I believe adamantly that science is well taught only if there is a careful pairing of labs with theory. Sometimes it is difficult to think of labs to pair with the theory. Thinking of a lab to pair with the theory for how the reproductive system works in a middle school textbook was definitely one of those cases. I was so proud of myself when I thought of this lab to use in *RSO Biology 2*. I was pretty disappointed when neither Kate, my publisher, nor Sean liked this lab. (It is actually interesting to me how often these two agree.) I love this lab, because it very effectively shows how a limited number of chromosomes can lead to so much variability.

Why Are We All so Different? Lab

People come in all shapes and sizes. We have different hair color, eye color, and skin color. We are all so different. Unless you have an identical twin, you do not even look exactly like your siblings. How does that happen?

Humans are diploid. They have 2 x 23 chromosomes equaling 46 chromosomes total, 2n = 46. That is two sets of 23 chromosomes. One set comes from the mother's egg and one set from the father's sperm.

You are going to determine how many genetically different gametes a male and female organism could make with 3 chromosomes in each set, 2n = 6. That means that the gametes of this organism each have 3 chromosomes. Remember the gametes of diploid organisms are haploid, n. That way when the male and female gametes fuse during fertilization their offspring have 2n chromosomes, the same as their parents have. After you have determined all the possible gametes these two parents can make you are going to look at all the possible combinations that could occur during fertilization.

It is random chance, which chromosomes are in a gamete. Your mother and father got half their chromosomes from their mother and half from their father. That means you have chromosomes from your grandparents in you. Each of the two gametes that made you might have had only chromosomes from your grandmother, only those from your grandfather, or each gamete might have chromosomes from both your grandmother and your grandfather.

Materials

- Four different colors of markers, pencils, or pens
- Scissors
- Lab Sheets,

Procedure

1. Select two colors to use on the female gamete worksheet. One color represents the grandmother's chromosomes and one color represents the grandfather's chromosomes. Using the numbers 1, 2, 3, list all the possible combinations of chromosomes for meiosis Metaphase I, this is the first column of circles on the sheet. For example, the first gamete might have all the numbers in one color on one side and all the numbers of the other color on the other side. In that case, the resulting gametes will only get chromosomes from each grandparent. Three sets of homologous chromosomes can line up four different ways. Remember 1 can only pair with 1, 2 with 2, and 3 with 3. It is the color pairings that will vary.
2. The chromosomes will separate, forming two gametes. Each will have only the chromosomes that were on their side. Under the two columns titled Gametes, write the number of the chromosomes, 1, 2, 3. Make sure you get the correct colors in each gamete.
3. Do the same thing for the Male Gametes Lab Sheet using two different colored pens.
4. Cut out all 16 gametes. What are all the possible combinations of genetically distinct zygotes that could form from these gametes?
5. Make a pile with the female gametes. Lay the male gametes out like cards so you can see all eight of them. Take one female and make all the possible different combinations with the eight male gametes. Do this with each female gamete. Remember, only one female and one male gamete can combine.
6. Complete the questions on Page 3 of the lab sheets.

*This lab does not go through the entire process of meiosis. The two gametes that form from each of the two cells after cytokinesis II have the same complement of chromosomes as those from cytokinesis I. From a statistical standpoint, these duplicate gametes are not significant.

Why Are We All so Different? Lab Sheet, 3 pages

1. Assuming no mutations, how many genetically different offspring can two parents with 2n = 6, 3 pairs, of chromosomes have?

2. Humans have 23 pairs of chromosomes. Do you think two human parents can have more, less, or the same number of genetically different offspring as an organism with 3 pairs of chromosomes? Defend your answer.

3. There is a process called crossing over. During meiosis, parts of homologous chromosomes can cross over each other, break off, and each reattach to the other chromosome. How do you think this affects variability in an organism's gametes?

Bonus: There is a mathematical rule for how many different types of gametes an organism can produce. Think about this lab and how many different gametes were formed. Can you figure out what the rule is? Hint: The rule involves an exponent.

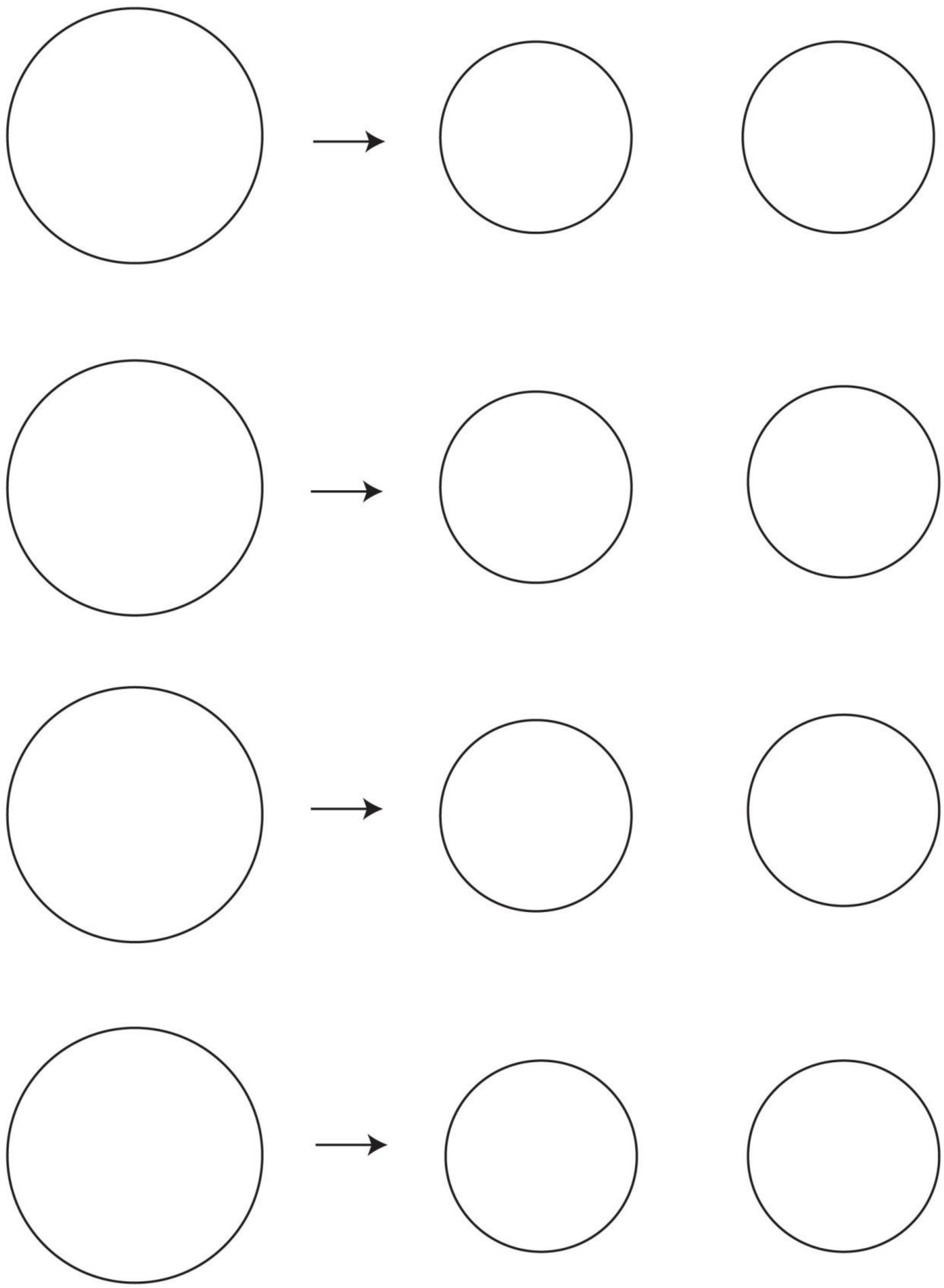
Using the rule, you can peek at the answer if you need to, how many different types of gametes can one human make. Aren't you glad we didn't use two humans for this lab?

Fraternal twins often look very different. Explain why based on the results of this lab.

Variability Lab Sheet, Female Gametes

Meiosis
Metaphase I

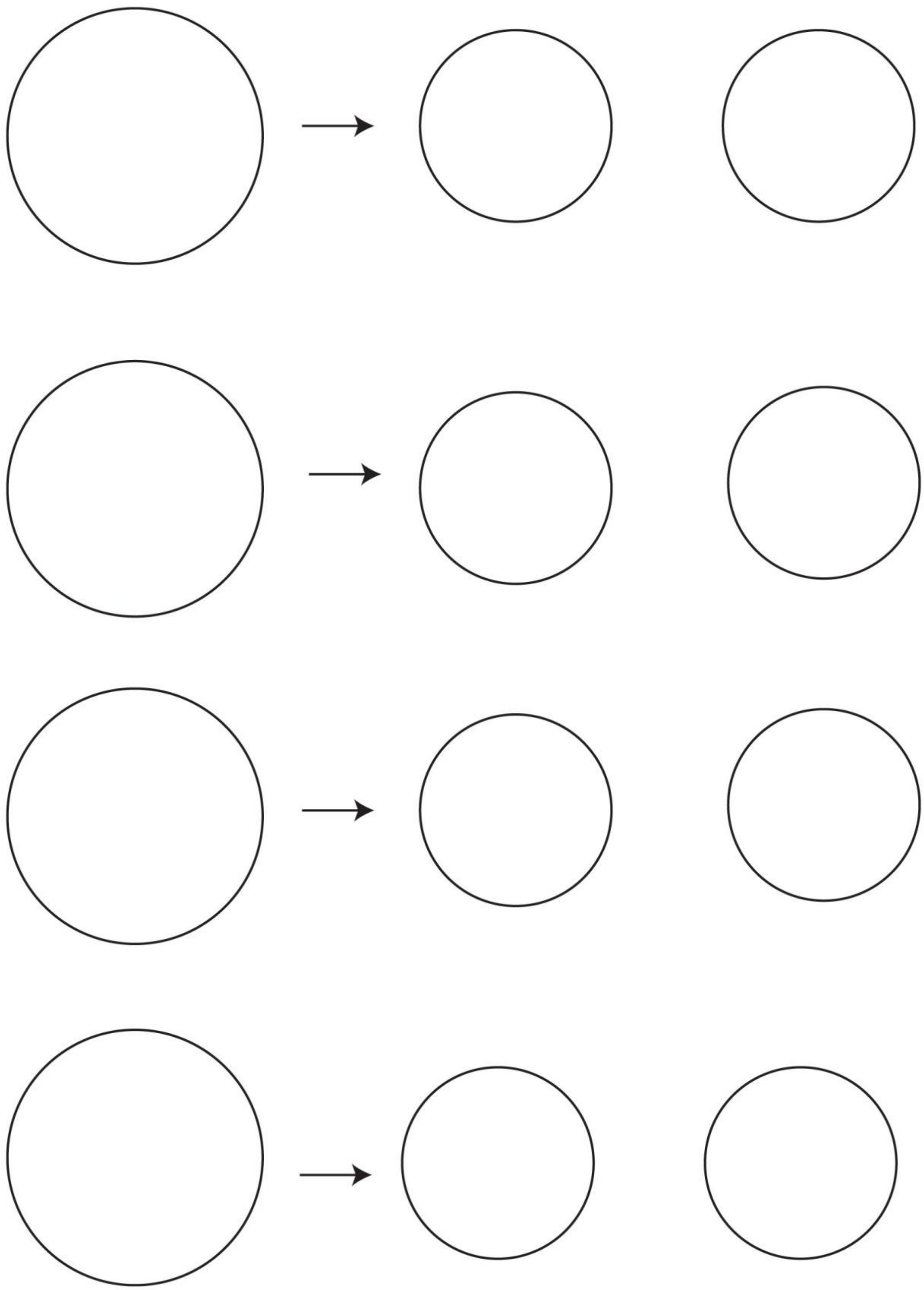
Gametes



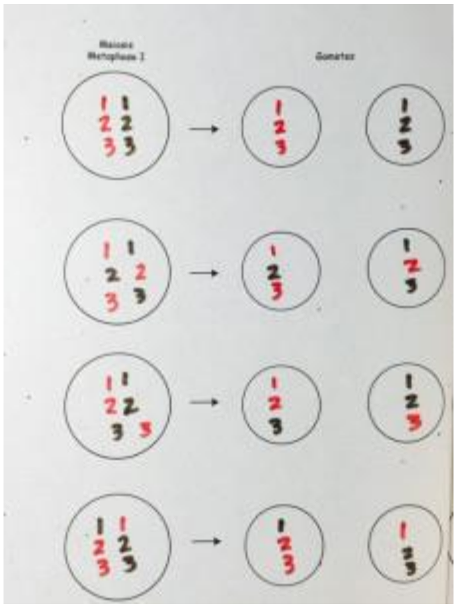
Variability Lab Sheet, Male Gametes

Meiosis
Metaphase I

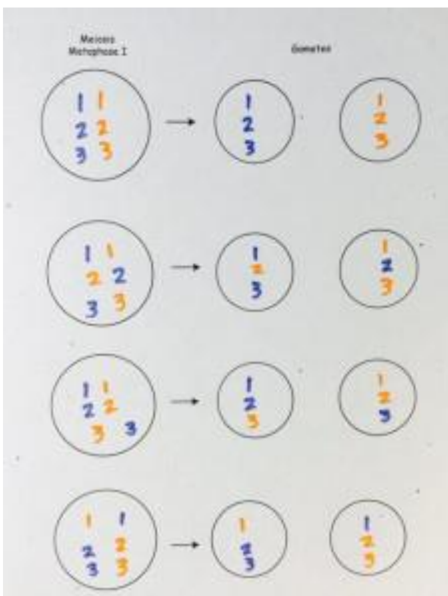
Gametes



Why Are We All so Different? Answer Key

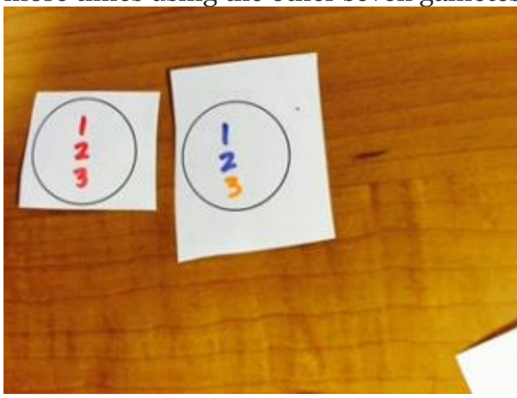


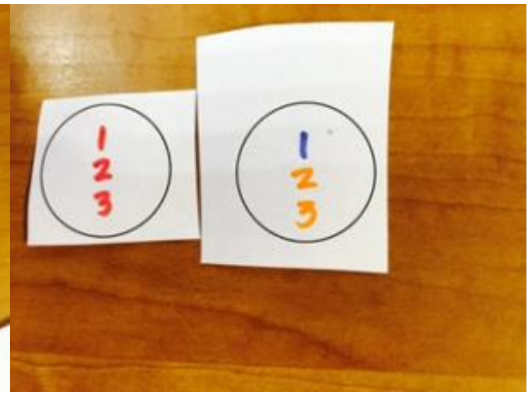
The red chromosomes are from the paternal grandmother. The brown chromosomes are from the paternal grandfather. These are the possible gametes the father can make from his mother's and father's chromosomes.

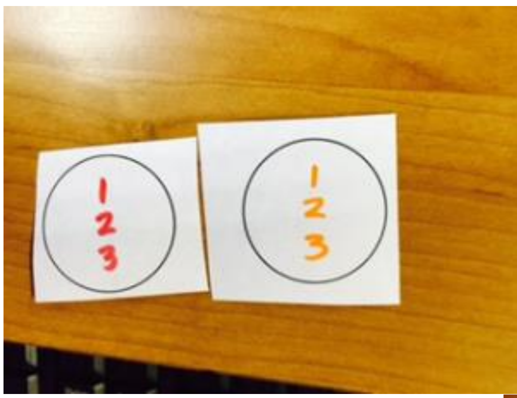


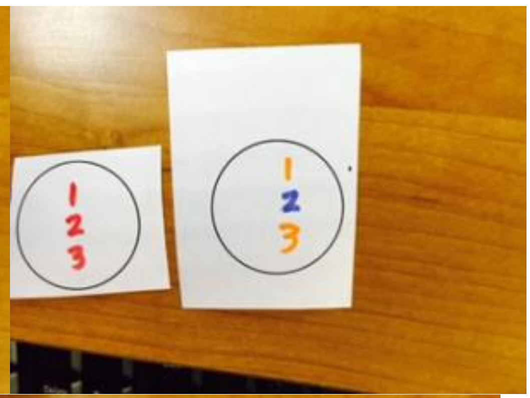
The blue chromosomes are from the maternal grandmother. The orange chromosomes are from the maternal grandfather. These are the possible gametes the mother can make from her mother's and father's chromosomes.

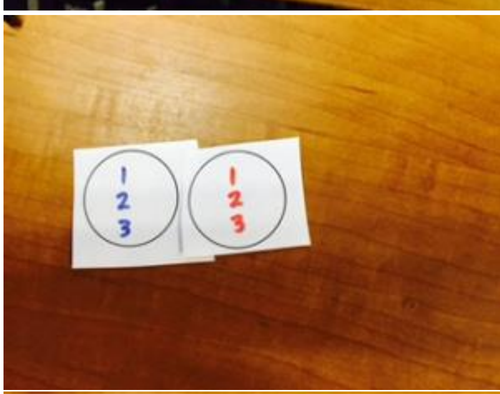
This series shows the possible combinations of gametes using one gamete from the father and all eight gametes of the mother. To show all possible combinations I would need to do this for seven more times using the other seven gametes from the father.

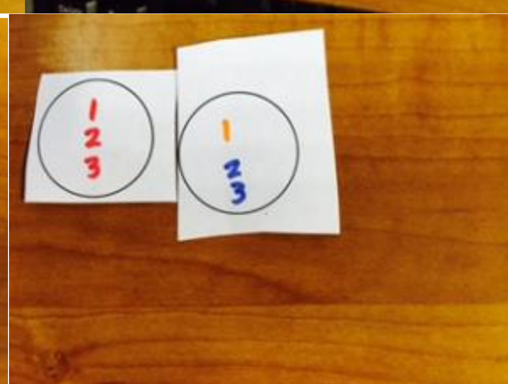


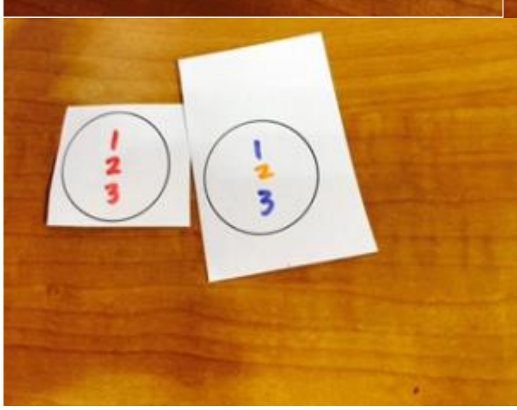


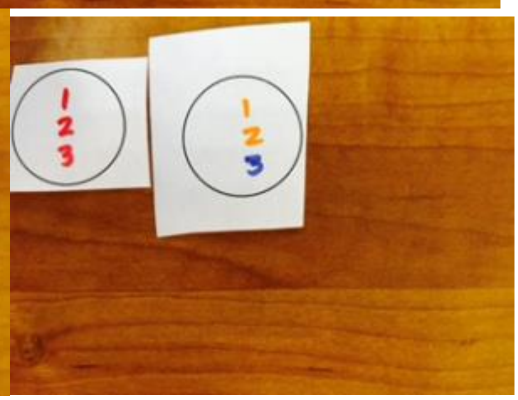












1. Assuming no mutations, how many genetically different offspring can two parents with 2n = 6, 3 pairs, of chromosomes have? **8+8+8+8+8+8+8+8 = 8×8 = 64**

2. Humans have 23 pairs of chromosomes. Do you think two human parents can have more, less, or the same number of genetically different offspring as an organism with 3 pairs of chromosomes? Defend your answer. **Humans have more pairs of chromosomes, so there is the possibility of more genetically different offspring than in an organism with three pairs of chromosomes.**

3. There is a process called crossing over. During meiosis, parts of homologous chromosomes can cross over each other, break off, and each reattach to the other chromosome. How do you think this affects variability in an organism's gametes? **Crossing over greatly increases the potential variability in an organism's gametes. With crossing over, part of your grandmother's chromosome can be incorporated into your grandfather's chromosome. Creating a unique chromosome that has parts from two different individuals who are only related by marriage.**

Bonus: There is a mathematical rule for how many different types of gametes an organism can produce. Think about this lab and how many different gametes were formed. Can you figure out what the rule is? Hint: The rule involves an exponent. **8 = 2^3 n = 3, from this you can determine that the answer is 2^n; You can also tell that the number of possible genetically different offspring, assuming no mutation and no crossing over, will be 2^{2n}**

Using the rule, you can peek at the answer if you need to, how many different types of gametes can one human make. Aren't you glad we didn't use two humans for this lab? **For humans n = 23, therefore the number of different types of gametes one human can make is to 2^{23} = 8,388,608; the possible combinations of genetically different offspring assuming no mutations and no crossing over would be 70,368,744,177,664.**

Fraternal twins often look very different. Explain why based on the results of this lab.

There is a 1 in 70,368,744,177,664 chance that two siblings who are not identical twins will have the exact same genes.