Chapter 12: The Cell Cycle

Overview:

1. What are the three key roles of cell division? State each role, and give an example.

<table>
<thead>
<tr>
<th>Key Role</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reproduction</td>
<td>An amoeba, a single-celled eukaryote, divides into two cells. Each new cell will be an individual organism.</td>
</tr>
<tr>
<td>Growth and development</td>
<td>A sand dollar embryo forms two cells shortly after the fertilized egg is divided.</td>
</tr>
<tr>
<td>Tissue removal</td>
<td>Dividing bone marrow cells will give rise to new blood cells.</td>
</tr>
</tbody>
</table>

2. What is meant by the cell cycle?

The cell cycle is the life of a cell from the time it is first formed from a dividing parent cell until its own division into two daughter cells.

Concept 12.1 Most cell division results in genetically identical daughter cells

3. What is the meaning of genome?

A genome is a cell’s endowment of DNA, its genetic information.

4. How many chromosomes are in a human somatic cell? 46

5. Name two types of somatic cells in your body. Possible examples include any cells in the body, except for reproductive cells.

6. What is a gamete? A reproductive cell

7. Name the two types of gametes. Sperm and eggs

8. How many chromosomes in a human gamete? 23


The complex of DNA and proteins that makes up eukaryotic chromosomes. When the cell is not dividing, chromatin exists in its dispersed form, as a mass of very long, thin fibers that are not visible with a light microscope.
10. Think carefully, now. How many DNA molecules are in each of your somatic cells? 46

11. You are going to have to learn the difference between several similar-sounding terms. The sketch below that looks like an X represents a replicated chromosome that has two sister chromatids. The narrow “waist” represents the location of the centromere. Students often get all these terms confused, so take time now to label the indicated areas of the figure and then define each of the terms below.

See page 229 of your text for the labeled figure.

**chromosome**: A cellular structure carrying genetic material, found in the nucleus of eukaryotic cells. Each chromosome consists of one very long DNA molecule and associated proteins. (A bacterial chromosome usually consists of a single circular DNA molecule and associated proteins. It is found in the nucleoid region, which is not membrane bounded.) See also chromatin.

**chromatid**: One of two identical joined copies of the original chromosome

**centromere**: In a duplicated chromosome, the region on each sister chromatid where they are most closely attached to each other by proteins that bind to specific DNA sequences; this close attachment causes a constriction in the condensed chromosome.

**chromatin**: The complex of DNA and proteins that makes up eukaryotic chromosomes. When the cell is not dividing, chromatin exists in its dispersed form, as a mass of very long, thin fibers that are not visible with a light microscope.

12. Study Figure 12.5 in your text. Label the figure below, and summarize what occurs at the DNA level in each stage.

See page 230 of your text for the labeled figure.

One of the multiple chromosomes in a eukaryotic cell is represented here, not yet duplicated. Normally it would be a long, thin chromatin fiber containing one DNA molecule and associated proteins; here its condensed form is shown for illustration purposes only.

Once duplicated, a chromosome consists of two sister chromatids connected along their entire lengths by sister chromatid cohesion. Each chromatid contains a copy of the DNA molecule.

Molecular and mechanical processes separate the sister chromatids into two chromosomes and distribute them to two daughter cells.

13. What is mitosis? How is it different from cytokinesis?

Mitosis, the division of the genetic material in the nucleus, is usually followed immediately by cytokinesis, the division of the cytoplasm.
14. What occurs in meiosis? How is the chromosome number of daughter cells different?

The human body produces gametes—eggs or sperm—by a variation of cell division called meiosis, which yields nonidentical daughter cells that have only one set of chromosomes (23), half as many chromosomes as the parent cell.

15. Select either mitosis or meiosis to answer the following questions.

Mitosis By what process are the damaged cells in a wound replaced?

Meiosis By what process are eggs formed?

Mitosis By what process does a zygote develop into a multicellular organism?

Mitosis In which process are identical daughter cells produced?

Meiosis Which process reduces chromosome number of daughter cells?

16. Don’t skip the Concept Check Questions! They are a good way to verify your understanding. Here is a variation of question 3. Answer it here: A hedgehog has 90 chromosomes in its somatic cells.

a. How many chromosomes did the hedgehog inherit from each parent 45

b. How many chromosomes are in each of the hedgehog’s gametes? 45

c. How many chromosomes will be in each somatic cell of the hedgehog’s offspring 90

Concept 12.2 The mitotic phase alternates with interphase in the cell cycle

17. Label each of the parts of the cell cycle listed below, and give a brief explanation of what happens in each phase.

See page 231 of your text for the labeled figure.

G1: “First Gap” The first part of interphase

S: “Synthesis” When the chromosomes duplicate

G2: “Second Gap” The last part of interphase

M: In the M phase, mitosis distributes the daughter chromosomes to daughter nuclei, and cytokinesis divides the cytoplasm, producing two daughter cells.

18. What are the components of the mitotic spindle? What is the source of these components?

This structure consists of fibers made of microtubules and associated proteins. While the mitotic spindle assembles, the other microtubules of the cytoskeleton partially disassemble, providing the
material used to construct the spindle. The spindle microtubules elongate (polymerize) by incorporating more subunits of the protein tubulin and shorten (depolymerize) by losing subunits. The source of these components is the cytoplasm during prophase.

19. In animal cells, the assembly of spindle microtubules starts at the centrosome. What is another name for the centrosome? Microtubule-organizing center

20. Sketch and label a centrosome with two centrioles.

See page 232 in your text to view the “G2 of Interphase” portion of the figure.

21. What are the components of the mitotic spindle?

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22. Describe what happens to the centrosome during interphase and then prophase.

During interphase, a cell that is about to divide grows and copies its chromosomes in preparation for cell division. During prophase, the centrosomes move away from each other, propelled partly by the lengthening microtubules around them.

23. What is a kinetochore? Read your text carefully, and then make a labeled sketch that shows a replicated chromosome with two kinetochores and some attached spindle fibers. Figure 12.8 in your text may help.

See page 236 of your text for the labeled figure.

A structure of proteins attached to the centromere that links each sister chromatid to the mitotic spindle

24. You will need to spend some serious time with Figure 12.7 in your text. Use it to help you label this figure. Label each phase by name; then label the smaller structures. Finally, make two or three summary statements that indicate important features to note about the phase.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Important Features of Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>G2 of interphase</td>
<td>Answers may vary; refer to the chart in Figure 12.7 on pages 232-233.</td>
</tr>
<tr>
<td>Prophase</td>
<td>Answers may vary; refer to the chart in Figure 12.7 on pages 232-233.</td>
</tr>
<tr>
<td>Prometaphase</td>
<td>Answers may vary; refer to the chart in Figure 12.7 on pages 232-233.</td>
</tr>
</tbody>
</table>
25. Explain the difference between *kinetochore* and *nonkinetochore* microtubules. What is the function of each?

During prometaphase, some of the spindle microtubules attach to the kinetochores; these are called kinetochore microtubules. Meanwhile, microtubules that do not attach to kinetochores have been elongating, and by metaphase they overlap and interact with other nonkinetochore microtubules from the opposite pole of the spindle.

26. At which end do kinetochore microtubules shorten during anaphase? Explain the Inquiry Figure that supports where this shortening occurs.

As the chromosomes moved poleward, the microtubule segments on the kinetochore side of the mark shortened, while those on the spindle pole side stayed the same length. During anaphase in this cell type, chromosome movement is correlated with kinetochore microtubules shortening at their kinetochore ends and not at their spindle pole ends. This experiment supports the hypothesis that during anaphase, a chromosome is walked along a microtubule as the microtubule depolymerizes at its kinetochore end, releasing tubulin subunits.

27. Describe *cytokinesis* in an animal cell. Use a labeled sketch that shows the *cleavage furrow*.

See page 235 of your text for the labeled figure (12.10a).

In animal cells, cytokinesis occurs by a process known as cleavage. The first sign of cleavage is the appearance of a cleavage furrow, a shallow groove in the cell surface near the old metaphase plate. On the cytoplasmic side of the furrow is a contractile ring of actin microfilaments associated with molecules of the protein myosin. The actin microfilaments interact with the myosin molecules, causing the ring to contract. The contraction of the dividing cell’s ring of microfilaments is like the pulling of a drawstring. The cleavage furrow deepens until the parent cell is pinched in two, producing two completely separated cells, each with its own nucleus and share of cytosol, organelles, and other subcellular structures.

28. Describe cytokinesis in a plant cell. Use a labeled sketch that shows the *cell plate*.

See page 235 of your text for the labeled figure (12.10b).

Cytokinesis in plant cells, which have cell walls, is markedly different. There is no cleavage furrow. Instead, during telophase, vesicles derived from the Golgi apparatus move along microtubules to the middle of the cell, where they coalesce, producing a cell plate. Cell wall materials carried in the vesicles collect in the cell plate as it grows. The cell plate enlarges until its
surrounding membrane fuses with the plasma membrane along the perimeter of the cell. Two daughter cells result, each with its own plasma membrane. Meanwhile, a new cell wall arising from the contents of the cell plate has formed between the daughter cells.

29. How is the cell plate formed? What is the source of the material for the cell plate?

Vesicles derived from the Golgi apparatus move along microtubules to the middle of the cell, where they coalesce, producing a cell plate.

30. Prokaryote reproduction does not involve mitosis, but instead occurs by binary fission. This process involves an origin of replication. Describe binary fission.

A method of asexual reproduction by “division in half.” In prokaryotes, binary fission does not involve mitosis, but in single-celled eukaryotes that undergo binary fission, mitosis is part of the process.

31. Notice that now you are learning a number of differences between prokaryotic and eukaryotic cells. Besides the fact that prokaryotes lack a membrane-bounded nucleus, describe the following differences:

Mode of reproduction? Prokaryotes divide by fission, and eukaryotes by mitosis.

Number of chromosomes? Prokaryotic cells have a single circular chromosome, whereas eukaryotic cells have distinct linear chromosomes. The number varies by species in eukaryotes.

Shape of the bacterial chromosome? Circular (prokaryotes) versus linear (eukaryotes)

**Concept 12.3 The eukaryotic cell cycle is regulated by a molecular control system**

32. What controls the cell cycle? Study the Inquiry Figure 12.14 in your text to help you answer this question.

Molecules present in the cytoplasm during the S or M phase control the progression to those phases.

33. What is a cell cycle checkpoint?

A control point in the cell cycle where stop and go-ahead signals can regulate the cycle.

34. Summarize what happens at each checkpoint. You may add to this chart as you study this section.

<table>
<thead>
<tr>
<th>Checkpoint</th>
<th>What Happens? How Is It Controlled?</th>
</tr>
</thead>
<tbody>
<tr>
<td>G₁</td>
<td>If a cell receives the go-ahead signal at this checkpoint, the cell cycle will continue. It is regulated by the cyclin-CDk complexes.</td>
</tr>
<tr>
<td>G₂</td>
<td>When sufficient MPF accumulates, the G₂ checkpoint is passed, and mitosis is promoted.</td>
</tr>
<tr>
<td>M</td>
<td>The kinetochores must all be attached to spindle fibers during metaphase. This will activate an enzyme (separase), which allows the sister chromatids to separate and...</td>
</tr>
</tbody>
</table>
35. What is the $G_0$ phase? Describe this phase.

$G_0$ phase is a nondividing state occupied by cells that have left the cell cycle, sometimes reversibly, such as liver cells.

36. What is a protein kinase?

An enzyme that transfers phosphate groups from ATP to a protein, thus phosphorylating the protein.

37. Kinases drive the cell cycle, but they must be activated by attachment of a cyclin.

38. The activity of cyclin-dependent kinases (CDks) rises and falls. Why?

The activity of CDks rises and falls with changes in the concentration of its cyclin partner, MPF.

39. What does MPF trigger? What are some specific activities that it triggers?

MPF triggers the cell’s passage past the $G_2$ checkpoint into M phase.

40. What happens if all the chromosome kinetochores are not attached to spindle fibers? When this occurs, which checkpoint is not passed?

If all the chromosome kinetochores are not attached to spindle fibers, the sister chromatids remain together, delaying anaphase. When this occurs, the M phase checkpoint is not passed.

41. What are growth factors? How does platelet–derived growth factor (PDGF) stimulate fibroblast division?

Growth factor is a protein released by certain cells that stimulates other cells to divide. Fibroblasts have PDGF receptors on their plasma membranes. The binding of PDGF molecules to these receptors triggers a signal transduction pathway that allows the cells to pass the $G_1$ checkpoint and divide.

42. Cancer cells exhibit different behaviors than normal cells. Here are two normal behaviors they no longer show. Explain each behavior.

**density-dependent inhibition:** Cells normally divide until they form a single layer of cells on the inner surface of the culture container, at which point the cells stop dividing. If some cells are removed, those bordering the open space begin dividing again and continue until the vacancy is filled. Follow-up studies revealed that the binding of a cell-surface protein to its counterpart on an adjoining cell sends a growth-inhibiting signal to both cells, preventing them from moving forward in the cell cycle, even in the presence of growth factors.

**anchorage dependence:** To divide, they must be attached to a substratum, such as the inside of a culture jar or the extracellular matrix of a tissue.
43. Cancer cells also show loss of cell cycle controls and may divide without being checked. The story of HeLa cells is worth noting. What is their source? How old are they? Note that, unlike normal cells, HeLa cells are immortal!

HeLa cells’ original source was a tumor removed from a woman named Henrietta Lacks. This cell line has been reproducing in culture since 1951.

44. What is transformation? What is metastasis?

Transformation is the conversion of a normal animal cell to a cancerous cell.

Metastasis is the spread of cancer cells to locations distant from their original site.

45. Distinguish between a benign tumor and a malignant tumor.

A benign tumor is a mass of abnormal cells with specific genetic and cellular changes such that the cells are not capable of surviving at a new site and generally remain at the site of the tumor’s origin.

A malignant tumor is a cancerous tumor containing cells that have significant genetic and cellular changes and are capable of invading and surviving in new sites. Malignant tumors can impair the functions of one or more organs.

46. List two specific cancer treatments, and tell how each treatment works.

Radiation, Chemotherapy

A tumor that appears to be localized may be treated with high-energy radiation, which damages DNA in cancer cells much more than it does in normal cells, apparently because the majority of cancer cells have lost the ability to repair such damage. To treat known or suspected metastatic tumors, chemotherapy is used, in which drugs that are toxic to actively dividing cells are administered through the circulatory system. Chemotherapeutic drugs interfere with specific steps in the cell cycle.

47. In the light micrograph below of dividing cells near the tip of an onion root, identify a cell in each of the following stages: prophase, prometaphase, metaphase, anaphase, and telophase.

See page A-11 (Appendix) in your text for the labeled figure.

Test Your Understanding Answers

Now you should be ready to test your knowledge. Place your answers here:

1. b 2. a 3. c 4. c 5. a 6. b 7. (above) 8. a 9. e