DNA – Teacher Preparation Notes

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In this activity, students extract DNA from their cheek cells and relate the steps in the procedure to the characteristics of cells and biological molecules. Students learn key concepts about the function of DNA during the intervals required for the extraction procedure. A second optional section develops student understanding of the fundamentals of DNA structure, function and replication; this section includes hands-on modeling of DNA replication.

If school policies do not allow your students to extract DNA from their cheek cells, we recommend the directions for extracting DNA from Haloferax (available at https://sites.google.com/site/biologypd/home/biological-molecules) or the DNA Extraction Virtual Lab (available at http://learn.genetics.utah.edu/content/labs/extraction/), either of which can be used together with our analysis and discussion activity about DNA structure, function and replication (available at http://serendip.brynmawr.edu/exchange/bioactivities/DNA).

Learning Goals

- DNA carries the genetic information in all types of living organisms. Each chromosome contains a DNA molecule which contains multiple genes.
- DNA consists of two strands of nucleotides wound together in a spiral called a double helix. Each nucleotide is composed of a phosphate group, a sugar molecule, 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**.
- The sequence of nucleotides in a gene gives the instructions for the sequence of amino acids in a protein, and the sequence of amino acids determines the structure and function of the protein. Proteins have many important functions in our cells and different versions of proteins can result in different characteristics such as albinism versus normal skin and hair pigmentation. Thus, the sequence of nucleotides in a gene can influence our characteristics by determining the structure and function of a protein.
- 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, the double helix structure of DNA and the base-pairing rules provide the basis for producing two identical copies of the original DNA molecule.
- In eukaryotic cells, each chromosome consists of DNA wrapped around proteins. The chromosomes are contained in the nucleus inside a nuclear membrane.

In accord with the Next Generation Science Standards[2]:

- Students will gain understanding of the Disciplinary Core Ideas:
  - LS1.A, Structure and Function, "All cells contain genetic information in the form of

[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] Next Generation Science Standards (http://www.nextgenscience.org/next-generation-science-standards)

DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins."
    - LS3.A, Inheritance of Traits, "Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA."
- Students will engage in the Scientific Practices, using models and constructing explanations.
- This activity provides the opportunity to discuss the Crosscutting Concept, "structure and function".
- This activity helps to prepare students for several Performance Expectations:
    - HS-LS1-1, "Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life…"
    - MS-LS3-1, "Develop and use a model to describe why structural changes to genes located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism."
    - HS-LS3-1, "Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring."

Equipment and Supplies for DNA extraction:
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 for DNA extraction
Before Class:
1. Cut string into 2.5 ft pieces.
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.

Supplies and Preparation for Modeling DNA Replication

Students use nucleotide diagram pieces and tape to carry out DNA replication (adapted from *Instructor Guide to Biology – A Guide to the Natural World* by Jennifer Warner). A template for making enough nucleotide pieces for nine students or pairs of students is provided on the last page of these Teacher Preparation Notes. Obviously, you will need to photocopy enough copies for the number of students you have. You can:

- precut each page in nine parts and provide your students with scissors as well as tape or
- recruit student helpers to precut each page to make 9 packets of 10 nucleotides each.

To reduce the amount of cutting, you may want to remove the blank columns and rows which have been inserted to clarify where the cuts should be made to produce the pieces with 10 nucleotides for each student or pair of students.

Instructional Suggestions and Additional Information

As background for this activity, students should know that DNA is contained in chromosomes inside the nucleus inside each cell. It will also be helpful if students have a basic understanding of the structure and function of proteins. A suggested sequence of learning activities for introducing students to proteins and DNA is provided in "Understanding the Functions of Proteins and DNA" (available at http://serendip.brynmawr.edu/exchange/bioactivities/proteins).

The first part of this activity will probably require a 50-minute laboratory period, and the second part may require as much time if your students are not familiar with DNA structure and replication.

For the second part of this activity, in order to maximize student participation and learning, I suggest that you have your students work in pairs or individually to complete groups of related questions and then have a class discussion after each group of related questions. In each discussion, you can probe student thinking and help them develop a sound understanding of the concepts and information covered before moving on to the next group of related questions. You will probably want to have class discussions after pages 3, 4, 5 and 6 of the Student Handout.

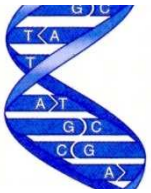
The proteases in the meat tenderizer not only digest histones (the proteins that DNA wraps around), and also break down enzymes in cells which could digest the DNA. Cold alcohol helps to precipitate the DNA molecules by reducing the temperature and dehydrating the salty soapy solution of DNA immediately 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.

The first part of this activity combines hands-on extraction of DNA from human cheek cells with questions on DNA that students answer during the wait times for DNA extraction. The Student Handout for this introductory activity includes multiple simplifications. For example, with regard to question 2, students are expected to respond that all cells in a human body have DNA (unless your students are already aware that mature mammalian red blood cells and platelets do not have DNA). Also, we have omitted mention of the DNA in mitochondria. Similarly, the definition of a gene near the top of page 1 in the Student Handout ignores multiple complexities, including the facts that many genes code for more than one polypeptide and many genes code for RNA that has different functions than mRNA. Also, no mention is made of the importance of regulatory DNA.

Question 4 provides the opportunity to reinforce student understanding that DNA carries the genetic information in all types of living organisms. You may also want to point out that the structure and function of DNA is similar in all types of organisms.

The flowchart on the bottom of page 4 of the Student Handout provides important background for helping students understand why accurate replication of the sequence of nucleotides in DNA is so important, as discussed in question 10. You may want to show your students the following version of the flowchart.

sequence of nucleotides in the DNA of a gene



↓

determines the sequence of amino acids in a protein

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determines the structure and function of the protein
(e.g. normal vs. defective enzyme
to make skin pigment)

↓

influences the characteristics or traits of the organism
(e.g. normal skin pigmentation vs. albino)

The image shown for the folded protein in this version of the flowchart differs from the image shown on page 2 of the Student Handout. The image shown on page 2 is more accurate (http://www.ebi.ac.uk/thornton-srv/databases/cgi-bin/enzymes/GetPage.pl?ec_number=1.14.18.1); the second and third images in the flowchart are designed to suggest how a polypeptide folds into a functional protein.

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 sickle cell anemia. (Additional information is provided in "Understanding the Functions of Proteins and DNA" (available at http://serendip.brynmawr.edu/exchange/bioactivities/proteins).

To ensure student understanding of the basic process of DNA replication, this activity ignores many of the complexities observed in actual DNA replication. For more information, see:

– helpful resources available at http://learn.genetics.utah.edu/content/molecules/ and http://www.hhmi.org/biointeractive/teacher-guide-dna

– a college textbook for biology majors such as Campbell, Reece, et al., Biology; Freeman et al., Biological Science; or Raven et al., Biology

– videos available at http://www.hhmi.org/biointeractive/chemical-structure-dna , http://www.hhmi.org/biointeractive/dna-replication-basic-detail and http://www.hhmi.org/biointeractive/dna-replication-advanced-detail .

Follow-Up Activities

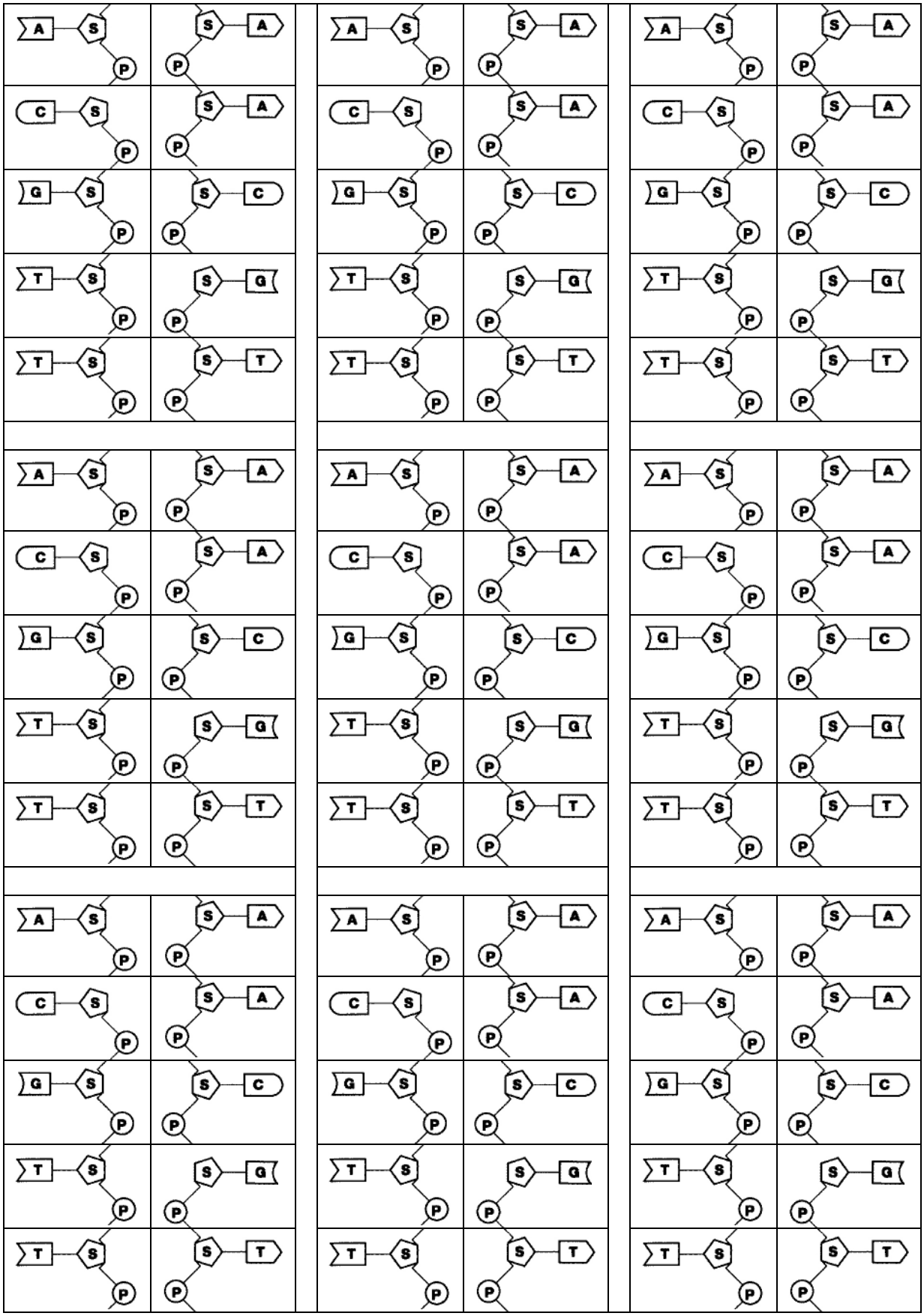
To further develop student understanding of how DNA provides the instructions for protein synthesis and influences our characteristics, we recommend our hands-on modeling activity "From Gene to Protein – Transcription and Translation" (available at http://serendip.brynmawr.edu/sci_edu/waldron/#trans).

To help students understand how chromosomes are separated during cell division and how genes are transmitted from parents to offspring, we recommend our hands-on modeling activity, "Mitosis, Meiosis and Fertilization" (http://serendip.brynmawr.edu/sci_edu/waldron/#mitosis).

Additional suggestions for follow-up activities are provided in:

– "Molecular Biology: Major Concepts and Learning Activities" (available at http://serendip.brynmawr.edu/exchange/bioactivities/MolBio) and

– "Genetics – Major Concepts and Learning Activities" (available at http://serendip.brynmawr.edu/exchange/bioactivities/GeneticsConcepts).



Nucleotides for Nine Students or Pairs of Students