**Genetic markers-based DNA detective activity to solve phyto-forensics case**

**Plant genetics tools used to resolve farmers’ proprietary disputes**

(Grades 9th-12th)

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| **Introduction**: Pull key information from wiki <https://en.wikipedia.org/wiki/DNA_profiling> **Video:** <https://www.youtube.com/watch?v=tpPkmDeS3Dg> **Hands On**: (A) <https://www.fybikon.no/file/andre/06061_dna-fingerprintingbyggesett_molymod.pdf> (B) Solving “The Phyto-Forensics Case” using DNA Fingerprints <https://www.tnstate.edu/tsuaged/PhytoForensics%20Class%20Activity.pdf>  |

 Why DNA is Responsible in Plants’ Hereditary?

### Purpose

Students will understand that DNA is responsible for inheritance of traits from parent to offspring. Activities include assembling puzzle pieces to demonstrate the structures of nucleotides, monomers, DNA strands and double helix.

### Essential Files (maps, charts, pictures, or documents)

* [Talking Glossary of Genetic Terms](https://www.genome.gov/genetics-glossary/g#glossary)
* [Nucleotide Definition and Structure](https://biologydictionary.net/nucleotide/)
* [Genetics and DNA Basics](https://www.youtube.com/watch?v=eOvMNOMRRm8)

### Vocabulary

**Genetic Hereditary:** Inheritance or passing on of traits from one generation (parents) to next (their offspring) through reproduction process.

**DNA (Deoxyribose Nucleic Acid):** The molecule (nucleic acid) that carries genetic instructions in all living things for passing on traits from parents to their offspring(s).

**Nitrogenous Base:** The molecule with central information carrying part of the nucleotide structure, i.e., adenine (A), cytosine (C), guanine (G), and thymine (T).

**Deoxyribose:** A pentose-sugar-ring where two of carbons are named, i.e., one as 5′-end ("five-prime end" and attached to a phosphate group), and another as 3′-end (usually pronounced "three-prime end"), which typically is unmodified from the ribose -OH substituent.

**Nucleotide:** A basic building block of a nucleic acid or a monomer, consisting of a sugar molecule (deoxyribose) attached to a phosphate group and one of the four nitrogen-containing bases, i.e., A, C, G, and T.

**Nucleic Acid Polymer:** Each DNA strand is a polymer made of long chains of nucleotides making a backbone consisting of alternating sugar (deoxyribose) and phosphate groups in 5’ to 3’ direction, while attached to each sugar is one of four bases- A, C, G, and T.

**Double Helix:** A shape formed for the DNA molecule when its two strands wind around one another like a twisted ladder. The two Strands of a DNA molecule are held together by hydrogen bonds (HB) between the bases; A has two HBs T, and C has three HBs with G.

### Background/Agricultural Connections

This lesson will introduce students to DNA (Deoxyribose Nucleic Acid) for plants (also animals etc.) genetic hereditary concepts. Activities through Discovering DNA Ltd. MDNA-STR-408 (molymod®/miniDNA®, Spicing Enterprises Limited, UK) puzzle pieces are modeled after real-life hereditary molecular structures to promote critical thinking skills. The puzzle kit explains the structure of DNA molecule well containing chain of monomeric units each having three components. Unit monomer is called nucleotide which comprises of a sugar (black or white Deoxyribose), a phosphate (purple) and a base (yellow, green, blue or orange for Nucleic Acid). The joining (ligation from 5’ to 3’) of nucleotides through covalent bonds yield single stranded DNA molecule. The hydrogen bonds between the complementary nucleotides (A-T and C-G) joins two single stranded DNA molecules yielding a DNA double helix structure.

### Interest Approach – Engagement

1. Students will explore to know why children appear similar to their parents. Introduce them to plant gametes, i.e., pollen grains and eggs that combine their genetic materials to produce offspring. Explain that the genetic material that these gamete cells contain is called DNA (Deoxyribose Nucleic Acid) which is responsible for hereditary.
2. Watch the Heredity and DNA video clip, [Genetics](http://www.genesinlife.org/genetics-101/how-does-genetics-work).
3. Activity participants should be informed that they will:
	* Explore unit DNA structure, single strand and double helix molecules
	* Learn on three components (sugar, phosphate & base) of a nucleotide
	* Use online resources to identify four kinds of nucleotides as per component bases; A (Adenine, Blue), T (Thymine, Orange), C (Cytosine, Yellow) or G (Guanine, Green)
	* Research how several nucleotides are part of a DNA double helix

### Procedures

**Materials**

**For the class:**

* Discovering DNA Ltd. MDNA-STR-408 (molymod®/miniDNA®, Spicing Enterprises Limited, UK) kit (two boxes and instruction booklet)
* Internet access for research (this part may be done at home for homework)

**For BioFuel (BF) sorghum group:**

* Cytosine (C- Yellow) pieces (C embossed on edge of the base)- 4
* Guanine (G- Green) pieces (G embossed on edge of the base)- 4
* Adenine (A- Blue) pieces (A embossed on edge of the base)- 7
* Thymine (T- Orange) pieces (T embossed on edge of the base)- 7
* Deoxyribose Sugar (Black) puzzle pieces- 22
* Phosphate (Purple) puzzle pieces- 22

**For Traditional Food (TF) sorghum group:**

* Cytosine (C- Yellow) pieces (C embossed on edge of the base)- 3
* Guanine (G- Green) pieces (G embossed on edge of the base)- 3
* Adenine (A- Blue) pieces (A embossed on edge of the base)- 8
* Thymine (T- Orange) pieces (T embossed on edge of the base)- 8
* Deoxyribose Sugar (Black) puzzle pieces- 22
* Phosphate (Purple) puzzle pieces- 22

**For suspicious sample (Unknown Seeds-'XS') group:**

* Cytosine (C- Yellow) pieces (C embossed on edge of the base)- 4
* Guanine (G- Green) pieces (G embossed on edge of the base)- 4
* Adenine (A- Blue) pieces (A embossed on edge of the base)- 7
* Thymine (T- Orange) pieces (T embossed on edge of the base)- 7
* Deoxyribose Sugar (Black) puzzle pieces- 22
* Phosphate (Purple) puzzle pieces- 22

**For each student:**

* Pencil for Lab drawings
* Lab worksheet/ Drawing paper

**Preparation**

* Before the lesson, confirm the contents of Discovering DNA Ltd. MDNA-STR-408 (molymod®/miniDNA®, Spicing Enterprises Limited, UK) kit in two boxes.
* On benches for each the three students’ groups, distribute A (Adenine, Blue), T (Thymine, Orange), C (Cytosine, Yellow) and G (Guanine, Green) puzzle pieces along with that for Deoxyribose Sugar (Black) as well as for Phosphate (Purple).
* Check assembling by pushing the bent knob (5' prime end) from the black/white sugar into the hole in the purple phosphate, the knob from which will then sticks out as 5' prime end. To complete assembling a nucleotide, push the colored base (green, orange, blue or yellow) onto the straight knob on the sugar.
* For yielding single stranded DNA molecule, check joining (ligation from 5’ to 3’) of nucleotides through covalent bonds. The DNA double helix structure has hydrogen bonds between the complementary nucleotides (A-T and C-G) from two opposite single stranded DNAs. The unit of this DNA double helix structure is called base pair (bp) which has two complementary nucleotides (A-T and C-G) joined together.

**Hands-On Activity:**

1. Tell students that in this lab they will learn to DNA in a plant identification case for resolving a farmers’ proprietary dispute.
2. Ask students if they know DNA monomeric unit is called nucleotide which comprises of a sugar (black or white Deoxyribose), a phosphate (purple pieces) and a base [Adenine (Blue), Thymine (Orange), Cytosine (Yellow) and (Guanin (Green) for Nucleic Acid).
3. Inform students that a single stranded DNA molecule is yielded by joining (ligation from 5’ to 3’) of nucleotides through covalent bonds, while the DNA double helix structure has hydrogen bonds between the complementary nucleotides (A-T and C-G) from two opposite single strands.
4. Tell students that they will be assembling DNA molecule that will be used in DNA fingerprinting for phytoforensics. Demonstrate to the students how to build upon model sequentially from each of the three steps.
	* Build unit monomers called nucleotide which comprises of a sugar (black or white Deoxyribose), a phosphate (purple) and a base (yellow, green, blue or orange for Nucleic Acid).
	* Use monomeric units to grow (direction from 5’ to 3’) single stranded DNA molecule by joining of nucleotides through inserting the knob of purple phosphate (attached at 5’ end of sugar) into the hole (3’ end) of next sugar (of another nucleotide).
	* Assemble DNA double helix structure by inserting knobs into holes between the complementary nucleotide bases (A-T and C-G) from two opposite single stranded DNAs.
5. Instruct students to draw the information on DNA monomers, single stands and double helix for discussion in class as groups sharing their concepts.

### Concept Elaboration and Evaluation:

After conducting these activities, review and summarize the following key concepts:

* Genetics is the science of hereditary and plant breeding.
* Geneticists as well as Plant Scientists use their knowledge of DNA and crops to help farmers achieve maximum hereditary potentials. This in turn helps provide a more plentiful food supply in the world.
* Two DNA-strands are held together by hydrogen band between complementary bases (A-T and C-G), while nucleotides within a strand are joined through covalent bonds.

### Variations:

* Instead of preparing demo samples of DNA monomers, single stands and double helix, ask student to build the three structures from random puzzle pieces of phosphate, sugars and bases.
* In addition to the double helix assembly via DNA pieces instruct students to draw the two (A and T) and three (C and G) hydrogen bonds between complementary nucleotide bases on lab worksheet.

### Sources/Credits

This lesson was developed per Formats of Utah Agriculture and California Foundation for Agriculture in the Classroom

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