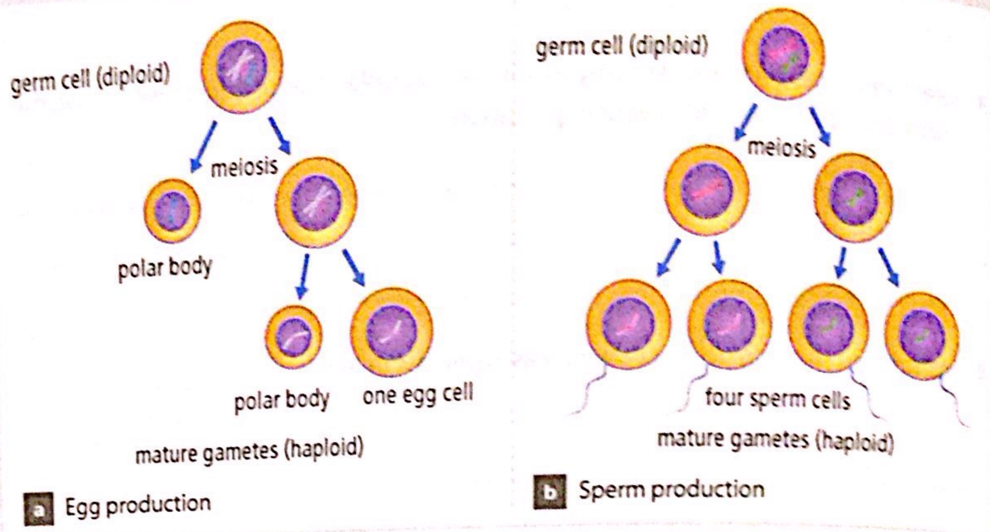
Gametogenesis

The haploid cells produced by meiosis are not able to be fertilized until they go through additional changes to produce mature gametes. The final stages of this process, called gametogenesis, differ between the sexes.

FIGURE 8: Gametogenesis in egg and sperm cells. (Cells are not drawn to scale.)



INFER Use the model of gametogenesis to infer which descriptions below accurately compare and contrast the production of sperm cells and the production of egg cells in gametogenesis. Select all correct answers.

- ☐ **a.** Both sperm and egg production involve meiosis.
- ☐ **b.** Gametogenesis results in more eggs per germ cell than sperm per germ cell.
- ☐ **c.** The sperm cell is much larger than the egg cell.
- ☐ **d.** Both sperm and egg production begin with diploid cells.
- ☐ **e.** Sperm production results in diploid cells and egg production results in haploid cells.

The formation of an egg, the female gamete, begins before birth inside the developing body of a female embryo. The process is not finished until a sperm fertilizes that egg many years later. Only one of the cells produced by meiosis actually makes an egg. The other cells produced are called polar bodies and are not typically able to be fertilized. Nearly all of a zygote's cell structures come from the egg. Since mitochondria carry their own DNA, the mitochondrial DNA in the embryo is identical to the mother's.

The sperm cell, the male gamete, is much smaller than the egg. The sperm cell's main contribution to an embryo is DNA. Yet it must swim to an egg to fertilize it, so the ability to move is critical. Sperm formation starts with a round cell and ends by making a streamlined cell that can move rapidly. During this process, significant changes occur. DNA is tightly packed and much of the cell body is lost, resulting in a compact head. The sperm cell develops a whip-like flagellum that acts as a propeller, and a neck region, with mitochondria that provide the energy needed to move the cell's flagellum.

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Evidence Notebook According to the models of meiosis and gametogenesis, do all the gametes produced by an organism have the same genetic material? Use evidence to support your claim.

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Meiosis and Genetic Variation

One of the advantages of meiosis and sexual reproduction is the resulting increased genetic diversity within a species. Genetic variation refers to the differences in the genetic material of individuals in a population.

FIGURE 9: Genetic variation is responsible for the different versions of traits you see in this cat's offspring.

Mechanisms of Genetic Variation

Meiosis and sexual reproduction increase genetic diversity, or genetic variation, within a population. Gametes have different combinations of genes than their parent cells due to independent assortment and crossing over, which both occur during meiosis.

Independent Assortment

When homologous chromosomes pair up in metaphase I of meiosis, the chromosomes from your father and the chromosomes from your mother line up randomly on either side of the cell's equator. This assortment of chromosomes is a matter of chance. The arrangement of any one homologous pair does not depend on the arrangement of any other homologous pair. Therefore, it is referred to as independent assortment.

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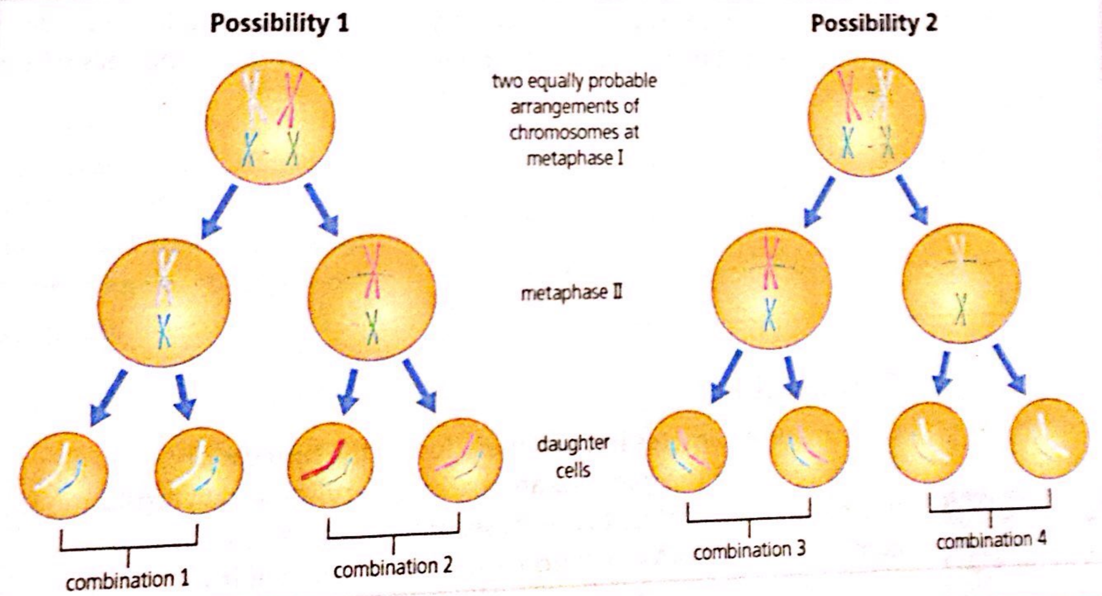

FIGURE 10: Independent assortment results in many different genetic combinations.

Problem Solving

To determine the number of possible chromosome combinations that can result from independent assortment, you can use this formula:

$$\text{Combinations} = 2^n$$

where n = number of different chromosomes.

APPLY What is the approximate number of possible chromosome combinations for a human cell with 23 different chromosomes?

Evidence Notebook How does your answer to the Problem Solving question support the claim that independent assortment increases variation in an organism's offspring? How could this affect the evolution of a species?

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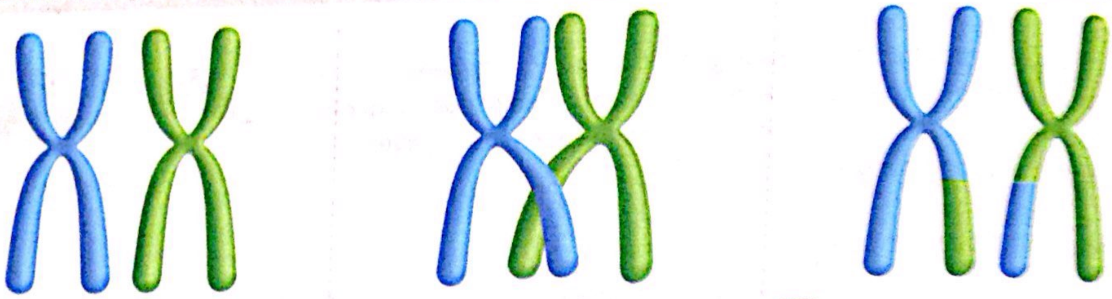
Crossing Over

The exchange of chromosome segments between homologous chromosomes is called crossing over. It happens every time a germ cell divides. It occurs during prophase I in meiosis I, and it is a regulated process. At this stage of meiosis, each chromosome has been duplicated, the sister chromatids are still connected, and homologous chromosomes have paired up. Some of the chromatids are very close to each other. Part of one chromatid from a chromosome may break off and reattach to the other chromosome. Crossing over can happen many times within the same pair of homologous chromosomes. Because crossing over results in new combinations of genes, it is an example of genetic recombination.

FIGURE 11: Crossing over increases genetic variation.

Explore Online



1. Two homologous chromosomes pair up with each other during prophase I in meiosis.
2. In this position, some chromatids are very close to each other and segments cross.
3. Some of these segments break off and reattach to the other homologous chromosome.

EXPLAIN Use the model of meiosis that you made earlier in the lesson to explain how crossing over contributes to genetic diversity. How did you modify your model? How do you think crossing over affects the expression of certain traits compared to the cells where crossing over didn't occur?

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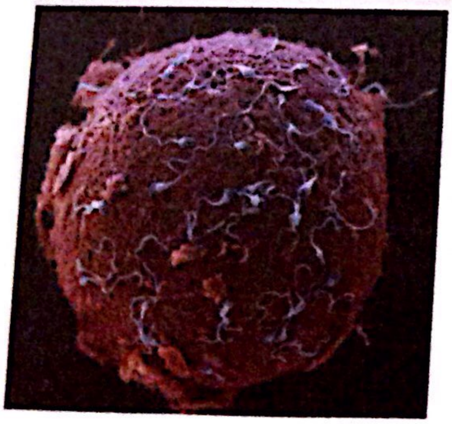
FIGURE 12: Fertilization results in a genetically unique organism. (Colored SEM)



Fertilization

Once mature gametes have formed during the process of gametogenesis, the gametes are ready for fertilization. In fertilization, two gametes of different types fuse, producing a zygote with a complete set of DNA—half from one parent and half from the other. The resulting zygote will have a unique combination of genes. The mixing and matching of genetic material during meiosis and fertilization is responsible for the genetic variation in sexually-reproducing organisms.

For example, in humans a sperm cell with one of 2^{23} chromosome combinations fertilizes an egg cell, which also has one out of 2^{23} chromosome combinations. If sperm cells and egg cells were combined at random, the total number of possible combinations is the product of $2^{23} \times 2^{23}$, or more than 70 trillion. So, a human couple can produce a child with one of about 70 trillion different combinations of chromosomes.

Evidence Notebook Use evidence you have gathered about meiosis and sexual reproduction to construct an explanation for why offspring are not exact replicas of their parents. In your answer, include a discussion of sexual reproduction, independent assortment, and crossing over.

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