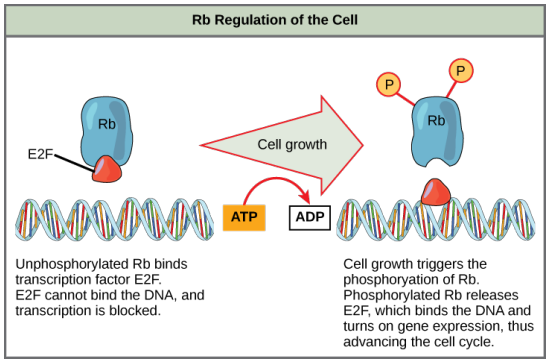
Biology 2e
Unit 2: The Cell
Chapter 10: Cell Reproduction

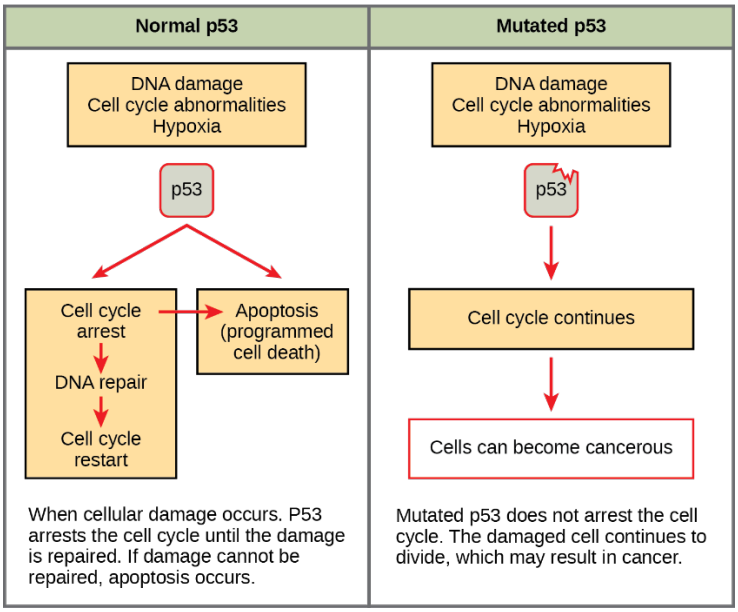
Visual Connection Questions

1. Rb and other proteins that negatively regulate the cell cycle are sometimes called tumor suppressors. Why do you think the name tumor suppressor might be appropriate for these proteins?



Rb and other negative regulatory proteins control cell division and therefore prevent the formation of tumors. Mutations that prevent these proteins from carrying out their function can result in cancer.

2. Human papillomavirus can cause cervical cancer. The virus encodes E6, a protein that binds p53. Based on this fact and what you know about p53, what effect do you think E6 binding has on p53 activity?



d. E6 binding marks p53 for degradation.

Review Questions

3. A diploid cell has_____ the number of chromosomes as a haploid cell.
c. twice

4. An organism's traits are determined by the specific combination of inherited _____.
b. genes.

5. The first level of DNA organization in a eukaryotic cell is maintained by which molecule?
d. histone

6. Identical copies of chromatin held together by cohesin at the centromere are called _____.
d. sister chromatids

7. Chromosomes are duplicated during what stage of the cell cycle?
b. S phase

8. Which of the following events does not occur during some stages of interphase?
d. separation of sister chromatids

9. The mitotic spindles arise from which cell structure?
b. centrosome

10. Attachment of the mitotic spindle fibers to the kinetochores is a characteristic of which stage of mitosis?
b. prometaphase

11. Unpacking of chromosomes and the formation of a new nuclear envelope is a characteristic of which stage of mitosis?
d. telophase

12. Separation of the sister chromatids is a characteristic of which stage of mitosis?
c. anaphase

13. The chromosomes become visible under a light microscope during which stage of mitosis?
a. prophase

14. The fusing of Golgi vesicles at the metaphase plate of dividing plant cells forms what structure?
a. cell plate

15. Which of the following is the correct order of events in mitosis?
prophase, prometaphase, metaphase, anaphase, telophase, and cytokinesis

16. At which of the cell-cycle checkpoints do external forces have the greatest influence?
a. G_1 checkpoint

17. What is the main prerequisite for clearance at the G_2 checkpoint?
c. accurate and complete DNA replication

18. If the M checkpoint is not cleared, what stage of mitosis will be blocked?
d. anaphase

19. Which protein is a positive regulator that phosphorylates other proteins when activated?
d. cyclin-dependent kinase (Cdk)

20. Many of the negative regulator proteins of the cell cycle were discovered in what type of cells?
c. cancer cells

21. Which negative regulatory molecule can trigger cell suicide (apoptosis) if vital cell cycle events do not occur?
a. p53

22. _____ are changes to the order of nucleotides in a segment of DNA that codes for a protein.
c. Gene mutations

23. A gene that codes for a positive cell cycle regulator is called a(n) _____.
c. proto-oncogene.

24. A mutated gene that codes for an altered version of Cdk that is active in the absence of cyclin is a(n) _____.
d. oncogene.

25. Which molecule is a Cdk inhibitor that is controlled by p53?
d. p21

26. Which eukaryotic cell cycle event is missing in binary fission?
c. karyokinesis

27. FtsZ proteins direct the formation of a _____ that will eventually form the new cell walls of the daughter cells.
b. cell plate

Critical Thinking Questions

28. Compare and contrast a human somatic cell to a human gamete.

Human somatic cells have 46 chromosomes: 22 pairs and 2 sex chromosomes that may or may not form a pair. This is the 2n or diploid condition. Human gametes have 23 chromosomes, one each of 23 unique chromosomes, one of which is a sex chromosome. This is the n or haploid condition.

29. What is the relationship between a genome, chromosomes, and genes?

The genome consists of the sum total of an organism's chromosomes. Each chromosome contains hundreds and sometimes thousands of genes, segments of DNA that code for a polypeptide or RNA, and a large amount of DNA with no known function.

30. Eukaryotic chromosomes are thousands of times longer than a typical cell. Explain how chromosomes can fit inside a eukaryotic nucleus.

The DNA double helix is wrapped around histone proteins to form structures called nucleosomes. Nucleosomes and the linker DNA in between them are coiled into a 30-nm fiber. During cell division, chromatin is further condensed by packing proteins.

31. Briefly describe the events that occur in each phase of interphase.

During G_1, the cell increases in size, the genomic DNA is assessed for damage, and the cell stockpiles energy reserves and the components to synthesize DNA. During the S phase, the chromosomes, the centrosomes, and the centrioles (animal cells) duplicate. During the G_2 phase, the cell recovers from the S phase, continues to grow, duplicates some organelles, and dismantles other organelles.

32. Chemotherapy drugs such as *vincristine* (derived from Madagascar periwinkle plants) and *colchicine* (derived from autumn crocus plants) disrupt mitosis by binding to tubulin (the subunit of microtubules) and interfering with microtubule assembly and disassembly. Exactly what mitotic structure is targeted by these drugs and what effect would that have on cell division?

The mitotic spindle is formed of microtubules. Microtubules are polymers of the protein tubulin; therefore, it is the mitotic spindle that is disrupted by these drugs. Without a functional mitotic spindle, the chromosomes will not be sorted or separated during mitosis. The cell will arrest in mitosis and die.

33. Describe the similarities and differences between the cytokinesis mechanisms found in animal cells versus those in plant cells.

There are very few similarities between animal cell and plant cell cytokinesis. In animal cells, a ring of actin fibers is formed around the periphery of the cell at the former metaphase plate (cleavage furrow). The actin ring contracts inward, pulling the plasma membrane toward the center of the cell until the cell is pinched in two. In plant cells, a new cell wall must be formed between the daughter cells. Due to the rigid cell walls of the parent cell, contraction of the middle of the cell is not possible. Instead, a phragmoplast first forms. Subsequently, a cell plate is formed in the center of the cell at the former metaphase plate. The cell plate is formed from

Golgi vesicles that contain enzymes, proteins, and glucose. The vesicles fuse and the enzymes build a new cell wall from the proteins and glucose. The cell plate grows toward and eventually fuses with the cell wall of the parent cell.

34. List some reasons why a cell that has just completed cytokinesis might enter the G_0 phase instead of the G_1 phase.

Many cells temporarily enter G0 until they reach maturity. Some cells are only triggered to enter G1 when the organism needs to increase that particular cell type. Some cells only reproduce following an injury to the tissue. Some cells never divide once they reach maturity.

35. What cell cycle events will be affected in a cell that produces mutated (non-functional) cohesin protein?

If cohesin is not functional, chromosomes are not packaged after DNA replication in the S phase of interphase. It is likely that the proteins of the centromeric region, such as the kinetochore, would not form. Even if the mitotic spindle fibers could attach to the chromatids without packing, the chromosomes would not be sorted or separated during mitosis.

36. Describe the general conditions that must be met at each of the three main cell cycle checkpoints.

The G_1 checkpoint monitors adequate cell growth, the state of the genomic DNA, adequate stores of energy, and materials for S phase. At the G_2 checkpoint, DNA is checked to ensure that all chromosomes were duplicated and that there are no mistakes in newly synthesized DNA. Additionally, cell size and energy reserves are evaluated. The M checkpoint confirms the correct attachment of the mitotic spindle fibers to the kinetochores.

37. Compare and contrast the roles of the positive cell-cycle regulators negative regulators.

Positive cell regulators such as cyclin and Cdk perform tasks that advance the cell cycle to the next stage. Negative regulators such as Rb, p53, and p21 block the progression of the cell cycle until certain events have occurred.

38. What steps are necessary for Cdk to become fully active?

Cdk must bind to a cyclin, and it must be phosphorylated in the correct position to become fully active.

39. Rb is a negative regulator that blocks the cell cycle at the G_1 checkpoint until the cell achieves a requisite size. What molecular mechanism does Rb employ to halt the cell cycle?

Rb is active when it is dephosphorylated. In this state, Rb binds to E2F, which is a transcription factor required for the transcription and eventual translation of molecules required for the G_1/S transition. E2F cannot transcribe certain genes when it is bound to Rb. As the cell increases in size, Rb becomes phosphorylated, inactivated, and releases E2F. E2F can then promote the transcription of the genes it controls, and the transition proteins will be produced. 4

40. Outline the steps that lead to a cell becoming cancerous.

If one of the genes that produces regulator proteins becomes mutated, it produces a malformed, possibly non-functional, cell cycle regulator, increasing the chance that more mutations will be left unrepaired in the cell. Each subsequent generation of cells sustains more damage. The cell cycle can speed up as a result of the loss of functional checkpoint proteins. The cells can lose the ability to self-destruct and eventually become "immortalized.

41. Explain the difference between a proto-oncogene and a tumor-suppressor gene.

A proto-oncogene is a segment of DNA that codes for one of the positive cell cycle regulators. If that gene becomes mutated so that it produces a hyper-activated protein product, it is considered an oncogene. A tumor suppressor gene is a segment of DNA that codes for one of the negative cell cycle regulators. If that gene becomes mutated so that the protein product becomes less active, the cell cycle will run unchecked. A single oncogene can initiate abnormal cell divisions; however, tumor suppressors lose their effectiveness only when both copies of the gene are damaged.

42. List the regulatory mechanisms that might be lost in a cell producing faulty p53.

Regulatory mechanisms that might be lost include monitoring of the quality of the genomic DNA, recruiting of repair enzymes, and the triggering of apoptosis.

43. p53 can trigger apoptosis if certain cell-cycle events fail. How does this regulatory outcome benefit a multicellular organism?

If a cell has damaged DNA, the likelihood of producing faulty proteins is higher. The daughter cells of such a damaged parent cell would also produce faulty proteins that might eventually become cancerous. If p53 recognizes this damage and triggers the cell to self-destruct, the damaged DNA is degraded and recycled. No further harm comes to the organism. Another healthy cell is triggered to divide instead.

44. Name the common components of eukaryotic cell division and binary fission.

The common components of eukaryotic cell division and binary fission are DNA duplication, segregation of duplicated chromosomes, and division of the cytoplasmic contents.

45. Describe how the duplicated bacterial chromosomes are distributed into new daughter cells without the direction of the mitotic spindle.

As the chromosome is being duplicated, each origin moves away from the starting point of replication. The chromosomes are attached to the cell membrane via proteins; the growth of the membrane as the cell elongates aids in their movement.