DNA, How is it Packaged? (At Home)

Middle School

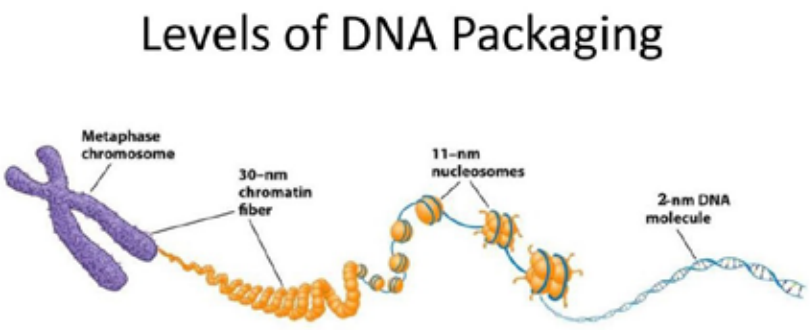
Overview

It is important for students to understand what DNA is and how all cells utilize it. One major difference in this DNA lab is that we attempt to build a physical and mental model of how DNA is packaged in cells. After building a model, the students then attempt to utilize their newly acquired knowledge of the structure and packaging of DNA to determine how to get DNA out of the cell.

Learning Objectives

- Students will learn that DNA is the storage molecule for genetic information in the cell.
- Students will create a model of the structure of DNA.
- Students will extract DNA from corn.

Background



- 2-nm double-stranded DNA molecule
- 11-nm nucleosomes
- 30-nm chromatin fiber
- Organization around a central scaffold

In recent years, scientists have decoded the DNA of humans and a menagerie of creatures but none with genes as complex as a stalk of corn, the latest genome to be unraveled.

A team of scientists led by The Genome Center at Washington University School of Medicine in St. Louis published the completed corn genome in the Nov. 20, 2009 journal of science, an accomplishment that will speed efforts to develop better crop varieties to meet the world's growing demands for food, livestock feed and fuel.

"Seed companies and maize geneticists will pounce on this data to find their favorite genes," says senior author Richard K. Wilson, Ph.D., director of Washington University's Genome Center, who led the multi-institutional sequencing effort. "Now they'll know exactly where those genes are. Having the complete genome in hand will make it easier to breed new varieties of corn that produce higher yields or are more tolerant to extreme heat, drought, or other conditions."

Corn, also known as maize, is the top U.S. crop and the basis of products ranging from breakfast cereal to toothpaste, shoe polish and ethanol. The corn genome is a hodgepodge of some 32,000 genes crammed into just 10 chromosomes. In comparison, humans have 20,000 genes dispersed among 23 chromosomes.

The $29.5 million maize sequencing project began in 2005 and is funded by the National Science Foundation and the U.S. departments of agriculture and energy. The genome was sequenced at Washington University's Genome Center. The overall effort involved more than 150 U.S. scientists with those at the University of Arizona in Tucson, Cold Spring Harbor Laboratory in New York and Iowa State University in Ames playing key roles.

The group sequenced a variety of corn known as B73, developed at Iowa State decades ago. It is known for its high grain yields and has been used extensively in both commercial corn breeding and in research laboratories. The genetic code of corn consists of 2 billion bases of DNA, the chemical units that are represented by the letters T, C, G and A, making it similar in size to the human genome, which is 2.9 billion letters long.

But that is where much of the similarity ends. The challenge for Wilson and his colleagues was to string together the order of the letters, an immense and daunting task both because of the corn genome's size and its complex genetic arrangements. About 85 percent of the DNA segments are repeated. Jumping genes, or transposons, that move from place to place make up a significant portion of the genome, further complicating sequencing efforts.

A working draft of the maize genome, unveiled by the same group of scientists in 2008, indicated the plant had 50,000-plus genes. But when they placed the many thousands of DNA segments onto chromosomes in the correct order and closed the remaining gaps, the researchers revised the number of genes to 32,000.

"Sequencing the corn genome was like driving down miles and miles of desolate highway with only sporadically placed signposts," says co-investigator Sandra Clifton, Ph.D., of Washington University. "We had a rudimentary map to guide us, but because of the repetitive nature of the genome, some of the landmarks were erroneous. It took the dedicated efforts of many scientists to identify the correct placement of the genes."

Interestingly, plants often have more than one genome and corn is no exception. The maize genome is composed of two separate genomes melded into one, with four copies of many genes. As corn evolved over many thousands of years, some of the duplicated genes were lost and others were shuffled around. A number of genes took on new functions.

Corn is the third cereal-based crop after rice and sorghum – and the largest plant genome to date to have its genome sequenced, and scientists will now be able to look for genetic similarities and differences between the crops. "For example, rice grows really well in standing water, but corn doesn't," explains co-investigator Robert Fulton, of Washington University. "Now, scientists can compare the two genomes to find variations of corn genes that are more tolerant to wet conditions."

The United States is the world's top corn grower, producing 44 percent of the global crop. In 2009, U.S. farmers are expected to produce nearly 13 billion bushels of corn, according to the U.S. Department of Agriculture.

Discussion

Introduce the topic and assess students for prior understanding.

- What is DNA?
- Where can we find DNA?
- How is DNA stored?
- Is DNA the same for plants and animals?

Activity 1: Modeling DNA Structure

Creating a Model of DNA: Let's Make a Model of DNA!

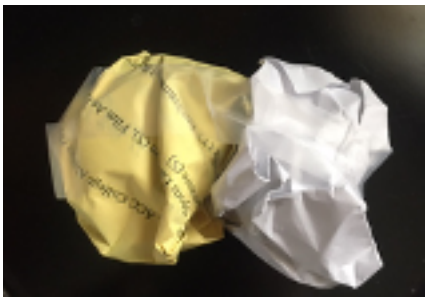
Materials

- DNA, How is it Packaged? PowerPoint (available at kansascornstem.com)
- Plastic wrap (long roll) you could also substitute grocery store plastic bags
- 32 ping-pong balls or substitute wadded up paper made into balls
- 55-gal. clear trash bags or any large trash bag
- Velcro, hot glue, super glue or any type of adhesive
- Tape
- Sharpie

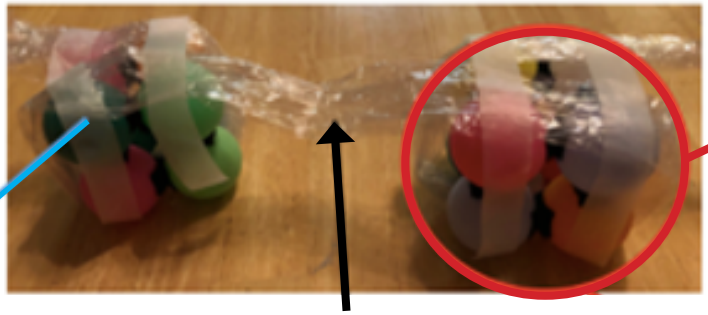
Directions

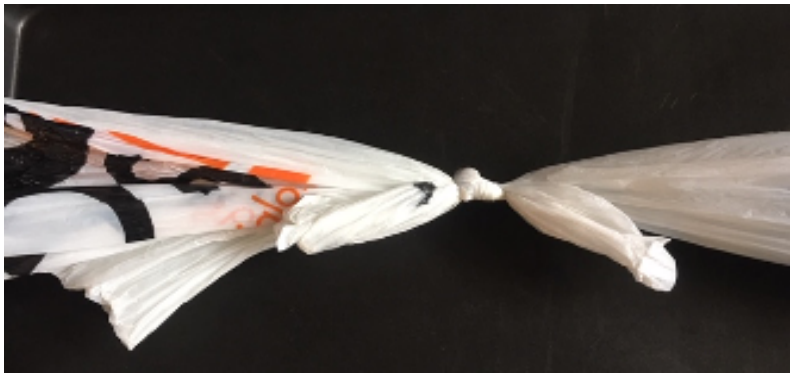
1. Connect eight ping-pong balls or paper balls into the arrangement of a double stack of 4 (see photos). These stacks represent a nucleosome (made up of 8 histone proteins).

or



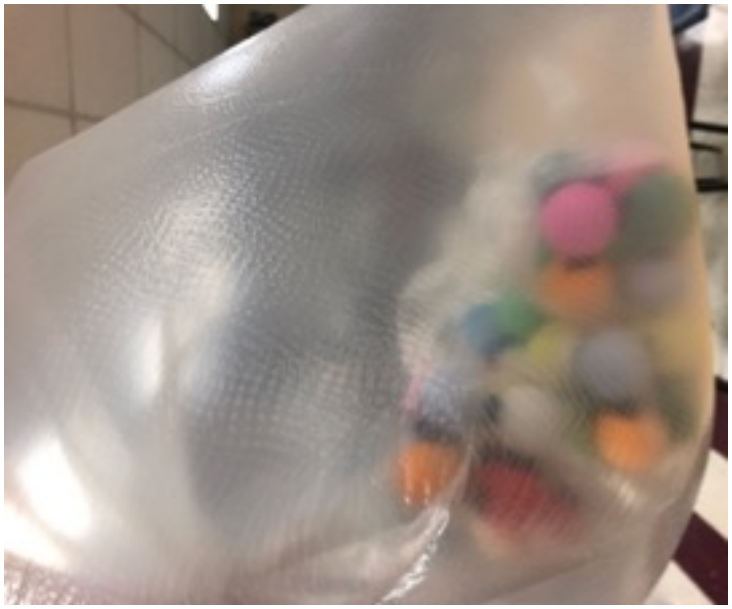
2. After all of the nucleosomes have been arranged, start with one set and pull out about 10 ft. of plastic wrap. Squeeze this into a long rope shape and wrap it around one of the nucleosomes (see photo). Continue with the plastic wrap and wrap all of the other nucleosomes in a sequence. After all of the nucleosomes are wrapped with the plastic wrap, use a couple pieces of clear tape to secure the nucleosomes to the plastic wrap. The plastic wrap represents DNA.
   *Note: If you are using the grocery store bags you will take 5-6 bags and tie them together, then wrap around the nucleosomes instead of the plastic wrap.


Clear Tape to connect the wrapped DNA to the Nucleosome
Nucleosome
Saran Wrap will Represent DNA
The Saran Wrap will be wrapped around the nucleosome



3. To show how a chromosome is formed, you will need to pull/push all the nucleosomes together to make a condensed arrangement of the DNA. This is how a chromosome forms (just much more condensed).

4. When the arrangement is condensed, place the whole arrangement in a large 55-gal. clear trash bag. Try to fill the bag about half full of air. Twist the bag opening to close off the bag (you can tape it closed). The trash bag represents the nuclear membrane.



5. Take another clear trash bag and place your nucleus with DNA into this bag. You will also seal this bag by closing the opening with tape. This outer bag will represent the cell membrane.
6. Looking at your model think about the following questions:
   - What are some barriers that we need to get through to get to the DNA? Answer: Cell membrane (outside bag) and nuclear membrane (inside bag).
   - What are those barriers made up of? (you might have to research what both of those membranes are made up of.) Answer: Bi-lipid Layers (fats)
   - What can we do to open up or get rid of those fats when attempting to get to the DNA? (research how to break up bi-lipid membranes.) Answer: Detergent (soap) breaks apart bi-lipid layers
7. The nucleosomes are made up of histone proteins. If we want to extract DNA, we will need to get rid of those histone proteins. Propose a way to get rid of the histone proteins from the DNA. (Research how to get rid of the histone proteins from the DNA.)

Activity 2: Extracting DNA from canned corn

Materials

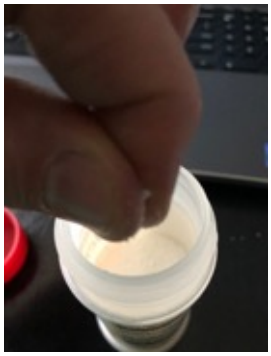
- Blender
- Canned corn
- Salt
- Measuring cup
- Measuring spoons
- Strainer
- Meat tenderizer or contact solution
- Isopropyl alcohol (70-95%)
- Small, clear cups/glasses/jars
- Straw, toothpick, popsicle stick or wooden skewer

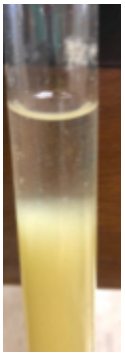
Directions

1. Blend 100 mL (1/2 cup) of canned corn, 1 mL (1/8 tsp) of table salt, and 200 mL (1 cup) of cold water in a blender for 15-20 seconds.

2. Slowly pour the corn soup from the blender into a metal strainer positioned over a plastic cup. Make sure you allow all the soupy mixture to drop the liquid portion into the cup. Slowly add 30 mL (2 tbsp) of liquid detergent into the mixture and gently swirl the cup (do this slowly so you do not form bubbles). Let this mixture sit for 5-10 minutes.

3. Gently pour this mixture into small, clear cups/glasses/jars until they are about a third full.
4. Add a pinch of meat tenderizer or contact solution(enzymes) into each container and stir gently. If you stir too hard, you will break up the DNA.





5. Tilt the container slowly and pour ice cold rubbing alcohol (70-95% isopropyl or ethanol) down the side of the container. You will add enough alcohol so that you have about a 1-inch layer of alcohol on top of the mixture. Let this sit for 5-10 minutes.

6. The DNA will begin appearing at the alcohol and water interface layer. You can use a straw, toothpick, popsicle stick or wooden skewer to gently reach down into the DNA layer below the alcohol and gently twist to collect the DNA.

Conclusion

After completing part 3, you will need to answer the following questions:

- What was the purpose of using liquid detergent (soap) in the procedure?
- What did the salt do to the mixture?
- What is the role of the meat tenderizer or contact solution?
- Why was cold alcohol used in the procedure?

Conclusion- Answer Key

- What was the purpose of using liquid detergent (soap) in the procedure?
  - When we wash dishes, we use liquid detergent (soap) to remove the grease from our dishes. These grease, fat, or lipid molecules are broken down in the cell and nuclear membrane allowing the DNA molecules to be released.
  - This video, How soap kills the coronavirus provided vox.com, shows how soap combats the COVID-19 virus is a great demonstration of how soap impacts the lipid molecules. https://www.msn.com/en-us/news/coronavirus/how-soap-kills-the-coronavirus/vi-BB11mLOe?ocid=msedgntp

- What did the salt do to the mixture?
  - Now that the nuclear and cell membranes have been broken down, the DNA is floating freely in the water. Recall that the DNA is made of the bases adenine, thymine, cytosine and guanine which are attached to the DNA phosphate backbone that makes up the double helix shape. The phosphate backbone carries a negative charge while the bases are positive creating the bonds between them, however the DNA molecule itself has a collective negative charge. When the DNA is released into the water, which has a positive charge, a solution is formed. In order to remove the DNA from this solution salt, which has a stronger positive charge than water is added to "pull" the DNA out of the solution due to the greater positive attraction.

- What is the role of the meat tenderizer or contact solution?
  - Meat tenderizer and contact solution both contain enzymes which break down proteins in the cellular components releasing the DNA into the water.

- Why was cold alcohol used in the procedure?
  - Alcohol and water have different densities causing them to separate into two different layers. In addition, DNA is soluble in water, but not in alcohol, causes the DNA to precipitate out of the water solution and clump together making it more visible.

Resources

- kansascornstem.com
- Daily Science (2009)- https://socratic.org/questions/what-are-chromatin-and-chromosomes-made-from