look for thin layers of cells. Then, use the high-power objective to observe mitotic stages in individual cells.
10. Describe in writing what you observe.

[1] This activity was taken from http://www.carolina.com/calendar_activities/2001/0111.asp, Used by permission. The procedure for creating a squash mount slide is from the Onion Mitosis BioKit®. The materials for the procedure can be purchased independently elsewhere.

Cell Cycle Cookies

Ingredients

- Eight cookies or 8 graham crackers
- White frosting
- Four different colors of sprinkles

Cooking

1. Frost eight cookies or graham crackers with white frosting.
2. **Interphase:** In the center of the first cookie, add 8 "sprinkle chromatids" (2 of each of 4 different colors) in a clump. (Use the same 4 sprinkle colors on all 8 cookies.)
3. **Prophase:** In the center of the second cookie, pair 8 sprinkle chromatids of the same 4 colors to make 4 chromosomes.
4. **Metaphase:** In a line down the middle of the third cookie, pair and arrange 8 sprinkle chromatids of the same 4 colors to make 4 chromosomes.
5. **Anaphase:** On one side of the fourth cookie, place 4 sprinkle chromatids of the same 4 different colors, and place their 4 partners on the other side.
6. **Telophase:** Put the fifth and sixth cookies side-by-side *touching*. Place 4 sprinkle chromatids of the same 4 different colors on one cookie, and put their 4 partners on the other.
7. **Cytokinesis:** Place the seventh and eighth cookies *separated by a space*. Place 4 sprinkle chromatids of the same 4 different colors on one cookie, and put their 4 partners on the other.

Documenting

1. Create in your notebook a colored sketch of each phase, labeling the phases.
2. Describe in words what is occurring in each phase.

Eating

Once your teacher has approved your documentation, you may eat the cookies, if you wish.

Cell Cycle Vocabulary Pyramid

The cell cycle contains the phases of interphase, prophase, metaphase, anaphase, and telophase, as well as cytokinesis.

1. On the top level of the pyramid, write the term you feel will be the *most difficult* to remember. On the next level, write the next two hardest terms. Write the last three terms on the bottom level.
2. On six individual sticky notes, draw a picture of each phase and cytokinesis, and place each note over the corresponding term.
3. On another set of six individual sticky notes, describe what happens in each phase, and place each note over the corresponding image.
4. Trade pyramids with another student. Try to identify the phases, based on their descriptions. If you need a hint, lift the sticky note to reveal the picture. Practice trading with other students until you've got it!