

## Crossing-over Shuffles Alleles

*Adapted from Norton "Discovery Biology", 2011 Anu Singh-Cundy and Micheal L. Cain  
(adapted 2/28/15, L. Coleman)*

Meiosis generates enormous genetic diversity because each pair of homologous chromosomes separates and is distributed randomly to gametes. The number of possible combinations is  $2^n$  where  $n$  = the number of homologous pairs for that species. In humans that means there are  $2^{23}$ , or 8,386,608 possible combinations of chromosomes in our gametes. However, the amount of diversity generated is increased further (to a degree approaching infinity) by another event that happens during meiosis. That event, called **crossing over**, is of great interest to biologists because it appears to have no purpose other than to increase variation in the species.

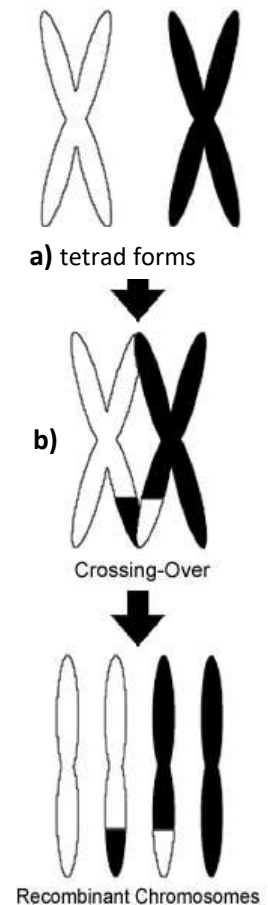
**Crossing-over** is the name given to the physical exchange of chromosomal segments between non-sister chromatids of homologous pairs when tetrads form in meiosis. When homologous pairs line up parallel to each other at the equator a chromatid from one member of the pair may contact a chromatid from the other member and they may exchange corresponding segments. This contact and exchange can occur at one or more random places along the length of the chromatids in any homologous pair. Crossing over is the rule, not the exception. In other words, when meiosis occurs there is almost always crossing over in every single homologous pair.

The swapped segments of chromatids contain the same genes positioned in the same order. But, as we have seen, genes can exist in different versions, called alleles. So crossing-over exchanges alleles between the two homologous chromatids. Therefore, crossing over creates chromatids carrying new combinations of alleles compared to those on the original chromosomes in the diploid parent cell. This is known as genetic recombination. Without crossing-over, every chromosome inherited by a gamete would be just the way it was in the parent cell. Crossing over at even one location in a homologous pair produces at least four genetically distinct gametes, as shown.

### SUMMARY of HOW IT HAPPENS:

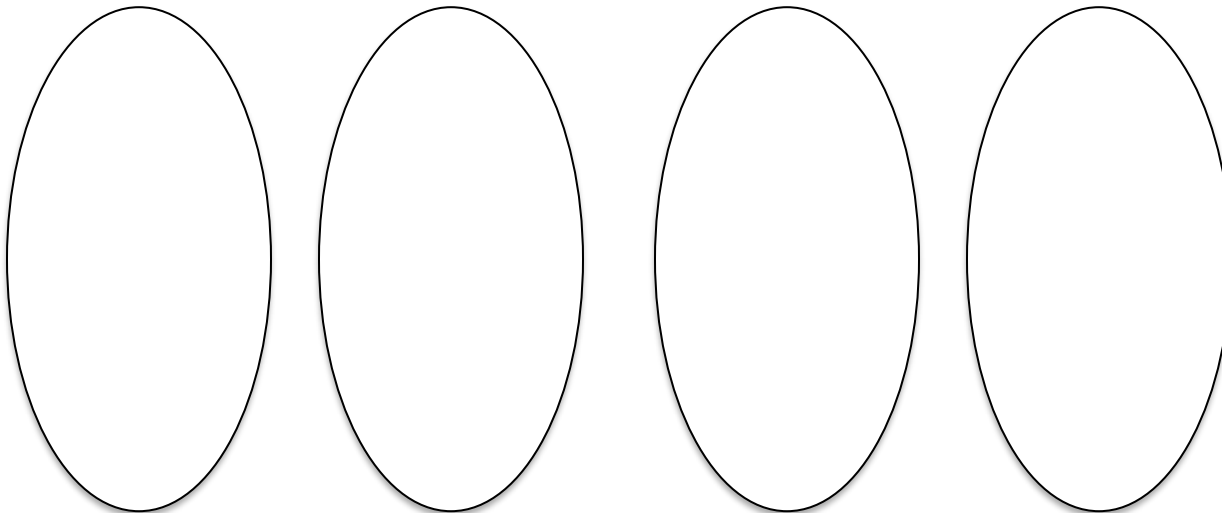
- Tetrads form. Members of each homologous pair are parallel, very close together.
- Non-sister chromatids touch and exchange DNA segments.
- Crossing-over gives rise to 4 genetically unique recombinant chromosomes.

**DIRECTIONS FOR ACTIVITY:** *Cut out the chromosomes on the attached page and glue them on the back of this paper according to the directions given. Then answer the three questions.*

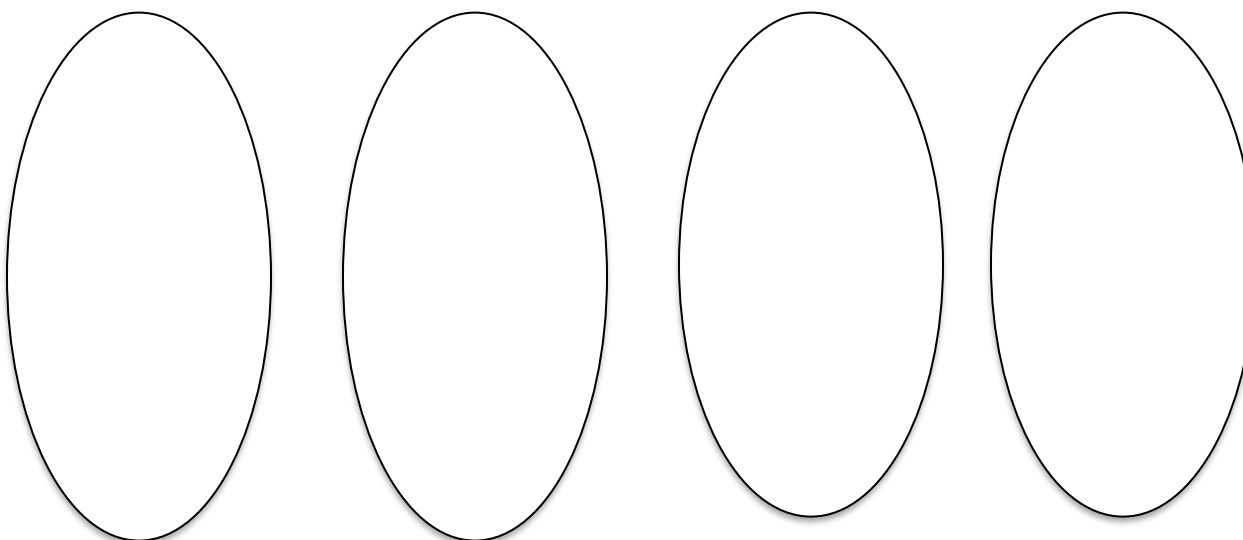


Name: \_\_\_\_\_ Period: \_\_\_\_\_ Date: \_\_\_\_\_

**Part 1: "No Crossing Over": POSSIBLE GAMETES:**



**Part 2: "WITH Crossing Over" POSSIBLE GAMETES:**



**H and h are alleles for hair body:**

**H = straight hair; h = curly hair.**

**R and r are alleles for hair color:**

**R = brown hair; r = red hair.**

**DISCUSSION QUESTIONS:**

1. a. In Part 1, how many different combinations of the genes for hair body and hair color are possible? List them.  
b. How many in Part 2? List them.
2. Without crossing over would it ever be possible for a gamete carrying the allele for straight hair to also carry the allele for red hair? Explain.
3. In your own words, explain why crossing over causes such a huge increase in the amount of variation possible in an organism's gametes.