



## Cancer Education Project

# Cancer and the Cell Cycle

### Overview:

This series of 6 learning experiences is designed to give students a basic understanding of the cell cycle in the context of skin cancer. As students move through the activities, their understanding shifts from a simplistic definition towards an understanding of regulation of the cell cycle and how lack of regulation can lead to cancer. Learning experiences include:

- Part 1: Information gathering in the context of a young female who has been diagnosed with skin cancer.
- Part 2: Exploration of a basic understanding of cancer from a historical perspective. This experience utilizes a series of four short video clips from the NIH Supplement: Cell Biology and Cancer.
- Part 3: Class Lecture Notes.
- Part 4: Mitosis Lab that includes a mitosis simulation using red and yellow popping beads, and online and hands-on experiences identifying cells in various stages of mitotic division.
- Part 5: Cell animations from the NIH Supplement, *Cell Biology and Cancer* that bridge cell cycle and cancer information.
- Part 6: Modeling the cell cycle in a normal cell
- Part 7: Modeling the cell cycle in a cancer cell

### Living Environment Major Understandings:

- Gene mutations in a cell can result in uncontrolled cell division, called cancer. Exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer.
- Feedback mechanisms have evolved that maintain homeostasis.

**Lesson Setup:**

Time	Part #: Title	Materials
Homework 20 minutes for review of answers	Part 1: Catching Some Killer Rays	<ul style="list-style-type: none"> <li>• Part 1: Catching Some Killer Rays handout</li> <li>• Student text or other resource to gather information</li> <li>• Cell Cycle Chart</li> </ul>
20 minutes	Part 2: Cancer a Historical Perspective	<ul style="list-style-type: none"> <li>• Handout for Activity 2 from NIH: <i>Cell Biology and Cancer</i>. Master 2.1a Section 1 available on CD or online at <a href="http://science.education.nih.gov/supplements/nih/1/cancer/default.htm">http://science.education.nih.gov/supplements/nih/1/cancer/default.htm</a></li> <li>• To print, select “Teachers Guide” then “PDF Files for Printing” then “Activity 2 Masters”, download and print “Understanding Cancer” worksheet.</li> <li>• To view videos online: <a href="http://science.education.nih.gov/supplements/nih/1/cancer/">http://science.education.nih.gov/supplements/nih/1/cancer/</a> Click on “Web Portion of Student Activities”, then click on “Cancer and the Cell Cycle”</li> </ul>
20 minutes	Part 3: Class Notes on Mitosis	<ul style="list-style-type: none"> <li>• Part 3: Class Notes on Mitosis handout. Student version and key for teachers provided.</li> </ul>
80 minutes	Part 4: Mitosis in Plant and Animal Cells	<ul style="list-style-type: none"> <li>• Part 4: Mitosis in Plant and Animal Cells laboratory handout.</li> <li>• Popping bead kits</li> <li>• Internet access to: <a href="http://www.biology.arizona.edu">www.biology.arizona.edu</a> Click on “Onion Root Tips” on left side column.</li> <li>• Slides of onion root tip or other sample cells in mitosis</li> <li>• Microscope</li> </ul>
40 minutes	Part 5: Causes of Cancer Animations	<ul style="list-style-type: none"> <li>• Worksheet for Activity 2 from NIH: <i>Cell Biology and Cancer</i>. Master 2.1a Section 2 available on CD or online at <a href="http://science.education.nih.gov/supplements/nih/1/cancer/default.htm">http://science.education.nih.gov/supplements/nih/1/cancer/default.htm</a> To print, select “Teachers Guide” then “PDF Files for Printing” then “Activity 2 Masters”, download and print “Understanding Cancer” worksheet.</li> <li>• To view animations online: <a href="http://science.education.nih.gov/supplements/nih/1/cancer/">http://science.education.nih.gov/supplements/nih/1/cancer/</a> Click on “Web Portion of Student Activities”, then click on “Cancer and the Cell Cycle”, then click on “Cell Cycle Animations”</li> </ul>
40 minutes	Part 6: Modeling the Normal Cell Cycle	<ul style="list-style-type: none"> <li>• Cell Cycle Wheel</li> <li>• Cell Cycle Modeling Kit (one per group of 4 students)</li> <li>• Part 6: Modeling the Normal Cell Cycle</li> </ul>

		<ul style="list-style-type: none"><li>• Bingo chips</li></ul>
40 minutes	Part 7: Modeling the Cell Cycle and Cancer	<ul style="list-style-type: none"><li>• Cell Cycle Wheel</li><li>• Cell Cycle Modeling Kit (one per student group of 4 students)</li><li>• Part 7: Modeling the Cell Cycle and Cancer</li></ul>

**Teacher Instructions - Part 1**  
**Catching Some Killer Rays**

1. Distribute copies of *Part 1: Catching Some Killer Rays*.
2. Read through scenario in class.
3. Assign questions #1-6 to be completed for homework using textbooks or other resources.  
Alternate: May be assigned in class as group work.
4. Review answers in class the following day round-robin style.

## Part 1: Catching Some Killer Rays

Sheena had always liked to lie out in the sun. She just wasn't happy unless her skin was a golden brown color. Even in the winter, she insisted upon removing the cold white appearance of her skin. "I've got to get to the tanning bed!" would be her weekly slogan.

Towards the end of her senior year in college, Sheena began to notice a strange black spot on her back. It had not been there a few years ago, and it seemed to look a little different everyday.

Sheena decided to show this strange black mark to her doctor. He diagnosed her with malignant melanoma, a serious form of skin cancer. Her doctor described "Melanoma" as a disease of the skin in which cancer (malignant) cells are found in the cells that color the skin (melanocytes)." He further explained that the first step in treatment is the removal of the melanoma, and the standard method of doing this is by surgical excision - cutting it out. If the cancer has spread, then chemotherapy will be necessary.

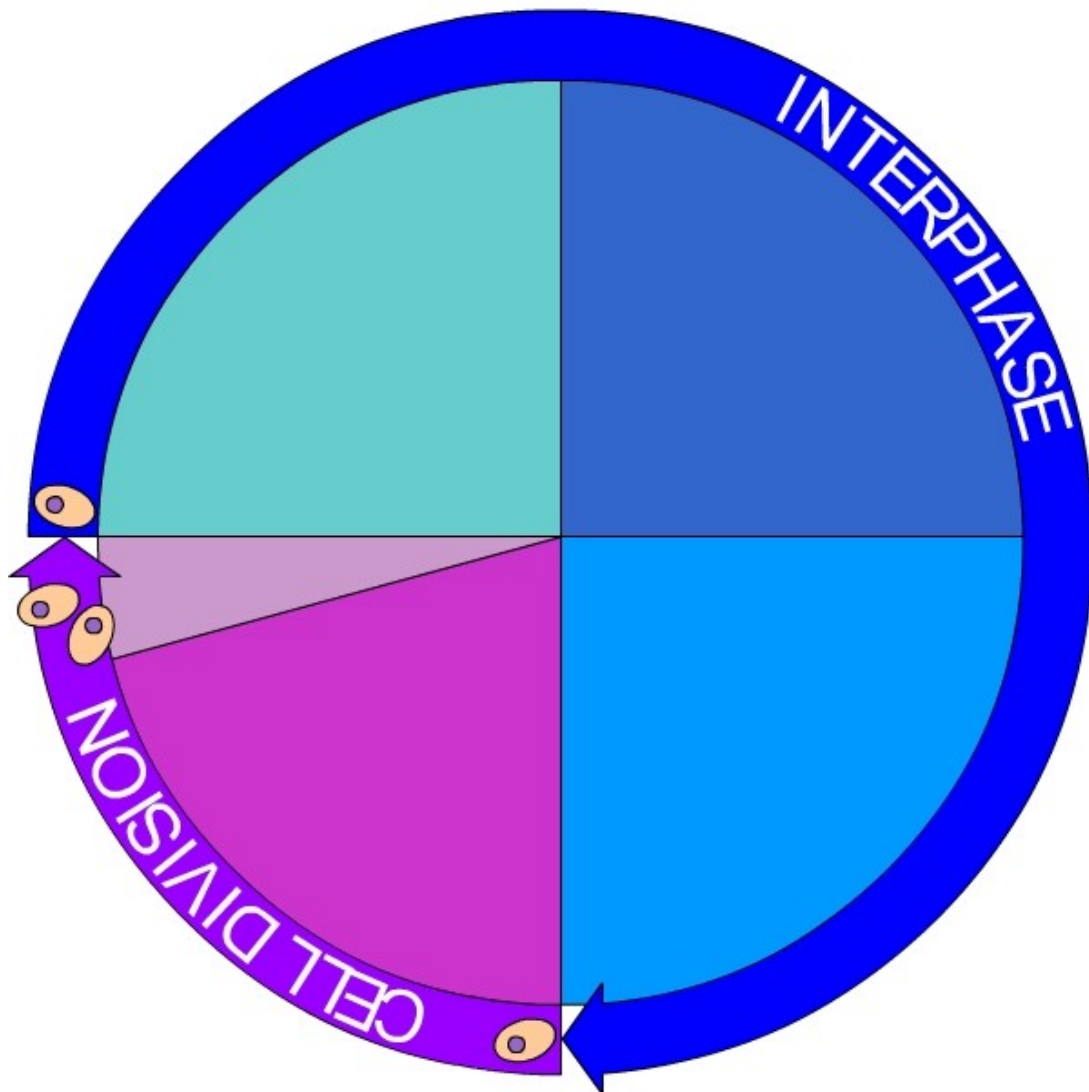
Sheena's head was spinning. She knew she needed a minute to digest the information just given to her. Before Sheena made any decisions, she decided to do a little research.

Much of the information that Sheena found centered upon the cell cycle. She remembered taking biology in high school, but couldn't recall anything about the cell cycle. She decided to investigate a little further.

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1. Define cancer.
  2. What is the cell cycle?
  3. What is the process of cell division called?

4. What is the period of growth between cell divisions called?

5. Using the following terms (mitosis, G<sub>1</sub>, G<sub>2</sub>, S, and cytokinesis), complete the Cell Cycle Diagram that shows the phases of the cell cycle.



5. Complete the following chart by explaining what happens to the cell and the chromosomes during each phase:

<b>Cell Division</b>	<b>Mitosis</b>
	<b>Cytokinesis</b>
<b>Interphase</b>	<b>G1</b>
	<b>S</b>
	<b>G2</b>

## Teacher Instructions - Part 2

### Cancer a Historical Perspective

1. Explain to students that the cancer and cell cycle information Sheena found was not the result of one person's research. Rather, our knowledge of cancer has developed slowly over a period of time. The four video clips students will watch highlight some historical knowledge of the causes of cancer.
2. Distribute one copy of the worksheet from Activity 2 Section 1 to each student. This handout for Part 2 is available from NIH: Cell Biology and Cancer. Master 2.1a, Section 1 available on CD or online at <http://science.education.nih.gov/supplements/nih1/cancer/default.htm> To print, select "Teachers Guide" then "PDF Files for Printing," then "Activity 2 Masters", download and print "Understanding Cancer" worksheet.
3. Using a computer projector, distribute one copy of CD to each student group, open "Cell Biology and Cancer". Click on "Cancer and the Cell Cycle", then click on "news Alert Videos". Or, to view videos online go to: <http://science.education.nih.gov/supplements/nih1/cancer/> Click on "Web Portion of Student Activities", then click on "Cancer and the Cell Cycle".
4. Watch News Alert Video #1, "Cancer and Chemical Poisons".
5. Have students individually fill in the chart on worksheet that corresponds to this video.
6. Watch News Alert Video # 2, "Cancer and Your Family History".
7. Have students individually fill in the chart on worksheet that corresponds to this video.
8. Watch News Alert Video #3, "Cancer and Radiation Exposure".
9. Have students individually fill in the chart on worksheet that corresponds to this video.
10. Watch News Alert Video #4, "Cancer and UV Light".
11. Have students individually fill in the chart on worksheet that corresponds to this video.
12. Give students 5-7 minutes to discuss their answers with their group.
13. Create a classroom "Understanding Cancer" chart by discussing answers with whole group.



**Teacher Instructions - Part 3**  
**Class Notes on Mitosis**

1. Explain to students that much of our knowledge of cancer focuses on how cells divide. This activity allows students to follow the major changes in the nucleus during cell division. Distribute one copy of *Part 3: Class Notes on Mitosis* to each student
2. Complete as lecture notes or as a group study guide.

### Part 3: Class Notes on Mitosis

1. The process of **mitosis** is used as a method of \_\_\_\_\_ for single-celled organisms and some multicellular organisms. Mitosis is also used for for \_\_\_\_\_ and \_\_\_\_\_ in multicellular organisms.
2. When mitosis is used for reproduction, it is considered \_\_\_\_\_.

What does this mean? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

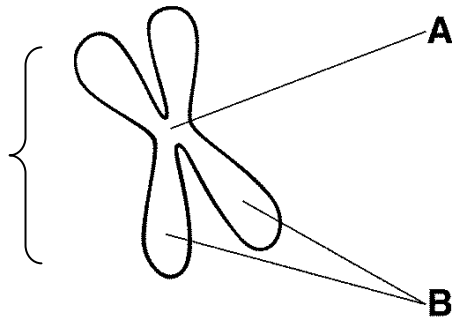
3. Examples of **asexual reproduction** include:
  - a.
  - b.
  - c.
  - d.
4. Mitosis occurs during **early embryonic development**. Remember that the one-celled zygote must divide and become the millions of cells that make a human body!!.

5. Process of **mitosis**:

**Step 1:** Chromosomes \_\_\_\_\_.

What does this mean? \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

**Step 2:** Chromosomes become double stranded (label)



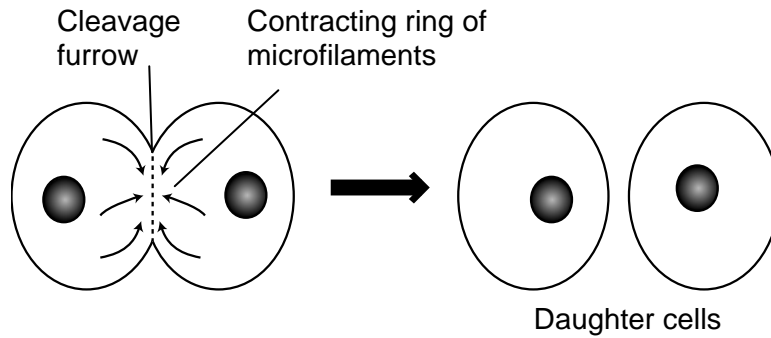
**Step 3:** Chromosomes line up in the \_\_\_\_\_ of the cell.

**Step 4:** Double stranded chromosomes \_\_\_\_\_  
\_\_\_\_\_

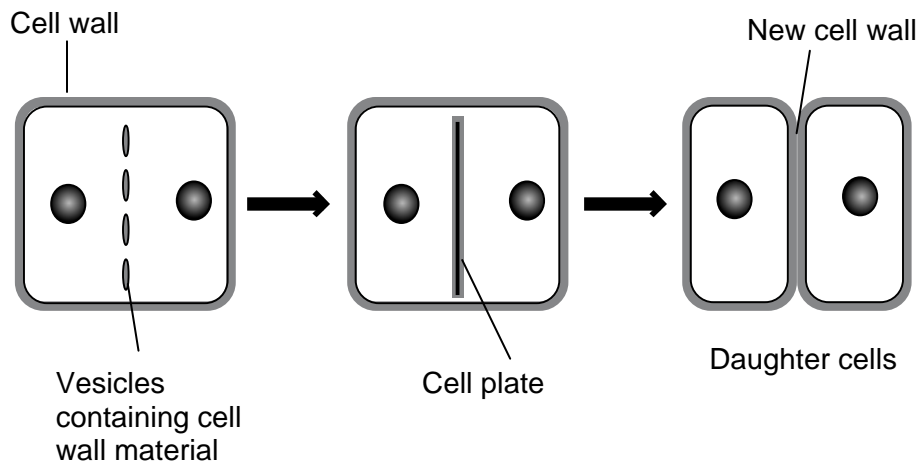
**Step 5: Cytokinesis** \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

6. Differences between plant and animal cell cytokinesis:

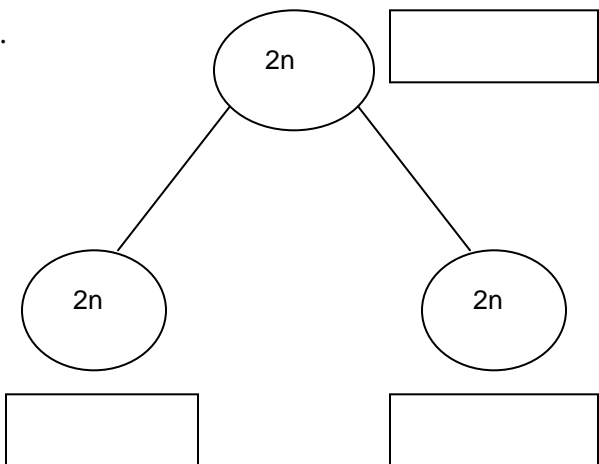
### Cleavage of an animal cell



### Cell plate formation in a plant cell



7.



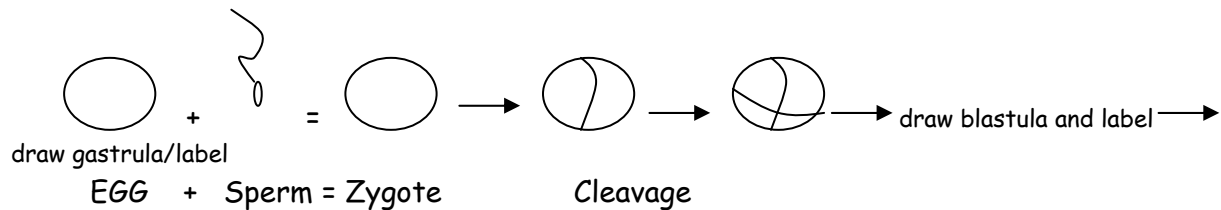
**Part 3: Class Notes on Mitosis Teacher Key**

1. The process of **mitosis** is used as a method of reproduction for single-celled organisms and some multicellular organisms. Mitosis is also used for growth and repair in multicellular organisms.
2. When mitosis is used for reproduction, it is considered asexual.

What does this mean? One parent, offspring are genetically identical to parent and to each other.

3. Examples of **asexual reproduction** include:
  - a. **binary fission**
  - b. **budding**
  - c. **tubers, bulbs, runners, rhizomes**
  - d. **vegetative propagation**

4. Mitosis occurs during **early embryonic development**. Remember that the one-celled zygote must divide and become the millions of cells that make a human body!! (Draw on board and have students copy)

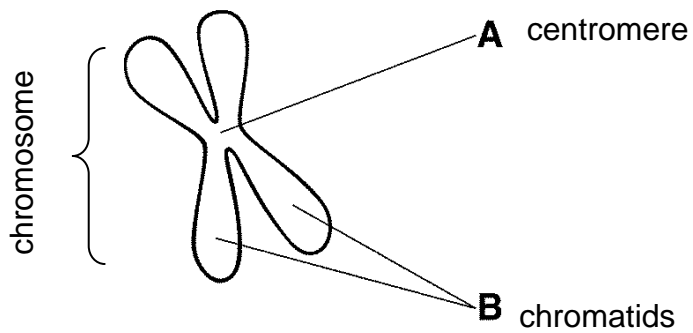


## 5. Process of mitosis

**Step 1:** Chromosomes replicate.

What does this mean? Make exact copies of themselves, Make reference to DNA replication.

**Step 2:** Chromosomes become double stranded: (Label)



**Step 3:** Chromosomes line up in the middle of the cell.

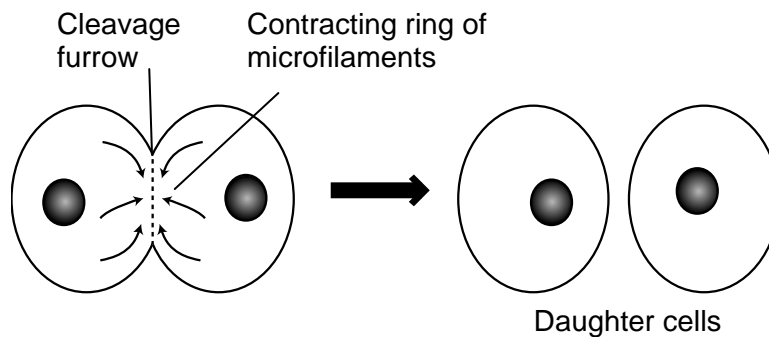
**Step 4:** Double stranded chromosomes begin to separate to the poles of the cell.

**Step 5: Cytokinesis-** After division of the chromosomes, the cytoplasm divides forming two new cells.

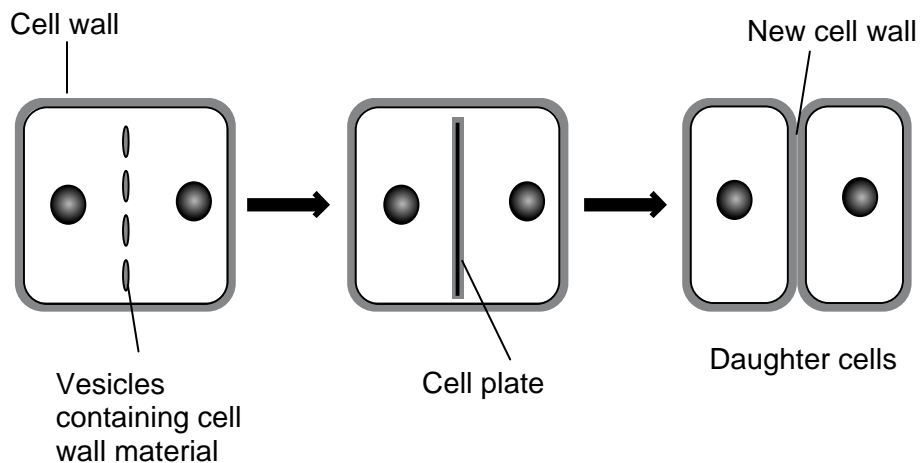
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6. Differences between plant and animal cell cytokinesis:

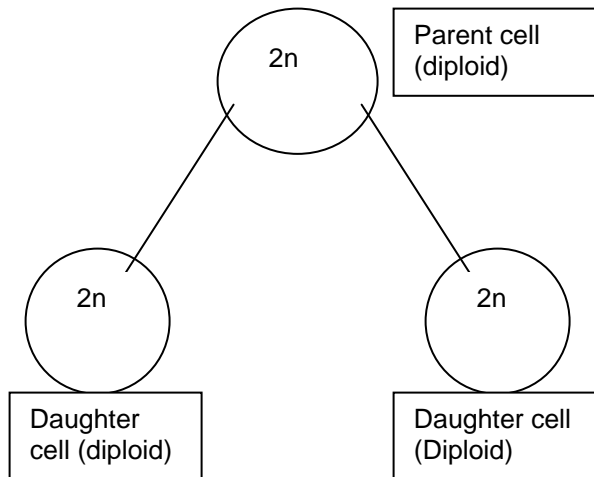
### Cleavage of an animal cell



### Cell plate formation in a plant cell



7.





## Teacher Instructions - Part 4

### Mitosis in Plant and Animal Cells

1. Distribute one copy of *Mitosis in Plant and Animal Cells* lab instructions.
2. Distribute one supply bag of popping bead models to each pair of students. These beads are available from Wards # 36W1602, Chromosome Simulation Lab activity. Each bag should contain:
  - two 10-bead long red chromosomes
  - two 10-bead long yellow chromosomes
  - two 4-bead long red chromosomes
  - two 4-bead long yellow chromosomes
3. Instruct students to divide a blank sheet of paper into 6 sections (6 “boxes”).
4. Label box 1 “original cell,  $2n=4$ ”. Instruct students to pull out four chromosomes from the supply bag: 1 long red (10 beads), 1 long yellow (10 beads), 1 short red (4 beads), 1 short yellow (4 beads). Lay these chromosomes on the table in front of them. Draw what they have in box 1. It helps to use colored pencils. Use this opportunity to discuss chromosome packing, structure, homology, etc. NOTE: This simulation is imperfect because the DNA in the original cell would be unpacked as chromatin and would be similar to a piece of thread.
5. Label box 2 “chromosomes replicate”. Have students pull out the remaining chromosomes from their supply bag and “replicate” the original ones on their desk, making sure that copies are held together by the centromere magnet. This is a good time to explain that replication means exact copies. (the long red will make a long red copy, etc.) Also discuss chromosome structure, chromatid, centromere, etc. Students should draw what they have on their desk in box 2 and label their drawings.
6. Label box 3 “Metaphase, chromosomes line up in the middle”. Have students orient their red and yellow chromosomes so that the chromosomes are lined up along the equator of the cell. Students draw their results in box 3.
7. Label box 4 “Anaphase, chromosomes begin to separate.” Students should separate chromatids and move them about 2” away from each other towards the poles of the cell. Students draw what they see in box 4.
8. Label box 5 “Telophase, nuclear division complete.” Students should move chromatids to poles. Students draw what they see in box 5.
9. Label box 6 “Cytokinesis, division of the cytoplasm.” Students should then draw the chromosomes as they see them, but this time a cell membrane should be drawn around each set of chromosomes, creating two new cells. Teacher should spend time discussing chromosome number, two daughter cells, identical to each other and to original parent cell.
10. Using the materials, each lab partner should explain the sequence of events in mitosis with the other partner. Switch roles.
11. Gain student access to internet website: [www.biology.arizona.edu](http://www.biology.arizona.edu) Click on “Onion Root Tips” on left side column.
12. Students may work individually, in pairs, or as a whole class if access to multiple computers is not available.

13. Teacher should explain that this website will give students a chance to gain confidence in locating cells in the different phases of mitosis. Each time a new cell is shown, the student should select the phase that is best demonstrated by that cell. If the student is incorrect, a hint is given and the student must choose again.
14. Students should create a data table logging the number of cells in each phase as they move through the internet activity.
15. After completing, the internet lesson, students should then continue with step 6 in their lab instructions. Students should obtain a microscope, and a slide of onion root tip mitosis.
16. Draw five circles on a sheet of paper.
17. Students should be instructed to locate one cell for each phase of mitosis (Interphase, Prophase, Metaphase, Anaphase, Telophase). These cells should be drawn in the circles in their data section and correctly labeled with the appropriate mitotic phase.
18. Conclusion questions should be assigned for homework.

## Part 4: Lab - Mitosis in Plant and Animal cells

### Introduction:

Mitosis, as you remember from seventh grade life science, is the process by which cells reproduce themselves. Mitosis is only part of a bigger process called the cell cycle. Although mitosis is usually studied in depth, the most important phase of the cell cycle is the first stage (interphase) in which the chromosomes are replicated. After this, the chromosomes line up in the middle and then separate to the poles. Following chromosomal separation, cytokinesis occurs, dividing the cytoplasm into two new cells. This method of reproduction is asexual.

### Pre lab:

1. Give several characteristics of asexual reproduction.
2. Why is mitosis important?
3. If our original cell has fourteen chromosomes, how many should each of our final cells have? How do you know?

### Procedure:

1. Draw five circles in your data section. (About the size of a beaker bottom)
2. Label the circles using the following phrases
  - a. Original cell  $2n=$
  - b. Chromosomes replicate
  - c. Chromosomes line up in the middle
  - d. Chromosomes separate to poles
  - e. Chromosomes at poles, cytoplasm begins to divide
3. Following your teacher's instructions, and using your popping bead chromosomes, perform the process of mitosis. Draw each phase in the appropriate circle.
4. Have each lab member orally perform the process again.
5. Log on to a computer and navigate to [www.biology.arizona.edu/cell\\_bio/activities/cell\\_cycle/cell\\_cycle.html](http://www.biology.arizona.edu/cell_bio/activities/cell_cycle/cell_cycle.html)
6. Complete the online activity to practice identifying stages of mitosis in actual cells. Copy the data table into the data section of your lab report.
7. When finished, Obtain a microscope, and slide of onion skin mitosis. Scan in low (10X) power. Focus in high (40X) power. Locate, draw and label each of the five phases of mitosis.

**Conclusions:**

1. There are many signals that control cell division. What do you think would happen if the signal to "shut down" mitosis was never given? What do you think this is called?

2. Some cells can have several nuclei in a single cell. Considering the events in a typical cell cycle, which phase of the cell cycle is not working?

3. The nerve cells in humans seldom undergo mitosis. Based on this information, explain why complete recovery from injuries to the nervous system may not occur.

## Teacher Instructions - Part 5

### Causes of Cancer Animations

1. Give each student has a copy of the “Understanding Cancer” worksheet from the *NIH: Cell Biology and Cancer* curriculum guide. This is available online at:  
<http://science.education.nih.gov/supplements/nih1/cancer/guide/pdfs/ACT2M.PDF>  
(To see the entire *Cell Biology and Cancer* curriculum guide, go to  
<http://science.education.nih.gov/supplements/nih1/cancer/default.htm>)
2. Use a computer and projector to show students the 5 animations available online at:  
[http://science.education.nih.gov/supplements/nih1/cancer/activities/activity2\\_animations.htm](http://science.education.nih.gov/supplements/nih1/cancer/activities/activity2_animations.htm)
3. Watch each animation and then complete Section 2 of the worksheet. Have students work individually to write a one-sentence summary on the worksheet that corresponds to each animation.
4. Give students 5-7 minutes to discuss their answers with their group.
5. Discuss answers with whole group.
6. Student groups should complete Section 3, “Explaining Factors Associated with Cancer”.
7. Discuss answers as a group.

## Teacher Instructions - Part 6 Modeling the Normal Cell Cycle

1. Prepare Cell Cycle wheels before class. Purchase enough materials so that each team of four students will have one wheel.
  - 10" cardboard cake bases (available at most craft stores)
  - Color copy of the labeled cell cycle wheel (see document entitled cell "cycle wheel.doc")
  - One brad to hold the paper to the wheel
  - One copy of the arrow (found in graphics folder)
  - Optional: The color copy of the cell cycle can be laminated or covered in clear contact paper to add to its durability.
  - Optional: Teachers may choose to use "business card magnets" cut into small pieces to use as a centomere. With this option, chromatids will "stick" together and will be harder to pull apart.
2. Prepare a 1 gallon Ziplock bag of materials for each team of 4 students and label this bag "Materials". The bag contains the following items:
  - 1 strip of 4 hole reinforcements
  - 8 pieces of black or white plastic lanyard (boondoggle) approximately 10" long. Take four pieces and tie into a knot at one end. Do the same with the other four.
    - Tie a paper clip to each untied end of the lanyard.
  - ½ sheet of blank pink paper, ½ sheet blank blue paper
  - black markers
  - dried beans
  - A sandwich size Ziploc bag, labeled "cell" with the following inside:
    - 2 chromosomes graphics copied in pink (see document entitled "pink chromosome master.doc"), cut out and a small white ring reinforcement attached to the black dot.
    - 2 chromosomes graphics copied in blue (see document entitled "blue chromosome master.doc"), cut out and a small white ring reinforcement attached to the black dot.
3. Prepare the following Teacher Signs: Ras Cyclin, p53, Mad1, ATM/Nibrin. (see document entitled "teacher signs.doc")
4. Students should be divided into groups of four. Each student in the group is responsible for one chromosome in the cell model activity.
5. Distribute one copy of *Part 6: Modeling the Normal Cell Cycle* worksheet to each student.
6. Distribute one large Ziploc bag of materials, one balance, 2-4 pairs of scissors, tape and an assembled Cell Cycle Wheel to each group.

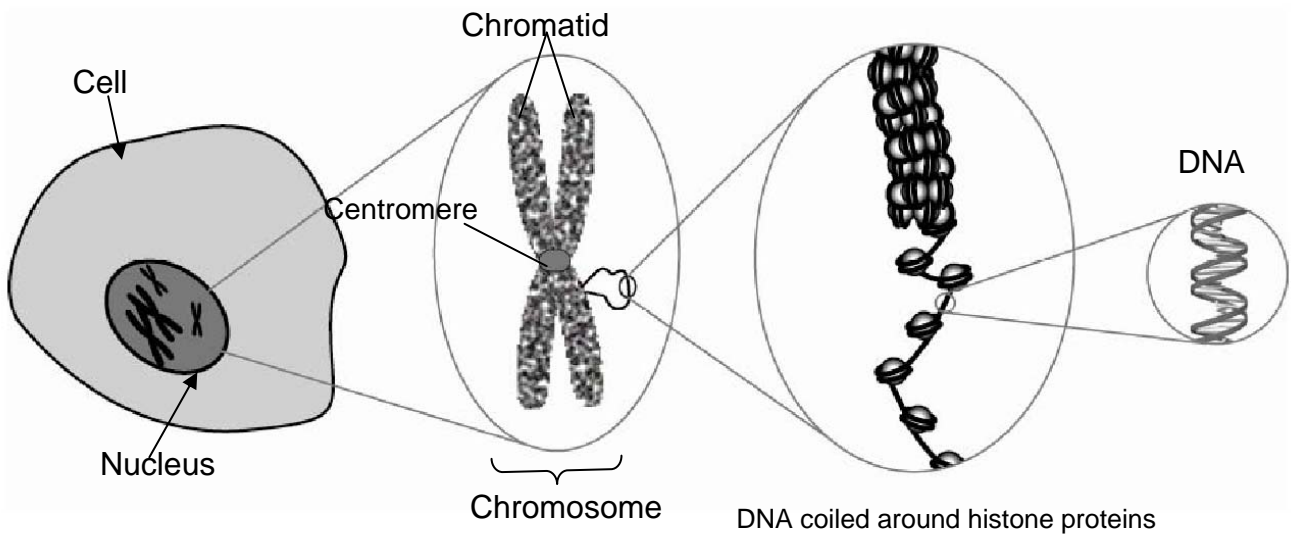
7. Beginning at step 1 on the worksheet, read the instructions together as a class. Students should locate the two pairs of chromosomes. Teacher should circulate to check that each group has correctly located the two chromosome pairs. Discuss DNA packaging and the accompanying diagram.
8. Continue reading steps 2-3.
9. Read step 4. Students should add beans to their small cell bag one at a time to simulate cell growth. Give students a minute or two to add beans.
10. Read step 5. Teacher should now wear the “Ras Cyclin” sign. Students should complete procedure by checking the mass of their cell. Teacher circulates and checks the mass of the “cells”. Cells that are large enough (\_\_\_grams) are given a bingo chip as a signal from Ras Cyclin that they may proceed.
11. Read step 6 together. Teacher should now wear “p53”sign. Teacher should circulate and check for DNA damage (there is none). Make a big point about how nice their DNA is!
12. Read step 7. Teacher should monitor progress of student groups. Each student is in charge of copying one chromosome.
13. Read step 8. Teacher should now wear the “ATM/Nibrin” sign. Teacher should circulate among groups checking their replicated chromosomes. Student groups who accurately copy their chromosomes should be given a bingo chip as their “go ahead” signal.
14. Read step 9.
15. Read step 10. Students should follow directions to perform mitosis. Chromatids should NOT be separated at this point!
16. Read step 11. Teacher should now wear the “Mad1” sign. The teacher should circulate among groups and check their mitosis setup. If it is OK, give them a bingo chip as a signal to continue. If their setup is not OK, discuss changes to be made. Note: the most common error is to attach non-chromatids together at the small white rings.
17. Read step 12.
18. Read step 13.
19. Complete step 14.
20. A closing discussion can revolve around the make up the two new cells. Students should recognize that the chromosomes are the same as when we began, however, the size of the cell is much smaller because of the division of cytoplasm.

## Part 6: Modeling the Normal Cell Cycle

Your Task: Model the events and the controls of the cell cycle. Work in groups of 4 students. At your station you should have:

- A cell cycle wheel
- A large Ziploc bag with materials
- Scissors
- Tape
- Dried lima beans
- Balance

1. First, become familiar with the chromosomes that will be used in your cell model. Your cell has 2 pairs of chromosomes. These are made from blue and pink paper.
  - Each pair is the same length. Find the 2 pairs. Throughout this simulation, each person in the group will be responsible for one of the chromosomes.
  - Each pair of chromosomes is made up of 2 partners, a maternal chromosome and a paternal chromosome.



During this simulation, how would you tell the difference between the maternal and paternal chromosomes?

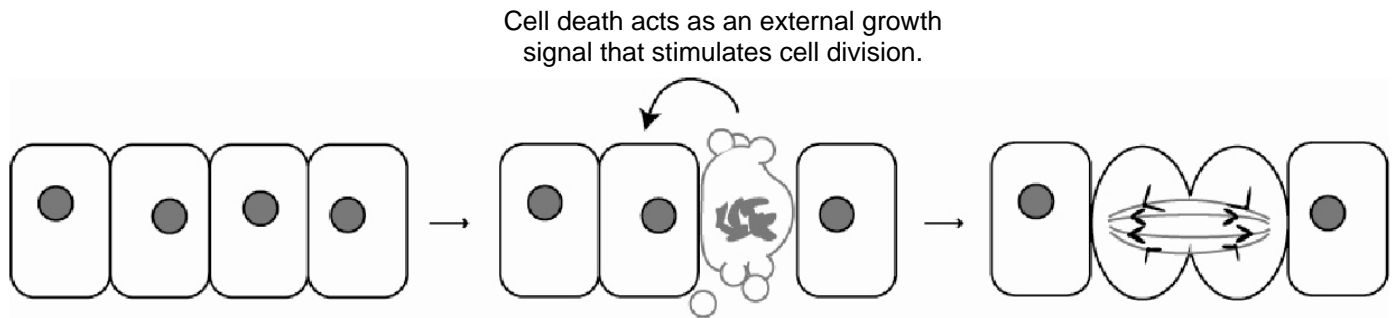
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- The chromosomes are found inside your cell that is represented by the small Ziploc bag labeled "CELL". Place your 2 pairs of chromosomes into the small Ziploc bag. The remainder of the materials will be used throughout the activity and should be kept in the large bag labeled "MATERIALS", as a supply/synthesis area.
- Let's Begin Mitosis! A cell next to your cell has died. This cell's death causes an **external growth signal** and tells your cell to begin the cell cycle.



- Turn your wheel to the **G<sub>1</sub> phase**. This is the growth phase. According to the cell cycle chart (from Part 1), what should happen during **G<sub>1</sub> phase**?

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- To simulate growth of your cell, beans will be added to your small bag to represent an increase in the mass of your cell. Please add beans one at a time to your cell until the mass of your cell is \_\_\_\_\_grams. Leave your cell with increased mass on the balance
- Turn your wheel until you reach the first checkpoint (●). At this checkpoint, a growth regulator protein, called **Ras cyclin**, checks that cells are big enough to enter the next part of the cell cycle.
  - Ras cyclin** is a protein that functions during this checkpoint. As the cell grows, the amount of **Ras cyclin** increases. When the amount of **Ras cyclin** reaches a certain level, it signals the cell to proceed to the next part of the cycle. Raise your hand so that **Ras cyclin** (your teacher) may check the mass of your cell.

- If **Ras cyclin** does not give cells the signal to continue, the cells remain in this part of the cycle and continue to grow.
- Why is it important to check that the cell is big enough to continue with the cell cycle?

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- Once you have been given the signal to continue, proceed to step 7.

7. Before your cell is allowed to enter the next part of the cell cycle, it must pass a second checkpoint. Turn your wheel to the next checkpoint (●).

- DNA in these chromosomes can be damaged by a number of agents including radiation, toxic chemicals, and free radicals. At this checkpoint, another protein known as **p53** will inspect the chromosomes' DNA for damage. If there is DNA damage, **p53** will stop the cell cycle until DNA repair enzymes can fix the damage. If the DNA damage can't be repaired, **p53** may signal programmed cell death, called apoptosis.
- Raise your hand to have **p53** (your teacher) check your DNA for damage.
- What do you think would happen if this p53 surveillance system did not work properly?

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8. If your cell has cleared the two checkpoints (that is, it is large enough and has suffered no DNA damage), turn your wheel to the **S phase** of the cell cycle. During this part of the cell cycle, DNA must be replicated. You must complete the following steps in order to replicate your DNA:

- Using the materials from the supply bag, (black markers, pink and blue paper strips, scissors, small white rings) **make exact copies of each of your DNA strands.**
- These two copies (chromatids) are held together at the centromere region. Place the centromere regions of the chromatids on top of each other to simulate how the chromatids are held together.
- Summarize the events that occur during the S phase of the cell cycle

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9. Turn your wheel to the next checkpoint (●). At this checkpoint, another protein complex called **ATM/Nibrin** inspects to make sure that the DNA was copied without mistakes.

- Raise your hand to have **ATM/Nibrin** (your teacher) check your replicated DNA for damage.
- Why is it important to check the replicate DNA?

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10. Once you have been given the 'go ahead' to continue, turn your wheel and enter the **G<sub>2</sub>** part of the cell cycle. During this part of the cell cycle, the cell prepares for mitosis by synthesizing the materials it will need. Please prepare your cell for mitosis by assembling the following materials:

- Spindle apparatus (black/white lanyard and paper clips). Pull black/white lanyard out of large bag. Notice that paper clip hooks are attached to the ends of the lanyard.

*G<sub>1</sub>*, *S*, and *G<sub>2</sub>* of Interphase used to be called the "resting phase". Why is resting phase not a good name?

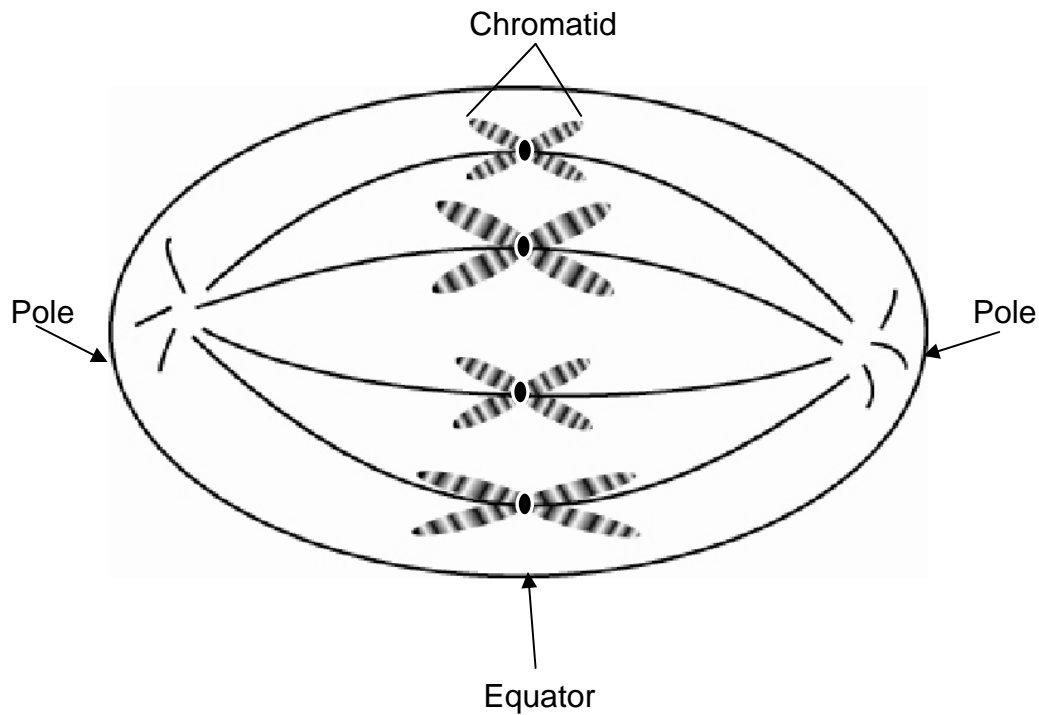
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11. Move your wheel to the next part of the cell cycle, **Mitosis**. Proceed with mitosis by completing the following steps

- During **Prophase**, DNA in the chromosomes condenses and coils. To simulate this process, wrap each chromatid around a pencil and then remove the pencil. Attach your two coiled chromatids together by placing the centromeres on top of each other. These attachment sites now represent the centromere region.
- During **Metaphase**, the chromosomes line up in the center of the cell. Line up your chromosomes in the middle of your cell.



- Place one set of black and white spindle fibers at each side (pole) of your desk (cell).
  - Next, attach one spindle fiber from the left side of your desk to the centromere on one chromatid. Attach a spindle fiber from the right side of your desk to the centromere on the other chromatid. Poking the paper clip through the black region inside the white reinforcement makes these attachments.
12. Turn your wheel to the next checkpoint (●). At this checkpoint another protein called **MAD1** checks to be sure that the spindle fibers have attached properly. Spindle fibers need to be attached correctly so that when the spindle fibers pull on the centromeres, the chromosomes are equally distributed to the new cells. Raise your hand to have **Mad1** (your teacher), check your spindle attachment.
  13. If **MAD1** recognizes proper spindle attachment, your cell may proceed to **Anaphase** by pulling on the spindle apparatus to separate chromatids at the centromere.

14. Remember that process of mitosis occurs in a cell. Complete **Telophase** by removing the spindle from the chromosomes. Place the spindle fibers back in the supply bag. Turn your wheel to next phase.
15. **Cytokinesis:** You may now divide your cell in half. Cut your small Ziploc bag, labeled "CELL" in half. You should now have two smaller baggies. Place the chromosomes from the left side of your desk into one half of the bag, and the chromosomes from the right side of your desk in the other half. Tape the open ends closed. You should now have two smaller cells.
- Compare the chromosome content of the two cells.

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16. Each of these new cells will now enter **G<sub>1</sub>** phase and repeat the cell cycle. Save these two new cells for the next class.


## **Teacher Instructions - Part 7**

### **Modeling Cancer**

1. Students should be divided into groups of four. Each student in the group is responsible for one chromosome in the cell model.
2. Distribute one copy of the cell cycle activity worksheet to each student.
3. See Appendix A for pieces to be copied for use when assembling the Ziplock bag of materials. Distribute one large Ziploc bag of materials, one balance, 2-4 pairs of scissors, dried beans, tape and a Cell Cycle Wheel to each group.
4. Beginning at number one on the cell cycle activity worksheet, student groups may complete the Cancer Model as a group. One student should be the reader, one the recorder, one the timekeeper and the last should be the director.
5. Continue reading steps 1-2. Teacher should circulate as student groups cut off part of one of the long chromosomes.
6. Continue with step 3. Teacher should circulate and check that DNA damage is copied during replication. Make a big point about how this damage has been copied and nothing is checking for the damage.
7. Read step 4.
8. Read step 5 and 6. Students should follow directions to perform mitosis. Chromatids should NOT be separated at this point!
9. Read step 7.
10. Read step 8.
11. Questions should be assigned to groups or for homework.
12. A closing discussion can revolve around the make up the two new cancer cells as compared to the two new non-cancer cells from the previous lesson. Students should recognize that the cancer cells have damaged DNA, extra chromosomes, etc.

## Part 7: Modeling the Cell Cycle and Cancer


We will now model **cancer** by ignoring the checkpoints in the cell cycle. Let's Begin Mitosis! A cell next to your cell has died. This **external growth signal** tells your cell to begin the Cell Cycle. Turn your wheel to the **G<sub>1</sub> phase**, the first growth phase. To simulate growth of your cell, please add beans to your small bag.

1. You have a mutation in the gene that produces the **Ras protein** and this checkpoint (  ) does not work. Do NOT check the mass of your cell. How might a malfunction at this checkpoint affect the cell?

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2. Your cell has been exposed to UV radiation (sunlight). This radiation causes DNA damage. Simulate this DNA damage by cutting off a small part of one of the LONG chromosomes. You have a mutation in the gene that produces the **P53 protein**. Because of this mutation, there is no checkpoint (  ), and the cell can proceed with the cell cycle even though this DNA damage has occurred. How might a malfunction at this checkpoint affect the cell?


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3. Turn your wheel to the **S phase** of the cell cycle. During this part of the cell cycle, DNA must be replicated. You must complete the following steps in order to replicate your DNA:

- Using the materials from the supply bag, (black markers, pink and blue paper strips, scissors, small white rings) make exact copies of each of your DNA strands. *Even the damaged chromosome should be copied exactly.*
- These two copies (chromatids) are held together at the centromere region. Place the centromere regions on top of each other.
- Turn your wheel to the next checkpoint (  ).

4. You have a mutation in the gene that produces the **ATM/Nibrin protein**. You may proceed to the next step without passing through the checkpoint (  ).

- How would a malfunction at this checkpoint affect the cell?


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5. Turn your wheel and enter **G<sub>2</sub> phase**. During this phase, the cell synthesizes the materials it will need to do mitosis. Please prepare for mitosis by synthesizing the following:
  - Spindle apparatus (black/white rope and paper clips). Pull black/white lanyard out of large bag.
  - Notice that paper clip hooks are attached to the ends of the lanyard.
6. Move your wheel to the next part of the Cell Cycle, **Mitosis**. Proceed with mitosis by completing the following steps (add graphic)
  - During **Prophase**, DNA in the chromosomes condenses and coils. To simulate this process, wrap each chromatid around a pencil and then remove the pencil. Attach your two coiled chromatids together by placing the centromeres on top of each other. These attachment sites now represent the centromere region.
  - During **Metaphase**, the chromosomes line up in the center of the cell. Line up your chromosomes in the middle of your cell.
  - Place one set of black and white spindle fibers at each side (pole) of your desk (cell).
  - Next, attach one spindle fiber from the left side of your desk to the centromere on one chromatid. Attach a spindle fiber from the right side of your desk to the centromere on the other chromatid.

OH NO! You have a faulty spindle apparatus. One of the spindle fibers fails to attach to the centromere.

7. You have a mutation in the gene that produces the **Mad1 protein**. There is no checkpoint! You may proceed to **Anaphase** by pulling on the spindle apparatus to separate chromatids at the centromere. Complete **Telophase** by removing the spindle from the chromosomes. Place the spindle fibers back in the supply bag.
  - What problems may occur as a result of having a mutation at the **Mad1** checkpoint (  )?

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8. Turn your wheel to next phase: **Cytokinesis**. You may now divide your cell in half. Cut your small Ziploc bag in half. Tape the open-end closed. Place the correct number of chromosomes in each half.



- Compare your new "cancer" cells to your original cells. List 2 differences between the cancer cells and your original cells.

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- Each new daughter cell will now enter  $G_1$  phase and repeat the cell cycle. What do you think will happen if the "cancer" cell proceeds with further cell cycles without checkpoints?

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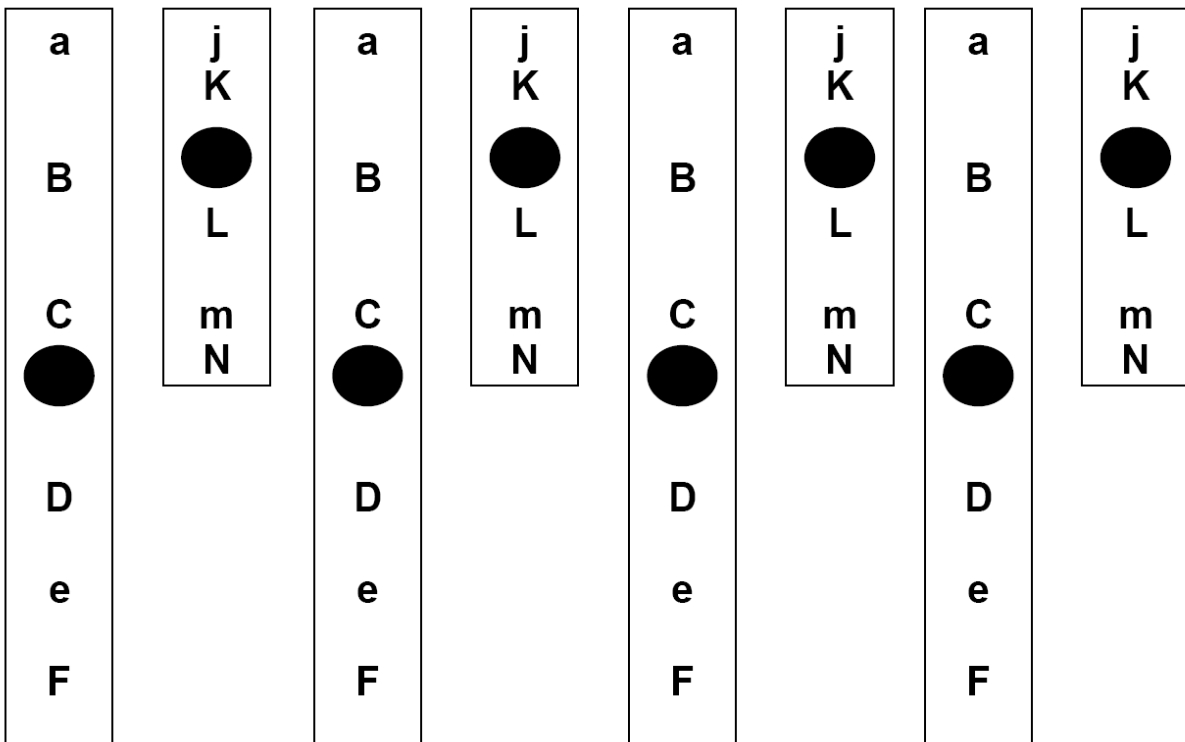
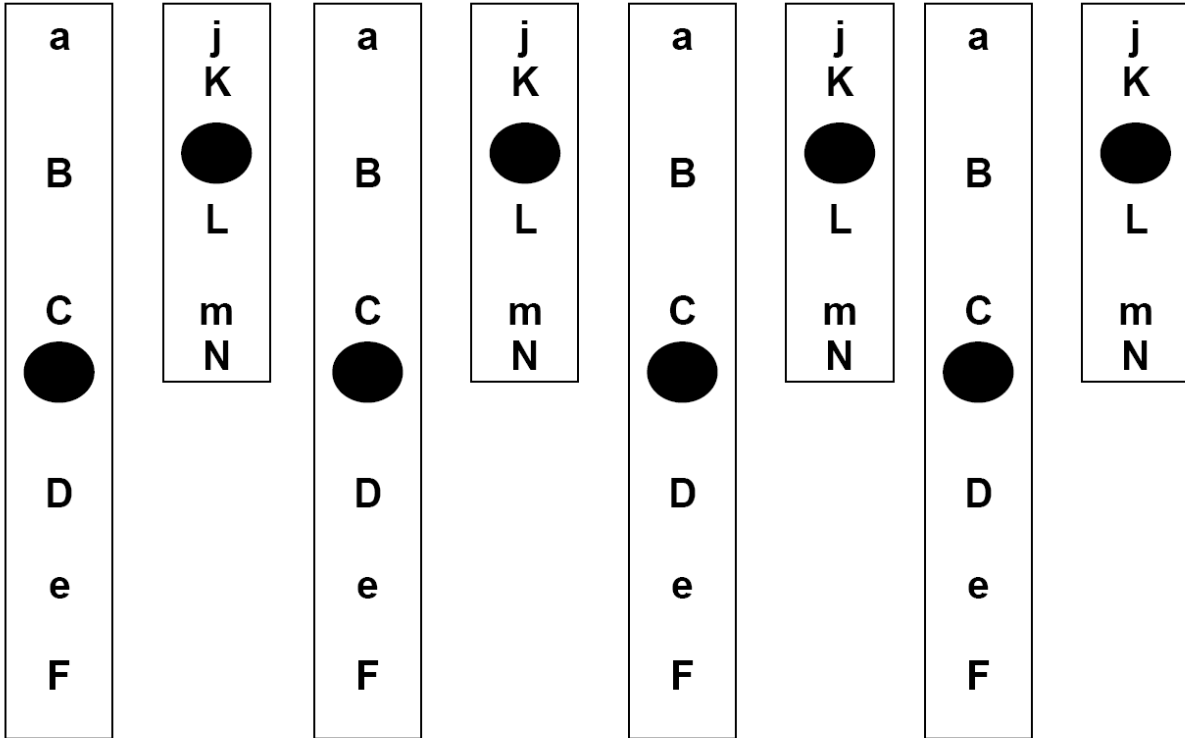
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**Questions:**

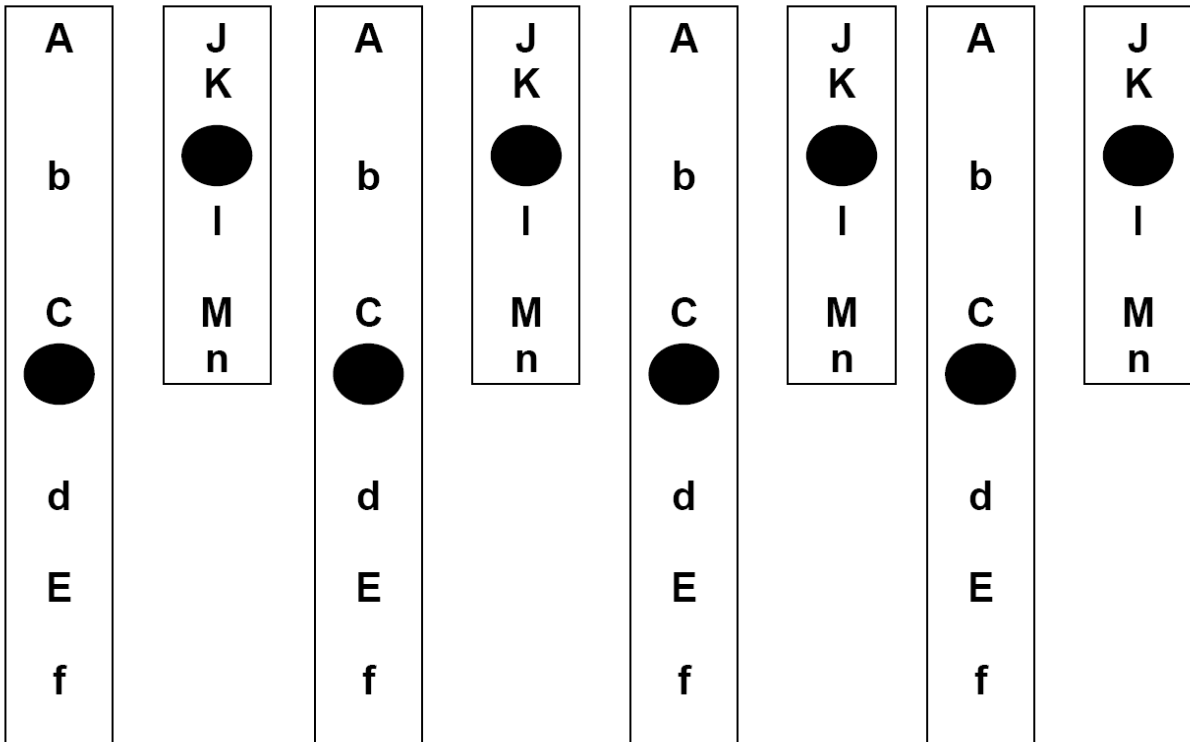
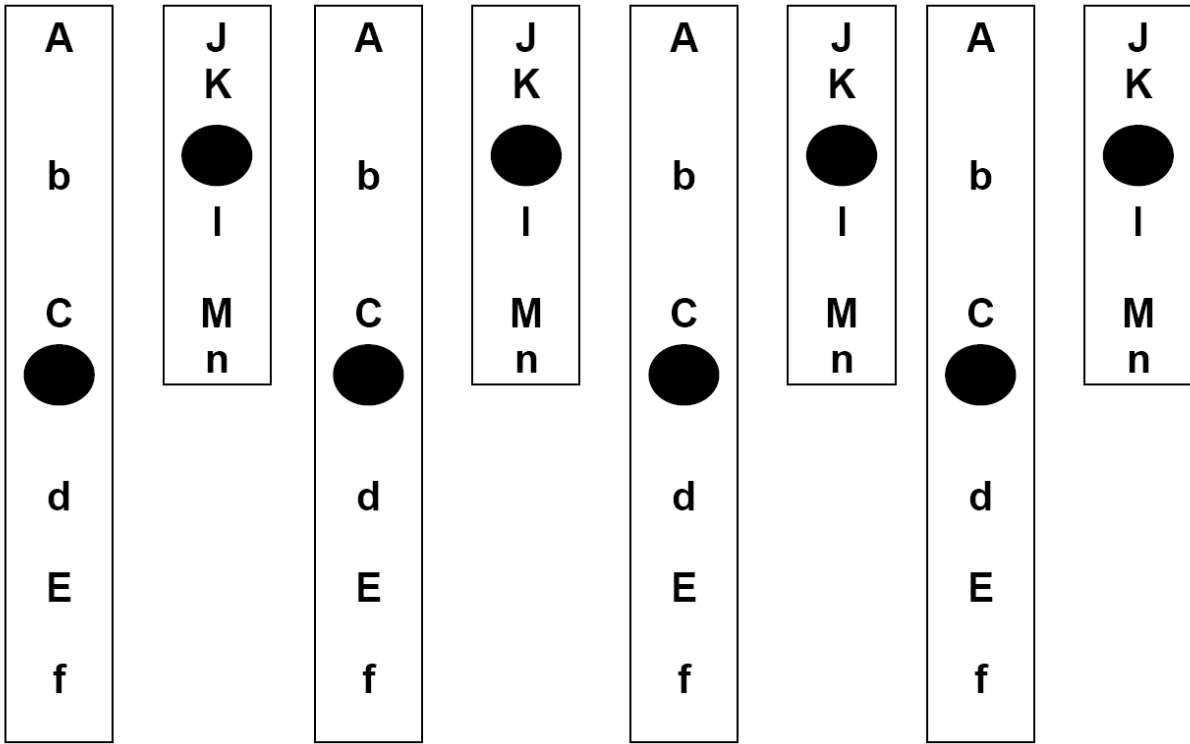
1. Summarize the importance of checkpoints (  ) during the cell cycle.
2. What is the relationship between the cell cycle and cancer?
3. Over half of all sporadic (random, non-hereditary) cancers have a mutation in the P53 gene. Why do you think a mutation in the p53 gene leads to so many cancers?
4. If you were a cancer researcher, what approach might you use to prevent, diagnose, treat and cure cancer?
5. Research one current cancer treatment and explain what it targets and how this relates to the cell cycle.

Appendix A: Copy to create pieces needed for Parts 6 and 7.

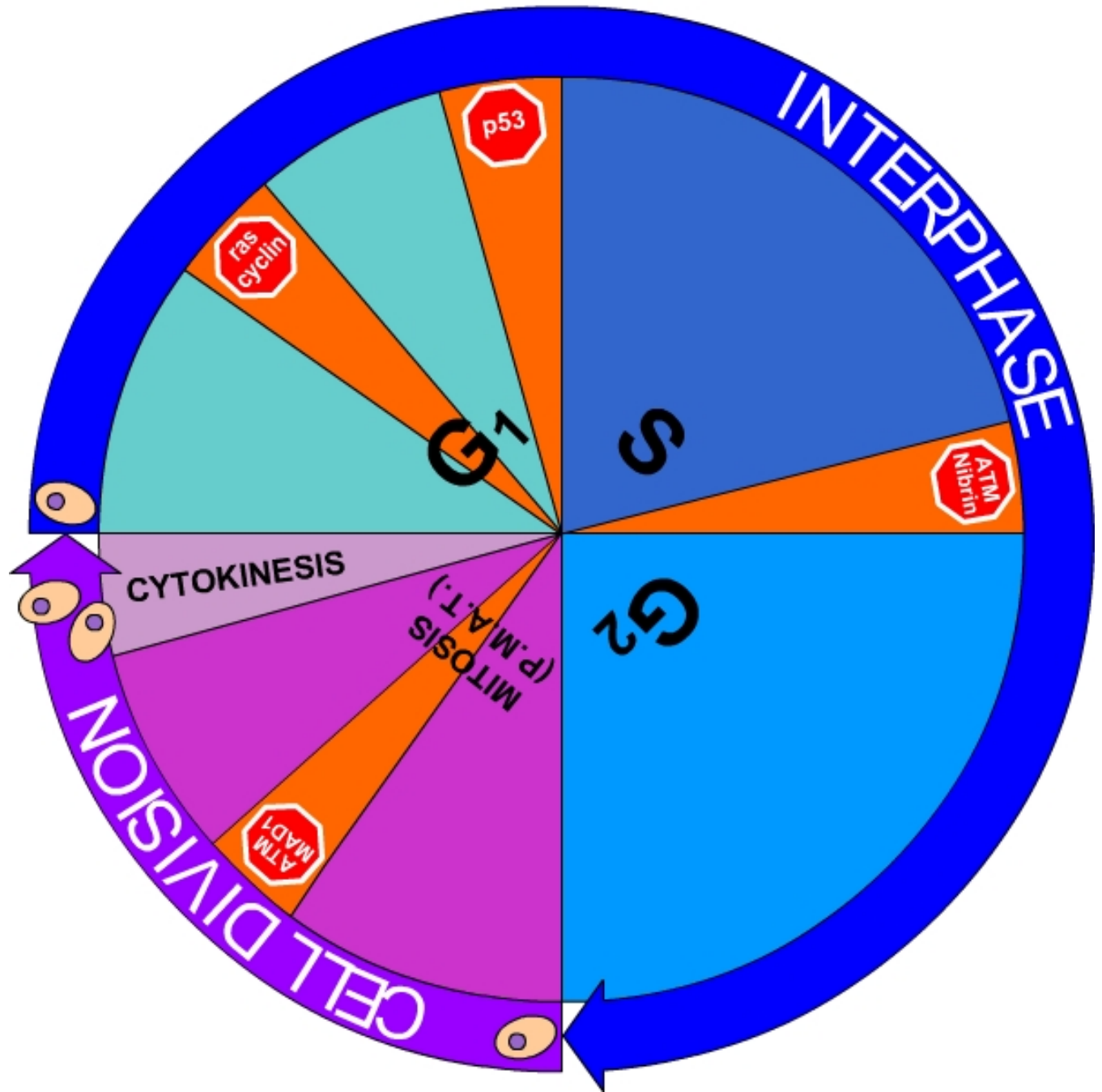
Blue chromosome - copy on blue paper



Pink chromosome - copy on pink paper



Cell Cycle Wheel



**p53**

# ATM/Nibrin

# Ras cyclin



**MAD1**