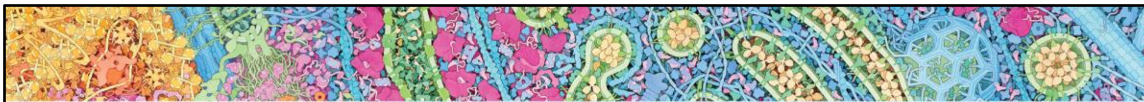
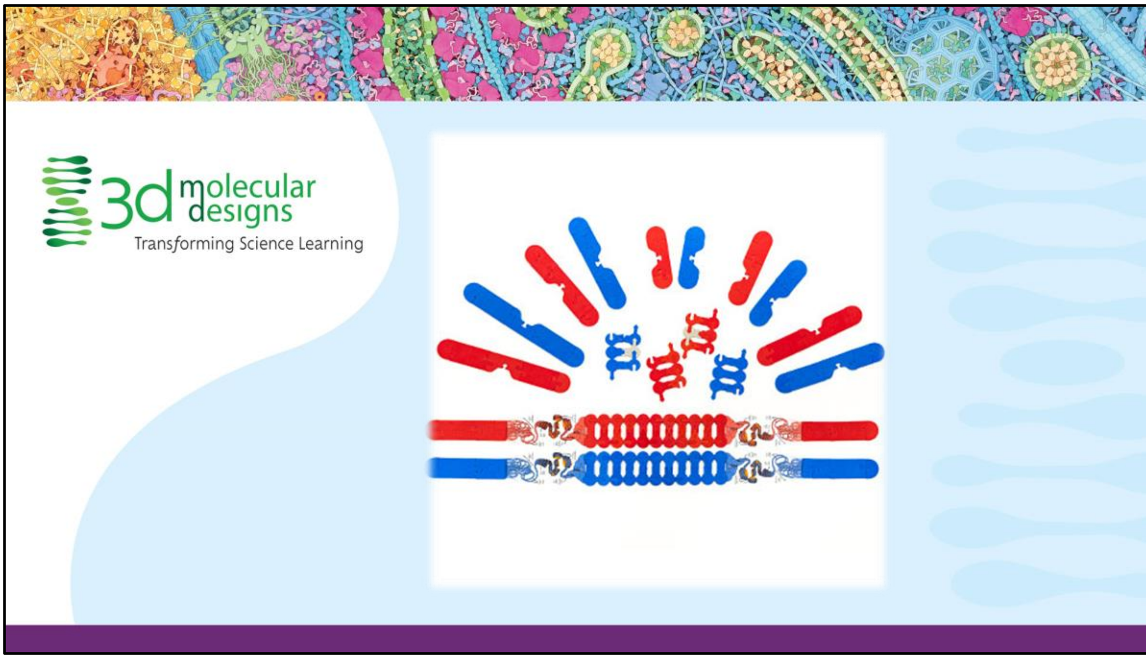


3d molecular designs
Transforming Science Learning

Chromosomes in Action: New Ways to Model Mitosis and Meiosis

Ruth Hutson, MSSE

OSTA 2023



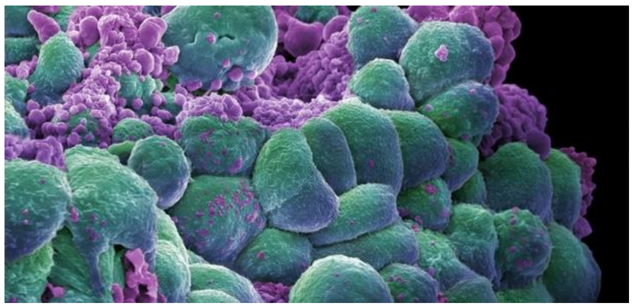
In this 50-minute session, educators will explore how physical models foster an understanding of the importance of mitosis and meiosis to the growth and development of living things using the Chromosome Connections Kit♥.

Workshop Outcomes

- Use a model to illustrate the role of mitosis and differentiation in producing and maintaining complex organisms.
- Explain how mitosis alternates with interphase in the cell cycle.
- Make and defend a claim based on evidence that genetic variations result from a variety of factors
- Demonstrate what processes in meiosis increase gamete diversity.

3

Why do cells divide without stopping?



Breast cancer cells. Image credit: Annie Cavanagh (CC BY-NC 4.0

Construct a chromosome

- **Start with one centromere**
- Add 3 to 4 chromosome connectors to each side of the centromere
- Add a cap piece to each end of the chromatid.

5

Walk students through the construction of a chromosome by starting with one centromere.

Construct a chromosome

- Start with one centromere
- **Add 3 to 4 chromosome connectors to each side of the centromere**
- Add a cap piece to each end of the chromatid.

6

Have students add three to four chromosome connectors to either side of the centromere.
Student chromosomes can have variations in how many connectors are on either side.
Allowing for this diversity opens an opportunity to talk about chromosome classification later in the lesson.

Construct a chromosome

- Start with one centromere
- Add 3 to 4 chromosome connectors to each side of the centromere
- **Add a cap piece to each end of the chromatid.**

7

Start with a centromere piece
Add 3-4 chromosome connectors on each side of the centromere piece.
Add a cap piece to each end of the chromatid.
Give students freedom to make a chromosome of their own so you can explore chromosome classification later in the lesson.

Create a sister chromatid

- Create a duplicate copy of the chromosome to make a sister chromatid.

8

Next create a duplicate copy of the chromosome to make a sister chromatid by using the other components found in the Chromosome Connections Kit (*Note: your chromosome does not need to look exactly like the one pictured, but it does not to have all the components.*)

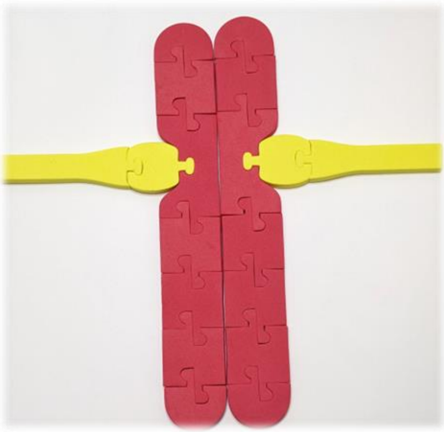
Create a sister chromatid

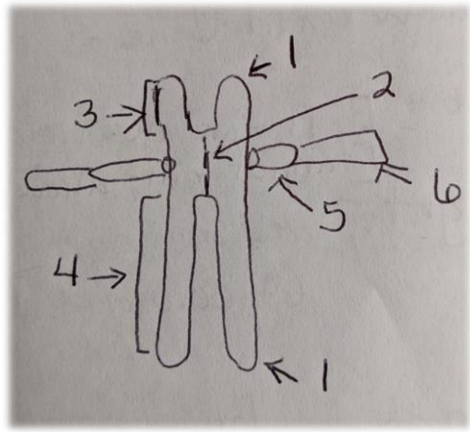
- Create a duplicate copy of the chromosome to make a sister chromatid.

9

Next create a duplicate copy of the chromosome to make a sister chromatid by using the other components found in the Chromosome Connections Kit (*Note: your chromosome does not need to look exactly like the one pictured, but it does not to have all the components.*)

Label the parts to create a shared vocabulary

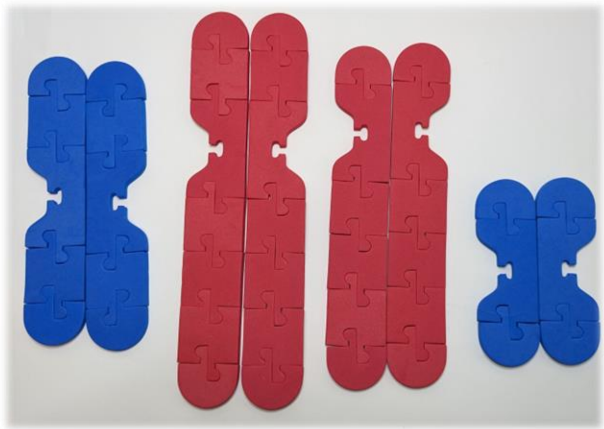




10

Label the *telomere*, *centromere*, *p and q arms*, *kinetochore*, and *spindle fibers*. Identify their color on the model. Compare and contrast your sister chromatids with that of another student or group. In the space provided on the student answer sheet, describe how they are the same and how they are different. Refer to the NIH's Chromosome Fact Sheet (https://www.genome.gov/about-genomics/fact-sheets/Chromosomes-Fact-Sheet) if you need assistance in determining the parts of the chromosome.

Let’s compare chromosome structure and classification



11

Classification of chromosomes is based on the position of the centromere and is useful in karyotyping.

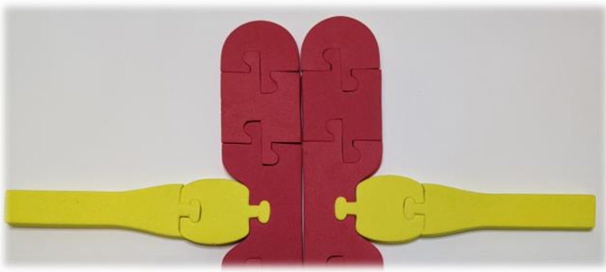
Telecentric chromosomes have a very small p-arm, a centromere, and a longer q arm.

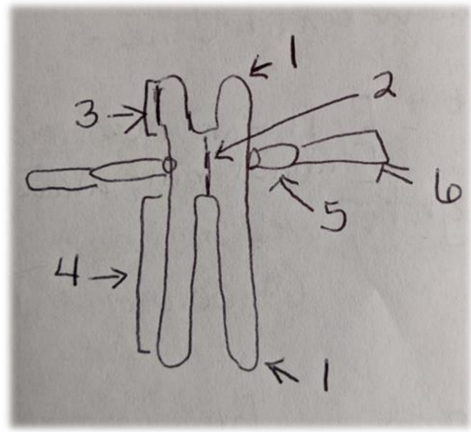
Acrocentric chromosomes might have a satellite (a segment separated from the rest of the chromosome by a secondary constriction) and has a p arm shorter than a q arm.

Sub-metacentric chromosomes have a slightly shorter p arm than q arm.

Metacentric chromosomes have p and q arms that are equal in length.

A closer look at the spindle apparatus





12

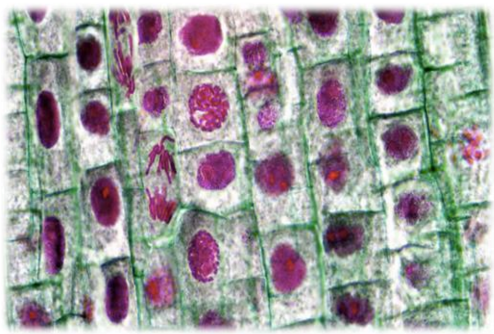
A closer look at the spindle apparatus

Direct your attention to the center of your sister chromatids where the spindle apparatus attaches to the centromere. Using the following resource, *Role of a Kinetochore during Cell Division* (https://www.thoughtco.com/kinetochore-definition-373543) and the model you created, speculate the purpose of each part of the spindle apparatus.

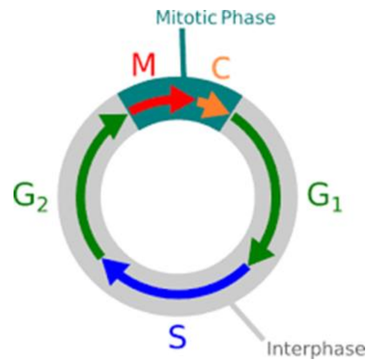
A closer look at the centromere

Now direct your attention to the center of your sister chromatids where the centromeres come together. Refer to the NIH's Centromere glossary page (https://www.genome.gov/genetics-glossary/Centromere). Consider the purpose of the centromere and its purpose in the cell cycle.

Onion Root Tip Lab



Berkshire Community College Bioscience Image *Library (2014)*



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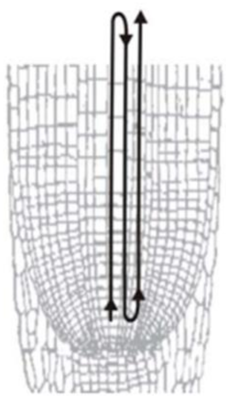
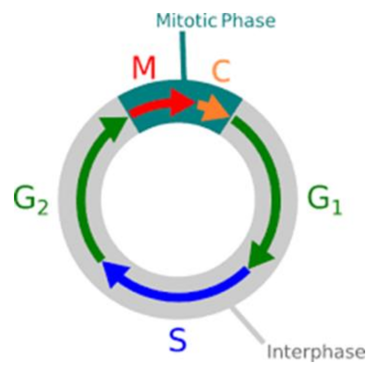
13

For simplicity's sake, you will only use six chromosomes in this model, but remember that onions have sixteen. Start this activity by building six chromosomes and their sister chromatid of any sizes using both the blue and the red foam pieces. Using your images from the lab and the sister chromosomes that you built, demonstrate what is occurring in the snapshots from the onion cell. Properly identify and chronologically order each phase shown below. Then make a model that determines how the chromosomes can condense, organize, and finally end up into two identical daughter cells

Onion Root Tip Lab



Use an inverted S pattern to count cells



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14

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Onion Root Tip Lab

	Interphase	Prophase/ Prometaphase	Metaphase	Anaphase	Telophase	Total
Number of cells						100
Proportion in each phase						1
Approximate Timing						24 hours

Data table for cell counts for student or professionally prepared slide

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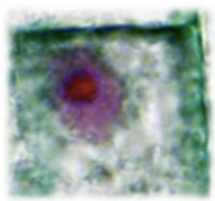
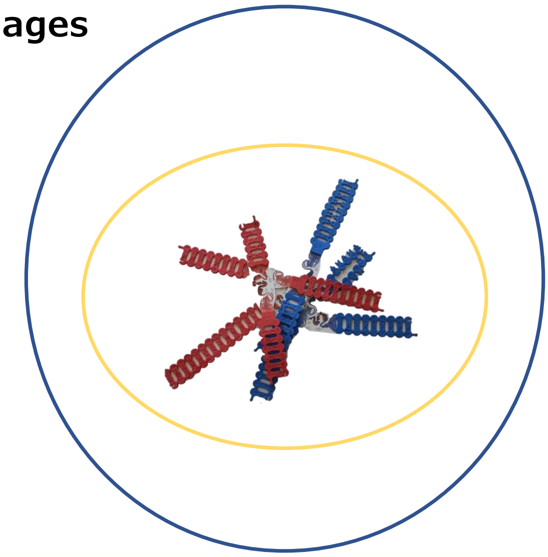
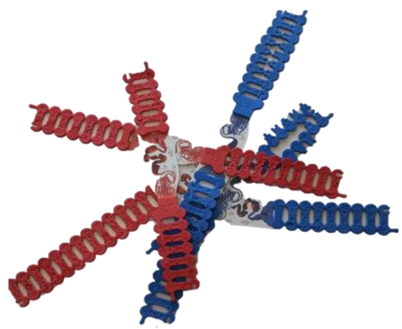
Modeling Allium lab images





A closer look at the Cell Cycle: Modeling Interphase

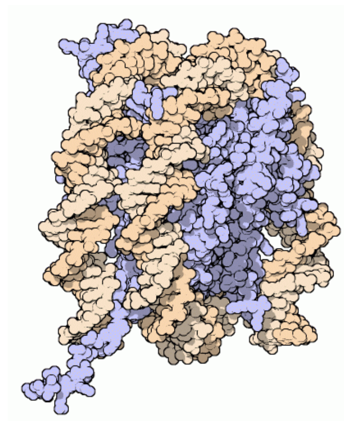


What are the key highlights in this phase that students need to understand?

What structures to students need to understand so they can understand cell processes in the future?

17

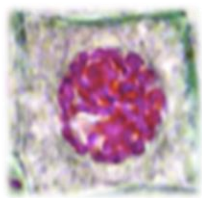
A closer look at the nucleosome

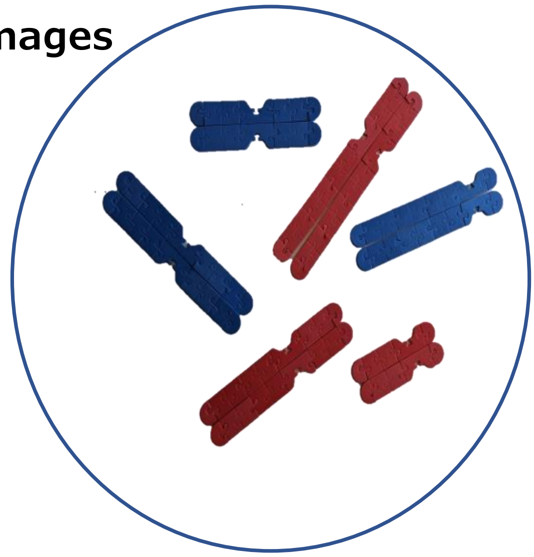


18

The model shows the eight histone proteins as tubes that follow the protein chain. The DNA is modeled as thinner white helix that follow the two strands as they circle around the protein octamer. The tails of the eight protein chains, seen extending outward from the center, are longer. Because they are so long and flexible, they are disordered in the crystal and cannot be seen. The one long chain shown in yellow gives a hint at what they might look like if we cold see the entire nucleosome in the cell This structure only includes a short piece of DNA. Millions of nucleosomes are arrayed along long strands of DNA.

Modeling Allium lab images





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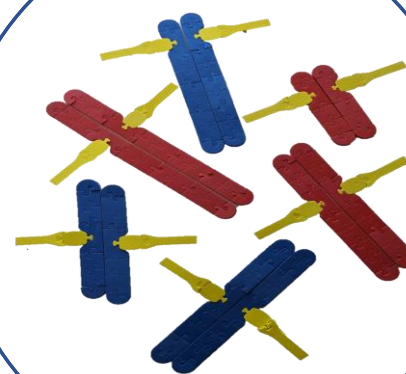
Cell Cycle: Modeling Prometaphase

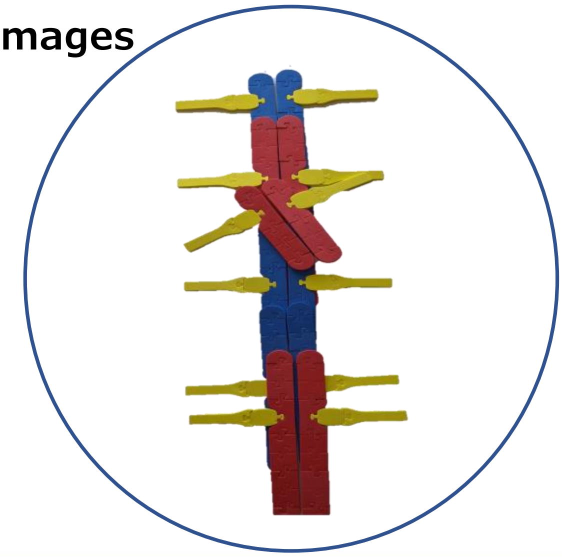
What are the key highlights in this phase that students need to understand?

What structures to students need to understand so they can understand cell processes in the future?

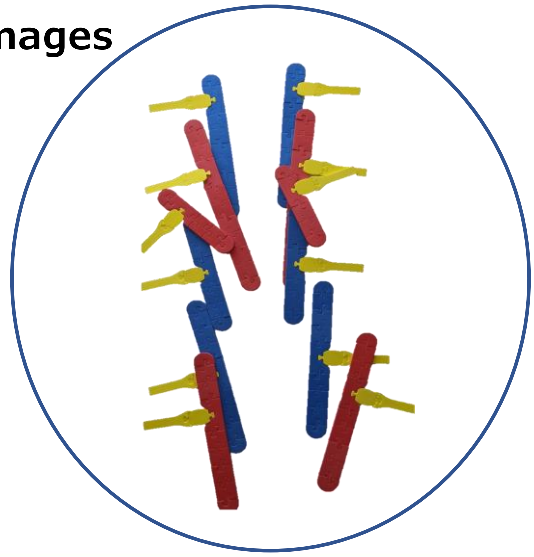


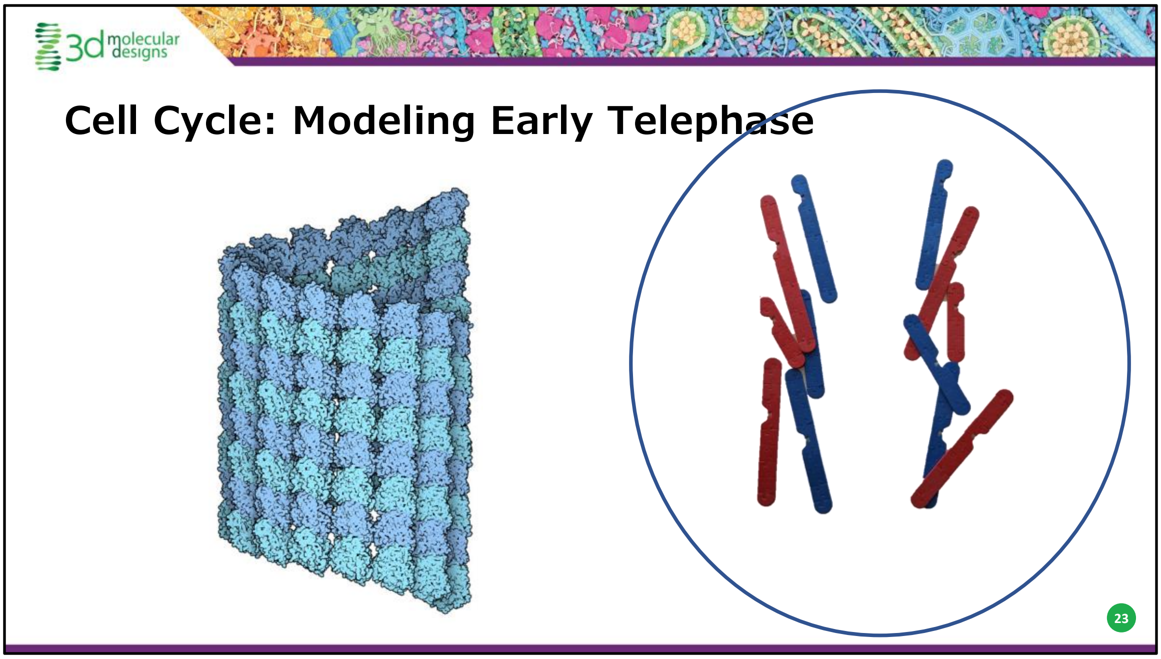
20

Modeling Allium lab images



Modeling Allium lab images

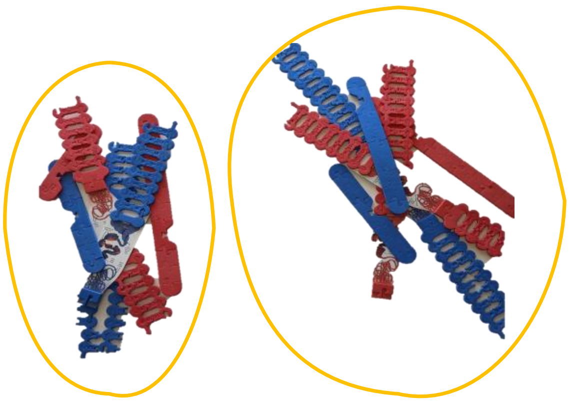




[PDB-101: Molecule of the Month: Microtubules (rcsb.org)]

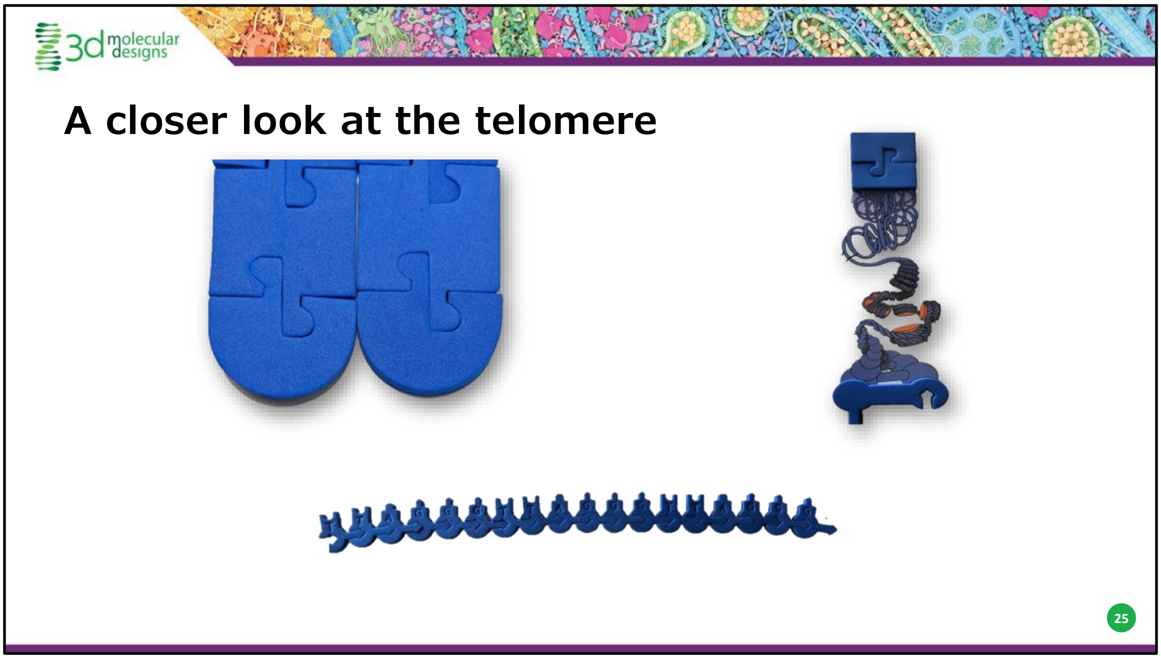
“Microtubules are composed of a cylindrical shell of the protein tubulin. This tubulin comes in two similar forms, called alpha and beta tubulin, which form a tight dimeric complex. They then stack side-by-side to form the cylindrical tubule. Microtubules are in a constant state of growth and shrinkage, in a process called dynamic instability. This is controlled by a molecule of GTP that is bound to the beta subunit of tubulin. Free tubulin dimers have GTP bound, and this forms a stable complex when it adds to a growing filament. But later, the GTP is cleaved to GDP, and the GDP-bound tubulin is less stable in the filament. If the GDP-bound tubulin is at the end of the filament, it can start a process of disassembly. If, however, a new GTP-bound tubulin binds to the shrinking end, it stops the process, and the microtubule starts growing again.”

Cell Cycle: Modeling Late Telephase



What extensions or phenomenon
might help student be interested
in this cell process?

24



Let's expand the telomere and look at it on the molecular level. Telomeres are receptive, non-coded sequences of DNA that keep the coded DNA from becoming damaged. In humans, the telomere sequence is TTAGGG. This sequence is usually repeated about 3,000 times and can reach up to 15,000 base pairs in length.

To model the telomere, remove the end cap, unspool the end of the sister chromatids by adding two Scaling Graphics (one to each chromatid) shown to the right, and add in three repeating units of TTAGGG and their complementary base pairs to the bottom of the chromosome to represent the molecular form of the chromosome. Remember that this sequence is found at all ends of the chromosome. Using the resource *Are Telomeres the Key to Aging and Cancer* found at Learn.Genetics from the Genetic Science Learning Center (https://learn.genetics.utah.edu/content/basics/telomeres) as a reference, create a model that demonstrates what happens to the telomere through subsequent cell divisions.

A closer look at the telomere

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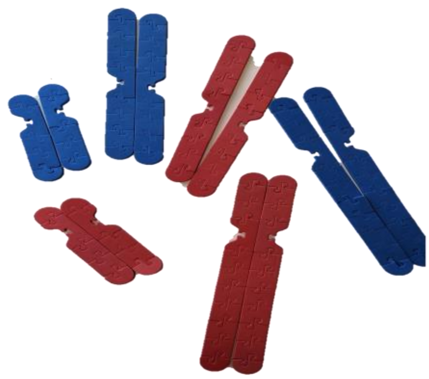
Cell Cycle: Modeling Meiosis



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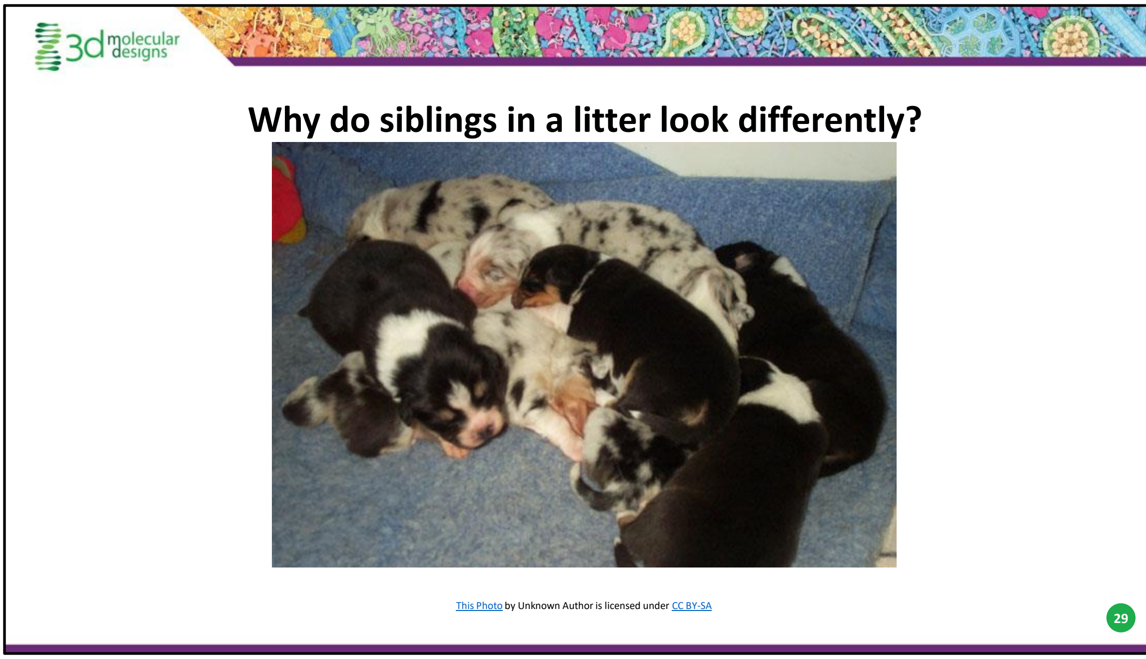
Why do I look different than my siblings?

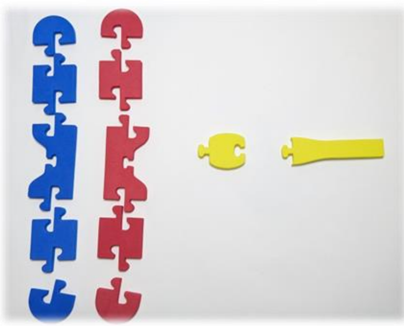
28

Storytime [Advance slide]
Indian muntjac (Muntiacus muntjak) 6/7: 2n = 6 for females and 7 for males.



Storytime [Advance slide]
Indian muntjac (Muntiacus muntjak) 6/7: 2n = 6 for females and 7 for males.

Suggested Chromosome Assembly

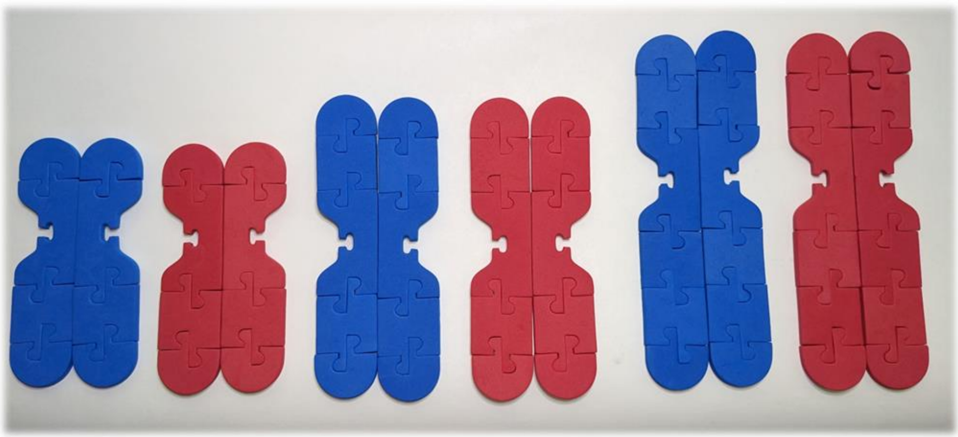


Chromosome Size	Part	Egg donating parent chromosome (Red Foam)	Sperm donating parent chromosome (Blue Foam)
Short chromosome (Acrocentric)	p arm linkers	0	0
	q arm linkers	1	1
Medium Chromosome (Metacentric)	p arm linkers	1	1
	q arm linkers	1	1
Long Chromosome (Submetacentric)	p arm linkers	1	1
	q arm linkers	2	2

30

Start with a centromere piece
Add 3-4 chromosome connectors on each side of the centromere piece.
Add a cap piece to each end of the chromatid.

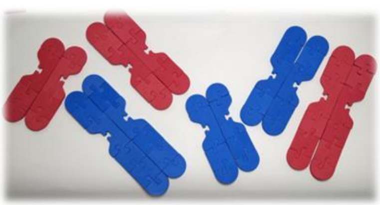
Create a duplicate copy to make a sister chromatid



31

Next create a duplicate copy of the chromosome to make a sister chromatid by using the other components found in the Chromosome Connections Kit (*Note: your chromosome does not need to look exactly like the one pictured, but it does not to have all the components.*)

What happens during meiosis?

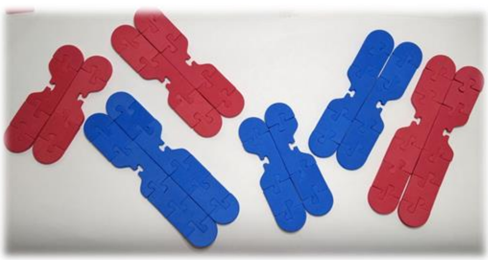


What occurs next so the end result are four haploid cells?

How can your students model what happens when eggs are made?

Two alleles of a single trait will separate randomly. There is a 50% chance that either allele will end up in either gamete.

Mechanisms that Contribute to Genetic Variation



Diploid number of chromosomes:

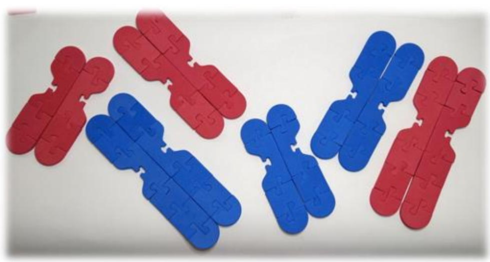
Haploid number of chromosomes:

How many possibilities of chromosome combinations during meiosis?

33

Genes are inherited independently of each other. Inheritance of one gene is not reliant on inheritance of another gene. Alleles received from one gene never influence the one received from the other gene. Takes place during meiosis. Mendel picked genes that were on different chromosomes. This law applies to genes located on different chromosomes. For genes located on the same chromosome, it depend how close they are to each other on the chromosomes. Closely located genes can be said to be linked.

Mechanisms that Contribute to Genetic Variation



Diploid number of chromosomes (2n): 6

Haploid number of chromosomes (n): 3

How many possible chromosome combinations during meiosis?
2^n or 8

How many possible combinations in humans?

34

Genes are inherited independently of each other. Inheritance of one gene is not reliant on inheritance of another gene. Alleles received from one gene never influence the one received from the other gene. Takes place during meiosis. Mendel picked genes that were on different chromosomes. This law applies to genes located on different chromosomes. For genes located on the same chromosome, it depend how close they are to each other on the chromosomes. Closely located genes can be said to be linked.

What happens during meiosis?

How do homologous chromosomes find each other?

35

Two alleles of a single trait will separate randomly. There is a 50% chance that either allele will end up in either gamete.

Crossing Over at the Microscopic Scale

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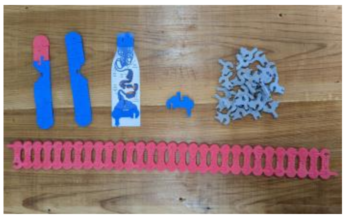
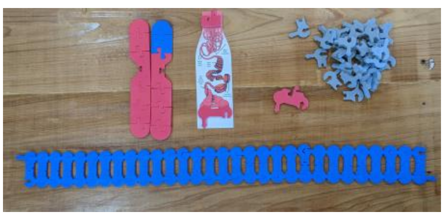
3d molecular designs

Crossing Over at the Microscopic Scale

Crossing Over at the Molecular Scale





- Add a 4X scaling graphic to help students under the relationship between DNA and the chromosome.
- Helps students better understand scale and proportion.
- Can explore the Holliday junction

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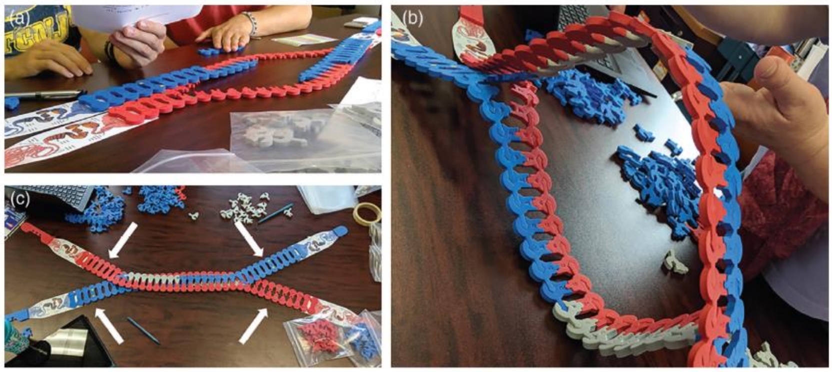
Crossing Over at the Molecular Scale



Wright, et al. 2022. Biochem Mol Biol Educ. 2022;50:44–54. https://doi.org/10.1002/bmb.21583

Crossing Over at the Molecular Scale

Workshop NGSS Connections

SEPs	CCCs	DCIs
Asking Questions and Defining Problems	**Systems and System Models**	**HS-LS1-4**
Developing and Using Models	**Cause and Effect**	**HS-LS3-2**
	Scale, Proportion, and Quantity	

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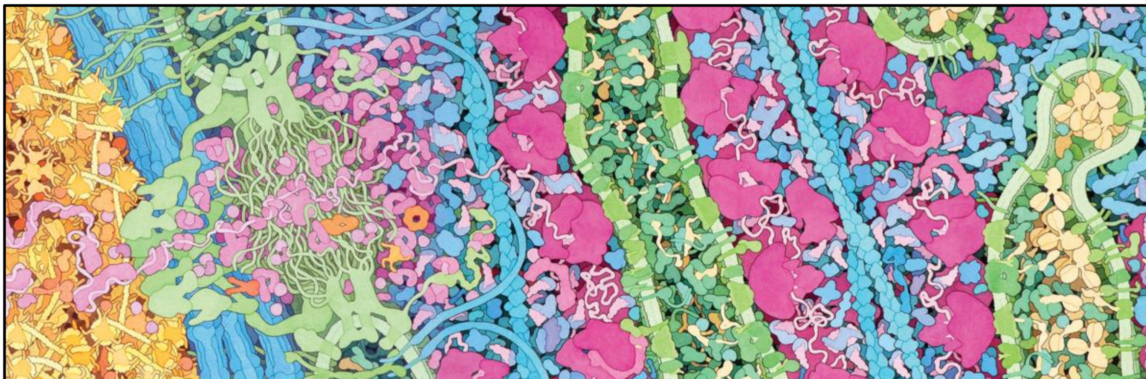
Ruth says: Here are the NGSS and TEKS Connections for this workshop.

We value your opinion! Let us know what you think.

Scan the QR Code and complete this short survey.



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