DNA -- Teacher Preparation Notes

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Teaching Points

- DNA is a nucleic acid made of two strands of nucleotides wound together in a spiral called a double helix.
- Each nucleotide is composed of a sugar molecule known as deoxyribose, a phosphate group, and one of four different nitrogenous bases: adenine (**A**), thymine (**T**), guanine (**G**), or cytosine (**C**).
- The phosphate and sugar parts of the nucleotides form the backbone of each strand in the DNA double helix.
- The bases extend toward the center of the double helix, and each base in one strand is matched with a complementary base in the other strand, in accord with the base-pairing rules: **A** pairs with **T** and **G** pairs with **C**.
- These characteristics are the same for the DNA of all organisms. The DNA of different organisms differs in the sequence of nucleotides, and these differences in nucleotide sequence are responsible for the genetic differences between different organisms.
- DNA replication produces two new DNA molecules that are identical to the original DNA molecule, so each of the new DNA molecules carries the same genetic information as the original DNA molecule.
- During DNA replication, the two strands of the original DNA double helix are separated and each old strand is used as a template to form a new DNA strand. The enzyme DNA polymerase adds nucleotides one-at-a-time, using the base-pairing rules to match each nucleotide in the old DNA strand with a complementary nucleotide in the new DNA strand. Thus, each new DNA double helix contains one strand from the original DNA molecule, together with a newly synthesized matching DNA strand.
- In eukaryotic cells, each chromosome consists of DNA wrapped around proteins. The chromosomes are contained in the nucleus inside a nuclear membrane.

Equipment and Supplies:

Sports Drink like Gatorade (10 mL per student)
Liquid dish soap (0.25 mL per student)
Meat Tenderizer (a pinch per student)
70-95% isopropyl or ethyl alcohol (4 mL per student)
String for necklace (2.5 ft per student)
3 oz. Dixie cups (1 per student)
Tub of ice, freezer, or refrigerator (1)
Tub for dirty test tubes (1)
Bleach (1% bleach solution to sterilize test tubes)
Small test tubes (tubes need to hold a minimum of 15 mL) (1 per student)
Test tube rack (1 per group)
0.5-1.5 mL fliptop microcentrifuge tubes (1 per student)
Transfer pipettes (1 per group)
Gloves (1 per student)

Preparations

Before Class:

1. Cut string into 2.5 ft pieces.

[1] These teacher preparation notes, the related student handout and other activities for teaching biology are available at http://serendip.brynmawr.edu/sci_edu/waldron/.

2. Set up a bucket of ice to keep alcohol cold or put alcohol in the freezer/refrigerator until needed.
3. Pour a small cup sports drink for each student.

During class:

1. Distribute cups of sports drink to each student. It is important for each student to swish the drink in his or her mouth vigorously for at least a minute in order to obtain enough cheek cells.
2. Distribute a test tube rack with one test tube per student to each group. Distribute one glove to each student. Pass out the soap and meat tenderizer. Alternatively, you can have a station somewhere in the classroom where the students can access the soap, etc.
3. After at least 10 minutes (when the students have completed the "DNA structure" portion of the student handout), pass out the cold alcohol and pipettes.
4. After 10 minutes (when the students have completed the "DNA replication" portion of the student handout), distribute one microcentrifuge tube and piece of string to each student.
5. Assist students' transfer of their DNA to their microcentrifuge tubes using the pipettes. It helps to twirl the DNA around the end of the pipette to get a large wad together before sucking the DNA into the pipette. Warn the students to be gentle while pipetting so they do not damage the fragile strands of DNA. Inexperienced pipetters have a tendency to blow air into the liquid and suck up and expel the DNA several times in the test tube before transferring it to the microcentrifuge tube; this tends to break the DNA strands.
6. Put on a pair of gloves and collect the test tube racks from the students. Pour test tube contents out down the sink, rinse the test tubes, and place them in a tub of 1% bleach solution for 10 minutes to sterilize them for the next class. (You may want to assign this job to a student).
7. Remove test tubes from bleach water and invert them in the racks to dry for the next class.
8. Return the alcohol to the ice bucket or freezer/refrigerator.

Instructional Suggestions and Additional Information

As background for this activity, students should know that DNA is the genetic material and DNA is contained in chromosomes inside the nucleus inside a cell. "Understanding the Functions of Proteins and DNA" (available at http://serendip.brynmawr.edu/exchange/bioactivities/proteins) provides a suggested sequence of activities for introducing students to DNA as the genetic material.

The proteases in the meat tenderizer not only digest histones (the proteins that DNA wraps around), but also break down enzymes in cells which could digest the DNA.

Cold alcohol helps to precipitate the DNA molecules by reducing the temperature and dehydrating the salty soapy solution of DNA immediately under the alcohol layer. The high salt concentration (from the sports drink and meat tenderizer) is also important since DNA molecules are negatively charged and the salt neutralizes the repulsion among the negatively charged strands of DNA and allows the DNA to clump together.

This activity combines hands-on extraction of DNA from human cheek cells with questions on DNA structure and replication that students answer during the wait times for DNA extraction. For question 3 on page 5 you may want to substitute an alternative hands-on simulation version in which students use nucleotide diagram pieces and tape to carry out DNA replication; templates for the nucleotide diagram pieces are provided in the Teacher Notes available at http://serendip.brynmawr.edu/exchange/bioactivities/DNA.

If you prefer to extract DNA from samples other than human cheek cells, we recommend the procedure for extracting DNA from split peas available at http://learn.genetics.utah.edu/content/labs/extraction/howto/. The directions for preparing the mixture of peas, salt and detergent to pour in test tubes will produce enough mixture for ~24 15 mL test tubes; then your students can carry out the steps of adding enzymes and alcohol and pulling out the DNA. In our experience you may want to use the blender for slightly longer than 15 seconds, you should not be surprised when you have a lot of leftover peas after the straining step, you can use somewhat less alcohol than suggested, and it seems to work best if the alcohol is cold. Alternatively, you can use the directions for extracting DNA from bananas (available at http://www2.le.ac.uk/departments/genetics/vgec (search for Go Bananas)) or wheat germ (available at http://learn.genetics.utah.edu/archive/wheatgerm/index.html).

Any of these extraction procedures can be used together with our discussion/worksheet activity about DNA structure and replication (available at http://serendip.brynmawr.edu/exchange/bioactivities/DNA). Frequently Asked Questions, including answers to questions about Trouble-shooting, Understanding the Science Behind the Protocol, Comparing the DNA Extracted from Different Cell Types, and Real-life Applications of the Science of DNA Extraction are available at http://learn.genetics.utah.edu/content/labs/extraction/howto/faq.html. Helpful figures for explaining how detergents break down lipids are available at http://learn.genetics.utah.edu/archive/wheatgerm/background.html. A DNA Extraction Virtual Lab is available at http://learn.genetics.utah.edu/units/activities/extraction/ .

To help students understand why accurate replication of the sequence of nucleotides in DNA is so important, you may want to use all or part of the following diagram in your discussion of question 3 on the top of page 5 of the Student Handout.

nucleotide sequence in the DNA of a gene

→ nucleotide sequence in messenger RNA (mRNA)
(transcription)

→ amino acid sequence in a protein
(translation)

→ structure and function of the protein
(e.g. normal hemoglobin vs. sickle cell hemoglobin)

→ person's characteristics or traits
(e.g. normal health vs. sickle cell anemia)

Our DNA activity teaches students about DNA structure and replication, but includes only minimal discussion of the function of DNA. We recommend that you follow this DNA activity with our activity "From Gene to Protein -- Transcription and Translation" to teach students about the function of DNA. This hands-on simulation activity (available at http://serendip.brynmawr.edu/sci_edu/waldron/#trans) helps students understand how the sequence of nucleotides in a gene specifies the sequence of amino acids in a protein which in turn determines the structure and function of the protein and results in characteristics such as sickle cell anemia.

One important point that is not mentioned in our Student Handout is that, during actual DNA replication, sometimes mistakes are made and the wrong nucleotide is added to the new strand of

DNA. DNA polymerase can "proofread" each new double helix DNA strand for mistakes and backtrack to fix any mistakes it finds. To fix a mistake, DNA polymerase removes the incorrectly paired nucleotide and replaces it with the correct one. If a mistake is made and not found, the mistake can become permanent. Then, any daughter cells will have this same change in the DNA molecule. These changes are called point mutations because they change the genetic code at one point, i.e. one nucleotide. Some point mutations result in significant effects, such as the genetic disease, sickle cell anemia.

To ensure student understanding of the basic process of DNA replication, this activity ignores many of the complexities observed in actual DNA replication. Also, although the same basic DNA double helix structure is observed in all living organisms (as emphasized in this activity), the structure of chromosomes differs between eukaryotes and prokaryotes. For more information on these topics, see a college textbook for biology majors such as Campbell, Reece, et al., Biology; Freeman, Biological Science; or Raven et al., Biology.