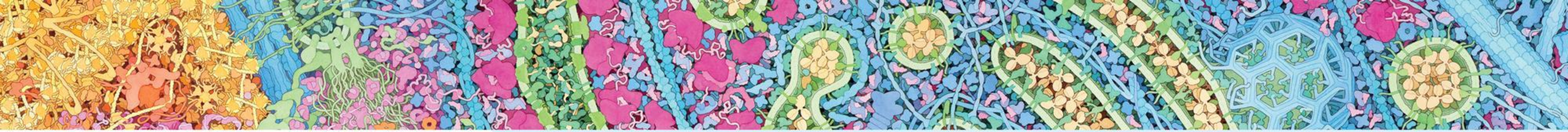
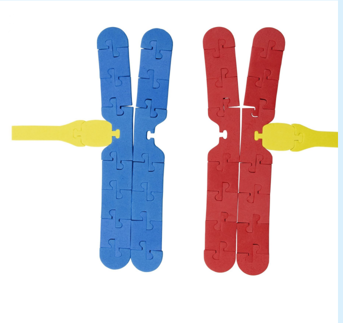


Oh Meiosis! Modeling the Processes that Create Genetic Diversity

Chromosome Connections Kit



Sue Remshak

NABT Baltimore 2023

Sue Remshak

MA Curriculum & Instruction, BA Biology & Secondary Instruction

Grayslake North High School, Grayslake IL

31 years as a biology educator

3DMD model teacher

Classes taught: AP Biology, Biology Honors, Biology, Zoology

Email: sremshak@d127.org

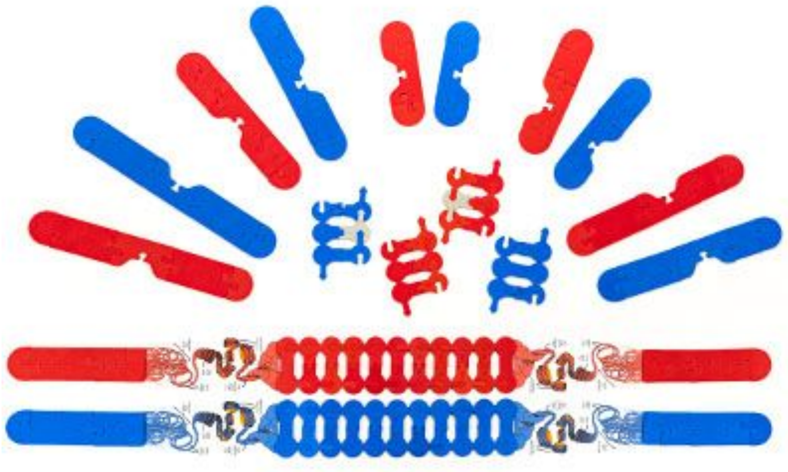
Workshop Goals

- Model the processes of meiosis that lead to genetic diversity.

- Address common student misconceptions

Chromosome Connections Kit

- Build homologous chromosome pairs and sister chromatids
- Identify chromosome structure and anatomy
- Construct Punnett squares with gene sequences as alleles
- Compare and contrast mitosis and meiosis
- Explore how genes can cross over during prophase
- Investigate chromosomal nondisjunctions, translocations, inversions, deletions and duplications



Online resources

General Misconceptions: Meiosis

- Students remember the names of stages but have difficulties with the events in these stages
- They fail to understand the mechanisms of diversity
- Understanding of the difference in chromosome numbers at the end of division
- Students often remember names of only some concepts—such as *tetrad*, *synapsis*, *chromatid*, and *chromosome*—but have problems remembering the meanings

Let's Model!

Materials:

Blue long paternal chromosome (2)

Red long maternal chromosome (2)

Blue short paternal chromosome (2)

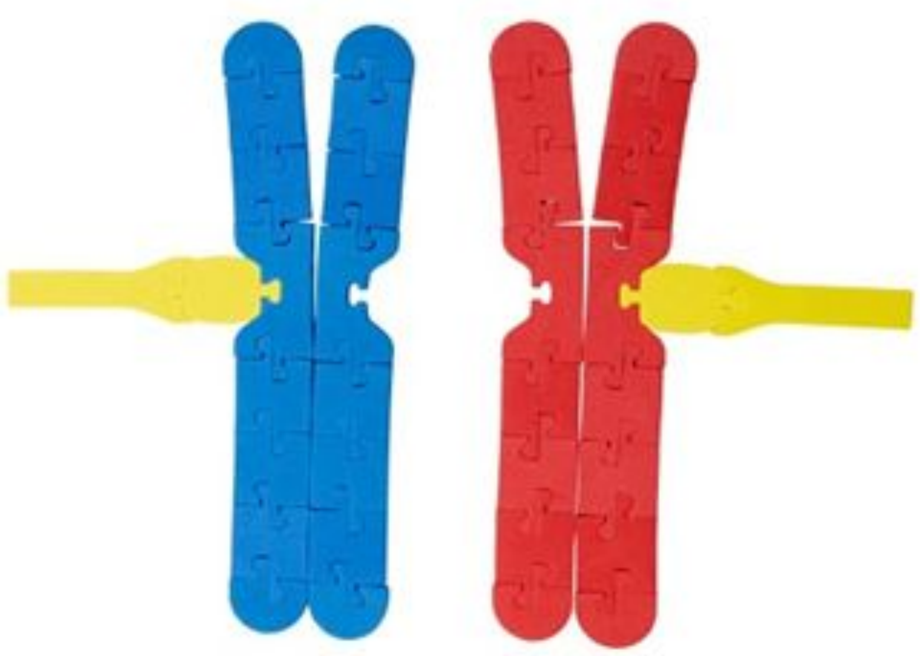
Red short maternal chromosome (2)

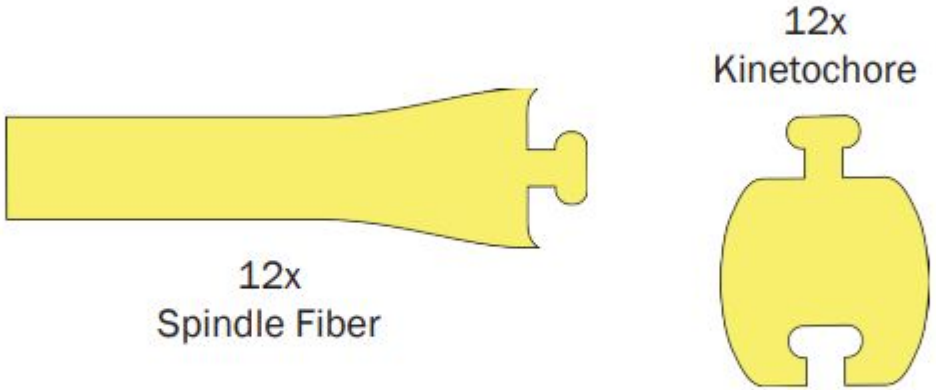
Kinetochores (8)

Spindle fibers (8)

Red and blue colored pencils

Table marker or chalk



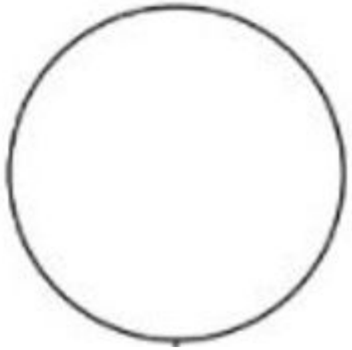


Modeling Directions

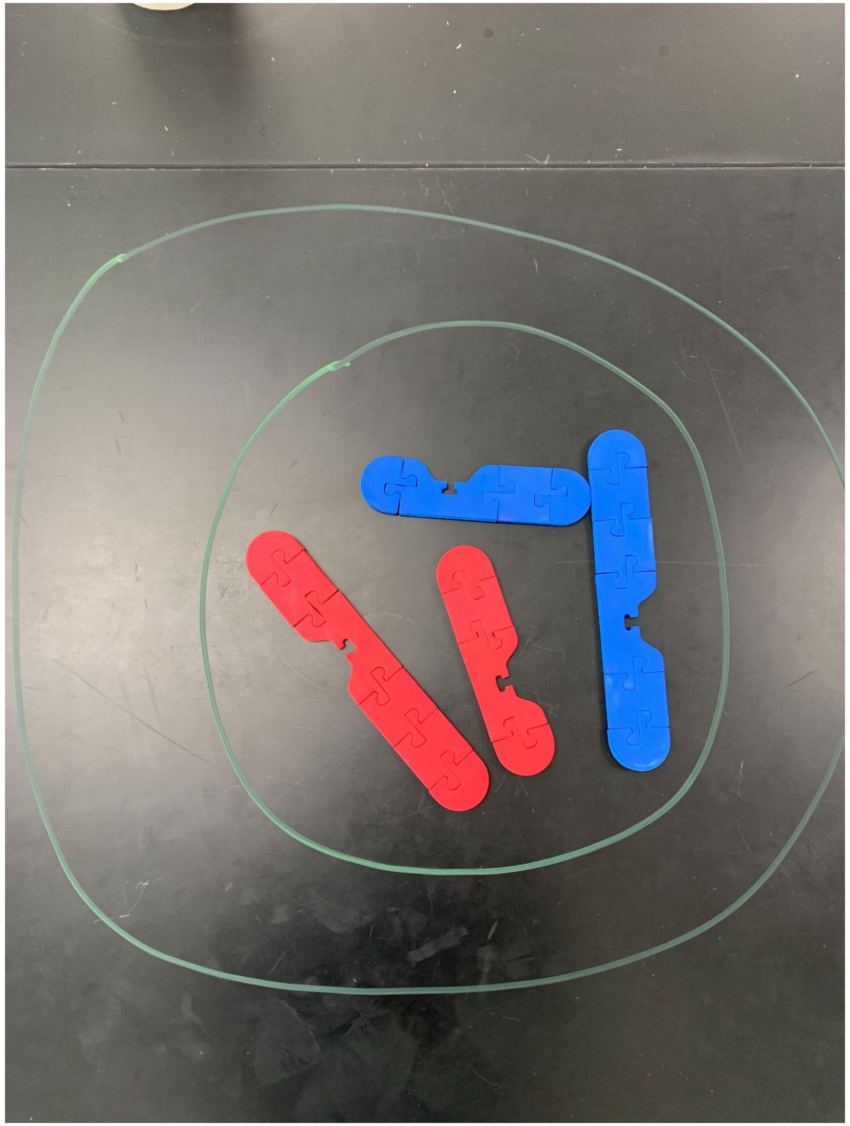
Parent Cell

1. Draw a circle with the table marker/chalk on the lab table to model the cell membrane. Draw a nucleus inside the cell.
2. Place one type of each chromosome inside the nucleus.
3. On your modeling meiosis data sheet, use colored pencils to draw the parent cell and answer the questions.

Parent cell
Number of chromosomes ______
Circle one: haploid   diploid



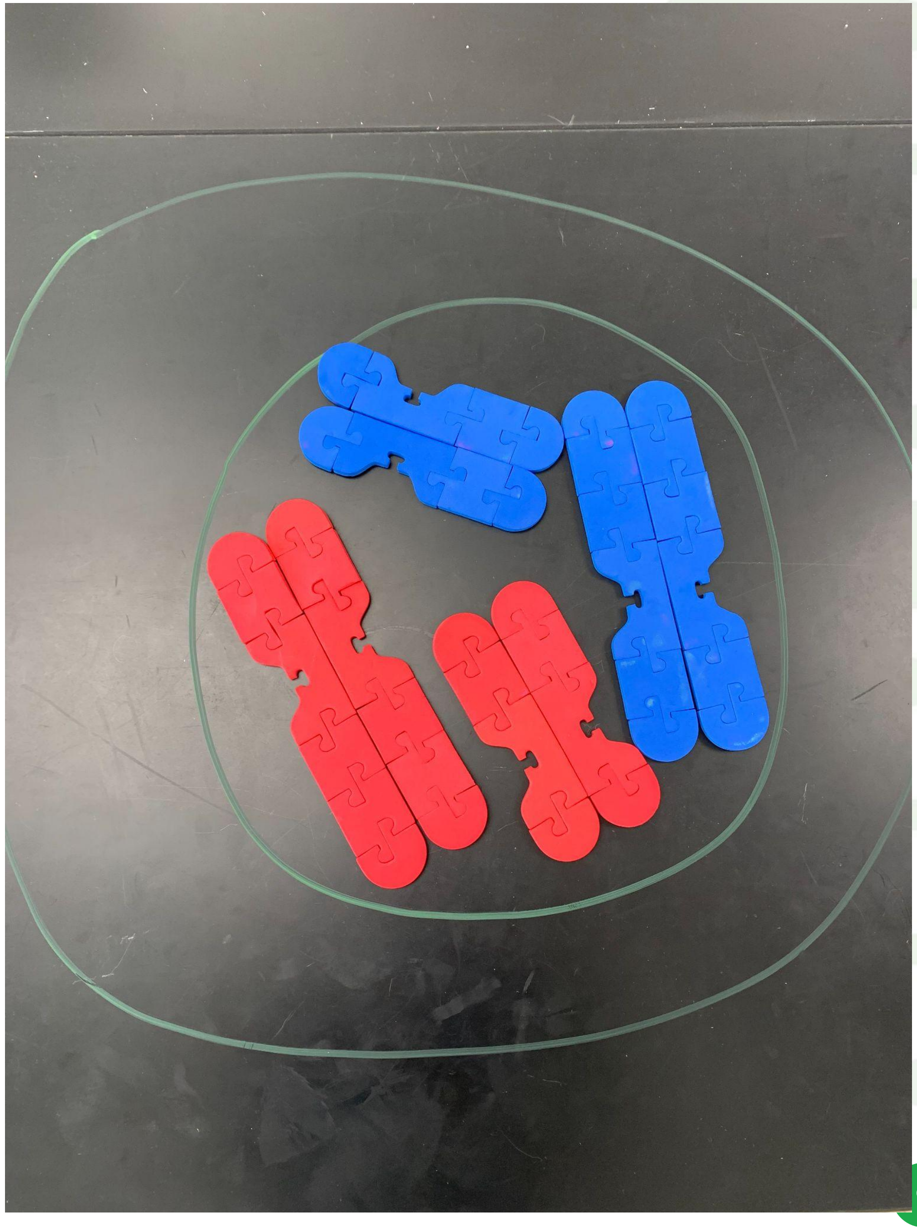
Parent Cell Model



Modeling Directions

<u>S phase: DNA Replication</u>

4. Replicate each chromosome by adding a copy of each one to your table top model. Put the duplicated chromosomes next to each other as shown in the picture above. Meiosis I begins following G_2 phase of the cell cycle.



Modeling Directions

<u>Prophase I</u>

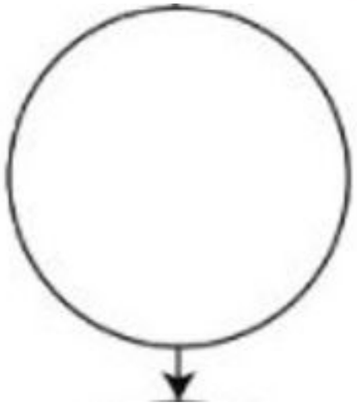
5. In this first stage of meiosis I, the homologous chromosomes will move toward one another and form a **tetrad**. Recall that **homologous chromosomes** are the same length, have the same centromere position, and have genes in the same locations. Align your homologous chromosomes to form two tetrads inside the nucleus. The alignment of the homologous chromosomes is known as **synapsis.**
6. During synapsis, **crossing over** may occur. In <u>each</u> pair of homologous chromosomes, exchange one segment of a blue paternal chromosome with a red maternal chromosome.

Modeling Directions

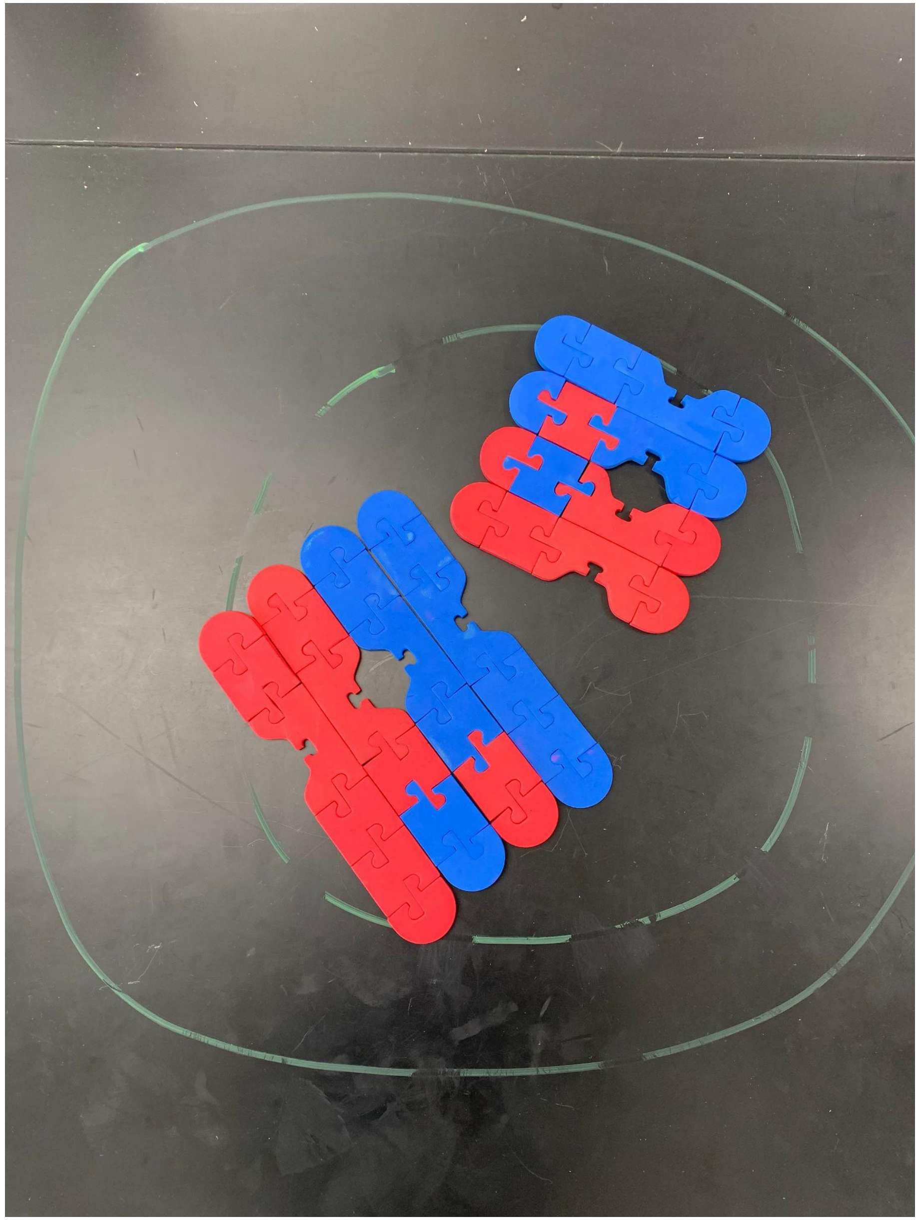
<u>Prophase I</u>

7. Towards the end of this stage, the nuclear membrane also breaks apart. Make your nuclear membrane a dotted line to show this event.
8. On your data sheet, use colored pencils to draw prophase I. Make sure that evidence of crossing over is shown in your drawings.

<u>Meiosis I</u>
Prophase I
Number of duplicated chromosomes ______
Circle one: haploid   diploid



Prophase I Model

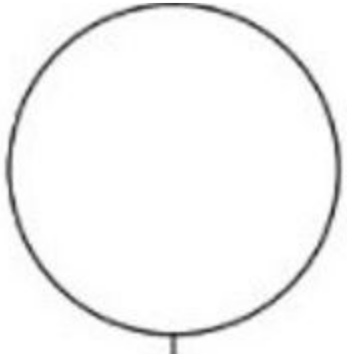


Modeling Directions

Metaphase I

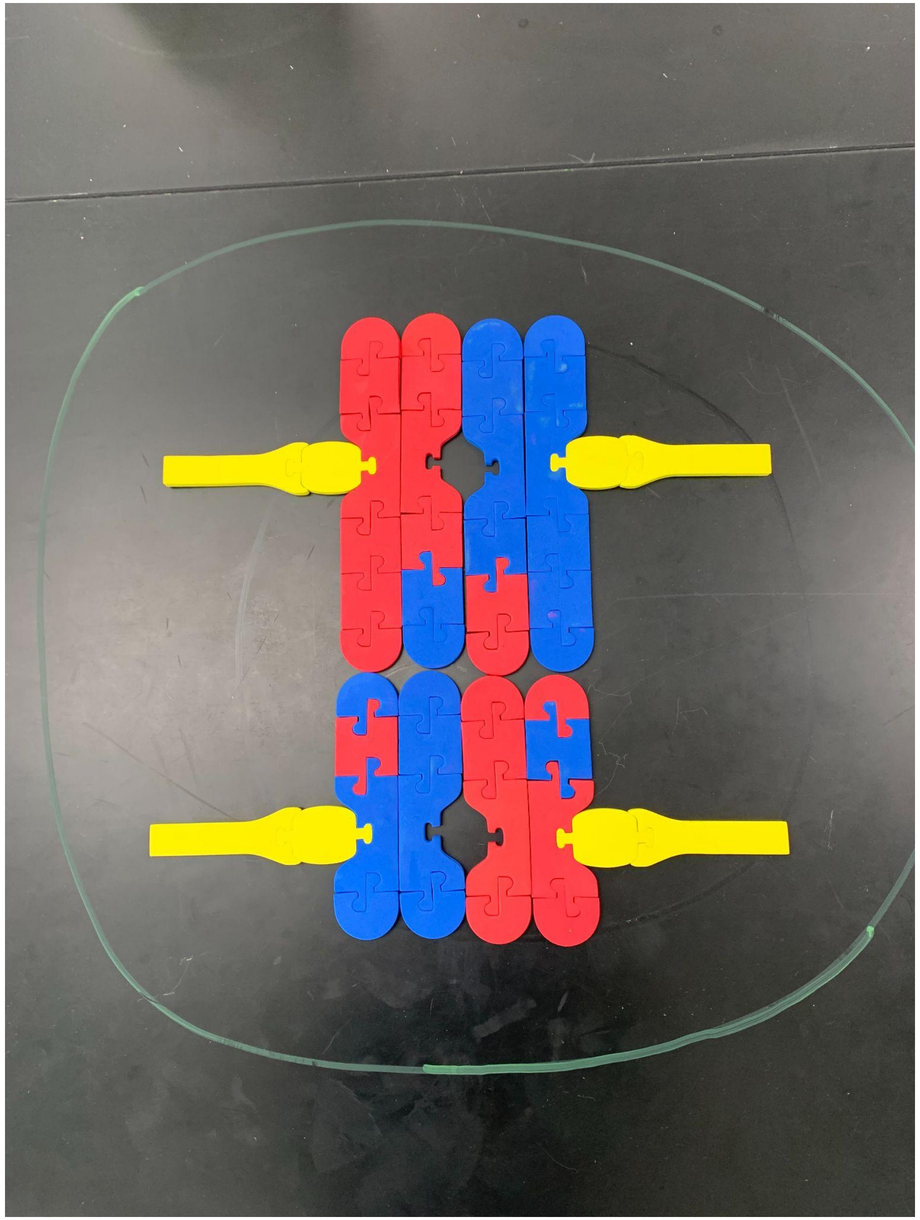
9. Next, the homologous chromosome pairs line up in the middle of the cell. Move each tetrad to the middle of your cell on the lab table. Recall that this is when the homologous chromosomes undergo independent assortment. In other words, each pair may orient with either its maternal or paternal copy closer to a give pole.
10. Using colored pencils, draw metaphase I on the data sheet.

Metaphase I
Number of duplicated chromosomes ______
Circle one: haploid diploid



Independent assortment of homologs occurs

Metaphase I Model

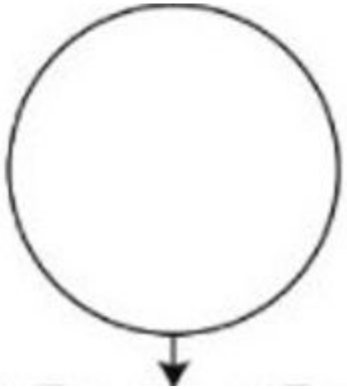


Modeling Directions

<u>Anaphase I</u>

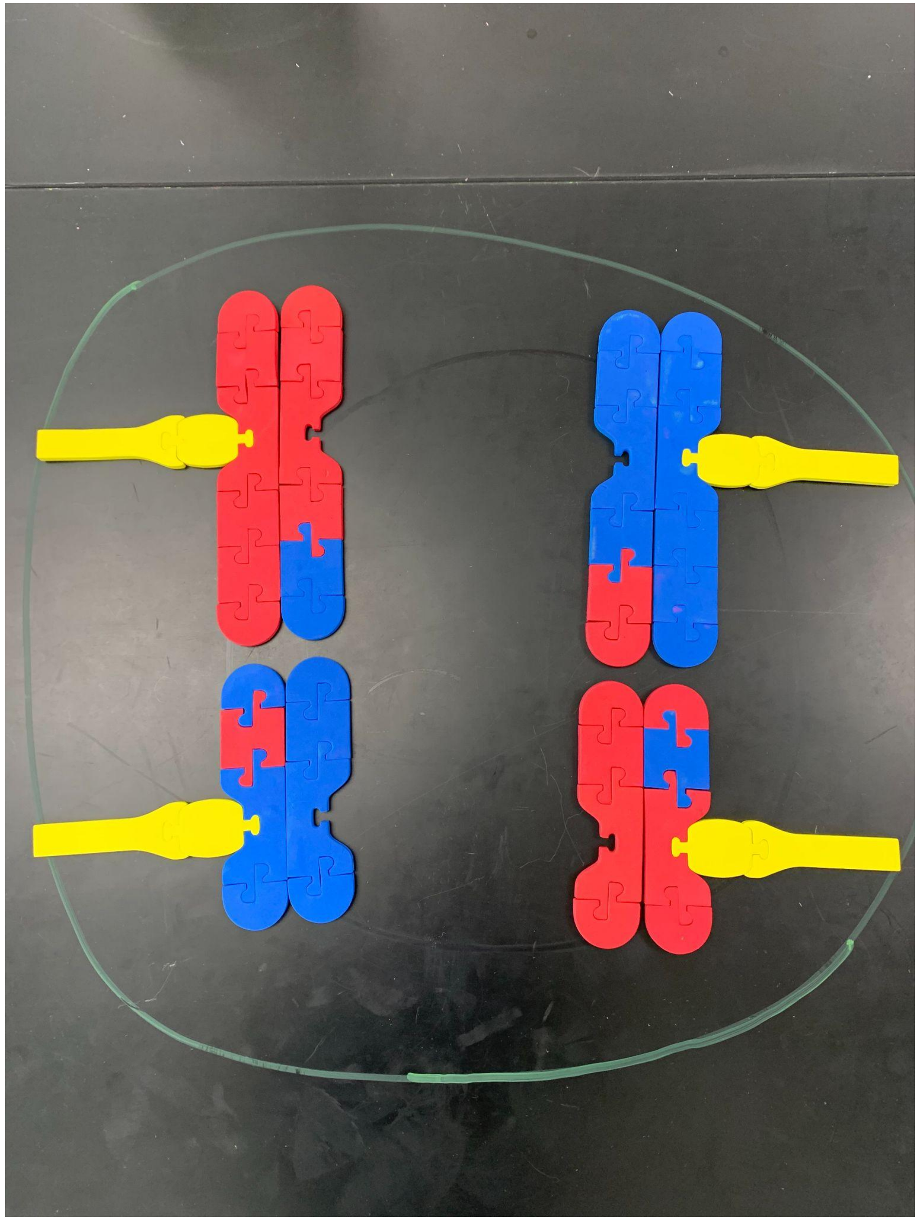
11. Now the tetrads separate so that one pair of homologous chromosomes moves to the opposite sides of the cell. Model this process on your lab table and draw the anaphase I on your data sheet.

Anaphase I
Number of duplicated chromosomes ______
Circle one: haploid diploid



Homologous chromosomes separate

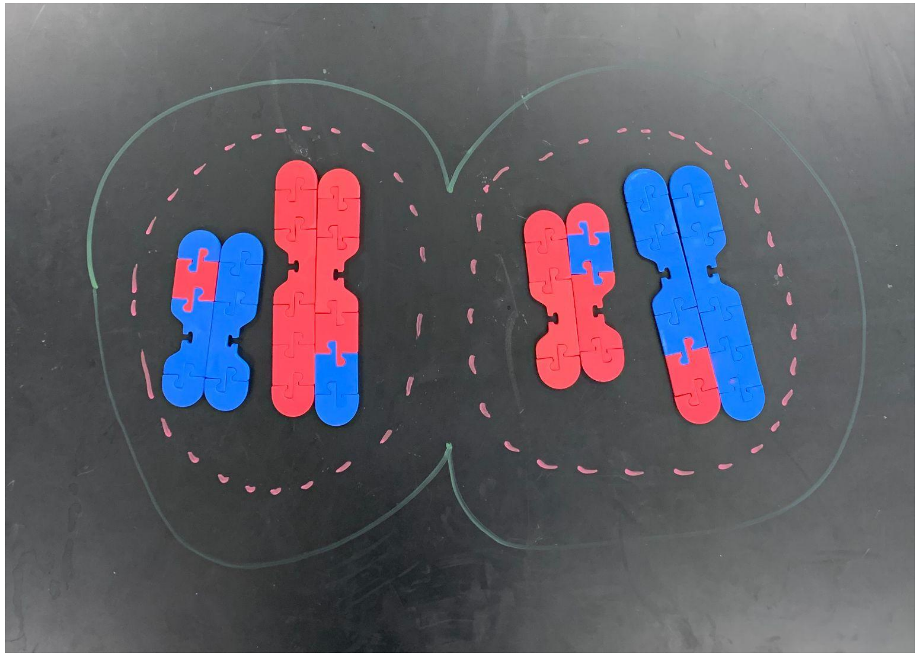
Anaphase I Model



Modeling Directions

Telophase I

12. The nuclear membranes reform around the chromosomes. Using the table marker/chalk, draw and model this phase and draw telophase I on your data sheet.



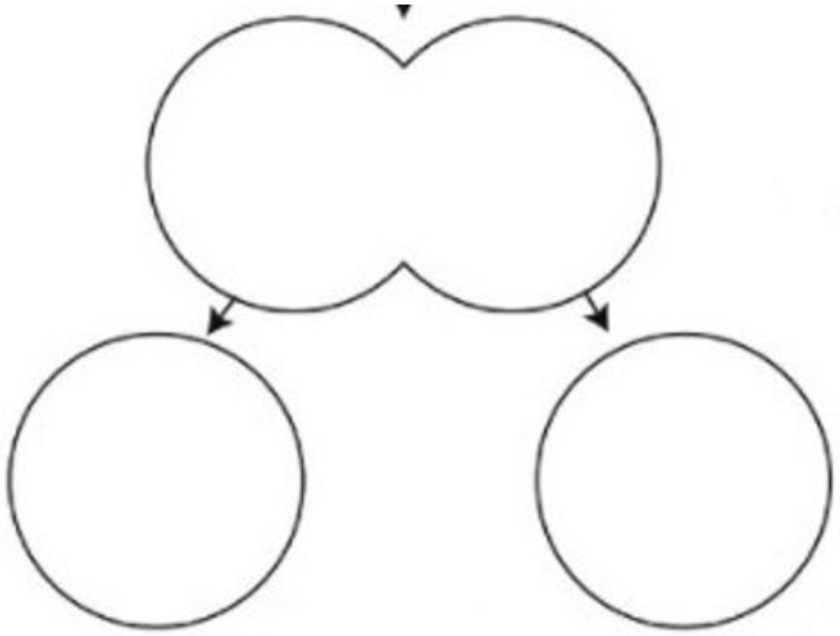
Modeling Directions

<u>Cytokinesis I</u>

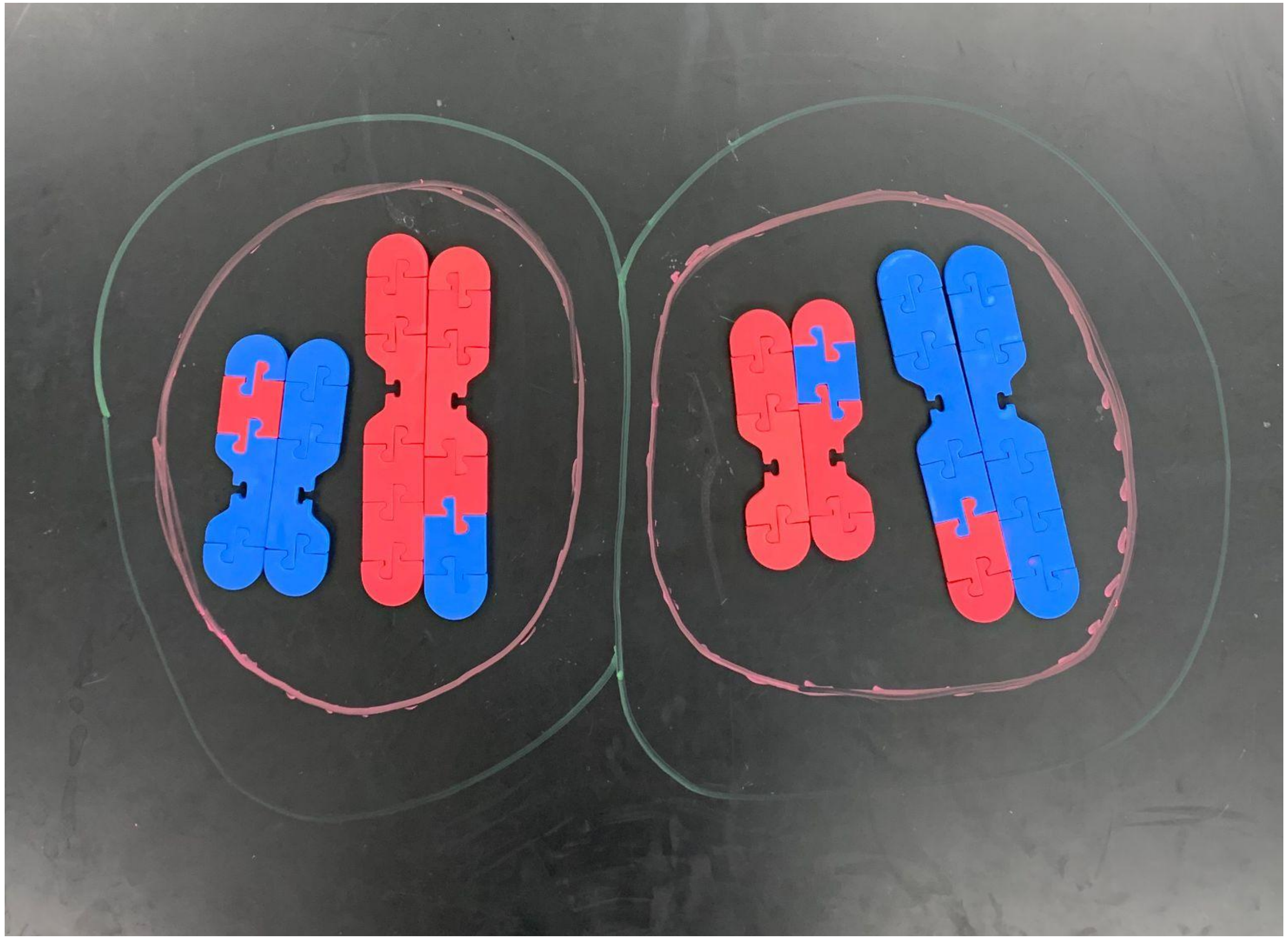
13. Draw a model of two cells on your table to show cytokinesis and draw cytokinesis I on your data sheet.
14. Answer questions 1 – 4 on the data sheet.

Telophase I
Number of duplicated chromosomes ______
Circle one: haploid diploid

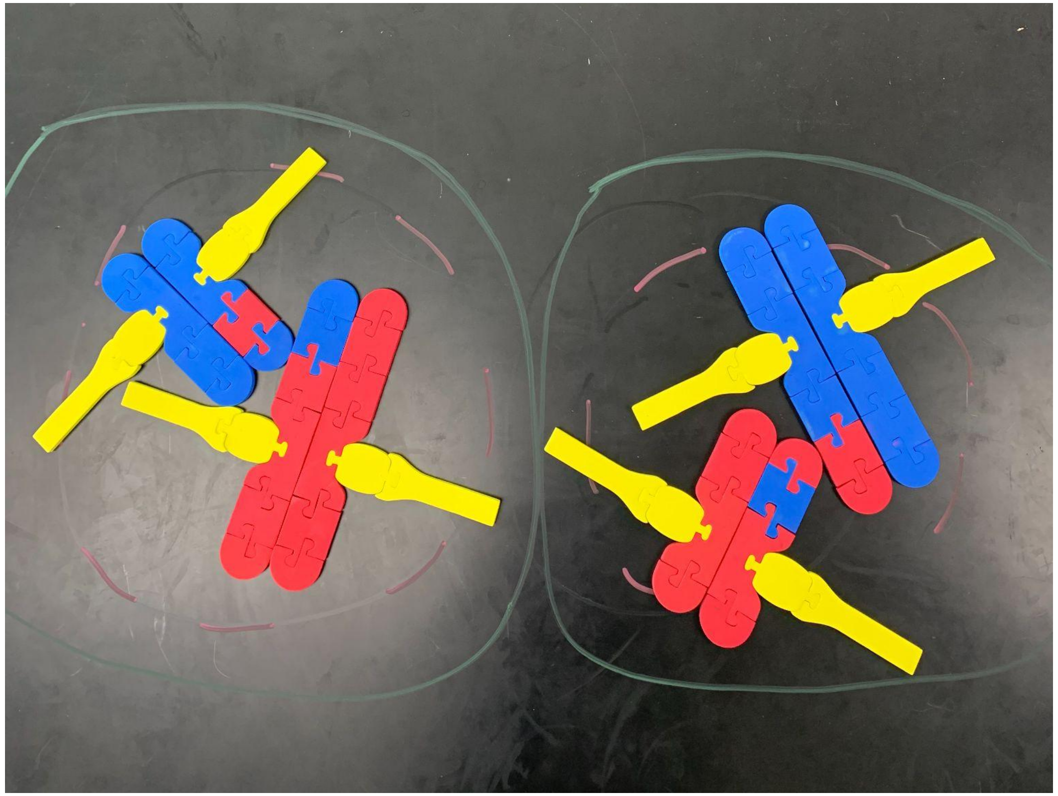
Cytokinesis I
Number of duplicated chromosomes ______
Circle one: haploid diploid



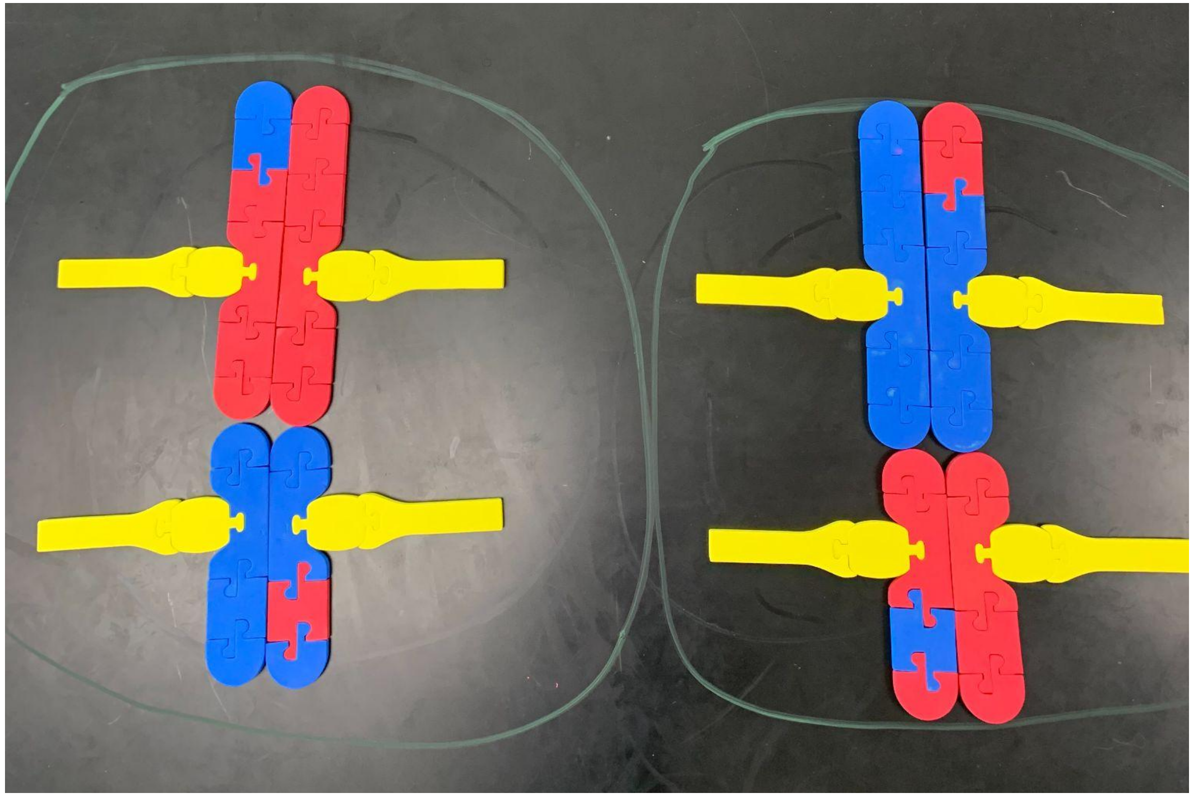
Cytokinesis I Model



Meiosis II Models

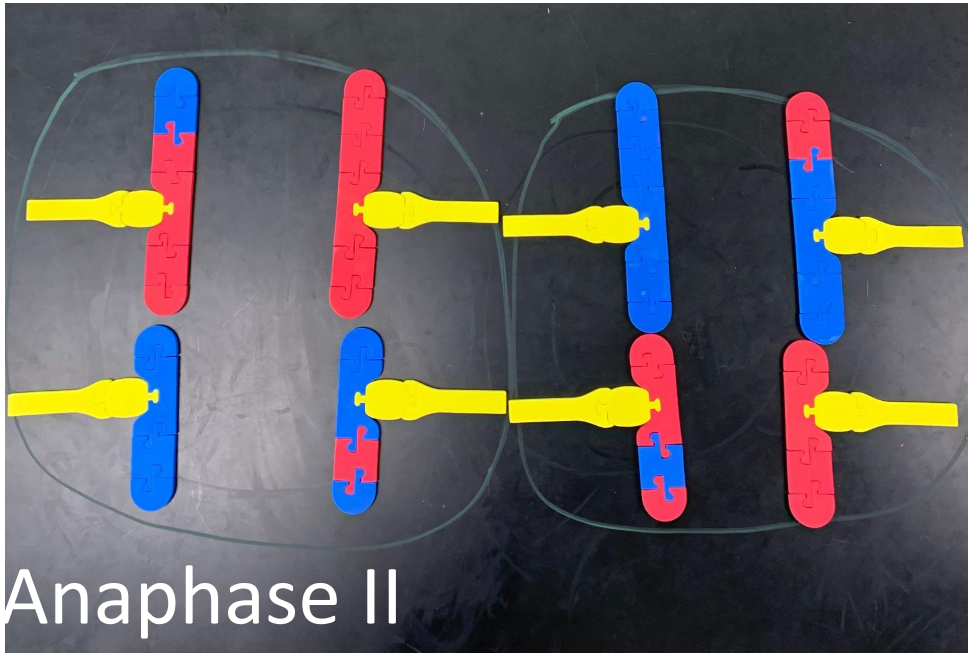


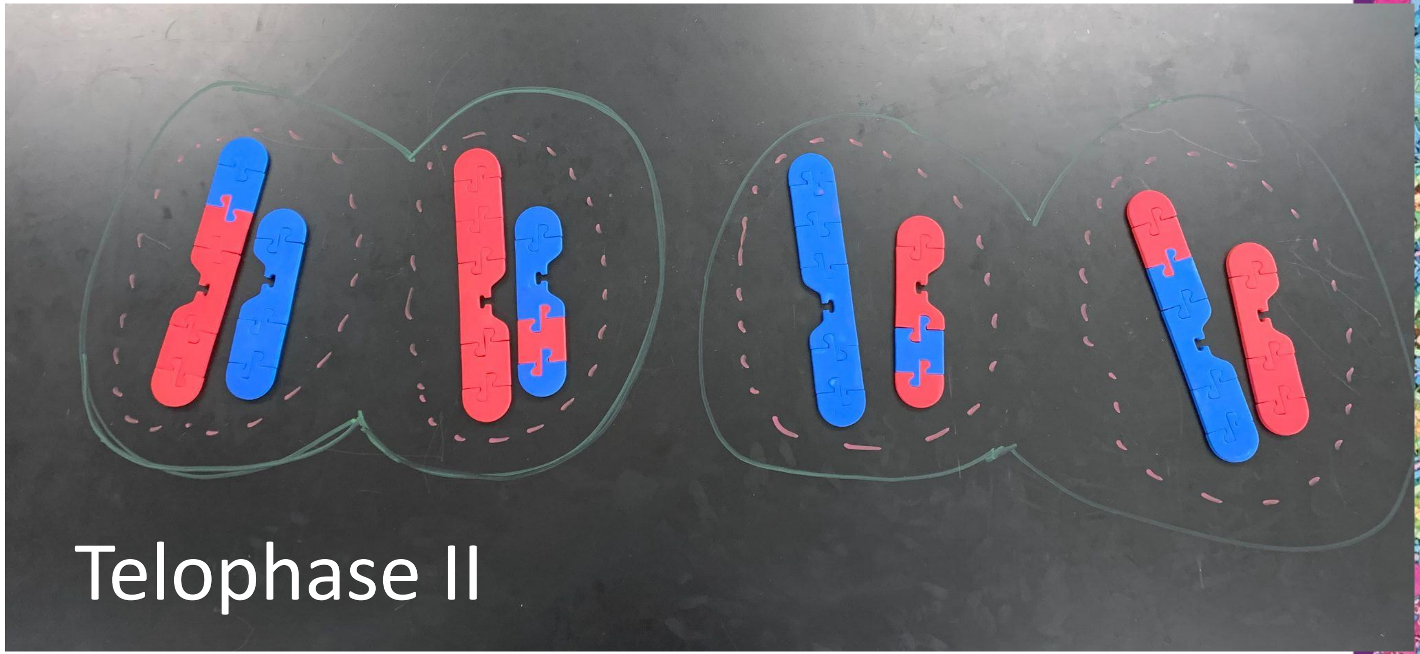
Prophase II

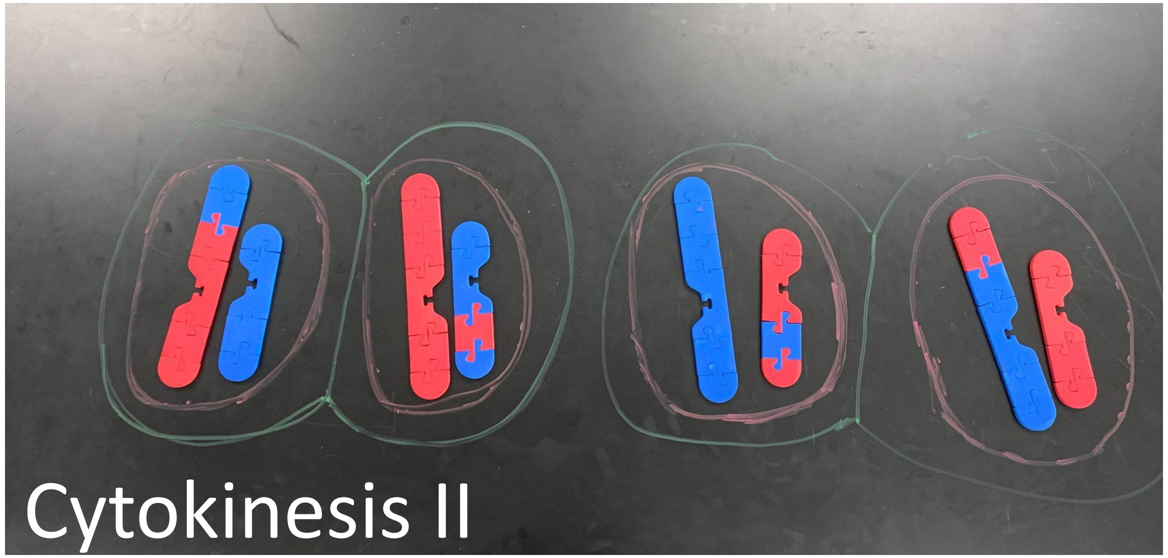


Metaphase II

Meiosis II Models Continued







Chromosome combinations due to independent assortment alone

- 2^n (n = haploid #)
- 2^2 = 4 combinations
- Humans 2^{23} = 8,388,608

Sources of Genetic Diversity

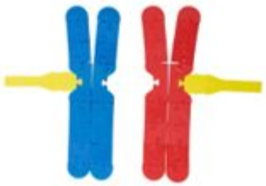
- Crossing over
- Independent assortment
- Random fertilization

Modeling Meiosis Directions

Modeling Meiosis: Chromosome Connections Kit

Directions: Refer to the meiosis reinforcement sheet as you model each phase on your lab table. On the data sheet, draw each phase of meiosis. Be sure to include the appropriate structures in each phase which may include: nuclear membrane, chromosomes, centromere with kinetochore, centrioles and the spindle apparatus. Fill in the chromosome number and identify if each cell is in the diploid (2n) or haploid (n) state.

Materials:
Blue long paternal chromosome (2)
Red long maternal chromosome (2)
Blue short paternal chromosome (2)
Red short maternal chromosome (2)
Kinetochores (8)
Spindle fibers (8)
Red and blue colored pencil
Table marker or chalk



Modeling Directions:

Parent Cell
1. Draw a circle with the table marker/chalk on the lab table to model the cell membrane. Draw a nucleus inside the cell.
2. Place one type of each chromosome inside the nucleus.
3. On your modeling meiosis data sheet, use colored pencils to draw the parent cell and answer the questions.

S phase: DNA Replication
4. Replicate each chromosome by adding a copy of each one to your table top model. Put the duplicated chromosomes next to each other as shown in the picture above. Meiosis I begins following G2 phase of the cell cycle.

Prophase I
5. In this first stage of meiosis I, the homologous chromosomes will move toward one another and form a **tetrad**. Recall that **homologous chromosomes** are the same length, have the same centromere position, and have genes in the same locations. Align your homologous chromosomes to form two tetrads inside the nucleus. The alignment of the homologous chromosomes is known as **synapsis.**
6. During synapsis, **crossing over** may occur. In each pair of homologous chromosomes, exchange one segment of a blue paternal chromosome with a red maternal chromosome.
7. Towards the end of this stage, the nuclear membrane also breaks apart. Make your nuclear membrane a dotted line to show this event.
8. On your data sheet, use colored pencils to draw prophase I. Make sure that evidence of crossing over is shown in your drawings.

Metaphase I
9. Next, the homologous chromosome pairs line up in the middle of the cell. Move each tetrad to the middle of your cell on the lab table. Recall that this is when the homologous chromosomes undergo independent assortment. In other words, each pair may orient with either its maternal or paternal copy closer to a give pole.
10. Using colored pencils, draw metaphase I on the data sheet.

Anaphase I
11. Now the tetrads separate so that one pair of homologous chromosomes moves to the opposite sides of the cell. Model this process on your lab table and draw the anaphase I on your data sheet.

Telophase I
12. The nuclear membranes reform around the chromosomes. Using the table marker/chalk, draw and model this phase and draw telophase I on your data sheet.

Cytokinesis I
13. Draw a model of two cells on your table to show cytokinesis and draw cytokinesis I on your data sheet.
14. Answer questions 1 – 4 on the data sheet.

Prophase II
15. This phase begins immediately after cytokinesis I. During this phase, attach kinetochores to each side of the centromere on all of the chromosomes. Then, attach a spindle fiber to each kinetochore.
16. Draw prophase II on your data sheet.

Metaphase II
17. Next, the duplicated chromosomes line up in the middle of each cell. Move your chromosomes by their spindle fibers to model this process on your lab table. Remember, independent assortment of chromosomes occurs during this phase.
18. Draw metaphase II on your data sheet.

Anaphase II
19. During this phase, the 2 sister chromatids separate and move away from each other to the opposite sides of the cells. Move your chromosomes by their spindle fibers to model this process on your lab table and draw anaphase II on your data sheet.

Telophase II
20. Using table markers/chalk, draw the nuclear membranes as they reform around the chromosomes. Draw telophase II on your data sheet.

Cytokinesis II
21. Each of the two cells divide. Draw the four cells on the lab table with the correct number of chromosomes in each nucleus. Draw cytokinesis II on your data sheet.
22. Clean up your station by placing the modeling pieces back in the Ziplock bag and wipe off your table top.
23. Answer questions 5 – 13 on the data sheet.

Student Data Sheet

Modeling Meiosis Data Sheet

Parent cell
Number of chromosomes ______
Circle one: haploid diploid

Meiosis I

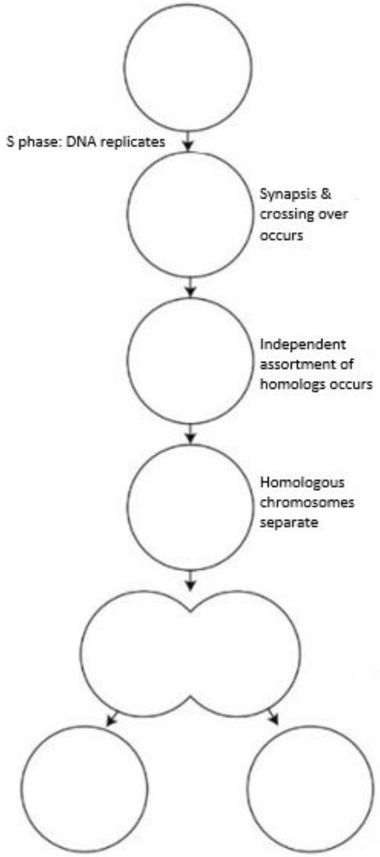
Prophase I
Number of duplicated chromosomes ______
Circle one: haploid diploid

Metaphase I
Number of duplicated chromosomes ______
Circle one: haploid diploid

Anaphase I
Number of duplicated chromosomes ______
Circle one: haploid diploid

Telophase I
Number of duplicated chromosomes ______
Circle one: haploid diploid

Cytokinesis I
Number of duplicated chromosomes ______
Circle one: haploid diploid



Meiosis II

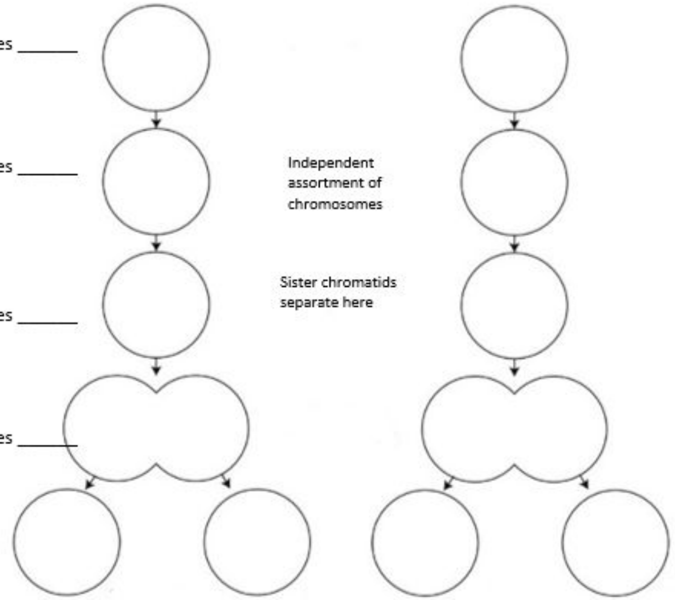
Prophase II
Number of duplicated chromosomes ______
Circle one: haploid diploid

Metaphase II
Number of duplicated chromosomes ______
Circle one: haploid diploid

Anaphase II
Number of duplicated chromosomes ______
Circle one: haploid diploid

Telophase II
Number of duplicated chromosomes ______
Circle one: haploid diploid

Cytokinesis II
Number of chromosomes ______
Circle one: haploid diploid



Analysis Questions:

1. How many cells are produced after telophase I? ___________
2. How many chromosomes are in each cell? ___________
3. Are these cells haploid or diploid? ___________
4. Go to another lab group, and compare your cytokinesis I cells to their cells. It is likely that your cells look different. What two processes occurred in meiosis I produced the differences in the cells produced at the end of meiosis I?

Student Data Sheet Continued

5. How many cells were produced after telophase II? ____________

6. How many chromosomes are in each cell? ____________

7. Are these cells haploid or diploid? ____________

8. Explain why meiosis is called reduction division.

9. A koala somatic (body) cell has a diploid (2n) number of 16. How many chromosomes would be in each gamete (sex cell)? ____________

10. Do all of the cells produced in cytokinesis II have the same combination of chromosomes? ________

11. Describe how the cells produced in cytokinesis II differ from the parent cell at the beginning of the activity.

12. Following meiosis, the cells develop into either sperm or egg cells. Explain how meiosis helps sexually reproducing creatures to maintain a constant number of chromosomes.

13. Write a summary statement the explains how the process of meiosis creates genetic diversity.

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Link to Today's Presentation & Raffle

Thanks for attending!

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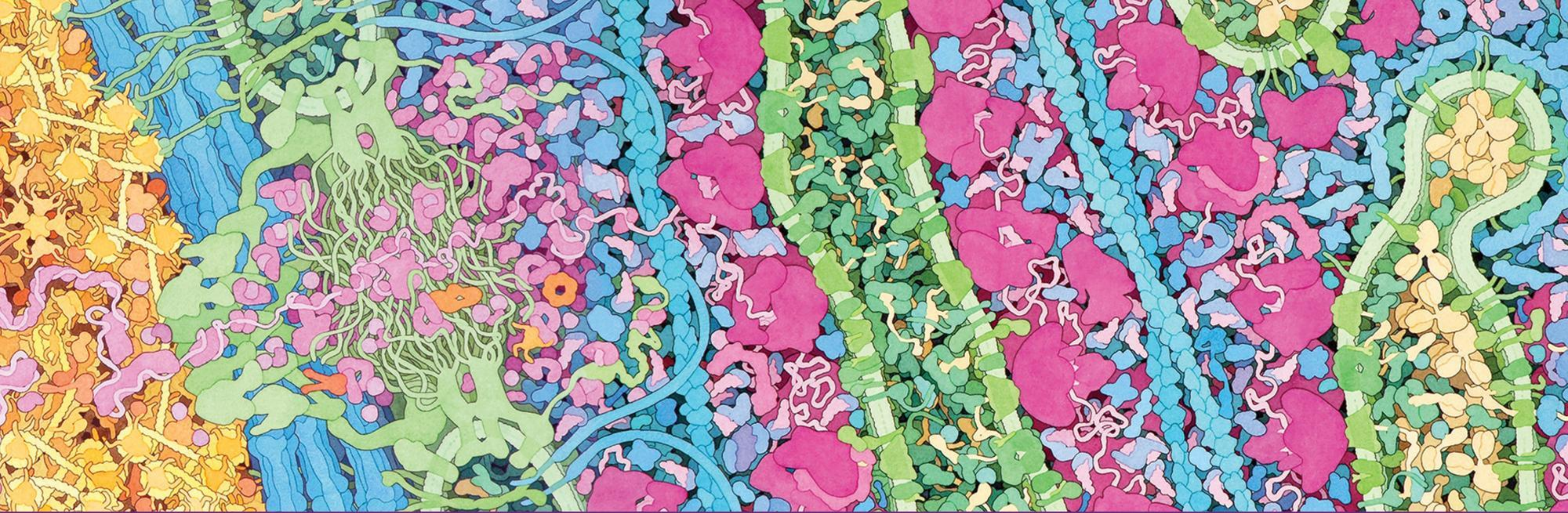
Teaching the Molecular Mechanisms of Addiction with Physical Models with Alan Allmen here in the Grand Ballroom at 11:15

Modeling the Molecular World in Milwaukee this summer:
July 29 – August 2 OR August 5 – 9



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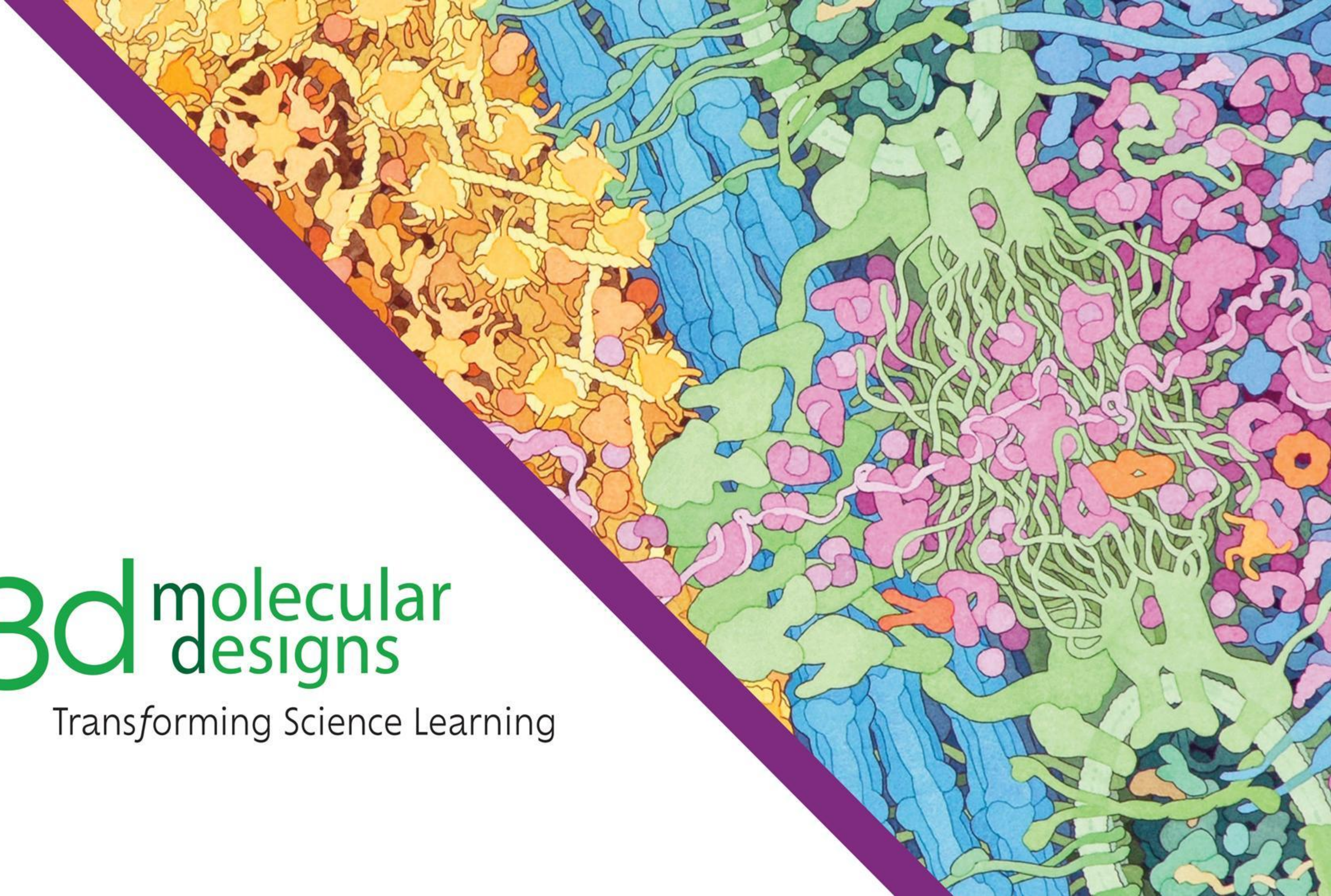

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