Larger than Life Meiosis

You will need 14 student volunteers for this demonstration.

Start with 2 pairs of homologous chromosomes (= 4 molecules of DNA)

Step 1: Interphase – 2 student volunteers to hold chromosomes

a. Two students stand inside a large circle of rope on the floor. The rope represents the nuclear envelope.
b. Student 1 holds 2 blobs of yarn of the same length but 2 different colors (red & blue) in front of him/herself. Student 2 holds 2 blobs of yarn of the same length (but shorter or longer than Student 1's yarn wads) but 2 different colors in front of him/herself.
c. <u>DNA duplication occurs</u>: Both students pull 2 <u>more</u> blobs of yarn from behind their backs to represent DNA duplication. Students hold matching color yarn blobs side-by-side.
d. Now there are 4 copies of each molecule of DNA, for a total of 8 DNA molecules inside the nucleus.

Clicker Question 1 "What phase is represented right now?" (Answer: S phase of interphase)

A. S phase of interphase
B. Prophase I
C. Prophase II

Teaching Note: The wadded, unorganized mass of yarn represents the relaxed state of chromosomes during interphase. At the start, each student holds a pair of blobs to represent homologous chromosomes. The 2 different colors represent the fact that homologous chromosomes have been inherited 1 from mom and 1 from dad.

Step 2: Prophase I – 8 student volunteers: 4 to hold chromosomes, designated Chromosome 1-maternal, Chromosome 1-paternal, Chromosome 2-maternal and Chromosome 2-paternal; 2 students to be stagehands, and 2 to be Centrosome 1 and Centrosome 2.

a. <u>Chromosomes condense</u>: (Steps 2.a.i and 2.a.ii should happen simultaneously)
   i. Chromosome 1 hands yarn blobs to Stagehand 1, who hands Chromosome 1 the maternal sister chromatids (2 pool noodles of same length, both red). Chromosome 1 student is now Chromosome 1-maternal. At the same time, Stagehand 1 hands Chromosome 1-paternal the paternal sister chromatids (2 blue pool noodles of the same length as the first pair). Chromosome 1-maternal and Chromosome 1-paternal hold their sister chromatids (pool noodles) side-by-side as if joined by cohesin.
   ii. Chromosome 2 hands yarn blobs to Stagehand 2, who hands Chromosome 2 the maternal sister chromatids of chromosome 2 (2 red pool noodles of same length as each other, but length is different from chromosome 1) At the same time Stagehand 2 hands Chromosome 2-paternal the paternal sister chromatids (2 blue pool noodles of the same length as the first pair of Chromosome 2 sister chromatids.) Chromosome 2-maternal and Chromosome 2-paternal hold their sister chromatids (pool noodles) side-by-side as if joined by cohesin.
b. <u>Homologous chromosomes form the synaptonemal complex</u>: Chromosome 1-maternal and Chromosome 2-paternal turn to face each other and push their pairs of sister chromatids together in the center[i]. Chromosome 2-maternal and Chromosome 2-paternal do the same.

Clicker question 2: "What can happen at this stage that increases genetic diversity?"
A. Synapsis
B. Kinetochores divide
C. Crossing Over

c. Crossing over occurs: Chromosome 1 students swap matching segments between non-sister chromatids by pulling sections of noodle off the supporting center rod. Chromosome 2 students do the same.
d. Nuclear membrane breaks down: Stagehand 1 removes the nuclear envelope (rope) and sets it aside at the back of the stage.
e. Spindle forms & spindle fibers attach to kineotchores: Stagehand 2 gives 4 pieces of thick yarn to Centrosome 1 and Centrosome 2. Centrosome 1 and 2 stand side-by-side on one side of the stage, holding their 4 pieces of yarn firmly at one end.
    i. Centrosome 2 moves to the opposite side of the stage from Centrosome 1.
    ii. Stagehand 1 takes one end of the yarn pieces held by Centrosome 1 and carries them to the closest Chromosome 1 and 2 chromatids. Chromosome 1 and 2 grab the yarn and hold one piece of yarn against each pool noodle. Stagehand 2 distributes yarn from Centrosome 2 to the closest Chromosome 1 and 2 chromatids. Each of the 8 chromatids should be connected to a spindle fiber (fat piece of yarn) so that sister chromatids are connected to the same centrosome as each other, but the sister chromatids of the homologous chromosome are connected to the opposite centrosome.

Teaching Note: The 2 sets of 4 pool noodles represent the 2 synaptonemal complexes – one complex for each pair of homologous chromosomes. The thick yarn represents the spindle fibers.

Step 3: Metaphase I – Same 4 volunteers holding chromosome 1 and chromosome 2 homologous pairs, same 2 centrosome volunteers holding yarn.

- Pairs of homologous chromosomes move to the metaphase plate. Students holding chromatids with yarn attached should remain in their synaptonemal complexes, but jostle about randomly and tug (gently) against the yarn. Centrosomes should resist. Students holding chromatids should end up lined up in the center of the stage, still attached to the yarn and still in their synaptonemal complex.

Clicker Question 3: "What is this phase?"
A. Metaphase I
B. Metaphase II
C. Prophase II

Step 4: Anaphase I – same 4 volunteers holding chromatids, same 2 volunteers holding yarn

- Centrosome 1 tugs nearest pair of Chromosome 1 sister chromatids (2 pool noodles held by same person) toward him/herself and nearest pair of Chromosome 2 sister chromatids toward him/herself. Centrosome 2 does the same at the same time.

Teaching Note: The Chromosome 1 homologous pair and Chromosome 2 homologous pair separate toward opposite poles of the cell. (Non-sister chromatids are separating.) At each pole there will be a pair of Chromosome 1 sister chromatids and a pair of Chromosome 2 sister chromatids.

Step 5: Telophase I – 4 volunteers holding chromatids, 2 volunteers as stagehands

a. The centrosomes step aside, taking their yarn with them, representing disappearance.
b. Stagehand 1 herds 1 set of chromosomes (2 students, each holding 2 pool noodles) toward 1 side of the stage and Stagehand 2 herds the other set of chromosomes toward the other side of the stage. Stagehand 1 then puts a rope around 1 pair of chromosomes and Stagehand 2 puts a rope around the other pair.

Teaching Note: Movement of chromosomes to opposite sides of stage indicates cytokinesis. Replacement of the rope around the chromosomes represents re-formation of the nuclear membrane.

Step 6: Prophase II – 12 volunteers: 4 Stagehands, 4 students to hold chromatids, 4 Centrosomes

a. Nuclear envelope disintegrates – Stagehands 1 and 2 remove ropes from around each set of chromosomes.
b. Centrosomes and Spindle re-form - Stagehand 1 gives 4 pieces of thick yarn to Centrosome 1 and Centrosome 2. Centrosome 1 and 2 stand side-by-side on one side of one chromosome group, holding their 4 pieces of yarn firmly at one end. Centrosomes 3 & 4 do the same with the 2nd chromosome group.
    i. Centrosome 2 and Centrosome 4 move over to the opposite side of the chromosomes (students holding noodles).
    ii. Stagehand 1 takes one end of the yarn pieces held by Centrosome 1 and carries them to the closest set of Chromosome 1 and 2. Each student holding a pair of pool noodles (chromatids of the same chromosome) holds one piece of yarn against each pool noodle. Stageshand 2, 3, and 4 do the same for Centrosomes 2, 3, and 4 at the same time. Stagehands step out of the way.

Step 7: Metaphase II – Same 4 volunteers holding chromatids, same 4 centrosome volunteers holding yarn.

- Pairs of sister chromatids move to the metaphase plate. Students holding chromatids with yarn attached should tug (gently) against the yarn. Centrosomes should resist. Students holding chromatids should jiggle about a bit, then end up lined up in middle of the space between their centrosomes, still attached to the yarn and still holding the chromatids next to each other.

Step 8: Anaphase II – Same 4 volunteers holding chromatids, same 4 centrosome volunteers holding yarn.

- Centrosome 1 tugs nearest Chromosome 1 chromatid (1 pool noodle) toward him/herself and nearest Chromosome 2 chromatid toward him/herself. Centrosome 2 does the same at the same time. Students holding the chromatids extend their arms straight out to the sides, so that chromatids are separated.

Clicker Question 4, "What stage just completed?"

A. Telophase I
B. Anaphase I
C. Anaphase II

Step 9: Telophase II and Cytokinesis – 8 students holding chromatids, 4 Centrosomes, 2 Stagehands

a. 4 more students step in to hold one pool noodle each (chromatid). One Chromosome 1 noodle & one Chromosome 2 noodle should be on opposite sides of each nucleus.
b. Centrosomes disappear. Centrosome actors step aside.
c. Stagehands herd each set of chromosomes (2 students, each holding 1 pool noodle) into 4 separate spots across the stage. (This separation represents cytokinesis)
d. Nuclear envelope re-forms: Stagehands put ropes around each set of chromosomes (1 noodle of Chromosome 1 & 1 noodle of Chromosome 2 in each nucleus)

Teaching Note: At the end, there should be 4 pairs of chromosomes inside 4 circles of rope (the nucleus). Each nucleus should contain 1 of each chromosome.

Clicker Question 5, "These gametes have ___ different chromosome(s) and are ____."
A. 1, haploid (1n)
B. 2, haploid (1n)
C. 2, diploid (2n)
D. 1, diploid (2n)

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[i] Script developed by Drs. Donna Pattison & Ann Cheek, Department of Biology & Biochemistry, University of Houston
Reference: Locke and McDermid, 2005, Genetics. 170:5-6. Available as full text pdf at http://www.genetics.org/content/170/1/5.full.pdf