

**Figure S1 Clicker questions and their associated learning objectives and Bloom's level**

**Mitosis and Meiosis questions**

**Q1:** Which of the following events does not occur during mitosis?

- A. Breakdown of the nuclear envelope
- B. Daughter cells are genetically identical
- C. Condensation of the chromosomal DNA

**D. Pairing of homologous chromosomes**

- E. All of these events occur during mitosis

**Learning Objective:** Differentiate between mitosis and meiosis

**Bloom's:** Comprehension- lower-order cognitive skill

**Q2:** If a dog cell has 39 chromosome pairs, how many sister chromatids are present in G2?

- A. 38
- B. 39
- C. 76
- D. 78
- E. 156**

**Learning Objective:** Predict how the DNA content changes during the cell cycle in a nonhuman species.

**Bloom's:** Application- higher-order cognitive skill

**Q3:** At which stage in meiosis does pairing of homologous chromosomes occur?

**A. Prophase I**

- B. Anaphase I
- C. Prophase II
- D. Anaphase II
- E. I don't know

**Learning Objective:** Identify what occurs during each of the stages of meiosis

**Bloom's:** Knowledge- lower-order cognitive skill

**Q4:** At which stage in meiosis does independent assortment of alleles occur?

- A. Prophase I
- B. Anaphase I**
- C. Prophase II
- D. Anaphase II
- E. I don't know

**Learning Objective:** Identify at which step in meiosis the homologous chromosomes separate from each other.

**Bloom's:** Comprehension- lower-order cognitive skill

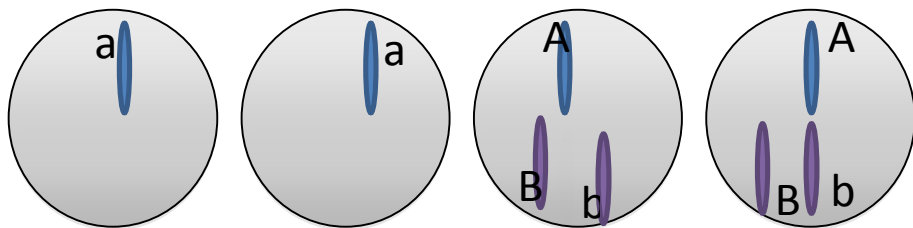
**Q5:** A diploid cell heterozygous for Genes A and B has an error in chromosome segregation during meiosis (nondisjunction) leading to the production of the following gametes:

At which step in meiosis was there a problem?

- A. Prophase I
- B. Anaphase I**
- C. Prophase II
- D. Anaphase II
- E. Can't determine

**Learning Objective:** Given a set of unbalanced gametes, predict during which stage in meiosis there was a segregation defect.

**Bloom's:** Application- higher-order cognitive skill



**Recombination Questions**

**Q6** Which of the following statements about recombination is incorrect

A. Genetic maps of chromosomes are based on the average number of crossovers during meiosis

**B. The recombination frequency will overestimate the genetic distance**

C. One crossover event can interfere with another crossover event

D. Tightly linked genes will have a recombination frequency close to 0

E. All of the statements are correct

**Learning Objective:** Recognize that recombination frequency underestimates the genetic distance

**Bloom's:** Knowledge- lower-order cognitive skill

**Q7** A female fly with long wings and a gray body, heterozygous for genes controlling body color and wing length, was crossed to a homozygous recessive mutant male with vestigial wings and black body generating the following progeny:

Long wings, Gray body      23 flies

Vestigial wings, Black body   26 flies

Long wings, Black body      124 flies

Vestigial wings, Gray body   127 flies

You interpret this to mean that

A. The genes are unlinked since the parental phenotypes are rare

**B. The mother fly received the dominant allele for body from one parent and the dominant allele for wings from the other parent.**

C. The genes for body and wings are on opposite ends of the chromosomes

D. The mother fly received the dominant alleles for body and wings from the same parent

E. I don't know

**Learning Objective:** Predict the parental genotypes given the phenotypes of the offspring

**Bloom's:** Application- higher-order cognitive skill

#### Probability and Pedigrees Questions

**Q8** After completing a trihybrid genetic cross, you propose a model suggesting that the phenotypes of your progeny can be explained by three genes each with 2 alleles one dominant over the other.

How would you test your hypothesis?

**A. Calculate Chi-squared value**

B. Calculate the recombination frequency between each gene

C. Use the Binomial Probability formula

D. Draw a Punnett Square

E. Don't know

**Learning Objective:** Choose the appropriate test to evaluate a genetic model.

**Bloom's:** Application- higher-order cognitive skill

**Q9** You cross two yellow mice and produce a mixture of yellow and agouti progeny. You propose a model predicting 3 yellow mice for every 1 agouti mouse. Do you reject your hypothesis after calculating a  $\chi^2$  statistic of 5.143?

Degree of Freedom	5% Critical Value
1	3.841
2	5.991

**A. Reject since  $\chi^2$  is above the 5% critical Value for 1 Degree of Freedom**

B. Don't reject since  $\chi^2$  is above the 5% critical Value for 1 Degree of Freedom

C. Reject since  $\chi^2$  is below the 5% critical value for 2 degrees of freedom

D. Don't reject since  $\chi^2$  is below the 5% critical Value for 2 Degree of Freedom

E. I don't know

**Learning Objective:** Know the criteria for rejection of the  $\chi^2$  statistic

**Bloom's:** Comprehension- lower-order cognitive skill

**Q10** If an individual is homozygous for a recessive trait and has children with a carrier for the trait. What is the probability that they will have one affected child and 2 unaffected children?

A. 0

- B. 1/8
- C. 1/2
- D.  $[(3!)/(2!1!)] \times (1/2)^2 (1/2)^1$
- E. Can't determine

**Learning Objective:** Identify the binomial formula as the correct way to predict

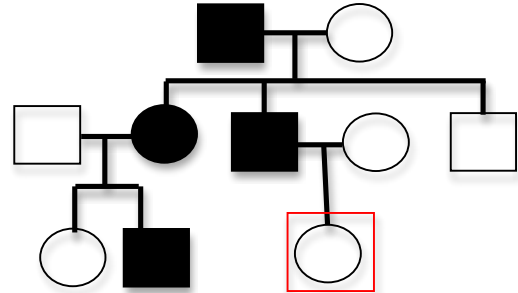
**Bloom's:** Knowledge- lower-order cognitive skill

**Q11** Assume the trait shown in the pedigree is very rare. What is the probability that the individual in the red box carries the mutant allele causing the trait?

- A. 0
- B. 1/4
- C. 1/2
- D.  $[(5!)/(3!2!)] \times (1/2)^3 (1/2)^2$
- E. Can't determine

**Learning Objective:** Interpretation of pedigrees and use of information to determine if an individual in the pedigree is a carrier

**Bloom's:** Application- higher-order cognitive skill



### Quantitative Genetics Questions

**Q12** After intercrossing the F1 produced from a cross between two inbred strains, which of the following statements about the F2 offspring is incorrect

- A. **The F2 with show increased hybrid vigor over the F1.**
- B. The F2 will show a decrease in heterozygosity from the F1.
- C. The F2 may exhibit inbreeding depression.
- D. The variance of the F2 population will be greater than the variance of the F1 population.
- E. I don't know.

**Learning Objective:** Recognize that increased heterozygosity will result in an increase in hybrid vigor.

**Bloom's:** Comprehension- lower-order cognitive skill

**Q13** In one study, the heritability of IQ is determined to be .7.

This means that

- A. In an individual, 70% of intelligence is due to genetic factors and 30% is due to environmental factors
- B. No matter what environment you are in the heritability will be 70%
- C. **70% of the variation in IQ seen in the population is due to genetic factors**
- D. 70% of the average of two parents' IQs will be equal to the mean IQ of their offspring
- E. All of the above

**Learning Objective:** Evaluate what heritability means.

**Bloom's:** Analysis- higher-order cognitive skill

**Figure S2 Sample in-class activity worksheet**

Group #:

Group Name:

Facilitator:

Recorder:

Monitor:

Reporter:

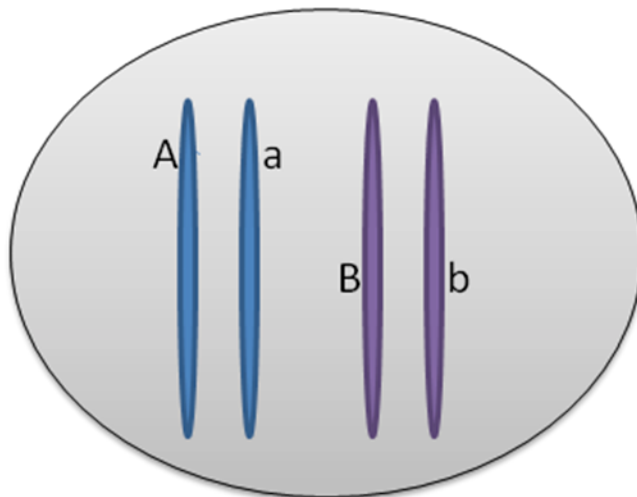
**Cell Division worksheet**

Today's exercise is about understanding the mechanisms of mitosis and meiosis. Learning how these processes work sets the foundation for understanding much of genetics.

Directions:

Each group needs to draw their answers to the following questions. Different color pens or pencils should be used to indicate different chromosomes and alleles should be labeled in each of the diagrams. Each group should turn in one copy of the worksheet at the end of the class period.

1. A diploid cell contains two sets of chromosomes and is heterozygous for a gene (containing alleles A and a) on chromosome one and is heterozygous for a gene (containing alleles B and b) on chromosome two. Draw this cell in G1 labeling the alleles on the chromosomes.

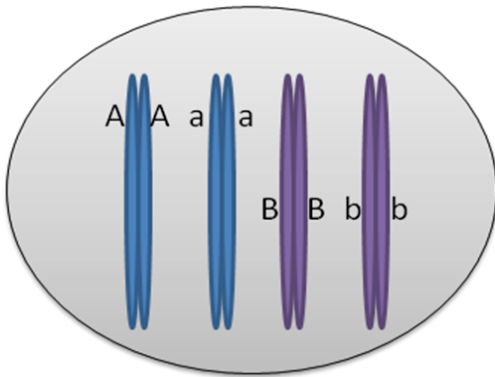


*A **good** answer is similar to the neighboring diagram including four chromosomes and the A and a on the same color chromosomes and B and b on the other color chromosomes. The total DNA content should be 2C. **Excellent** answers include drawing the chromosomes in a nucleus and indicating prior to mitosis the chromosomes would be decondensed. **Poor** answers will not have the correct number of chromosomes, will have the alleles labeled on the same chromosome, will show the chromosomes in a replicated state as an X, or will show the homologous chromosomes physically touching.*

2. This cell receives cues to duplicate itself.

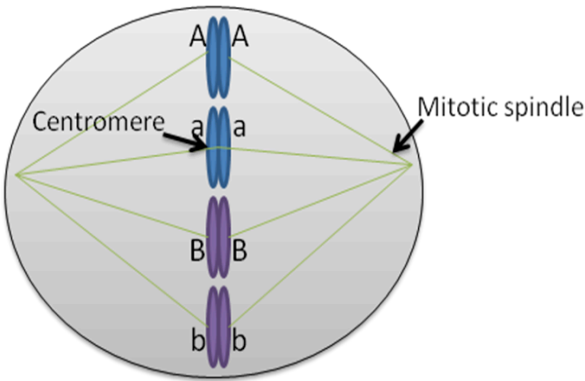
Draw your cell at the following stages:

- G2 just after DNA replication prior to mitosis



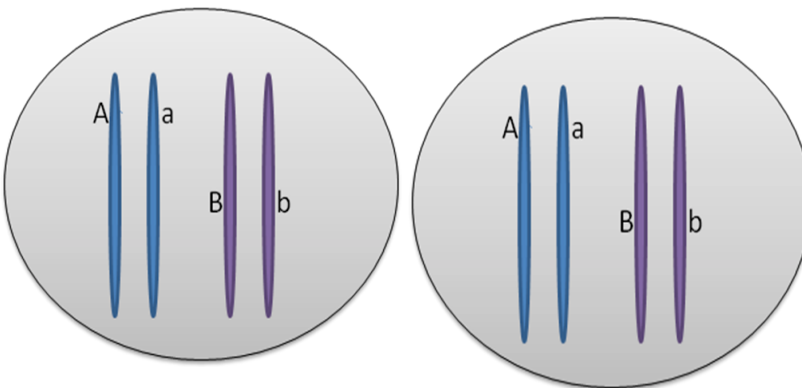
For **good** answers, students should have a total of 8 chromatids with each allele being present on the adjacent sister chromatids. The DNA content is 4C. **Excellent** answers will include an intact nuclear envelope and indicate that the chromosomes are still decondensed. **Poor** answers will label the sister chromatids with different alleles, will not have the sister chromatids physically touching, do not show duplication of the genetic material, or will already show the chromosomes entering into mitosis (aligning along the metaphase plate).

- Metaphase (Mitosis)



For a **good** answer, the students will show the chromosomes aligned along the metaphase plate and have the mitotic spindle and centromere labeled and 4C DNA content. **Excellent** answers will indicate nuclear envelope breakdown has occurred and chromatin condensation has happened. **Poor** answers will include a loss in the total number of chromatids from the previous section, will have the chromosomes rotated 90 degrees, or will pair the homologous chromosomes along the metaphase plate.

- After cytokinesis (Mitosis)



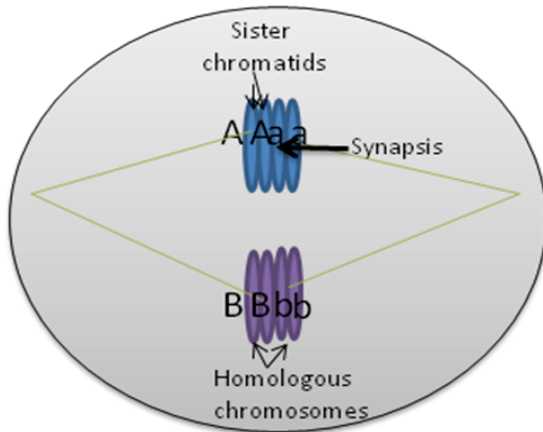
**Good** answers will diagram two identical cells the same as the cell in question 1. The DNA content of each cell is 2C. **Excellent** answers indicate that the DNA is now decondensed and the nuclear envelope has reformed. **Poor** answers will show daughter cells containing different genotypes and chromosome composition from the parent cell or will label the chromosomes as sister chromatids.

Label your pictures with terms such as centromeres and mitotic spindle. What is the DNA content (C) at each of these stages?

3. Your original cell (in question 1) enters **meiosis**.

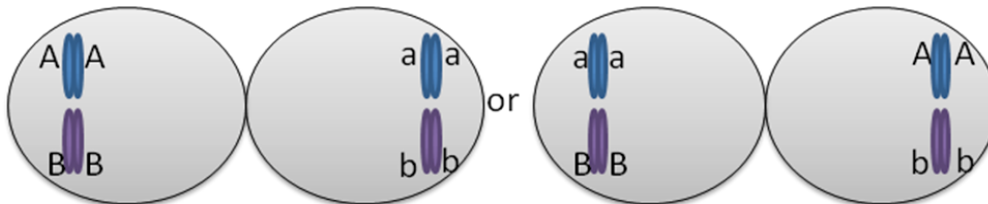
Draw your cell at the following stages:

- metaphase I



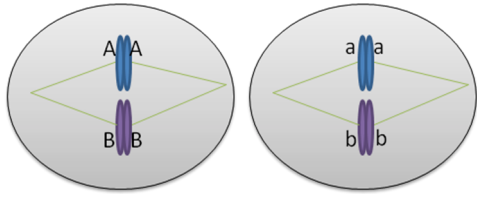
**Good** answers will pair homologous chromosomes on the metaphase plate and successfully indicate sister chromatids, homologous chromosomes, and synapsis. **Excellent** answers will indicate diagram recombination at the synapse and show appropriate genetic exchange of the alleles. **Poor** answers will not include the pairing of homologous chromosomes but instead show alignment similar to what occurs in metaphase during mitosis. Some students will quadruple rather than double the DNA content, will label the connection between sister chromatids as the synapse, or will mislabel the sister chromatids and homologous chromosomes.

- telophase/cytokinesis

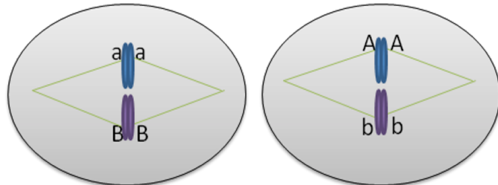


**Good** answers will have the homologous chromosomes separated to opposite poles with each new cell containing two sister chromatids of each chromosome. **Excellent** answers will diagram both potential results and explain that according to the principle of independent assortment the alleles will segregate independently. **Poor** answers will have cells lacking one of the chromosomes or containing two different alleles in each of the daughter cells assuming no recombination has taken place (i.e. Aa).

- metaphase II

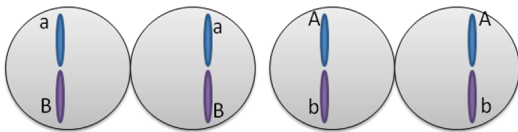


or

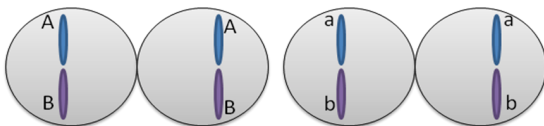


**Good** answers will show two of the daughter cells from meiosis I with the sister chromatids of the same allele aligning along the metaphase plate. **Excellent** answers will include the mitotic spindles and both scenarios depending on independent assortment. **Poor** answers will most likely occur if there were mistakes in the students' diagram of meiosis I and may include having A and a paired on the metaphase plate.

- telophaseII/cytokinesis.



or



**Good** answers will show four daughter cells each with half the DNA content (1C) of the original cell. **Excellent** answers will indicate that due to independent assortment you will generate daughter cells that contain AB and ab or daughter cells that are Ab and aB. **Poor** answers will not contain half the DNA content of the parent cells and will not have four daughter cells.

Label your model identifying sister chromatids, homologous chromosomes, and synapsis. Use your model to explain independent assortment.

3. Your original cell (in question 1) now enters into **meiosis**.  
 Draw your cell at the following stages:

- metaphase I
- telophase I/cytokinesis
- metaphase II
- telophase II/cytokinesis.

Label your model identifying sister chromatids, homologous chromosomes, and synapsis.  
 Use your model to explain independent assortment.

In metaphase, it doesn't matter which set of sister chromatids is pulled to which daughter cell. For example A could be with B or b.

Figure S3 Student completed cell division worksheet