Biology Honours Specialist – Summer 2010  
Concept Presentation  
Stuart Lithwick

**The Concept:**

**DeoxyriboNucleic Acid**

**Background**:

* Why is DNA so important in our world today?
  + DNA is the instructions used to build all living things
  + DNA is the future of medicine 🡪 Genetic medicine
  + DNA is everywhere:
    - The news: Human genome project, cloning, stem cell research
    - The media: Newspapers, television, radio
    - Careers in Medicine & Genetics
  + DNA-based genetic research has a huge base in Toronto:
    - The human genome project – Dr. S. Scherer at the Hospital for Sick   
       Children
    - Discovery of the CFTR Gene – Dr. L. C. Tsui at the Hospital for Sick   
       Children
    - Breakthrough in Stem Cell Conversions – Dr. Andras Nagy at Mount Sinai
* **DNA in the Curriculum:**
  + DNA appears in a variety of forms throughout the curriculum
    - We have “grade” expectations for our students ☺

|  |  |  |
| --- | --- | --- |
| **Grade** | **Expectations** | **Reference** |
| **1** | **Strand: Understanding Life Systems – Needs and Characteristics of Living Things**  **Specific Expectations:**   * 2.3: Investigate and compare the physical characteristics of a variety of plants and animals, including humans * 2.6: Use appropriate science and technology vocabulary, including *investigation*, *explore*, *needs*, and *food*, in oral and written communication’ * 3.2: Identify the physical characteristics of a variety of plants and animals * 3.3: Identify the location and function of major parts of the human body, including sense organs | **Ontario Curriculum Grades 1-8** |
| **2** | **Strand: Understanding Life Systems – Growth and Changes in Animals**  **Specific Expectations:**   * 2.2: Observe and compare the physical characteristics and the behavioural characteristics of a variety of animals, including insects, using student-generated questions and a variety of methods and resources * 2.7: Use appropriate science and technology vocabulary, including *lifecycle*, *migration*, *adaptation*, *body coverings*, and *classify*, in oral and written communication * 3.1 Identify and describe major physical characteristics of different types of animals | **Ontario Curriculum Grades 1-8** |
| **3** | **Strand: Understanding Life Systems – Growth and Changes in Plants**  **Specific Expectations:**   * 2.2: Observe and compare the parts of a variety of plants * 2.6: Use appropriate science and technology vocabulary, including *stem*, *leaf*, *root*, *pistil*, *stamen*, *flower*, *adaptation*, and *germination*, in oral and written communication. * 3.2: Identify the major parts of plants, including root, stem, flower, stamen, pistil, leaf, seed, and fruit, and describe how each contributes to the plant’s survival within the plants environment. | **Ontario Curriculum Grades 1-8** |
| **4** | **Strand: Understanding Life Systems – Habitats and Communities**  **Specific Expectations:**   * No expectations | **Ontario Curriculum Grades 1-8** |
| **5** | **Strand: Understanding Life Systems – Human Organ Systems**  **Specific Expectations:**   * 3.1: Identify major systems in the human body * 3.2: Describe the basic structure and function of major organs in the respiratory, circulatory, and digestive systems | **Ontario Curriculum Grades 1-8** |
| **6** | **Strand: Understanding Life Systems – Biodiversity**  **Specific Expectations:**   * 2.3: Use scientific inquiry/research skills to compare the characteristics of organisms within the plant and animal kingdoms * 2.4: Use appropriate science and technology vocabulary in oral and written communication * 2.5: Use a variety of forms to communicate with different audiences for a variety of purposes * 3.1: Identify and describe the distinguishing characteristics of different groups of plants and animals * 3.2: Demonstrate an understanding of biodiversity as the variety of life on earth, including variety within each species of plant and animal, among species of plants and animals in communities, and among communities and physical landscapes that support them | **Ontario Curriculum Grades 1-8** |
| **7** | **Strand: Understanding Life Systems – Interactions in the Environment**  **Specific Expectations:**   * No expectations | **Ontario Curriculum Grades 1-8** |
| **8** | **Strand: Understanding Life Systems – Cells**  **Specific Expectations:**   * 1.1: Assess the role of selected technologies in enhancing our understanding of cells and cellular processes * 1.2: Assess the potential that our understanding of cells and cell processes for both beneficial and harmful effects on human health and the environment, taking different perspectives into account * 2.1: Follow established safety procedures for handling apparatus and materials * 2.2: Use a microscope correctly and safely to find and observe components of plant and animal cells and make accurate drawings of their observations * 2.3: Prepare dry and wet-mount slides of a variety of objects for use with a microscope * 2.5: Use appropriate science and technology vocabulary in oral and written communication * 2.6: Use a variety of forms to communicate with audiences for a variety of purposes * 3.2: Identify structures and organelles in cells including the nucleus, cell membrane, cell wall, chloroplasts, vacuole, mitochondria, and cytoplasm, and explain the basic functions of each * 3.3: Compare the structure and function of plant and animal cells | **Ontario Curriculum Grades 1-8** |
| **9 Academic** | **Strand: Biology – Sustainable Ecosystems**  **Specific Expectations:**   * No expectations | **Ontario Curriculum Grades 9-10** |
| **9 Applied** | **Strand: Biology – Ecosystems and Human Activity**  **Specific Expectations:**   * No expectations | **Ontario Curriculum**  **Grades 9-10** |
| **10**  **Academic** | **Strand: Biology – Tissues, Organs, and Systems of Living Things**  **Specific Expectations:**   * B1.1 Analyse, on the basis of research, ethical issues related to a technological development in the field of systems biology and communicate their findings * B2.1 Use appropriate terminology related to cells, tissues, organs, and systems of living things, including prophase & anaphase * B2.2 Examine cells under a microscope or similar instrument to identify the various stages of mitosis in plants and animals * B3.1 Describe the cell cycle in plants and animals, and explain the importance of mitosis for the growth of cells and repair of tissues | **Ontario Curriculum Grades 9-10** |
| **10 Applied** | **Strand: Biology – Tissues, Organs, and Systems**  **Specific Expectations:**   * B2.2 Examine cells under a microscope or similar instrument to identify the various stages of mitosis in animals * B3.1 Describe the cell cycle in animals, and explain its importance for the growth of cells and repair of tissues | **Ontario Curriculum**  **Grades 9-10** |
| **11**  **Academic** | **Strand: Genetic Processes**  **Specific Expectations:**   * D1.1 Analyse, on the basis of research, some of the social, and ethical implications of research in genetics and genomics (e.g. genetic screening, gene therapy, in vitro fertilization) * D1.2 Evaluate, on the basis of research, the importance of some recent contributions to knowledge, techniques, and technologies related to genetic processes * D2.2 Investigate the process of meiosis, using a microscope or similar instrument, or a computer simulation, and draw biological diagrams to help explain the main phases in the process * D3.1 Explain the phases in the process of meiosis in terms of cell division, the movement of chromosomes, and crossing over of genetic material * D3.2 Explain the concepts of DNA, genes, chromosomes, alleles, mitosis, and meiosis, and how they account for the transmission of hereditary characteristics according to the Mendelian laws of inheritance   **Strand: Scientific Investigation Skills and Career Exploration**  **Specific Expectations:**   * A1.2 Select appropriate instruments and materials and identify appropriate methods, techniques, and procedures, for each inquiry. * A1.19 Draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge | **Ontario Curriculum Grades 11-12** |
| **11**  **College** | **Strand: Genetics**  **Specific Expectations:**   * D1.1 Evaluate, on the basis of research, some of the social and ethical implications of genetic research and reproductive technologies * D2.2 Investigate the process of meiosis, using a microscope or computer simulation, and identify, and draw biological diagrams of the phases of meiosis * D3.2 Explain how the concepts of DNA, genes, chromosomes, alleles, mitosis, and meiosis account for the transmission of hereditary characteristics from generation to generation   **Strand: Scientific Investigation Skills and Career Exploration**  **Specific Expectations:**   * A1.2 Select appropriate instruments and materials and identify appropriate methods, techniques, and procedures for each inquiry * A1.5 Conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data | **Ontario Curriculum Grades 11-12** |
| **12** | **Strand: Molecular Genetics**  **Specific Expectations:**   * D2.1 Use appropriate terminology related to molecular genetics including but not limited to Polymerase I, II, and III, DNA Ligase, Helicase, Okazaki fragment, mRNA, rRNA, tRNA, codon, anticodon, translation, transcription, and ribosome subunits * D2.2 Analyse a simulated strand of DNA to determine the genetic code and base pairing of DNA * D2.3 Conduct an investigation to extract DNA from a specimen of plant or animal protein * D3.2 Compare the structures and functions of RNA and DNA, and explain their roles in the process of protein synthesis * D3.6 Describe the functions of some of the cell components used in biotechnology * D3.7 Describe, on the basis of research, some of the historical scientific contributions that have advanced our understanding of molecular genetics.   **Strand: Scientific Investigation Skills and Career Exploration**   * A1.2 Select appropriate instruments and materials and identify appropriate methods, techniques, and procedures, for each inquiry. * A1.5 Conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data. | **Ontario Curriculum Grades 11-12** |

**Essential Expectations:** - Grade 11 Biology Course, Strand D. Genetic Processes:- D3.2 Explain the concepts of DNA, genes, chromosomes, alleles, mitosis, and meiosis, and how they account for the transmission of hereditary characteristics according to   
 Mendelian laws of inheritance

- Grade 12 Biology Course, Strand B. Biochemistry:  
 - B3.2 Describe the structures of important biological compounds, including carbohydrates, proteins, lipids, and nucleic acids, and explain their function within cells

**Misconceptions:**

**-** Since cells are small, the amount of DNA in each cell is not large.

**-** DNA looks like a double-helix when it is examined either under a microscope or with the naked eye.

**Challenges:**

- Making students comfortable with the structure of the DNA molecule (Can be complex)

- Maintaining accuracy while writing out DNA sequences

- Calculating the frequency of bases within DNA sequences (Numeracy)

**Activities: Please refer to the Lesson Sequence and Appendix for further materials and complete methods for the activities and demonstrations included in the “Advance Preparation” section**

**Advance Preparation:**

1) “Total length of DNA in every cell” demonstration  
 - Obtain tape measure

2) DNA modeling:

i) CanDNA – Models of DNA out of candy

- Cut red and black Twizzlers licorice (they are thinner and hollow so work the best) into ½” pieces

- Cut 40 6” lengths of medium-thickness string

- Purchase candy of 4 colours and toothpicks

- Put Twizzlers licorice pieces and candy into separate bowls

- Place bowls, toothpicks, and string onto worktables

- Place a copy of the instructions at every work table

2) BeaDNA – Models of DNA out of beads

- Place beads of 4 colours into separate bowls

- Cut 40 6” lengths of thread that fit the beads and tie knots into the ends

(if there is time)

- Place a copy of the instructions at every work table

3) OrigamiDNA – Paper models of DNA made through folding

- Place a copy of the DNA origami template at every work table

- Place a copy of the instructions at every work table

- Place scissors at every template

3) DNA extraction from bananas – Extraction of DNA from bananas using detergent & ethanol

- Place the 95% ethanol in the refrigerator so that it is chilled for use  
 - Potentially, grind up the banana slightly in advance, as it does take some time

4) Becoming DNA – Student-based reconstruction of a DNA molecule from its parts

- Prepare 8 ½ x 11” sheets of paper with a phosphate, a base, or a sugar on each. Hand one out to each student

**Special Materials Needed: Please refer to Appendix for all materials needed for activities.**

**Lesson Sequence:**

- Opener: Linking of DNA current events (e.g. Sequencing of Woolly Mammoth DNA)

- Lesson 1. Diagnostics lesson and introduction to DNA

1) Diagnostic assessment – Draw a picture of an animal cell

- Drawings are exchanged among peers and marked while student is drawing animal cell on the board

- Goal: To determine what students recall about the structure of the animal cell (from Grade 8)

- The most critical point here is to establish that students remember that DNA is normally found in the nucleus

2) What is the length of the DNA found inside the nucleus?

- Choose one student volunteer, give him/her the end of a tape measure and ask the person to back up until he or she feels that the distance represents the actual length of DNA in one cell.

- Allow other students to give the volunteer feedback.

- Also, select one student in the class (potentially one with low self- esteem, to boost their confidence) and tell them what the actual value is. They become the expert.

- Answers:

- 2 metres of DNA in every cell  
 - 10 trillion cells in the body at any one time 🡪   
 - 1 billion km total  
 - Equal to 35 trips from the earth to the sun and back

3) Introduction to the function of DNA:

- DNA is the recipe book for life

1) Analogy 1: A recipe book for making a cake

**-** DNA is the instruction manual for the building of life

2) Analogy 2: Instructions for building a bookshelf

**-** Both of these analogies are used, to address the diverse array of interests that will be present in the classroom. Inevitably, both analogies will be differentially relevant to different students across the classroom.

- **Lesson 2. The Structure of DNA:**

**-** DNA Structure: Structure of the DNA molecule is described by the teacher on the board using magnetic

- Students follow along using DNA sequence manipulative kits as well, that they are   
 provided with at the start of the unit

– The DNA concepts taught consist of:

**-** DNAis a double stranded molecule  
 - DNA is made up of 4 types of compounds called nucleotides (A, C, G, T)

**-** Inthe DNA molecule A in one strand binds only to T in the other strand  
 - In the DNA molecule G in one strand binds only to C in the other strand

**-** This binding is what holds the two strands together

- Each Nucleotide is made up of 3 parts (Sugar, Phosphate, Base)

**-** When depicting nucleotides, I will regularly replace the full molecular structure of the nucleotide with three shapes, one representing each of the parts.

- For students intimidated by the complexity of the DNA molecule, this can sometimes make it more palatable without significant loss of information.

- Assessment for Learning – Modeling of DNA Molecules – Refer to Appendix for full descriptions of these Modeling approaches1) CanDNA: Models of DNA made out of candy  
 - Great for visual learners, kinaesthetic learners  
 - Complete representation of DNA (sugar, phosphate, and bases)   
 - A lot of fun  
 - Product is edible  
 2) BeaDNA: Models of DNA made out of beads  
 - Great for visual learners, kinaesthetic learners  
 - Only a partial representation of DNA (backbone and bases)   
 3) Origami DNA: Models of DNA made out of paper  
 - Great for visual learners, kinaesthetic learners  
 - Only a superficial representation of DNA (no separate backbone and bases)  
 - Time consuming  
 - Assessment of Learning Exit key:   
 - Students are asked to make a drawing of the model of DNA that they have created, and using their diagram, answer the question, “It is often said that the DNA molecule closely resembles a ladder. Explain using your drawing.”

- By having both the drawing and the question to be answered this addresses two learning styles in a single assessment

- The drawings and answers should be collected at the end of class as students are leaving.

**- Lesson 3: Base Frequency in DNA**

- Assessment of learning at the start of class:

- Students are given the choice of 2 questions to complete:

1) What is the sequence of the opposite strand for the following DNA molecule?

2) Identify the mistakes present in the following DNA molecule. Why are these mistakes?

- Have peers exchange assessments and mark their own, as one student fills in the answer on the board.

- Frequency of nucleotides in DNA:

**-** Nucleotide Frequency: Frequency of nucleotides in a DNA molecule is described by the teacher on the front board using magnetics

- Students follow along using DNA sequence manipulative kits as well, that they are provided with at the start of the unit

- Method to calculate frequency of nucleotides:

- Count the number of nucleotides for a given nucleotide

- Divide by the total number of nucleotides

Example 1: **Teacher demonstrates** approach to solving, and students follow.

- What is the frequency of A, T, C, and G in the following molecule?

Example 2: **Students attempt question independently.** Student takes up the question (with teachers help as needed).

- What is the frequency of A, T, C, and G only in strand 1 of the following   
 molecule?

Example 3: **Student demonstrates approach to solving** with help from others. Students follow.

- What is the frequency of A, T, C, and G in the following molecule?

**-** Assessment for learning:

Problem set with 5 additional frequency problems, collected at the end of class as an exit key

**- Lesson 4: Becoming DNA & Extraction of DNA from Bananas** – Refer to appendix for full lab   
 procedure

**-** Students should begin the lab, reach the point of placing the banana filtrate in the refrigerator, and then participate in Becoming a DNA Molecule

**-** Assessment of Learning: Becoming a DNA Molecule

- Provide students with 8 ½ x 11“envelopes at the start of class

- Each will have a sheet of paper with a part of a nucleotide (sugar, phosphate, or base)

- Students assemble themselves into a DNA molecule

- 2 students will have sheets that say frequency – Those students will have to determine the frequency of each nucleotide in the molecule once it has been built by the rest of the students. The rest of the class can provide assistance

**- Lesson 5: Summative In-class Evaluation:**

- Students will complete a comprehensive in-class Summative Evaluation, to be handed in by the end of the class. This summative evaluation will be as comprehensive as possible, covering everything that pertained to this concept.

- A DNA molecule has base frequencies as follows 12.5% T, 37.5% G, 12.5% A,   
 37.5% C. Draw out a DNA molecule of 24 bp or more in length that exhibits these frequency characteristics. Make sure to include all parts of the nucleotides.

**- Applications and Societal implications**

There are many interesting applications of DNA to society that could be discussed in class at   
 length.

* Ethics of access to DNA information (To Know or not to Know) – Who has the right to have access to DNA information?
* Cloning – Is cloning a technology that is worth pursuing?
* Stem Cells – What potential does stem cell therapy hold in the future?
* Gene Therapy – What medical miracles will become possible through gene therapy?

**- Annotated references:**

**The Ontario Curriculum Grades 1-8, Science and Technology, 2007  
The Ontario Curriculum Grades 9 and 10, Science, 2008  
The Ontario Curriculum Grades 11 and 12, Science, 2008  
Di Giuseppe, M., Vavitsas, A., Ritter, B., Fraser, D., Arora, A., Lisser, B. Nelson Biology   
 12, Thompson Canada Publishers, 2003.  
Amount of DNA per cell -** [**http://hypertextbook.com/facts/1998/StevenChen.shtml**](http://hypertextbook.com/facts/1998/StevenChen.shtml) **DNA from Candy -** [**http://library.thinkquest.org/19037/making\_a\_candy\_model.html**](http://library.thinkquest.org/19037/making_a_candy_model.html) **DNA from beads -** [**http://www.accessexcellence.org/AE/AEC/AEF/1995/ross\_jewelry.php**](http://www.accessexcellence.org/AE/AEC/AEF/1995/ross_jewelry.php) **Origami DNA -** [**http://www.iro.umontreal.ca/~csuros/IFT3290/materiel/origami\_inst.pdf**](http://www.iro.umontreal.ca/~csuros/IFT3290/materiel/origami_inst.pdf) **DNA Extraction from Bananas** [**http://www.migeneticsconnection.org/genomics/Genetic%20Variation/DNAExtractionBanana.htm**](http://www.migeneticsconnection.org/genomics/Genetic%20Variation/DNAExtractionBanana.htm)

**Appendix**

**CanDNA – Models of DNA out of candy**

* Derived from the procedure given at the website listed in the annotated references.

Materials

Red Liquorice   
Black Liquorice  
Toothpicks  
Candy (4 colours)  
String

Procedure

1. Cut up red and black liquorice into ½” pieces and place into separate bowls
2. Cut string into 8” pieces

NOTE:

Black liquorice represents sugars  
Red liquorice represents phosphate groups  
Yellow candy = G  
Red candy = C  
Orange candy = A  
Green candy = T

1. Thread two pieces of string through alternating “sugars” and “phosphate groups”
2. Tie the ends of the strings together, to make sure nothing falls off
3. Puncture two bases (candies) that bond together with one toothpick, placing the candies in the middle of the toothpick.
4. Embed the ends of the toothpick into “phosphate groups” on both strands of the DNA model.
5. Continue until all Phosphate groups have bases.
6. Tie off the other end of the string.

**BeaDNA – Models of DNA out of beads**

* Derived from the procedure given at the website listed in the annotated references.

Materials

Thread   
Beads (4 colours)

Procedure

NOTE:  
  
Yellow beads = G  
Red beads = C  
Blue beads = A  
Purple beads = T

1. Tie a knot between the very ends of two pieces of thread to make sure no beads fall off
2. Thread beads corresponding to bases that bond to one another onto each of the threads
3. Continue until the end of the thread is reached.
4. Tie off the other end of the thread.

Origami DNA – Origami paper-folding DNA model

* Refer to reference given in the annotated references section and the PDF posted on the wikispaces wiki: HSbiology-physics-2010

DNA Extraction from Bananas – from [**http://www.migeneticsconnection.org/genomics/Genetic%20Variation/DNAExtractionBanana.htm**](http://www.migeneticsconnection.org/genomics/Genetic%20Variation/DNAExtractionBanana.htm)

**Banana DNA Extraction**

This DNA extraction is simple and works every time but the DNA is not pure. Some of the protein is still present. It is nice however because the students get to see and hold in their hand the substance they have been studying that seems so abstract and hard to believe it even exists.

Materials for each group of students:

* graduated cylinder
* beakers 100ml and 2x250ml (or jars that same size)
* liquid dishwashing detergent (clear solution works better than cloudy)
* 1/2 of a banana
* knife
* mortar and pestle
* salt
* coffee filter
* rubber band
* test tube
* **COLD** 95% ethanol (this is something that you can't substitute)
* wooden splint
* refrigerator

Procedure:

* Make a 10% solution of dishwashing detergent in one of your 250ml beakers (make enough to fill the mortar half way)
* Slice the banana into the mortar
* Add the 10% detergent solution to cover the fruit
* Add a pinch of salt
* Grind the banana in the soap solution until there are no lumps (this is the hardest part, have the students take turns)
* Fasten a coffee filter to the 250 ml beaker with a rubber band so there is room for the fruit to be poured into the filter
* Pour the fruit and soap mixture into the filter and place in a cold place to filter
* Clean up your lab area while you are waiting for the filtering to complete
* Remove the filter and through away the contents
* Pour enough of the liquid into a test tube to fill it 2 cm high
* Add twice the volume of 95% ethanol (try to layer the alcohol on top by gently pouring it down the side of the test tube)
* The DNA will precipitate in the boundary between the alcohol and the banana mixture as a cloudy mass
* Spool the DNA onto your wooden splint