Introduction

Diploid, sexually reproducing organisms produce haploid gametes at some point in their life cycle. Gametes fuse to form a diploid zygote containing two sets of chromosomes, one from each of the parents that produce the gamete. The mechanism that reduces the chromosome number from diploid to haploid is meiosis, from a Greek word meaning ‘to make smaller.’ One major function of meiosis, then, is to conserve chromosome number in sexually reproducing species. If not reduced through meiosis before gametic union, the chromosome number would double. From a genetic standpoint, meiosis allows maternal and paternal chromosomes to recombine in each gamete. Whereas mitosis preserves genetic identity between parent and offspring cells, meiosis is quite the opposite since it allows the possible formation of new genetic combinations in offspring.

Among animals, some protistans, and some fungi, meiosis is part of a process called gametogenesis that results in the production of gametes. Among plants, some protistans, and some fungi, meiosis occurs during sporogenesis, a process resulting in the production of spores. The haploid spores then develop into haploid gametophytes that produce gametes by mitosis. In organisms where gametes are morphologically different (oogamous) gametogenesis that produces ova, or ‘female’ gametes, is called oogenesis, while production of spermatozoa, or ‘male’ gametes, is called spermatogenesis. Characteristically, four haploid nuclei result from meiosis. In many organisms these nuclei end up in cells that are about the same size. However, during oogenesis in many animals the haploid nuclei end up in products of unequal size. Cytokinesis during oogenesis in these animals is extremely unequal. It leaves one of the products (ovum) with most of the cytoplasm and several polar bodies with little cytoplasm. During spermatogenesis in most organisms the two divisions of meiosis produce four cell of equal size (often referred to as spermatids). Each haploid cell matures into a functional sperm.

Objectives

For today’s exercise students will work in pairs and use a variety of learning resources to review the key events occurring during meiosis. In addition to memorizing the phases of meiosis, you must completely understand the genetic outcomes of the process. In particular you should be able to associate particular steps in meiosis with the three Mendelian principles of inheritance: the Principle of Dominance, the Principle of Segregation, and the Principle of Independent Assortment. After using the learning resources to review meiosis, you can test your knowledge by answering the homework problems at the end of this handout.

Learning Resources

Biology Textbook. Use a biology text to help you review the names and essential features of the phases of meiosis.

Wall Posters. These charts include diagrams as well as photomicrographs of cells undergoing meiosis.
Models. The models represent the various stages of oogenesis that occur in the parasitic roundworm, Ascaris megaloechpala bivalens. Ascaris is useful in studying meiosis because its low chromosome number simplifies observation of individual chromosomes and their behavior. Sperm penetration occurs when the female gamete is a primary oocyte, and triggers both the first and the second meiotic divisions. Ascaris sperm are not flagellated, but move by amoeboid movement. During oogenesis the sperm nucleus can be found as a darkly staining mass inside the oocyte undergoing meiosis. The meiotic events of the oocyte will occur toward the periphery of each oocyte. Upon completion of oogenesis, the sperm nucleus and egg nucleus unite to form the ‘pronucleus’ of the newly formed zygote. Your lab instructor will help you understand the meiotic stages represented in the models.

Computer Simulations. Observe and work with the interactive computer simulations of the chromosomal events that occur during meiosis. Test your knowledge by taking a quiz.

Pop-it Beads. Each pair of students will be provided with a set of colored plastic beads that represent maternal and paternal versions of chromosomes in an organism with 2N number of 4. These bead models are excellent for representing the key events in meiosis that influence Mendelian principles of inheritance. Your ability to successfully use these beads to simulate gamete formation is considered to be the ultimate test of your knowledge of meiosis.

Meiosis Problems. (Answers should be passed in on a separate piece of paper)

1. How many different chromosomal combinations can result from meiosis in a species that has a diploid (2N) number of 8? Assume no crossing-over occurs.

2. Develop a mathematical formula that allows you to compute the answer to Question #1.
   a. What is the formula?
   b. Using that formula, how many chromosomal combinations can result from meiosis when the diploid number is 16?
   c. How about when the diploid number is 46 (as it is in humans)?

3. The horse (Equus caballus) has a diploid complement of 64 chromosomes. The donkey (Equus asinus) has 62 chromosomes.
   a. What is the number of chromosomes that would be found in a hybrid offspring (mule) produced by mating a male donkey to a female horse?
   b. Mules are usually sterile (incapable of producing viable gametes). During what phase of meiosis would problems occur in forming viable gametes? Why?

4. Assume an organism with 2N number of 6 chromosomes. Draw diagrams comparing the appearance of the chromosomes:
   a. In prophase I of meiosis and prophase of mitosis
   b. In metaphase II of meiosis and metaphase of mitosis