5.1: Replication and division of nuclei and cells

1. **D**
   In cell W, DNA replication is complete but the cell has not reached maximum size (G_2 phase). In cell X, microtubule formation is nearly complete (late G_2 phase), but chromosomes have not yet condensed, as condensation happens during prophase.
2. **D**
   After one cell cycle, the number of chromosomes remains the same. The volume of cytoplasm decreases due to cell division, and telomere length shortens with each replication cycle.
3. **B**
   Starting with 12 cells and given a rate of 1 division every 32 hours, 3 divisions occur in 4 days (96 hours). Each division doubles the number of cells: $12 \rightarrow 24 \rightarrow 48 \rightarrow 96$ cells.
4. **A**
   Mitosis is involved in growth (diagram 1), repair (diagram 4), asexual reproduction (diagram 3), and replacement of cells (diagram 2). All diagrams show roles of mitosis.
5. **A**
   Interphase (preparation), anaphase (separation of chromatids), and cytokinesis (cell division) are all key phases of the mitotic cell cycle.
6. **D**
   Telophase (2) is the final stage of mitosis, while interphase (1) occurs before mitosis, and cytokinesis (3) happens after mitosis. Hence, only telophase is part of mitosis
7. **B**
   During the stages of the mitotic cell cycle, the DNA content changes. Here's how many copies of each DNA molecule will be found at the specified stages:
   G1 of interphase: At the start of interphase (G1), the cell is diploid (2n), meaning it has two copies of each DNA molecule. So, it has 2 copies.
   Cytokinesis: Cytokinesis is the stage at the end of the cell cycle where the cell divides into two daughter cells. Each daughter cell will receive a complete set of DNA, so they will each have 1 copy.
8. **D**
   Mitosis involves the formation of genetically identical nuclei. Recognizing the characteristic of mitosis that results in equal-sized daughter cells with identical genetic material is fundamental to understanding cellular replication and growth.
9. **B**
   Able to divide by mitosis to produce more stem cells: True. One of the key characteristics of stem cells is their ability to self-renew through cell division. This allows them to maintain a pool of undifferentiated stem cells.
   Able to differentiate into specialized cells: True. Stem cells have the capacity to differentiate into various types of specialized cells, which is essential for tissue repair and regeneration. This process is called differentiation.
   Able to repair damaged cells:Stem cells have the unique ability to turn into different types of cells in the body. This can help repair damaged tissues or organs and is done by replacing them with new cells, however, they cannot heal or repair a cell that is damaged.
10. **A**
    The mitotic cell cycle includes interphase (during which the cell grows and DNA is replicated), mitosis (which includes prophase, metaphase, anaphase, and telophase), and cytokinesis (when the cell divides into two daughter cells). Telophase and cytokinesis are part of the mitotic phase where the actual cell division occurs. Therefore, options 1, 2, and 3 are all parts of the cell cycle.
11. **C**
    To determine the percentage of red blood cells replaced each day, divide the number of cells replaced in a day by the total number of cells and then multiply by 100 to convert to a percentage.
    So the calculation is $2.5 \times 10^{11}/2.5 \times 10^{13} \times 100$.
12. **C**
    DNA polymerase is responsible for adding nucleotides to a growing DNA strand during replication. The enzyme catalyzes the formation of phosphodiester bonds between the phosphate group of the incoming

nucleotide and the 3' hydroxyl group of the preceding nucleotide in the DNA strand.

13. A

Telomerase is active in cells that divide frequently, such as cancer cells, stem cells, and activated memory B-lymphocytes, to maintain telomere length and sustain division.

14. B

The diagram shows the mass of nuclear DNA in a cell over time. The increase in DNA content indicates DNA replication, and the subsequent drop represents nuclear division where the DNA content is halved as the cell divides. The pattern repeats, showing that the process is cyclical, as in the cell cycle. Since the mass of DNA doubles and then halves, both DNA replication (which doubles the DNA content) and nuclear division (which would halve it during mitosis) are occurring. Cytokinesis, the process of cytoplasm division, typically follows nuclear division to form two separate cells.

15. B

The mutation preventing the production of p53 protein allows cells with damaged DNA to replicate, as p53 binds to damaged DNA and prevents its replication. This unregulated replication of damaged DNA can lead to cancer.

16. D

All listed processes involve cell division that produces genetically identical cells. Plant roots grow by mitosis, skin cells are replaced by mitosis, muscle tissue repair involves mitosis of muscle cells, and asexual reproduction in corals produces clones.

17. A

At the start of telophase in mitosis, each chromosome consists of two chromatids, each with one DNA molecule, giving a total of two chromatids and two DNA molecules per chromosome.

18. D

Embryonic stem cells have high levels of telomerase activity, an enzyme that adds nucleotide sequences to the ends of the telomeres, thereby maintaining their length through cell divisions. This telomerase activity prevents the shortening of telomeres that typically occurs with cell division in somatic cells. Therefore, in embryonic stem cells, the telomeres generally stay the same length despite repeated mitotic cycles.

19. B

Stem cells in the basal layer of the epidermis divide to produce new skin cells. Keratinocytes require organelles like ribosomes for synthesizing keratin, a protein that strengthens the skin.

20. A

Option A is the correct answer as if the telomeres become too short the cell may stop to divide in order to prevent the loss of any vital genetic information. Option B is incorrect as adding telomeres would decrease the aging of cells. Option C is incorrect as telomeres are repaired by telomerase. Option D is incorrect as telomeres only prevent damage to the ends of the DNA strands.

21. D

Option D is the correct answer as at the end of S phase and G2 phase the nucleus will have twice the amount of DNA that the nucleus had in the G1 phase of the cell cycle.

22. A

During interphase, the cell grows (stage 1) and replicates its DNA (stage 3). These processes are crucial for cell division and are part of the cell cycle's preparatory phases.

23. A

Option A is the correct answer as the main role of mitosis is to help in the growth of organisms. Meiosis produces genetically different cells. Mitosis produces new cells and does not repair existing ones. Mitosis does not replace cancerous tissue.

24. B

Option B is the correct answer as cell structures cannot be repaired using mitosis. Cloning, growth and reproduction of unicellular organisms all occurs via mitosis.

25. D

Option D is the correct answer as since telomerase adds nucleotides to telomeres it prevents their shortening. A low concentration of telomerase means that the body cells can divide a limited number of times as a point will comes where the telomeres will not completely removed.

26. B

Option B is the correct answer as the G_1 phase is where DNA replication occurs so the p53 protein stops the cell cycle just before the G_1 phase.

27. C

Option C is the correct answer as histone proteins are the most numerous as they are required for holding together the nucleosomes. This is followed by telomeres where each sister chromatid has 2 of them. Finally, DNA molecules are the least numerous.

28. D

Option A is incorrect as a centromere hold the chromatids together until the end of metaphase. Option B is incorrect as chromatids are made of DNA and are held together with each other using proteins. Option C is the correct answer as prokaryotes contain circular DNA. Hence, option D is the correct answer as a telomere are repeated nucleotide sequences that are found on the end of each chromatid.

29. B

Option B is the correct answer as interphase is the longest phase of the cell cycle and during uncontrolled cell division this phase is significantly shortened.

30. C

Option C is the correct answer as in the G_2 phase of the cell cycle replication will already have occurred meaning that there will be an extra set of DNA molecules meaning there will be 2 DNA molecules.

31. D

Option D is the correct answer as all of the listed processes occur during tissue repair as a result of mitosis.

32. C

Option C is the correct answer as histone proteins are most numerous since they allow the DNA to fit into the cell. This is followed by the telomeres are at present at the ends of the chromosomes. Finally DNA molecules are the least numerous.

33. A

This image shows the process of budding where asexual reproduction results in identical offspring. So this involves DNA replication followed by mitosis. Growth is also involved as the offspring slowly grows before eventually separating. Hence, option A is the correct answer.

34. C

Option C is the correct answer as the chromosomes are compose of 2 chromatids held together via a centromere in the interphase, prophase and metaphase.

35. B

Option B is the correct answer as the uncoiling of DNA takes place in the interphase for DNA replication which can be blocked to prevent the cells from dividing.

36. C

Option C is the correct answer as histone proteins are required for the packaging of the DNA compactly.

37. D

Option D is the correct answer as all the stages contain 2 copies of the DNA molecule at the start of the phase. 1 copy exists after cytokinesis takes place.

38. D

Option A is incorrect as at the beginning of interphase contains individual chromatids. Option B is incorrect as telomeres are present on both ends of the chromatids. Option C is incorrect as centromere does contain DNA. Hence, option D is the correct answer as histones hold together the DNA molecule.

39. C

Stem cells produce additional cells that can differentiate into the skin cells. Hence, option C is the correct answer.

40. C

Clonal selection does not involved mitosis whereas replacement of damaged skin cells and forming cells at the tip of a growing root both involve mitosis. Hence, option C is the correct answer.

41. D

Chromosomes condense and become visible in the M phase of the mitotic cycle which is represented by option D making it the right answer.

42. B

Option A is incorrect as centromeres do contain DNA. Option C is incorrect as centromeres are not responsible for the separation of the chromatids the spindle fibers are. Option D is incorrect as centromeres do not divide and telomeres do not join chromatids together. Hence, option B is the correct answer as it accurately describes the functions of each part.

43. D

In the prophase chromosomes exist as 2 sister chromatids meaning there are 64 chromatids. Since each chromatid has 2 telomeres the total number of telomeres will be 128 making option D the correct answer.

44. D

Telomeres exist as regions to prevent the loss of crucial DNA as a result of shortening when the chromosomes replicate. Hence, they are required in stage S making option D the correct answer.

45. C

First the chromosomes line up at the equator which is followed by the spindle fibers shortening. This is

followed by the nuclear envelope reappearing and finally the chromosomes uncoiling. Hence, option C is the correct answer.

46. C

Interphase is the longest meaning that it is represented by Z. Then mitosis is follows it which is represented by X and finally cytokinesis is the shortest phase represented by Y. Hence, option C is the correct answer.

47. D

In a cancer cell the length of the telomeres does not change. Hence, option D is the correct answer.

48. B

In the prophase chromosomes exist as 2 sister chromatids joined together by a single centromere. Each chromatid has 2 telomeres meaning total are 4. Additionally, there are 4 polynucleotide strands. Hence, option B is the correct answer.

49. B

The graph shows DNA replication, nuclear division and cytokinesis as the DNA mass is doubled after which division occur that halves the mass again and separate cells are produced as a result of cytokinesis. Hence, option B is the correct answer.

50. B

Centromeres separate in the anaphase while the chromosomes condense and become visible in the prophase. Hence, option B is the correct answer.

51. B

P1 matches with F2, P2 matches with F1 and P3 matches with F3. Hence, option B is the correct answer.

52. A

Metaphase is followed by anaphase meaning that the distance between the centromeres and the poles of the spindle rapidly decreases as the spindle fibers shorten. 2 then represents the distance between the centromeres of the sister chromatids since they move to opposite poles of the cells and 3 then represents the distance between the poles of the spindle as they separate into individual cells. Hence, option A is the correct answer.

53. B

During telophase the sister chromatids separate and chromosomes have one chromatid each. Since each chromosome has 2 telomeres the scientist will observe 76 telomeres making option B the correct answer.

54. A

During interphase the cell grows and the amount of DNA in it double. Hence, option A is the correct answer. 4 happens in prophase and 3 happens in prophase as well.

55. D

Only prophase is part of the M phase while cytokinesis has its own phase and interphase contains the G1, S and the G2 phases. Hence, option D is the correct answer.

56. D

Since the spindle fibers are pulled to the poles of the cell their length decreases when the chromatids are pulled to the opposite poles meaning that when their length decreases again to the minimum is when the centromeres detach. Hence, option D is the correct answer.

57. B

After prophase, metaphase proceeds where the centromeres of the chromosomes attach to the spindle microtubules. Hence, option B is the correct answer.

58. B

Statements 1 and 3 are correct as for the formation of a tumor the cell would need to divide indefinitely with mitosis not halted by cell to cell contact. Statement 2 is incorrect as migrating is not necessary for the formation of a tumor. Hence, option B is the correct answer.

59. B

During interphase before the S phase one copy of the DNA molecule will be found while in cytokinesis the 2 cells that have no separated will combined contain 2 copies. Hence, option B is the correct answer.

60. B

In a cell that has just undergone mitosis its main focus will be on cell growth meaning that ATP production and protein synthesis will be the first priorities while DNA replication will not be focused upon. Hence, option B is the correct answer.

61. B

First the nuclear envelope is broken which is followed by the production of spindle microtubules. This is followed by the centromeres separating and finally the nucleoli becoming visible again. Hence, option B is the correct answer.

62. A

Option B is incorrect as chromatid contains double stranded DNA. Option C is incorrect as chromatid

contains histone proteins. Option D is incorrect as centromeres do not split and chromatid does not contain single stranded DNA. Hence, option A is the correct answer as centromeres join the sister chromatids together, chromatid contains double stranded DNA associated with histone proteins and telomeres protects the tips of chromatid from shortening during replication.

63. C

Since telomerase prevents the shortening of telomeres if this enzyme is not produced the bone marrow cells will eventually stop to divide since further division would result in loss of valuable genetic material. Hence, option C is the correct answer.

64. D

Option D is the correct answer as in G2, metaphase and cytokinesis all the cells will contain 2 copies of the DNA molecule.

65. B

Option B is the correct answer as in metaphase the chromosomes attach to the spindle fibers and in anaphase as the fibers shorten the chromatids are pulled apart to opposite poles ensuring that each daughter cell receives one chromatid.

66. C

Statements 1 and 3 are incorrect as during cytokinesis the cells exist as one cell meaning that the structures do not replicate yet nor does the nuclear envelope reform. Statement 2 is correct as the cell structures are shared between the 2 cells. Hence, option C is the correct answer.

67. D

In human cells there are 92 chromatids and since each chromatid contains 2 telomeres that means that 184 telomeres are present. Hence, option D is the correct answer.

68. D

DNA replication takes place during the S phase making option D the correct answer.

69. D

Only telophase is part of mitosis. Hence, option D is the correct answer.

70. D

Cell repair does not depend on mitosis. Cell replacement, number of stem cells, tissue repair and tumor formation are all dependent on mitosis. Hence, option D is the correct answer.

71. A

Option A is the correct answer as curve 1 shows the distance decreasing which suggests that this indicates the distance between the centromeres and the poles of spindle as the fibers shorten the chromosomes are pulled to the poles in anaphase. This means that curve 2 must represent the distance between the sister chromatids since they move to opposite poles of the cell. Hence, option A is the correct answer.

72. D

In each of the stages mentioned there will be 2 copies of the DNA molecule found. Hence, option D is the correct answer.

73. D

P1 matches with F2, P2 matches with F1 and P3 matches with F3. Hence, option D is the correct answer.

74. C

Graph X shows the distance of the centromeres form the poles of the spindle as during anaphase they move towards the poles. Y represents the distance between the poles of the spindle which remains constant. Z represent the distance between sister chromatids which exponentially increases since they move to opposite poles. Hence, option C is the correct answer.

75. A

The telomeres in cancer cells remain of the same length meaning that they are capable of synthesizing telomerase that stops the shortening of the telomeres and allows for indefinite cell division. Hence, option A is the correct answer.

76. B

Option B is the correct answer as the cell will reach metaphase but will not be able to complete it since the chromosomes cannot separate from each other.

77. D

Option A is incorrect as it represent a centriole. Option B is incorrect as it represents histone proteins. Option C is incorrect as it represents centromere. Hence, option D is the correct answer as telomere contains repetitive nucleotide sequences that protect genetic material from being lost during replication.

78. C

Options A and B are incorrect since metaphase and cytokinesis will always take place. Option D is incorrect as not all tumor cells have mutated DNA. Hence, option C is the correct answer as interphase takes less time in tumor cells and it is the longest phase of the cell cycle.

79. B

Option A shows G1, option B the S phase, option C the G2 and option D the M phase. DNA replicates in the S phase making option B the correct answer.

80. B

Checkpoint 1 will be in phase G2 after DNA replication to check from errors in replication. Checkpoint 2 will be in the M phase since anaphase comes under the M phase. Checkpoint 3 will be in the G1 phase before the DNA replication that is S phase. Checkpoint 4 will be in S phase to stop replication if the DNA is still not repaired. Hence, option B is the correct answer.

81. C

The correct sequence in G1 to S to G2 to mitosis to cytokinesis. Hence, option C is the correct answer.

82. A

Telomerase is activated in cancer cells and this allows them to replicate indefinitely without the loss of telomeres. Hence, option A is the correct answer.

83. B

Statement 1 is incorrect as chromosomes do not migrate chromatids do. The correct order of the statements 2, 3 and 4 is 3 to 2 to 4. Hence, option B is the correct answer.

84. D

Options A and B are incorrect as the centrioles replicate in the S phase and the centrioles do not migrate to poles in the metaphase. Option C is incorrect as the nuclear membrane does not begin to reform in anaphase. Hence, option D is the correct answer as in telophase the nuclear membrane reforms, one centriole is beside each nucleus and spindle microtubules break down.

85. D

Options A and B are incorrect as bacteria divide via binary fission. Option C is incorrect as red blood cells are produced in the bone marrow. Hence, option D is the correct answer as cancer cells, lymphocytes and stem cells all divide via mitosis.

86. D

Just before the prophase the human cells contain 92 chromatids and 92 DNA molecules since each chromatid contains one. The spindle is not present and the nuclear envelope is still present. Hence, option D is the correct answer.

87. A

Option A is the correct answer as cytokinesis has its own phase, DNA replication occurs in the S phase and the interphase contains the G1, S and G2 phases.

88. C

Option C is the correct answer as in the prophase the spindle starts to form which means that this phase will be the one to be affected first.

89. A

Replacing the telomeres completely will result in the cells dividing continually whereas in the absence of substance X the cell division eventually stops as the telomeres shorten. Hence, option A is the correct answer.

90. B

Statements 1 and 3 are correct as asexual reproduction occurs via mitosis and mitosis produces genetically identical cells. Statement 2 is incorrect as growth is not a primary concern for single celled organisms. Hence, option B is the correct answer.

91. D

Option A is incorrect as centrioles replicate during the S phase. Options B and C are incorrect as formation of chromosomes takes place in interphase and replication takes place in the S phase. Hence, option D is the correct answer as centrioles separate in the prophase.

92. A

All the 3 statements are correct as cell cycle consists of interphase, mitosis and cytokinesis. DNA replication takes place in S phase which is a part of interphase and a cell can remain in interphase of several months until the signal for division reaches to it. Hence, option A is the correct answer.

93. D

P represents meiosis which produces haploid cells such as gametes. R represents mitosis which results in the growth of a zygote to an adult. Hence, option D is the correct answer.

94. D

Statement 1 is incorrect as division via mitosis does not repair the cell. Statements 2, 3 and 4 are all correct as diploid cells have 2 complete sets of chromosomes and can under meiosis to produce haploid cells. They can also undergo mitotic division to produce genetically identical cells for growth. Hence, option D is the correct answer.

95. C
Mitosis produces 2 diploid cells while meiosis produces 4 haploid cells. The product of fertilization is a diploid zygote. Hence, option C is the correct answer.

96. D
Option A is incorrect as in mitosis the chromosome number remain 2n. Option B is incorrect as in DNA replication the number goes from n to 2n. Option C is incorrect as in mitosis the number remains 2n. Hence, option D is the correct answer as in meiosis there is a reduction in chromosome number which goes from 2n to n and n mitosis the 2n chromosome number is conserved.

97. B
The 22 chromosomes are diploid so that means 11 will be the haploid number. Hence, option B is the correct answer.

98. D
Statements 2 and 4 correctly describe diploid and haploid number. Diploid means that there are 2 copies of each homologous chromosome and haploid means one copy of each homologous chromosome. Hence, option D is the correct answer.

99. B
Options A, C and D are incorrect as these statements are all correct about a diploid cell. Option B is the correct answer as a diploid cell cannot repair itself by undergoing a mitotic division.

100. A
Option B is incorrect as the mass is halved only after cytokinesis. Option C is incorrect as not all cancers are caused by mutations. Option D is incorrect as cells cannot be repaired via mitosis. Hence, option A is the correct answer as haploid eukaryotes can reproduce via mitosis and diploid eukaryotes via mitosis and meiosis.

101. D
Since each chromatid contains one molecule of DNA cell 1 has 92 molecules of DNA. Cell 2 has 46 molecules since it has chromosomes as single chromatids. Hence, option D is the correct answer.

102. B
Cloning of plasma cells and replacement of damaged cells is done via mitosis while gametes are produced via meiosis. Hence, option B is the correct answer.

103. B
The first fertile hybrid donates 14 chromosomes and another grass donates 7. This means that the sterile hybrid has 21 chromosomes. Doubling this gives us 42 as the number for the second fertile hybrid making option B the correct answer.

5.2: Chromosome behaviour in mitosis

READ & WRITE
PUBLICATIONS
www.readnwrite.org

1. D
At point D, the spindle fibers have shortened, indicating the end of anaphase when all the centromeres have detached, and chromosomes have moved to opposite poles. This marks the completion of chromosome separation.

2. D
In stage X (anaphase), the microtubules shorten, causing the spindle fibers to contract, which pulls the centromeres apart and separates the sister chromatids, leading to chromosome division.

3. C
During metaphase and anaphase, the centromeres move towards the poles (Graph X), and the sister chromatids move apart (Graph Y), leading to the correct assignment of distances.

4. C
At the start of anaphase, sister chromatids separate, DNA remains associated with histone proteins, and the cell surface membrane stays intact.

5. B
In metaphase, chromosomes align at the cell equator, and the nuclear envelope has broken down, as described in the photomicrograph.

6. A
The cell cycle consists of interphase and mitosis. DNA replication occurs during interphase, and cells can remain in interphase for extended periods, especially in non-dividing cells.

7. B
Each chromosome has two telomeres, so with 38 chromosomes, there will be $38 \times 2 = 76$ telomeres in one nucleus during telophase.

8. **D**
Chromosomes condense and become visible during prophase of mitosis, which corresponds to phase D in the diagram.

9. **B**
During prophase of mitosis, each chromosome consists of two sister chromatids, which means there are 4 DNA strands present, as shown in row B.

10. **B**
During telophase, chromosomes start to uncoil inside the newly formed nucleus, marking the final stage of mitosis before cytokinesis.

11. **C**
The cell is in anaphase. The centromeres are moving to opposite poles (2 correct), and the spindle microtubules are shortening to pull the chromatids apart (3 correct). Chromosome condensation (1) occurs during prophase, not anaphase.

12. **B**
The electron micrograph shows chromosomal condensation, making it difficult to distinguish between late anaphase and early telophase, as both stages involve chromosomal movement and reformation of the nucleus.

13. **B**
Chromosomes are visible as two chromatids during the stages of prophase and metaphase in mitosis. In this scenario, the number of cells in prophase is 73, and in metaphase is 16, totaling 89 cells where chromosomes appear as two chromatids. Out of 1000 cells observed, this represents 8.9% of cells ($89/1000 \times 100$). This percentage is a direct observation and does not require interpretation of mitotic stages beyond identifying when chromatids are visible.

14. **D**
Q represents the DNA. This DNA is wrapped around proteins called histones represented by P and R. Option D is the only correct statement because P and R represent the histone protiens and Q is the DNA strand, that folds and condenses around the histone protiens to form chromatids.

15. **C**
The correct statement based on the provided data is:
C Most of the cells undergoing cell division are closer to the tip of the root.
From the given data, you can see that the mitotic index is highest (around 12) closest to the tip of the root (around 0.2 mm from the tip) and gradually decreases as the distance from the root tip increases. This suggests that most of the cells undergoing cell division are closer to the tip of the root.

16. **C**
Observing stained onion cells undergoing mitosis involves recognizing the characteristic features of each mitotic phase, such as chromosome condensation, alignment at the metaphase plate, sister chromatids separation, and nuclear division.

17. **B**
At the end of prophase of mitosis, a single chromosome consists of two sister chromatids, each containing a double-stranded DNA molecule, held together at a common centromere, therefore having one centromere. Each chromatid has one DNA molecule, thus there are two polynucleotide strands in total.

18. **C**
During interphase, the cell undergoes DNA replication to prepare for cell division (process 1), and also carries out the synthesis of ribosomes (process 3), which are needed for protein synthesis. Microtubule organization does occur during interphase, but it is not exclusively an interphase event, as microtubules are continually forming and disassembling throughout the cell cycle. However, the organization of microtubules into the mitotic spindle specifically occurs during mitosis, not interphase.

19. **B**
Option B is the correct answer as in the prophase the nuclear envelope fragment and the nucleolus disappears. Additionally, the stained chromosomes become visible as they become coiled. Centrioles replicate in the metaphase not the prophase.

20. **A**
Option A is the correct answer as interphase, prophase and cytokinesis are all phases in the cell cycle.

21. **D**
Option A is incorrect as centromeres do not replicate in the prophase. Option B is incorrect as centromeres do not move to opposite poles in metaphase. Option C is incorrect as in anaphase the nuclear envelope does not begin to reform. Hence, option D is the correct answer as in the telophase the nuclear envelope reforms, the centromeres are at maximum distance from the equator and the spindle microtubules are broken down.

22. D

Since the cell is diploid this means that there are 52 chromatids and since each chromatid has 2 telomeres there will be a total of 104 telomeres making option D the correct answer.

23. C

Statement 1 is correct as cell P shows anaphase where the chromatids move to opposite poles of the cell. Statement 2 is incorrect as spindle formation occurs in cell R. Statements 3 and 4 are correct as all stages of mitosis have the same amount of DNA and the correct order is S to R to T to P to Q. Hence, option C is the correct answer.

24. A

Option A is the correct answer as 1, 2, 3 and 4 are all the stages of cell cycle in the mitosis stage and in mitosis the cell contains twice the amount of DNA as a cell that has just undergone cytokinesis.

25. D

Option D is the correct answer as stopping mitosis means that cell replacement and number of stem cells are affected since they divide mitotically. Tissue repair is also affected since mitosis accomplishes it. Tumor formation is also affected since tumors are essentially masses of cells dividing uncontrollably via mitosis.

26. B

Option B is the correct answer as curve P from W to X represents anaphase as the sister chromatids move to the opposite poles of the cell. Curve Q from T to W presents metaphase as in metaphase the chromatids just arrange themselves on the equator of the cell and attach to the spindle fibers.

27. A

Option A is the correct answer as in anaphase the chromosomes exist as sister chromatids with each having 1 centromere, 2 telomeres and 2 polynucleotide strands.

28. C

Option C is the correct answer as metaphase is not shown since it would show something like the chromosomes lined at the equator which is not seen in any of the images.

29. C

Option C is the correct answer as in the M phase there are 92 chromatids due to 46 chromosomes. In G_1 since DNA has not yet replicated there are 46 chromatids due to 23 chromosomes and then in G_2 there are 92 chromatids due to replication of DNA.

30. A

Option A is the correct answer as the cell that has undergone the most mitotic divisions is the one that has the least number of bases in the telomeres as telomeres shorten in each mitotic division.

31. C

Option C is the correct answer as aging is directly related to the shortening of telomeres meaning that these jellyfish most probably possess a mechanism that allows them to restore their telomeres to their original length than allows them to achieve immortality.

32. C

Option C is the correct answer as mitosis produces genetically identical cells and is used in asexual reproduction to produce genetically identical organisms to parent. Mitosis is not used to repair damaged cells nor does it occur immediately after cytokinesis.

33. B

Option B is the correct answer as in cytokinesis the cells split apart and the mass of the DNA is halved.

34. A

Option A is the correct answer as for one sister chromatid there is a single centromere meaning that sister chromatids are in greater number than centromeres. Histone proteins are in even greater numbers as they are required to make the DNA compact enough to fit into the nucleus.

35. B

Since there are 22 chromosomes with 2 chromatids each this means that the nucleus will contain 22 chromosomes with 1 chromatid each. Since each chromatid has 2 telomeres 44 of them will be observed making option B the correct answer.

36. B

Option B is the correct answer as the S phase in the interphase will be affected since this is the phase where DNA replication occurs and in the presence of this drug it cannot take place.

37. D

Option A is incorrect as in anaphase the chromosomes move to opposite poles. Option B is incorrect as in metaphase the chromosomes line up at the equator and attach to the spindle fibers. Option C is incorrect as in prophase the spindle starts to form and centrioles moves to opposite poles of the cell. Hence, option D is the correct answer as in telophase chromosomes uncoil to form chromatin.

38. B

Statements 1 and 2 are correct as producing genetically identical cells and asexual reproduction are important functions carried out via mitosis. Single celled organism cannot grow. Hence, option B is the correct answer.

39. A

p1 matches with f2, p2 matches with f1 and p3 matches with f3. Hence, option A is the correct answer.

40. D

Option D is the correct answer as metaphase is part of mitosis not interphase or cytokinesis.

41. A

Option A is the correct answer since 1 and 2 show prophase and metaphase respectively both of which are not affected by the drug. 3 and 4 represent telophase and cytokinesis which cannot proceed since the drug prevents the movement of the chromosomes to the opposite poles.

42. C

This shows a cell in the anaphase state since the chromosome are moving to the opposite poles. Form the diagram we can also see the centrioles meaning that this is an animal cell since plant cells do not have centrioles. Hence, option C is the correct answer.

43. C

The image shows the anaphase of the cell cycle where the spindle fibers are shortening and the chromosomes are moving to the opposite poles of the cell. Hence, option C is the correct answer.

44. B

A chromosome in prophase has 2 chromatids meaning that there are 2 DNA molecules and 4 DNA strands. Hence, option B is the correct answer.

45. B

1 shows the centromere while 2 shows the telomere at the end of the sister chromatid. There are 4 DNA strands since there are 2 DNA molecules and each molecule has 2 strands. Hence, option B is the correct answer.

46. C

Statement 1 is correct as the chromosomes can be seen lined up on the equator meaning that this is metaphase. Statement 2 is incorrect as DNA replication occurs in other cells as well not just cell R. Statement 3 is correct as P and Q are in different stages but the amount of DNA is the same. Statement 4 is correct as the order is correct from interphase up till telophase. Hence, option C is the correct answer.

47. A

This stage is the metaphase after which anaphase comes meaning that the chromatids will not be paired and the nuclear membrane will still be absent. Hence, option A is the correct answer.

48. C

Option A is incorrect as they attach to the spindle fiber in order to move to opposite poles. Option B is incorrect as they condense in order to make sure that the DNA is compact. Option D is incorrect as replication is done to form new cells not nuclei. Hence, option C is the correct answer as upon reaching the poles the chromosomes uncoil becoming longer and thinner.

49. B

The cell marked X is currently in prophase after which it will go into metaphase where the chromosomes line up along the equator of the cell and attach to spindle fibers. Hence, option B is the correct answer.

50. C

W is the centromere, X is the telomere and Y is the chromatid. Hence, option C is the correct answer.

51. B

1 represents the prophase, 2 the anaphase, 3 the metaphase, 4 the prophase and 5 the telophase. Hence, option B is the correct answer.

52. C

The last phase before cytokinesis is telophase where the spindle fibers break down as the chromosomes move to the opposite poles of the cell. Hence, option C is the correct answer.

53. C

Centrioles replicate in the interphase not the prophase. Chromosomes condense in the prophase and the spindle starts to form as well. Hence, option C is the correct answer.

54. D

The image shows the anaphase of the cell cycle where the spindle fibers are shortening and the chromosomes are moving to the opposite poles of the cell. Hence, option D is the correct answer.

55. D

Option A is incorrect as this is the metaphase. Option B is incorrect as this is the telophase. Option C is

incorrect as this is the interphase. Hence, option D is the correct answer as in anaphase the chromosomes are pulled to opposite poles of the cell as shown.

56. **B**
The correct order in X to Y to Z to W making option B the correct answer.

57. **B**
The correct order is from prophase to metaphase to anaphase to telophase and finally cytokinesis. This is shown by 3 to 5 to 1 to 4 making option B the correct answer.

5.3: Multiple topics

1. **B**
After cytokinesis, ATP formation (energy for cell activities) and protein synthesis (for cell growth and repair) are highly active. DNA replication occurs before cytokinesis, not after, so it is not active at this stage.

2. **D**
Stem cells can differentiate into various cell types, including phagocytes, but they do not inherently repair cells.

3. **C**
During sperm formation, histones are replaced by protamines, which enable tighter packing of DNA, facilitating denser chromosome organization.

4. **C**
Stem cells can self-renew (1), persist in adults for tissue repair (3), and have long telomeres allowing more divisions (4). Statement 2 is incorrect, as all body cells retain the full genetic information.

5. **C**
The protamine replace the telomeres since their function is needed in the S phase not mitosis. Hence, option C is the correct answer.

6. **A**
All the 3 statements are correct as bone marrow cells in the mitotic cycle ADP is formed form ATP, bonds between nucleotides form and tRNA anticodons form hydrogen bonds with mRNA codons during translation. Hence, option A is the correct answer.

7. **D**
Abnormal proteins produced by the p56, RAD51 and BRCA1 and BRCA2 are most likely to result in cancer. Hence, option D is the correct answer.

8. **C**
Only in prophase and the metaphase the chromosomes are visible are 2 chromatids. Since the total number of cells are 1000 and those in prophase and metaphase combined are 89 the percentage is 8.9. Hence, option B is the correct answer.

9. **C**
The death of the tumor cells upon activation of p53 suggests that it acts as the tumor suppressor gene. Hence, option C is the correct answer.

10. **C**
Only statement 2 is correct as in cytokinesis the organelles are equally divided among the 2 cells. Cell structures do not replicate in it and the nuclear envelope does not form yet. Hence, option C is the correct answer.

11. **A**
Since both the genes adversely affect tumors their mutated proteins are more likely to cause cancer together. Hence, option A is the correct answer.

12. **B**
Option B is the correct answer as in cases of cancer all the cells divide solely via mitosis.

13. **C**
Statement 1 is correct as faults in meiosis can produce diploid gametes. Statement 2 is incorrect as if there are 2 haploid gametes then the 2n number is conserved. Statement 3 is correct as the possible combinations of haploid and diploid gametes can result in 2n, 3n or 4n numbers. Statement 4 is correct as if in each generation there are diploid gametes or mutated gametes the total number can increase. Hence, option C is the correct answer.

14. **D**
Mutated BRCA1 and RAD51 genes cannot inhibit growth of breast cancer cells or repair damaged DNA and this results in breast cancer. Hence, option D is the correct answer.