

INCREASING STUDENT COMPREHENSION OF PROTEIN SYNTHESIS THROUGH
INQUIRY BASED LABORATORY ACTIVITIES AND DNA MODELS

BY

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ABSTRACT
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The goal of this project was to teach protein synthesis to high school juniors and seniors in a secondary Anatomy and Physiology class using DNA models and laboratory techniques. The activities were aligned to develop a macro-to-micro approach so that each activity was intentionally related to the overall goal of making a protein. The unit began with students learning about proteins and how they work in the body, and the activities were then organized to scale back to how the proteins are made. To objectively evaluate the learning, students were given a pre-test and a post-test that covered the points to be presented. Data analysis, which included a paired T-Test, indicated that participation in unit activities successfully increased the students' understanding of protein synthesis.

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TABLE OF CONTENTS

LIST OF TABLES	vi
LIST OF FIGURES	vii
INTRODUCTION	
THEORETICAL FRAMEWORK	1
RESEARCH AND DESIGN	6
DEMOGRAPHICS	13
IMPLEMENTATION	
OUTLINE OF ACTIVITIES	16
REVIEW OF ACTIVITIES	18
RESULTS AND DATA	29
DISCUSSION	41
CONCLUSION	46
APPENDICES	47
APPENDIX 1 –FORMS	
A. MDE HIGH SCHOOL CONTENT EXPECTATIONS	49
B. PARENT CONSENT FORM	51
C. STUDENT LABORATORY SAFETY CONTRACT	53
APPENDIX 2 – TEACHER NOTES AND INSTRUCTIONS	
A. LIST OF POWERPOINT LECTURES	55
B. PLANTING GUIDE	56
C. LECTURE AND CLASS DISCUSSION POINTS	57
D. TEACHER NOTES:	
GENETICALLY MODIFIED ORGANISMS RESEARCH	60
E. DNA MODELING ACTIVITIES: TEACHER NOTES	62
APPENDIX 3 – STUDENT ASSIGNMENTS AND ACTIVITIES	
A. MODEL ORGANISM READING HOMEWORK	65
B. FOUR LEAF STAGE DIAGRAM	68
C. GENETICALLY MODIFIED ORGANISM RESEARCH	69
D. PROTEIN RESEARCH ASSIGNMENT	70
E. KNOW YOUR NUCLEOTIDES	71
F. REPLICATION IS REFRESHING	75
G. PROTEIN SYNTHESIS SATISFIES	79
H. PROTEIN SYNTHESIS PRACTICE	84
I. STUDENT WORK EXAMPLE	85

APPENDIX 4 – ASSESSMENT TOOLS	
A. UNIT PRE/POST-TEST	90
B. DRAWING CONCLUSIONS ESSAY	93
REFERENCES	95

LIST OF TABLES

TABLE 1:	UNIT PLAN BY DAY	16
TABLE 2:	TEST SCORES BY STUDENT	30
TABLE 3:	TEST SCORES BY QUESTION	31
TABLE 4:	MICHIGAN HSCE'S	49
TABLE 5:	PLANTING OUTLINE	56
TABLE 6:	AMINO ACID SYMBOLS AND ABBREVIATIONS	84

LIST OF FIGURES

FIGURE 1:	STUDENT POPULATION	13
FIGURE 2:	ETHNICITY	14
FIGURE 3:	WRONG ANSWER ANALYSIS QUESTION 1	33
FIGURE 4:	WRONG ANSWER ANALYSIS QUESTION 2	33
FIGURE 5:	WRONG ANSWER ANALYSIS QUESTION 3	34
FIGURE 6:	WRONG ANSWER ANALYSIS QUESTION 4	34
FIGURE 7:	WRONG ANSWER ANALYSIS QUESTION 5	35
FIGURE 8:	WRONG ANSWER ANALYSIS QUESTION 6	35
FIGURE 9:	WRONG ANSWER ANALYSIS QUESTION 7	36
FIGURE 10:	WRONG ANSWER ANALYSIS QUESTION 8	36
FIGURE 11:	WRONG ANSWER ANALYSIS QUESTION 9	37
FIGURE 12:	WRONG ANSWER ANALYSIS QUESTION 10	37
FIGURE 13:	WRONG ANSWER ANALYSIS QUESTION 11	38
FIGURE 14:	WRONG ANSWER ANALYSIS QUESTION 12	38
FIGURE 15:	WRONG ANSWER ANALYSIS QUESTION 13	39
FIGURE 16:	WRONG ANSWER ANALYSIS QUESTION 14	39
FIGURE 17:	ARABIDOPSIS PHOTO	65
FIGURE 18:	LEAF DIAGRAM	68
FIGURE 19:	KNOW YOUR NUCLEOTIDES	73
FIGURE 20:	DNA REPLICATION	77
FIGURE 21:	PROTEIN SYNTHESIS KIT	82
FIGURE 22:	STUDENT WORK EXAMPLE	85

INTRODUCTION

THEORETICAL FRAMEWORK

It is no secret that teachers who work in urban communities face challenges and situations that are different than those that occur in rural and suburban areas. It is true that all school districts in the United States have struggled to keep up with the changes in technology, increased demand for higher test scores, and the need to make adequate yearly progress under the federal student achievement mandate, *No Child Left Behind*. Urban districts have the additional challenges of providing a safe educational environment, battling negative stereotypes, and providing meals and sometimes shelter to some of the more disadvantaged students. Unfortunately, for some students in urban districts, education is not a priority and teachers can find engaging these students in their learning more difficult (Brown, 2002).

Outward perceptions of urban communities are often that they are distressed areas where all children are in situations that make it hard or impossible to learn the same way that other children do. However, urban districts are home to millions of children where they build their hopes, dreams, and aspirations. Educators in urban districts are often people who have high hopes for their students and want to help them be successful in present and future endeavors (Brown, 2002). It is this love of community and profession that motivates educators to seek new ways to engage students in the classroom.

As a teacher in an urban district, the writer always tries to find ways to make science engaging and interesting for her students, while challenging them to think critically about the world around them. One of the most widely used strategies for engaging students in science classrooms throughout the United States has been the use of inquiry-based instruction. Inquiry-based instruction is a teaching method in which the teacher allows students to ask questions and

explore a problem to generate answers that are important to the classroom learning content. In 1996, the National Research Council described inquiry as a national goal for science education, to teach science in a way that mirrors the process of science (NRC, 1996). Unfortunately, due to limited resources in urban areas, many teachers succumb to the many pressures including a low budget, and the textbook ultimately becomes the center and the drive for many science classrooms. The problem with a classroom centered on textbooks and traditional lectures is that the learning becomes instructor centered. Often there is very little student participation in instructor-centered classrooms because students don't have the opportunity to make decisions or draw conclusions about their learning (McLoughlin and Padraig, 2009). Inquiry-based learning is different from instructor-centered instruction because the students are active participants in the learning and decision making process rather than being focused on what the teacher is doing. In inquiry based learning, which is a content-centered approach to instruction, every exercise, reading, discussion, and assessment focuses on the content and aids the student in solving a particular case study or problem related to it (McLoughlin and Padraig, 2009). Students have the opportunity to use classroom learning to draw their own conclusions, and essentially take control of their learning. In this way, inquiry-based learning allows students to develop critical thinking skills inherent to the process of science (Handelsman et al., 2007).

Obviously, all students who attend high school in the United States are not going to be interested in science, or pursue a science-related career. The goal of secondary science education is not to make students love the subject, or to memorize everything about it, but to inspire them to become independent thinkers and grasp essential ideas. Using inquiry in a science classroom has benefits for students because it can challenge them to discover how to think analytically, and view the world around them from a logical perspective (Bogiages and Lotter, 2011). Judah

Schwartz, Harvard professor, states that “raising a generation of people who know how to think should be central to the mission of all schools.” He further emphasizes that learners should not be expected to function like sheep, but rather challenged to develop skills of taste and judgment in all content areas (Kinnaman, 1990). The writer has observed that many students enter class expecting to be handed information to regurgitate back in written form and expect a pat on the back, and an excellent grade. Generally, they prefer multiple choice tests where they can guess the correct answer, and often assignments with open-ended questions are returned blank. For whatever reason, students enter high school accustomed to the instructor-centered process of learning, and resist any attempts to have them draw their own conclusions about the content. The goal of an experience with inquiry-based learning in the classroom is to have a positive effect on student participation, and their ability to think independently.

With the State mandate in Michigan to include all students classified as Special Education students into traditional science classes, classrooms became more crowded and included a wider range of learning styles and abilities. The instructor-centered classroom with traditional lectures, textbook readings, and daily worksheets are not the best approach when dealing with a class of students with varying abilities. Essentially, instructor-centered teaching is providing one form of instruction to students with very different learning styles, and students who don't fit the mold of class will not be successful. Inquiry-based learning in a content-centered classroom can provide essential scaffolding based on each student's abilities (Marshall and Horton 2011). Inquiry based investigations can provoke students to learn science content as a means to solving problems which can bring them to a deeper understanding of key science concepts (ibid).

One teaching strategy that supports inquiry-based instruction is the use of models in a science classroom. For the purpose of this research, the term “model” refers to a physical representation of an abstract concept. Model generation, critiquing, and revision are central to scientific inquiry (Darden, 2006; Neressian, 2008). Combining models with effective classroom discussions is another way to promote deeper understanding of science concepts. Discussions are a way to help students learn to “talk science” and construct understanding in a social context (Shwartz et al., 2011). A good combination of discussions and models is to conduct a “synthesizing discussion” with the students. In a synthesizing discussion, the teacher facilitates questions about the process of model construction to check for understanding, and allow students to integrate their ideas with the model. A synthesizing discussion would require students to use models to describe a certain concept and discuss what the model is and is not able to show (Shwartz et al., 2011). During the course of the discussion, students may generate and answer their own questions. This practice allows them to take control of their learning and affords the teacher time to take a facilitator role in instruction.

Inquiry and the use of models will only have a positive impact on the classroom if they are implemented correctly. The process of unit design is just as important as the process of unit delivery. One unit design process that supports a content-centered classroom is called The Backward Design Process, which essentially has three simple stages. Stage one is to identify the desired results of the unit, or learning goals, and provide them to students as clearly stated unit objectives. Ideally, these would be content and skill centered goals for the students to master at the end of the unit. Stage two in Backward Design is to determine acceptable evidence of achieving the goal. This would be the design of both formative and summative assessments. Stage three is to plan the learning experiences that the students will have, and the instruction that

will take place (Wiggins and McTighe, 1998). When developing activities through backwards design, teachers must make sure that all of the materials they are offering to the students are intentional and directly related to the type of assessment offered. This ensures that every activity that the students participate directly relates to the learning goals.

One of the road blocks for students in their learning is that they don't know what they don't know (D'Avanzo, 2003). One way to approach this problem as an instructor is to use paired problem solving. The DNA modeling activities are a perfect example of paired problem solving because one student will read the problem aloud while another student manipulates the model to try to solve the process of DNA transcription and translation. As the students continue to work together through the problem, they begin to formulate and answer their own questions through model manipulation. At the conclusion of the activity, students present their model to the instructor for review. This activity is good for students who learn by reading, working with their hands, or presenting information. Backwards Design was the approach used to design the unit using inquiry and models in this study.

RESEARCH AND DESIGN

The objective for this thesis project was to prepare and administer a unit plan in the writer's classroom based on research of both educational practices, and scientific content. The writer chose to focus on the unit titled "Genes, Proteins and Protein Synthesis" in the anatomy and physiology class due to its high difficulty and low student success rate in previous years. The hypothesis is that the students will significantly increase their knowledge of protein synthesis by participating in the unit. It is anticipated that data collection will support the hypothesis.

The writer spent ten weeks in the Day Lab, a plant pathology laboratory at Michigan State University. This placement was made possible by the Plant Genomics Summer Outreach Program for students and teachers that was funded by the National Science Foundation, and headed by Linda Savage at Michigan State University. This particular placement was chosen because it related to the unit on genes, and work on plants is both safe for the classroom and also very cheap to implement. The genes studied in the laboratory were closely related to disease resistance. The funding and research in this particular lab is directly linked to the agriculture industry. Plants face pathogens such as bacteria, fungi, oomycetes, and viruses that cost the agriculture industry billions of dollars every year. The danger that agricultural terrorists might seek to spread virulent plant pathogens means there is a heightened urgency on plant pathogen research (Meyers, 2004). Transgenic crop plants with heightened disease resistance to these pathogens are useful for many reasons, but foremost because they can reduce the amount of pesticides that farmers have to use, and raise the crop yield for each year. These transgenic plants have the potential to save farmers money, and are better for the environment than using traditional pest control practices.

The writer spent the first few weeks in the lab immersing herself in the lab culture and practicing lab protocols and techniques such as serial dilutions, aseptic bacterial plating, DNA washes, PCR, western blots, and loading DNA gels. The writer had the opportunity to work with all people in the lab and their individual projects. After the first few weeks the writer decided that the best project to study for use in the classroom was gene research with a small plant called *Arabidopsis thaliana*. The plant and the project were perfect for use in the classroom and could easily be modified into an inquiry-based lab with many extension options. *Arabidopsis* is an ideal organism for scientific research as well as for use in the classroom because it has a small, fully sequenced genome (chromosome two sequenced at MSU), a short life cycle of six weeks, and the ability to produce thousands of seeds (Arabidopsis, n.d).

The focus gene in *Arabidopsis* being researched is called NDR1. Through research, scientists have determined that NDR1 must code for a protein that significantly increases disease resistance in wild type plants. When the gene is removed, the plant is rendered completely vulnerable to every type of pathogen. The first step in developing the lab for the students in this study was to test the reaction of the NDR1 strain of *Arabidopsis* and its reaction to pathogen exposure. (Modified organisms are named for the genes that are altered, so the NDR1 strain of *Arabidopsis* is missing the gene NDR1). Before the hypothesis that NDR1 plays a role in disease resistance could be tested, the gene was removed from a wild type plant to construct the strain for the experiment. Modified strains of *Arabidopsis* are produced using a bacterium called *Agrobacterium tumefaciens* which typically causes tumors in the roots of dicot plants. The tumor-causing gene is removed from the DNA of *Agrobacterium*, and genetic information is then inserted to target and delete the NDR1 gene from *Arabidopsis*. (About arabidopsis, n.d.). *Arabidopsis* was grown in the greenhouse to the flowering stage, and the flowers were infected

with the altered *Agrobacterium* in hopes that the resulting infection would produce seeds missing the NDR1 gene. The process does not work all the time which is why it is beneficial for *Arabidopsis* to produce so many seeds. Once a few seeds of the NDR1 strain were obtained they were grown in isolation to produce thousands of seeds that could be used for research.

The purpose of the experiment is have the students grow both wild type, and NDR1 strains of *Arabidopsis thaliana* until they reach the two-four leaf stage which is the most vulnerable adult state for disease, and infiltrate each with a pathogen. The students will observe the effects to the plants over time and draw conclusions about NDR1 based on their observations. If all goes accordingly, as it did in the lab, the wild type will show little to no response to the disease while the NDR1 strains will become sick and yellow, or die. The students should then develop the hypothesis that NDR1 provides some resistance to disease. They will also have to use the information learned during the course of the unit to make the connection between genes and proteins in written form. The pathogen *Pseudomonas syringae* was selected because it is a common plant pathogen found almost everywhere, and does not affect humans. Normal safety precautions will also be taken in the lab with students since they will be working with a plant pathogen.

Pseudomonas syringae is a gram negative bacterium that is well known as a plant pathogen. This bacterium has the potential to infect many different types of plants, and cost the agricultural industry millions of dollars in lost crops (Campbell, 2008). *Pseudomonas* destroys the plants tissues causing nutrients and water to leak from the damaged cells making them accessible for the bacteria's growth and reproduction. One of the ways that *Arabidopsis* evolved to ward off harmful pathogens like *Pseudomonas* is to develop a waxy cuticle on the surface of the leaves that makes it more difficult for pathogens to get inside the plant. In evolutionary

response to this, *Pseudomonas* developed a type-three secretion system in which it injects enzymes directly into the plants cells. Once there, the enzymes dissolve the waxy cuticle and surrounding plant tissue which allows *Pseudomonas* to penetrate the plant's defenses. When the NDR1 gene is present, *Arabidopsis* has other ways to combat the disease that we do not yet understand, but when the gene is removed *Pseudomonas* is left to destroy *Arabidopsis* for the nutrients and water it contains. Due to the fact that students will need to infect both wild type and NDR1 strains of *Arabidopsis*, the students will increase the chances of a pathogenic infection by either mixing a surfactant with *Pseudomonas* to dissolve the waxy cuticle, or by wounding each leaf and actually injecting the bacteria directly into each plant.

When the writers experience in plant pathology came to a close, she had completed preparation for the inquiry lab portion of the unit and secured all the materials for completing it in the classroom. The second part of the research was to develop activities and discussions to give the students the foundational information that they needed to complete the lab. The backward design approach that was discussed earlier was used. To develop the unit, the writer compiled a list of the learning goals, using the Michigan High School Content Expectations for Biology (Appendix 1A). Four "big idea" objectives were selected that encompass all of the individual content expectations on which to base the assessment. The objectives for the unit are that students will demonstrate knowledge of the following: Why proteins are important, how genes provide information for proteins, how NDR1 plays a role in *Arabidopsis*, and how the process of scientific investigations is properly implemented.

Step two for the backward design process was to develop assessment to be used for data collection and to see what the students learn. Authentic assessment is not done to assign a child with a particular grade, but to determine what the children know and where to go next (Cox-

Peterson and Olson, 2002). For this unit, multiple forms of assessment were chosen to determine what the students learned. For statistical analysis, one summative assessment was offered as a pretest and posttest at the start and the end of the unit. The pretest offered the instructor a chance to select the areas where the students needed the most help and improve instruction in that area of the curriculum. Multiple formative assessments were also chosen to accommodate students with different learning needs. This is important because some students are good at relaying their content knowledge through a test, but others are better at demonstrating their learning in the form of a paper, or oral presentation.

The summative assessment was a fourteen-question, multiple-choice test that also had an area for discussion on each question. The questions were worth one point each; a half point for answering the question correctly, and another half point for explaining the concept behind the question in the discussion section. The discussion section was included because typically multiple choice tests do not indicate whether students understand a concept or whether they simply guessed correctly (Cox-Peterson and Olson, 2002). After the pretest was given and the answers analyzed, the instructor chose five questions that the most students got incorrect for more in-depth teaching. These questions included number seven, eight, and ten on nucleotides, question eleven on the scientific method, and question fourteen on pathogens. To accommodate students with different learning needs, multiple types of formative assessment were also given during to see what the students were learning, and facilitate higher order thinking. The DNA modeling activities are one example of formative assessment because they include an oral presentation to the teacher of the content learned. Another type of formative assessment is the essay that students will complete at the end of the unit that summed up the inquiry lab with *Arabidopsis* (Appendix 4B). This assessment was used to assess student knowledge of the big

ideas, but no data was collected from it for analysis. Inquiry-based learning is especially helpful to strengthen students' ability to recognize relevant information they already have, and will need to solve a problem (D'Avanzo, 2003). At the conclusion of the lab, students will use the data they collect, as well as their knowledge of genes and proteins to conclude that the missing gene caused a protein to be missing from the plant that provided some immunity to bacterial infections. Students will articulate their findings in the form of a short essay that will be used in conjunction with the posttest to determine their final grade.

Step three for backwards design was to construct activities that directly related to assessment, which took a lot longer to do. The writer started with four short lecture presentations to provide information to the students that would prepare them for future activities. The lectures included content on proteins, pathogens, safety, and model organisms. The activities students will complete both to learn, and to demonstrate their knowledge to their teacher include *Protein Synthesis Satisfies* and *Replication is Refreshing* shared by a teacher from Indiana (Flammer, 2007). The modeling activities were modified to assess multiple learning styles. A few short independent research activities were included in the unit to give students control over their own learning. One research activity was looking up different proteins and how they work in the body, and the other was researching and designing a presentation on a genetically modified organism.

Once the activities were selected or designed, the task of organizing them in a relevant order was necessary. After talking with other biology teaching colleagues, a "macro to micro" approach was taken, which essentially meant teaching what proteins are first and why they are important, and scaling back to how they are made. The hypothesis is that if students understand and are interested in the product (proteins), they will be more inclined and interested to learn

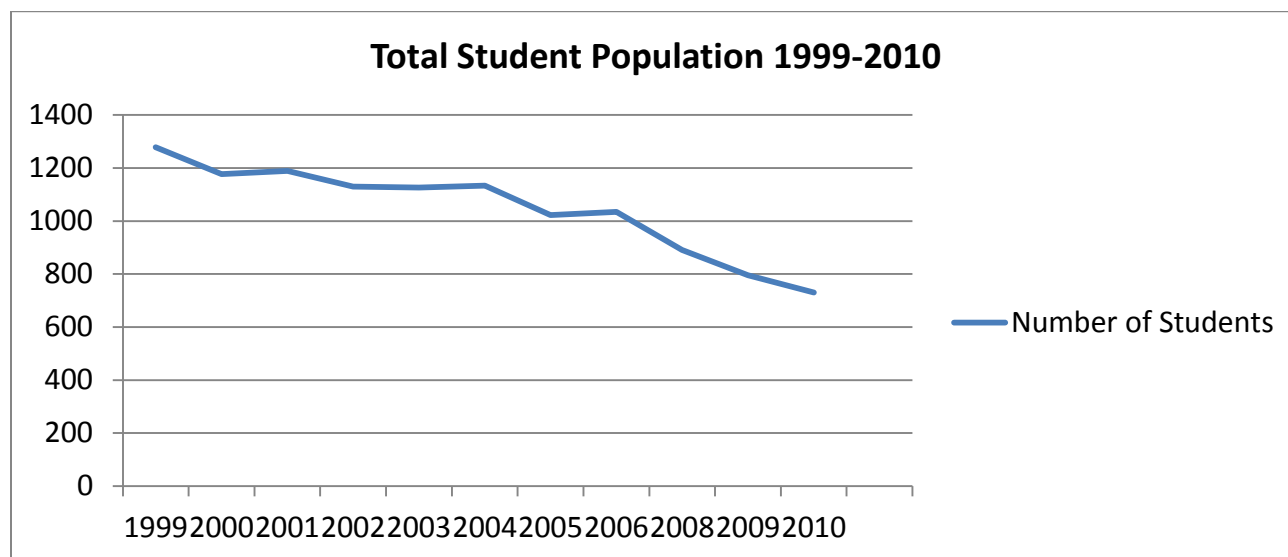
about the process of protein synthesis. Protein synthesis can be very complicated for a student to learn due to the fact that the process contains many steps that end in a complicated folding sequence. Protein folding is the least well characterized step in the process, and is not well understood by researchers, let alone high school students. Protein folding is important because it is the three dimensional structure that determines a proteins function, and loss of that structure called denaturation, results in a loss of protein function (Bondos and Matthews, 2008).

At the conclusion of the research experience, a full unit on protein synthesis had been developed that included both inquiry and the use of models using the backwards design approach. The total time expected to complete the unit was eighteen to twenty days. Based on the writers Theoretical Framework, the unit should be successful in helping the students learn the process of protein synthesis.

DEMOGRAPHICS

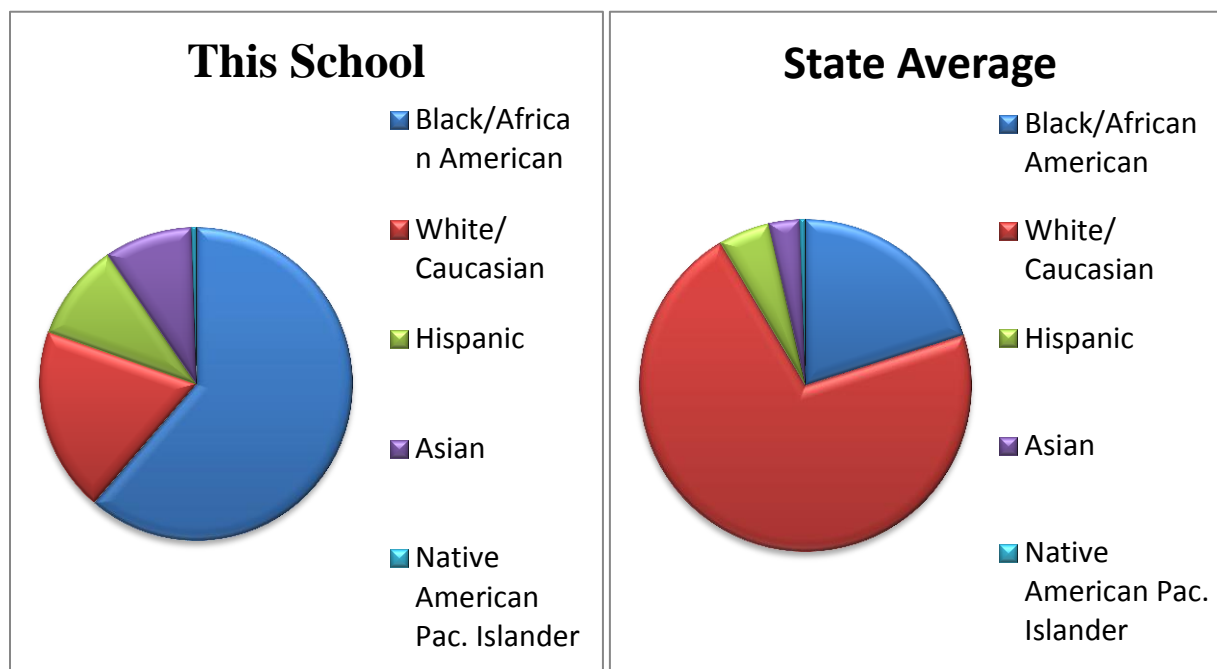
The research was conducted at a high school which services students in the ninth through twelfth grades, and is classified as an urban school. It is located in Michigan and is part of a larger district which also has two other high schools at various points in the city. The state of Michigan has seen a major decrease in population due in part to the loss of manufacturing jobs, and the decrease has been mirrored in the local school district. Further economic depression due to high unemployment and the crash of the real estate market in the area has also contributed to a greater decline in population in recent years. In 2005, the district had 18,014 students and that number has steadily decreased each year to 13,275 students in 2010. In the high school where the research was conducted a similar decline has also taken place as shown in figure 1(LSD, 2010). Over the last five years, there has been talk of closing one of the high schools to save money, but the loyal community base consisting of residents, alumni, and parents have a strong commitment to the area schools and an equally strong voice at board meetings. So far, the movement to close one of the high schools has not progressed.

Figure 1: Student Population- Figure 1 shows the decline in enrollment for this school over an 11 year span. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.



The students who attend this school live primarily in the city and city suburbs. The school has a minority population that is significantly higher than the state average as shown in figure 2 (LSD, 2011).

Figure 2: Ethnicity – Figure 2 shows the breakdown of ethnicity represented in enrollment for this school and compares that data to the average high school enrollment ethnicity



The families that the school services are also of a lower economic status than the state average which is indicated by the number of students who receive free and reduced lunches at the school. Fifty-six percent of students who attend this school receive free and reduced lunch compared to the state average of forty-two percent (Student economic level, 2007).

The research was conducted in a human anatomy and physiology class that has students enrolled in the eleventh and twelfth grade. *Anatomy and Physiology* is not an advanced placement course, but is considered more difficult than traditional science electives because a college textbook titled *Holes Essentials of Anatomy and Physiology* is used for required reading. Prerequisites for this course include successful completion of ninth grade biology and at least

and eleventh grade reading level. The students who take this class are of a wide range of interests and abilities. Some students are interested in medical school or nursing, but others have different career goals and are taking the course because they think it is interesting, or they need an additional science credit. In order to obtain an accurate sample of students for the study, consent forms were distributed, and the junior/senior English teachers offered extra credit to any students who returned a consent form (consenting or not). The students also had to submit the short paper that was completed at the end of the unit to their English teacher. Once consent forms were collected by English teachers, they were given to the researcher at the conclusion of the unit and a very accurate sample of students was obtained. Due to the offer of extra credit, students at all levels and abilities were motivated to return the forms to their English teacher. Ten students from the morning class and ten students from the afternoon class returned forms granting permission which constituted 31% of all students taking anatomy at the high school. After reviewing the demographics of students who returned the forms with consent, the subset of data used for this study was determined to be an accurate representation of the class as a whole.

IMPLEMENTATION

OUTLINE OF ACTIVITIES

The protein synthesis unit presented to high school anatomy and physiology students takes between eighteen and twenty days to complete and includes activities to help hold the interest of those participating, and attempts to facilitate higher order thinking skills. Activities include formal lecture, independent research, modeling activities, class presentations, and one scientific inquiry experiment to help students fully understand the mechanism and purpose of protein synthesis in the body. Table 1 contains a breakdown of the unit by activity and the number of days each assignment takes to complete, as well as the intended learning outcomes for each activity as identified during the backwards design planning process. The implementation of this unit in the proposed classroom was delayed by about two weeks due to administrative setbacks. It is due to these setbacks that some modifications to the original unit plan had to be made. Those changes will be reflected in the unit implementation section and reviewed during the discussion.

Table 1: Unit Plan by Day- Table 1 is a list of daily activities for the unit that includes the activity type, goals addressed by the activity, and the time required to

Activity Name	Activity type	MDE HSCE	Days	Unit Goals Addressed
Unit pretest	Assessment		.5	Students will take pretest for statistical analysis.
Safety contract&class discussion	Class discussion	B1.1C	.5	Students will learn the proper tools and techniques for working in the lab, and about proper waste disposal.
Protein Lecture Planting Slides	Formal lecture	B4.2D	.5	Student will learn why proteins are important and what happens when they do not work.
Planting Arabidopsis	In class activity	B1.1C	.5	Students will practice using proper tools and lab techniques to set up the inquiry lab

Table 1 continued

Protein Research	Independent research Assessment	B4.2D	1.5	Students will learn why proteins are important and what they do in the body
Know your nucleotides	Group modeling Activity		1	Student will be able to differentiate between nucleotides and define their structure
Replication is refreshing	Group Modeling Activity	B4.2B B4.2C B4.2F B4.2G	3	Students will describe DNA structure and how DNA replication occurs
Protein synthesis satisfies	Group modeling Activity	B4.2F B4.2G	1	Students will demonstrate how DNA codes for protein during protein synthesis
Arabidopsis lecture /Model organism homework	Formal lecture, Independent practice	B4.2B	1	Students will learn the importance of using model organisms in Biology and that each organism has its own DNA sequence
Plant Pathogens Lecture	Formal lecture and class discussion	B2.3C B2.4H B2.4i B2.r6C	1	Students will learn how pathogens such as viruses and bacteria can cause problems, and how pathogens and hosts interact.
Infiltrate plants with pathogen	In class activity	B1.1C	.5	Students will practice using proper lab tools and techniques while working on their inquiry lab
Modified Organism Research	Group research activity	B4.2H B4.r2i B4.4A B4.r5A B4.r5B	2	Students will learn the process for making a GMO and that doing so comes with great potential and responsibility
Drawing Conclusions	Independent writing and assessment	B1.1A B1.1C B1.1E B1.1H B4.4A	2	Students will use evidence from an investigation to draw a conclusion.
Protein synthesis practice	Independent practice	B4.2F B4.4A	1	Students will practice matching nucleotide bases to create proteins for their test.
Unit Posttest	Assessment		1	Students will complete the posttest assessment for data collection
Presentations of GMO	Formal presentation and assessment	B4.2H B4.r2i B4.4A B4.r5A B4.r5B	1	Students will explain how changing a gene changes a protein and how that effects and organism.
Total Time			18-20	

REVIEW OF ACTIVITIES

Pretest/Consent

The objectives for this activity were to have the students take and complete the pretest for the unit, and to review the consent form with them and have them take it home to be signed by their parents. Assessment for these objectives will be whether or not the students complete the pretest, and pay attention during the discussion about the research project. The instructor submitted the consent forms (Appendix 1B) to the class for authorization signatures. They were to fill them out and take them home for their parents to sign, and then return them to their English teacher, who would hold them for the instructor until the end of the unit. During the course of the initial presentation, many questions were answered about the research project. The students also took the pretest during this time (Appendix 4A). Due to absences, many students needed to make up the pretest upon return, but all of the students who were in class took the test and participated in the discussion about the research project. Most students were very excited about the project and eager to participate. They also seemed to like the idea of doing a pretest before the start of the unit. One student remarked that he felt it would help to see the test questions more than once, and that a pretest would help the important points in each unit be clearer. The class had some great questions for the instructor about the unit, and the consent forms. All that were present took the pretest, and took it seriously.

Safety Contract/Discussion

The objectives for this activity were to for students to learn the proper tools and techniques for the lab, as well as proper waste disposal. Assessment for this objective will be teacher observation of students as they work through the unit to obey the safety rules. The instructor passed out and read the student safety contract (Appendix 1C) with the students,

making sure to discuss all of the key concepts listed in the discussion points on lab safety (Appendix 2C). The students were attentive during this discussion and asked excellent questions about the differences in disposal of bacteria versus disposal of aprons or gloves. At the conclusion of the discussion, the students were to take the safety contract home and review it with their parents and have their parents sign the document with them which was worth points toward their grade.

Protein lecture

The unit was based on a “macro to micro” approach, which is opposite of how the textbook is set up. In this approach, students will learn why proteins are important, and then scale back to how proteins are made. This was the rationale for the start of the unit which was a formal lecture of proteins (Appendix 2A). The objectives for this lecture were for students to learn why proteins are important in the body, and what can happen when they don’t work. Assessment of this knowledge will be done when the students complete the independent research project on proteins in the computer lab. The lecture went very well and the students were interested in how proteins can cause disease conditions in the body. They also seemed to enjoy the fun facts about proteins that were included in the power point. The instructor had a long discussion with the class about sickle cell anemia after the lecture, as they seemed very interested and surprised that proteins were responsible for so many important body functions. This discussion was used to begin discussing how changes in DNA can change amino acids and proteins down the line.

Planting Arabidopsis

This activity began with the instructor showing a few power point slides on how to plant *Arabidopsis* (Appendix 2A). In this discussion student looked at pictures that showed how to plant the tiny seeds for optimum growth. The objectives for this lesson was for students to practice using proper lab techniques as outlined in the safety contract, and to set up the inquiry lab to be done towards the end of the unit. Assessment was done as an observation by the teacher on the planting techniques of students. Students took care to wear the proper personal protective equipment outlined in their contract to plant the seeds, and placed them in the greenhouse to begin growth. Each group of students ended up planting six plants based on the planting outline that was given to them (Appendix 2B). The students enjoyed getting their hands dirty, and visiting the greenhouse.

Protein Research Assignment

This assignment was intended both to help students learn more about proteins, and also to assess their learning. The objectives were for students to discover some of the reasons that proteins are important, and what their functions are in the body. Their knowledge of protein function will be assessed when the teacher grades the assignment. This activity was designed to allow students to research and explore attributes of proteins, and was taken from the writer's SME Molecular Biology class at MSU (Appendix 3D). Initially, the interest level was very high, but many students got frustrated very quickly at all the vocabulary pertaining to protein structure (ex: alpha helix, beta sheet). The instructor provided minimal assistance on the first day of the assignment such as pointing out in the book where they could find the answers to their questions and allowing them to work through their frustrations. By the end of the first day, most students had completed half of the assignment on their own, although it was a struggle. The next day the

instructor spent about fifteen minutes talking about the reading with the class that focused on protein structures. The class went back to the lab to finish their research, but only about half of the students finished, while the other half decided to take it home for homework. It was disappointing that the confidence that the students had after the discussion on proteins all but disappeared as the activity stretched into the second day which may have been in part due to the uncomfortable room conditions reviewed in the discussion section.

Know your Nucleotides

To prepare for the three DNA Modeling activities; “*Know your Nucleotides*”, “*Replication is Refreshing*”, and “*Protein Synthesis Satisfies*”, the instructor used the teacher notes available for these lessons (Flammer, 2007) (Appendix 2E). The class began with a short discussion on proteins and how they are made inside of cells. The instructor then distributed the *Know your Nucleotides* activity for the students to begin working on (Appendix 3E). The objective for this activity is for students to differentiate among nucleotides and define their structure, and will be assessed when the teacher grades the completed activity with an answer key. This assignment was a good one for students who may have trouble with reading because it is a hands-on activity that allows students to put nucleotides together like a puzzle using scissors and paste to model each of the nucleotides present in DNA and RNA. The activity was modified to make it align with the text book description of nucleotides for students to refer to in case they needed extra help. The students really liked this activity and were engaged, interested, learning, and working. It was obvious to the instructor that they picked up the new concept very easily. The challenging part of the activity was that the students were asked to build a molecule of ATP using only the molecules they needed to make nucleotides. The instructor used the fact that some students finished more quickly than others to her advantage by having those done early

help those who were struggling to figure out the structure of ATP. By the end of the class, the students came to the correct conclusion that ATP, the energy currency for the body, was essentially a big nucleotide. Overall, this was a successful day, and the students loved this activity.

Replication is Refreshing

The second in Flammer's series of DNA modeling activities was the next assignment that the students participated in, *Replication is Refreshing* (Appendix 3F). This assignment was modified to match the textbook, and be more like an active reading activity where one student would read, while the other would use the physical models to act out the process being described in the book. The objective for this assignment was for students to describe DNA structure, how DNA nucleotides fit together, and how DNA replicates. This was assessed by the instructor as she moved about the room asking students to present the process to her. The students cut out the model pieces, researched in their book about the process of transcription and when it occurs in the body, and presented the process to their teacher for credit. This is another activity that went really well. The students seemed nervous that they actually had to give an oral presentation to their teacher and in front of their peers, and worked very hard to make sure that they did it correctly. The instructor quickly gained an idea of how much each student was learning about transcription. Students earned all their points if they could demonstrate the process and answer the questions asked of them (which changed from group to group). If they were unable to articulate the process correctly, they were required to go back to the reading and models until they could present it correctly. This activity was student directed with hints from the instructor. It was interesting to watch them work together and sometimes struggle to find the right answers.

Protein Synthesis Satisfies

The *Protein Synthesis Satisfies* activity is the last of the DNA modeling activities and takes two days to complete (Appendix 3G). The objectives for this activity are for students to demonstrate how DNA codes for protein during protein synthesis, and will be assessed as the instructor interviews the students during their information presentation of translation to the teacher. The activity was scheduled for two days, but the instructor noted that there were some students who were ready to give their presentation on day one. One group of students came up with a funny story to remember the process of translation and all of the terms associated with it. They were also kind enough to share their story with other students so that the entire class could learn from it. The instructor was pleased to see this group working so hard to learn translation, and to help out other groups that were struggling and offered them extra credit if they would type their story up and hand it in. While some students finished early, some students needed some extra help pulling vocabulary out of the reading, and the instructor spent the remainder of the time walking around and pointing out important concepts and providing tips to help them along. By the end of the two days, all students had successfully presented the process of translation to their teacher and answered all appropriate questions to receive a passing grade.

Arabidopsis Lecture/Model Organism Homework

The objective for this activity was for students to learn the importance of using model organisms in Biology and that each organism has its own DNA sequence. This knowledge was assessed when students submitted the questions to the teacher from the Model Organism Article that they will read at home (Appendix 3A). This activity began with the instructor giving a formal lecture on *Arabidopsis* and why it is used as a model organism (Appendix 2A). The class discussed the process for making modified organisms using bacteria to add or remove genes, and the instructor used the discussion points to specifically address the NDR1 gene and aseptic

technique to make sure the students were provided with all relevant information (Appendix 2C). The class also talked about the process of plant growth after planting as detailed in the discussion points to make sure students were aware that they first “leaves” that grow from the plant are not true leaves, but cotyledon leaves and that the ideal stage for modification of *Arabidopsis* is the two to four leaf stage. The students also received a handout in class detailing this stage of plant growth (Appendix 3B). After the lecture, the students took home the article to read on Model Organisms and answered the questions based on the reading, and what they learned during the lecture for homework (Appendix 3A). Most students completed the assignment as planned and handed it in the next day in class, while others had to complete it for a late grade.

Plant Pathogens Lecture

The objective for this activity is for students to learn how pathogens such as viruses and bacteria can cause problems, and how pathogens and hosts interact. Their learning of this content will be assessed when they complete the *Drawing Conclusions* activity, and on the posttest. The instructor presented this lesson as a formal lecture on plant pathogens (Appendix 2A). The class discussed the different types of plant pathogens, focusing on *Pseudomonas syringae* and how it infects and causes damage to *Arabidopsis*. The instructor used the discussion points on how to inoculate plants with pathogens, and also on the type three secretion system that *Pseudomonas* uses to infect its hosts (Appendix 2C). In addition the instructor also provided detailed instruction during the presentation to explain how the type three secretion system works, and why it is so effective in causing disease in the host. The students seemed to be engaged and interested in the lecture, and were surprised that even tiny organisms like *Pseudomonas* had developed intricate abilities to suit their needs, like the type three secretion system to infect plants.

Infiltrate Plants with Pathogen

The objective for this activity was to continue work with the inquiry lab and for students to practice using proper lab tools and techniques. The assessment was based on instructor observation of their work, and whether or not the plants were properly inoculated. Unfortunately due to time constraints and other unforeseen problems, the class was not able to complete this activity. The objective, however, was met when the students worked on the *Planting Arabidopsis* activity in class.

Modified Organism Research/Presentations

The objective for this activity was for students to learn the process for making a genetically modified organism and that doing so comes with great potential and responsibility, and how changing a gene changes a protein and how that affects an organism. This content will be assessed when they give their Power point® presentation in front of the class in groups of two with the rubric provided in the teacher notes for this activity (Appendix 2D). Students were divided into groups of two for this presentation and given their organism to research based on the teacher notes that were provided (Appendix 2D). Students were also given the *Genetically Modified Organism Research Handout* which contained detailed objectives for completing the Power point® (Appendix 3C). This activity took two days for the students to complete their research, and another day set aside for presentations. This activity is an excellent one for students with different learning needs because it allows them to show their knowledge in the form of making a Power point®, or by an oral presentation of the content to the class and teacher. The students all seemed engaged and worked hard on this assignment. Almost all of the pairs split up the work to be more efficient by having one student research the content required in the rubric, while the other student set up the framework on the Power point® and looked for

relevant graphics and templates to make the presentation appealing. The presentations also went very well, better than the instructor had anticipated. Some students went as far as to compare their organism from the project to *Arabidopsis*, or to list the specific gene and protein altered to cause the phenotypic change in the organism. If the students had more than two days, the presentations may have been even more complete, but the instructor was impressed by how much research they had accomplished in such a short time. An example of a student GMO presentation has been included for the reader's review (Appendix 3I).

Drawing Conclusions

The objective for this activity was for students to use evidence from an investigation to draw a conclusion. It was to be assessed by the instructor upon completion of the activity based on the rubric included in the assignment. Due to problems with plant growth for this inquiry lab, the assignment was modified into a two-day class discussion with room for students to draw their own conclusions of the experiment in the form of an essay. On the first day of the activity, the teacher led a class discussion about *Arabidopsis* and the natural resistance that wild type plants have to *Pseudomonas*. The teacher asked questions about the gene NDR1, which the class answered verbally based on the NDR1 discussion points the teacher had gone over in an earlier lesson. The students also volunteered information on how the NDR1 gene would be removed from the plant to try to test what the role would be in disease resistance. The students then had to develop a hypothesis on whether or not they thought that the NDR1 gene would positively or negatively affect the overall disease resistance of the plant. The instructor also put pictures on the overhead of a fully grown Wild Type and NDR1 plant. Most students thought that removing the gene would cause the NDR1 plants to get sick when they were treated with the pathogen, but some students disagreed. The main cause for the disagreement was that the plants in the pictures

looked exactly the same to them; both plants looked healthy with the same number of leaves. These students developed a hypothesis that if the NDR1 mutation made the plant more susceptible to disease, it would look sick already for the diseases it could catch from the air. The teacher took all of the information from the class discussion home in the form of notes, and typed it up into a formal lab (Appendix 4B). The next day, each of the students received a copy of the typed up lab, and the instructor read through it to the class to remind them what was discussed the day before. Students were also provided with sample results from the experiment previously completed by the instructor, and pictures of all six plants were posted and labeled on the overhead. The students seemed to understand the information better from the pictures rather than the results provided in the lab, probably because it was easy to see which plants were sick and which ones were not. They had the entire hour to read through the lab, look at the results, and write an essay based on their conclusions. The students were to write a paragraph for each of the four objectives, determining if NDR1 has a role in disease resistance, and how that relates to the work that was done with protein synthesis. The student received up to twenty points depending on whether or not an accurate description of each objective was present. The average score on this report was 75%, meaning that most of the students understood most of the concepts from the lab, and it was a success.

Protein Synthesis Practice

The objective for this activity was for students to practice matching nucleotide bases to generate proteins for their test. This was given as an extra credit assignment for students that finished other work from the unit early, as a way for them to practice matching nucleotides, and learning vocabulary for the test (Appendix 3H). This assignment was completed rather quickly and easily by all the students who finished their work early, but that is to be expected.

Unit Posttest

The objective for this activity was for students to complete the unit posttest to the best of their ability for data collection, and for the summative assessment grade. Almost all of the students were in class, took the posttest, and were focused and working hard (Appendix 4A). Once the test was finished, the general mood of the room was relief. Most students seemed to be confident that the test went well. One thing that the instructor did notice was that some students seemed to have the attitude that they did not have to study for the test, because it was one they had already taken before and they already knew what the questions were. However, this philosophy only seemed to exist with a few students as the rest talked openly about studying for the test.

RESULTS AND DATA

Of the sixty-three students enrolled in Anatomy and Physiology at the school during the fall semester of 2011, twenty of them returned forms granting consent for use of their data for this report constituting 31.7% of the total population. Of the twenty students consenting for the study, exactly half were enrolled in the first hour class, and half were enrolled in the sixth hour class. Consenting students were of all academic levels, some dual enrolled in AP Biology that had very high grades, and some needing an additional science credit with overall grades around passing. The group of students granting consent is a good representation of the total student population enrolled in Anatomy and Physiology during the study.

The results show that the average score on the pretest was 52.5% which is not considered a passing grade. The results on the posttest which was administered after completion of the unit was an average score of 69.3% which is significantly better. In the school where the research was conducted, a good average grade for any particular test is considered to be 70%. The average score of 69.3% is very close to the goal of a 70% average, and considered to be an acceptable average score. The scores show an increase of 16.8% after completion of the unit

Of the twenty from which data was collected, fifteen of them improved their test scores as shown in table 2. Four students, or 20% of the testing group, had no change between the pretest and posttest, and one student, or 5%, had a drop in score from pretest to posttest.

Table 2: Test Scores by Student- Table 2 lists the pretest and posttest scores for each student participating in the study, and the change in their percentages between tests.

Student	Pretest	Posttest	Change
1	78.6%	89.3%	10.7%
2	64.3%	57.1%	-7.1%
3	57.1%	85.7%	28.6%
4	64.3%	78.6%	14.3%
5	21.4%	64.3%	42.9%
6	21.4%	57.1%	35.7%
7	28.6%	64.3%	35.7%
8	28.6%	46.7%	18.1%
9	42.9%	42.9%	0.0%
10	100.0%	100.0%	0.0%
11	78.6%	85.7%	7.1%
12	92.9%	92.9%	0.0%
13	50.0%	64.3%	14.3%
14	85.7%	92.9%	7.1%
15	35.7%	85.7%	50.0%
16	50.0%	71.4%	21.4%
17	21.4%	57.1%	35.7%
18	42.9%	57.1%	14.3%
19	50.0%	50.0%	0.0%
20	35.7%	42.9%	7.1%
Average	52.5%	69.3%	16.8%

One explanation for the decline in test score for student number two is that this particular student missed 25% of the classes for the unit, and did not make up the work that was missed before the posttest.

A paired T-Test was performed on the pre and post test scores for all students to determine whether or not the data sets for the pretest and posttest were significantly different than one another. The T-value was $T = -4.61$. Using this T value, with a p value of .05, the null hypothesis can be rejected because there is a significant difference between the data sets and one can accept the alternative hypothesis that the data sets for the pretest are significantly different than the data sets for the posttest. Accepting the alternative hypothesis would indicate that the unit was successful in that the students increase knowledge in protein synthesis over the course of the unit.

However, before the data analysis is complete the pretest and posttest scores must be analyzed by question. This will determine if there were any anomalies in the test. An example

of an anomaly would be a question that many students got wrong due to poor wording or a trick answer. The data are presented in table 3.

Table 3: Test Scores by Question-

Table 3 represents the percentage of students that got each question correct for the pretest and posttest.

Question	Pretest	Posttest	Change
1	60.0%	65.0%	5.0%
2	75.0%	65.0%	-10.0%
3	50.0%	65.0%	15.0%
4	75.0%	60.0%	-15.0%
5	75.0%	95.0%	20.0%
6	65.0%	95.0%	30.0%
7	45.0%	50.0%	5.0%
8	25.0%	60.0%	35.0%
9	75.0%	85.0%	10.0%
10	30.0%	50.0%	20.0%
11	40.0%	70.0%	30.0%
12	65.0%	85.0%	20.0%
13	55.0%	70.0%	15.0%
14	35.0%	50.0%	15.0%

Table 3 shows the percentage of students who got each question correct for the pretest and the posttest, as well as the percent change between the two tests. Twelve of the fourteen questions, or 85%, show gains in percentage indicating improvement in knowledge over the course of the unit while two of the questions actually show a negative change in percentage. Both of the questions that show a decrease from pretest to posttest are questions that pertain to vocabulary from the unit. One question asks students to understand the meaning of the term transgenic, and the other is about aseptic technique. The questions that show gains in student

improvement of 20% or more include questions 5, 6, 8, 10, 11, and 12. Questions 8, 10, and 11 were 3 of the 5 focus questions that were selected by the teacher at the beginning of the unit for in depth teaching due to the large amount of students who gave incorrect answer for those questions on the pretest. This suggests that material that the teacher deems important and emphasizes during the course of a unit is directly proportional to student learning of that content. In this unit, where nucleotide bases, scientific method, and pathogens were emphasized, students did the best on those test questions at the end of the unit.

The last portion of data analysis was a “wrong answer analysis”. This was done by compiling what each student selected as an answer for each question and determining if all students who got the question wrong put the same wrong answer. This could indicate a misconception that was not properly addressed, a poorly worded question that was left open to interpretation, or a question with a “trick” answer. All of the data for each question was put into a graph (Figures 3-16) for easy analysis. After carefully examining the wrong answers for all questions, it was determined that none of the questions included any misleading wrong answers, or trick questions. All wrong answers were evenly distributed between all possible guesses suggesting a random selection. The analysis of each question is shown below in Figure 3 through Figure 16. The asterisk (*) next to an answer in the graphs shows the correct selection. Double Asterisk (**) next to a question indicates a question selected as a focus question by the teacher once the pretest was complete.

Figure 3: Question 1- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

Model organisms, like Arabidopsis (a small radish like plant) are used by scientists to study biological concepts because:

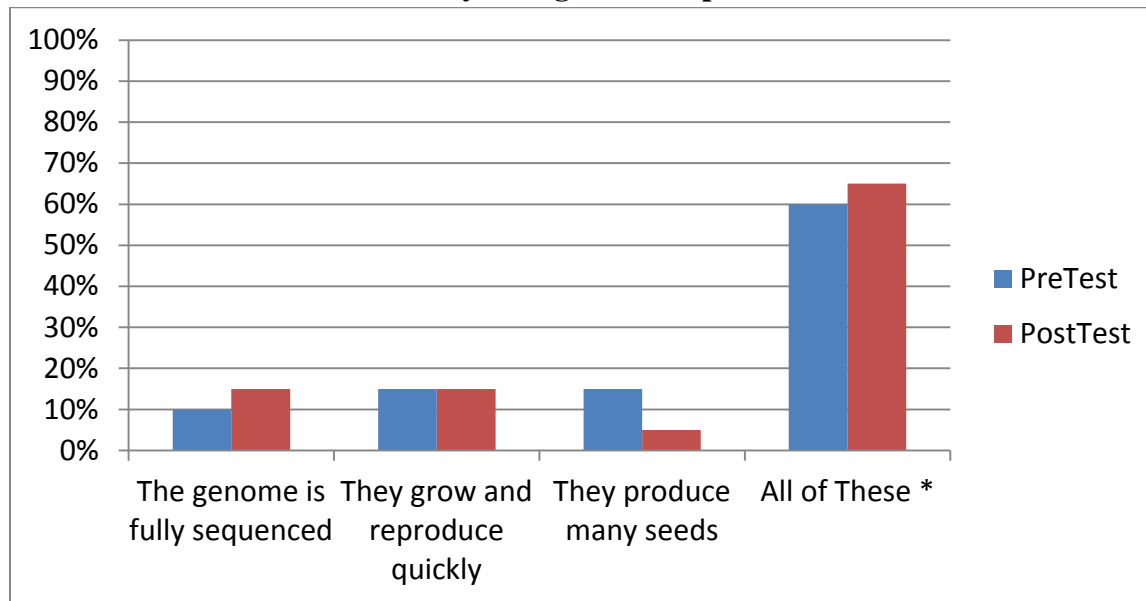


Figure 4: Question 2- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

The term “transgenic” means that:



Figure 5: Question 3- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

When conducting an experiment, why might it be wise to use a control?

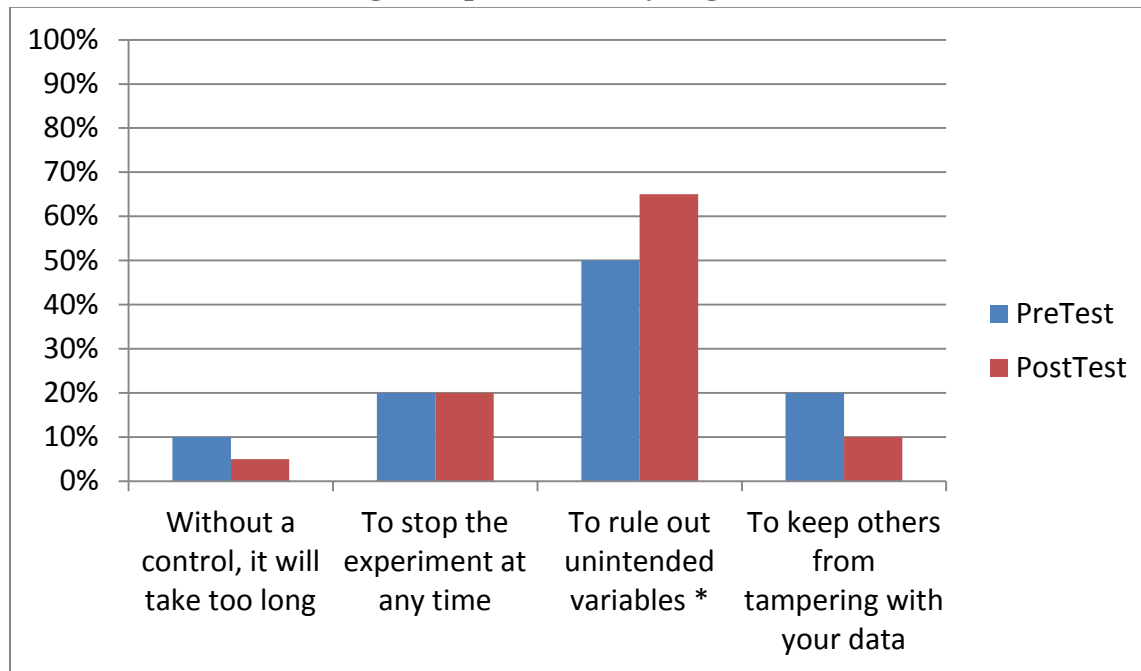


Figure 6: Question 4- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

What are some of the consequences of using improper aseptic technique when plating bacteria?

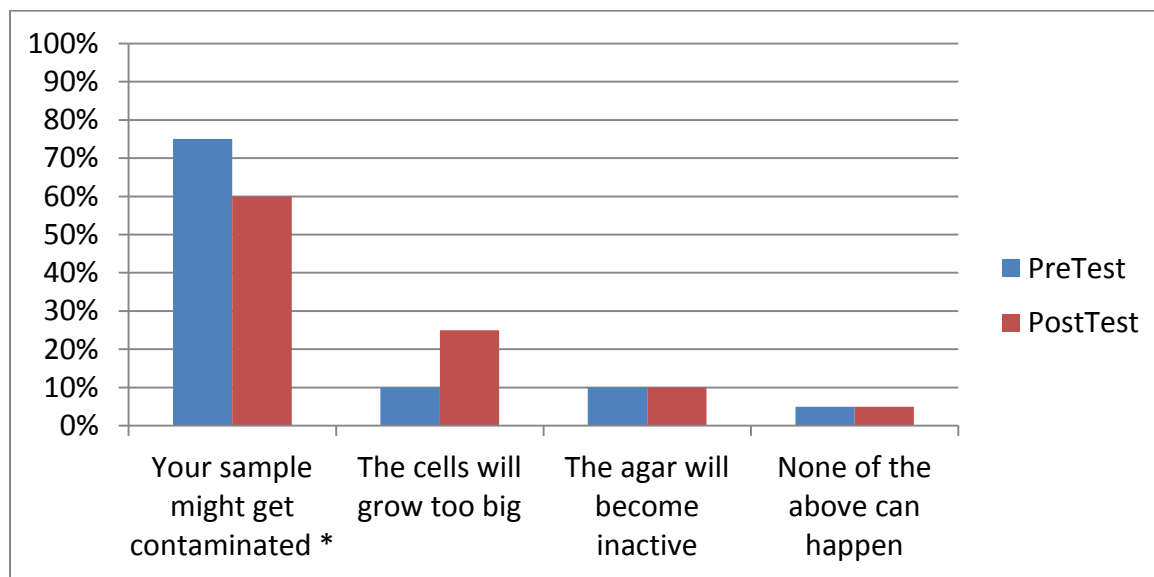


Figure 7: Question 5- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

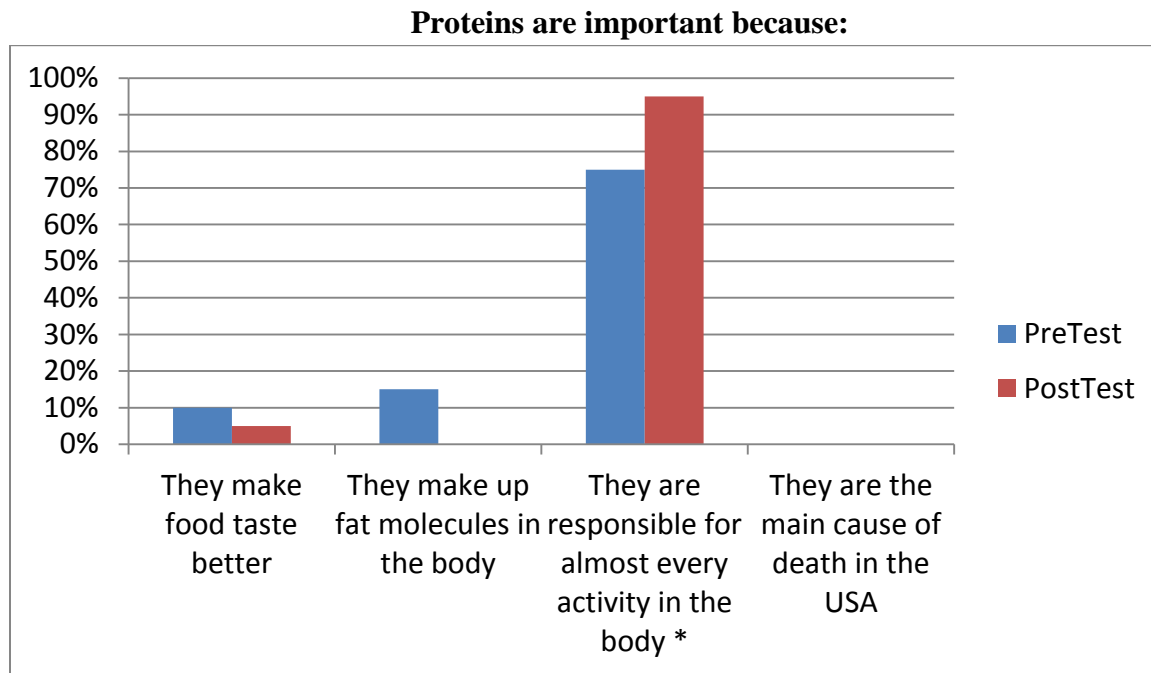


Figure 8: Question 6- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

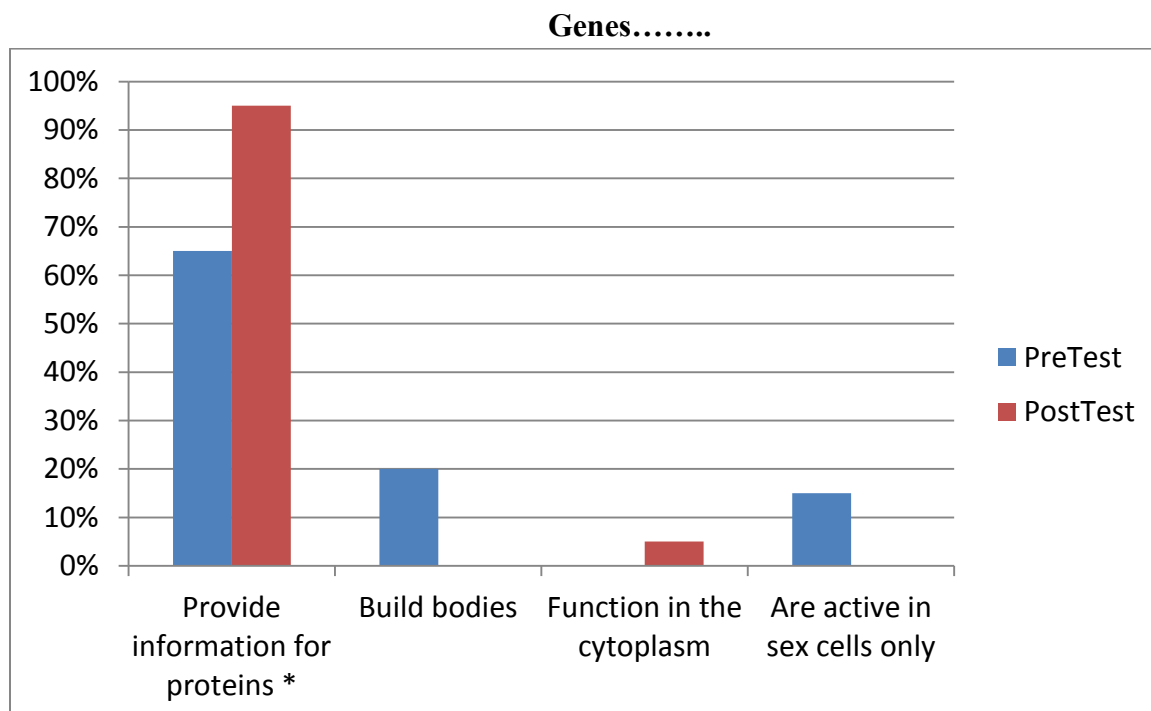


Figure 9: Question 7**- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

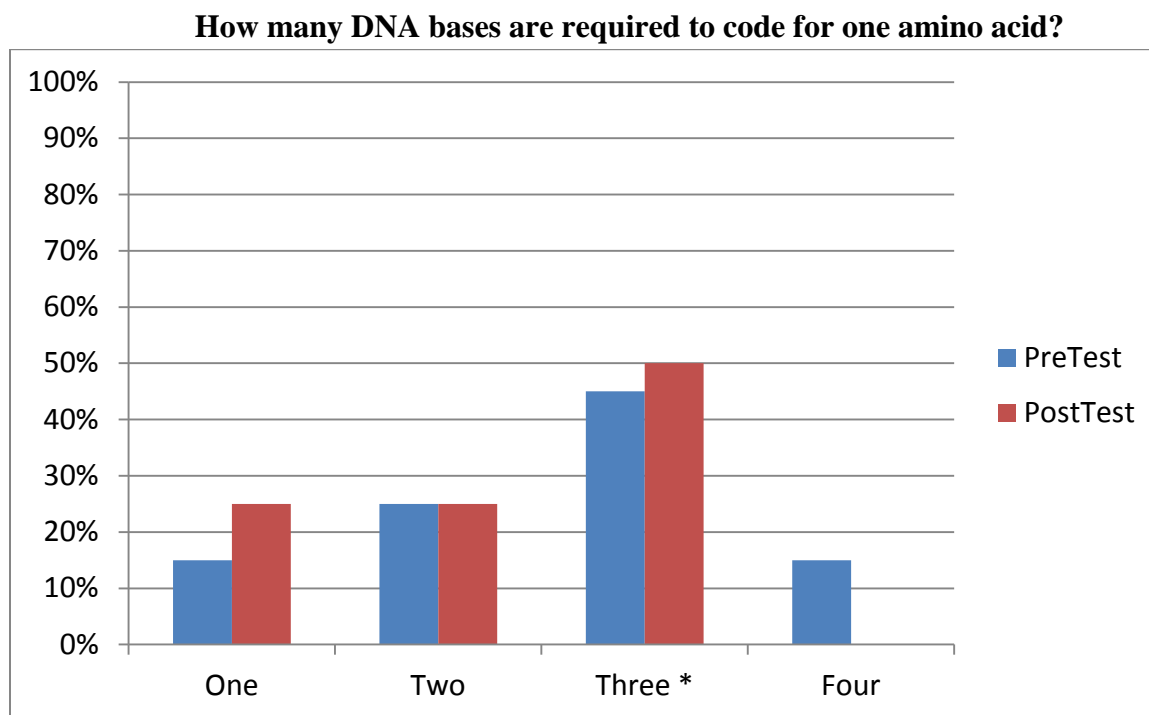


Figure 10: Question 8**- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

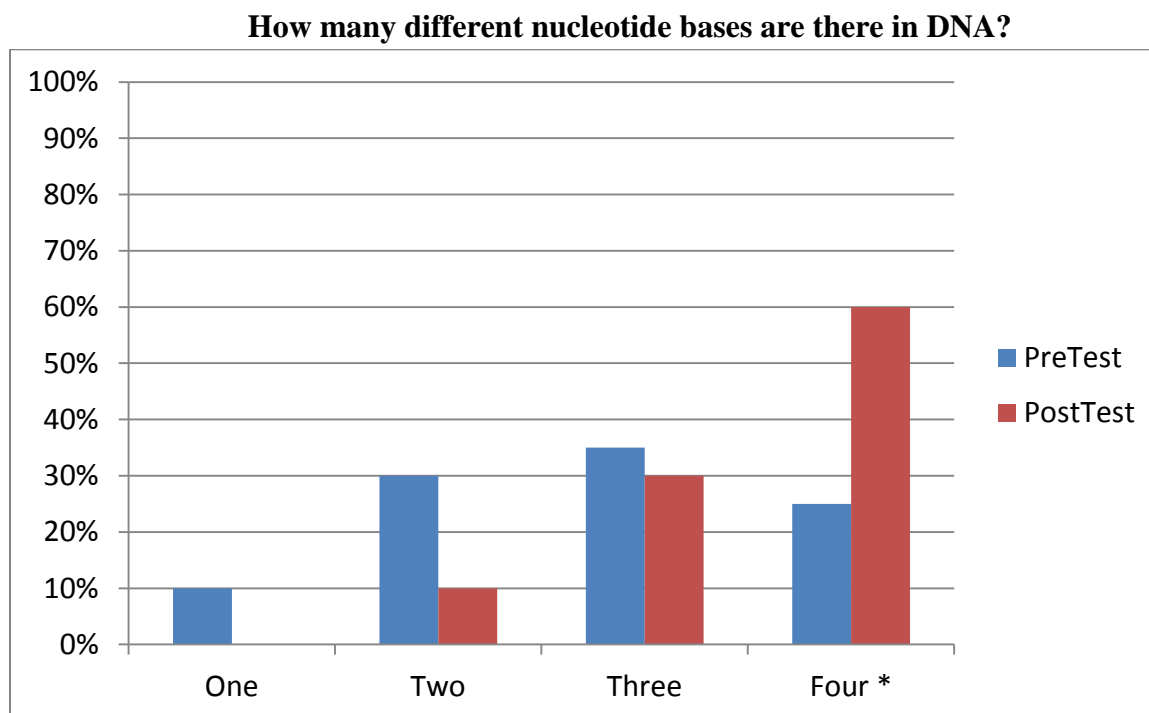


Figure 11: Question 9- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

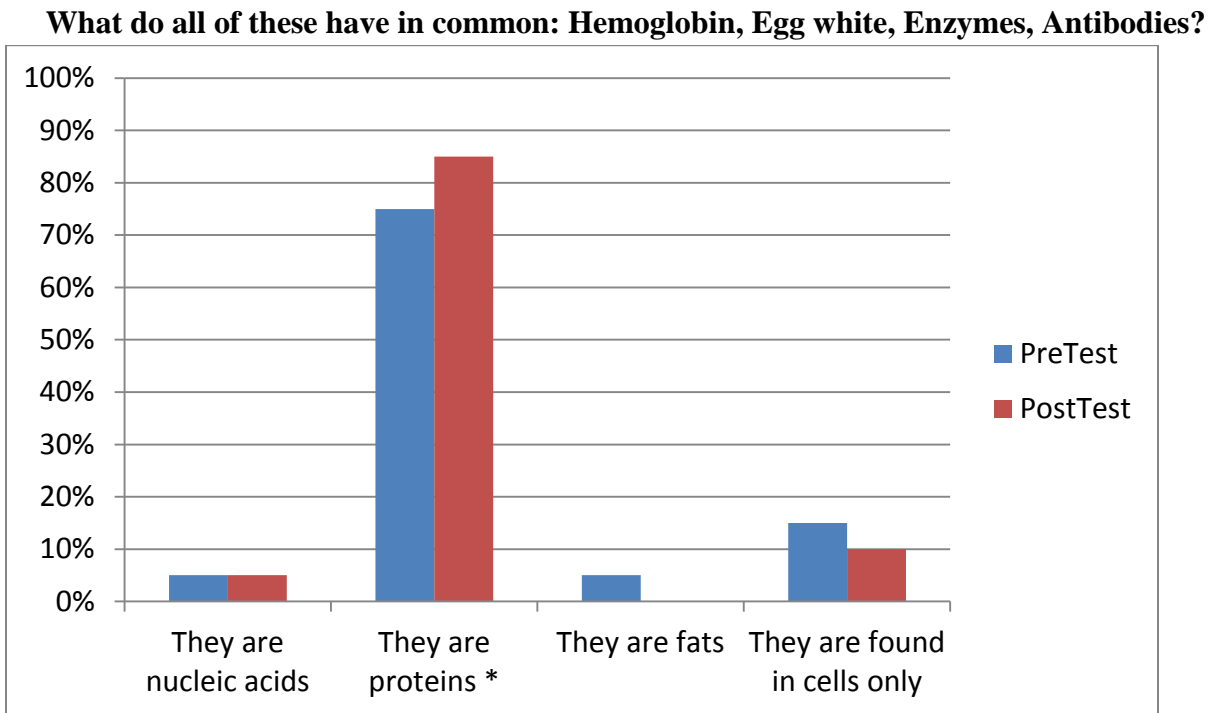


Figure 12: Question 10-** Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

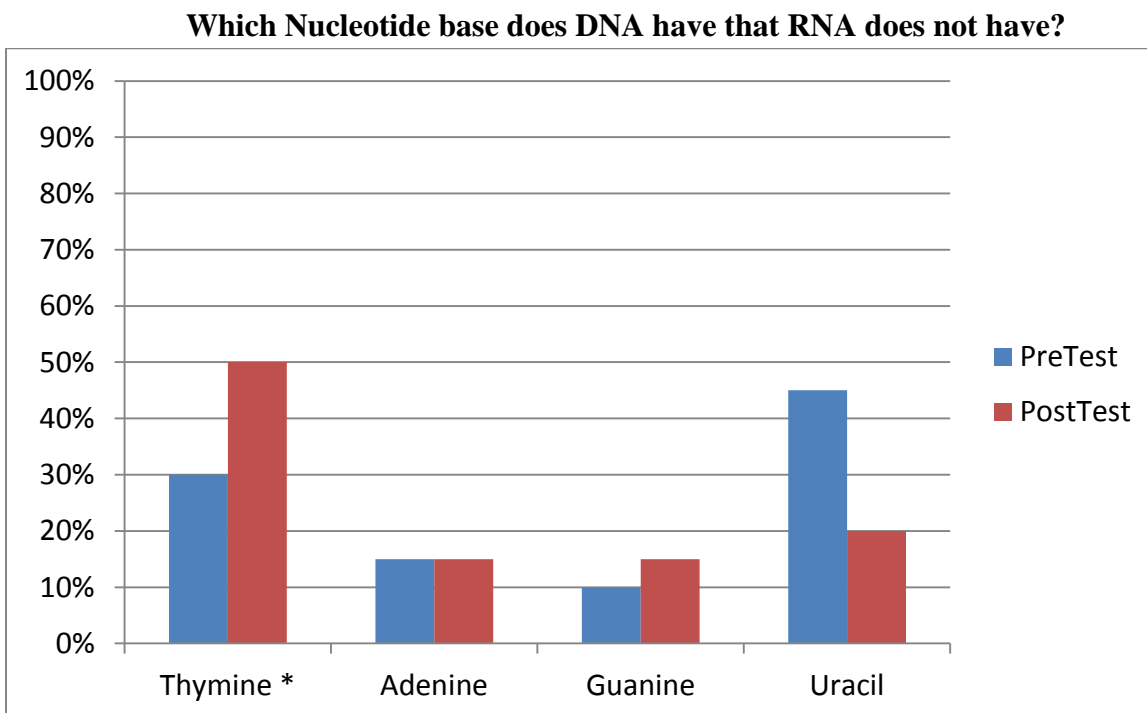


Figure 13: Question 11**- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

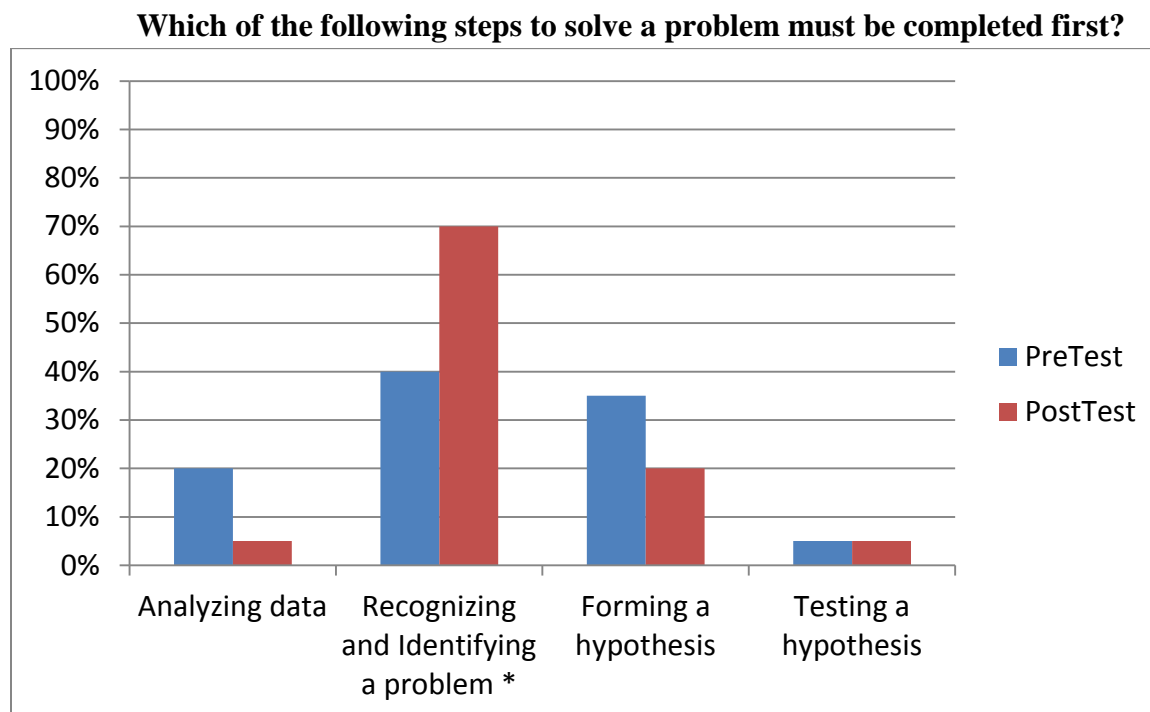


Figure 14: Question 12- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

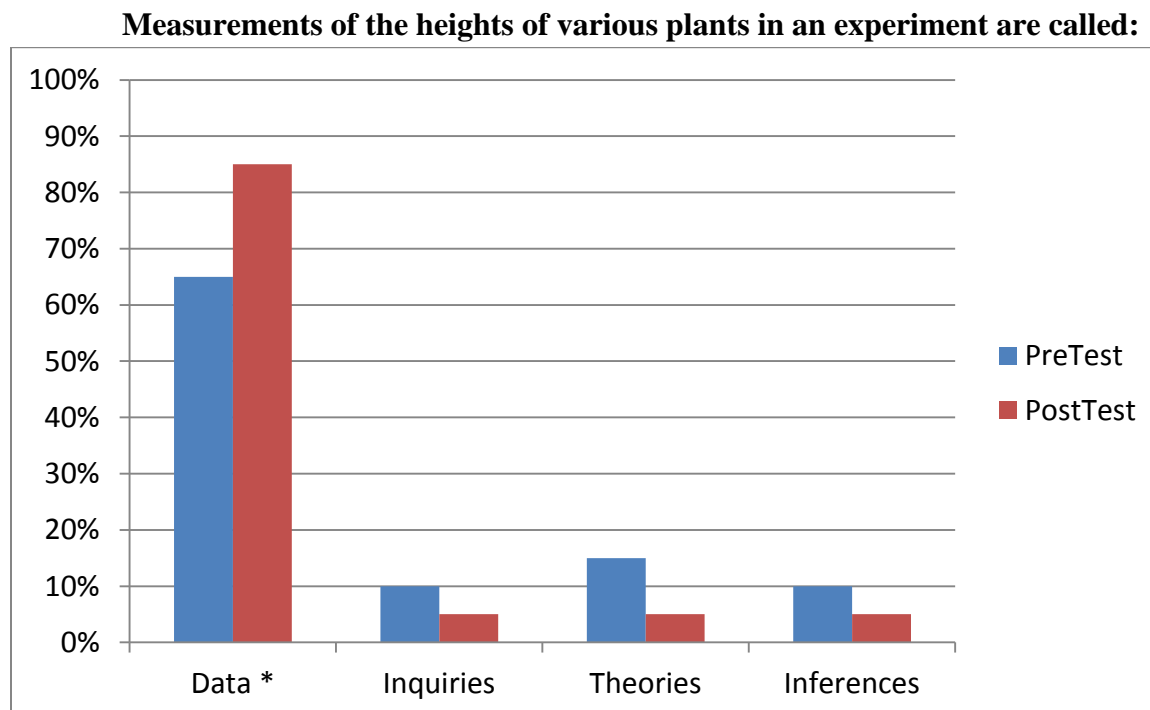


Figure 15: Question 13- Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

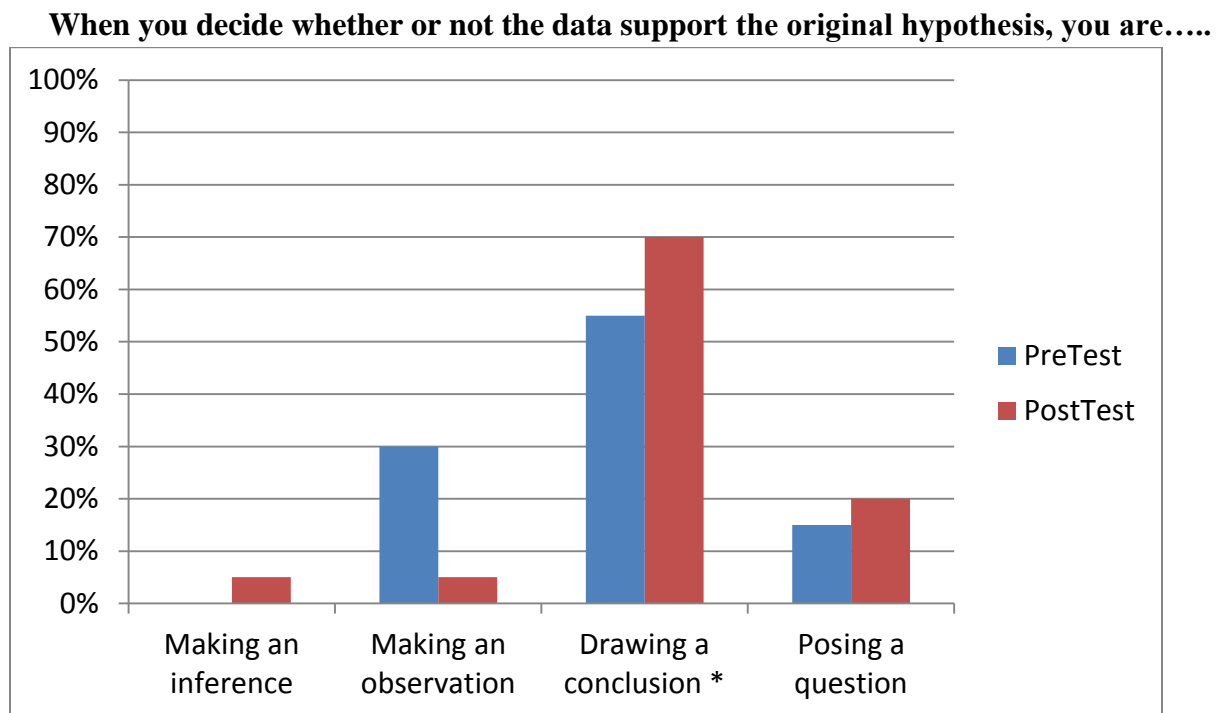


Figure 16: Question 14-** Figures 3-16 contain all of the answers provided by students on the pretest and posttest by question so that a wrong answer analysis of the data could be conducted by the instructor.

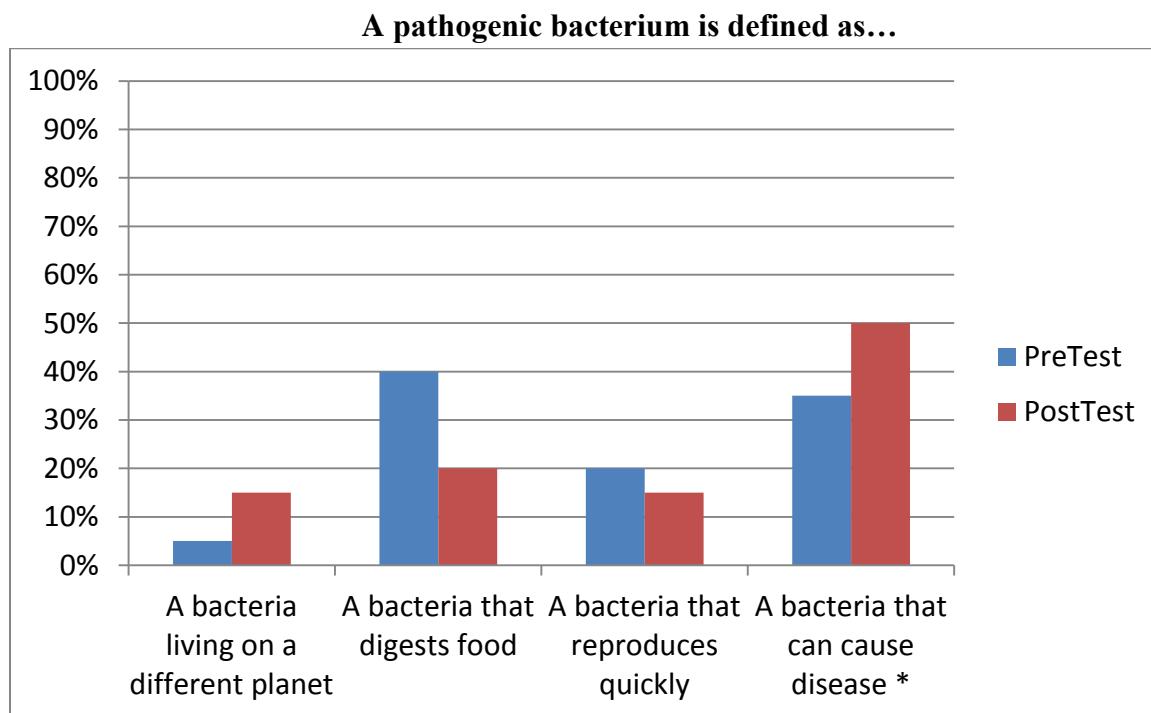


Figure 3 through Figure 16 shows that there were no anomalies in the questions. This can be determined because for both the pretest and the posttest, the wrong answers were evenly distributed between the answers. If there had been one wrong answer that all students selected over the correct one, it would indicate that a “trick” question may be there, or a misconception was not properly addressed. However, this did not happen during the course of this research (See Figures 3-16).

DISCUSSION

Overall, the instructor was pleased with the outcome of the unit. Students seemed to genuinely enjoy the activities that were selected to help teach them about protein synthesis, and most of the time they were engaged in learning. However, some modifications were made to the unit to accommodate problems that arose during research. In teaching, even the best plans have to be modified on a constant basis for this reason. No classroom environment is ever going to be perfect and sterile enough to perfectly execute a plan, and this repetitive adaptation is probably required more in an urban district than a suburban one.

The first disruption was an administrative one, with the instructor waiting for approval from central office to begin research with the students. Due to the time-sensitive window for conducting the unit as part of a year-long anatomy curriculum, the teacher was upset when approval did not go through in time. This unfortunate problem was due to an employee out on sick leave, but eventually a colleague in the same department approved the research. By the time approval had been granted, however, two weeks slated for the unit had passed and the teacher was forced to cut some activities out to make sure that all year-long objectives were adequately covered. Another problem faced during the unit, and one that is ongoing in the class and in the district is the high number of student absences. When students are absent during a lecture or class activity, it can be difficult, or even impossible, to make up the work that they missed. This can be made more difficult in an urban district where many students work after school to support their families, babysit, or otherwise take care of family members. Students almost always make up tests that they miss, but they do not necessarily do well on them if they missed a lot of other work.

One unforeseen issue that occurred took place in the greenhouse with lab materials. The reason that the students were not able to complete the inquiry lab as planned was the plants that they planted did not grow. A few reasons for this may be that they were not properly cold treated prior to planting by the instructor, the seeds may have been old or damaged by heat, or they could have not been planted correctly by the students. After approximately two weeks with absolutely no sprouting, the instructor had to cancel the inoculation with the pathogen and develop an assignment that mimicked the inquiry lab as close as possible without the materials. The instructor held a class discussion about how the experiment would be conducted, had the students generate a hypothesis, and shared pictures of experimental data for them to analyze. For the circumstances, the instructor was happy with how the assignment turned out and the students seemed to get as much out of the experience as possible.

One of the biggest issues was a classroom environment issue. With the research being done in November, the heat was turned on in the building for the winter for the first time. Working in an old building definitely has its problems, and the boiler is one of them. The computer lab where most of the research was conducted sits right next to the greenhouse with no windows, and temperature was measured during this time frame to be about ninety-five degrees. At this temperature, students get hot and cranky and often times fall asleep rather than doing their work. This was the case when completing both the *Proteins Research Assignment*, and the *Genetically Modified Organism* presentations. The heat definitely made it more difficult for the students to work on their research, as it was nearly unbearable in the lab. Repeated calls to the office, and finally to Physical Plant resulted in the resolution of the heat issue, but it took two weeks. By that time, the students were done with the unit and back in the classroom. The heat had an impact on student learning; many got frustrated and gave up quickly. It is difficult to say

whether or not the scores were low on this assignment due to the heating issues, or the nature of the *Protein Research Assignment*, but the instructor assumes the heat played a large role.

Another building issue that occurred during the unit was a major gas leak in the building. All the science classrooms have natural gas running to them and there are usually one or two gas leaks a year. This portion of the unit was slated for review of material for the test, and questions about the content, but when the leak occurred, the students were forced to file outside and wait for the clearance from the gas company to return to the classroom. The entire building waited as professionals came in to check the building, and after about forty-five minutes, many of the students started calling their parents for rides, or left for home. The attendance for the remainder of the day averaged about ten percent, with only four students showing up for class that afternoon. Since the test couldn't be postponed, the review day didn't happen and students were left to review on their own for the test.

One of the worst disruptions that happened was a fight that broke out in the classroom between two cousins during the *Genetically Modified Organism Research* that took place in the computer lab. The two students had a short argument that instantly escalated into a fight. The instructor intervened in the altercation, removing the offending student from the classroom and calling security. When security came to the door with the other student, he apologized to both the instructor and the other student but was asked to remain out of the class for the rest of the afternoon. Regardless of the fact that the fight ended rather quickly and painlessly, the rest of the classroom was restless for the remainder of the hour. Some were upset and some thought it was funny, but ultimately the majority of the students were not as focused on their work as they should be. Despite the teacher's best efforts, minimal work was completed during the remainder

of class. The next day, both students came back to class on a verbal agreement that they would not sit together or work together for the remainder of the week.

Despite the multiple setbacks to the research, the instructor thought that the unit went very well. There were not any more disruptions during the unit than are typical during the course of the school year, and modifying plans and activities is practically written into an urban teacher's job description. Fights, fire alarms, students in the hall, gas leaks, heating issues and other disruptions are all part of daily life in the school where this unit was taught. It doesn't necessarily mean that the school is worse or better than other schools, but it definitely points to the fact that students here have to work harder to overcome these disruptions to learn the content and to do well. Teachers in this building also are constantly adapting to these distractions, while also providing a curriculum that is relevant and challenging for their students. The fact that this instructor was able to provide a rigorous unit based on research in anatomy and physiology in this school with few modifications, and that students who participated in the unit showed an improvement in knowledge of protein synthesis points to even greater support for the use of models and inquiry based learning in the classroom. If anything, urban districts should consider switching their science classes to an inquiry based curriculum to help hold student interest, and boost learning of science content.

Overall, student reactions to the unit were positive. Comments from students included that they enjoyed doing a pretest at the beginning of a unit to see what they would be learning about, enjoyed the DNA modeling activities, and liked the idea of participating in the *Arabidopsis* activity. Students gave the impression that they felt important to be participating in something bigger than just what goes on in the classroom, and it felt more like a game to them to try to determine the role of the NDR1 gene in *Arabidopsis*. It was also impressive to see how

well the students did with the DNA modeling activities (*Know Your Nucleotides, Replication is Refreshing, and Protein Synthesis Satisfies*). At first they were very skeptical about the assignments, but the instructor felt that all the students did very well with their oral presentations. The Genetically Modified Organism assignment was another impressive part of the unit which required the students to do independent research, and the resulting presentations were outstanding as shown in the student work example (Appendix 3I).

After years of teaching protein synthesis to high school anatomy students and trying different things each year to make it more exciting or more memorable, the unit that the instructor presented for this project proved to be one that worked well. This unit plan will be implemented every year in the future to teach this protein synthesis, but with some changes. In the future the research activity on protein types may be eliminated, or more information about protein folding will be incorporated into the unit so that the students don't get frustrated and lost in the vocabulary. The Protein Synthesis Practice will also be removed from the unit due to time constraints, and the *Arabidopsis* inquiry lab will remain. Hopefully this unit can be fully incorporated in the future, but at least a backup lesson is ready in case of another setback. Unfortunately, there is not enough time in the curriculum to do all of the activities to their fullest extent, but the lessons that promote the most learning will be incorporated on a regular and consistent basis.

CONCLUSION

The data collected for the pretest and posttest indicate that the hypothesis stating students will significantly increase their knowledge of protein synthesis was supported. The average test scores show an increase of 16.8% after completion of the unit, and the T value of -4.61 with a p value of .05 for the pre and post testing data dictate acceptance of the hypothesis. Further analysis of the testing data shows that the questions asked on the test were not ones that “tricked” students into putting a wrong answer. It was interesting to see that the questions chosen after completion of the pretest for emphasis by the teacher were also the questions that showed the highest gains in improvement by students on the posttest. Questions eight and eleven, on nucleotide bases and scientific problem solving respectively, showed the highest gains in student test scores from pretest to posttest. These anecdotal data indicates that the material that the teacher finds important also translates to increased student learning of that material.

APPENDICES

APPENDIX 1

FORMS

APPENDIX 1-A

MICHIGAN DEPARTMENT OF EDUCATION HIGH SCHOOL BIOLOGY CONTENT EXPECTATIONS

Table 4 – High School Content Expectations; this is a list of the Michigan Content expectations that are covered during the course of this unit and the corresponding codes.

Standard B1

Inquiry, Reflection, and Social Implications

CODE	STATEMENT
B1.1A	Generate new questions that can be investigated in the laboratory or field.
B1.1C	Conduct scientific investigations using appropriate tools and techniques.
B1.1E	Describe a reason for a given conclusion using evidence from an investigation.
B1.1h	Design and conduct a systematic scientific investigation that tests a hypothesis. Draw conclusions from data presented in charts and tables.

Standard B2

Organization and Development of Living Systems

CODE	STATEMENT
B2.3C	Explain how stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents.
B2.4h	Describe the structure of viruses and bacteria.
B2.4i	Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells.
B2.r6c	Recognize and explain that communications and/or interaction are required between cells to coordinate their diverse activities.

Table 4 continued

Standard B4

Genetics

CODE	STATEMENT
B4.2B	Recognize that every species has its own characteristic DNA sequence.
B4.2C	Describe the structure and function of DNA.
B4.2D	Predict the consequences that changes in DNA composition of particular genes have on an organism (sickle cell anemia).
B4.2f	Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism in all life forms.
B4.2g	Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.
B4.2h	Recognize that genetic engineering provides great potential and responsibility.
B4.r2i	Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes.
B4.4a	Describe how inserting, deleting, or substituting DNA segments can alter a gene.
B4.r5a	Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes.
B4.r5b	Evaluate the advantages and disadvantages of human manipulation of DNA.

APPENDIX 1-B

PARENTAL CONSENT FORM

I would to welcome you back to school and invite you to participate in a research project I will conduct as part of Human Anatomy this semester. I am currently a master's degree student at Michigan State University, and am conducting research to complete my degree.

What is the purpose of this research? I have been working on effective ways to teach Proteins, Genes and Protein Synthesis and I plan to study the results of this teaching approach on student comprehension and retention of the material. The results of this research will contribute to teachers' understandings about the best way to teach science topics.

What will students do? You will participate in the instructional unit about Proteins, Genes and Protein Synthesis and will complete the usual assignments just as you do for any other unit. There are no unique research activities – participation in this study will not increase or decrease the amount of work that students do. I will simply make copies of students' work for my research purposes. This project will take place during the first semester. I am asking for permission from both students and parents/guardians to use copies of student work for my research.

What are the potential benefits and risks? There are no foreseeable risks other than those associated with completing course assignments or laboratory experiments and activities. In fact, completing course work should be very beneficial to students. During the experiment, I will not know who is participating and who is not. I will have English Teachers store the consent forms in a locked file cabinet that will not be opened until after I have assigned the grades for this unit of instruction. Please submit this form directly to English Teachers. You may also withdraw from the study at any time.

How will privacy and confidentiality be protected? Information about you will be protected to the maximum extent. Students' names will not be reported in my thesis or in any of the results of this research. Instead, the data will consist of class averages and samples of student work that don't include names. The data will be stored on password-protected computers (during the study) and in a locked file cabinet in Dr. Heideman's locked office at MSU (after the study) for at least three years after the completion of the study

Who can you contact with questions and concerns? If you have concerns or questions about this study you can contact me at angela.kolonich@lansingschools.net or by phone at (517) 755-1070. You can also contact Dr. Merle Heideman at MSU heidema2@msu.edu or by phone at (517) 432-2152. Her address is at 118 N. Kedzie, East Lansing, MI 48824. If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

PARENTAL CONSENT AND STUDENT ASSENT FORM

Name of science course: HUMAN ANATOMY AND PHYSIOLOGY

Teacher: ANGELA KOLONICH

School:

Parents/guardians should complete this following consent information:

I voluntarily agree to have _____ participate in this study.
(print student name)

Please check all that apply:

Data:

_____ I give Angela Kolonich permission to use data generated from my child's work in this class for her thesis project. All data from my child shall remain confidential.

_____ I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of their participation in this research.

Photography, audiotaping, or videotaping:

_____ I give Angela Kolonich permission to use photos, audiotapes, or videotapes of my child in the class room doing work related to this thesis project. I understand that my child will not be identified.

_____ I do not wish to have my child's images used at any time during this thesis project.

Signatures:

(Parent/Guardian Signature) (Date)

I voluntarily agree to participate in this thesis project.

(Student Signature) (Date)

APPENDIX 1-C

STUDENT LABORATORY SAFETY CONTRACT

PREPARE FOR LABORATORY WORK

- Study laboratory procedures prior to class.
- Never perform unauthorized experiments.
- Keep your lab bench organized and free of apparel, books, and other clutter.
- Know how to use the safety shower, eye wash, fire blanket and first aid kit.

DRESS FOR LABORATORY WORK

- Tie back long hair.
- Do not wear loose sleeves as they tend to get in the way.
- Wear shoes with tops.
- Wear lab coats during all laboratory sessions.
- Wear safety goggles during all laboratory sessions.
- Wear gloves when using chemicals that can be absorbed through skin.

AVOID CONTACT WITH CHEMICALS

- Never taste or "sniff" chemicals.
- Never draw materials in a pipette with your mouth.
- Never carry dangerous chemicals or hot equipment near other people.

AVOID HAZARDS

- Keep combustibles away from open flames.
- Use caution when handling hot glassware.
- Turn off burners when not in use.
- Keep caps on reagent bottles. Never switch caps.

CLEAN UP

- Consult teacher for proper disposal of all materials.
- Wash hands thoroughly following experiments.
- Leave laboratory table clean and neat.

IN CASE OF ACCIDENT

- Report all accidents and spills immediately.
- Place broken glass in designated containers.
- Wash all acids and bases from your skin immediately with plenty water.
- If chemicals get in your eyes, wash them for at least 15 minutes at the eyewash.

I, _____, agree to: (a) Follow the teachers instructions, (b) protect my eyes, face, hands and body during laboratory, (c) conduct myself in a responsible manner at all times in the laboratory, and (d) abide by all of the safety regulations specified above.

APPENDIX 2

TEACHER NOTES AND ACTIVITY INSTRUCTIONS

APPENDIX 2-A

LIST OF POWERPOINT LECTURES

Four power-point presentations were given as a part of this unit and are intended to give students background information specific to the content learned. Although these presentations are not wholly included in the appendix, they are available upon request.

1. Arabidopsis – A model Organism
 - a. B4.2B- Recognize every species has its own characteristic DNA sequence
 - b. B4.2h- Recognize genetic engineering comes with great potential & responsibility
2. Arabidopsis – Planting guide slides
 - a. B1.1C- Conduct scientific investigations using appropriate tools and techniques
3. Plant Pathogens
 - a. B2.3C- Explain how stability is challenged by changing physical, chemical, and environmental conditions, as well as the presence of disease agents.
 - b. B2.4h- Describe the structure of viruses and bacteria
 - c. B2.4i- Recognize that while viruses lack cellular structure, they have the genetic material to invade living cells
 - d. B2.r6c- Recognize and explain that communications and/or interactions are required between cells to coordinate their diverse activities.
4. Proteins
 - a. B4.2D- Predict the consequences that changes in DNA composition of particular genes have on an organism

APPENDIX 2-B

PLANTING OUTLINE

Table 5 – Planting Outline; This table depicts the number and type of plants that should be planted during the inquiry experiment by students. Also listed is the proper pathogen application to conduct the experiment with a positive and negative control.

<p>COLUMBIA</p> <p>Positive control same conditions as all plants, no bacteria</p>	<p>NDR1</p> <p>Positive control same conditions as all plants, no bacteria</p>
<p>COLUMBIA</p> <p>Negative control same conditions as all plants, spray with empty vector bacteria. Plants can't recognize invader, all should die</p>	<p>NDR1</p> <p>Negative control same conditions as all plants, spray with empty vector bacteria. Plants can't recognize invader, all should die</p>
<p>COLUMBIA</p> <p>Experiment, same conditions as all plants, spray with <i>P. syringae</i>. Record results over time</p>	<p>NDR1</p> <p>Experiment, same conditions as all plants, spray with <i>P. syringae</i>. Record results over time</p>

Students will record the results of their experiment and use the notes that we have taken in class to determine the conclusion of the experiment.

APPENDIX 2-C

LECTURE AND CLASS DISCUSSION POINTS

Lab Safety Discussion and Contract

Read over the safety contract with the students and point out where all the safety equipment and personal protective gear are in the room. Emphasize parts of the contract that are particularly important for the experiment that we will be conducting, and remember to continue to remind students throughout the project. As we are reading through the contract, be sure to point out where the different waste receptacles are and what items are to be thrown away in which container. Post signs above each waste receptacle that will list items which are appropriate to throw away in them.

NDR1 Discussion points

Is a gene that is currently being tested in Arabidopsis. Researchers know that it provides resistance to many pathogens such as viruses, bacteria, fungus, oomycetes, and pests. What they don't know is exactly how it provides this resistance for the plant, and what pathogens are included in this resistance. They hope to do many tests to map the exact pathway for resistance and use it for agricultural applications. Remember GENES CODE FOR PROTEINS ALWAYS! So "western blots" are at the core of this research where they extract proteins from the plant and try to determine which ones are affecting resistance, and in what order. Before performing the blot test on the plant proteins, the tissue will go through many levels of processing to select what researchers hope are the right ones. Remember also, many different genes, and therefore proteins can code for one result. So this research, on this one gene, may take many years to complete.

Inoculation discussion points

Different types of inoculation include direct inoculation with a syringe where the plant is slightly injured and the solution of bacteria is injected directly into the leaves, spray inoculation which requires the solution include a surfactant to penetrate the waxy cuticle of the leaf, and dipping which is primarily to transmute genes within seeds where the flowering plant is literally dipped into a solution of bacteria. Although direct inoculation with a syringe has a much better chance of greater infection, it is an extremely difficult procedure that can take weeks to perfect (we will try another time). For our purposes the spray should work very well and is a much easier way to introduce the inoculation procedure.

Aseptic technique discussion points.

When working with bacteria it is extremely important that you do NOT contaminate the sample with foreign bacteria. Remember bacteria are everywhere, in the air, on your skin and absolutely in your body. Always wear gloves, try not to expose the bacteria to the air for great lengths of time, and do not breathe directly on the sample, or on the plates during plating. In addition, any items used in the handling of bacteria or transgenic plants must immediately go into the special autoclave waste (which I will point out). The bacteria used to create transgenic plants are antibiotic resistant, and although these bacteria don't infect humans, we want to be extra careful. Give handout highlighting important lab procedures and techniques.

Plant growth

Will draw a diagram on the board of seed to seedling including discussion of what the cotyledon leaves are for and why we need 2-4 true leaves for our experiment. I will distribute and go over the handout with students so that they can recognize the various stages of primary plant growth (very brief)

Type Three Secretion System

Show students the diagram and website that describes how *P. syringae* infects plants. Talk about the different ways that pathogens cause damage to plant cells and relate it to the way that *P. syringae* causes damage. Can spend some time talking about the Evolutionary arms race between pathogens and hosts, and how specifically both *A. thaliana*, and *P. syringae* have evolved over time.

APPENDIX 2-D

TEACHER NOTES: GENETICALLY MODIFIED ORGANISMS RESEARCH 1

Prep Time: close to none if any – you may want to create groups based on academic ability and assign groups an organism based on difficulty level

Suggested Class Time: One 50 minute class period for research in the computer lab.

Another day could be used to present projects if desired.

Classroom management: Make sure the students use appropriate websites while in the computer lab and circulate around to give them suggestions.

Suggestions: This project would best work if students were grouped into groups of 2 to 4 depending on how many groups you want. If you have time and not too many groups you could have students present their final projects to each other to give students a larger view of the various applications of creating transgenic organisms.

- Use the list of modified organisms and assign each group an organism – there is a blank on the top of the student handout to be filled in with the modified organism you choose for the group. Some organisms, such as the animals, on the list below have several applications. Have the students research these and choose one to do their project on.

WOW! Wild or wonderful information found could be optional or bonus.

1 Special thanks to Thomas Dean, Katie McKinley, and Tracy D'Augustino

MODIFIED ORGANISMS LIST

Plants

Rice – Beta carotene

Bt Cotton – *Bacillus thuringiensis* (Bt)

Bt Corn – *Bacillus thuringiensis* (Bt)

Bt Rice - *Bacillus thuringiensis* (Bt)

Tomato resistant to tobacco mosaic virus

Tobacco able to break down bromoxynil

Tomatoes able to grow in saline soils

Terminator genes – plants produce sterile seeds

Biopharmaceuticals – students choose an organism with this application

Human growth hormone

Human antibodies

Protein antigens – vaccines

Animals – students choose an application for transforming this organism

Sheep

Chickens

Pigs – enviroPig, lower levels of phosphorus emissions

Primates

GE Salmon

Goats – milk

APPENDIX 2-E

DNA MODELING ACTIVITIES: TEACHER NOTES

Be sure to run off the sheets using paper colored as indicated below. Then assemble into packets for each part. For the **Work/Study Plan**, you may want to insert (or provide) specific page numbers from your text. The **DNA Unit Objectives** should be modified (items removed or added or changed) as reflected in your text, standards and approach.

MATERIALS: You will need to provide scissors and paste (or glue sticks) or tape for all students. Once the pieces are all cut out (for kits #2 and 3), they can be placed in appropriately labeled envelopes, and these placed in a larger envelope. At the end of your unit, collect them so future classes (in future years) won't have to do so much cutting out. Include an inventory strip for each kit (shown below)

For kit # 1, the cutting out and pasting in are important kinesthetic tools to help instill the basic structures of nucleotides, so that kit should be cut out and pasted by all students every year.

KNOW YOUR NUCLEOTIDES

- 1.1 Preparation and Instructions for Building Nucleotides from sub units (text: 1 page, **white**)
- 1.2 Worksheet: Nucleic Acid Structure (text and a little artwork: 1 page, **pink**, for pasting or drawing on)
- 1.3 Models of Nucleotide Sub-Units (artwork for cutting out and pasting onto Worksheet: 1 page, **white**)

REPLICATION IS REFRESHING

- 2.1 Preparation and Procedures (text: 1 page, **white**)
- 2.2 Model of DNA Molecule (artwork for cutting out: 1 page, **white**)
- 2.3 DNA-Nucleotides (artwork for cutting out: 1 page, **pink**)

PartIII: PROTEIN SYNTHESIS SATISFIES:

- 3.1 Preparation and Procedures (text: 2 pages, **white**, back-to-back)
- 3.2 RNA Nucleotides and Models of Ribosome Surface and Nuclear Membrane (artwork: 1 page, **blue**)
- 3.3 Transfer-RNA Molecules (artwork: 1 page, **yellow**)
- 3.4 Amino Acids (artwork: 1 page, **green**)

INVENTORY: Do It Yourself DNA Kits #2 & 3

INVENTORY: KIT #2: (Replication)

2 **White** strands ("unzipped" model of DNA ladder)

26...**Pink** DNA nucleotides ("L"-shaped units):

3right A's,

7 left A's

2 right G's, 1 left G

2right C's,

2 left C's

7 right T's, 2 left T's

INVENTORY: KIT #3: (Protein Synthesis)

13 **Blue** RNA nucleotides ("L" shaped units):

3 A's, 2 C's, 2 G's, and 6 U's

1 **Blue** "Nuclear Membrane" strip

1 **Blue** "Ribosome Surface" strip

6 **Yellow** transfer-RNA (t-RNA) molecules (all different)

6 **Green** Amino Acids (all different)

APPENDIX 3

STUDENT ASSIGNMENTS AND ACTIVITIES

APPENDIX 3-A

MODEL ORGANISM READING HOMEWORK

Science News

Database on Tiny Plant Will Help Scientists Create Better Crops, Biofuels and Medicines
Science Daily (July 10, 2009) — A tiny plant with a long name (*Arabidopsis thaliana*) helps researchers from over 120 countries learn how to design new crops to help meet increasing demands for food, biofuels, industrial materials, and new medicines. The genes, proteins, and other traits of this fast-growing, tiny mustard plant reside in a vast database dubbed the *Arabidopsis* Information Resource (TAIR), which has over 1.6 million page hits each month.

The TAIR group, headed by Dr. Eva Huala at Carnegie's Department of Plant Biology, just released a new version of the genome sequence of this model plant, which includes an array of improvements and novel features that promise to accelerate this critical research.

The new TAIR9 genome release contains detailed information on all 33,518 genes that make up this tiny plant (including 114 newly discovered genes and 168 new pseudo genes), the proteins produced by these genes, and extensive new experimental and computationally predicted gene-function information.

Huala highlighted the advances: "We now have a ranking system that provides a measure of our confidence that the structure of a specific gene is correct; we've overhauled information on pseudo genes—the evolutionary remnants that start out as copies of conventional protein-coding genes and sometimes take on interesting new functions; and we've made extensive updates to the genome sequence based on new sequence data submitted to TAIR."

Figure 17-Arabidopsis photo



In 2000, *Arabidopsis* was the first plant genome to be sequenced. Partly due to the vast experimental data on gene function, which TAIR has painstakingly extracted from the literature and associated to the genes, and because of an extensive set of molecular tools developed for this plant, the *Arabidopsis* genome is the most advanced plant genome in the world and is the most commonly used experimental plant today. Its small size and fast growth allow large-scale experiments on drought and salt tolerance, resistance to plant diseases, and other topics with a direct impact on economic and food quality issues to be carried out quickly and economically, and the results applied to important crop species. "TAIR is a crucial resource for plant sciences, but its impact goes far beyond,"

remarked Dr. Wolf Frommer, director of Carnegie's Department of Plant Biology. "TAIR9, as the 'green' reference database, is crucial for understanding the function and engineering of algae as well as crop plants. It is the basis for all improvement of crop plants to meet the challenges of a growing population as well as climate change." The *Arabidopsis* Information Resource (TAIR) collects information and maintains a database of genetic and molecular biology data for *Arabidopsis thaliana*, a widely used model plant. TAIR is produced by the Carnegie Institution's Department of Plant Biology in Palo Alto, CA. Funding is provided by the National Science Foundation, (Carnegie Institution, 2009)

APPENDIX 3-B FOUR LEAF STAGE DIAGRAM

Figure 18 – Leaf Diagram; This diagram is used to show students the difference between the true leaves, and the first cotyledon leaves of plants. The cotyledon leaves sprout first and die, and the first true leaves sprout after.



(USDA, 2006)

APPENDIX 3-C

GENETICALLY MODIFIED ORGANISM RESEARCH 2

Congratulations! You've been hired as lead journalist investigating Assigned organism. You and your partners will need to research the process of genetic engineering as related to your assigned topic. You should prepare a short, 5-10 minute presentation to teach us about your topic. Please include the following information.

1. Why was your organism genetically transformed?
 - a. What is the desired trait?
 - b. What is the application for this technology?
 - c. How does this transgenic organism benefit society?
2. What are some problems and benefits of transforming organisms?
3. What current or future concerns should be considered by society?
4. Find one article related to your research and summarize the main concepts presented and conclusions you can draw from the research and any data presented.
5. How valid is the research data in the article?
6. Is the source of the article credible?
7. Is there any bias in the article? If so, what is it?
8. WOW! Any wild or wonderful information you found.

APPENDIX 3-D

PROTEIN RESEARCH ASSIGNMENT

Protein Class Research Guide

Name: _____

Date: _____

Protein	Class	Protein Structure	Function
<i>Keratin</i>	<i>Structure</i>	<i>Twisted together, a coiled coil.</i>	<i>Coils allow for strength and elasticity in skin and hair</i>
	<i>Enzyme</i>		
	<i>Recognition</i>		
	<i>Defense</i>		
	<i>Storage</i>		
	<i>Regulator</i>		
	<i>Hormones</i>		
	<i>Carrier</i>		
	<i>Mechanical</i>		

APPENDIX 3-E

KNOW YOUR NUCLEOTIDES

A. PREPARATION

1. Before you begin, read the section in your text which introduces DNA and its nucleotide structure. Indicate under "A. Examples" on the Nucleic Acids outline sheet (pink) where in a cell most of the RNA and most of the DNA are found.
2. Now, read overall the steps below before proceeding. (The sub-unit cut-outs are simplified models of their respective molecular structures).

B. BUILDING NUCLEOTIDES

1. INFORMATION: Nucleic acids (DNA and RNA) are all long chains, each link of which is a main building block called a NUCLEOTIDE. Each nucleotide is, in turn, made up of 3 sub-units:
 - a) a PHOSPHATE group;
 - b) a PENTOSE sugar (ribose in RNA, or deoxyribose in DNA)
 - c) one of 5 possible nitrogenous

BASES (adenine, guanine, cytosine, or thymine in DNA; adenine, guanine, cytosine, or uracil in RNA).
2. Cut out one of each of the different model sub-units (next page) involved in the sub-structures of different nucleotides, and paste or glue each one in its proper space provided on the pink outline sheet (partB-1).
3. Now, cut out the remaining sub-unit models, and arrange the appropriate units together to build each of the nucleotides named under "Examples of Nucleotides" in the outline (partB-2). Follow the example shown for the first one: Adenine ribonucleotide. Of course, for ribonucleotides, use ribose sugars, and for deoxyribonucleotides, use deoxyribose sugars.
4. As you work with each sub-unit and each nucleotide, repeat its name over and over. By doing this, you will be learning the names for these vital parts of the "thread of life".
5. Place each set of sub-units (each nucleotide assembled as above) in the appropriate space (beneath its name) in the outline. When you are certain it is correctly done paste or glue each piece in place.
6. Connect the sub-units of each nucleotide to each other by bond lines at the proper positions (marked by short marks in the sub-units). When high energy bonds exist, show each by a wavy line (as in ATP).
7. When you finish, all cut-out pieces will have been used. Have your completed Nucleic Acid outline sheet ready to be checked tomorrow.

- 1 .Look over the objectives (below)
2. Read text pages on DNA structure; then do Part I (Nucleotide Kit).
3. Read text pages on Replication; then do Part II (DNA Replication Kit).
- 4 .Read text pages on Protein Synthesis; then do Part III (Protein Synthesis Kit). Report the secret word (discovered while doing this) to your teacher, quietly; don't tell anyone else!
- 6 .Reread text pages on Protein Synthesis, then finish the DNA chapter(s). Review all reading, until you can respond to all objectives.

Figure 19 – Know your nucleotides; The cutouts were used as students build various nucleotide structures from the molecules provided for the know your nucleotides activity.

A. EXAMPLES OF NUCLEIC ACIDS (precisely where in the cell is each found)

1. RNA (Ribonucleic Acid) _____

2. DNA (Deoxyribonucleic Acid) _____

B. NUCLEOTIDES: The main structural units of nucleic acids

1. SUB STRUCTURE OF NUCLEOTIDES each nucleotide is composed of 3 bases, all shown here in simplified diagrams.

a. Phosphate Group (Phosphoric Acid)



b. Pentose Sugars

Ribose (RNA)



Deoxyribose (DNA)



c. Nitrogenous bases

Pyrimidines:

Cytosine



Thymine



Uracil

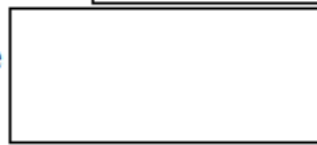


Purines

Adenine

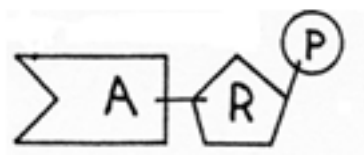


Guanine



RIBONUCLEOTIDES

1. Adenine Ribonucleotide



2. Guanine Ribonucleotide

DEOXYRIBONUCLEOTIDES

1. Adenine deoxyribonucleotide

2. Guanine deoxyribonucleotide

3. Cytosine Ribonucleotide

|

3. Cytosine Ribonucleotide

4. Uracil Ribonucleotide

4. Uracil Ribonucleotide

Figure 19 continued

Models of Nucleotide Sub-Units

Cut out each model sub-unit and past into proper space on the **Nucleic Acid Structure** sheet (part B). Then show how each nucleotide is assembled by pasting their sub-units side-by-side as shown in the example for Adenine ribonucleotide (#1), and connect them with bonds.

RIBOSE SUGARS



DEOXYRIBOSE SUGARS



PHOSPHATE GROUPS



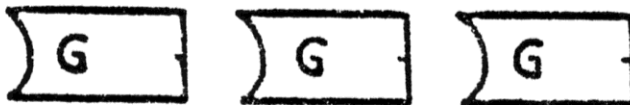
CYTOSINE BASES



THYMINE BASES



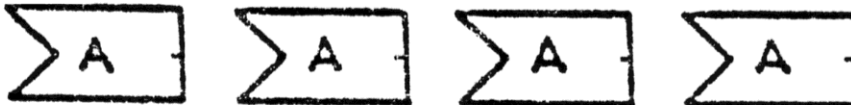
GUANINE BASES



URACIL BASES



ADENINE BASES



(Flammer, 2007)

APPENDIX 3-F

REPLICATION IS REFRESHING

A. PREPARATION

1. Read the section in your text which explains DNA replication
2. The diagram on the next page represents only a very short piece of a DNA molecule, but will be referred to herein as the "DNA molecule". Note how it is constructed as two parallel chains of matching nucleotide pairs. This arrangement is a very simplified version of its true structure, so that you can discover its basic operation more easily.
3. Cut out the entire DNA molecule, in one piece, then carefully cut out the shaded spaces between the bases. The resulting ladder-like structure can now be twisted slightly to illustrate the helical (screw-like) shape of DNA.
4. In order to demonstrate the unique ability of DNA to duplicate itself ("replicate"), first cut out all the L-shaped DNA-nucleotides on the next page (pink). These will represent the "DNA-nucleotide pool" available in the cell's nucleus.

B. THE PROCESS OF REPLICATION (Read all steps first):

1. Replication begins when the DNA molecule "unzips". Show this by cutting down the middle of the "ladder", following the curved and angled shapes of the ENDS of each base pair where they meet. This will produce two strands, left and right. Move these two strands about 10 cm apart on your table.
2. Now, move the DNA-nucleotides from the nucleotide pool (already cut out) in to positions so that their base ends fit with the exposed base-ends of each of the original, unzipped DNA strands. In a cell, this typically starts at one end of a strand and works toward the other. The other strand builds in the opposite direction. First bring an "A"

nucleotide which fits the upper left hand "T" nucleotide, then move another "A" nucleotide to fit the lower right hand "T" nucleotide. Continue adding the nucleotides which fit as you go (moving down the left hand strand, and up the right hand strand) until both halves of the ladder have been matched with new nucleotides. (Not all of the pink nucleotides will be used up. They remain as part of the nucleotide "pool" for the next replication episode). This process is very fast. In a cell, new nucleotides are added at a rate of about 50 per second, involving more than a dozen enzymes.

3. Notice the pattern? What always matches (fits) with T (thymine)? _____ What always matches with C (cytosine)? _____ What always matches with A (adenine)? _____ What always matches with G (guanine)? ____ How many DNA molecules did we start with? _____ How many DNA molecules do we have now? _____ In terms of their respective sequences of base pairs, they are _____ (identical, similar, and different).
4. As the nucleotides move into position, they would normally attach to the previously placed nucleotide (phosphate of one to sugar of the other), and the matching base pairs would join each other with weak Hydrogen bonds, forming two new double-stranded DNA molecules which are identical to each other. However, in order to practice this process and demonstrate it to others, do not actually attach the nucleotides in this model. DO practice the process. Be prepared to demonstrate and explain DNA replication to another student and/or your teacher upon request. Review the text material on DNA replication.

Figure 20 – DNA replication; the cutouts that the students used during this activity to model DNA replication.

MODEL OF DNA MOLECULE

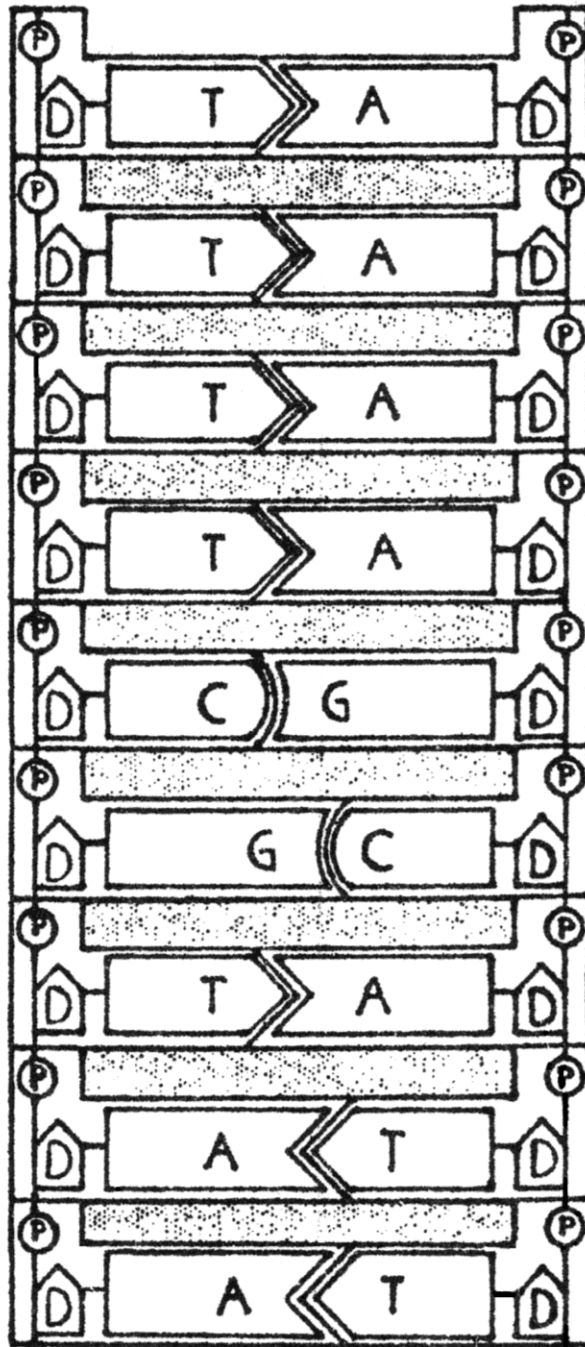
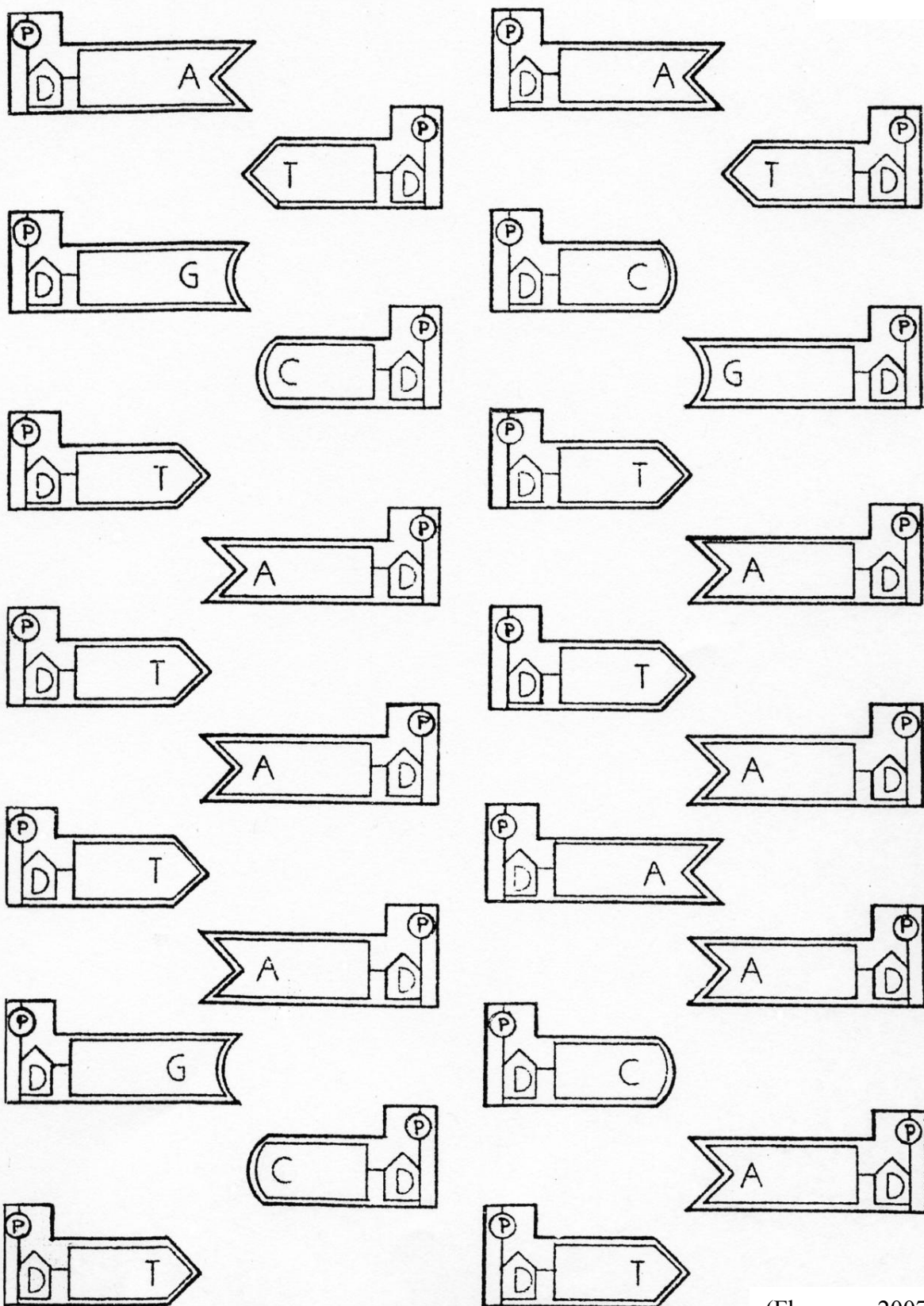


Figure 20 continued



(Flammer, 2007)

APPENDIX 3-G

PROTEIN SYNTHESIS SATISFIES

A. PREPARATION

1. Read the section in your text that explains how DNA directs protein synthesis.
2. Cut out all of the pieces on the three attached cut out pages (keep the pieces in an envelope when not in use).
3. SETUP: Place the "Nuclear Membrane" strip vertically on the middle of your desk. Take the original (white) DNA molecule used in the REPLICATION kit, and place it to the right of the "membrane", along with all the blue mRNA (messenger-RNA) nucleotides scattered next to it. This represents the contents of the nucleus.
4. Now, on the left side of the membrane (in the "cytoplasm"), place the "ribosome" surface in a horizontal position across the bottom of that area, and scatter the yellow tRNA(transfer RNA) pieces and the green amino acids around in the area above the ribosome surface.

B. THE PROCESS OF PROTEIN SYNTHESIS:

Think of protein synthesis as a construction process, in which the finished product is a particular protein (perhaps an enzyme), and it was assembled according to the directions from the "Master Plans" (DNA) in the nucleus.

1. FIRST, blue print copies of the building plans must be made from the Master Plans (DNA) in the nucleus, and sent out to the construction site (ribosomes in the cytoplasm):
 - a. The DNA "unzips", separating the two DNA strands. Set aside the left strand, and use only the right strand for the next step.
 - b. Move the blue mRNA nucleotides, one at a time, to positions where their base-ends fit the exposed DNA base-ends, starting at one end of the DNA and working toward the other

end: A to T, U to A, etc. There will be some unused nucleotides left over in the "nucleotide pool"

c. The chain of mRNA nucleotides (blue) would now be attached to each other, in a sequence which matches (in a complementary way) the original DNA sequence. You could paste, glue, or tape them RNA nucleotides together, but for now, just hold them in position with your fingers, and move them away from the DNA, "through" (under) the "nuclear membrane", and over on to the ribosome surface, with their base ends exposed upward. The mRNA serves as a "blueprint" copy of the DNA message (gene), and carries that message out of the nucleus and in to the cytoplasm, where ribosomes help to assemble a chain of amino acids into a sequence dictated by that message.

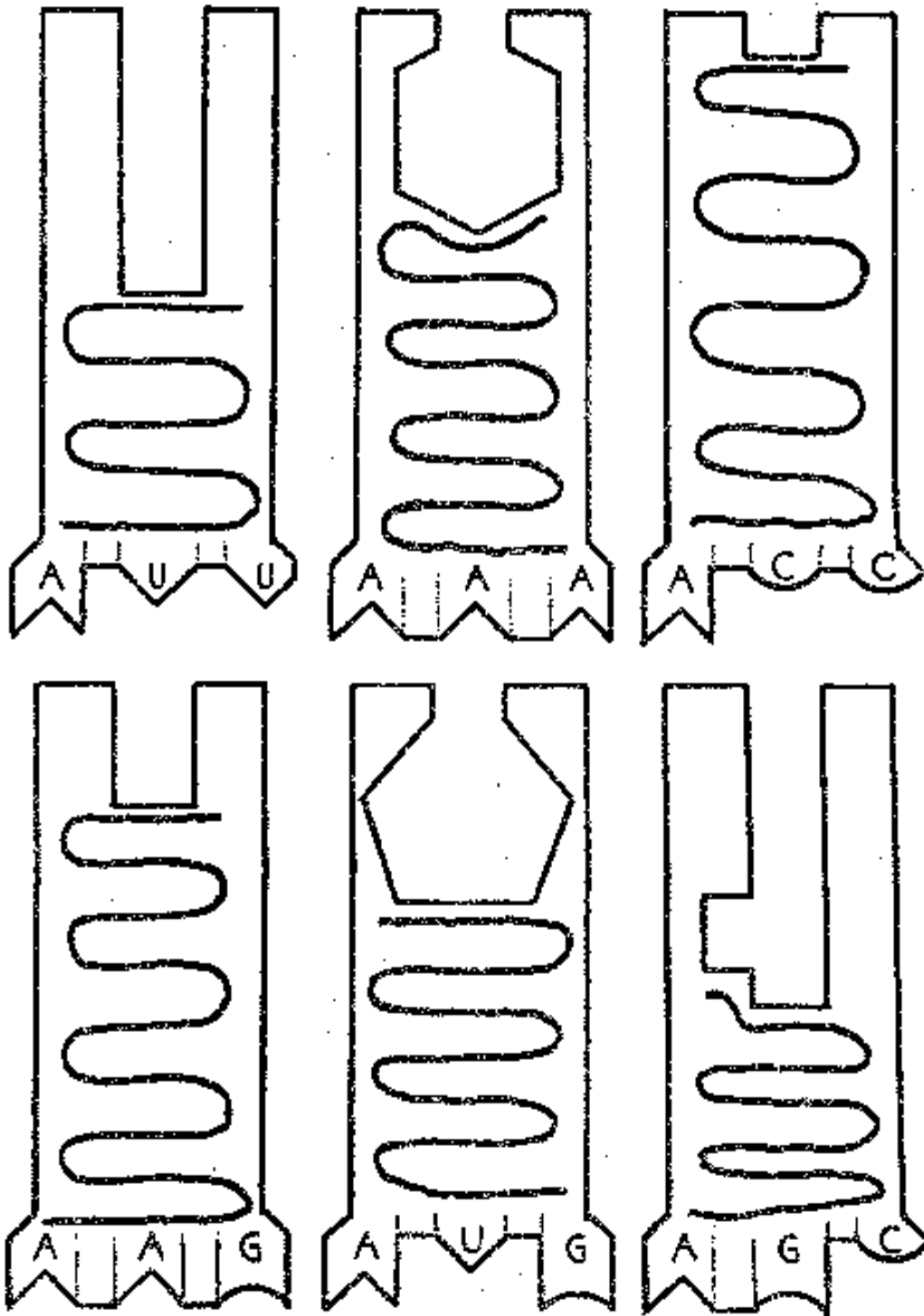
2. NEXT, the Construction Supervisor (ribosome) reads the blueprints (mRNA) for the building (protein), and directs the assembly of all the building parts (amino acids) into their proper places to make the finished building (protein).

Yellow "specialty" trucks (tRNA) have picked up their appropriate loads of concrete, bricks, lumber, glass, plumbing, etc. (green amino acids), and can bring them only to specific locations at the unloading dock, according to the supervisors' directions (sequence of nucleotide shapes in the mRNA "unloading dock"), so the 3-nucleotide sequence in the "bumper" of each tRNA truck must fit a 3-nucleotide sequence in the mRNA "unloading dock".

- a. Fit each amino acid (green) into its matching tRNA (yellow)
- b. Move the tRNA (with its amino acid load) which fits the first 3-nucleotide sequence in the mRNA ("UUU" at the left end), and position it so its nucleotide shapes are touching the mRNA shapes.

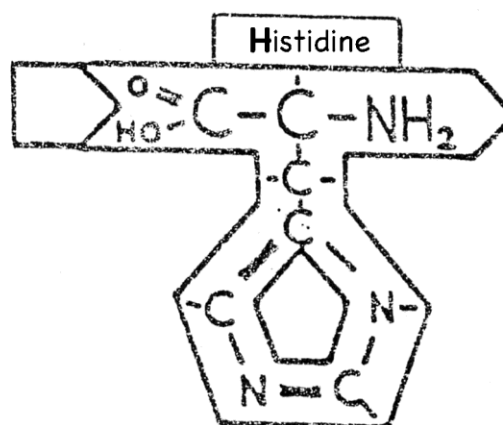
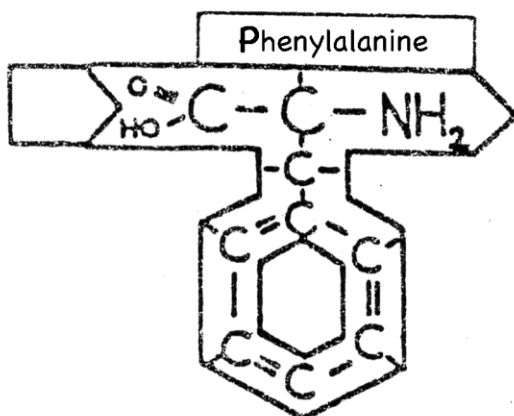
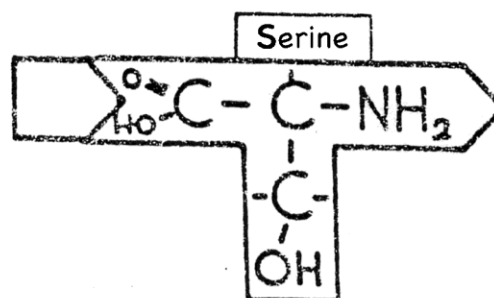
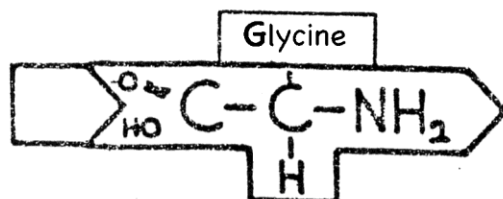
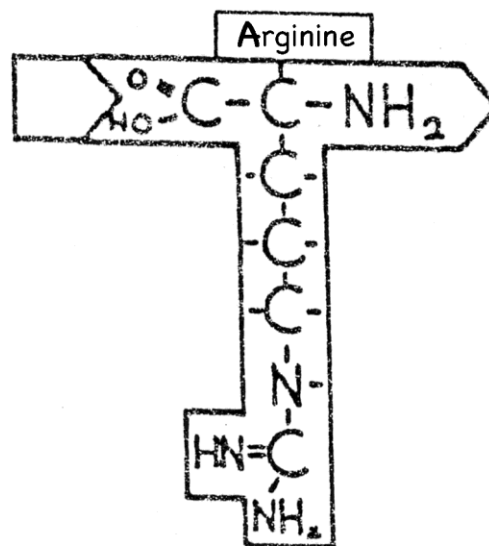
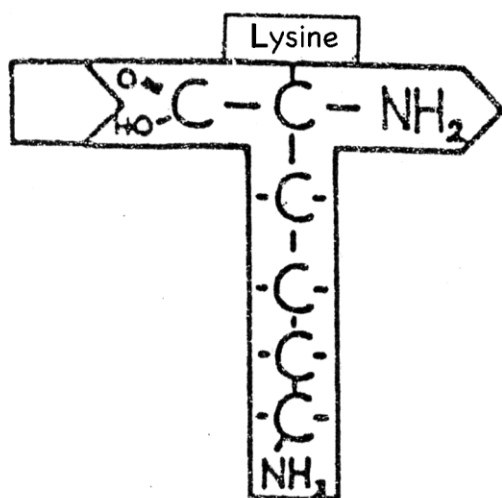
- c. Move the next tRNA (with its load, too) which fits the NEXT 3-nucleotide sequence, and position it so that their matching nucleotide base ends touch, too.
 - d. Finally, move the third tRNA and its amino acid load, and fit it in to the last 3-nucleotide sequence of the mRNA.
 - e. The three amino acids should be touching "head-to-tail" in such a way that they could be glued together, but for repeated practice, just pretend that they become attached to each other (remember "dehydration synthesis"?) by placing your fingertips on their connecting points, and moving the three amino acids away as a "polypeptide unit", representing a much reduced version of the final protein product. (The yellow tRNA molecules would move away and pick up new loads of amino acids, ready for the next assembly).
 - f. If you have done this properly, the first letter of the name for each amino acid assembled here should spell out a simple 3-letter word. DO NOT TELL ANY OTHER STUDENT WHAT THAT WORD IS. Write it on a slip of paper, and show it secretly to your teacher. If it is correct, your teacher will do something exciting, and give you another, longer message to decode on paper, following the special instructions provided. This should be more fun than a barrel of ribosomes!
3. After a little practice, review the text material on protein synthesis. Also read about (a) variations and further details about the process, (b) the "one-gene-one-enzyme" concept, (c) the nature of mutations, (d) the relation of DNA to chromosomes, and (e) the work in recombinant DNA and genetic engineering.
4. All living things are built and controlled with this same DNA code!

Figure 21 – Protein Synthesis Kit; The following cutouts were used by students during the protein synthesis satisfies activity.



(Flammer, 2007)

Figure 21 continued



(Flammer, 2007)

APPENDIX 3-H PROTEIN SYNTHESIS PRACTICE

GIVEN:

DNA GAA TAG AAA CTT ACT TAG AGC ATT CCT GCC CTT CGA TGC ATC

Step 1.

mRNA CUU AUC UUU GAA UGA AUC UCG

Step 2.

tRNA GAA UAG AAA CUU ACU UAG

Step 3.

Amino Acids LEU ISO PHE GLU - ISO

Step 4.

Symbols L I F E - I

Table 6 – Amino Acid Symbols and Abbreviations; Students will use the information from this table to complete the PROTEIN SYNTHESIS PRACTICE activity.

tRNA	sym	AA		tRNA	sym	AA		tRNA	sym	AA		tRNA	sym	AA
AAA	F	Phe		CAA	V	Val		GAA	L	Leu		UAA	I	Iso
AAC	L	Leu		CAC	V	Val		GAC	L	Leu		UAC	M	Met
AAG	F	Phe		CAG	V	Val		GAG	L	Leu		UAG	I	Iso
AAU	L	Leu		CAU	V	Val		GAU	L	Leu		UAU	I	Iso
ACA	C	Cys		CCA	G	Gly		GCA	R	Arg		UCA	S	Ser
ACC	W	Trp		CCC	G	Gly		GCC	R	Arg		UCC	R	Arg
ACG	C	Cys		CCG	G	Gly		GCG	R	Arg		UCG	S	Ser
ACU	-	Spc		CCU	G	Gly		GCU	R	Arg		UCU	R	Arg
AGA	S	Ser		CGA	A	Ala		GGA	P	Pro		UGA	T	Thr
AGC	S	Ser		CGC	A	Ala		GGC	P	Pro		UGC	T	Thr
AGG	S	Ser		CGG	A	Ala		GGG	P	Pro		UGG	T	Thr
AGU	S	Ser		CGU	A	Ala		GGU	P	Pro		UGU	T	Thr
AUA	Y	Tyr		CUA	D	Asp		GUA	H	His		UUA	N	Asn
AUC	-	Spc		CUC	E	Glu		GUC	Q	Glu		UUC	K	Lys
AUG	Y	Tyr		CUG	D	Asp		GUG	H	His		UUG	N	Asn
AUU	-	Spc		CUU	E	Glu		GUU	Q	Glu		UUU	K	Lys

Flammer, 2007

APPENDIX 3-I

STUDENT WORK EXAMPLE

Figure 22 – Student work example; Taken from the GMO research group activity



What Are They?

- A terminator gene is a specific genetic sequence inserted into a seed DNA whose offspring (seedlings) are rendered sterile.
- This means that plants grown that possess this gene produce sterile seeds.
- This produces a disparity between the conies that produce these seed and the farmers who buy them.

Figure 22 continued

How They Are Produced?

- First, they add a gene encoding a toxin which is lethal to developing seeds but not to maturing seedlings or plants.
- They use an enzyme called recombinase.
- This enzyme removes the spacer in the toxin gene thus allowing it to be expressed.
- A repressor gene is then added in, and then the protein product of the gene is used to bind the promoter of the recombinase, thus keeping it inactive.

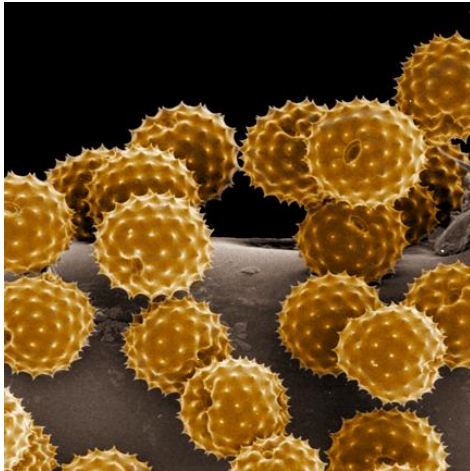
Applications



- Being transgenic plants, they are more resistant to harmful outside factors such as pests that would destroy normal crops.
- Main purpose: companies that sell the seeds gain more economically since farmers have to buy these seeds yearly.
- Puts career farmers at a economic disadvantage.

Figure 22 continued

Problems/Concerns



- Terminator genes put farmers at an economically disadvantage since they have to purchase new seeds every year from corporate tech companies.
- Pollen from these transgenic plants can pass on this sterility to other plants and crops.
- This type of contamination brings yield losses to farmers as well.
No control system with these types of plants.

Controversy

MONSANTO



- The terminator genes make a cytotoxin named a ribosome inhibitor protein, which renders the seed nonviable and sterile.
- This forces farmers to buy fresh seeds for the next season rather than harvesting and saving seeds from the current crop.
- Biotech firms and companies claim that this income stream produced from selling these seeds compensates them for the research done to produce transgenic plants.

Figure 22 continued

References

- <http://nd.edu/~chem191/f2.html>
- <http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/TransgenicPlants.html>

APPENDIX 4

ASSESSMENT TOOLS

APPENDIX 4-A

UNIT PRE/POST-TEST

Anatomy and Physiology
Pre-Assessment

Name: _____

Date: _____

Multiple Choice:

Please provide the best answer for each question. In the space provided, describe briefly why you chose your answer.

1. D Model organisms, like Arabidopsis (a small, radish-like plant) are used by scientists to study biological concepts because:
- a. The genome is fully sequenced
 - b. They grow and reproduce quickly
 - c. They produce many seeds
 - d. All of the above

2. B The term “transgenic” organism means that
- a. The specimen had its sex changed
 - b. The specimen had its genes altered
 - c. The specimen’s species was changed
 - d. The specimen is dead

3. C When conducting an experiment, why might it be wise to use a control?
- a. Without a control, it will take too long
 - b. To stop the experiment at any time.
 - c. To rule out unintended variables
 - d. Keep others from tampering with your data

4. A What are some consequences of using improper aseptic technique when plating bacteria?
- a. Your sample might get contaminated
 - b. The cells will grow too big
 - c. The agar will become inactive
 - d. None of the above can happen

5. C Proteins are important because....

- a. They make food taste better
 - b. They make up fat molecules in the body
 - c. They are responsible for almost every activity in the body
 - d. They are the main cause of death in the USA
-
-
-

6. A Genes....

- | | |
|-------------------------------------|---------------------------------|
| a. Provide information for proteins | c. Function in the cytoplasm |
| b. Build bodies | d. Are active in sex cells only |
-
-
-

7. C How many DNA bases are required to code for one amino acid?

- | | |
|--------|----------|
| a. One | c. Three |
| b. Two | d. Four |
-
-
-

8. D How many different nucleotide bases are there in DNA?

- | | |
|--------|----------|
| a. One | c. Three |
| b. Two | d. Four |
-
-
-

9. B What do all of these have in common: Hemoglobin, Egg White, Enzymes, Antibodies?

- | | |
|---------------------------|---------------------------------|
| a. They are nucleic acids | c. They are fats |
| b. They are proteins | d. They are found in cells only |
-
-
-

10. A Which nucleotide base does DNA have that RNA does not have?

- | | |
|------------|------------|
| a. Thymine | c. Guanine |
| b. Adenine | d. Uracil |
-
-
-

11. B Which of the following steps to solve a problem must be completed *first*?

- | | |
|---|-------------------------|
| a. Analyzing Data | c. Forming a Hypothesis |
| b. Recognizing and Identifying a problem. | d. Testing a Hypothesis |

12. A Measurements of the heights of various plants in an experiment are called

- | | |
|--------------|---------------|
| a. Data | c. Theories |
| b. Inquiries | d. Inferences |

13. C When you decide whether or not the data support the original hypothesis, you are...

- | | |
|--------------------------|-------------------------|
| a. Making an inference | c. Drawing a conclusion |
| b. Making an observation | d. Posing a question |

14. D A pathogenic bacterium is defined as...

- | | |
|--|---------------------------------------|
| a. A bacteria that lives on a different planet | c. A bacteria that reproduces quickly |
| b. A Bacteria that digests our food | d. A bacteria that can cause disease |

APPENDIX 4-B

DRAWING CONCLUSION ESSAY

Name:

Hour:

Scientific Investigation – Please read the following scientific investigation and use the results to form your own conclusion. Use the information that you learned from the lessons that we did in class on Protein Synthesis and transgenic organisms to do this

PURPOSE:

Perform an experiment to determine the role of the gene NDR1 in *Arabidopsis thaliana*.

BACKGROUND:

Arabidopsis is a small mustard like plant that grows in North America. It is often used in genetic research because grows very quickly, and produces a lot of seeds. Researchers at Michigan State University have been working with *Arabidopsis* in hopes that they can find a “disease resistance” gene that may have applications for farmers in other crops (tomato, cucumber etc). The Gene NDR1 has been identified as one that may aid in disease resistance for the plant, but an experiment must be conducted to find out for sure. We will test the disease resistance of both types of plants using a pathogen called *Pseudomonas syringae* at the stage where the plants are most susceptible to disease (the four-leaf phase). Both a positive and a negative control will be used to ensure that we draw a correct conclusion from our observations.

MATERIALS:

- Wild type *Arabidopsis* plants
- *Arabidopsis* plants with NDR1 Gene deletion
- *Pseudomonas syringae* pathogen (bacteria)
- Spray bottles
- Water
- Syringe

PROCEDURE:

1. Plant three seeds each of both *Arabidopsis* Wild-type and *Arabidopsis* NDR1 in separate pots.
2. Allow the plants to grow until the plants reach the “4 leaf stage”
3. Spray one of each plant with plain water. This will be the positive control (no disease conditions should be seen)
4. Inject both plants with *Pseudomonas*. This will be the negative control (both plants should become diseased)

5. Spray the outside of both plants with *Pseudomonas*. This will be our experiment. By comparing these to our positive and negative controls, we should be able to tell whether the plants become diseased or not.
6. Wait two weeks and check the plants. Compare the Wild-type and NDR1 plants in the experiment to both the positive and negative controls. Determine which plants (if any) became diseased.
7. Explain in a detailed conclusion what you think role of the gene NDR1 is in Arabidopsis. What is happening when this gene is present V.S. when it is absent? Please discuss the significance of Protein synthesis in this situation.

Results: (I have pictures if you would prefer to see those)

Positive Control (water)

Wild Type- No Disease Conditions NDR1- No Disease Conditions

Negative Control (pathogen injection)

Wild Type – Diseased and dead NDR1- Diseased and dead

Experiment (pathogen sprayed)

Wild Type – No Disease Conditions NDR1- Diseased and Dead.

Conclusion:

Must be typed and include the following:

- What is the role of the gene NDR1 in Arabidopsis?.....5
- What was the purpose of using a positive and negative control?.....5
- What is occurring when this gene is deleted (talk about Protein synthesis)?.....5
- How might studying this gene be beneficial to us and to farmers?.....5
- Total.....20

You should write a paragraph for each of the four objectives and will receive five points for each objective that you correctly address for a total of twenty points.

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