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H. Bio. per. 3
5 / 30 / 15

The Cell Cycle and Mitosis Study Guide

Steps (overview)

Mitosis

1. interphase
    a. Cell does regular activity (G1)
    b. DNA replicates (S stage)
    c. centrioles replicates (G_2)
2. prophase
    a. DNA (as chromatin) winds around histone proteins, forming chromosomes
        i. nucleolus disappears
    b. centrioles move to opposite poles of cell
        i. mitotic spindle is formed between them
3. prometaphase
    a. nuclear membrane separates into membrane vesicles
    b. chromosomes disperse
    c. kinetochores form, connecting chromosomes to spindle fibers (only one per fiber)
4. metaphase
    a. chromosomes (sister chromatid pairs) line up in the center of the cell
5. anaphase
    a. centromeres dissolve
    b. sister chromatids are pulled apart (one to each pole) by the spindles
        i. motor proteins pull kinetochores towards a pole
6. telophase
    a. nuclear membranes form (around each nucleus)
    b. mitotic spindle disintegrates
    c. DNA unwinds back into chromatin
        i. nucleolus reforms
    d. cytokinesis (cytoplasm division (membrane and organelles also divide as well))
        i. in animals cells, cleavage furrow forms between cells as motor proteins form a ring and close the membranes
        ii. in plant cells (which are not pliable), cell wall vesicles line up, and form the cell wall in between them

Meiosis

Meiosis I

1. interphase
    a. like normal interphase
2. prophase
    a. chromosomes arrange themselves in tetrads (homologous chromosomes (a pair of sister chromtids) pair up), and both chromosomes are on one spindle (vs. only one in mitotic prophase)
    b. crossing over takes place
        i. genes from the two adjacent chromatids can switch (but not outer ones), so that those two chromosomes are different from the parent chromosomes and from each other

3. metaphase
    a. same as mitotic metaphase (except with tetrads instead of single chromosomes)
4. anaphase
    a. homologous chromosomes (sister chromatid pairs) get pulled apart (sister chromatids, which are mostly identical, stay together) to opposite cells
5. telophase and cytokinesis
    a. same as mitotic telophase and cytokinesis, except that DNA usually doesn't unwind back into chromatin
    b. now each cell only has one of chromosome (each one is duplicated, with two almost identical (from the crossing-over) strands of DNA)

Meiosis II

1. interphase
    a. same as mitotic interphase, except that chromosomes don't usually have to be wound (see telophase I), and no replication occurs (only 46 chromosomes, or 23 pairs, to divide amongst the cells)
2. prophase:
    a. same as mitotic prophase
3. metaphase:
    a. same as mitotic metaphase
4. anaphase
    a. same as mitotic anaphase
5. telophase and cytokinesis
    a. same as mitotic telophase and cytokinesis
    b. now each cell only has one chromosome from each pair

Questions

1. **What is mitosis?**
    a. the division of a cell's DNA into two identical sets of DNA
    b. (when followed by cytokinesis, which divides the membrane, cytoplasm, and organelles, then cell division occurs)

2. **What are the main purposes for mitosis?**
    a. prokaryotes/unicellular organisms: reproduction
    b. eukaryotes/multicellular organisms: growth, healing

3. **How many daughter cells are made from one mother cell by mitosis?**
    a. 2 (identical DNA)

4. **How do the daughter cells compare in size to the mother cell? How do they compare in number of chromosomes?**
    a. smaller (half the size)
    b. same number of chromosomes (before DNA was duplicated)

5. **What is the name of the phase when the cell is not in mitosis?**
    a. interphase

6. **What three phases make up interphase?**

a. G_1 (gap 1), S (synthesis), G_2 (gap 2)

7. What happens during the G_1 phase?

a. the cell grows and goes through metabolic processes
b. "normal" cell living
c. first checkpoint at end of G_1, signalling beginning of S phase and doesn't (really) stop until cell has divided

8. What happens during the S phase?

a. synthesis (duplication) of DNA
b. now 92 chromosomes (46 pairs)

9. What happens during the G_2 phase?

a. centrioles are duplicated
b. some proteins for mitosis are synthesized
c. when finished, cell passes through second checkpoint at the end of G_2 into mitosis (prophase)

10. What are the four phases of mitosis?

a. prophase (and prometaphase)
b. metaphase
c. anaphase
d. telophase (usually simultaneous with cytokinesis)

11. Explain what happens during each of the four phases of mitosis.

a. prophase (longest of phases)
    i. chromatin wound (around histone proteins) to form chromosomes
        1. nucleolus disappears
    ii. centrioles go to pole to start forming mitotic spindle
    iii. nuclear membrane dissolves (beginning of prometaphase)
    iv. chromosome pairs attach to spindle fibers (only one per fiber)
b. metaphase
    i. chromosome pairs line up on the metaphase plate at the center of the spindle (and cell)
        1. so that chromosomes would split evenly and the two daughter cells' DNA would be identical
c. anaphase
    i. centromeres dissolve
    ii. sister chromatids become unattached, go to opposite poles
d. telophase (shortest of phases)
    i. chromosomes (previously chromatids) clump together at the poles
    ii. mitotic spindle dissolves
    iii. nuclear envelopes form around the two clumps of chromosomes
    iv. the DNA unwinds back into chromatin
    v. Opposite of prophase

12. How does prophase compare to telophase?

a. they are almost the opposite:
    i. prophase dissolves nuclear envelope; telophase creates (2) nuclear envelopes
    ii. prophase creates mitotic spindle; telophase dissolves it

iii. prophase bundles chromatin into chromosomes (and nucleolus disappears); telophase turns chromosomes into chromatin (and nucleolus reappears)
iv. prophase is the longest phase, and telophase is the shortest

13. How is chromatin different from chromosomes?
a. chromatin is unwound, so that its genes can be accessed easily
b. chromosomes are tightly wound around histone proteins, so that genes are hard to access

14. Why is it helpful to the cell to condense the DNA into chromosomes?
a. it will prevent tangling and damage to the DNA

15. Why does the DNA need to replicate?
a. there has to be two sets of identical DNA for the daughter cells
b. DNA controls all cell activities

16. What is the name of the structure that holds two sister chromatids together?
a. centromere

17. Why is it necessary for the nuclear membrane to dissolve?
a. the chromosome pairs have to be split evenly, and it does that with the mitotic spindle (outside the nucleus)
i. only way for chromosomes to get out is by breaking the nucleus

18. What creates the mitotic spindle?
a. centrioles

19. What is the purpose of the mitotic spindle?
a. to evenly divide the chromosomes to each cell, creating 2 identical sets of DNA

20. Why is it extremely important that the chromosomes line up single file? What does this allow for? What does it ensure?
a. it makes sure that for each pair of chromosomes, exactly one goes to each side
b. if they weren't lined up (if two were on the same spindle or if they were off to one side) the chromosomes might have trouble going to the right cell

21. What is a sister chromatid? How does it compare to a chromosome? Are the two sister chromatids within a chromosome identical?
a. a (sister) chromatid is one of two chromosomes attached to another, identical sister chromatid with a centromere
b. the chromatids go to opposite sides, thus giving each side a single copy of an identical chromosome

22. What is cytokinesis?
a. "division of the cytoplasm"
b. last step of cell division
c. not part of mitosis, but happens at starts during anaphase or telophase

23. How does cytokinesis differ in an animal and a plant cell?
a. animal cells:

i. when the cell membrane pinches to separate the cytoplasm and the nuclei (and divide the organelles roughly in half)

b. plant cells:
   i. when vacuoles with the cell wall material line up in the middle of the cell, forming a cell wall plate, and form the cell wall, separating the two cells
   ii. a cell membrane forms from the vesicle membranes

24. How many pairs of chromosomes does a human typically have?

a. 23 (46 total)

25. Why do we have PAIRS of chromosomes?

a. each pair consists of a chromosome from the father and from the mother

26. Are the two chromosomes within a pair identical? Explain.

a. no: the mother and the father have different DNA

Review Questions: Mitosis and Meiosis

1. You need to be familiar with the main differences between mitosis and meiosis. Sample questions:

- **How do mitosis and meiosis differ in purpose?**
  - mitosis is used to create two genetically identical daughter cells from a cell (asexual reproduction)
    - grow
    - Infect
    - heal
    - replace cells lost during infections
    - reproduction (single-celled organisms)
  - meiosis is used to create four genetically different daughter (haploid) cells from a cell for sexual reproduction
    - animals, multicellular organisms
    - to create unique sperm, egg, and pollen cells

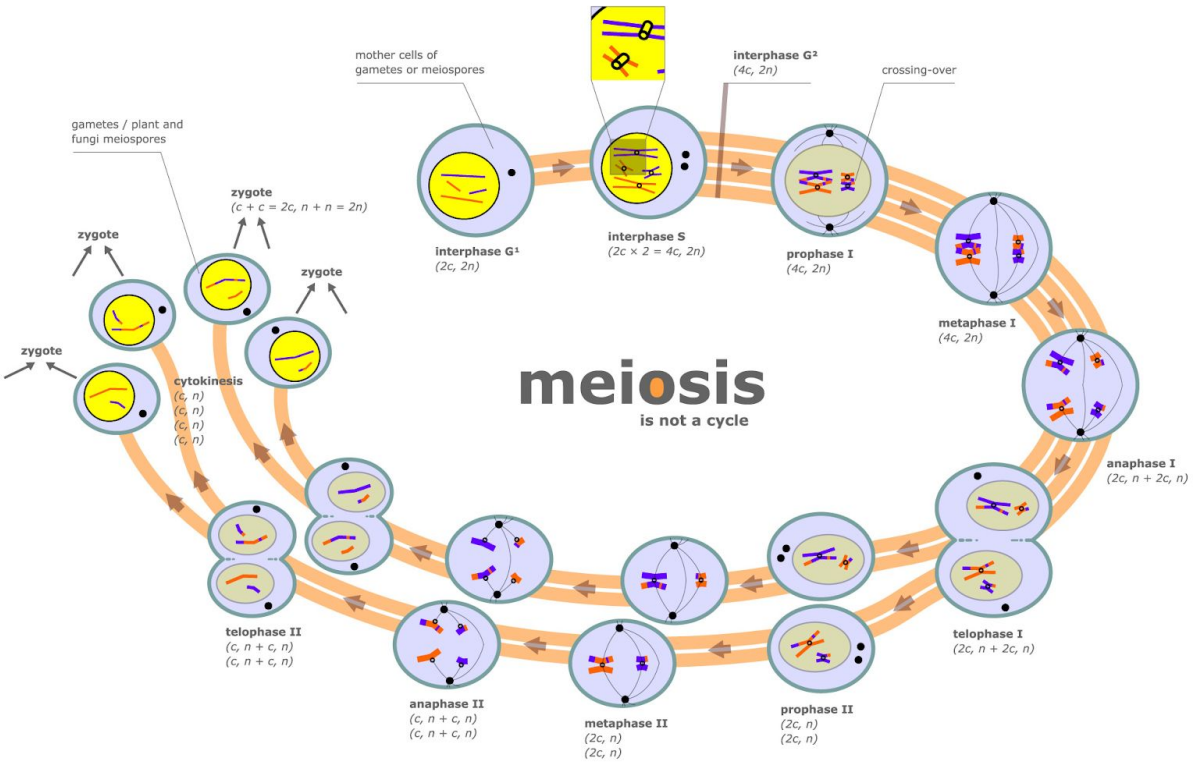
- **Where in the body does mitosis take place? Where in the body does meiosis take place?**
  - Mitosis: Everywhere, for each cell
  - Meiosis: Only for sex cells
    - happens in cells in ovaries and testes
    - happens in ovaries (later plants) and anthems in plants

- **How many times does the cell divide during mitosis? How many times does the cell divide during meiosis?**
  - Mitosis: Once
  - Meiosis: Twice (Theoretically three divisions in total)

- **How many cells are produced from one cell by mitosis? How many cells are produced from one cell by meiosis?**
  - Mitosis: Two
  - Meiosis: Four (Each with half the number of chromosomes)

- **Are the cells produced by mitosis haploid or diploid? Are the cells produced by meiosis haploid or diploid?**
    - Mitosis: Two Diploid (whole: 46 chromosomes)
    - Meiosis: Four Haploid (half: 23 chromosomes)
        - only produces one viable egg, however (all the cytoplasm goes to that one)

2. **You will need to be able to identify diagrams of the cell in various stages of meiosis.**



a.

3. **You will need to be familiar with the stages of both mitosis and meiosis so that you can make comparisons between the two types of cell division. Sample questions:**

- **What is the difference between prophase I of meiosis and prophase of mitosis?**
    - in prophas I two chromosome pairs (a tetrad) are on a spindle
    - there is a "crossing-over"
        - the chromosomes become a little tangled, and genes from any of the four chromatids can be exchanged with another, leading to two of the chromosomes being different from the parent chromosomes

- **What is the difference between prophase I and prophase II of meiosis?**
    - in prophase II, there is no crossing over, and only one pair of chromatids are on a spindle

- **What is the difference between metaphase I and metaphase II of meiosis (and mitosis)?**
    - they are basically the same, except for the changes that were present in prophase

- **What is the difference between anaphase I of meiosis I and anaphase II of meiosis (and mitosis)?**
    - in anaphase I, homologous chromatid pairs separate (a pair for each pole)
    - in anaphase II, sister chromosomes separate (like in mitosis)

- **What is different about the interphase between meiosis I and meiosis II and the interphase before meiosis begins? What is the same?**
    - interphase I is like in mitosis
    - in interphase II, there is no duplication of chromosomes, so that each of its daughter cells will have only one of each chromosome (while somatic cells have chromosome pairs)

4. **Why all of these differences are necessary? Sample questions:**

- **Why is it important that the chromosomes line up "double file"?**
    - So that there is an exchanging of genes when anaphase starts

- **Why is it important that the chromosomes line up next to their homologous partners?**

- so that during the “crossing over” only genes from the same type of chromosome (a homologous chromosome) will be switched

- **Why is it important that the DNA does not replicate in between meiosis I and meiosis II?**
    - So that each daughter cell is a haploid cell so that when the egg and sperm come together a diploid cell is created.

- **Why is it important that the centrioles do replicate?**
    - So that both daughter cells have them. Also so that the mitotic spindle can be created

- **Why is it important that sex cells contain only half the DNA**
    - So that when the zygote is created that their is a mix of genes
        - This is good for a better natural selectivenessity

5. **You will need to be familiar with the vocabulary. You will need to be able to explain the terms and identify the meaning of the terms. You also need to be able to understand questions that use the vocabulary.**

- **Haploid**
    - informally: Having half the number of chromosomes (23)
    - more technically: having only one chromosome per pair (no homologous pairs)
        - having two identical copies of the same chromosome (two sister chromatids of a chromosome), such as the intermediate cell in meiosis, counts as having only one chromosome for that pair

- **Diploid**
    - informally: Having the full number of chromosomes (46)
    - more technically: having homologous pairs of chromosomes (two different chromosomes per pair), the full set, one from the mother and one from the father
    - in somatic cells

- **Crossing over**
  - When genes are mixed between *adjacent* chromatids of the two chromosomes on the mitotic spindle (therefore only two chromatids, not all four are different from the parent ones)

- **Fertilization**
  - When a sperm penetrates an egg

- **Chromatin**
  - The loose (un-spiraled) form of DNA in the Nucleus

- **Chromosomes**
  - Spiraled pieces of DNA

- **Sister chromatids**
  - the pair of identical chromosomes from a duplicated chromosomes
  - bond together with a centromere
  - in mitosis and meiosis II, they are separated during anaphase
  - in meiosis I, they stay together

- **Homologous pair**
  - Pair with the same set of genes
  - in meiosis I, a homologous pair of chromosomes form a tetrad and are separated during anaphase I

- **Centromere**
  - A thingy that holds the chromosomes together

- **Mitotic spindle**
  - structure created by centrioles to equally divide the chromosome pairs to the two poles

- **Centrioles**
  - organelles used to create the mitotic spindle during mitosis and used for basal bodies, and cell microtubule organization
  - part of the centrosome

- **Mother cell**
  - the original cell in mitosis or meiosis
  - gets duplicated (genetically identical copies made; two diploid cells made) in mitosis
  - turns into four different haploid cells in meiosis

- **Daughter cells**
  - the cells that are duplicated versions of their mother cell
    - both sets of daughter cells in meiosis are haploid cells (only have one chromosome, or two identical sister chromatids (one chromosome))

- **Gametes**
  - a mature haploid/germ/sex cell

- **Tetrads**
    - a set of four chromosomes (two sets homologous chromosomes(two sister chromatids))
    - formed during synapsis (prophase I) of meiosis

Review Sheet: Cell Division - Related Topics

Topics related to mitosis

1. **What two classes of genes control the cell cycle? Explain how they do so.**
    - proto-oncogenes
        - speed up/signal the growth of cells
        - allow the cell to grow
    - tumor-suppressor genes:
        - slow down the rapid proliferation of cells
        - at checkpoints make sure cells are ready to prevent error (and tumors)

2. **What are checkpoints? Why are they important?**
    - they are points in the cell cycle in which the cycle does not continue— rather, the cell waits for a signal to continue
    - three (major) checkpoints:
        - end of G_1 (start of mitosis preparation)
        - end of G_2 (start of mitosis)
        - end of metaphase (chromosomes can be separated evenly)

3. **What is cancer?**
    - a tumor with the ability to metastasize (and therefore have a very deadly potential)
    - a malignant tumor

4. **What are several environmental factors that can cause cancer?**
    - Radiation
        - UV rays from sun
        - X-rays
    - Genetics
        - faulty or missing genes
    - age
        - telomeres shorten, start to fall apart and allow DNA fraying
    - free radicals
        - oxygen radicals are high energy molecules that can damage DNA
    - toxins
        - tobacco smoke

5. **How do environmental factors, in general, cause cancer? What do they do to our DNA? Explain the connection between genes and proteins, and what cancer has to do with making too much or too little of certain proteins.**
    - mutate our DNA
    - DNA causes genes, including those that regulate cell division, therefore it can cause cancer

6. **What is a tumor?**
   - a quickly growing mass of cancer cells
   - a mutated cell
     - doesn't follow density-dependent inhibition
     - doesn't need anchorage
     - usually has at least 6 mutated genes related to cell division and regulation

7. **What is the difference between a benign and a malignant tumor?**
   - Benign tumors stay where they are (But still grow and can cause damage)
   - malignant tumors have the ability to metastasize

8. **What does it mean if the cancer cells have metastasized?**
   - to be over a million cells and start to have the ability to send signals to have blood vessels grow towards themselves
   - tumor cells will have source of nutrients, and a way to spread

9. **How are cancer cells able to travel to a new part of the body? What two systems in the body transport the cells? What is the difference between these two systems?**
   - metastasis
   - blood vessels: carry blood cells and plasma
   - lymph nodes: carry white blood cells and plasma

10. **Do all tumors have blood vessels bringing them nutrients? Explain.**
    - no: benign tumors do not have the ability to metastasize

11. **Some cancer drugs (chemotherapy drugs) work by stopping the cell from being able to produce a mitotic spindle. Why would this stop the growth of a tumor?**
    - the mitotic spindle is a necessary part of cell division— if the cell cannot divide and reproduce, no growth can occur

12. **Why can chemotherapy drugs also cause hair loss, nausea, and an immune deficiency?**
    - (chemotherapy is killing or slowing cancer growth with drugs)
    - it doesn't only target cancer cells: it also targets quickly dividing human cells

13. **What are other forms of treatment for cancer?**
    - studying mdm2
    - studying fungus, antifungal medicine can target blood vessels (that allow metastasis)
    - surgery
    - powerful radiation (kill the cells, not mutate them)
    - sometimes cell transplants

14. **How many times do normal cells divide before they die? How many times do cancer cells divide before they die? How is this possible?**
    - normal: 50
    - cancer: infinite:
      - low levels of mdm, high/continued levels of PGAM after cell becomes senile— cell doesn't exit cell cycle
      - sometimes can produce telomerase, allowing telomeres to forever stay long and DNA not to unravel

- increased/mutated proto-oncogenes and decreased/mutated tumor suppressors to speed up cell growth and reproduction

15. How is aging related to mitosis?

- aging happens when mitosis happens too many times
- telomeres get shortened every time there is a cell division
  - when they are too short, the DNA starts to unravel and mutations can occur much easier

16. What are telomeres? What is the function of telomeres?

- telomeres ↔ DNA :: aglets ↔ shoelaces
- at the tip of DNA strands
- long repeating nucleotide sequences
- get shorter every time cell divides
- to prevent the genes from being mutated

17. How are telomeres related to aging? What happens each time a cell replicates and the DNA divides?

- more cell division ⇒ shorter telomeres (except in fetuses) ⇒ more mutations ⇒ more aging

18. What is telomerase? What is its function? Is it present in normal human cells after birth? Theoretically, why could the injection of telomerase into adult human cells cause eternal youth? Why could the injection of telomerase into adult human cells increase the chance of developing cancer?

- telomerase is the protein that extends the telomeres (slow or stop aging)
- in fetuses because there is rapid cell division as the fetus grows (a lot), but want to prevent aging
- theoretically, it can cause eternal life/youth of human cells
  - eventually, in practice, there will always be a buildup of mutations, eventually leading to cancer
  - CANCER IS THE REASON BEHIND NON-ETERNAL LIFE
- it is not present in humans after birth, except maybe in cancer cells
  - if in cancer cells, then cancer cells will never age and can reproduce forever

19. What is progeria? How does it relate to our conversations of mitosis, telomeres, and aging?

- being born with short telomeres
- ages extremely fast, because telomeres run out very quickly
- usually don't live very long (as if they were born senile and lived a life like that)

20. Name several types of cells that have short life spans and divide frequently.

- skeletal, smooth muscle cells
- stomach and intestine lining
- hair follicle, nail, skin cells

21. Name several types of cells that have long life spans and rarely or never divide.

- cardiac muscle cells
- bone cells
- nerve cells

22. What is cell differentiation, also known as cell specialization?

- when stem cells turn into a certain type of cell (become a specialized cell at a specialized task)

23. When does cell specialization occur? Does it occur when you cut yourself? How about when you are sick? How about when you are growing? When is the only time it occurs?

- happens mainly when we are embryos (studies have been done on embryonic stem cells), but also a little bit throughout our growth (adult stem cells, such as basal cells)

24. What are stem cells and how are they different from other cells?

- cells that are non-differentiated/non-specialized — can become specialized
    - can turn into cells that don't regrow, such as neurons
- have all DNA like other cells but it is not a specific type of cell
- mostly in embryos, a little bit in adults
- have telomerase so that they do not grow old after many divisions— they divide a lot (e.g. embryo cells or skin basal cells)

25. Why are scientists interested in stem cells?

- they can be used for healing (can turn into any type of cell based on hormones)
- they have telomerase

26. How are embryonic stem cells different from adult stem cells?

- embryonic stem cells can turn into any type of cell
- adult stem cells are limited to cell types of their tissue of origin

27. What is a blastocyst?

- early development of a mammal (usually five days after fertilization and only a few hundred cells)
- after a zygote
- becomes an embryo, has some stem cells that start to become specialized

28. What types of diseases are scientists most hopeful of treating through the use of stem cells?

- since it can be used to create cells (even in adults) that cannot normally be regrown, it can be used for
    - diabetes, to create insulin-creating cells
    - Alzheimer's, to repair and recreate neurons
    - heart attack, to repair and recreate cardiac muscle cells

Topics which are related to meiosis:

29. Describe what a karyotype is and be able to recognize and name a karyotype when you see one.

- an orderly representation of a person's chromosomes
- some chromosomal diseases can be diagnosed by looking at chromosomes

30. Explain the chromosomal characteristics used to match chromosomes when preparing a karyotype.

- to match up correct chromosome pairs (homologous chromosomes):
    - length
    - G-bands

31. Identify the genders and chromosomal syndromes of individuals based on their karyotypes.

- sex chromosomes:
    - 23rd chromosome pair
    - X = longer, y = (much) shorter
    - XX = female
    - XY = male
    - XXY = usually male, sometimes intersex (Klinefelter's syndrome)
    - X = female (turner's syndrome)

32. Use/identify proper chromosomal notation (e.g., 47, XY, +13).

- notation: "num, sex [, ext]" where num = number of chromosomes, sex = sex chromosomes, ext = extra/missing chromosomes

33. Explain what an amniocentesis is, the procedure itself, and why the procedure is performed.

- when some of the amniotic fluid (fluid surrounding a fetus) is taken out and examined to see the DNA
- can be used to determine chromosomal abnormalities or gender before birth

34. You will need to be able to explain nondisjunction. You will need to explain what it is and when it occurs. You will need to explain the result of nondisjunction. You will need to put combinations of eggs and sperm together and explain the possible outcomes.

- when three chromosomes line up on one spindle thread and one on another in meiosis (I or II)
- it will lead to some of the haploid cells having three (trisomy) or one (monosomy) of a chromosome instead of two

35. Aside from nondisjunction, what else can cause a chromosomal abnormality and chromosomal disorder?

- duplications
- deletions
- translocations
- inversions

36. What are the two types of chromosomal deletions? How are they similar? How are they different?

- terminal: one break happens and the end piece is lost
- interstitial: two breaks happen, and the first and third piece rejoin— chromosome loses some middle material

37. What are the two types of chromosomal translocations? How are they similar? How are they different?

- reciprocal: when two corresponding parts of two homologous chromosomes switch
    - can cause abnormalities
    - sometimes doesn't because same genes just switch
- Robertsonian: when two q sections of homologous chromosomes switch, resulting in the loss of the p sections
    - usually doesn't cause abnormalities (only smaller sections lost)

38. How do chromosomal deletions and translocations cause chromosomal disorders?

- they can cause rearrangements in regular DNA

39. Are chromosomal disorders inherited? Explain why or why not. Try going through the three categories of chromosomal disorders (EXTRA/MISSING CHROMOSOMES, DELETIONS, TRANSLOCATIONS) and consider whether or not individuals typically have these disorders because their parents had them.

- assuming that the parent survives to reproduction age (which can often happen with these disorders)
    - extra/missing: can be carried on, because if missing or extra chromosome is passed on to haploid cell (½ chance) then child could have it
    - deletions and translocations could also be carried on if they are in the haploid cells

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Vocabulary:

- **Autosomes**
  - first 22 pairs of chromosomes
  - the “regular” chromosomes
  - come in pairs
- **Sex chromosomes**
  - last two chromosomes
  - “sex chromosomes”
  - X and Y (XX for female, XY for male)
- **Zygotes**
  - fertilized egg cell (has sperm DNA)
- **G bands**
  - darkened area with a high concentration of A and T nitrogenous bases, caused by the dying of a chromosome with Giemsa dye
- **Giemsa dye**
  - dye used to color chromosomes, used to create G bands and identify genes
- **P and Q arms**
  - “p” for petite, used to refer to the smaller end of a chromosome (divided by a centromere)
  - “q” because it is the next letter of the alphabet, the larger end of the chromosome
- **Down Syndrome**
  - trisomy 21: third 21st chromosome (47, XY, +21)
- **Turner Syndrome**
  - monosomy X: only 1 X chromosome (47, X)
  - sexual growth problems, webbed neck
- **Klinefelter’s Syndrome**
  - XXY (47[+], X[+])
  - sexual growth problems, usually a man or intersex
- **Chromosomal notation**
  - a method to show the amount of chromosomes in a karyotype in a single statement
- **Cri du chat**
  - “cry of the cat”: child makes sound like crying cat
  - deletion in chromosome 5p (46, XY, del(5p))
- **Williams Syndrome**
  - deletion in chromosome 7q (46, XY, del(7q))
  - developmental delays, circulatory system problems,
- **Philadelphia chromosomes**

- reciprocal translocation of 9 and 22 (46, XY, T(9; 22))
- leukemia

- **CDC**
  - see “cri-du-chat”

- **CDK**
  - gene that is needed for brain developme)nt (46, XY, del(22p))
  - seizure and intellectual ability may occur

- **Carcinogens, carcinogenic**
  - cancer-causing
  - examples: see above

- **Palpable**
  - easily, noticable (can be felt, seen)

- **Proliferation**
  - rapid spread of cells (i.e. rapid reproduction)

- **Senescence**
  - state of cell when it is still metabolically active but no longer able to reproduce
  - cancer cells do not go through this stage

- **Density dependent inhibition**
  - non-cancerous cells cannot divide if there is too much pressure from the outside from other cells— if there are too many cells, then it cannot divide and reproduce
  - cancer cells do have density dependent inhibition, and therefore can form hard masses of many cells