Meiosis

Strand Life at the Molecular and Cellular Level

Topic Investigating meiosis and genetic variation

Primary SOL BIO.5 The student will investigate and understand common mechanisms of inheritance and protein synthesis. Key concepts include
a) cell growth and division;
b) gamete formation;
f) genetic variation.

Background Information

Asexual reproduction (vegetative reproduction) is a form of duplication that is accomplished by **mitosis.** Examples of asexual reproduction are binary fissions in bacteria and strawberries growing from shoots of existing strawberries. In such cases, the offspring are genetically identical clones of the parents since all growth and divisions are by mitosis. This is a fast and effective method of reproduction and propagation of an organism. Since the offspring are identical, the only mechanism for introducing variation is mutation.

Sexual reproduction occurs only in eukaryotes and is accomplished by the process of **meiosis,** which forms new individuals by a combination of two single sets of chromosomes. These single sets of chromosomes produce haploid sex cells (gametes) in each of two parents: the female produces eggs, while the male produces sperm. Upon fertilization of an egg by the sperm, the genetic information from the two gametes combines to form complete chromosomes. The haploid condition is changed to a diploid condition.

Materials

- Scissors
- Copies of the two attached handouts
- Various reference books or Web sites

Vocabulary

alternation of generations, anaphase, crossing over, daughter cell, diploid, gamete, germ cell, haploid, homologous chromosome, independent assortment, interphase, law of segregation, metaphase, oogenesis, prophase, random fertilization, specialization, spermatogenesis, spore, telophase, zygote

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)

1. Distribute scissors and copies of the attached Animal Chromosomes Chart handout. Direct students to choose phenotypes of their preference for each of the eight animal traits in the table, but instruct them that everyone should choose a heterozygous black coat color. Have students cut out each of the 16 “chromosomes” shown at the bottom of the handout, fold them so that only one “chromatid” in each chromosome is showing, and keep like-numbered chromosome pairs together.

2. Once all chromosomes are cut and folded, have students write the letter for one allele on one chromatid in each chromosome. For example, in chromosome pair number 1, a large "B" is written on one chromatid of one chromosome, and a small "b" is written on the one chromatid in the other chromosome, as shown. Have students repeat this process for the remaining 15 chromosomes. (At this point, each of the 16 chromosomes should be folded in half and have one letter written on it.)
3. Walk students through the steps of meiosis while they use their personal sets of chromosomes as manipulatives to demonstrate the process.

   Meiosis I
   - Interphase, G1: State that the cell grows.
   - Interphase, S: State that organelles are copied; unfold each chromosome to create a "copy" of it by writing its letter again on the adjoining sister chromatid to simulate DNA replication. (At this point, each of the 16 chromosomes should be unfolded and have the same letter written on both chromatids.
   - Interphase, G2: State that the cell grows.
   - Prophase I: Group chromosome pairs together to simulate homologous chromosome pairing. (You may want to mention crossing over as a source of variation, but these manipulatives cannot demonstrate crossing over.)
   - Metaphase I: Align chromosome pairs in a row to simulate homologs aligning on the equatorial metaphase plate. (Discuss independent assortment at this time.)
   - Anaphase I: Cut each of the homologs in half, and move each half to a separate pole (side) to simulate sister chromatids separating and segregating.
   - Telophase I/Cytokinesis: Point out that there are now two daughter cells, each having eight chromosomes.

   Meiosis II

   At this time, discuss the fact that interphase does not happen twice and, therefore, the DNA is not copied a second time, resulting in haploid cells at end of meiosis II.
   - Prophase II: Again, group chromosome pairs together to simulate homologous chromosome pairing. Stress that this occurs simultaneously in the two daughter cells.
   - Metaphase II: Align chromosome pairs in a row to simulate homologs aligning on the equatorial metaphase plate.
   - Anaphase II: Cut each of the homologs in half, and move each half to a separate pole (side) to simulate sister chromatids separating and segregating. (Discuss the law of segregation at this time.)
   - Telophase II/Cytokinesis: Point out that there are now four daughter haploid cells.
4. Discuss the difference between the parent and daughter cells and between metaphase I and metaphase II. Discuss gametogenesis.
5. Have each student randomly select one of the four daughter cells to become his/her "gamete." Tell students that they will simulate the process of random fertilization by combining gametes from two separate individuals to create a diploid zygote. Pair students, and have them create an "offspring." Have them use the chart on the handout to determine their offspring's physical traits.

6. Have each student pair fill in the attached Certificate of Birth for their offspring. Also, have them create a visual representation of the offspring's phenotype in the form of a "photograph" (drawing) of the offspring on the back of the certificate.
7. Optional: Have students create more than one offspring, birth certificate, and drawing to illustrate similarities and differences in siblings.
8. Ask students what would happen if meiosis were to happen incorrectly before gametes united at fertilization (nondisjunction). Discuss the causes and effects of Down syndrome (trisomy 21), Klinefelter syndrome (XXY), Turner syndrome (X). Utilize karyotypes to show the resulting nuclear content.
9. Optional: Have students analyze karyotypes resulting from nondisjunction. (Karyotypes can be found by searching on the Internet for the keyword "karyotype" together with the name of a disorder of interest.)
10. Optional: Provide a raw egg for each student to "parent" for a week and record his/her experience in a journal.

Assessment

- **Questions**
  - What is the purpose of meiosis?
  - Humans normally have 46 chromosomes in their body's cells. How many chromosomes does an egg cell have?
  - In meiosis, how do metaphase I and metaphase II compare?
  - What are the similarities and differences between mitosis and meiosis?
  - What can be the effects of nondisjunction?
- **Journal/Writing Prompts**
  - Discuss the role of meiosis in creating diversity, using the principles of crossing over, law of independent assortment, law of segregation, and random fertilization.
  - Explain why you are similar but different from your parents in terms of genetic material.
  - Compare and contrast the processes of oogenesis and spermatogenesis.
- **Other**
  - Have students create a Venn diagram comparing and contrasting mitosis and meiosis, using interactive computer software or cut and paste. Provide a list of words and phrases for students to add to their diagram, or brainstorm a list as a class for individuals or pairs to use.

Extensions and Connections (for all students)

- Have students relate what goes on in meiosis to Mendel's laws of heredity.
- Discuss the definitions of *allele, genotype,* and *phenotype*.
- Have students create Punnett crosses, using their original genotypes to predict ratios, and discuss the role of meiosis to create the male and female gametes on either side of the Punnett square.
- Discuss the difference in the inheritance pattern of the paw print (incomplete dominance) and sex chromosomes.
- Have students create genotypes based on selected phenotypes

- Have students investigate natural and artificially induced polyploidy in plants.
- Have students explain how polyploidy can be induced.
- Have students research disorders that results from nondisjunction.
- Have students examine the various life cycle diagrams for the organisms listed below and create a table to compare and contrast the types of meiosis, types of gametes, names of haploid cells, and dominant phases of the life cycles.
  - Human
  - Nitella
  - Rhizopus
  - Moss
  - Fern
  - Ulva
  - Chlamydomonas

Strategies for Differentiation

- Provide students with a completed set of chromosomes, and have them demonstrate their understanding of meiosis by creating an educational "video" of the events in the process.
- Provide students with a complete or partially complete set of Punnett squares (one at a time) and an image of an "offspring." Ask students to decide whether the two parents could have created this offspring and to justify their decision.

Animal Chromosomes Chart

Chromo #	Trait	Phenotype and Genotype Possibilities		
1	Coat Color	Black (BB)	Black (Bb)	Teal (bb)
2	Tongue	Pink (KK)	Pink (Kk)	Red (kk)
3	Nose	Black (PP)	Black (Pp)	Pink (pp)
4	Ears	Round (RR)	Round (Rr)	Pointed (rr)
5	Teeth	Pointed (NN)	Pointed (Nn)	Flat (nn)
6	Whiskers	Present (AA)	Present (Aa)	Absent (aa)
7	*Paw Print	5 Pads (FF)	4 Pads (Ff)	3 Pads (ff)
Sex	Sex	Female (XX)	Male (XY)	

Allele _B_	1	Allele ___	2	Allele ___	3	Allele ___	4
Allele ___	1	Allele ___	2	Allele ___	3	Allele ___	4
Allele _b_	1	Allele ___	2	Allele ___	3	Allele ___	4
Allele ___	1	Allele ___	2	Allele ___	3	Allele ___	4
Allele ___	5	Allele ___	6	Allele ___	7	Allele ___	Sex
Allele ___	5	Allele ___	6	Allele ___	7	Allele ___	Sex
Allele ___	5	Allele ___	6	Allele ___	7	Allele ___	Sex
Allele ___	5	Allele ___	6	Allele ___	7	Allele ___	Sex

CERTIFICATE OF BIRTH

This certifies that a certificate of birth has been filed with the

State Registrar of Vital Statistics for

_____, *sex*_____

born on _____ *in* _____, *Virginia.*

Right Paw Print:

Name of Father: _____

Maiden Name of Mother: _____

Date filed: _____ *Signed:* _____