Chromonoodles: Jump Into the Gene Pool

Using pool "noodles" to model chromosomes in the biology classroom

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Chromosomes, alleles, chromatids, genotype, phenotype, mitosis, meiosis, fertilization—this vocabulary can be overwhelming, confusing, and difficult for students to tie together. However, these terms are commonplace in the high school biology classroom; they are the basis for understanding both DNA and heredity. Students must understand these topics not only for state testing but for everyday applications, as well. But how do we teach them so that students truly understand them?

As high school biology teachers with limited budgets, we are always on the lookout for inexpensive ways to teach DNA and heredity. We have tried pipe cleaners, flip books, coloring worksheets, and online lessons—but one of our best discoveries was made in the swimming pool. Brightly colored pool "noodles" make great chromosome models, and since they are seasonal in most places, they go on sale at the end of summer. We paid less than $1 per noodle!

In this article, we explain how we use noodles to help students gain a greater appreciation of the interdependence of DNA and inherited traits.

Noodles as models

Many of the lessons and demonstrations we attempt in our classrooms use nonlinguistic representation and cooperative learning. We find that student comprehension increases dramatically when mental imagery and kinesthetic learning are incorporated into classroom activities. Working cooperatively in groups enhances student understanding, and completing this kind of activity encourages interactions between students and teachers—increasing both knowledge and recall ability (Marzano, Pickering, and Pollock 2001).

For this activity, we buy noodles in two different colors and cut, modify, and tape them to make noodle chromosomes, or what we call *chromonoodles*. Students love them because they are fun, colorful, and big enough for all to see. We love them because they are easy to make, inexpensive, and can be used repeatedly to introduce, demonstrate, reinforce, and make connections between genetic concepts.

Making chromonoodles

Making chromonoodles is easy and requires only a few inexpensive supplies: six pool noodles in two different colors to represent the sexes (we use three blue and three green), permanent markers, and several colors of tape in different widths.

The number of chromosomes symbolized can vary, depending on the availability of noodles and your ability to store them. Representing the entire human karyotype—23 chromosome pairs—is too bulky and cumbersome, so we start with 6. Cut the noodles into six groups of four chromosomes. Within each group, there are two chromonoodles of each color (e.g., in our case, two blue and two green) and all chromonoodles are the same length (Figure 1A). Vary the length of the chromonoodles from group to group—except for the X and Y pair, which should be cut so that the X chromonoodle is longer (Figure 1B). This allows the set to be used for the cell cycle, mitosis, and meiosis.

Next, using the colored tape, make a pattern on the four same-size chromatids. The tape represents the banding pattern found on an actual karyotype of stained chromosomes. You can use different colors, widths, or types of tape—just make sure that the four same-size chromatids also have the same pattern. Repeat in varying patterns for each chromonoodle (Figure 3, p. 36). (**Note:** The bands represent regions of DNA that stain differently. Depending on the section of the chromosome, there may be hundreds or very few genes in each band, so students should not misinterpret the bands as representing a single gene.)

Use a marker to write letters on the bands, representing alleles on the different homologous chromosomes. Make sure that the two chromatids that are the same size and color also have identical letters—including identical capitalization, since they represent identical sister chromatids; this demonstrates the end of the S phase during the cell cycle. Since chromonoodles that have the same length but different colors represent homologous chromosomes, make some of the alleles on each chromonoodle dominant (i.e., capital letter) and some recessive (i.e., lowercase letter), so you can show heterozygous and homozygous genotypes (Figure 4, p. 37).

Next, make the sex chromosomes. Leftover odd-shaped pieces work well for this. Mark an "X" on two of the female color chromonoodles and a "Y" on two of the shorter, male-color chromonoodles. Make sure the X and Y chromonoodles are different sizes, since the sex chromosomes are not homologous (Figure 2, p. 36). We mark ours with alleles that are carried on the sex chromosomes, so they can be referred to during lessons involving sex-linked traits.

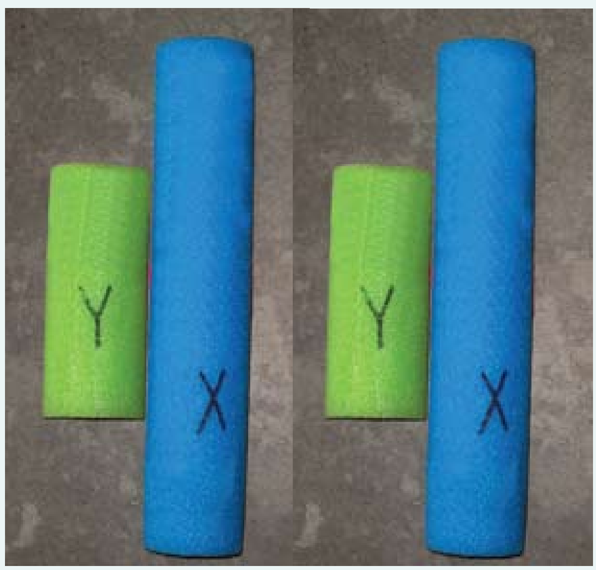
FIGURE 1A

Four chromosomes.

Each group of four should look like this: two groups of duplicated homologous chromosomes (i.e., two pairs of sister chromatids).

FIGURE 1B

Duplicated sex chromosomes (X and Y).



To show "sister" chromatids that have replicated during the cell cycle, use pieces of hook-and-loop tape. Stick opposite sides of the tape on the sister chromatids to simulate the centromeres. Be sure to also stick the opposite pieces on the homologous partner so that they can be stuck together, as well.

Safety note

CAUTION Chromonoodles must be cut by an adult prior to classroom use; a utility or serrated kitchen knife works well, or—if your school has a willing industrial arts teacher—a band saw. Students should be warned against striking each other with the noodles, or swinging them around. Manipulating the noodles on the floor or tables can help reduce the probability of horseplay.

Chromonoodle activities

After introducing the terms and basic concepts, we use the following chromonoodle activities to teach DNA and heredity. We dedicate one class period to each activity.

Fertilization

Choose a chromonoodle color to represent the female. Place one of each size female chromonoodle into a clear trash bag to model the haploid egg, and one of each size male chromonoodle into a separate trash bag. Attach a long piece of string or ribbon to the outside of the bag containing the male chromonoodles; this serves as the haploid sperm. For added realism, use a larger bag for the egg and fill it with balled-up pieces of newspaper, to show that the egg is much larger than the sperm. This serves as a springboard for discussion of haploid, diploid, and fertilization.

Show the egg cell and its contents to students, discuss, and then bring out the sperm cell. Point out that both cells are haploid because they only contain one chromosome of each size—or one of each homologous pair. Ask students what will happen when fertilization occurs. Then, fertilize the egg!

FIGURE 2

The sex chromonoodles.

FIGURE 3

Two chromonoodles with varying band patterns and sizes.

Dump the contents of each cell on the floor or lab table and have student volunteers match up the homologous chromosomes: There should be one of each color and size. If matched correctly, they can be attached using hook-and-loop tape to show the homologous partners and the alleles. This is a great demonstration of how half our DNA comes from our mothers and the other half from our fathers.

Next, calculate the diploid number as a class and discuss heterozygous and homozygous traits. This is a great introduction to meiosis: How did these cells end up with only half the diploid number of chromosomes?

Cell cycle

This activity should be done in a large area so that all students can see the chromonoodles manipulated through each stage of the cell cycle. Take digital pictures of the chromonoodles in each stage and use them later for review or as assessment tools.

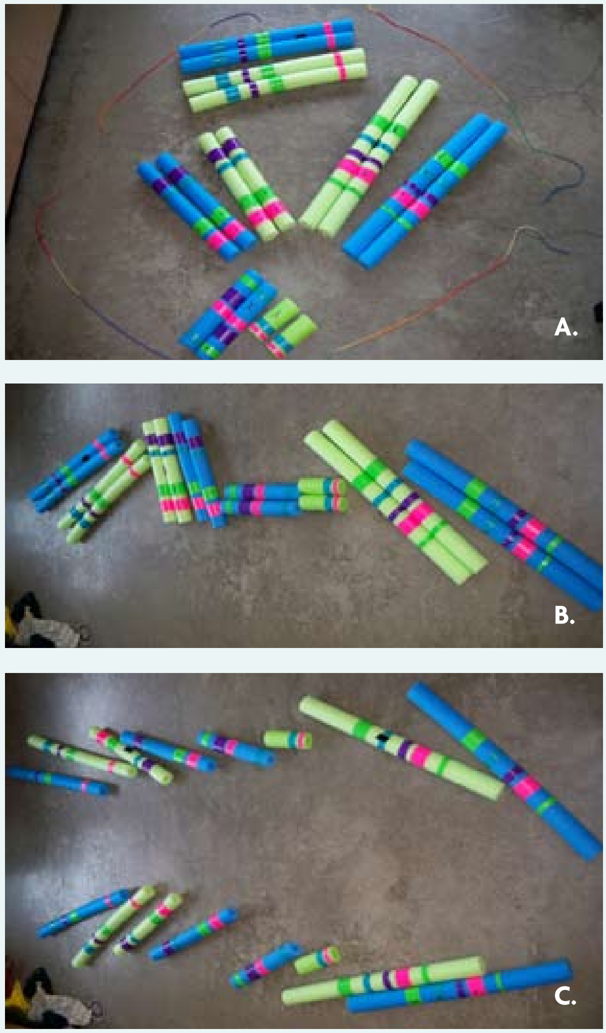
For this activity, the first phase of the cell cycle is the G1 phase of interphase. Randomly place one color of each size chromonoodle on the floor. Explain that this cell is the diploid

FIGURE 4

Homologous chromosome pairs.

FIGURE 5

The four phases of mitosis.



A. Phophase

B. Metaphase

C. Anaphase

D. Telophase

Addressing the Standards.

According to the National Science Education Standards, students at the high school level must understand the complex relationship between the DNA sequence, the chromosome, and the expressed phenotype. This leads to further application in the variations within populations and inheritance of traits (Life Science Content Standard C; NRC 1996, p. 181). The chromonoodle activity addresses all of these topics in a manner that stimulates and engages students. Though others have suggested using noodles in the classroom (e.g., to represent chromatids during mitosis and meiosis; Locke and McDermid 2005), most do not develop the allele concepts for each chromatid or use them in other genetics activities, as we have done.

because it has two copies of each chromosome—even though they may not be together. (**Note:** It is important to explain that condensed chromosomes are not present during interphase, and really only become visible [at high magnification] during the early stages of mitosis.)

The cell then makes a copy of each DNA segment (i.e., DNA replication) during the S phase. Bring out the other copy of each chromonoodle and have students match up the sister chromatids and attach them within the nucleus—again noting that these structures do not become condensed and visible until mitosis begins.

The nucleus now contains four copies of each chromosome. (**Note:** We repeat this activity when we cover replication.) This step is often confusing for students, as they do not understand the "X" pattern found in most science textbooks. This activity allows them to see that the "X" is actually two sister chromatids held together by a centromere, which appears during mitosis. In a human cell, there are 92 chromatids at this point—which is often overlooked.

Now, have students manipulate the chromonoodles to model the phases of mitosis (Figure 5, p. 37) and cytokinesis. We use a large piece of string to represent the nuclear membrane. During telophase, cut the string into two pieces and then tie the pieces around each of the two new nuclei. Stop before each phase and discuss what will occur; this provides an opportunity for students to take notes.

We have also had each student hold a chromatid and walk through the stages of mitosis, explaining what is happening within the cell. Take pictures of each phase and use them at the beginning of each day of the unit—about six or seven class periods—to reteach. Print the images and make flash cards that can be used as an intervention device (have students sort and place the cards in their proper sequence) or as an assessment (print the scrambled images on a test or quiz and have students label each stage and list them in order).

Meiosis

Start this activity by showing the cell in its diploid state. Then, have student volunteers move the chromonoodles through the phases of meiosis. While the chromonoodles are in prophase I, physically swap one piece of chromonoodle with a corresponding piece from its homologous partner (Figure 6)—this simulates the crossing over that occurs while they are in the tetrad state.

Be sure to point out that this occurrence makes new allele combinations on each chromonoodle, which helps students see one way different genotypes can result from the same two parents. More hook-and-loop tape can be used for the swapping and reattachment.

Genetics concepts

Allele 1

Students can also develop phenotypes for their chromonoodle genotype. Divide students into groups of two to four, depending on class size and number of chromonoodle pairs. Give each group a pair of homologous chromosomes and have them determine whether they are heterozygous,

FIGURE 6

Chromonoodles demonstrate crossing over during meiosis.

homozygous dominant, or homozygous recessive for each of the alleles on the chromosomes and what physical characteristics they will express. Then, ask each group to share their phenotypes with the class. Student groups, or the class as a whole, can then draw a picture of the individual based on these phenotypes.

Allele 2

To show what truly makes alleles different at the DNA base-pair level, write DNA base pairs beside the letter on the band (the letter represents the allele). This helps students see how a dominant allele is different from a recessive allele (e.g., how a "K" is different from a "k"), based on the DNA and its resulting polypeptide sequence. Have students analyze the sequences for differences and then transcribe and translate them. This allows them to see the differences created in the final protein.

Using chromonoodles as teaching tools provides a large, visual manipulative that can be referenced throughout the year.

Karyotyping

Place the full set of chromonoodles on the floor in a random pattern. Then, have students match up the homologues and organize them by size, as in an actual karyotype. This activity can be used in place of the traditional activity in which students cut out pictures of the chromosomes and tape them together—and it takes a lot less time. Since the banding pattern is more visible in this activity, it is easier for students to find and match the homologous partners. Any extra noodle pieces can be added to the chromonoodles on the floor to show trisomy, nondisjunction, or other chromosomal abnormalities.

Pedigree

Use a pair of homologous chromonoodles as the genotype of an offspring and determine the possible genotypes of the parents.

Punnett square

Using tape or string, mark a large Punnett square on the floor, bulletin board, or chalkboard. Place one pair of chromonoodles along the top and the other similar-size pair along the opposing side. These can then be separated and individually placed into the four offspring squares to display potential genotypes of the offspring—emphasizing that only one allele is inherited from each parent.

Assessment

There are many ways to assess these chromonoodle activities. Informal formative assessments, based on observation and class discussion, allow teachers to address misconceptions about the cellular processes of mitosis and meiosis. Students can also take a "physical quiz" in which they physically move the chromonoodles through the stages of the cell cycle and explain what happens within the cell. A student handout, rubric, and teacher directions for a physical quiz are available online (see "On the web").

Remedial students can practice the stages and conditions of the cell cycle using the chromonoodles or the digital images. Display photos using a projector or flash cards so that students can review the stages. Have them match the photos with actual pictures of mitosis.

Formal evaluations of student understanding demonstrate competence in sequencing, identification, and vocabulary comprehension. Incorporate images into a written assessment, and have students describe the stages, label them, and place them in the proper order. Assess higher-level thinking skills with extended-response questions and ask students to tie together the concept of a DNA sequence to the resulting polypeptide and, ultimately, the phenotype.

Conclusion

Using chromonoodles as teaching tools provides a large, visual manipulative that can be referenced throughout the year as genetics concepts are emphasized. We find that students remain enthusiastic and recall more concepts.

Eventually, we would like to build an entire complement of homologous chromosomes and display them year-round in our classrooms. Because chromonoodles are so versatile, they have proven to be one of the best teaching tools we have ever used. They have been a lifesaver in the classroom and confirm that effective teaching tools do not have to be expensive! ■

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On the web

Physical quiz on the cell cycle and student handout: *www.nsta.org/highschool/connections.aspx*

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