

Manitoba

Education, Citizenship and Youth

Grade 12 BIOLOGY A Foundation for Implementation Part 1 - Genetics Unit 2 – Mechanisms of Inheritance

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For more information or to provide feedback, contact:

Aileen Najdich

Science Consultant

Program Development Branch

W240-1970 Ness Avenue

Telephone: 1-800-282-8069 ext. 2138 or 945-2138 (local)

E-Mail: anajdich@gov.mb.ca

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S4B-2-01 Outline significant scientific contributions/discoveries that led to our understanding of the structure and function of the DNA molecule. Include: timeline, individual contributions, multidisciplinary collaboration, competitive environment...

Entry-level Knowledge

None

Teacher Notes

The historical development of the structure and function of DNA is an excellent example of how science operates. The challenge for teachers is to make the excitement of the discoveries come alive to students and help them gain an understanding of the nature of science

Teacher Background

Contributions/Discoveries

- Friedrich Miescher: isolated nucleic acids from the nuclei of white blood cells.
- Phoebus Levene: showed that DNA and RNA are distinct nucleic acids but that both are composed of long chains of nucleotides.
- Walter Sutton and Theodor Boveri: suggested the genetic material of the cell is contained in chromosomes (chromosomal theory of inheritance)
- T.H. Morgan et al: showed that genes are linear arrays on chromosomes
- Fred Griffith: experiments indicated that DNA is probably the genetic material
- Oswald Avery et al: experiments indicated that DNA is probably the genetic material
- Alfred Hershey and Martha Chase: clearly showed that DNA is the genetic material of the cell
- Edwin Chargaff: number of adenines always equals the number of thymines, number of cytosines always equals the number of guanines
- Rosalind Franklin and Maurice Wilkins: X-ray crystallography indicated helical structure of DNA
- James Watson and Francis Crick: proposed the double-helix model of DNA structure

Suggestions for Instruction

Activate

Opening Question

Pose the following question to students:

We often see diagrams and models of DNA in electronic and print media. How do you think scientists determined the structure of DNA?

**Acquire/Apply
Investigation**

DNA extraction labs are readily available in textbooks, lab manuals and on the internet. They are relatively simple to perform, use inexpensive materials (dish soap, NaCl, ethanol and plant or animal tissue...) and simple equipment (beakers, test tubes, mortar and pestle...).

The extraction technique used is in fact similar to that developed by Friedrich Miescher in 1869, however students today have the advantage of modern refrigeration to keep ice and ethanol cold. The DNA produced will form long strands that can be spooled on to a glass rod or stir stick. The actual double helix structure cannot be seen with the naked eye.

Assess student lab skills during the investigation using a lab skill checklist. The lab report can be assessed as well.

Research Project and Presentation

To individual or groups of students, assign a scientist or team of scientists that contributed to our understanding of the structure and function of the DNA molecule. See assignment details below in Suggestions for Assessment.

After the presentations, students create a chain concept map (flowchart) summarizing the information. The flowchart should show how the developments in our understanding of DNA relied on and used the ideas and techniques developed by previous workers.

Assess student understanding of the nature of science by asking the following: Historians debate the extent to which key individuals actually changed the course of history. Do you think the individual scientists or teams of scientists discussed in this section influenced the progress of knowledge? Explain your answer.

Suggestions for Assessment**Research Project and Presentation**

To individual or groups of students, assign a scientist or team of scientists that contributed to our understanding of the structure and function of the DNA molecule. Students research the following:

- Date of work or publication
- Key finding
- Biographical information (e.g. where the research took place, background of the researcher...)

Students present their work to the class in a skit format. For example, TV interview, debate between scientists, TV news report, dramatization of the event... Assess presentations using the Performance Assessment: Skit Rating Scale (See Appendix 1).

Resources

The DNA Interactive website (www.dnai.org) has a timeline outlining the history of DNA science. Text biographies of contributors are available, as well as video and audio clips of interviews with researchers including James Watson, Maurice Wilkins, and Raymond Gosling (Rosalind Franklin's graduate student). Students can follow how the researchers discovered the structure of the DNA molecule.

The PBS series DNA (aired January 2004) Episode 1: The Secret of Life traces the race to determine the structure of DNA. The series website www.pbs.org/wnet/DNA contains a historical timeline and a 3D DNA explorer.

The PBS Nova episode The Secret of Photo 51 (aired April 2003) investigates the role played by Rosalind Franklin in the discovery of the structure of DNA. The episode website www.pbs.org/wgbh/nova/photo51 contains interviews, slide shows and interactives.

The science journal Nature has a special November 22, 2004 feature commemorating the 50th anniversary of the structure of DNA. It can be viewed on-line at <http://www.nature.com/nature/dna50>.

S4B-2-02 Describe the structure of a DNA nucleotide.

Include: deoxyribose sugar, phosphate group, nitrogenous bases.

S4B-2-03 Describe the structure of the DNA molecule.

Include: double helix, nucleotides, base-pairing, gene

Entry-level Knowledge

Students are familiar with the terms DNA, chromosomes and genes from Senior 1 Science. They have not previously studied the structure of DNA, but may have prior knowledge gathered from the media.

Teacher Notes

Review with students that DNA is the nucleic acid that stores and transmits the genetic information of a cell from one generation to the next. The use of diagrams, videos, models and computer animations to illustrate and describe the structure of nucleotides and DNA will enhance student understanding of the structure of DNA.

Teacher Background

A DNA molecule is made of building blocks known as nucleotides. Each DNA nucleotide consists of a 5-carbon sugar (deoxyribose), a phosphate group, and one of four possible nitrogenous bases (adenine, thymine, guanine, cytosine). The nucleotides are linked together to form chains that can vary in length and in

the sequence of the nitrogenous bases. It is sequence of nitrogenous bases that provides the genetic code of the DNA.

Suggestions for Instruction

Activate

Opening Question

Write the letters DNA on the board or overhead. Ask students what comes to mind when they see these letters. Invite students to call out their responses. Accept all responses, and write them all down on the board/overhead, clustering them into categories. For example, nucleotide, ACGT, double helix = structure; DNA fingerprinting, crime investigation TV shows = forensic uses; frankenfoods, GMO, recombinant DNA = gene technology...

Acquire/Apply

Direct Instruction

Use diagrams, videos, models or computer animations to illustrate and describe the structure of nucleotides and DNA. Discuss with students that a nucleotide is composed of a 5-carbon sugar (deoxyribose), a phosphate group and a nitrogenous base. As there are 4 different nitrogenous bases (adenine, guanine, thymine and cytosine), there are 4 possible nucleotides.

Analogy

When examining the structure of the DNA molecule, use the analogy of a twisted ladder. The rails of the ladder correspond to the sugar-phosphate backbones of the DNA molecule, while the rungs of the ladder equate to the paired nitrogenous bases. The rails of a ladder are strong as they lend stability to the ladder. The “rails” of DNA are held strongly together by covalent bonds, while each half of the “rung” is joined to the other by weaker hydrogen bonds. Both a ladder and DNA have complementary halves.

In order for a ladder to support the weight of the climber, the rungs of the ladder must all be of the same width. Therefore, thymine can only bond with adenine, and cytosine only with guanine. If cytosine and thymine bonded, the rung would be too short. A bond between guanine and adenine would make the rung too long. The double helix shape of the DNA molecule is the result of the twisting of the ladder into a corkscrew shape.

Suggestions for Assessment

Exit Slip

While analogies can be useful when learning new concepts, they are not perfect representations concept. Discuss the strengths and weaknesses of the ladder analogy for describing the structure of DNA.

Student responses should be accurate and logical.

Strengths of the analogy can include:

- Double helix shape well represented
- Location of sugar-phosphate backbone accurate
- Location of nucleotides accurate

Weaknesses of the analogy can include:

- Individual different nucleotides (A,T,C,G) not represented
- Individual sugars and phosphates not shown
- Base pairing (A-T, C-G) not represented

Model Building

DNA model building activities are readily available in textbooks, lab manuals and on the Internet. They are relatively simple to perform, having students build DNA models from paper “nucleotides”, clay and paperclips, beads and pipe cleaners, or other materials.

Assess student models for accuracy in base pairing. Be sure the base pairs are able to readily separate as the models can be used in the future to simulate DNA replication and mRNA transcription.

Resources

The DNA Interactive website (www.dnai.org) contains 3D animations of the structure of the DNA molecule. Students can play an interactive game and build a fragment of DNA.

The Genetic Science Learning Center website <http://gslc.genetics.utah.edu> contains a section called the Basics and Beyond. Information on the structure of DNA as well as DNA replication, transcription and translation is provided in tutorials and interactive animations.

S4B-2-04 Describe the process of DNA replication.

Include: template, semi-conservative replication, role of enzymes

Entry-level Knowledge

None

Teacher Notes

Discuss the accuracy of the replication process by emphasizing how one side of the molecule acts a template for the formation of the other. The process is semi-conservative because each new DNA molecule formed contains one half of the original molecule.

Describe the role enzymes play in the replication process. One enzyme causes the strands of DNA to separate, exposing the bases. A second enzyme recognizes the exposed bases and matches them up with free, complementary nucleotides. The enzyme then bonds the sugars and phosphates together to form the backbone of the new strand. Other enzymes “proofread” the new strands to ensure accuracy, and make corrections if required.

Teacher Background

Emphasise the fact that the two new DNA molecules formed in replication should be identical to the original molecule. The accuracy of the replication process maintains the integrity of genetic code from one generation of cells to the next, and from parent to offspring.

DNA replication occurs fairly quickly; as many as 4000 nucleotides per second are replicated. This helps explain why bacterial cells, under ideal conditions, can reproduce in twenty minutes.

Suggestions for Instruction

Activate

Opening Question

Pose the following to students:

When Watson and Crick developed their model of DNA structure, they immediately recognized that the complementary nature of the two sides of the helix could provide a mechanism for accurate DNA replication. Given your knowledge of DNA structure, can you propose a mechanism for accurate DNA replication?

Acquire/Apply

Direct Instruction

Use diagrams, videos, models or computer animations to illustrate and describe the semi-conservative replication of DNA.

Model Building

Using the DNA models they built for the previous outcomes, students simulate the process of DNA replication. Two new DNA models should result, each model having one original DNA strand and one new strand.

Suggestions for Assessment

Exit slip

Pose the following questions to students:

How does the structure of DNA lend itself to replication?

Why is accuracy so important in replication?

Assess answers for logic and accuracy. See the Teacher Notes and Teacher Background in this section for more information.

Resources

The DNA Interactive website (www.dnai.org) has 3D animations illustrating the processes of replication, transcription and translation.

The Genetic Science Learning Center website <http://gslc.genetics.utah.edu> contains a section called the Basics and Beyond. Information on the structure of DNA as well as DNA replication, transcription and translation is provided in tutorials and interactive animations.

S4B-2-05 Compare DNA and RNA in terms of their structure, use and location in the cell.

S4B-2-06 Outline the steps involved in protein synthesis. Include: mRNA, codon, amino acid, transcription, tRNA, anticodon, ribosome, translation.

Entry-level Knowledge

In grade 8, students learn about the major structures in plant and animal cells and their functions. The role of proteins in the body is discussed in Senior 3 Biology.

Teacher Notes

While students can generally understand the processes of DNA replication and transcription, the concept of translation can be difficult for them to grasp. The use of a variety of instructional strategies can help students to better understand protein synthesis.

Teacher Background

RNA differs from DNA in the following ways:

- RNA contains the nitrogenous base uracil instead of thymine
- RNA contains ribose instead of deoxyribose
- RNA is single-stranded
- RNA carries the genetic information found in DNA in the nucleus to the ribosomes in the cytoplasm
- RNA comes in three forms (messenger, transfer, ribosomal), all of which are involved in translating the genetic information into the amino acid sequence of proteins.

Suggestions for Instruction**Activate*****Opening Question***

Ask students to recall the location and function of the following cell parts: nucleus, nuclear membrane, cytoplasm, ribosome.

Pose the question to students: If the genetic code for proteins is contained in the DNA in the nucleus of the cell, and the ribosomes that construct the proteins are located in the cytoplasm of the cell, how is it possible that proteins get built?

Acquire/Apply***Analogy***

With the assistance of a few students, simulate the assembly line manufacture of “widgets”, and relate this to the processes of transcription and translation.

Big Boss (DNA) has the plans for widgets

Supervisor (mRNA) makes a copy of the plan and carries the copy to the shop floor assembly line

Runners (tRNA) bring the required components (amino acids) to the assembly line from stock shelves

Assembler (ribosome) links the components together to form widgets (proteins).

Direct Instruction

Use diagrams, videos, models or computer animations to illustrate and describe the processes of transcription and translation. Students can complete a Compare and Contrast frame to differentiate between DNA and RNA or transcription and translation.

Concept Map

Using information gathered from direct teaching or text material, students create a chain concept map (flow chart) to illustrate the process of protein synthesis.

Suggestions for Assessment***Investigation***

The Construct a Critter activity simulates the mechanism of protein synthesis and determines the traits of fictitious animals called critters. See Appendices 2a and 2b for the investigation and answer key.

Exit slip

Ask students to complete the chart using the mRNA genetic code:

DNA complement	DNA template	mRNA codon	tRNA anticodon	amino acid
<u> </u>	<u> </u>	<u> </u>	<u>GCG</u>	<u> </u>
<u>GTA</u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
<u> </u>	<u> </u>	<u>AAC</u>	<u> </u>	<u> </u>
<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u>Tryptophan</u>
<u> </u>	<u>AGC</u>	<u> </u>	<u> </u>	<u> </u>

Answers

DNA complement	DNA template	mRNA codon	tRNA anticodon	amino acid
CGC	GCG	CGC	GCG	arginine
GTA	CAT	GUA	CAU	valine
AAC	TTG	AAC	UUG	asparagine
TGG	ACC	UGG	ACC	tryptophan
TCG	AGC	UCG	AGC	serine

Resources

The DNA Interactive website (www.dnai.org) has 3D animations illustrating the processes of replication, transcription and translation.

The Genetic Science Learning Center website <http://gslc.genetics.utah.edu> contains a section called the Basics and Beyond. Information on the structure of DNA as well as DNA replication, transcription and translation is provided in tutorials and interactive animations.

S4B-2-07 Relate the consequences of gene mutation to the final protein product.

Examples: point mutation in sickle cell anemia, frameshift mutation in B-thalassemia...

S4B-2-08 Discuss implications of gene mutation to genetic variation. Include: source of new alleles.

Entry-level Knowledge

In Senior 1, students investigated and described environmental factors and personal choices that may lead to genetic mutation.

Teacher Notes

Be sensitive to the fact that students in your class may have a condition such as sickle cell anemia or thalassemia, or may have a family member, neighbour or friend with the condition.

Review with students the fact that only mutations that arise in sex cells can be passed on the next generation. Somatic cell mutations cannot be passed on to offspring.

Teacher Background

Mutation is the only mechanism by which new genetic material enters the gene pool. Often mutations involving base substitutions are neutral or without effect. For example, redundancies in the genetic code mean that a single amino acid may be specified by several codons. Therefore, a change in one base may not result in a change of amino acid. Also, the substitution of one amino acid for another may not affect the function of an enzyme, as the enzyme's active site is not changed.

In general, random changes in DNA nucleotides result in altered proteins that do not function as well as the normal protein. Hemoglobin molecules in individuals with severe (homozygous) forms of sickle cell anemia and thalassemia cannot carry oxygen as efficiently. Sickle cell anemia is an example of a point mutation, the substitution of one DNA nucleotide for another, so that one codon may code for a different amino acid. B-thalassemia is an example of a frameshift mutation, involving the deletion or addition of nucleotides, so that every codon beyond the point of insertion or deletion is read incorrectly during translation. See Appendix 3: Point and Frameshift Mutations for more detail.

Occasionally however, the altered protein function more effectively, or works in a way that gives a selective advantage to its possessor. This is how new alleles arise and contribute to evolution. In the case of sickle cell anemia and thalassemia, individuals heterozygous for the condition are only mildly affected by anemia. However, they have a higher resistance to malaria than do those whose have homozygous normal hemoglobin. This is an example of heterozygous advantage in which individuals with two alleles of a gene have an increased survival rate.

Suggestions for Instruction**Activate*****Opening Question***

Ask students what comes to mind when they hear the word "mutation". Accept all student contributions. Note that most, if not all student contributions have negative connotations. Ask students if they think that a mutation could ever be a good thing. Why or why not?

**Acquire/Apply
Investigation**

Provide the following 15 nucleotide sequence of a DNA template to students:

TAC GCA TGG AAT TAT

Ask students to determine the mRNA codons for the DNA, and then determine the amino acid sequence.

Answers:

AUG CGU ACC UUA AUA

MET-ARG-THR-LEU-ISO

Next, ask students to individually change one DNA nucleotide at random (i.e. simulate a point mutation), and to determine the effect of the DNA change on the amino acid sequence. Compare all resulting amino acid sequences in the class. Note that not all point mutations lead to changes in the amino acid sequence. These are called neutral mutations. This is due to the redundancies in the code; that is a single amino acid may be specified by several codons. For example, four different codons all code for glycine.

Using the original DNA sequence, ask students to individually add or remove one DNA nucleotide at random (i.e. simulate a frameshift mutation), and to determine the effect of the DNA change on the amino acid sequence. Compare all resulting amino acid sequences in the class. Note the significant change in the amino acid sequence caused by the insertion or deletion of a nucleotide. This can lead to a devastating impact on protein function and serious consequences for the organism affected.

Direct Instruction

Use the examples of sickle cell anemia and thalassemia to demonstrate how random changes in DNA nucleotides often result in altered proteins that do not function as well as the normal protein. In the discussion, note how individuals heterozygous for either condition have an advantage over homozygous dominant and recessive individuals in their resistance to malaria.

Suggestions for Assessment**Exit Slip**

Describe the difference between a point mutation and a frameshift mutation.

Which is likely to have the greatest impact on an organism?

Assess student responses for logic and accuracy. See the investigation in this section for more information.

S4B-2-09 Investigate an issue related to the application of gene technology in bioresources.

Include: understanding the technology/processes involved, economic implications, a variety of perspectives, personal/societal/global implications.

Entry-level Knowledge

In Senior 1 Science students investigated Canadian and international contributions to research and technological developments in the field of genetics. Students also discussed current and potential applications and implications of biotechnologies including their effects upon personal and public decision making, and used the decision-making process to address a current biotechnology issue. Topics of discussion included genetic engineering, cloning, Human Genome Project, DNA fingerprinting.

Teacher Notes

On-going research in the field of gene technology has provided both great promise and possible threat for the future. The knowledge base and its technological applications are rapidly advancing and quickly changing. However, many ethical and practical issues surrounding the use of gene technology are hotly debated today.

Teacher Background

Possible topics include:

- Xenotransplantation
- Genetically modified organisms (GMO's) for food production
- Production of drugs/vaccines using genetically modified organisms
- Patenting of transgenic organisms
- Species conservation
- Cloning animals, including pets
- "recreating" extinct species (e.g. Jurassic Park)

Suggestions for Instruction**Activate*****Bioethics Questions***

Present students with the series of statements and ask them to predict which are true and which are false. See Appendix 4 for the blackline master. The correct answers are included.

Headlines

Introduce this activator by presenting a headline and article that you have found on the topic to the class. Brainstorm possible topics with students. Then ask

students to find a newspaper or magazine headline about the application of gene technology in bioresources. Examples may include:

<u>Bioresource</u>	<u>Issue</u>
Food Production	Use of genetically modified organisms (GMOs)
Agriculture/Horticulture	Patenting of transgenic organisms (e.g. seeds)
Microbiology	Production of drugs/vaccines using GMOs
Animals	Cloning animals including pets
Animals/Plants	Recreating extinct species (e.g. Jurassic Park)
Animals/Plants	Species conservation, storing DNA

Post the headline on the class bulletin board. The headlines and articles will be the introduction to the presentation later in the unit.

Acquire/Apply

Headlines

Ask students to read the article that accompanied their headline and consider the following:

- What technology or processes are outlined?
- What issue is discussed in the article?
- What perspectives are presented?
- What implications (societal, global and personal) are there?
- If there are any visuals, what story do they tell?

Throughout your instruction in the unit, ask students to highlight or make a separate list of key vocabulary that you would like them to use in their presentation.

Field Trip/Guest Speaker

Students visit a lab where gene technology is used, or invite a gene technologist to the classroom. Students prepare questions in advance of the tour or visit.

Questions may include:

- Who are your clients? (if appropriate)
- What background/education/experience is required to work in the field of gene technology?
- What gene technology methods are used?
- What proportion of your work generates revenue? What proportion is pure research?
- Does your work provide a service to the public?

Suggestions for Assessment

Presentation

Students prepare oral presentations, accompanied by visuals, that outlines the technology, issue, perspectives and implications of the use of gene technology in

bioresources. See Appendices 5a, 5b, 5c, and 5d for Gene Technology: Student Information, Student Worksheet, Teacher Information and Student Presentation Rubric.

Resources

Introducing a Gene to a Cell: Recombinant DNA Technology. This animation illustrates how a transgenic plant is created.

<http://www.bioteach.ubc.ca/TeachingResources/Applications/GMOpkgJKloseGLampard.html>

The article “Genetically Modified Foods” by Arshad Chaudhry outlines the process involved in developing genetically modified crops, the ethics of GM foods, and how GM food is regulated in Canada. It is available on the BioTeach website <http://www.bioteach.ubc.ca/Bioengineering/btcorn>

The article “A Controversy in Our Corn: Is Bt Corn Safe?” by Hardy Hall outlines the process involved in developing the genetically modified corn, as well as the pros and cons of its use. It is available on the BioTeach website <http://www.bioteach.ubc.ca/Bioengineering/GeneticallyModifiedFoods>

Council for Biotechnology Information www.whybiotech.com provides information about the benefits of biotechnology.

S4B-2-10 Investigate an issue related to the application of gene technology in humans.

Include: understanding the technology/processes involved, ethical and legal implications, a variety of perspectives, personal/societal/ global implications.

Entry-level Knowledge

In Senior 1 Science students investigated Canadian and international contributions to research and technological developments in the field of genetics. Students also discussed current and potential applications and implications of biotechnologies including their effects upon personal and public decision making, and used the decision-making process to address a current biotechnology issue. Topics of discussion included genetic engineering, cloning, Human Genome Project, DNA fingerprinting.

Teacher Notes

On-going research in the field of gene technology has provided both great promise and possible threat for the future. The knowledge base and its technological applications are rapidly advancing and quickly changing. However,

many ethical and practical issues surrounding the use of gene technology are hotly debated today.

Teacher Background

Possible topics include:

- DNA fingerprinting
- Cloning humans
- Gene therapy
- Stem cell research
- DNA sequencing
- Human Genome Project
- Use of DNA in evolution research
- “Designer” babies
- Genetic screening

Suggestions for Instruction

Activate

Movie

Show a movie or video incorporating themes of gene technology such as GATTACCA. Set in the future, this 1997 science fiction thriller incorporates the themes of gene manipulation and genetic testing. It can be used as a springboard to a discussion of bioethics.

Discussion

Knowledge of one’s genetic screen could profoundly affect the cost of insurance. Insurance companies operate on a risk assessment basis, where individuals with a greater potential of developing health complications are charged more than individuals who are deemed healthy. Actuaries look at statistics to determine how much their clients should be charged. With current advancements in genetic testing, there is the potential to discriminate those with “bad genes”. It is quite possible that individuals classified as high risk may be denied the opportunity to purchase insurance. However, insurance companies must operate as a business, looking out for themselves, their shareholders, and their clients’ best interests.

Divide the class into two large groups. Assign each group a different role.

Group 1:

You represent an individual who has obtained a genetic screen and would like to purchase life insurance. Results show that you are at extremely high risk for developing cancer and hypertension (high blood pressure). However, you are currently a healthy individual who doesn’t smoke, watches your diet and exercises on a regular basis. Explain why you should be given the opportunity to purchase life insurance at a reasonable price.

Group 2:

You represent an insurance company. A potential client approached your company about the possibility of purchasing life insurance. After reviewing the file, including the genetic screen, you realize she falls into a high risk category. Explain to the potential client why you need to charge him/her considerably more for life insurance.

(Adapted from Yas Shirazu and Donna Lee. GATTACA Activities. BioTeach website www.bioteach.ubc.ca)

Acquire/Apply

Stem Cell Activity

ENGAGE: Stem Cells is a high school teaching resource on stem cell research developed through the Ontario Genomics Institute (OGI) by Genome Canada, and the Joint Centre for Bioethics (JCB) at the University of Toronto. The resource was developed in collaboration with teachers and students and has been distributed at no charge to high schools across Canada. Downloadable copies of the resource materials are available in English and French on the site (www.stemcellnet.ca).

The resource consists of class modules, developed as lessons with support material. Four modules explore the ethical implications of controversial new technologies. The modules center on an exercise that introduces students to stem cells and the medical potential of stem cell research, raises associated ethical issues and challenges them to develop legislation that would govern the use of stem cell research.

Investigation

Using DNA Fingerprinting in Forensic Science is an activity in which students are introduced to the processes used in DNA fingerprinting. The investigation demonstrates how restriction enzymes and gel electrophoresis are used in making DNA fingerprints that can then be utilized to make a positive identification of a criminal from a group of murder suspects. Student responses to questions and their simulated gel electrophoresis results can be assessed. See Appendix 6a for the investigation, and Appendix 6b for the answers to the discussion questions.

Suggestions for Assessment

Microtheme – Gene Technology

Microthemes are writing assignments designed to help students learn the material by looking at it in a different way (Martin, 1989). They require more than simply reading the text or articles and memorizing notes. A specific problem is addressed in each microtheme, allowing the writer to illustrate his/her understanding. See Appendices 7a & 7b for assignment details and an assessment rubric.

Teacher's reference:

The National Association of Criminal Defence Lawyers website (www.nacdl.org) contains online *The Champion* magazine. The August 1998 issue has the article "The Ordeal of Guy Paul Morin: Canada Copes With Systemic Injustice", which provides an overview of the case.

Resources

The Bio Teach website (www.bioteach.ubc.ca) contains a variety of teaching resources including animations, articles, tutorials, classroom activities, games etc. related to this topic.

The Genetic Science Learning Center website <http://gslc.genetics.utah.edu> contains sections on a variety of topics that could be examined in this outcome. Information is provided by tutorials and interactive animations. Sections include The Biotechniques Laboratory (gel electrophoresis), Gene Therapy, Cloning in Focus, and Stem Cells in the Spotlight.

The Canadian Broadcasting Corporation has a number of titles available on videotape for this topic.

The Gene Squad (1998). This documentary traces the solution to a 20 year old murder case in British Columbia using new developments in DNA fingerprinting. The case raises questions about the impact of DNA fingerprinting on the presumption of innocence, and privacy concerns related to DNA databases.

Amanda's Choice (2003). As she watches her mother's rapid decline at age 39 due to early onset Alzheimer's disease, a young woman is faced with the dilemma of being tested the presence of the gene.

Appendix

Appendix 1: Performance Assessment: Skit Rating Scale (BLM)

Element	Rating			
1. The skit presents information that is appropriate to the assignment	1	2	3	4
2. The story line of the skit is interesting and helps to present the information	1	2	3	4
3. The actors convey the information accurately.	1	2	3	4
4. Props, sound and/or costumes support the characters and to enhance the presentation of the information	1	2	3	4
5. Dialogue supports the development of the characters, the story line and presentation of information	1	2	3	4
6. The skit was rehearsed sufficiently	1	2	3	4
7. The audience could easily hear and see the skit	1	2	3	4
8. The skit is entertaining to the audience	1	2	3	4

Comments

Appendix 2a: Construct a Critter (BLM)

Introduction:

Proteins play many vital roles to living organisms, ranging from catalyzing chemical reactions to providing movement and support. This variety of roles requires proteins to have a variety of structures. Differences among proteins are the result of their amino acid sequence.

The amino acid sequences for proteins are coded for in each individual organism's DNA in segments called genes. In a process known as transcription, the DNA code for a protein is copied by messenger RNA (mRNA) in the nucleus of the cell. The mRNA then carries the copy of the code to ribosomes in the cytoplasm of the cell.

The process of translation occurs when a second type of RNA, called transfer RNA (tRNA), brings the amino acids to the ribosomes in the order specified in the mRNA. The ribosomes function to join the amino acids in the correct order to form the protein.

Purpose:

In this activity, you will simulate the mechanism of protein synthesis and determine the traits of fictitious animals called critters. Critters have two chromosomes, each containing four genes. Each gene (A, B, C, D, E, F, G, H) is responsible for the proteins that create a certain trait.

Materials (per student):

Colored pencils, markers or crayons

Procedure:

1. Determine the trait for Gene A of your critter by completing the box labelled Gene A in the Data Table. Note the DNA sequence and then list the corresponding mRNA codons in the space provided.
2. Determine the sequence of amino acids by matching the mRNA codons to the specific amino acids found in Table 1. List the amino acid abbreviations in the space provided in the data table, using a hyphen to separate each amino acid.
3. Use Table 2 to identify the trait that matches the amino acid sequence. Record this information in the Data Table.
4. Repeat steps 1 – 3 for the remaining traits.
5. Using all 8 traits, sketch a diagram of your critter.

Observations:

Data Table

Gene A

DNA AAC TTA TAC GTT

mRNA _____

amino acid
sequence _____

trait _____

Gene B

DNA GGG CTC

mRNA _____

amino acid
sequence _____

trait _____

Gene C

DNA GGG AAG TGA

mRNA _____

amino acid
sequence _____

trait _____

Gene D

DNA GTG AAC GTT ATG

mRNA _____

amino acid
sequence _____

trait _____

Gene E

DNA CAC ACG TCG

mRNA _____

amino acid
sequence _____

trait _____

Gene F

DNA CCC CGT ACC ACG

mRNA _____

amino acid
sequence _____

trait _____

Gene G

DNA TAA GCG

mRNA _____

amino acid
sequence _____

trait _____

Gene H

DNA CTA TTC TTA

mRNA _____

amino acid
sequence _____

trait _____

Table 1:

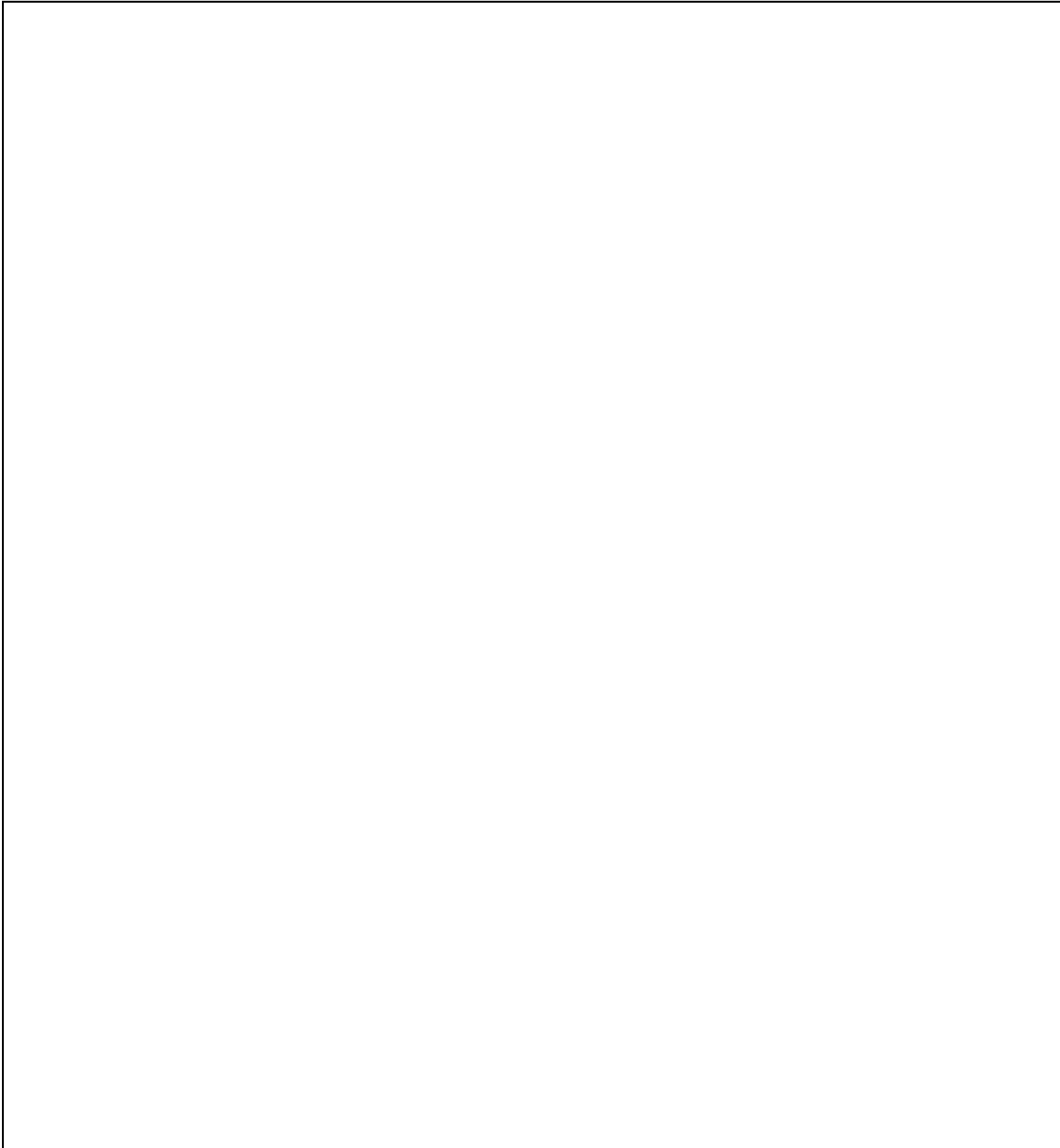
mRNA codon	Amino Acid	Amino Acid Abbreviation
GAU	aspartic acid	ASA
AUG	methioine	MET
UUG	leucine	LEU
GAG	glutamic acid	GLA
UGG	tryptophan	TRY
CAA	glutamine	GLU
AAG	lysine	LYS
UAC	tyrosine	TYR
AAU	asparagine	ASP
CCC	proline	PRO
UGC	cysteine	CYS
UUC	phenylalanine	PHE
ACU	threonine	THR
CAC	histidine	HIS
AUU	isoleucine	ISO
GCA	alanine	ALA
CGC	argenine	ARG
GUG	valine	VAL
AGC	serine	SER
GGG	glycine	GLY

Table 2:

Amino Acid Sequence	Trait
PRO-PHE-THR	small nose
PRO-LEU-THR	big nose
ASA-LYS-ASP	freckles
ASA-LEU-ASP	no freckles
PRO-GLA	four-legged
VAL-CYS-SER	male
GLA-CYS-LYS	female
ISO-ARG	four antennae
PRO-ALA-TRY-CYS	blue fur
GLY-ALA-TRY-CYS	orange fur
LEU-ASP-MET-GLU	plump
LEU-ASP-MET-ISO	skinny
HIS-LEU-GLU-TYR	purple eyes
VAL-PHE-GLU-TYR	yellow eyes

Questions

1. Sketch a diagram of your critter in the box below.

A large, empty rectangular box with a thin black border, intended for a student to draw a diagram of a critter.

2. Where in the cell:
 - a) are the DNA instructions located?
 - b) does transcription occur?
 - c) does translation occur?
3. Describe three similarities and three differences between DNA and RNA.
4. Why is specific base pairing is essential to the processes of transcription and translation?
5. How could the change in one DNA nucleotide alter the protein formed?
6. Suppose you knew the sequence of amino acids in a protein. How could you determine the DNA sequence for that gene?
7. Create two additional traits for your critter (e.g. foot size, number of teeth...). Give their DNA sequences, the mRNA codons and the resulting amino acid sequences.

Appendix 2b: Construct a Critter Answer Key**Observations:**

Data Table

Gene A		Gene B	
DNA	AAC TTA TAC GTT	DNA	GGG CTC
mRNA	UUG AAU AUG CAA	mRNA	CCC GAG
amino acid sequence	LEU-ASP-MET-GLA	amino acid sequence	PRO-GLA
trait	plump	trait	four-legged
Gene C		Gene D	
DNA	GGG AAG TGA	DNA	GTG AAC GTT ATG
mRNA	CCC UUC ACU	mRNA	CAC UUG CAA UAC
amino acid sequence	PRO-PHE-THR	amino acid sequence	HIS-LEU-GLU-TYR
trait	small nose	trait	purple eyes
Gene E		Gene F	
DNA	CAC ACG TCG	DNA	CCC CGT ACC ACG
mRNA	GUG UGC AGC	mRNA	GGG GCA UGG UGC
amino acid sequence	VAL-CYS-SER	amino acid sequence	GLY-ALA-TRY-CYS
trait	male	trait	orange fur
Gene G		Gene H	
DNA	TAA GCG	DNA	CTA TTC TTA
mRNA	AUU CGC	mRNA	GAU AAG AAU
amino acid sequence	ISO-ARG	amino acid sequence	ASA-LYS-ASP
trait	four antennae	trait	freckles

Questions:

1. The critter drawn should show the following traits:
 - Plump
 - Four-legged
 - Small nose
 - Purple eyes
 - Male
 - Orange fur
 - Four antennae
 - Freckles

2. a) The DNA instructions are located in the nucleus of the cell.
b) Transcription occurs in the nucleus of the cell.
c) Translation occurs in the cytoplasm of the cell.

3. Similarities between DNA and RNA.
 - Both contain adenine, guanine and cytosine
 - Both are nucleic acids
 - Both contain phosphate groups
 - Both use base pairing during their formation

Differences between DNA and RNA.

 - DNA contains thymine, RNA contains uracil
 - DNA contains deoxyribose, RNA contains ribose
 - DNA is double-stranded, RNA is single-stranded
 - DNA stores the genetic code, RNA transmits the genetic code by assembling proteins

4. Specific base pairing is essential to the processes of transcription and translation to ensure the genetic code found in DNA is correctly transferred to the amino acid sequence during protein formation.

5. One change in one DNA nucleotide could alter the mRNA codon, thereby changing corresponding amino acid in the protein.

6. You could determine the DNA sequence for a gene if you knew the sequence of amino acids in a protein by working backwards. From the amino acid sequence, you could decode the mRNA sequence, and then determine the DNA sequence.

7. Examine the DNA sequences, the mRNA codons and the resulting amino acid sequences for accuracy in the two additional critter traits.

Appendix 3: Point and Frameshift Mutations (BLM)

Point mutation: substitution of one DNA nucleotide for another, so that one codon may code for a different amino acid.

Normal beta hemoglobin chain

ATG GTG CAC CTG ACT CCT **GAG** GAG AAG TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT...
Val His Leu Thr Pro **Gln** Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly...

Sickle Cell beta hemoglobin chain

ATG GTG CAC CTG ACT CCT **GTA** GAG AAG TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT...
Val His Leu Thr Pro **Val** Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly...
^

Substitution of thymine for adenine causes coding for valine instead of glutamine. This causes the beta hemoglobin chain to fold incorrectly, producing defective hemoglobin. The red blood cells are distorted into a sickle or crescent shape and their oxygen-carrying capacity is reduced.

Frameshift mutation: deletion or addition of nucleotides, so that every codon beyond the point of insertion or deletion is read incorrectly during translation.

Normal beta hemoglobin chain

ATG GTG CAC CTG ACT CCT GAG GAG AAG TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT...
Val His Leu Thr Pro Gln Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly...

B-Thalassemia hemoglobin chain

ATG GTG CAC CTG ACT CCT GAG GAG **AAG** TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT...
Val His Leu Thr Pro Gln Glu Lys Ser Ala Thr Ala Leu Trp Gly Lys Val Asn Val Asp Gln Val Gly

-AA

ATG GTG CAC CTG ACT CCT GAG GAG **G** TCT GCC ACT GCC CTG TGG GGC AAG GTG AAC GTG GAT GAA GTT GGT...

ATG GTG CAC CTG ACT CCT GAG GAG **GTC** TGC CGT TAC TGC CCT GTG GGG CAA GGT GAA CGT GGA TGA
Val His Leu Thr Pro Gln Glu **Val** Cys Arg Tyr Cys Pro Val Gly Gln Gly Glu Arg Ala **Stop**
^ ^

Missense from point of nucleotide deletion creates an early polypeptide chain termination. The beta hemoglobin molecule is short, producing a defective hemoglobin molecule. The red blood cells are smaller than normal and their oxygen-carrying capacity is reduced.

Appendix 4: Bioethics Questions (BLM)

Which of the following statements is false?

1. Although strongly condemned, it is still legal to clone humans in Canada.
2. In 1991, a pharmaceutical company signed a contract in Costa Rica, estimated to be home to between 5 to 7% of all the worlds' species. In exchange for the right to screen, develop and patent new products from plants, microorganisms and animals in the Costa Rican rainforests, this company paid \$1.1 million to a local biodiversity program. With an estimated 500,000 species in Costa Rica, this works out to \$2 per species.
3. In 1989, 37 people in the United States died after consuming a food supplement called L-tryptophan that had been produced by genetically engineered bacteria. The food supplement was considered "substantially equivalent" and safe for human consumption.
4. The Human Genome Diversity Project, nicknamed the "Vampire Project" by critics, was intent on harvesting DNA samples from as many as 722 human populations, many of them indigenous peoples. Researchers were collecting blood, tissue and hair samples from, amongst others, the San people of the Kalahari, the Saami of northern Scandinavia and the Penan of Sarawak.
5. A company called "Genetic Savings and Clone" provides gene banking and genetic services for clients. This includes the cloning of your favourite pet.

Answer:

1. FALSE. In 2001 the federal government passed a law stating that human cloning is illegal in Canada, with a possible fine of no more than \$500,000 and a jail term of no more than 10 years.
2. TRUE. The pharmaceutical company in the question is MERCK. This topic addresses the controversial issue of biopiracy, whereby multinational businesses offer deals to developing nations in return for full rights to the country's natural flora and fauna. In some respects, these deals are often unfair to the country (for example, if MERCK has made a similar agreement with the entire planet, the deal would cost only about \$20 million). However, it should be stressed that these deals are seldom all inclusive, meaning that some percentage of revenue (usually small) is returned to the country.
3. TRUE. This brings up a number of points. Firstly, arguably the weakest link in the argument for GM crops is current mechanism of food testing. Termed as Substantial Equivalence, this is a rather archaic method derived

from selective breeding practices (i.e. if you cross one kind of corn with another kind of corn, you will get something that should be a corn plant as well!). Although the introduced gene itself may have full FDA approval which does go through rigorous standards and tests, the plant is seldom tested as a whole after the introduction of the gene. In other words, there is a distinct possibility that the organism is somehow altered in a desirable way. This is actually how a variant of the tryptophan amino acid came along, resulting in health effects. BUT, it should also be stressed that the health problems ultimately stemmed from an allergic reaction, which in truth, is something that always has the possibility of happening in any scenario (GM or not).

4. TRUE. However, the project has since been cancelled. The idea being that through the examination of populations and also examining their disease/genetic history, you have an incredibly powerful tool of correlating health with genetic data. For instance, you would argue that the Sherpas in the Himalayas are probably going to have some genetic code that allows them to withstand the effects of high altitude better. Still, although in theory, this project sort of sounds like a good idea, but realistically it is a cultural and intellectual nightmare. There are however similar projects underway - check out DeCode Pharmaceuticals in Iceland.
5. TRUE. Crazy as it seems, but that is a hallmark of what biotechnology can be about. Is it wrong or right? That's actually a tough call, and really depends on personal opinion. These are the guys that cloned the cat (named "cc:" or copycat). Check out their website at <http://www.savingsandclone.com/index.cfm>.
In December of 2004, a Dallas-area woman had her cat successfully cloned. She paid \$50,000 (US) for Little Nicky, the clone of her deceased 17 year old cat Nicky.

Author David Ng, from

<http://www.bioteach.ubc.ca/TeachingResources/Bioethics/BioethicsQs.html>

Appendix 5a: Gene Technology Presentation - Student Information (BLM)

Review the headlines presented throughout the unit and the issues discussed in class. Which issue interests you the most? On which issue can you find adequate information for your presentation (e.g. current, covers a variety of point of view, catchy visuals etc.)?

Prepare a presentation that outlines the technology, issue, perspective and implications. Focus on the varied point of view - what are the concerns of each side? You must use two current sources of information (within the last two years).

Your presentation will have two parts, visual and oral. The visual may take a variety of forms such as slideshow, model, poster, demonstration and so on, and is meant to outline the key ideas of your presentation. You must give the details in your 5 – 7 minute oral presentation.

In the oral presentation, introduce your topic, the type of technology involved, and the issue, then, discuss two differing perspectives on the issue, as well as the societal, global and personal implications. Back up your points with facts from your research. See the Student Worksheet for more information.

Throughout the unit, you have learned how genes work in organisms and how we can manipulate that knowledge to our advantage. You must use the facts and vocabulary of the unit in your presentation.

Appendix 5b: Gene Technology Presentation Outline – Student Worksheet (BLM)

Your presentation outline must be approved before you proceed. Bring in at least two resources to review with your teacher.

Topic: _____

Type of Technology: _____

Issue: _____

Perspective A: _____

Perspective B: _____

Possible Actions: _____

Societal Implications: _____

Global Implications: _____

Personal Implications: _____

Other Key Points: _____

Type of Visual Presentation: _____

Appendix 5c: Gene Technology Presentation - Teacher Information

Present a headline from a magazine or newspaper article about the application of gene technology in bioresources. Brainstorm possible topics with the students. Schedule deadlines for finding headlines and presentation dates.

You can expect that students may bring a variety of headlines that many not fit the topic, or will be factual and not issue-based. This is a good opportunity to discuss the dynamic nature of biology, even if the article is not suitable for the presentation.

Sample Presentation Outline:

Topic: Genetically Modified Food

Type of Technology: Genes do not always work when spliced into foreign surroundings; they need help to function. Biotechnologists do not simply insert genes; instead they use promoters. A promoter is a gene fused to a DNA section from a pathogenic virus that promotes gene expression. The gene then functions, but not in its natural way. It acts like an invading virus.

Issue: Do the benefits of using Genetically Modified Foods outweigh their detriments?

Perspective A: Traditional breeding methods are slow and labour-intensive. Through genetic modification, organisms can be given a desirable gene in one generation. That gene can be from similar or distantly related species. For example, Ingard, a genetically modified cotton, contains a gene from a soil bacterium that makes it more resistant to a caterpillar pest. The economic benefit of using the GM cotton is that it requires less herbicide use. The crop may also be healthier. The economic detriment of using the GM cotton is that the seeds are much more expensive to buy.

Perspective B: The major arguments against GM foods are the potential risks to the environment and possible risks to humans. There is a concern that the GM gene will spread into the environment, as evidenced by the case of contamination of local crops by Round-Up Ready Canola in Saskatchewan in the late 1990's. Will we see new allergic reactions, exposure to toxins and new diseases emerge by using viral and bacterial vectors to transfer genes?

Possible Actions:

- Grow GM crops (recognizing limitations on distribution)
- Use some GM crops only for animal feed
- Do not use GM crops without further testing

Societal Implications:

- A healthier human population from improved food sources (e.g. rice that contains Vitamin A that helps prevent blindness)

Global Implications:

- Accessibility of GM crops – can everyone afford to grow them?
- Growing GM crops in marginal areas (e.g. developing salt-tolerant crops)
- Growing GM crops over a larger range (e.g. frost/drought resistant crops such as frost-tolerant strawberries)

Personal Implications:

- Healthier food sources (e.g. potatoes that absorb less oil when fried are being developed)
- Choosing whether or not to grow GM crops

Other Key Points: Monsanto versus Schmeiser court case over the use of Round-Up Ready Canola.

Type of Visual Presentation:

- Powerpoint
- Lots of GM food pictures, canola pictures, focus on how genes are spliced, picture of a label for GM food.

Appendix 5d: Assessment Rubric for Gene Technology Student Presentation (BLM)

Name: _____

Criteria	4	3	2	1
Content	Excellent depth of understanding evident, issue, two perspectives and implications clearly identified	Good understanding of topic evident, issue, two perspectives and implications identified	Basic understanding of topic evident, issue, two perspectives and implications identified somewhat	Minimal understanding of topic evident, issue, two perspectives and implications poorly identified
Organization	Presentation is very well organized, logical, and interesting	Presentation is organized, logical and interesting	Presentation shows signs of organization but some parts do not fit the topic	Presentation shows poor organization and lack of preparation
Visual	Excellent use of visual, visual supports the key ideas well	Good use of visual, visual supports the key ideas	Adequate use of visual visual supports the key ideas somewhat	Poor use of visual, visual does not support the key ideas
Delivery	Words clear, spoken at correct speed, voice loud enough to be heard easily	Most words clear, often spoken at correct speed, voice loud enough to be heard easily	Some words clear, spoken too quickly at times, voice sometimes too low to be heard easily	Many words unclear, spoken too quickly or slowly, voice too low to be heard easily
Audience	Audience is very involved and interested	Audience is involved and interested	Audience is somewhat involved and interested	Audience is not involved or interested

Comments:

Score: _____
20

Appendix 6a: USING DNA FINGERPRINTING IN FORENSIC SCIENCE (BLM)

Introduction

The use of DNA fingerprinting for identification purposes is becoming more and more accepted. The laboratories doing the work must be meticulous in following correct procedures, as sloppy lab work has caused this type of evidence to be thrown out of court in a trial.

Note that, in order for this procedure to be used, the criminal must have left some DNA behind. This generally means cellular material (sperm cells in the case of a rape, blood, skin scraping under the fingernails of the victim, roots attached to hair that had been pulled out, etc...).

This activity will demonstrate how restriction enzymes and electrophoresis are used in making DNA fingerprints that can then be used to make a positive identification of a criminal from a group of suspects.

The Crime

Late one night the famous rock star, Rockina, returned to her luxurious apartment after an appearance at a concert. As she entered her locked apartment, she noticed that everything in her apartment was a mess – the drawers had been emptied out onto the floor, the cushions from the couch were ripped open, and the safe behind the picture on the wall had been opened. Then she noticed that the lights were on in her bedroom. She stormed into the bedroom and surprised a burglar in the process of removing her magnificent (and expensive) jewellery from its hiding place under the mattress. Indignant, she jumped on the burglar and tried to stab the person with her nail file. While she was able to inflict a small wound, she was no match for the assailant's knife. In the subsequent struggle, she was killed, and the murderer escaped with her jewellery.

The Clues

When the housekeeper, Casparina, entered her apartment the next day, she saw the body and immediately called the police. When the police noted that there had been no signs of forced entry, the investigation narrowed to people who knew Rockina and who had a key to her apartment. The suspects included:

- Casparina, the housekeeper, who had recently had a bitter argument with Rockina over a refused raise in salary.
- Lucifer, Rockina's her former boyfriend, who she had just jilted for another man.
- Pinky, the leader of her weight lifting class, who was Rockina's new boyfriend. It was rumored that Pinky was insanely jealous of Rockina's fame.

When it was established that all three of the suspects had a key to Rockina's apartment, that all three had a motive for killing her, and that all of them had no ironclad alibi for the evening that Rockina was killed, the police realized that they had a problem. They decided to hire a world famous forensic science team to use DNA fingerprinting to prove which of the suspects was guilty of Rockina's murder.

The Science

Forensic scientists make DNA fingerprints from DNA found in blood, sperm, skin and other body cells. These scientists make use of a type of enzyme called *restriction endonucleases*, more commonly called **restriction enzymes**. When these enzymes recognize a certain area of a DNA molecule (ie. a specific order of bases), they cut the DNA at that point. When they cut the DNA, they do so unevenly, making a jagged cut.

e.g. the restriction enzyme EcoRI cuts DNA at the following base sequence:

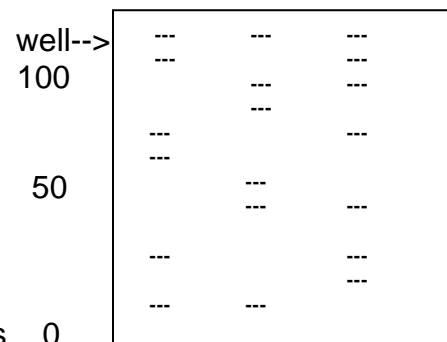
GAATTC
CTTAAG

e.g. the restriction enzyme HindIII cuts DNA at the following base sequence:

AAGCTT
TTCGAA

Restriction enzymes produce a DNA fragment where cuts have been made. Since each restriction only cuts DNA at one particular sequence of bases, different size fragments are produced.

After the restriction enzymes have cut the DNA, the fragments in each sample are separated by size using a technique called **gel electrophoresis**. In this technique, each sample is placed in a well (a hole going part way into the material) in a block of agarose gel (which is similar to a block of highly purified Jello-like substance). An electric current is passed through the agarose, which then pulls the smaller fragments through the gel faster than the larger fragments. The separated fragments end up as lines sorted by size and form a recognizable pattern.



The Investigation

1. Divide into investigative teams of 2 – 3 individuals, and obtain 3 sheets showing the same portion of DNA from each of the suspects and the DNA from the sample of blood taken from Rockina's nail file and 3 sheets for showing the results of gel electrophoresis.
2. One investigator will analyse the DNA using the restriction enzyme EcoRI, the second investigator will analyse the DNA using the restriction enzyme HindIII, and the third investigator will analyse the DNA using both restriction enzymes simultaneously. To do this:
 - a) Look for sequences of bases where the restriction enzyme(s) will make cuts in the DNA and mark on the sheet exactly where the cuts occur.
 - b) Count the bases that will be in one strand of that fragment and write that number above the fragment.
Note: Always use the top strand of the fragment when counting.
 - c) Use the fragment size count numbers to estimate the location of the bands in agarose gel after electrophoresis. Draw the bands (as ruler lines), labelling the sheet with the restriction enzyme(s) used. Above each band, write the number of bases in that fragment.
Note: Use two different colours when drawing the bands on the sheet with both restriction enzymes.

Solving the Crime

Answer the following questions based on the results of your team's investigation:

1. What do the EcoRI gel results show?
2. What do the HindIII gel results show?
3. Who murdered Rockina?
4. Explain why scientists use a combination of restriction enzymes rather than just one.
5. Suppose the lab technician did a poor job of making the agarose gel and the agarose was not dissolved well in the water when the gel was made. As a consequence, the gel has pockets of more dense material interspersed in a less dense background. Explain how this could affect the electrophoresis results.
6.
 - a) What would happen if the restriction enzymes were damaged somehow and didn't work?
 - b) How would this affect the gel electrophoresis results?
 - c) Explain how the gel would look and why it would look that way.

7. This method of using gel electrophoresis for separating DNA fragments is the basis for procedures used in areas other than forensic science. For instance, it is the basis of one of the procedures for identifying genetic diseases in fetuses and for determining which individuals are carriers of certain genetic diseases.
- If a mutation occurred where one base was changed to another within the cutting area of a restriction enzyme, what would happen?
 - Would the gel electrophoresis results look the same?
 - Explain how this could be used in identifying the presence or absence of genetic diseases.

(from *Favorite Labs From Outstanding Teachers Vol. II*, National Association of Biology Teachers)

PORTIONS OF DNA – STUDENT HANDOUT

Restriction Enzyme: EcoRI

From the nail file

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Casparina's DNA

TTGAGTATTCAAGCTTCCGATGGAATTCGAGAATTCAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCATAAGTTCGAAGGCTACCTTAAGCTCTTAAGTTTGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Pinky's DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Lucifer's DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAGCTTGATCGTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTGAAGTAGCAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

PORTIONS OF DNA – STUDENT HANDOUT**Restriction Enzyme: HindIII**

From the nail file

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Casparina's DNA

TTGAGTATTCAAGCTTCCGATGGAATTCGAGAATTCGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCATAAGTTCGAAGGCTACCTTAAGCTCTTAAGTTCGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Pinky's DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Lucifer's DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAGCTTGATCGTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTGAAGTAGCAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

PORTIONS OF DNA – STUDENT HANDOUT**Restriction Enzymes: EcoRI and HindIII**

From the nail file

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTTCGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Casparina's DNA

TTGAGTATTCAAGCTTCCGATGGAATTCGAGAATTCAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCATAAGTTCGAAGGCTACCTTAAGCTCTTAAGTTCGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Pinky's DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAATCAGAAGCTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTAGTCTTTCGAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

From Lucifer's DNA

TTGAGAATTCAAGCTTCCGATGGAATTCGAAGCTTGATCGTTATAGAATTCGCGCTAAGCTTCCCGGAATTCGTTCCATA
AACTCTTAAGTTCGAAGGCTACCTTAAGCTTTCGAAGTAGCAATATCTTAAGCGCGATTTCGAAGGGCCTTAAGCAAGGTAT

GEL ELECTROPHORESIS RESULTS – STUDENT HANDOUT

Restriction Enzyme: EcoRI



GEL ELECTROPHORESIS RESULTS – STUDENT HANDOUT

Restriction Enzyme: HindIII



GEL ELECTROPHORESIS RESULTS – STUDENT HANDOUT

Restriction Enzyme: EcoRI and HindIII



Appendix 6b: Answers to Discussion Questions

1. The EcoRI gel results show that Pinky and Lucifer have a pattern similar to that found on the nail file.
2. The HindIII gel results show that Casperina and Pinky have a pattern similar to that found on the nail file.
3. Pinky murdered Rockina.
4. The use of a combination of restriction enzymes will produce a greater variety of different size fragments of DNA. This will increase the probability of producing a different pattern in the gel for each person.
5. If the agarose gel was of an uneven consistency, then the different size fragments would not move through it as they should. Fragments would move more slowly through a more dense area, and more quickly through a less dense area. This would make the comparison of one person's gel pattern to that of the DNA left at the crime scene unreliable.
6. a) If the restriction enzymes were damaged, then they wouldn't cut the DNA into smaller fragments.
 - b) The gel results would be useless.
 - c) You would see only one band on the gel and it would be near the well, because the larger the piece of DNA, the less it travels.
7. a) A change of one base in the cutting area would mean that DNA would not be cut by the restriction enzyme.
 - b) A larger fragment would result, giving a different appearance on the gel.
 - c) In order to diagnose the presence or absence of a genetic disease in a person, you would first obtain the gel result of a individual with the disease, and an individual without the disease. Then you would get a DNA sample from the person being diagnosed, and produce a gel. Finally, you would compare the three gels. If the person does not have the disease, his/her gel would be similar to that of the unaffected individual. If the person has the genetic disease, his/her gel would be similar to that of the individual with the disease.

Appendix 7a: Gene Technology Microtheme Assignment - Student Handout (BLM)

Microthemes are writing assignments designed to help you learn the material by looking at it in a different way (Martin, 1989). They require more than simply reading the text or articles and memorizing notes. A specific problem is addressed in each microtheme, allowing the writer to illustrate his/her understanding.

The microtheme should be 300-400 words in length and may include diagrams. In this case, dialogue format should be used. Spelling and grammar will be checked. Any work simply rewritten from a text with little attempt at dialogue format, or work with many errors will be returned to be rewritten.

Did you know that...

- In a 1986 National Science Foundation study, 57% of Americans claimed to have little or no understanding of DNA
- In a 1987 survey, the majority of Americans claimed that they had not heard of gene technology
- The state of public ignorance threatens our ability to make informed public decisions about gene technology issues (e.g. regulations governing the use of recombinant DNA, the validity of DNA science in the legal system, the use of fetal stem cells in research...)

Do you think our understanding has improved measurably?

Microtheme

The Guy Paul Morin criminal case is a famous Canadian example of how DNA evidence freed an innocent man from life imprisonment for murder. Research the case and the use of DNA fingerprinting or profiling. Include one article on the Morin case and one article on the DNA fingerprinting procedure. Highlight the key points. When you have done your reading, prepare to write your microtheme.

Imagine that the defence attorney in the 1995 trial wants to use DNA fingerprinting evidence to prove Morin's innocence. His problem is that the jury is not very familiar with the DNA fingerprinting procedure. You have been called as an expert witness for the defence, as it is felt that your explanation would be more easily understood by the jury. The defence attorney does not want a technical expert that will talk above the heads of the jury.

Prepare your presentation and write it up as a dialogue between you and the defence attorney. Be sure to outline the DNA fingerprinting procedure. As mishandling of the evidence has been a problem in this case, you must indicate how the materials were properly collected and tested. What are the proper guidelines to follow? Include one diagram that you will use to instruct the jury.

Appendix 7b: Gene Technology Microtheme Assessment Rubric (BLM)

Criteria	0	1	2	3
DNA Fingerprinting Content	little content is directed to this topic	content is inaccurate, little or no attempt is made to use scientific terms	content is accurate but not detailed, maybe lacking in scientific terms	content presented is accurate and detailed, content is written at the high school level using scientific terms
Link to Case	no mention made of specific case	case is mentioned but no specifics are included	some specifics of case are mentioned, but link to DNA evidence is unclear	specifics of case are referred to, DNA fingerprinting is presented as a reasonable option in this case
Resources	no articles attached, or they are	one article on the topic is attached	two articles are attached, but not the two specific topics	two articles are attached, one on the Morin case one on DNA fingerprinting
Visual	no diagram	diagram is inaccurate or not detailed	diagram is approaching level of accuracy and detail expected	diagram is adequate, accurate, detailed and labelled
Format	no dialogue or, at least 200 words short	little dialogue is used, or at 100 words short	some dialogue is attempted, proper length	stayed in character in dialogue format, proper length