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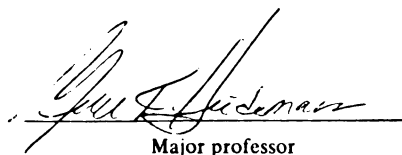
Using Labs and Activities to Teach
High School Genetics

presented by

Matthew Richard Withers

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of the requirements for

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USING LABS AND ACTIVITIES TO TEACH HIGH SCHOOL GENETICS

By

Matthew Richard Withers

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ABSTRACT

USING LABS AND ACTIVITIES TO TEACH HIGH SCHOOL GENETICS

By

Matthew Richard Withers

Nearly all students enjoy learning about the topics of genetics, but few understand them. Misconceptions created by textbooks, the abstract nature of genetics, and poor student motivation can all contribute to poor student achievement. This unit was designed to address specific misconceptions, as well as create hands-on opportunities for students to make genetics an enjoyable and learnable subject. A good background is necessary to proceed to advanced genetics topics, so the focus of this redesigned unit is basic genetics. After using the summer of 2001 to design and create exciting labs and activities, as well as creating colorful and engaging PowerPoint presentations for notes, I have made a genetics unit that allows maximum student understanding as measured by the various assessment tools used in the unit. I began the unit with a pretest to assess students' prior knowledge of the subject. Following the unit I gave a posttest, which scores support the effectiveness of the redesigned unit I have created. Students, after doing the activities, labs, and other exercises of this unit, are much more prepared to proceed to an applied genetics unit because they have a stronger background on the molecular basis of genetics, which is a building block for all other applied genetics topics.

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INTRODUCTION

Teaching genetics to a classroom of high school students is a challenging task. There are several obstacles that must be overcome to get students to understand the science of genetics and apply that knowledge to more advanced genetics topics. The problem I focused on for this new unit was how to teach genetics to an Advanced Biology class by overcoming student misconceptions of genetics, and by increasing student motivation through hands on labs and activities.

The first obstacle that must be overcome is poor background information. Without a strong background in molecular genetics, application of the information related to genetics is almost impossible. To the average high school student, “genetics is something to do with a monk named Mendel who lived in Switzerland in the middle of the last century who made pea plants grow” (Bradshaw and Darlington, 1963). But genetics is much more than that. It is a field of science with a variety of information and as much diversity such as Mitosis, Meiosis, the genetic material, and many forms of inheritance. Students will often say that Genetics is why we look the way we do, which is not necessarily wrong but is certainly an oversimplified definition. Misconceptions about Genetics are perpetuated by every generation of science educators and science textbooks. The historical approach of genetics is presented in a manner which only memory can master, with topics presented by discoverer or by date. Genetics instruction must be presented, instead, in a functional way that includes a natural order of the information and how it controls the cell and eventually the organism itself. (Bradshaw and Darlington, 1963)

To teach genetics you must start with information that provides a foundation for learning. At the very center of this is the cell itself. The cell is the smallest unit of an organism that still maintains the function of that organism. We are made of about “100 trillion cells, the result of approximately 50 rounds of cell divisions, starting with one fertilized egg” (Carlson, 1984). Human cells contain a constant chromosome number, 46. This means we have 23 pairs of chromosomes or 46 individual chromosomes. The chromosome carries the information that is coded by the genes and is really how that information is passed on from generation to generation in organisms, as well as in all cells. The specific way the information is passed on for all organisms, with the exception of viruses, is well documented. All cells must divide to reproduce, although they don’t always do this the same way. The life of a cell can really be described by what is known as the cell cycle. The cell cycle has no real beginning or ending as it is a circular process. For sake of this description we will begin with what is known as the G₁ phase. This is the phase where the cell grows and prepares for DNA duplication. It will replicate, or copy its DNA in the S phase of the cell cycle, so when the cell eventually separates, each daughter cell will possess its own DNA packaged into chromosomes. Following the S phase, the cell will enter into G₂, where the cell will again grow in anticipation of splitting. Finally, the cell will undergo the M phase of the cell cycle, mitosis. Mitosis is the process where non-sex cells split their DNA and cell division is when those cells divide into two separate daughter cells, each with identical DNA. Mitosis is a process composed of a series of steps commonly referred to as “IPMAT”. Interphase is the first step, but is not generally considered part of Mitosis. Interphase is a combination of G₁, S, and G₂ of the cell cycle. The stages of Mitosis are Prophase, Metaphase, Anaphase, and

Telophase. These stages are a doe-si-doe where duplicated chromosomes line-up, split, and eventually separate to opposite poles of the cell. The cell then separates somewhere in the middle, allowing each cell to have identical genetic material. It has been my experience as an instructor that many student misconceptions persist about how the chromosomes line-up, how they separate, and at what point they are called a chromosome or chromatid. Another fundamental process for proper understanding of genetics is the formation of gamete cells or reproductive sex cells, most commonly termed the sperm and egg. The sperm and egg are produced via a process called Meiosis. This process is different from Mitosis in that the Meiotic division of the cell reduces the chromosome number of that cell by half. The resulting products of meiosis are described as haploid, as they have only a single set of instructions from one of each of the pairs of chromosomes present in a diploid cell (Howell, 1998).

Learning about chromosomes is one of the first topics of genetics to be taught because chromosomes contain the individual instructions for virtually all of the activities of an organism. Genes, located on chromosomes, encode the information for making proteins that regulate cell activities and control mechanisms of all cell machinery (Carlson, 1984). My students seem to struggle with the idea that the genes do not directly control the cell or organism. Instead, the genes provide the instructions for necessary amino acids, which in turn are assembled into specific proteins. These proteins are the real workers of the cell. They are responsible for everything that happens within the cell.

DNA, which stands for Deoxyribonucleic Acid, is the “Genetic Material” for all living organisms. Swiss physician Friedrich Miescher first discovered DNA in 1869, but his and other scientists’ belief in its importance was low (Clarke, 2003). They could not

have been further from the truth. It would prove to be the discovery of the most important molecular structure to all living organisms. They actually believed that proteins, some of which are larger and more complex than DNA, were the molecules passing information on from generation to generation. Researchers now know that DNA is made up of several to thousands of genes, which is variable according to the species. A single segment of DNA can create tens or even hundreds of thousands of different proteins, according to how the cell reads its genetic information, and how proteins are chopped up or chemically modified (Pearson, 2003). Since its discovery, DNA has been extensively studied by many people. In 1953, perhaps the most important discovery made in biology in this century was made concerning DNA (Cohen and Portugal, 1977). On the heels of Chargaff's discovery that DNA possesses only four Nitrogenous bases, James Watson and Francis Crick released details about the physical structure of DNA. The model Watson and Crick proposed is still accepted today and has since been supported by visualization with microscopy and numerous chemical and biochemical experiments. Their model describes DNA as a twisting double helix molecule made of two complimentary strands. Each side is made of a backbone of alternating sugar and phosphate molecules (Watson and Crick, 1953). Within the bonds of the backbone lie nitrogen bases which Chargaff described as complimentary, meaning they can only bond with a specific base on the opposite side. These chemicals are the treasures of the code that if put into the correct order can supply life, cause growth, instigate cell death, as well as control everything that a cell does throughout its life by way of gene products, proteins, and strings of nucleotides, which control the cell by providing a blue print to making specific polypeptides and amino acids assembled in a certain order. The so-

called Central Dogma, theorizes that DNA codons, which are a group of 3 nucleotides, are transcribed to an RNA molecule. This RNA is then a “messenger” molecule, which can leave the nucleus. The RNA transcript is then translated into a series of amino acids, or a polypeptide, at the ribosome. Once produced to order, these proteins are shipped throughout the cell to wherever they are needed.

Students often are confused why we study Mitosis and Meiosis before learning about DNA and proteins. The reason is that it is important for students to see how DNA is incorporated into the chromosome and the processes of Mitosis and Meiosis. The DNA, as stated earlier, is located in the nucleus. When it is necessary for the cell to reproduce, it will prepare for reproduction by replication, or copying, of the DNA. Then the DNA, which is wrapped around a protein called Histone, will super coil and condense into a structure called a chromosome. The chromosome is a structure allowing the division of a cells genetic material to occur. It is easier to divide the chromosomes into equal portions for each new daughter cell than it would be to do the same thing with unwound DNA.

Since its discovery almost 150 years ago, the use of DNA technology has grown. There are countless applications of DNA technology in our past, current, and future society. One notable technology has changed the way our society studies and solves crimes. Forensic DNA evidence can be used in many ways to prove or disprove a suspect’s guilt on a crime. The United Kingdom, who was the first to use DNA fingerprinting, has a national database that contains over 700,000 profiles and has been used to link evidence to 75,000 criminals (Davies, 2001). In the United States, the technology has not been used for as long as in the United Kingdom, but significant

numbers of persons have been linked to evidence, and a national database of the United States contains some 250,000 profiles. Davies (2001) also says that there seems to be few limits to the potential applications of DNA fingerprinting. Recently, DNA fingerprinting has been used to exonerate suspects. The process of DNA profiling is done based on comparisons and examinations of “three to ten highly variable portions of our DNA.”(Eckert, 1997) Human beings have about three billion base pairs of DNA nucleotides in their code. According to Eckert (1997), most of these are identical in most humans, but some regions are more variable in length or sequence. These are the parts of the genome used in DNA fingerprinting. Once the DNA is extracted, the copies of the DNA are made by a process called Polymerase Chain Reaction, or PCR. PCR takes the gene sequence in question and makes multiple copies of it, all needed for forensic analysis. Scientists add restriction enzymes to the DNA samples to cut the DNA at known nucleotide sequences, breaking the DNA into smaller, more usable chunks. The DNA chunks are now run and separated based on size using electrophoresis. The relative sizes as well as other more specific information are used to compare suspects’ samples with evidence.

The future of DNA technology has great potential for all living organisms. There is a good chance that someday we will be able to examine an organisms’ genome, and be able to cure diseases before they develop, or alter its genes to make it produce new traits that may make it better suited for its environment. Technology such as cloning and genetic engineering are amazing breakthroughs of which we have not even seen a small part of their potential.

A second obstacle that needs to be overcome to successfully teach genetics lies within the students themselves. One problem that all teachers face is student motivation. There is an abundance of data to support the claim that student motivation is a key factor in determining academic success (Griffin, 1993). If a student is motivated, he/she will at least try harder than with little or no motivation. This effort may not equate directly to higher test scores, but it may correspond to better grades just by students doing homework, projects, and labs they may not have been motivated to do in the past. If the student can be intrinsically motivated, both the teacher and student will benefit because the student will be doing things because they want to and not necessarily because they have to. Some research suggests that ultimately, teachers do not truly motivate students, but can try to affect some of the variables that stimulate students' motivation to learn (Ralph, 1998). Perhaps you cannot directly motivate students but you can influence the factors they possess to motivate themselves.

There are many tools teachers can use to increase student motivation. Raffini (1996) states that students are much more apt to be intrinsically motivated if there is a challenge to the task. Science is a challenging field and genetics is certainly no exception. The sheer amount of information required to master genetics coupled with the complexity of the material makes learning a challenge. Stahl (1994) states that learning only occurs when an individual's mind is engaged, and that the learning will come only through trial and error. Genetics labs and activities can be difficult but are certainly not impossible. Students attempt to solve a problem and if it does not work, they will go back and try other options to find a solution. This is the essence of trial and error. It also gives them the opportunity to be actively engaged in their own education.

Another way this unit motivates students is that it gives them the chance to be successful. Included in the rigors of the unit are several forms of alternate assessment such as drawings, oral student explanations, essays, and the physical building of models. The labs in the unit provide a situation where anyone can achieve “high scores”. Griffin (1993) states that success is an excellent motivational tool. How often does failure provide a motivation to achieve in education? That seems to have a negative impact more often than a positive one. Students withdraw or get discouraged and wind up accomplishing less than if they hadn’t received the failing grade from the teacher at all (Griffin, 1993). By providing students with several chances to be “victorious”, this unit allows students to celebrate their education by obtaining higher levels of motivation. Alternatively, teachers should not be in the habit of always giving “good grades” to students, especially if it is not deserved. Lately, it seems as though many of my students “expect” good grades even if they are doing poorly in my class. Based on success in previous materials or even prior classes, students believe they deserve the exception to be made for them. If students are doing poorly, there are always opportunities to prime them in meaningful ways with a few chances to get some high scores. By using a variety of different forms of alternative assessment, this unit provides several opportunities for students to receive high scores.

There is a huge push in education for alternative assessments that reflect “honest” work (Bourdillon and Storey, 2002). These kinds of assessments, such as problem based assessments, and oral assessments, when done correctly can “not only improve levels of understanding, but also increase acceptance of ownership for their performance, product, and grade.” (Shepardson, 2001) By not just using traditional paper and pen tests, quizzes,

and assignments, students can be assessed based more on their performance on a specific task, and not on “how much information they can recite based on memorization. The hands-on labs, activities, and performance assessments included in this unit do just that. They allow students to show off what they can do. Traditional tests can also be stifling for a majority of students. Every year I hear many students tell me the same thing about tests. They proclaim that they are “poor test takers” and that is the source of their frustrations in the classroom. According to Putnam (1997), “there is clear evidence that test scores can provide inappropriate and biased information that can be detrimental to students.” This unit is designed to assess student knowledge and mastery in a way that is consistent with the way it is presented.

One final component of the unit I have developed to help motivate students is to make the unit itself interesting and “fun.” Obviously there are different levels of fun, and fun is a very subjective topic for all people. Being able to work with peers, move about the classroom, and get your hands dirty is more fun than many teacher-centered learning techniques. Raffini (1996) states that making a topic fun for your students will help to intrinsically motivate students, and increase their involvement in the classroom community.

As a high school science teacher, I strive to provide an educational and nurturing environment in which students work both cooperatively and individually to learn scientific concepts. Students in my class can expect to do hands-on labs and activities on an average of three days per week. Students are undergoing various forms of assessment almost daily. The genetics unit I developed is not unique to these guiding principles of my teaching methods. In addition to sticking to these beliefs, I also worked diligently to

provide students with a good foundation of basic and molecular genetics and pertinent background information. Underlying the goals of teaching the subject matter, the unit I have created also attempts to increase student motivation by engaging students with challenging tasks and problems that are solvable, and provide students with chances to be successful throughout the unit through alternative assessments. Students are also provided the opportunity to have fun with the hands-on cooperative learning style I employ.

Michigan Center Public School district borders the southeast corner of Jackson, Michigan, in the village of Michigan Center. It is a small school system with two elementary schools and a consolidated Jr. and Sr. High School and a total enrollment of 1200 to 1300 students. The village has limited racial and ethnic diversity and the population is predominantly lower middle to upper lower class blue-collar workers. The predominant employers in the area are the Jackson State Prison, the largest single employer in Jackson County, and many automotive parts production facilities. Michigan Center High School houses 625 students from grades 7 – 12. Approximately 400 students are enrolled in a senior high school curriculum that varies from general to college prep. The majority of Michigan Center graduates (50 – 60 %) will enroll in a college, university, or trade school. Others will enlist in the armed forces (5 – 10 %), enroll in an apprenticeship (1 – 5 %), or seek employment (20 – 25 %). Our dropout rate is between 3 – 5 % and our daily attendance rate is between 93 – 97 %.

IMPLEMENTATION

I currently teach Biology, Advanced Biology, and Chemistry, which is one-half of the science curriculum we have at the high school. All students are required to take General Biology as sophomores and must average at least a C – on a 4.0 scale to take Advanced Biology as a junior or senior. I began teaching at Michigan Center six years ago and the 2001 – 2002 school year was my first year teaching the Advanced Biology class. The basis for my MSU research was to design new teaching materials for a unit that will be taught to my students on the subject of Genetics. I chose the Advanced Biology class as the target group of my thesis because it was a new class and I was trying to develop units for the class that were both meaningful and motivational for my students. I felt the class needed a genetics unit that was both exciting to learn, as well as a challenge for students to master. I also taught all sections of general Biology and I felt this was a good target group because I have taught all of them before and had a good idea of what prior knowledge these students had on the subject of genetics. They do have some materials presented to them as sophomores on the topic, but the depth and scope were minimal. The class was comprised of 20 students who all read and signed a release form (Appendix A) to allow me to analyze and report on their work. Also, each had a parent or guardian do the same.

The unit I developed was based on six clear subject-matter goals (Table 1) for all students. These goals were to be able to differentiate between DNA, chromosomes, and genes. Goals two and three were for students to be able to draw Mitosis and Meiosis respectfully. Goal four was that students know about the process of Gel Electrophoresis.

Goal five was that students can differentiate between gametes and zygotes, and goal six was that students could do simple Mendelian genetics monohybrid crosses.

Table 1 – Goals of expected student mastery	
Goal	Task
1	Students will be able to differentiate between DNA, chromosomes, and Genes.
2	Students can draw and explain Mitosis.
3	Students can draw and explain Meiosis
4	Students will know what Gel Electrophoresis is, and restriction enzymes role in this process.
5	Students will know the difference between zygotes and gametes.
6	Students will be able to do simple Mendelian genetics problems such as monohybrid crosses.

The unit I developed, based on my MSU research experience, is a genetics unit that required 6 weeks of class time (Table 2). All labs, activities, and assessments were new to the class and were developed over the course of the summer at Michigan State University.

Table 2 – Unit outline		
Week #	Topic(s) covered in order	Teaching tools used
Week 1	Consent form & Prior Knowledge	Unit Pretest
	Mitosis	Mitosis Lab 1 Mitosis Lab 2 PowerPoint Notes Oral assessment
Week 2	Cell Cycle	PowerPoint Notes Cell Cycle lab
	Meiosis	Dipstick Meiosis Oral Assessment
Week 3	DNA Structure and Function	PowerPoint Notes DNA from fruits and veggies
	What is Gel Electrophoresis	Electrophoresis Assignment Gel Electrophoresis of food coloring
	Start Mating Fruit Flies	Mating Fruit Flies
Week 4	Gel Electrophoresis & Restriction Enzymes	Electrophoresis of Lambda DNA Restriction Enzymes Quiz
	Continue Mating and scoring Fruit Flies	Mating Fruit Flies Lab PowerPoint Notes
	Review Mendelian Genetics	
Week 5	Application of unit and review	Fruit Fly Applied Genetics Projects
	Continue scoring Fruit Flies	
Week 6	End of scoring of Fruit Flies	Lab report summarizing Lab
	Population Genetics and review	Human Heredity Studies of Families and populations
	Final Assessment	Unit Post test

I began the unit with a pretest (Appendix B) to test students for prior knowledge of the

topics to be taught. The pre test was graded based on a common rubric (Table 3) based on a 3-point scale.

Table 3 – Pre test Grading Rubric	
Points	Rationale
3	Completely Correct
2	At least half Correct
1	Less than half correct
0	Blank

The rubric in Table 3 is provided as a guide to how all questions were generally scored. The nature of the questions themselves affords a great number of possible answers to the questions. The questions also are different from each other in many ways. I have provided a few sample rubrics to give readers a feel for what was expected of students' answers. Question 2 on the pretest (Table 4) is a simple monohybrid cross involving the trait for height of plants. Students were rewarded based on correct answer as well as effort in answering the question.

Table 4 – Pretest rubric sample 1 Question 2 – Explain everything you can about the cross Tt x Tt where T = tall and t= short	
Points awarded	Expected answer(s) to receive points
3	Tall is dominant trait to shortness. Cross will give 1 TT:2 Tt:1 tt genotypic ratio and a 3 tall:1 short phenotypic ratio. Tt plants will show tallness but will be carriers of shortness.
2	Tall is dominant trait in cross. Offspring will be 3 tall:1 short. Some plants will be tall and can produce short offspring. OR Tall is dominant trait in cross. Offspring will be 1 TT (tall):2 Tt (tall but carriers of short):1 tt (short)
1	All but 1 plant is tall (tt) Or Any response given even if incorrect
0	No response given

Question 8 on the pretest (Table 5) is a question to see if students can tell the difference between individual sex cells, called gametes, and fertilized sex cells, called a zygote. It also is intended to see if students know how these apply to traits on a punnett square.

Table 5 – Pretest rubric sample 2	
Question 8 – What is the difference between a gamete and a zygote? What significance do they have in a punnett square? How much of the possible amount of information does each one have (Haploid and Diploid)?	
Points awarded	Expected answer(s) to receive points
3	A gamete is an unfertilized sex cell (egg or sperm) and a zygote is a fertilized sex cell that becomes an embryo. The traits from each gamete are placed on the outside of the Punnett square and they possess half the genetic information of an organism and are called haploid. Inside the Punnett square, the letters are combined, representing the genotype of a possible zygote. These individuals possess the full amount of genetic information and are called diploid.
2	A gamete is an egg or sperm and a zygote is a fertilized egg. The egg and sperm possess half the genetic information. Once the sperm hits the egg, it has all the information. Or The gamete goes outside the square and the zygote goes inside the square. They box has all the information. Haploid has something to do with half.
1	A punnett square is the box used to see what kids will look like. Or Any response given even if incorrect
0	No response given

As with other questions, students were rewarded for the amount of information they know as well as the quantity of effort they put into answering the question. If any answer at all is given, students received at least 1 point. Question 9 (Table 6) is a question pertaining to Mitosis and Meiosis. Students were asked to differentiate between the two processes in terms of the individual stages, the end products, and the types of cells that undergo each process. Students may explain all this information or may draw the

individual stages of each process, or a combination of both. Since the drawing is such a specific task, I don't, at this point, expect anyone to draw the processes.

Table 6 – Pretest rubric sample 3	
Question 9 – What is the difference between Mitosis and Meiosis in terms of each of the following: Final products, cells undergoing each process, Stages in each, types of cells or organisms that undergo each can be drawn below.	
Points awarded	Expected answer(s) to receive points
3	Mitosis is a process to divide diploid cells and give two identical daughter cells to the parent cell when finished. It is composed of the stages “IPMAT”. The chromosomes copy themselves, then split in half and eventually split into 2 separate cells. Each new cell is also diploid. Cells formed this way may also be referred to as “clones.” Meiosis is the process where reproductive cells, sperm and egg, are produced. For each diploid cell that divides in this process, 4 haploid cells are produced. These cells become the sperm or egg that is used in reproduction of the organism. The process involves Meiosis I and Meiosis II. Or Acceptable student drawings showing complete stages of Mitosis and Meiosis. May be combined with any of above information.
2	Mitosis involves the splitting of the chromosomes of a cell and it goes through stages IPMAT. The new cells look identical to the parent they came from. It gives 2 new cells. Or Meiosis is the way sex cells reproduce. It forms sperm and egg. The chromosomes split in half through a bunch of steps called IPMAT. The cells have half the genetic information than the parent cells they came from. It gives 4 new cells. Or May combine drawings of some stages with above information.
1	Mitosis provides 2 cells and Meiosis gives 4. Or Any response given even if incorrect
0	No response given

Following the pretest, students engaged in three activities to support written text and lecture material on the topic of Mitosis. The first one, *Mitosis Lab 1* (Appendix C), has students look at and draw prepared slides of plant and animal tissue undergoing Mitosis and cell division. Various cells are suspended at different stages of Mitosis and

can be identified easily by looking at the pre-stained chromosomes. Students used their textbooks to help them identify cells at the various stages of Mitosis both in plant and animal tissue. They also looked for the subtle differences between plant and animal Mitosis. The students turned in completed drawings made during the activity. *Mitosis Lab 2* (Appendix C), “Dipstick Mitosis”, is an activity that uses tongue depressors painted different colors to represent duplicated Fruit fly chromosomes. Each group of students received a freezer bag with pre-painted tongue depressors, string to represent spindle fibers, paperclips to represent the centromere to hold the chromatids together, and two envelopes to represent the nuclear envelopes that surround the nucleus. Students used this kit to copy the stages of mitosis to show what the chromosomes / chromatids do during each stage. When finished, students take an un-graded oral quiz in which they, as a group, must be able to recreate the steps as well as recite written material about each stage. The final lab, *Mitosis lab 3* (Appendix C), addresses the “cell cycle”, which describes how much time a typical cell spends undergoing each stage of Mitosis as well as S, G₁ and G₂. Students use the prepared slides as before, but this time they are counting how many cells they observe at each stage of Mitosis. They found the percentage of each stage the cells based on the entire tissue. Since these are fixed tissue we correlate these numbers to time spent in each stage. When finished, the class was polled to see if they have numbers that are reasonable with respect to the whole class. Anyone with drastically different numbers usually could not differentiate between the stages. I also used a microscope camera and had students identify stages on a television. This activity provided a review of the first Mitosis lab as well as an authentic assessment.

After covering Mitosis, we did the *Dipstick Meiosis Lab* (Appendix C), modeled after Mitosis Lab 2. Students used the same lab materials as Mitosis Lab 2, but modeled the stages of Meiosis. Students were assessed by reiterating the stages of Meiosis, what occurred during each stage, and turned in drawings of the entire process made following the activity. Following this lab, students must be able to differentiate between the stages of Mitosis and Meiosis, describe what types of cells undergo each process and what the resulting cells look like in terms of amount of information they each possess. Student understanding was assessed after all four labs were completed, with students writing an essay. Instructions were contained at the end of both “Dipstick” labs for the essay. It was graded as complete / incomplete as the students had a list of topics to address on the essay.

Following the topics of Mitosis and Meiosis, students learned about the nature of genetic material, specifically, the structure of DNA and how it is packaged into chromosomes. Students drew the double stranded DNA of at least 12 base pairs long. They also must show in that drawing how a chromosome is a structure that has all the cell’s DNA wrapped around proteins and condensed into an x-shaped structure at Metaphase of Mitosis. The next activity involved students isolating and extracting the DNA of fruits and vegetables (Appendix C). When finished, we discussed the fact that all living cells possess DNA as well as why we were able to see more in some foods than in others. After students could correctly identify and draw a picture of a DNA strand and describe how it condenses to make a chromosome, we shifted to the three activities that illustrate how pieces of DNA, corresponding to genes, can be separated by gel electrophoresis of DNA. The first lab, *Gel Electrophoresis of Food Coloring Lab*

(Appendix C), is a lab designed to teach students how to run model gels using proper technique. Students ran four different colors of food coloring through the gel and a mixture of all 4 colors to see how the colors separate based on size of the molecules. Students were now ready to repeat the lab using DNA. Students electrophoresed the Bacteriophage lambda DNA to determine its size. We also talked about the applications of electrophoresis technology to society. Students cut DNA using three restriction enzymes. The assessment for these activities was a written quiz, *Restriction Enzymes Quiz* (Appendix B). Students were able to explain the three restriction enzymes we used, where they cut DNA, and what the relative sizes of gene segments are in terms of base pairs. All this information can be displayed in a restriction map, which the quiz asked students to make.

Following all the molecular genetics materials, Mendelian genetics was introduced based on the genetics of the fruit fly, *Drosophila melanogaster*. For the *Mating Fruit Flies Lab* (Appendix C), my students successfully sexed, mated and identified flies with different traits. Students had a choice of mutant flies with one of three different traits to mate with wild-type flies: White eyed, sepia eyed, and vestigial winged. This activity, in addition to reviewing Mendelian genetics, also was used to introduce the topics of life cycles, and sex-linked (X-linked) traits. Students had to document the life cycle of the fruit fly, keep track of the sex and traits of all flies seen through the F₂ generation. Upon completion of the entire project, students were assessed based on the paper they submitted. Students were required to draw and explain all stages of the fruit fly life cycle, and describe phenotypes and genotypes of the generations of flies they hatched. They were required to do monohybrid crosses for the flies they mated

for theoretical offspring and support this with their actual findings. This assessment was very informal and its purposes were for student accountability, and as a means to decide if the class could move on to the next topic.

The next thing students did was an *Applied Genetics Project* (Appendix C), to study some other aspects of the information on Mendelian and molecular genetics. The purpose of the project was to see how the information learned earlier in the unit is used by scientists, and why it is important for students to know this information. There are three parts to this group project. Part one addressed transformation of DNA from plasmid into fruit fly. Students conducted library and Internet research on fruit fly genes and were required to apply restriction enzyme technology, as a paper and pen activity, to these genes. The project also required students to review protein synthesis and gel electrophoresis in preparation for the impending post test. The second part of the project was a review of different kinds of point mutations. Students showed the position of each type of point mutation for the gene sequence they researched on the fruit fly. The third and final portion of the project was on genetic engineering. In short, students explained the steps they would follow to clone their chosen gene, and describe how society could use this cloned gene. That is, where could they stick this gene into foreign DNA to make a beneficial and possibly unique difference in that genome.

The last activity in this unit was *Human Heredity Studies of Families and Populations* (Appendix C), based on easily identifiable dominant and recessive traits of human beings. It required students to analyze many of their own traits to see what genotype and phenotype they possessed, such as a widows peak, Darwins' ear point, or colorblindness. After analyzing themselves for these traits, students went around the

school and polled 100 people for two of the traits contained on the list. They used the Hardy-Weinberg principle to determine what percent of the population are heterozygous for a particular trait. Next, students chose two traits to track through their families. In theory, this would allow students to see from whom they received a few of the traits they possess. It also provides the carrier frequency of a population, so students can see how many people are theoretical carriers of a trait that they may not show.

The post test (Appendix A) concluded the unit. The post test is slightly modified from the pretest. It contains the same main topics, but the questions may have been asked in a slightly different way or required more application of knowledge of the subject to answer the questions correctly. This test was used as the overall assessment of how well my unit was planned, implemented, and most importantly, learned by advanced biology students at Michigan Center High School. Just as in the pretest, this test was graded on the same common rubric (Table 7), but contained the same difficulties in using it. Therefore, I will provide three sample rubrics to clarify how students were assessed. These three questions correlate directly to the three questions that were discussed regarding the pretest.

Table 7 – Post test Grading Rubric	
Points	Rationale
3	Completely Correct
2	Mostly Correct
1	Little to none correct
0	Blank

Question 2 on the post test (Table 8) is similar to question 2 on the pretest, which asks about a monohybrid cross. This problem is a much more advanced version of the same problem and requires a different rubric for grading. This question deals with a

cross between two people and the blood types of their possible children. In addition to knowing how to cross traits, students must also know the related information on blood type, which was covered by the population studies activity. Students are rewarded for the amount and quality of the answers they provide on this question.

Table 8 – Post Test rubric sample 1	
Question 2 - A man with AB blood marries a woman with O blood. What are the possible blood types they could have for kids? Explain as much as possible about blood types, the cross, and the possible children.	
Points awarded	Expected answer(s) to receive points
3	Blood type is a case of multiple alleles, where both A and B are dominant to O, and there are 4 blood types: A, B, AB, and O. O has the genotype ii, and AB is the genotype of type AB blood. Their kids have the possibility of 2 blood types, A and B. The genotypes are Ai and Bi, which means they are heterozygous for A and B, possessing recessive O alleles.
2	There are 4 blood types: Ai, Bi, AB, and O. The kids are Ai and Bi. Or There are 4 blood types: A, B, AB, and O. The kids are either type A or B.
1	The kids are Ai and Bi. Or Any response given even if incorrect
0	No response given

Question 8 on the post test (Table 9) asks students to compare the processes of Mitosis and Meiosis only in terms of the final product of each process. Some of the descriptive information that should accompany the answer to this question is found on the same number question on the pretest. The assessment of this question is consistent with other questions and again, students were rewarded for both quantity and quality of work.

Table 9 – Post Test rubric sample 2	
Question 8 – Using the Pictures of Mitosis and Meiosis below, describe the final products each process creates in terms of amount of information and specific names or descriptions of each.	
Points awarded	Expected answer(s) to receive points
3	Mitosis creates 2 identical daughter cells that are diploid, meaning they have the full amount of genetic information. Meiosis creates 4 haploid cells that only possess $\frac{1}{2}$ the genetic information of an organism. The original cell would be diploid. The 4 cells produced are gametes, which are unfertilized sex cells, sperm or egg. When the sperm and egg meet, they are called a zygote.
2	Mitosis produces 2 cells and Meiosis produces 4. The cells from Mitosis are diploid and the ones from Meiosis are haploid Or Mitosis produces diploid cells and Meiosis makes sperm and eggs, which have $\frac{1}{2}$ the information, and are called gametes.
1	Mitosis produces 2 cells and Meiosis produces 4 Or Any response given even if incorrect
0	No response given

Question 9 on the post test (Table 10) is almost identical to question 9 on the pretest. On the pretest, I expected few, if no drawings to explain the stages of Mitosis and Meiosis. On this question on the post test, I expected nearly everyone to use drawings to describe these processes. Students were rewarded for effort and quality of answers. One point of emphasis was the specific number of chromosomes / chromatids that their drawings contained, as I expected students to overlook this issue or have drawings with too many or too little numbers of chromosomes / chromatids.

Table 10 – Post Test rubric sample 3	
Question 9 – Draw a generic diagram of Mitosis and Meiosis using fruit fly chromosomes (4). You only need to label the following on one picture: Chromosome, Chromatid, Centromere, and Spindle fibers. Make sure you label the stages.	
Points awarded	Expected answer(s) to receive points
3	Mitosis is a process to divide diploid cells and give 2 identical daughter cells to the parent cell when finished. It is composed of the stages IPMAT. The chromosomes copy themselves, so there are 4 duplicated pairs, which then split in half and eventually split into 2 separate cells. Each new cell is also diploid containing 4 individual pairs. Cells formed this way may also be referred to as “clones.” Meiosis is the process where reproductive cells, sperm and egg, are produced. Each diploid cell duplicates its chromosomes and contains 4 duplicated pairs that divide in this process and eventually form 4 haploid cells with 4 corresponding chromatids/chromosomes. These cells become the sperm or egg that is used in reproduction of the organism. The process involves Meiosis I and Meiosis II. Or Acceptable student drawings showing complete stages of Mitosis and Meiosis showing 4 chromosomes of the correct colors. May be combined with any of above information.
2	Mitosis involves the splitting of the chromosomes of a cell and it goes through stages IPMAT. The new cells look identical to the parent they came from. It gives 2 new cells. Or Meiosis is the way sex cells reproduce. It forms sperm and egg. The chromosomes split in half through a bunch of steps called IPMAT. The cells have half the genetic information than the parent cells they came from. It gives 4 new cells. Or May combine drawings of some stages with above information but have too many or too little a chromosome number.
1	Mitosis provides 2 cells and Meiosis gives 4. Or Any response given even if incorrect
0	No response given

RESULTS

Based on the results of the various assessment tools I used for this unit, a pretest, quiz on restriction enzymes, an applied genetics project, the post test, and several forms of authentic assessment, I can determine if the new unit I have made is a successful teaching tool for the subject matter.

The pretest was designed to determine prior knowledge, to serve as a guide for meeting outcomes as an instructor, and to help me keep in mind what outcomes I wanted for my students upon completion of the unit. Scores on the pretest (Graph 1) were based on a 3-point scale and the rubric, and in general were very low. The average score for the pretest (Table 11) was 0.9 out of a possible 3 points.

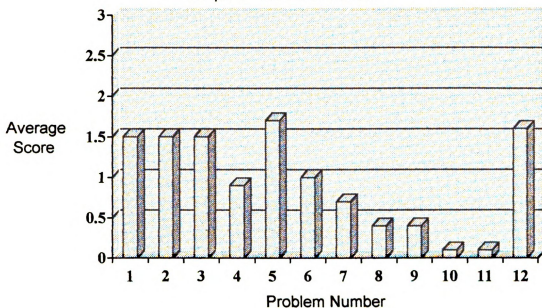
Table 11 - Pretest class results (N=20)			
Problem #	Score	Problem #	Score
1	1.5	7	0.7
2	1.5	8	0.3
3	1.5	9	0.4
4	0.9	10	0.1
5	1.7	11	0.1
6	1.0	12	1.6
Average score	0.9		

The scores on the post test (Table 12) were higher. The class average jumped to a 2.3 out of 3 points possible.

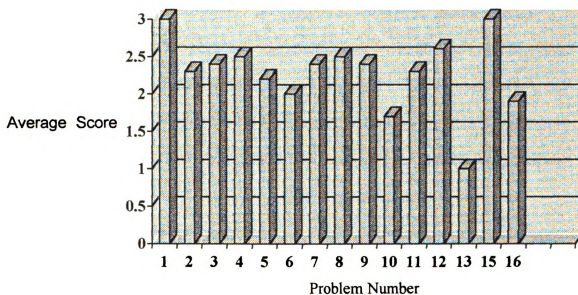
Table 12 - Post test class results (N=20)			
Problem #	Score	Problem #	Score
1	3.0	9	2.4
2	2.3	10	1.7
3	2.4	11	2.3
4	2.5	12	2.6
5	2.2	13	1.0
6	2.0	14	N/A
7	2.4	15	3.0
8	2.3	16	1.9
Average score	2.3		

The post test contains four questions at the end of the test that do not correspond to any questions on the pretest. These questions are advanced trait problems that were included in the test. The graph of the post test clearly demonstrates higher test scores in every category. (Graph 2)

Graph 1 - PreTest Results



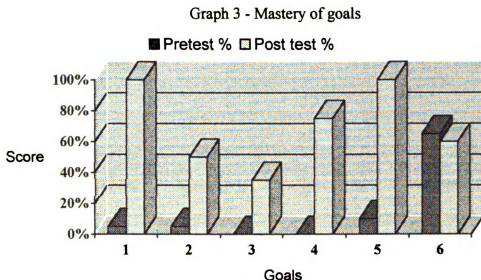
Graph 2 - Post Test Results



When I taught this unit, I had a set of goals (Graph 3) for all 20 of my students to achieve. Goal 1 was to be able to differentiate between DNA, chromosomes, and Genes. Based on the common rubric, nineteen students (95 %) could not do this at the outset of

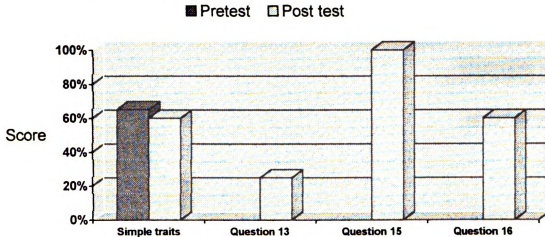
the unit and when asked to do the same thing on the post test, 20 students (100 %) could correctly draw and define them. Goals 2 and 3 were for students to be able to draw and differentiate between Mitosis and Meiosis. On the pretest, only 1 student (5 %) could correctly draw the stages of Mitosis and no students could draw Meiosis. Six students (30 %) knew there was “something about chromosomes splitting” or “dividing” and eleven students (55%) did not even attempt the problem. When this question was asked on the post test the percentage of correct responses was higher. Only 1 student (5 %) did not attempt the problem and seven students (35 %) could completely draw and define both processes. The other twelve students (60 %) were at least half correct with one or the other process or were missing details. Goal 4 was that students would know what Gel Electrophoresis is, and the role of restriction enzymes in this process. Fifteen students (75 %) did not even attempt to answer this question on the pretest. For the post test, twelve students (60%) of the class said “Gel electrophoresis can be used to solve crimes” and one other student (5 %) could “tell the parent of a child”. Based loosely on labs and activities we ran on Gel Electrophoresis and the quiz we took on it, eighteen students (90 %) not only knew what a restriction enzyme was, but could name 3 different ones as well as at what base sequence each one cleaved. Goal 5 was for students to know the difference between zygotes and gametes. They should also know that gametes are sex cells and zygotes are fertilized sex cells. The pretest showed only 2 students (10 %) of students could make this distinction. I gave an alternate assessment orally where all students had to tell me the difference between Mitosis and Meiosis, as well as describe gametes and zygotes following the dipstick meiosis lab and all students were able to correctly walk through the stages of both Mitosis and Meiosis with the aid of tongue

depressors and their lab partner. They all were also able to correctly identify at what point the chromatids / chromosomes represent gametes and zygotes.



Goal 6 was that students would be able to do simple Mendelian genetics problems such as basic monohybrid crosses (Graph 4). On the pretest, thirteen students (65 %) could make a Punnett square to figure out the possible offspring of two heterozygous tall parents. On the post test, only twelve students (60 %) got similar problems correct. There were multiple questions pertaining to this goal and results are a combination of all of them. On related questions for genetics problems that are more advanced, twelve students (60 %) got question 16 on the post test, regarding sex-linked traits, correct. Question 15 on the post test is a family tree containing colorblindness. All twenty students (100 %) were able to answer this question correctly, while five students (25 %) were able to discuss other forms of inheritance based on the genotype of the individual in question 13.

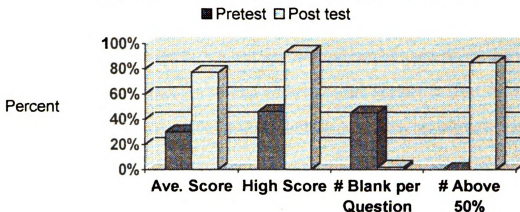
Graph 4 - Questions related to different types of inheritance



The overall scores of the pretest and post test could not be any more dramatically different. I analyzed these scores in two different ways (Graph 5). The first is based on score alone. All twenty students (100 %) had a score less than 1.5 on the pre test. The highest score any student received was 1.4, which 2 students obtained. The average score was a very low 0.9 for the entire class. The post test results were better. The lowest score by any student was 1.2, which is not much lower than the high score on the pretest. Seventeen students (85 %) posted a score of 1.5 or above. The high score was 2.8 and the average score jumped up to a 2.3 on a 3-point scale.

The second way I compared the pretest to the post test was based on number of unanswered questions. The pretest had a rate of just over nine students (46 %) per question leaving blank answers. The post test saw this number drop to less than 1 student (2 %) leaving questions with no response.

Graph 5 - Overall Comparisons of Pretest to Post test



Students had the option to comment on the unit they had just completed on the back of the post test. This was an informal invitation to comment on anything they would like to tell me such as: did the unit improve your knowledge of the areas of molecular genetics we studied? Of those that replied, 100 percent of them said “yes” and “I definitely know more than I did a few weeks ago.” I also invited them to comment on this unit compared to others I have taught to them. Responses I received were “I thought it was fun. We did a lot of cool labs” and “It was hard but I learned lots”. I also received the comment “I didn’t think this was really any different from any of the others we have done in the past. You always teach this way.” To me this was a real tell tale sign that all the hard work was worth it. Only one student comment was negative: “It sucked. There was too much work. All the labs were boring except the DNA one”. Several students replied that “it was pretty hard” which could be viewed as negative or positive feedback.

DISCUSSION

Without a doubt, I feel the new unit I have developed to teach genetics to high school students was successful. The unit was designed carefully with six explicit goals in mind (see Table 1). Genetics is a difficult subject for many students to learn. This unit was designed to help students overcome this difficult material by helping build a strong foundation on background information, addressing misconceptions both before and after they become visible to me, and included several tools to provide a motivational push for students to succeed, such as fun and exciting hands on activities, and several chances for all students to be successful with authentic assessment methods. Data presented in this paper clearly supports my claim that the unit successfully improved student knowledge of genetics. The average score on a pretest was 0.9 out of a possible 3-point scale. Those same questions were asked on a post test and the student average score increased to 2.3 out of 3. Both tests were graded based on a common rubric. Also, students' confidence on the subject of genetics improved. The pretest saw a high incidence of unanswered questions, at just over nine students out of twenty total per question. This equates to forty six percent of the class not answering each question each time, suggesting that they lacked knowledge of the subject and therefore lacked confidence to even attempt the question. On the post test, the rate of students' unanswered questions fell to under one in twenty. I feel the confidence they gained through the unit provided them with the willingness to try answering questions, even when they did not necessarily know the correct answer.

I feel that a majority of the unit was successful and worked as planned. The six major subject matter goals I set at the beginning of the unit were clearly achieved. These

were topics we spent a lot of time on and prior exposure was limited. There is no surprise then that there were such huge gains in student achievement for these topics. They really had nowhere to go but up. I expected that the scores would increase on the post test, but maybe not such a large increase. I also find it interesting that not only were students scores higher on the post test, but students also left many fewer unanswered questions. This is interesting because the post test was a more difficult a test than the pretest. I attribute this to the motivation aspect of the unit. I think students were compelled to do better and were more confident in themselves, thus were willing to “go out on a limb” and try answering questions they may not normally have tried. I tried to make this unit about success and victories rather than defeats. The many forms of authentic assessment that allowed all students a good deal of success throughout the unit should be mentioned as an integral part of the overall success of the students scores from pre to post test.

Not all parts of the unit proved to be effective. According to the pretest, scores show that students came into the unit with good knowledge of using a punnett squares for predicting the outcomes of simple crosses. The post test saw a five percent drop in correct responses. Does this mean five percent of the class forgot how to use a punnett square to make these predictions? I believe the decline in the score is because the post test question was asked in a more difficult way, and a more difficult cross was the basis of the question. Proof of this was in the more advanced application crosses on questions 14 – 16 on the post test. Students’ scores on those problems were consistent with the easier Mendelian genetics crosses. Students’ post test scores were clearly lower on the topics taught in the latter portions of the unit. The emphasis of the unit was on the

background material and the application was to show that it could indeed be useful. We moved more quickly through this material, did less work with it, and post test scores reflect this. Question 13 on the post test is about other forms of inheritance, and students' scores on this question were the worst on the post test at an average score of 1 out of a possible 3 points. You cannot always believe test scores, but I did find it interesting that nine of the twenty students could tell me that a mutation was a mistake in the DNA or gene of an individual on the pretest, yet they could not correctly differentiate between the two on the post test. It shows you that sometimes, how a question is asked rather than what the question is asking can mean all the difference in the score and even interpretation of the question.

All units a teacher develops have portions that are more effective than others for a variety of reasons. Anything by poor planning from the teacher to poor execution by students can be a factor in the success of the unit. There are things that teachers "fix" for next time, things they keep as is, and of course, things to throw away and start over. This unit is no exception. I worked very hard for six weeks at Michigan State University planning and creating these labs and activities, as well as countless hours during the implementation and assessment of the unit. In the future, I would break the unit into two units. The first unit would be all the background information as outlined in this paper. The second would be an applied genetics unit where application is the emphasis. Two or three activities that encompass applied genetics, Biotechnology, Cloning, and different inheritance types, as was the case of this unit, are too few to be effective in the long run. These topics were not the emphasis of this unit, thus the corresponding scores on the post test were low as compared to other topics taught in greater detail. The only drawback

would be in time constraints. There is very little time for a lot of additions to our Biology curriculum based on the state benchmarks that must be taught. I also wonder if the Fruit fly lab is a worthwhile activity. There probably are easier ways to introduce Mendelian genetics that is both less time consuming and less expensive as well. I would like to explore short term and inexpensive alternatives for future lessons. The entire exercise requires about three weeks to successfully complete.

Successes and failures aside, overall, I feel the unit was both effective at teaching genetics and reaching my goals, as well as successful in attaining higher student understanding. By using a variety of tools to improve student motivation, such as visual hands-on activities, cooperative learning, authentic assessment, and colorful and engaging lecture notes using PowerPoint, I feel I was able to reach a broad spectrum of students. I think this experience has reminded me of something I had forgotten, that all students learn differently. The number of students that learn from traditional teacher centered methods is small. As a teacher, I have to work hard to implement tools for all units I teach to provide multiple learning styles as well as incorporate multiple methods to continually increase students' motivation in my class.

APPENDIX – A

Consent Form

Date: July 20, 2001

To: Parents, Guardians, and Students

From: Mr. Withers

Re: Collection of data for Master's thesis

For the past 4 years, I have been working on my Master's degree at Michigan State University. Last summer I designed a genetics unit, which focuses more on a hands-on approach with more labs and activities and a tie-in to real world situations. The unit will take approximately 10 weeks to complete.

In order to evaluate the effectiveness of this unit to your student, I will be utilizing several different kinds of assessment tools. A pre- and a post-test will show beginning versus final knowledge of the subject material. Labs, activities, writing samples, and informal student interviews all will be used to gauge students' improvements in this unit. Homework responses also may be gathered. These tools will be required of all students in the course of the class. With your permission, I would like to use data from the above mentioned for my Master's thesis. At no time will any students name be used in or connected to the thesis.

Please fill out the bottom portion of this letter and return it to me as soon as possible. For clarification, I am asking to use your student's data from the Genetics unit for my thesis. There is no penalty for denying permission to use your data and your decision will not affect your student's grade in any way. No students will be exempt from any of the work, as stated earlier. This just means I cannot use the data in my thesis. Your privacy will be protected to the maximum extent allowable by law.

Please contact the Internal Review Board chairperson David E. Wright at (517)-355-2180 for questions about participants' rights as human subjects for research. If you have additional questions about this or any other thing involving your student or this class don't hesitate to call me (517)-764-1440. Thank you for your time and cooperation.

Yours in education,

Matthew R. Withers

.....
_____ I give Mr. Withers my permission to use my data collected from the Genetics unit in Advanced Biology. I have been informed that Mr. Withers will not use my name and that all student data will remain confidential.

_____ I do not wish for Mr. Withers to use my data in his thesis. I have been informed that I will not be penalized for choosing to withhold my results.

Student Name _____ Student Signature _____

Parent/Guardian Signature _____ Date _____

APPENDIX – B

Genetics Unit Pretest
“What do you know already?”

1. Below, draw a picture of each of the following in as much detail as you can.
 1. A DNA molecule (10 bases)
 2. A gene
 3. A chromosome before and after replication

1	2	3
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2. Explain everything you can about the cross $Tt \times Tt$, where T = tall and t = short.

3. What is a trait? How are traits passed on from one generation to the next?

4. Is there anything wrong with cloned organisms as far as health to that organism itself?

5. Cloning is a huge new topic related to genetics that is constantly in the news. What can you tell me about cloning? Can you remember anything that has been cloned?

6. Differentiate between Brian and Mike Cram versus Jason and Jenny Craft? How are they similar? How are they very different (genetically speaking)?

7. Last year we talked briefly about Genetic Engineering and its uses in society. Tell me what Genetic Engineering is and a few places it would or could be helpful. Examples you make up are ok if applicable. Possible areas of choice are food, athletics, medicine, conservation, and agriculture.
8. What is the difference between a gamete and a zygote? What significance do they have in a punnett square? How much of the possible amount of information does each one have (Haploid and Diploid)?
9. What is the difference between Mitosis and Meiosis in terms of each of the following: Final products, cells undergoing each process, Stages in each, types of cells or organisms that undergo each can be drawn below.

Mitosis	Meiosis

10. What is Gel Electrophoresis? Where could it be used?

11. What is a restriction endonuclease or restriction enzyme? Name a few.
12. All traits are not inherited according to Mendelian Laws. Below are some other ways traits can be passed on from generation to generation. Explain each process and give an example.
1. Mutations-
 2. Incomplete Dominance-
 3. Codominance-
 4. Selective Breeding in animals-
 5. Genetic Engineering (any type)-

Restriction Enzymes Quiz

1. For the “Withers” gene below, draw a restriction map with each enzyme and one with all three enzymes.

ACGCTTCGATACGACCCTAGGTCTAGATCTAGCTAGCTGATTGAATGAATGCT5
AATTCTTCATCTCTTTTCGAGATTTCGAATGTCTCGCTCGCTAGTAGCTGATAA
AGCTGCCTGCTCGGCTCGTAGATCCTACGATGCGTACCGAGCCTAGGCGAAA
CTCATATCAGAGAGGAGATCTCGATGTAGCCTTTATATATAGGAGATAAAGC
ATGAGAGAGGGGGCGCGCGCGTGTGTTTTGTGATTAGATGCTGCTACACATC
TCTGTGAGATCTGCTGATCGATGCTAGCTGCTACTGGTAGAGACATCACACCC
ATATCAACTTTGGGAGATTCTCGCTGCTATCGTAAAATTATTATATACTTAAG
CGATACGAGGGAGATCTAGATCTAGCTAGCTGATTGAATGAATGCTAACTAT
ATTCTTCATCTTTCGAACGAGAGATAGATGTCTCGCTCGCCTTAAGCTGATATA
TTCTCGCTGCCTGCTCGGCTCGTAGATCCTACGATGCGTACCGAGGGAGCGC
GACCCTCTCTCTCATATCAGAGAGGAGATCTCGATGTAGCCTTTATATATAGG
AGATGATCGCTGCGACACATGAGAGAGGGGGCGCGCGCGTGTGTTTTGTGAT
TAGATGCTGCCTAGGATCTCTGTGAGATCTGCTGATCGATGCTAGCTGCTACT
GGTAGAGACATCACACCCATATCAACTTTGGGAGATTCTCGCTGCTATCGTG
GAGAGAGAGAGGTTGTGTTTATATGCCCCGCGATAGTGCTATGCTGATCAC
ACACTTTTCTCTCGCCCTAGGGGCGAGATCTGCTAGCTGCTGTTTCGTGCTGT
TCGCGCGTGTTCGCGTGAATATCACCCA

CTTAAG - EcoRI
CCTAGG - BamHI
TTCGAA – HindIII

2. For the gene below, show what the gene would look like after the enzyme cuts it

ACGCTTCGATACGACCCTAGGTCTAGATCTAGCTAGCTGATTGAATGAATG
CTCAATTCTTCATCTCTTTTCGAGA

Fruit Fly Applied Genetics Projects

1. Transformation of Plasmid DNA into Fruit Fly
 - a. Choose one of the following given gene sequences of the fruit fly: Apterous (2), Clift, Vestigial (2), or Hairless.
 - b. Print or write out the base pair sequence for that gene.
 - c. Using one of the 3 restriction enzymes (EcoRI, HindIII, and BamHI), find the specific gene sequence the enzyme recognizes. Show what that gene would look like after the enzyme has cut it into smaller pieces.
 - d. Draw a Restriction map of the gene.
 - e. Using your base pair rules and an Amino Acid chart, convert the codons to the Amino Acid sequences for each segment of that gene.
 - f. Make your own lab for food colors. You will need to make a set of 3 samples that when run on gel will resemble the Maverick gene cut with EcoRI, HindIII, and Bam HI. Do this during Electrophoresis of food coloring lab.
2. Mutations
 - a. Using the gene you just cut, choose one region (I would choose the shortest!). Using the sequence of that segment, show how that segment would look after each of the following point mutations occurs to the segment: Substitutions, Insertions, and Deletions.
3. Genetic Engineering
 - a. Choose a gene from the dipstick chromosomes of Drosophila. Explain what trait you chose and what is appealing socially about that trait. Why clone it???
 - b. Explain the steps you would need to go through to clone the gene in question. Explain this process from beginning to end. You are starting with 1 specific gene of a fruit fly. When finished you need to replace that gene elsewhere. This will involve making a Chimera (remember transgenic plants and animals?)

Genetics Unit Post Test

1. Draw a picture of DNA, genes, and chromosomes.
2. A man with AB blood marries a woman with O blood. What are the possible blood types they could have for kids? Explain as much as possible about blood types, the cross, and the possible children.
3. Clift eyes are autosomal recessive on chromosome # 2. A Clift eyed male is crossed with a normal female carrier. What % chance do they have of having a wild type female?
4. There are all sorts of animals being cloned and even companies advertising for you to clone your pet. What aren't scientists telling you about cloned animals
5. Briefly describe the way to clone a sheep.

6. Describe a natural way to clone an organism and describe what we commonly call them.
7. You are the paternity tester for the Jerry Springer show. This particular group of freaks has a real problem... who is the father of little Johnny? Below is the sequence of all their DNA run before the show. From this data, determine who the father is.

Mom	John	Rick	Ted	Jim	Father: _____
—	—		—	—	Evidence: _____
	—	—	—	—	_____
—	—		—	—	_____
—	—		—		_____
—	—	—		—	_____
—	—	—	—	—	_____
—		—	—	—	_____

8. Using the Pictures of Mitosis and Meiosis below, describe the final products each process creates in terms of amount of information and specific names or descriptions of each.

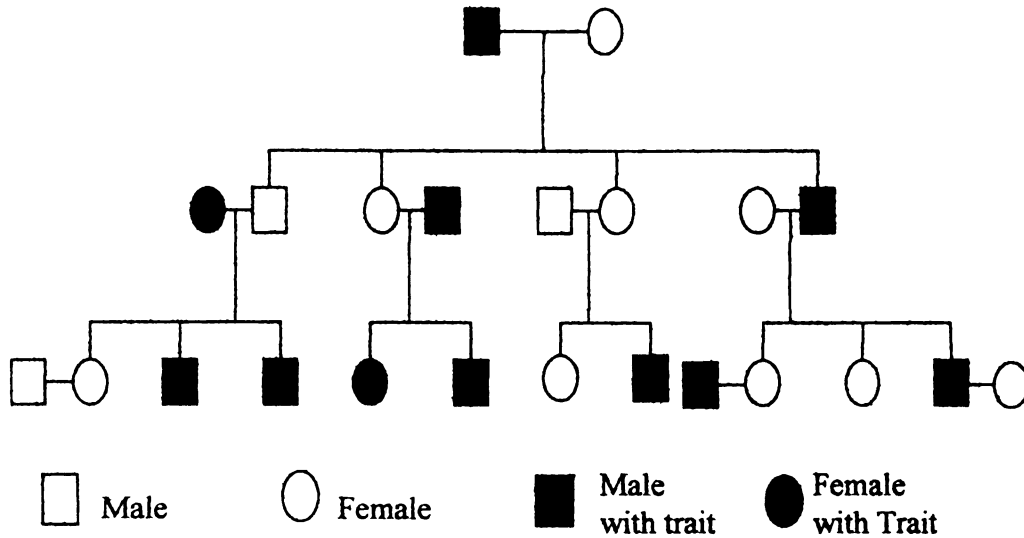
9. Draw a generic diagram of Mitosis and Meiosis using fruit fly chromosomes (4). You only need to label the following on one picture: Chromosome, Chromatid, Centromere, and Spindle fibers. Make sure you label the stages.

MITOSIS	MEIOSIS

10. You are working for the State Police in the Forensics Unit. What would you use Gel Electrophoresis for in this job?
11. What steps would a scientist use to create the gel plate shown on number 7 above?
12. Where could I find DNA if I wanted to find it? Be very specific in terms of all organisms as well as food products. I Need both items answered.

13. How can you explain the following? Hairy wings are dominant to normal wings in fruit flies. Also hairless is recessive to hair possession. How could a fly with the dominant hairy wing gene be hairless? Assume no random mutations have occurred.

14. Below is the pedigree of a family with colorblindness



15. What role do women typically play in this scenario?

16. Label the genotype of all individuals of the F₂ generation above.

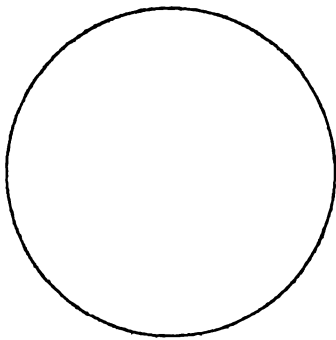
APPENDIX – C

Mitosis Lab 1

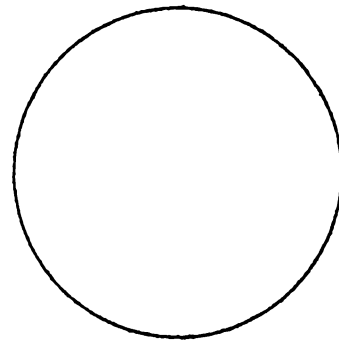
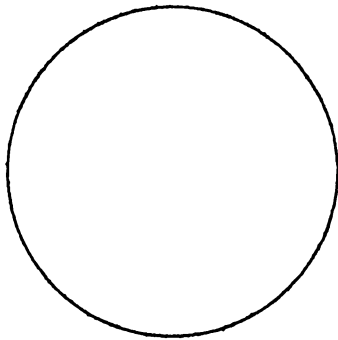
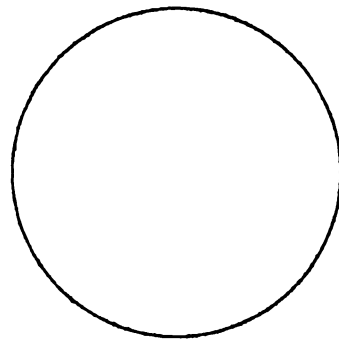
Purpose: Compare Animal Mitosis to Plant Mitosis.

Directions: Look at, compare and Draw Plant Mitosis (Onion or Allium Root Tip) vs. Animal Mitosis (Whitefish) at each stage of Mitosis. Also, briefly describe what is happening to those cells at each stage. There are general statements that can be made about all cells undergoing Mitosis and there are also subtle differences between Plant and Animal Mitosis. Be sure to note those subtle differences no here as well.

Plant



Animal



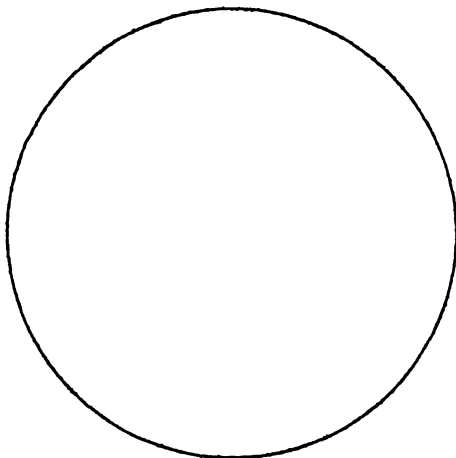
Mitosis Lab 2 “Dipstick Mitosis”

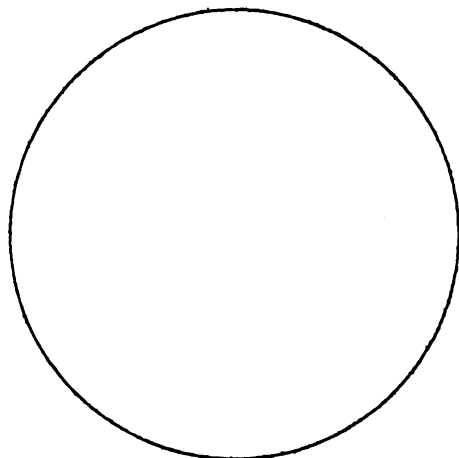
Background: Mitosis, also known as cell division, is a process that diploid cells undergo to create identical copies of themselves. Nearly all organisms at one point or another undergo a mitotic division. Refer to your notes for the exact steps for this lab. Fruit Flies have 4 chromosomes so this activity will use 4 chromosomes undergoing Mitotic division. Remember the goals of Mitosis so you have cells with the correct amount of Genetic Material when finished. Also remember that for all organisms $\frac{1}{2}$ of the information comes from Mom and $\frac{1}{2}$ comes from Pop.

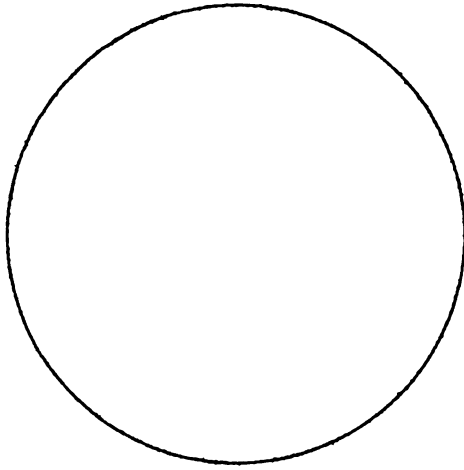
Materials: Pre-made chromosome packages containing: 1 Ziploc bag, 16 tongue depressors of varying colors (2 light and 2 dark of each color), 8 large paper clips, 2 envelopes, 16 pieces of string. Note: For this lab we will be using the side without the genes on the Chromosomes.

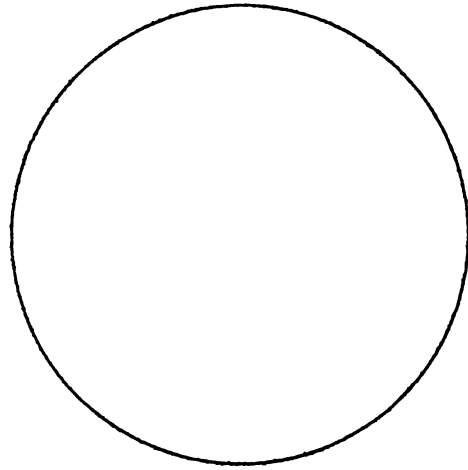
Procedure

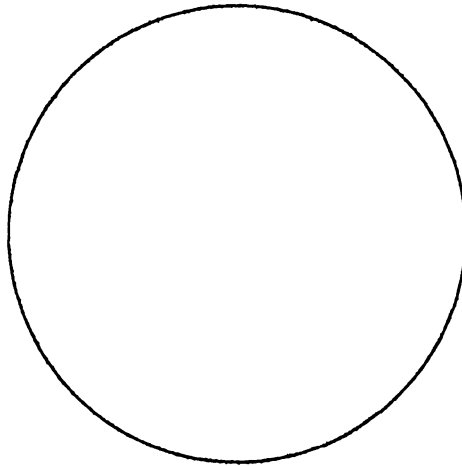
1. Follow the stages of Mitosis using 4 chromosomes and a paper clip as the centromere. The light colored chromosomes were from the mother and the dark colors were from the father. String will represent spindle fibers.
2. Draw, label the phases of Mitosis, and label the structures involved at each phase of Mitosis in the circles below.
3. Count the number of chromosomes in each cell at each stage.
4. You must be able to go through and explain each stage with your kit without notes before you are finished.











Follow-up: Write a 1-page typed essay explaining your lab. Cite specific references from the lab and the thought questions below.

1. Explain fully the comparison of the parent to offspring following Mitosis.
2. What happens to the chromosomes following Telophase?
3. What cellular events occur during Interphase?
4. What do the Spindle fibers do for the cell?
5. Compare and Contrast Human Mitosis to Fruit Fly Mitosis.
6. Why are there 2 colors for chromosomes?

Mitosis Lab 3 The Cell Cycle

Purpose: To determine How Long a cell spends doing certain tasks.

Instructions: Looking at the prepared slides of Mitosis (plant or animal), Choose one of the tissue samples (there are 3 root tips and 12 whitefish samples per slide). Count the number of cells in each stage of Mitosis. Figure out the percent of cells at each stage of Mitosis. This will be impossible to be 100 % accurate. Do your best!

Stage of Mitosis	# Cells seen in this stage	Percent of total cells in stage
Interphase		
Prophase		
Metaphase		
Anaphase		
Telophase		

Post Lab Questions

1. Draw and explain the cell cycle
2. Relate your lab results to the cell cycle
3. Why would you not want all cells at the same stage of Mitosis at the same time?
4. Which stage was definitely at the highest percent in your tissue sample? Why is this so?

“Dipstick Meiosis”

Introduction

Gametes are specialized cells that are used in sexual reproduction. It is important that gametes have half the number of chromosomes as regular body cells. Male gametes, called sperm, are made by a process called Spermatogenesis, and female gametes, called egg cells, are made by Oogenesis. When the sperm and egg unite to form a zygote during fertilization, the resulting cell must have the diploid number of chromosomes. In order to maintain the proper number of chromosomes in offspring, gametes must undergo a reduction division called Meiosis.

In this activity you will be simulating the phases of meiosis using models of fruit fly (*Drosophila melanogaster*) chromosomes. These chromosome models contain specific genes that we will be working with later during the fruit fly lab.

Materials

Pre-made chromosomes package containing: 1 Ziploc bag, 16 Pieces of String, 8 Paper Clips, 16 Tongue Depressors of varying colors (8 dark colors and 8 light colors), 4 envelopes, Colored pencils.

Procedure

1. Using the kit provided to you model the stages of Meiosis.
2. Draw and label each of the stages of Meiosis below or on another piece of paper. Be sure to label the following for each drawing if applicable: Haploid number, Diploid number, Number of chromosomes, and the stages of Mitosis.
3. You must be able to explain each step without the aid of a book or notes in order to move on.

Post-Lab

In a 1-page typed essay explain Meiosis. You must cite specific information from the lab as well as information from the following thought questions.

1. What is the purpose of Meiosis?
2. What is a gamete, zygote, haploid, diploid, homologous pair?
3. Why does Replication occur in Meiosis I but not in Meiosis II?
4. One of the great advantages of organisms that use Meiosis to reproduce is genetic diversity. List at least 2 possible sources of genetic diversity besides mutations.
5. What happens to 2 Meiotic cells that unite? How do they progress (grow) into an organism?

Extracting DNA from fruits and veggies

The purpose of this lab is to extract DNA from several different fruit and vegetable matter. DNA, which stands for deoxyribonucleic acid, is a double – stranded polymer molecule loaded with the cells instructions. DNA is made up of genes, the units of inheritance that convey information within a cell for cellular duties and from parents to offspring. DNA is found in any cells that are considered living.

In order to extract DNA from different samples we will need a buffer solution. A buffer is a substance that resists changes in the concentration of H^+ and OH^- . As a result of a buffer, biological fluids resist change to their pH when acids or bases are introduced. Buffers work by accepting hydrogen ions from the solution when they are in excess and donating hydrogen ions to the solution when they have been depleted. Most buffers are weak acids or weak bases that combine reversibly with hydrogen ions. A buffer is necessary in this experiment for its ability to break apart the structure of DNA. A buffer carries with it a negative charge. A strand of DNA gets its structure as result of the hydrogen bonds between nitrogenous base pairs. Chromosomes also contain histones, which are electrically charged. The negative charge of the buffer attracts the histones and breaks apart the bonds. This allows the DNA to be separated and easily extracted. Baking soda (Na_2CO_3) is also used in this experiment because when placed in an aqueous solution, the baking soda is converted to $2Na^+ + CO_3^{2-}$. The negative charge on CO_3^{2-} attracts the electrically charged amino acids and H^+ . This helps the buffer solution to separate the DNA, and at the same time it maintains the pH of the solution. Dishwashing liquid aids in breaking apart and separating DNA from the proteins.

MATERIALS:

Buffer solution, Distilled water, 2 Fruit or vegetable samples, Mortar and Pestle, 4 clean test tubes, 2 Rubber stoppers, 2 Coffee Filters, 2 wooden sticks, Ice cold ethanol (95%), Electronic balance, 2 pipettes, 2 pieces of filter paper.

Part 1 – Obtaining DNA from Fruits and Veggies

- 1) Dice a 10-g sample of the fruit/vegetable matter.
- 2) Place the diced sample in the pestle.
- 3) Add 20 ml of warm distilled water to the pestle.
- 4) Crush the sample with the mortar until all dices are gone and you have a thick liquid.
- 5) Pour 10 ml of the buffer solution into the test tube.
- 6) Filter out 10 ml of the sample. If you have lots of chunks of fruit in there, filter again.
- 7) Pour the sample in with the buffer.
- 8) Cap the test tube gently mix for 2 minutes (invert). DO NOT SHAKE THE TEST TUBE!

- 9) Slightly tilt the test tube and gently pour 10 ml of ice-cold ethanol on top of the solution.
- 10) Record your observations on the data table.
- 11) Insert a narrow wood rod through the alcohol layer -- just below the boundary of the alcohol and buffer. Gently twist the wood stick and spool the DNA around the stick.
- 12) Repeat Steps 1-12 for your second sample.
- 13) Label both tubes and share with classmates that need them.

Data Table 1

Fruit or Veggie	COLOR	SPOOLABLE?

Part 2 - A Quantitative look... Which one gave the most DNA?

1. You will find the Percent Composition of the DNA from both your samples.
2. Mass a piece of filter paper.
3. Using a disposable pipette, suck up the DNA in the test tube that is suspended between the ethanol and the buffer/filtrate solution. Be sure you don't get the filtrate. The ethanol will evaporate off.
4. Place the filter inside a funnel and squirt the pipette through it into a test tube.
5. Wash with ethanol by pouring about 10 mL of ethanol through the filter.
6. Set your filter somewhere to dry (probably overnight).
7. Re-mass your filter paper.
8. Fill in Data Table 2 below.

9. Calculate the Percent composition of the DNA collected by:

$$\% \text{ comp} = \frac{\text{Mass sample}}{\text{Mass DNA}} \times 100\%$$

Mass DNA

DATA TABLE 2

Sample	Mass Sample	Mass of DNA	Percent Composition

Conclusion – write an essay to explain the lab and its results. Include things to think about below as well as other stuff from the lab and results.

1. Which ones seemed to produce the Best DNA? Worst?
2. Which ones produced the Most DNA? Least?
3. Why did we wash the sample with more ethanol?
4. Why does the DNA Spool (or why should it?)
5. Why did we need to smash up the fruits and veggies?
6. What is the purpose of the buffer?
7. Should this work on animal as well as plants as we have done?

Teacher Reference

Suggested fruits and veggies

1. Broccoli (florets)
2. Cauliflower (florets)
3. Kiwi (peeled)
4. Onion
5. Banana (peeled)
6. Tomato
7. Lemon (peeled)
8. Lime (peeled)

To create the buffer solution

1. 120 mL distilled water
2. 1.5 g table salt or NaCl
3. 5 g Baking Soda (Na_2CO_3)
4. 5 mL Ultra Dawn (Blue) dish soap

Results

1. I have found that the Broccoli, Cauliflower and Banana work the best. There is as much DNA in each of the floret's as other cells however these are smaller and more numerous cells! The Banana is questionable if it is DNA or RNA but works just the same.
2. The others don't work as well due to the size of the plant cells they are found in. They are large and filled with lots of carbohydrates and water for storage. They have small nuclei per space compared to above. I found the onion to be the worst!

Modified from original lab at:

[http://biology.damien.edu/biology/ap/students/aricalde/labs/DNA Extraction.html](http://biology.damien.edu/biology/ap/students/aricalde/labs/DNA%20Extraction.html),
and Michael Sampson at Redford Union Schools

Electrophoresis Assignment

1. What is a restriction enzyme?
2. Name the 3 enzymes we used to cut Lambda DNA
3. What is a Bacteriophage?
4. What are the specific sequences that BamHI, EcoRI, HindIII cut?
5. Look up the maverick gene on Chromosome 4 of a fruit fly. Print the sequence out and attach to the paper. How many base pairs is it?

Go to: <http://www.ncbi.nlm.nih.gov/cgi-bin/Entrez/getff?gi=7316093&form=2&db=N&from=12847734&to=12854690>

6. Using the 3 restriction enzymes above, show what the maverick gene would look like when each enzyme is applied to it. And one with all 3.
7. Draw a Restriction Map of the Maverick gene in well 1, HindIII in #2, BamHI in #3, and EcoRI in #4, and all 3 in #5.

Food Color Gel Electrophoresis

Gel Electrophoresis is a process that can be used to separate DNA fragments. Scientists use this process to look at and compare DNA strands. It is used for research purposes, solving crimes, and determining heredity within families. The process is similar to chromatography in that molecules are separated based on size. DNA is a negatively charged molecule and therefore runs toward a positive charge. Heavier molecules will separate out early and therefore will not move as far through the gel. The lightest molecules will run the longest distance towards the positive electrode.

Molecules that are not DNA can also be separated using this process with a few variations, however. Food Coloring is a variety of dyes to give the characteristic "color" you are looking for. Different dyes will separate similarly according to size. We will be separating different colors of food coloring based on size. The purpose of doing this activity is to model the process of Gel Electrophoresis and to practice setting up these labs.

Materials: 1 Gel Electrophoresis set-up (box, comb, 9 volt batteries, clips, Carbon fibers, 20 ul micropipettes), several samples of food coloring solution (pre-made), Agarose, distilled water, TBE buffer.

Procedure:

1. Pour enough 3% Agarose gel into your well to cover the bottom but not overflow the chamber.
2. Place the comb in the well in the appropriate spot. Let this sit until it solidifies.
3. Choose 4 different colors of food coloring. Take those vials back to your seat with you.
4. On a clear piece of paper, label wells 1-4 with the 4 colors you will use so you know what was in each well of the gel box.
5. Cut 2 carbon fibers 22 mm x 42 mm. These will be the electrodes to pass the current through.
6. Place an alligator clip on each carbon fiber (one black and one red).
7. Put the batteries together so three or five are together. The more you use, the faster the gels will run.
8. Place the other end of the clips on the batteries. Red is positive and Black is negative.
9. If your gel has solidified, slowly remove the combs, leaving 4 nice deep wells.
10. Pour enough TBE buffer (running buffer) to completely cover the gel and fill the ends of the well. Don't be afraid of having too much as more is better than less!
11. Using the given micropipettes put 20 ul food coloring in the corresponding well. Be careful to not poke a hole in the gel, just fill the well. The liquid is less dense than the TBE buffer so it should sink to the bottom of the well.
12. Once all 4 wells are full, place the electrodes in the chambers at each end with the red at the opposite end of the solutions.
13. Let these run until they are almost to the end of the gel box. If you let them go too long they will run right off the gel to the electrode.
14. When the dyes are finished, dump the liquid down the sink.

15. Place your box on the white paper you labeled earlier to see the colors and distinct bands.

Diagram 1

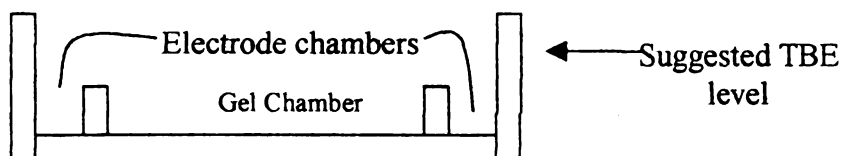
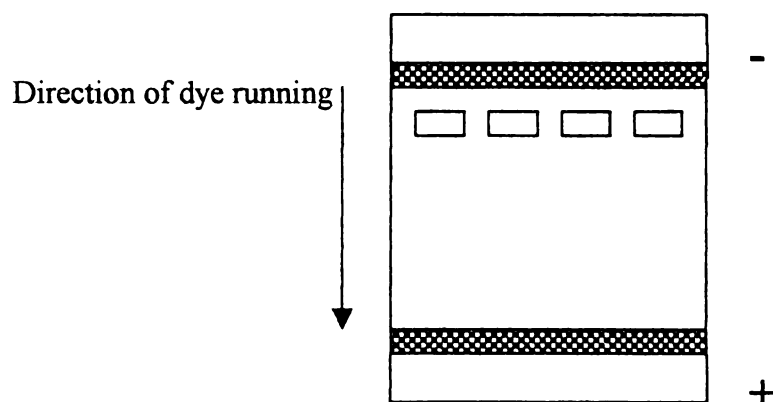


Diagram 2



Conclusions and analysis – Answer and explain the following questions

1. Draw a picture of your results for all four samples.
2. Measure the length each color moved from the original well. Add to picture.
3. Explain each color. Original color, colors now seen, length of movement and why they moved the length they did.
4. Based on your data and others, can you guess what the unknown is or what dyes are in the unknown?
5. Why is the red clip at the far end of the gel box?
6. What would the results be if we used thicker gel? Thinner?
7. Would a strand of human DNA probably run slower or quicker than these dyes? Why?

Teacher Reference

Kool-aide can be substituted for food coloring. The names of the dyes used are on the back of the package. I found the food coloring to be better for seeing bands than the Kool-aide.

To make the Food Coloring solutions (Should be enough for the entire class)

1. 50 ml TBE buffer: Can get from Carolina or make it yourself by the following recipe.
 - a. 10.8 g Tris Base
 - b. 5.5 g Boric Acid
 - c. 20 ml 0.5M EDTA (pH 8.0)
 - Disodium salt, dihydrate, crystal, Ethylenedinitrilotetraacetic acid
 - 3.722 g EDTA in enough distilled water to make 20 ml
 - d. 1 L distilled water
2. Glycerine 5 ml
3. Food coloring 10 drops

The gels used were 1.5 % and 3 % Agarose. The thicker the gel the better the results seemed to be as the Dye runs slower. To make the gel dissolve 1.5 g Agarose in 100 ml distilled water for 1.5 %. For 3 % dissolve 3 g Agarose in 100 ml distilled water. You can heat this up with gas burners or microwave. Make sure no chunks are in the gel. Cover and this can be re-used until gone.

These run pretty fast as they are pretty small molecules. With 27 volts they were done after 1-½ hours. You may be able to speed it up with more juice. Also more concentrated mixtures may help with darker coloration of the bands.

Unknown mixtures can be made by mixing colors. The limitation is that only 3 colors can be made to separate out.

Gel boxes can be obtained a number of ways. They can be made or purchased. I purchased these from Carolina Biological. Classroom Kit \$230.00 each. This gives 5 gel boxes and supplies for at least 10 labs.

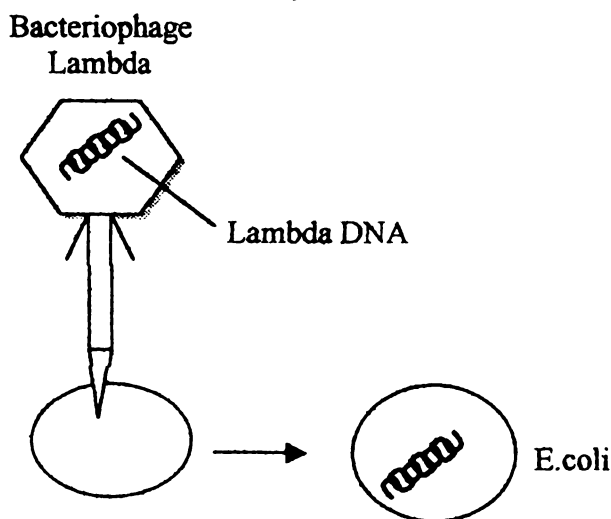
Gel Electrophoresis of Lambda DNA

"Using Restriction Enzymes"

All living organisms share certain characteristics, among which is the possession of genetic material, DNA. This is not limited to common things such as plants and animals. Bacteria, and even Viruses have their own DNA.

A Bacteriophage is a Virus that invades bacteria (see picture below). They are like little hypodermic needles that insert their DNA into a host. Once inside the bacteria, the phage DNA takes over the machinery of the host, or reproduces and kills the host. The Lambda phage is a well-known Bacteriophage. It has double stranded DNA wrapped around a protein core. It has a genetic make-up of 48,502 base pairs, of which location and order are all known.

Bacteria have a defense against invading viruses such as Lambda phage. They produce enzymes called restriction enzymes or restriction endonucleases. These enzymes cut DNA into pieces, rendering it useless. These enzymes are site specific as each recognizes a specific sequence of bases within a strand of DNA and cuts at that point. There are many types of these enzymes and each recognizes a different sequence. We will be working with 3 such restriction enzymes called EcoRI, HindIII, and BamHI.



Preparing the gel

1. We are using a 3 % Agarose gel. Melt your gel using the microwave or a burner. Make sure there are no clumps in the gel. Careful... Very HOT!
2. On a flat surface, pour enough Agarose gel into your box to fill the central cavity (10 ml?).
3. Place the comb in the slot provided.
4. Let sit for 20 – 30 min.
5. Once solid, add 15-20 ml TBE running buffer to the gel. The buffer should overflow the electrode chambers.
6. Gently pull the comb out of the gel box.

Prepare the electrodes and batteries

1. Cut 2 carbon fibers about 22 mm x 42 mm. These will be the electrodes to pass the current through.
2. Put 3 9V batteries together.
3. Put a red alligator clip on the positive terminal of one battery. Put a black on the negative.

Rehydrating the Lambda DNA

1. Add 100 ul (micro liters) distilled water to the lambda DNA.
2. Cap and allow the tube to stand for 5 minutes.
3. Mix the tube by flicking the side for 1 minute.
4. Allow the tube to stand 5 minutes.

Cutting DNA

1. With a new tip for each tube, add 20 ul Lambda DNA to the enzyme solutions. Make sure you mix each thoroughly by drawing the solution up and down the micro tip several times. Change tip before next tube.
2. Place the tips on the foam rack provided. Incubate at 37 °C in a water bath or incubator for 30 minutes.
3. Place the tubes in hot water bath at 65 °C for 10 minutes. This breaks down the enzymes.
4. If out of time you must either freeze this or run it!

Loading the DNA

1. Add 2 ul loading dye to the tube you wish to run first. Mix by drawing both liquids in the tip several times.
2. Transfer the contents of the tube into the first well on the gel. Go slowly and don't tear the gel.
3. Repeat for each tube.
4. Once all 4 wells are filled you are ready to go.
5. Place one carbon fiber in each electrode tray. They can stick against the glass.
6. Alligator clip each one. Remember DNA is Negatively charged.
7. Let these run until finished probably 2 – 3 hours.

Staining the DNA

1. Unhook the electrodes and batteries (so we can re-use them).
2. Pour off the buffer into a waste jar.
3. Pour about 10 ml Carolina BLU™ on the gel.
4. Let stain sit for 4 minutes on the gel.
5. Pour this into a waste jar.
6. Wash off the gel with distilled water.
7. Put the gel box in a plastic bag overnight.
8. The next day wash the gel again several times. Try leaving the water in longer.

Analysis and conclusions

1. Name the 3 enzymes we are using, their purpose and the sequence they each recognize.
2. Draw a picture of your gel box with results of the lab. Measure length of band from well.
3. Draw a restriction map of Lambda DNA with each enzyme.
4. Explain your results compared to the restriction map. Why do you not have the same number of bands? Which bands represent which parts of the map? Why?
5. What kind of results would we have if we changed the number of batteries to utilize different time periods?
6. This lab was a lot of work for you and me. Also, it is quite expensive. Did you enjoy it... was it worth it? Be brief

Teacher Reference

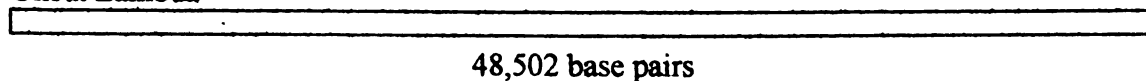
This lab was done using kits purchased from Carolina Biological. . Classroom Kit \$230.00 each. This gives 5 gel boxes and supplies for at least 10 labs. There are also Student guides that are both informative and visual.

4. 50 ml TBE buffer: Can get from Carolina or make it yourself by the following recipe.
 - a. 10.8 g Tris Base
 - b. 5.5 g Boric Acid
 - c. 20 ml 0.5M EDTA (pH 8.0)
 - Disodium salt, dihydrate, crystal, Ethylenedinitrilotetraacetic acid
 - 3.722 g EDTA in enough distilled water to make 20 ml
 - d. 1 L distilled water
5. Glycerine 5 ml
6. Food coloring 10 drops
7. 1.5 % and 3 % Agarose

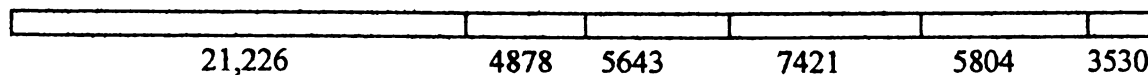
The thicker the gel the better the results seemed to be as the Dye runs slower. To make the gel dissolve 1.5 g Agarose in 100 ml distilled water for 1.5 %. For 3 % dissolve 3 g Agarose in 100 ml distilled water. You can heat this up with gas burners or microwave. Make sure no chunks are in the gel. Cover and this can be re-used until gone.

Restriction Map of Lambda DNA

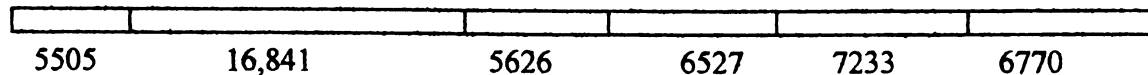
Uncut Lambda



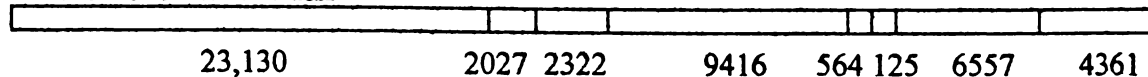
Lambda cut with EcoRI



Lambda cut with BamHI



Lambda Cut with HindIII



Mating Fruit Flies

The genetics and heredity of common fruit flies, *Drosophila melanogaster*, is well documented. Since Thomas Morgan first did his studies on these flies in 1910, fruit flies have been a model for Mendelian inheritance. We will use the fruit flies to understand the basics of heredity and genetics to build off. We will also be taking a closer look at a few specific genes (traits) such as sepia eyes, white eyes, vestigial wings, and ebony body. These are all traits that differ from the “wild type” of the trait, which is the normal trait.

Day 1

Get your vial of flies. Note the parental traits already crossed for you. You may need to look up what this means. You will need to do the following tasks.

1. Determine the general differences between males and females. Go to FlyBase
2. Count the flies in the container based on traits.
3. Place an equal amount of males and females in a new vial with fresh media. Should be between 5 and 7 of each.
4. Let grow for about 10 days or until you see lots of little larvae.
5. Check these daily to keep a good handle on them.

Day 2

1. When larvae are very active take out your F_1 generation.
2. Let sit until F_2 generation appears.

Day 3

1. Knock out your F_2 flies.
2. Count the trait and sex of each individual in the vial.

Analysis and Conclusions

1. Make a data table listing the results of all 3 generations of flies.
2. Make punnett squares of the crosses that created these different flies.
3. What would happen if your trait was epistatic and those traits were expressed in your fly at the same time?
4. Which type of inheritance does this trait use? Why did you come to that conclusion?
5. How do your results compare to another inheritance (x-linked vs. autosomal)?
6. Write an essay to explain the lab you have done. This is inclusive of results, charts, tables, etc. You may draw pictures or anything you wish to make this look nice.

Teacher Reference

Carolina Biological sells flies of the F₁ generation so you don't have to worry about virgin flies. The P generation is removed before shipping so you should get your F₁ flies soon after. They also sell a number of different traits to look at. The F₁ vials are \$16.95 each.

To make nutrient media about (40 vials)

Materials needed

1. 9 g Bacto-agar
2. 450 ml cold tap water
3. 62.5 ml Unsulphured Molasses
4. 44 g Corn meal
5. 18 g Yeast
6. 125 ml cold tap water
7. 12.5 ml 10 % PHBA in 95 % Ethanol

Steps to make media

1. Add water and agar to a 1 L flask. Stir with a stirring bar and bring to a low boil. Place a watch glass on top of the flask. Watch the agar it boils over easy.
2. While waiting for your agar to boil, combine corn meal, yeast, and tap water in a 1 L beaker. Mix with a stir bar.
3. Add Unsulphured molasses and bring to a low boil. Keep top on as much as possible.
4. Pour beaker to flask. Reduce heat and cook 10 – 15 minutes, stirring often.
5. Cool 5 minutes then add 10 % PHBA in 95 % Ethanol.
6. Soak plastic vials in 10 % commercial bleach for 2 hours and rinse.
7. Pour media into sterile vials and plug with sterile cotton.
8. Cool before refrigerating.

Human Heredity Studies of Families and populations

Many traits are a result of the variation of only one gene, such as Dominant and Recessive for one trait. Below is a list of several Human traits we can observe phenotypically in families. We cannot always determine Genetically what these traits look like. A dashed line is used to represent an allele not known. For example if Purple flower is dominant to white, a Purple plant could be PP or Pp. If we do not honestly know the genotype of the plant we would write P- to represent a purple plant.

Attached Earlobes Most people have earlobes that dangle free. A person homozygous for recessive allele (e) would have attached earlobes and the genotype (ee). When looking at other people's ears you will see much variation in size and appearance, all separate genes. Only concentrate on lobes for this.

Widow's Peak Some people's hairline drops downward and forms a distinct point in the center of the forehead. It is caused by a dominant allele (W). Unless you are bald, you should be able to see this phenotype easily.

Tongue Rolling A dominant allele (R) gives about 70 % of the population the ability to roll their tongues into a U-shape or funnel shape. Others who don't possess this gene can do little more than curve the tongue downward slightly.

Hitchhiker's Thumb Next time you are trying to get a ride home from school try bending the top of your thumb back as far as possible. Some people can move it to almost a 90 ° angle. The recessive allele (h) is responsible for the ability to do this.

Bent Little Finger A dominant allele (B) causes the last joint of the little finger to bend inward toward the 4th finger. Lay both hands flat on the table, relax the muscles and see if you have a bent or straight or bent little finger.

Long Palmar Muscle A homozygous person for the recessive allele (l) has a long Palmar muscle that can be detected by examination of the tendons of the inside of the wrists. Clench the fist and flex the hand toward the biceps. Feel the tendons. If there 3 you possess the trait for a long Palmar muscle. If there are 2 you do not have this muscle and are dominant (L). Check both wrists as it is sometimes present in one but not the other because of variations in the expression of the genes.

PTC Tasting The ability to taste a chemical known as PTC (phenylcarbamide) is controlled by a dominant allele (T). Homozygous recessive individuals cannot taste this chemical in the weak concentrations used for the test. If you are a taster you will know it. If you are wondering what you are supposed to taste you aren't.

Color of the Iris of the Eyes A dominant allele (P) causes the pigment melanin to be deposited in the front part of the iris, while the recessive allele (p) codes for a lack of melanin in the iris. The eyes of those without the melanin, (pp) will appear blue because of the reflection of the blue rays from the deeper layers of the iris, the same reason that causes deep water to appear blue. The longer the wavelengths are not reflected as readily as the blue. Those with the pigment may have eyes that range from green to very dark brown, depending upon the amount of Melanin present. Other genes determine the amount to be deposited. People with any shades are pigmented and blue is unpigmented.

Mid-digital Hair Some people have hair on the second, middle, joint of the fingers while others do not. The complete absence of hairs from all fingers is due to a recessive allele (m) and its presence is due to a dominant (M). There seems to be a number of these alleles which determines whether the hair shall grow on 1, 2, 3, or 4 fingers. The hair may be fine you may need a hand lens to check your fingers.

Blood Groups Find out your blood type. There are 4 such types for humans. They are A, B, AB, and O. Type A and B blood can be heterozygous with an (i) allele. Type AB is just as it sounds and O is recessive (ii). The + or – is due to the Rh factor which is another set of genes.

Second finger shorter than the Fourth Hold your fingers together and see if you possess this trait. Many believe this is sex-linked (x-linked). It is dominant in males and recessive in females. Use the symbol S^s for short-fingered alleles and S^L for long alleles.

Population Heredity assignment

As a class, fill in the chart for your own phenotypes and genotypes based on the instructions above. Then on the board add your results to the running totals for our “population”. Make sure you answer each column that is applicable to you. When done with this choose one of the 11 traits of interest. You need to find the same information (Just for that Trait) for a total population of 100 people. Keep a list of the people and their phenotypes. Fill this in on Chart 2 for 100 people. Then Use the Hardy-Weinberg principle, which states the distribution of dominant and recessive alleles in a population remains constant from one generation to the next as long as no external factors affect the population. What would be such external factors?

_____. Using the “HWP” will tell us the frequency of the dominant to recessive alleles in a population. We can compare “expected” data using HWP to our collected population data. How should they compare???

Data Chart class

Trait	Your Phenotype	Your Genotype	Number of each in class
Attached earlobe			
Free earlobes			
Widow's Peak			
No widow's Peak			
Tongue Roller			
No Tongue Roller			
Hitchhikers thumb			
No hitchhikers thumb			
Bent little finger			
Straight little finger			
Long Palmar muscle			
Short Palmar muscle			
Pigmented Iris			
Blue Iris			
PTC taster			
Non Taster			
No hairy fingers			
mid digital hair			
1 finger with hair			
2 fingers with hair			
3 fingers with hair			
4 fingers with hair			
Type O blood			
Type A blood			
Type B blood			
Type AB blood			
2 nd finger shorter than 4 th male			
2 nd finger shorter than 4 th female			
2 nd finger longer than 4 th male			
2 nd finger longer than 4 th female			

Chart 2
Population 100 people

Trait	Number expressing trait
Trait	
Opposite of trait	
Percent of trait	
Percent of opposite	
Possible Genotypes of trait	
Possible Genotypes of opposite traits	

Post Lab

You are required to turn in charts 1 and 2 all filled in with data. You also must turn in a brief explanation of what Hardy-Weinberg is, and what its purpose is, in addition to your HWP calculations. Please make comparisons to the population of this class, 100 and possible results of a theoretical population of 200.

Tracking Traits within families assignment

Choose 2 of the 11 traits below and track them within your family to at least 3 generations (immediate family only). You are the 1st generation and you will work backwards from there. For each person tell name phenotype and possible genotype. The goals of this assignment are to see who gave you some quirky traits and to try to figure out exactly what the genotype of each person is.

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