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USING YEAST TO TEACH GENETICS AND IMPROVE
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USING YEAST TO TEACH GENETICS AND IMPROVE OVERALL COMPETENCY IN HIGH SCHOOL BIOLOGY

By

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ABSTRACT

USING YEAST TO TEACH GENETICS AND IMPROVE OVERALL COMPETENCY IN HIGH SCHOOL BIOLOGY

By

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A 10 week lab-based approach to teaching genetics using yeast was implemented in a 9th grade team-taught biology class. Emphasis was placed on teaching process skills through laboratory instruction with yeast, and using the laboratory experience as a platform for investigating basic Mendelian genetics and modern molecular genetics. Major goals of the unit included improving overall competency in general biology, and genetics in particular. Other goals of the unit were to increase student interest and attitude toward genetics and provide students with experience using sterile technique to culture microorganisms.

Students evaluated each new component in the study by indicating their interest level toward the activity and whether they had learned from it. Students also were asked to provide written comments in these evaluations. An average positive response was given for each new lab, activity, and teaching technique, and written comments confirmed that students enjoyed the new activities and learned from them. In order to evaluate the effectiveness of the unit in increasing student understanding, students were given a two-part pre and post-test. The results showed that the treatment of the new genetics unit significantly improved student scores in areas of both review topics and those topics specifically related to genetics.

I dedicate this thesis to my mother, who always took great pride in my educational achievements. I will never forget your love and support.

ACKNOWLEDGMENTS

The process of teaching and re-teaching this unit has taken place over many years and I have many people to thank for accomplishing an end result. First of all, I would like to thank my students from the past three years for their participation in the development of this new unit. They were a very patient and cooperative group.

My mentors in the Division of Science and Mathematics Education deserve praise for providing a strong program for science teachers. The classes I have taken have been extremely valuable in my teaching career. Special thanks to Merle Heidemann and Kenneth Nadler for their guidance in my research that helped me reach this point.

I also need to thank fellow teachers Dr. Tim Knittle for his expertise and interest in the project, and Jennifer Hatton for her help with collecting the data needed to write this thesis.

Finally, my family and friends deserve special thanks for helping out when I needed time to compile data and write. In particular, I thank my father Don for the many hours of babysitting my daughter Laura, and my wife Carol for her support and understanding during a very busy year.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Background of Curriculum

As a relatively young science teacher, I am always in search of new ideas, techniques, and laboratory exercises for the classes I teach. Although teaching schedules change on a regular basis, I have had the opportunity to teach my preferred subject of biology every year. The nature of the subject matter in biology is both interesting and challenging. More than any other science, biology has changed dramatically since I've been in high school a mere 12 years ago. With the advent of molecular technologies, research in biology has accelerated and given society a whole new perspective on life. I've always enjoyed biology, but the new content I get to teach is most exciting.

The major problem I've encountered in teaching biology is trying to balance the pressures of covering the objectives set forward by the state and local school board with doing what is "natural" in the study of science: asking questions and seeking answers. As a first year teacher with little direction from the school, I scanned our textbook and decided that, other than human biology, most of it should be taught. The text being used was Prentice Hall's Biology (Miller and Levine, 1993). I began teaching in chapter one and proceeded through the text, covering some areas in more detail than others. As the year progressed, I decided to increase the pace in order to finish, but never did. In the next few years, I vowed to develop a timeline and stick to it. However, the nature of science education is to explore topics and ideas, not to race through them to please others. The typical sequence of topics as they were taught in my

high school is shown in Table 1, along with the number of textbook chapters and time I devoted to each topic.

Table 1: Original Sequence of Topics in Freshman Biology

Topics:	No. of Chapters	Time (weeks)
Introduction to Science and Biology	2	3
Ecology	3	3
Basic Chemistry and Biochemistry	2	4
Cells	1	3
Photosynthesis and Respiration	1	2 ½
DNA and Protein Synthesis	1	3
Cell Growth and Division	1	3
Genetics	4	5
Evolution	3	2
Viruses and Monerans	1	1
Protists and Fungi	2	1 ½
Plants	6	3
Animals	11	4

Making Changes:

In my fourth year of teaching, our school hired a new teacher with an extensive background in biology. He earned a Ph.D. from Vanderbilt University studying sodium channels, and had worked in both commercial and university research labs. We shared many ideas and began working together on a regular basis. He shared my frustrations with trying to cover large amounts of material, so I asked him to look at a schedule I made for reorganizing the sequence of topics taught in biology. He thought it had promise, and together we modified the plan.

The basis of the new schedule addresses our belief that what students enjoy most in biology is studying living organisms (plants, animals, etc.). These organisms provide relevance to biology education for the layperson. Interestingly, biology was instituted

as part of the curriculum nearly a century ago to be a science of the people that would prepare citizens and legislators to make good decisions regarding good health and management of resources (Lung, 1999). Biology education began as an integration of three basic life sciences: zoology, botany, and human anatomy and physiology, which made biology relevant to the ordinary person. Today, the biological sciences are expanding so fast we tend to forget the original intent of biology education. My high school biology students tend to lose interest when abstract topics such as biochemistry, cell biology, and genetics are covered. It's not until the end of the year that we get into organismic biology, when student interest seems to pique and there is only limited time to address it. In order to change this, I thought we should focus on some group of living organisms at all times, even when learning the more abstract topics. The idea was to target a separate group of organisms each marking period, and attempt to develop lessons using representatives from the group to study the other topics at hand. The topics in biology were arranged to make this most convenient, as shown in Table 2.

The new arrangement begins the school year with a unit that includes basic classification, introducing students to the diversity of life by learning characteristics and examples of organisms from each of the five kingdoms. Then, each marking period involves studying a specific kingdom or kingdoms of organisms in more detail (1st Plants, 2nd Monerans and Protists, 3rd Fungi, and 4th Animals). As we investigate other topics in the quarter, we try to use organisms from these kingdoms as examples in our discussions and labs. This provides a theme for each quarter of the year and reminds students that they are learning biology. In addition, this approach breaks up some of the more difficult topics, giving students a break and hopefully preventing burnout.

Table 2: New Sequence of Topics in Freshman Biology

Topics for Semester 1:	No. of Chapters	Time (weeks)
Introduction to Biology/Origins of Life/Classification	4	3
Plants	3	2 ½
Ecology (project oriented)	2	3
Chemistry of Life	2	4
Microbes	2	1 ½
Photosynthesis and Respiration	1	2
DNA and Protein Synthesis	1	3
Topics for Semester 2:		
Fungi	1	1
Cell Growth and Division	2	2
Mendelian Genetics	1	3
Modern Genetics	3	3
Evolution	3	3
Cell Structure and Function (a review)	1	3
Animals (comparitive zoology project)	11	4

Statement of problem and rationale for study:

With this new year-long, theme-oriented plan in mind, I had to choose an area to work on for my master's research. I chose genetics for various reasons. According to the plan, fungi would be the organisms of interest as we investigate genetics. Of the four groups, the fungi were definitely the most neglected in our biology curriculum. During a Frontiers workshop (Mendoza, 1998), Leonel Mendoza assured me that this is not unusual, which is discouraging considering the importance of fungi in so many areas of biology. Having little knowledge or experience with fungi, I thought it would be difficult to use them as model organisms for studying anything, genetics included. This seemed to be the most critical part of the plan to work out, and it seemed a summer of research with fungi would be appropriate.

Also, I have been surprised by a lack in student interest in genetics. To me, genetics is one of the most interesting areas of biology to teach. It is the topic that ties the world of molecular biology with the world of the living organisms that students seem to enjoy learning about. I believe understanding the basic concepts of genetics allows students to gain a whole new perspective on life. In addition, for students interested in pursuing a career in the biological sciences, genetics offers opportunity and is important to every field.

I believe my students' lack of interest in genetics has to do with the absence of real lab work. My high school emphasized the use of "dry labs" involving pencil, paper, scissors, coins, dice, construction paper, and Punnett squares. These are merely simulations of something that the students must assume to be real. These exercises do serve a purpose and can be a source of learning, but they do not give students the practical lab experience important to science education. I had been aware of this, but did not have good genetics labs that were practical to implement in my classroom and within my budget.

Ultimately, developing a genetics unit using fungi became my research target. Our textbook seemed satisfactory for providing content, but the laboratory activities did not seem to measure up and they definitely did not involve fungi. In developing new genetics labs, I also wanted to provide students with new challenges. Genetics is taught in the second semester when the freshmen are more acclimated to the high school environment, and should be accomplishing something significant in the lab. I wanted the lab experience to simulate research in a way that requires students to apply biological concepts in their lab work.

Developing the New Unit:

After learning about the GENE project at Kansas State University, I had a starting point for my research. Those folks had developed an entire set of genetics labs using mutant yeast. The written materials, supplies, and yeast strains are currently available from Carolina Biological Supply. After obtaining and surveying the materials, I realized these lab exercises provided a valuable experience absent from our biology program, i.e., culturing microorganisms using sterile technique. This interested me and I began to plan two new units using yeast. The first of these would cover basic Mendelian principles, and the second would cover modern molecular genetics.

The new units were developed with some basic criteria in mind. The new yeast labs would replace the typical "dry" pencil and paper activities we were using with real "wet" lab experiences in genetics. To provide a challenge in the second semester, students would be transitioned from recipe-like lab activities to labs that better simulate real research. This would force students to think scientifically by forming their own hypotheses, designing experiments, collecting and analyzing data, and forming conclusions. To measure the effectiveness of the unit, I would be interested in student performance related to five objectives:

<u>Performance Objectives to be measured:</u>

Objective 1: Raise student interest in genetics.
Objective 2: Improve student competency in genetics.
Objective 3: Refine and improve laboratory skills of students by teaching sterile technique used in culturing microorganisms (yeast).
Objective 4: Get students to think scientifically. Students should form their own hypotheses, design experiments, collect and analyze data, and form conclusions.

*Objective 5: Use the new genetics unit as a review of key concepts previously taught in biology that are important to gaining a deeper understanding of genetics.

The fifth objective grew out of teaching and modifying the units for two years (1997-98, 1998-99). These were developmental years needed to implement the new approach successfully. During this time, I realized that teaching students how to culture yeast also reviewed topics that were taught previously. These review topics included the scientific method, microscopy, ecology, respiration, fermentation, cell growth, mitosis, and meiosis. Before writing the unit, I was convinced it must be taught near the end of the school year to provide the time necessary to build a foundation of biological concepts necessary for understanding the unit. Now I realize that the most valuable aspect of this unit might be that it is a platform for reviewing key biological concepts. In order to test this belief, I designed the pre and post-tests with two major sections, one testing students on previously learned concepts, and the other on topics specifically addressed in the genetics unit.

Review of Pedagogical Literature

According to Hodson (1990), there are three dimensions to an education in science: learning science, learning to do science, and learning about science (Osborne, 1996). Science is not a body of knowledge to be transmitted from one who knows to one who does not know, rather it is a process of creating new knowledge in response to problems that arise with existing models that explain nature (Finkel, 1996). This needs to be reflected in science education, although many educators fail to consider how scientists come to know what they know in their teaching practices (Osborne, 1996).

Furthermore, sociologists see scientific practice as a collaborative activity, and this too must be modeled in the science classroom (Finkel, 1996).

Constructivism

In developing a new genetics unit, I chose to implement a pedagogy that I've had most education and experience in, the constructivist approach to learning. In this model, students construct knowledge by attempting to associate it with what they already know (Lord, 1997). Once a student has "learned" the information, they can then use it to make predictions and explain the information to others. Also known as the conceptual-change model, constructivist learning occurs as students "restructure knowledge and develop their cognitive abilities through the process of progressively changing their conceptual schemes" (Duschl & Gitomer, 1991). Other tenets of this approach are: emphasizing the development of concepts and thinking closely related to student experiences, emphasizing student interaction and application, and appropriate use of coaching and support from the teacher (Dittmer et. al., 1994).

The educational literature on constructivism is enormous and growing rapidly, with most authors having conflicting viewpoints of what constructivism is and how it looks in the classroom (Phillips, 1955). Many of these authors are concerned about constructivism as a philosophy, and through debate leave the practitioner in the field confused (Crowther, 1997). I found it discouraging that most researchers of education seem to spend more time criticizing or defending specific theories and definitions than discussing practical classroom applications. However, according to Gil-Perez and Carrascosa-Alis (1994), most constructivist approaches to teaching seem to involve three basic steps:

1. An elicitation phase of pupils' ideas, making them conscious of the plausibility and fruitfulness of those ideas.
2. A restructuring phase, creating cognitive conflict, generating pupils' dissatisfaction with their current ideas, and preparing them for the introduction of scientific conceptions.
3. An application phase which gives opportunities for using the new conceptions in different contexts and consolidating them.

In addition, they suggest a conceptual change model should organize learning as a treatment of open and interesting problematic situations. Once established, assessment of student knowledge should also follow with a constructivist approach. Evaluation should be a process where students make knowledge claims which are discussed and challenged (Duschl & Gitomer, 1991).

Yager (1991) believes science teachers can move towards constructivist teaching by simply reorganizing their current approaches with new emphases such as: using student questions and ideas to guide lessons, promoting student leadership and collaboration, using open-ended questions, and encouraging students to test their own ideas. Getting student ideas before presenting new ideas helps students to recognize their misconceptions and allows them to build upon what they already know. Students need time to reflect upon and analyze new information, and should be challenged to collect real evidence to support ideas.

I believe the constructivist approach to teaching has merit, and often attempt to approach teaching with this model of student learning in mind. However, knowing how students learn does not make one a good teacher. The reality of teaching is that not all students are there to learn in a meaningful way, which involves connecting and integrating new concepts with what they already understand. Most students prefer rote learning as a method of getting through a class. Rote learning has been defined by

Edmondson and Novak (1993) as "the acquisition of new information without specific association with existing elements in an individual's conceptual structure (i.e., memorization)". The depth of student understanding is ultimately related to their choice of learning strategy (Edmonson & Novak, 1993). This is something over which the educator has only limited control. To overcome this, a successful teaching strategy must organize learning as a treatment of problematic situations that pupils can identify as worth pondering (Wheatley, 1991).

The Importance of Laboratory Instruction

My foremost objective in designing a new genetics unit was for students to be in the lab doing genetics, not just simulating genetics with paper or discussing the topic with words. It has been shown that greater educational gains are possible in approaches that are more student-involved and inductive (Ingelsrud & Leonard, 1988). The "dry labs" of the original approach seemed to fit this description, but did not provide a lab experience.

The laboratory experience is intrinsic in the development of positive student attitudes toward science (Freedman, 1997). Getting students involved in the laboratory would be my first step in improving student attitudes toward the subject matter at hand. Good attitude toward science is directly related to achievement in science knowledge. It has been shown that students who receive regular laboratory instruction score significantly higher on objective examinations and exhibit a better overall attitude toward science (Freedman, 1997). Furthermore, if science teachers desire that their students have positive attitudes toward laboratory work and skills, they must provide them with the opportunities to manipulate equipment and observe experiments in

progress during laboratory activities (Okebukola, 1985). The laboratory gives teachers an opportunity to make students conscious of their learning strategies, and to help them move beyond thinking procedurally toward thinking "like real scientists" (Edmonson and Novak, 1993)

It is important that laboratory investigations be organized properly to accomplish the intended goals. If process skills are to be developed in the laboratory, students must be engaged in hands on, task-related activities (Okebukola, 1985). Most lab manuals do not deal with the process of scientific investigation, having simple tear-out sheets for the students to turn in as "lab reports" (Deutch, 1994). When students perform these "cookbook-like" labs, they may learn scientific facts but not the relevant process skills (Okebukola, 1985). I wanted to tie basic techniques in yeast culturing with genetics in a way that illustrates the process of science.

After two years of teaching a prototype of the new unit, I realized that my observations of student behavior and attitude fit with a study by Fisher, Henderson, and Fraser (1993). They were interested in how different science laboratory environments affect student attitudes and performance, and collected data based on five attributes of the laboratory environment. These are summarized below.

Student Cohesiveness	Extent to which students know, help, and are supportive of one another.
Open-Endedness	Extent to which the laboratory activities emphasize an open-ended, divergent approach to experimentation.
Integration	Extent to which the laboratory activities are integrated with non-laboratory and theory classes.
Rule Clarity	Extent to which behavior in the laboratory is guided by formal rules.

Material Environment	Extent to which the laboratory equipment and materials are adequate.

Of the five laboratory attributes studied, all correlated positively with examination scores except open-endedness. This would seem to be a desirable attribute in lab and would fit with a constructivist approach. However, many students in the study did not wish to diverge from the curriculum when faced with tests in the end. I believe a lot can be learned from open-ended investigations, but I definitely see the students' point. In developing the new unit, a reward system would be necessary for investigations of this type.

The Nature of Genetics

Genetics is one area of biology considered difficult by both teachers and students (Cho, Kahle, & Nordland, 1985). Unlike other topics in biology that can be learned by mastering descriptions of events, students get evaluated in genetics on their ability to problem-solve (Collins and Stewart, 1989). The abstract nature of molecular genetics requires the learner to draw connections between concepts they may not have yet mastered. For example, the importance of understanding meiosis and how it relates to genetics is often absent from instruction in genetics (Cavallo, 1996). Meiosis is often studied independently, and the connection with genetics is not made clear by the teacher or with the students. For this reason, I've attempted to include review and application of concepts important to genetics in this new unit.

Due to the difficulty of understanding genetics, I have tried to sequence topics to maximize student success. According to the constructivist model of learning, students make sense of what we present to them by associating the information with prior

knowledge (Lord, 1994). Students seem to have some prior knowledge in genetics, although it is usually laden with misconceptions. I felt the yeast labs would provide a common experience related to genetics that might facilitate the construction of new knowledge in a large group of students. An experience of this kind would provide a common foundation on which all students could construct their knowledge.

Review of Scientific Literature

The early framework of molecular biology grew out of research using the bacterium *E. coli*, for reasons of simplicity and cost (Flannery, 1997). The use of bacteria had many advantages to the researcher: bacteria grow quickly, are easy to manipulate, and share fundamental biological properties with all other organisms (Botstein and Fink, 1988). However, the biology of eukaryotic cells is significantly different from bacteria. For this reason, a model organism for studying eukaryotic genetics was needed, and the most developed model to date is that of common baker's yeast, *Saccharomyces cerevisiae.*

Yeast offer many advantages to the researcher. Like bacteria, yeast are microorganisms, providing a simple model organism with a small genome that can grow relatively fast. The entire yeast genome of approximately 7000 genes has been mapped, providing a working description of the genes in a eukaryotic cell. Cancer research suggests that the most important cellular controls are so ancient and fundamental to cell functioning that they are common to both human and yeast cells (Flannery, 1997).

Yeast are simple unicellular fungi of the phylum Ascomycetes. They prefer simple sugars as a food source, but can also survive on a reduced carbon source as simple as acetate. Yeast also require a nitrogen source in the form of inorganic compounds such as ammonium sulfate, or organic compounds such as urea and certain amino acids. Like all organisms, they require trace amounts of a variety of salts and certain elements. The only other complex compound they require is the vitamin biotin. (Manney, 1996)

Yeast can grow either aerobically or anaerobically. Under aerobic conditions, yeast use oxygen to completely oxidize their carbon source, usually sugars, into carbon dioxide and water. When deprived of oxygen, yeast will ferment these sugar sources into carbon dioxide and ethanol, recovering significantly less energy. This ethanol has been important to the brewing industry for years, and more recently has been used as a fuel or fuel additive.

Yeast cells divide rapidly through budding when nutrients are abundant (Figure 1). A small bud emerges from the surface of the parent cell and begins to grow. During this time, the DNA is being replicated in the parent cell. The bud will increase in size until it is almost as large as the parent cell. At this point, mitosis will divide the nucleus of the parent cell and one of the nuclei will be transferred into the bud. Finally, the two cells separate. This form of asexual reproduction occurs in both haploid and diploid cells.

The sexual life cycle of baker's yeast is shown in Figure 2. Like other sexual organisms, the life cycle consists of a series of events that alternate between haploid and diploid phases. Through two rounds of nuclear division, the process of meiosis reduces the chromosome number from the diploid to haploid. In yeast, meiosis occurs during

the formation of spores, called sporulation. Diploid yeast cells form spores when environmental conditions become poor for growth. The end result is a single ascus containing four haploid spores.

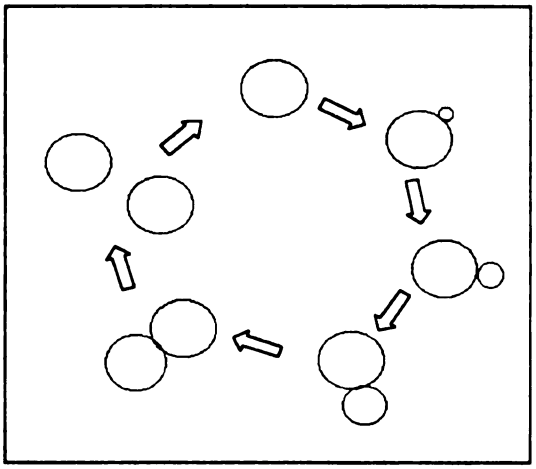

Figure 1: Asexual Cell Division (budding) in *Saccharomyces cerevisiae*

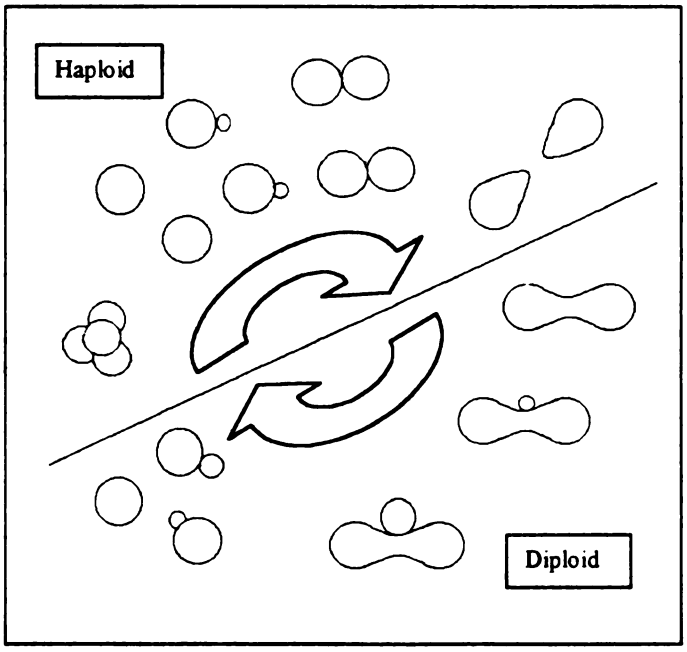

Figure 2: The Sexual Life Cycle of *Saccharomyces cerevisiae*.

When conditions become suitable for growth, haploid spores will germinate into one of two mating types. Sexual reproduction occurs when haploid cells of opposite mating types form schmoos and conjugate. Schmoos are haploid yeast cells getting ready to mate, and are considered the gametes in yeast. They are formed as haploid cells elongate and become pear-shaped. During conjugation, schmoos of opposite mating type fuse together making a single diploid peanut-shaped zygote. The zygotes will grow and divide through budding to produce more diploid cells.

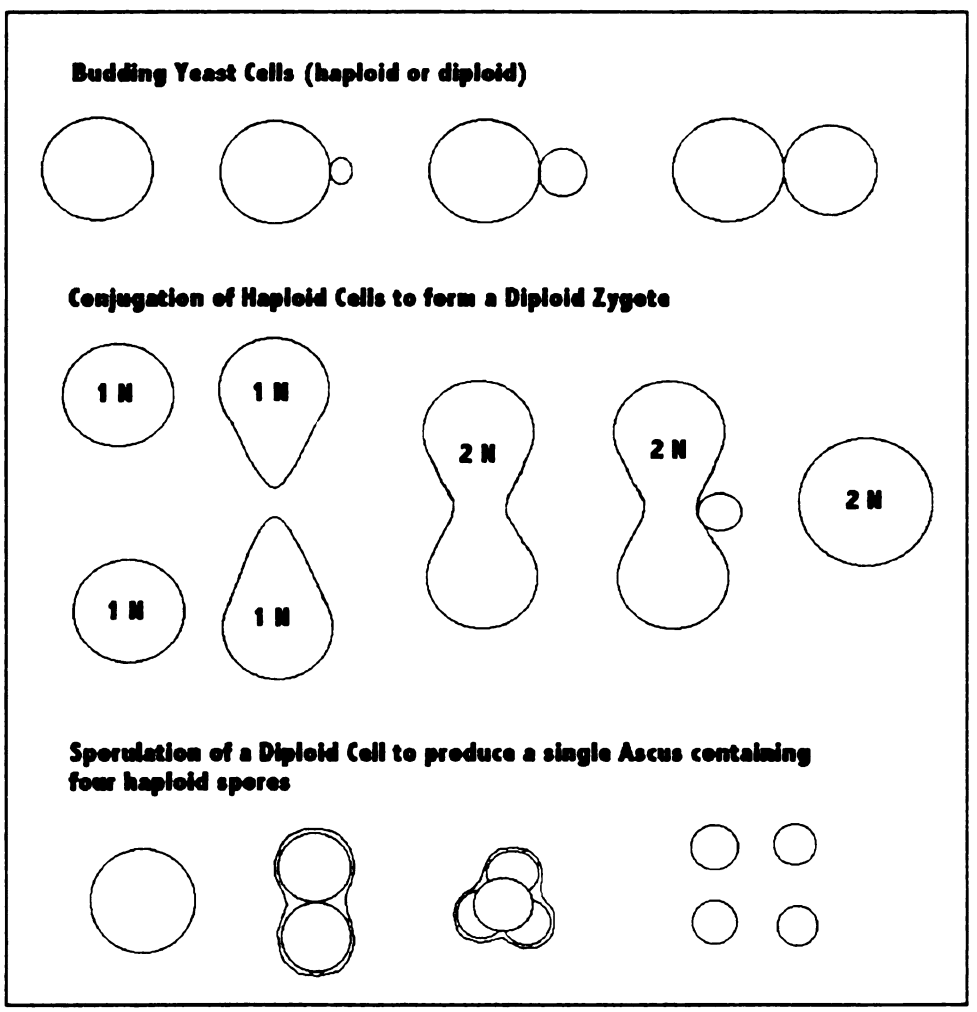

Figure 3: Summary of Morphological Cell Types in Yeast

A summary of morphological shapes in yeast is shown in Figure 3. The first sequence illustrates typical yeast cells budding. The second sequence shows sexual reproduction in yeast, with haploid cells forming schmoos which conjugate to form a diploid zygote. The zygote then divides asexually through budding to produce diploid cells with more typical morphology. The final sequence shows meiosis of a single diploid cell during sporulation. This process produces an ascus containing four haploid spores.

Growing Yeast in the Classroom:

The most helpful resource for learning yeast background and microbiological lab techniques was A Classroom Guide to Yeast Experiments (Manney et al., 1996). This manual documents the essential techniques for successfully culturing yeast in the classroom.

Yeast are easy to grow in the high school classroom. Basic equipment is necessary to culture yeast, but is rather inexpensive. A pressure cooker or autoclave is necessary for sterilizing all equipment and media. Glass pipettes or micropipetters, innoculating loops, and a flame source are necessary for many manipulations. A classroom incubator allows one to complete experiments in a more timely manner. Yeast can be grown at room temperature, but the growth rate can be maximized by incubating at 30°C. All other equipment is basic laboratory glassware and hardware.

Yeast can be grown in suspension or on agar containing dextrose and yeast extract (YED). The recipes for this and other media used in the lab exercises can be found in Appendix A.

Demographics of Classroom

I teach in a rapidly growing suburban district in Michigan that is home to many commuting professionals. The high school population during the 1999-2000 school year was over 2100 students in grades 9-12. The district lacks ethnic diversity, with approximately 98% of the student body being Caucasian. The district is steadily becoming more affluent, as new construction in the area is with higher-end housing. Due to this trend, many couples with older children move into the area, making the high school population disproportionately large.

The study group for this thesis was students from two sections of a Biology-English team that is an alternative regular-education class in these subject areas. This is a relatively new program in a high school that requires all freshmen to take either a regular education biology class or special education life science. The team sections are taught to freshman with both a regular and special education teacher in the classroom. The regular education teacher provides the majority of instruction and delivery of the content, while the special education teacher provides extra support to the students that need it.

On average, team-taught classes number 25 or 26 students with approximately 8-9 special education students. The special education students are selected according to their abilities and work ethic. These are usually hard-working students that are a little slow, or rather bright students that may have organizational difficulties. Although other team students are to be randomly selected from the freshman class, that has not been my experience. At-risk kids are frequently placed in the team, and on occasion, regular education students have been dropped from class lists early in the year due to parent

requests. Although the team classes have a unique make-up, the intent is not to alter instruction, but rather to help students succeed in a regular education setting. I attempt to treat all team students the same, and hold them to the same standards as in the other biology classes I teach.

The Biology and English portions of the team are taught separately, but share a common group of kids. Very few co-curricular activities are planned, but the teachers often meet early in the school year to share experiences with the common group of students. The team-taught curriculum is identical to what is taught to all other freshman biology students. I always ask to teach at least one other regular biology class for comparison and to keep perspective on student progress.

I have been teaching the biology team classes for three years. In general, the biology team appears to be a very typical freshman class. Often students struggle more early in the year, with low homework and test averages. However, with the extra help available to them, they eventually transition into being successful students. Many of the brighter regular education students on the team are willing to offer help, and the team usually shows more camaraderie than seen in my regular biology classes.

So that I could understand the interests of my students, I asked them to fill out the Student Interest Survey (Appendix B). The results were quite interesting, and provided valuable information about the mindset of typical freshmen and their plans for the future. Only 37.5% of the students said they enjoyed school. Although most do plan on going to college (85.4%), very few plan on going into a science-related career. The majority of students said they liked science, but it was generally not their favorite subject. A smaller majority of students said they liked biology, with many of these

students stating that it seemed rather difficult. Results of this survey are summarized in Table 3.

Table 3: Summary of Responses to Student Interest Survey.

Survey Question:	Yes	No	Undecided
Do you enjoy school?	37.5%	22.9%	39.5%
Do you like science?	62.5%	16.7%	20.8%
Do you like biology?	52.1%	27.1%	20.8%
Is science your favorite subject?	22.9%	47.9%	29.2%
Are you taking Geophysical Science next year?	79.2%	20.8%	0.0%
Do you plan on taking more than 2 years of science?	54.2%	27.1%	18.8%
Do you plan on attending college?	85.4%	2.1%	12.5%
Do you plan on going into a science-related career?	14.6%	58.3%	27.1%

It seems that in general students find science interesting for an academic subject, but don't see it being a part of their future. I also think the survey shows that as freshman, students don't have a clear idea about what they want to do. Only a small fraction of students on the team will be taking Chemistry next year, which is the upper track that ultimately leads students toward the more advanced science courses.

IMPLEMENTATION OF UNIT:

Using yeast as an organism of study involved changing my entire approach to teaching genetics. New laboratories, activities, and teaching techniques were incorporated into a plan that not only taught basic genetics, but also provided a review of general biological and scientific principles. The new lab exercises and activities were designed during my research in the summer of 1997. These lessons were first taught as part of two new genetics units during the 1997-98 and 1998-99 school years. The first of these units covered Mendelian genetics and addressed simple dominance, monohybrid and dihybrid crosses, Punnett squares, and probability. The second unit covered modern molecular genetics and involved topics of more recent interest such as the chromosome theory of inheritance, mutagenesis, DNA fingerprinting, cloning, and transgenic organisms. These were developmental years during which many changes were made to the lessons and my approach to teaching them. During the 1999-2000 school year, the improved genetics units were taught and data were collected. Each new component taught in these units addressed objectives set forth in the introduction. A brief description of each new lab exercise, activity, and teaching technique used over these three years follows. Copies of the actual materials used for these exercises can be found in Appendices C-E.

Laboratories Involving Mutant Yeast

The Yeast Life Cycle (Appendix C-I.)

This lab involves a one-factor cross between two mutant strains of yeast and takes yeast cells through their complete life cycle. It requires eight days of lab over

approximately two and a half weeks. In the first day, students innoculate nutrient-rich petri dishes with two mutant strains of haploid yeast. Each strain has an easily recognizable phenotype: one is a typical creamy-white color whereas the other develops pinkish-red colonies. After growing colonies of each type, students mate the yeast by transferring small amounts of each parent colony to the center of the plate using sterile toothpicks. These parent strains are then mixed together and spread thinly over the agar. Students prepare wet-mount slides of the mating mixture to observe the morphological changes that occur to the yeast cells during sexual reproduction. After a few days, students notice a white phenotype in the resultant diploid colonies that grow from the mating mixture. Healthy diploid colonies are then isolated on a new growth medium where the haploids cannot survive. These diploids are placed back on the nutrient-rich agar to stimulate rapid growth, and then placed onto a sporulation medium low in nutrients that causes them to produce haploid spores through meiosis. The spores are then isolated and grown up, and students once again look for the original phenotypes seen in the haploid parent strains.

This lab introduces students to genetics by letting them be geneticists. They cross yeast colonies with different characteristics for a single trait, and analyze the results. Students are introduced to Mendel's principle of dominance (white is dominant over red), as well as basic genetics vocabulary (haploid, diploid, genotype, phenotype, dominant, recessive, mutant).

This lab exercise also provides an opportunity to review many basic concepts in ecology and cell biology. Exponential growth and carrying capacity are reviewed as students see how quickly visible yeast colonies can appear, and then see this growth

come to a stop when the cells in a colony become crowded. Mitosis and meiosis are reviewed through observations of budding and sporulating yeast cells. Students also become more proficient with the microscope through frequent use.

Finally, the lab skills students gain in sterile technique and culturing yeast become valuable in the subsequent labs and when they need to set up their own experiments. This lab does not allow the students to be very creative. It has a recipe-like protocol that students are to follow, but is valuable for establishing basic skills and vocabulary. Students focus on making qualitative observations and predictions, but are not testing their own ideas.

UV Lethality and Mutagenesis Lab (Appendix C-II.)

Students test the effect of ultraviolet radiation on growing yeast colonies. A dilute suspension of red mutant yeast (HA2) prepared by the teacher is pipetted onto petri dishes. Students sterilize glass "hockey-sticks" by flaming them in alcohol and use them to spread the yeast cells evenly over the surface of the agar in each petri dish. Petri dishes are then exposed to UV-C radiation in a standard germicidal goggle cabinet for varying periods of time (0, 15, 30, 45, 60, 75, 90, and 115 second exposures). For this lab, the entire class functions as one large group. Two groups of 2-3 students are assigned to each exposure time, for which they need to collect data. Exposed plates are incubated for two or three days to grow up colonies from the surviving cells. Ideally, control plates (no exposure) should grow 300-500 colonies. Once the plates show visible colonies, students look for the mutation that changes the red mutants back into white mutants. Students count the total number of surviving colonies (red and white) and the total number of mutant colonies (only white). These data are combined for the

entire class, and each student prepares a data table summarizing the results. Students calculate the surviving percent and the percent of mutants in the surviving colonies for each exposure time, and graphically present this information.

This lab work fine-tunes the lab skills of students, while allowing them to collect more quantitative data for analysis. Students must decide how best to organize the data as they prepare a table, and get the practice they desperately need in preparing graphs. The data collected by the class becomes useful in the next lab when students are designing their own experiments.

Photoreactivation Lab (Appendix C-III.)

In this laboratory students use their knowledge and skill to design their own experiment. Students are provided information on a phenomenon known as photoreactivation. When DNA is damaged in yeast cells, a repair mechanism attempts to fix the damage. However, the repair enzyme requires low frequency UV-A radiation. In the previous mutagenesis lab, petri dishes containing irradiated yeast cells were put immediately into the incubator. They were exposed to the fluorescent light in the classroom momentarily, and then stored in an area that gets only reduced light. The task for the student is to design an experiment that will provide data either supporting or refuting the hypothesis of photoreactivation. Students work in groups for this lab and need to write their own procedure that will be incorporated into a formal lab report.

Designing a Controlled Experiment (Appendix C-IV.)

This project involves research. Students working in groups of two to four design a controlled experiment using the yeast strains available in class. They chose from pure cultures of wild baker's yeast, mutant diploid yeast, yeast spores, or the haploid strains HA2 (red) and HBT (white). To help students generate ideas, they were given general

ideas for experiments and a list of variables that could possibly be tested. One possibility was to design an experiment similar to the *UV Lethality and Mutagenesis* lab done as a group. Students were told that this experiment could most likely be improved if we identified the hidden variables in the procedure. Many students were also interested in comparing the effect of UV-C radiation on different types of yeast. Another idea was to test the hypothesis of photoreactivation, which states that UV-A radiation in sunlight helps to repair DNA damage in yeast. A third possibility was to design a growth experiment that compared yeast growth in different environments or compared the growth of two different types of yeast in the same environment.

Students received an outline of parameters (Appendix C-IV.) for the experiments. Each group was to receive six nutrient-rich YED plates and all the usual lab equipment would be provided. Five days of lab time were set aside for completion of experimental setups and data collection. Other that these restrictions, students were limited only by their imagination.

New "Dry-Lab" Activities:

Simulating a Two-Factor Cross (Appendix D-I.)

In this activity, students compare expected outcomes for a cross with an observed outcome generated from a simulation. In the first part of the activity, students review a dihybrid cross in pea plants. They first reason out a parental cross between different purebred varieties of pea plants, and then use a Punnett square to determine what would result from mating heterozygous F_1 plants to produce the F_2 generation. The Punnett square for this cross is analyzed, and students tally the expected genotypic and

phenotypic ratios. This information is used to predict the outcome for a sample of 64 offspring.

In the second part of the activity, students simulate the cross with bingo chips that are labeled for each gene. Each student receives a cup with two bingo chips, one with sides labeled "N" and "n", the other labeled with "Y" and "y". Students pair up and simulate "mating" to produce 64 offspring by tossing their chips onto the table. The data are tallied according to the resulting offspring genotype, and then the experimentally determined phenotypic ratio is determined.

Finally, data from each lab group are reported on the board, and students total the class results. These experimentally determined ratios are then compared to the predicted outcome they worked out in the Punnett squares. This activity introduces students to the idea of probability. It shows quite clearly that the results fit the expected ratios only with a large number of trials. It also reinforces the idea that Punnett squares only provide an expected ratio based on probability.

DNA Fingerprinting Simulation (Appendix D-II.)

This simulation was modified from an activity prepared by Kathie F. Nunley (The Science Teacher, March 1996). I basically used her idea of recording DNA sequences on adding machine tape. However, I had students generate DNA samples that more accurately reflect the composition of our DNA. Rather than having students generate DNA sequences by randomly copying down letters, I gave them all 10 identical gene sequences. They copied these sequences down the side of the adding machine tape. Between each gene, students inserted "junk" DNA by rolling a pair of dice to determine the number of repeated letters between genes. In the end, students had DNA samples

that differed only in the junk DNA. I emphasized that DNA fingerprinting relies on differences in this junk, and that very little variation exists in our functional genes.

The second part of the activity simulated DNA fingerprinting. Students cut their DNA strands in specific locations according to the restriction enzyme described. The fragments were then separated by size, and a fingerprint was made on a paper version of an electrophoresis gel. Students copied fingerprints from three other classmates, and compared these with the fingerprint from the suspect in a crime scenario.

This activity provides a review of basic DNA structure (nucleotide pairing), and gives students more insight on how similar we all are. It is also a platform for discussing basic techniques in genetics, such as the use of PCR to amplify DNA samples, the use of restriction enzymes to cut DNA, and the use of electrophoresis to separate DNA fragments.

New Teaching Techniques:

Lab Notebook (Appendix E-I.)

The idea of maintaining a lab notebook was introduced to students in the second semester of the study year (1999-2000). The purpose of the lab notebook was to have students organize their thoughts and observations from each lab exercise. In the first two years of teaching genetics with yeast, students were given handouts to be filled in for each day of lab. By requiring a lab notebook, students have more responsibility to keep track of progress in the lab and are forced to plan and organize. The notebook format included a title page, table of contents, and entries for each day of lab. These lab entries included a title, objective, procedure, observations, analysis questions to be answered in complete sentences, and a daily progress report. Students first made entries

into the notebook in the unit prior to the yeast life cycle (Cell growth and division). We made the first few entries together as a class to practice the format, and then the entire *Yeast Life Cycle* lab was documented in the notebook by each student.

Note Outlines (Appendix E-II.)

Taking good notes from a lecture is an important part of learning biology. I have never taken a biology class where this was not the case. In teaching high school biology, most teachers have students take notes in a very organized way. All students that take freshman biology at our high school copy class notes from an overhead projector or the markerboard. This seems to help students in many ways. It takes time for students to master the vocabulary, and seeing the terms written out allows them to follow along better. Notes help students to organize the content. The textbook we use is very lengthy, so the notes also help to emphasize what students are responsible for. Many students find it easier to read the book after taking notes.

As a student in NSC 856 during the summer of 1996, I was taught a brief lesson on statistics from Dr. Howard Haggerman. He provided students with an outline of the information to be covered in his lecture. This outline was incomplete, and was to be filled in by students as he lectured. Personally, I found this method of lecturing to be very effective, spending less time writing and more time focusing on the lecture. I had time to personalize my notes with examples that were valuable to me. In the end, the outline provided me with an organized account of the lecture that was easy to study from.

The use of note outlines was applied in teaching several units in freshman biology, including the genetics units. Because note outlines were not developed for every unit,

students were exposed to various ways of taking notes in this biology class. Students were surveyed to help me determine how valuable notes and note outlines are to a high school biology student.

Formal Lab Report (Appendix E-III.)

As a follow-up to the yeast lab *Designing a Controlled Experiment*, students prepared a formal lab report to document the experiment designed by the group according to the format outline in this assignment description. Prior to setting up experiments, students were to develop a hypothesis, and have rough drafts of a materials list and a procedure written out. After setting up the experiments, procedures were revised, and data collected. Students were each responsible for submitting their own copy of the lab report. Data were to be organized into tables. An analysis was to include calculations, graphing, and a written description of what the data show. Finally, students formed conclusions by comparing their result with the hypothesis they had formed, and described sources of possible error and areas of possible improvement.

The purpose of the report was for students to document an experiment they designed from scratch in a professional manner. It also gave students interested in taking chemistry practice in writing lab reports. Students were told that this would be an excellent project to put in their high school portfolios because it meets so many of the high school science objectives.

Developing Units Involving Mutant Yeast:

The yeast-based labs integral to the new genetics units were first incorporated into my teaching during the 1997-98 and 1998-99 school years. During these developmental years, time was spent working out the logistics of running the labs efficiently, making

them practical for freshman that didn't have any experience with microbiological techniques. Timelines had to be established for each set of labs and for each day of lab. An outline of the plan followed during the first two years is shown in Table 4. Due to time constraints, the photoreactivation lab was not taught either year.

Table 4: Outline of Genetics Units during Developmental Years.

Unit:	Time:	New Labs/Activities/Methods
Classical Genetics	4 weeks	1. The Yeast Life Cycle Lab 2. Simulating a Two-Factor Cross 3. Use of Note Outlines
Modern Genetics	4 weeks	1. UV Lethality and Mutagenesis 2. DNA Fingerprinting Simulation 3. Photoreactivation Lab* 4. Use of Note Outlines

During the 1997-98 school year, it was apparent that more small-group instruction would be necessary to teach the lab skills important to the yeast-based genetics labs. Students seemed to really enjoy working with yeast, but their curiosity and lack of discipline interfered with the goal of learning genetics. They were amazed by agar, and wanted to touch and poke it. They did not use care in transferring yeast with sterile toothpicks, and would often gouge the agar. Contamination was a regular problem. They also had the idea that "more is better" and would often transfer mounds of yeast onto fresh plates without spreading them out over the surface of the agar. These large visible quantities of yeast were unable to grow and students would be left with inactive yeast cultures.

To improve these labs for the 1998-99 school year, students were provided with more practice and preparation. Before beginning the first series of labs (*The Yeast Life Cycle*), students were given an opportunity to explore the "mysterious" agar on petri

dishes. Plates of plain agar were available for students to touch, feel, and practice the technique of gently scraping toothpicks across the surface without tearing it. Students were also given the opportunity to learn about contamination by working with plates of nutrient-rich YED agar. These plates were touched and opened to the air. After being incubated, the contaminants that had grown were shown to students. This impressed upon them the importance of sterile techniques.

Small group instruction became a common practice during the 1998-99 school year. To get students started on *The Yeast Life Cycle*, only two or three groups would work in lab at a time. This allowed me to work one-on-one with lab groups while other students used time for completing assignments from the textbook. This greatly improved the consistency of our lab observations. Within a week, most students had mastered the basic techniques and could work independently.

In many ways, implementation of the new genetics units during the 1998-99 school year was successful. Students were interested in doing the labs, became proficient with sterile technique, and obtained good lab results. However, their poor performance on quizzes and tests was disappointing. Students seemed to be lacking the understanding of genetics that I considered important.

After evaluating the year's experience, two major problems needed to be worked out. First, students were not making the connection between *The Yeast Life Cycle* lab and the basic Mendelian genetics as presented in our textbook. This was probably because we were trying to cover too much material in too little time. In trying to juggle both, students became confused about what they would be responsible for. Also, we did not have much time to discuss the lab observations in class. Students seemed to enjoy

time in lab, but really didn't learn much from it. Compared with the amount of time being dedicated to lab, students were held responsible for learning very little. I thought students should be more responsible for learning the content it was intended to deliver. In order to encourage students to be more responsible for learning lab content, *The Yeast Life Cycle* lab should be taught separately from the genetics content in the book, with more time dedicated to preparation and follow-up.

Another problem with the labs was the format for students' work. Students were working with procedures dictated to them, and they followed these procedures closely without understanding their purpose. Students were expected to preview the labs ahead of time, but very few did. This reduced lab time to simply following step-by-step procedures from my handouts in order to accomplish the day's work. Students simply recorded their observations in the handouts for each day of lab. These daily handouts had places to draw and record petri dish and microscopic observations. They also contained daily analysis questions that were to be completed by each student. This approach did not seem to help students understand what was happening in lab. Students should have spent more time preparing for lab and organizing observations for themselves. Before teaching this unit for a third year, I decided major changes in its format were necessary.

The most significant change in teaching genetics during the 1999-2000 school year would be increasing the responsibility of each student in preparing for lab and understanding the results. Replacing daily lab handouts with the lab notebook appeared to improve student comprehension of *The Yeast Life Cycle* lab. Maintaining the lab notebook was a lot of work for the students, but they were willing to do it because it

was the basis for the third quarter project grade. Projects in biology are equivalent to a test grade, so most students take them seriously. In addition, a considerable amount of classtime was available for working in the notebook during small group instruction or on days where only 15-20 minutes of lab work were necessary.

Basic Outline of Improved Genetics-Related Units:

The final version of the new genetics unit was taught during the 1999-2000 school year. It ultimately became a hybrid, combining material and activities from our textbook and previous years of teaching with labs, activities, and techniques derived from my research. To implement the lab-based approach more successfully, I devoted more time to it. *The Yeast Life Cycle* lab became its own mini-unit with notes, labs, quizzes and a full test. In addition, students were responsible for keeping all lab observations and analyses organized in a lab notebook according to a standard format. I felt it was important for students to master this material to insure success in future yeast labs. Other labs and activities were incorporated into the general plan shown in Table 5:

Table 5: Revised Timetable for New Genetics-Related Units.

Unit:	Time:	New Labs/Activities/Methods
Yeast Life Cycle	2 ½ weeks	1. The Yeast Life Cycle Lab 2. Lab Notebook
Classical Genetics	2 ½ weeks	1. Simulating a Two-Factor Cross 2. Use of Note Outlines
Modern Genetics	3 weeks	1. UV Lethality and Mutagenesis 2. DNA Fingerprinting Simulation 3. Use of Note Outlines
Project: Designing a Controlled Experiment	2 weeks	1. Designing a Controlled Experiment* 2. Formal Lab Report

The Yeast Life Cycle lab sequence was presented separately from the genetics in our textbook. This was a major difference between implementation during the previous two years. Students spent 2 ½ weeks working through the lab procedures (Appendix C-I.) and maintaining lab notebooks (Appendix E-I.). They also took notes from our discussion of the lab techniques and the yeast life-cycle (Appendix G). This lab became an introduction to genetics and served as a common experience for all students when studying Mendelian genetics from the book. A summary of the schedule used for this lab can be found in Appendix H.

When finished, students were tested on *The Yeast Life Cycle* lab before going on to a more traditional approach to learning (and reviewing) basic Mendelian genetics. This unit on genetics was similar to units taught in the past, using "dry" lab activities to teach the basics principles of genetics, including *Simulating a Two-Factor Cross*. Students worked through story problems using Punnett squares to work out results of one and two-factor crosses. We also covered probability and analysis of genetic data. The major difference in teaching this material was the fact that we had already done basic genetics in *The Yeast Life Cycle* lab. Students compared what we had done with yeast to what Mendel had done with his pea plants. The lab experience gave students something to relate to, rather that just learning what someone else had done. We also made use of note outlines (Appendix E-II.) during lectures over this material, which reduced lecture time because students were doing less writing. We saved about one week of instructional time by using note outlines and eliminating dry labs that addressed concepts learned in yeast labs.

In teaching modern genetics, I combined material from three different chapters in our textbook, along with topics of recent popular interest. Topics taught included the chromosome theory of inheritance, gene linkage, gene mapping, sex linkage, mutations and mutagenesis, gene interactions, the human genome project, cloning, and DNA fingerprinting. We continued using note outlines (Appendix E-III.) to guide our discussions, and did the *DNA Fingerprinting Simulation* (Appendix D-II.) and the *UV Lethality and Mutagenesis* lab (Appendix C-II).

The final project for the 1999-2000 school year was *Designing a Controlled Experiment*. Initially, I had planned on having all students design a Photoreactivation experiment, something described in A Classroom Guide to Yeast Experiments (Manney et al., 1996) However, I decided to have students do something more creative. Many students enjoyed the *UV Lethality and Mutagenesis* lab, and there were many questions asked about altering the procedure. As a class, we generated a list of interesting ideas for experiments involving radiation exposures and various types of yeast (Appendix I). Some students chose to try the photoreactivation experiment, while others wanted to test the growth rate of yeast in different environments. This activity put all responsibility on the students to do their own independent thinking in order to design a good experiment, with the instructor acting only as a resource person and "trouble-shooter".

After two days of brainstorming ideas, students had a third day to submit a research proposal (Appendix C-IV.). Once the research proposals were approved, groups worked on the logistics of their experiments. Lab time was scheduled for each group over five days. I worked with small groups of students doing similar experiments,

helping to teach them new techniques such as the use of innoculating loops, using micropipettes, and doing serial dilutions. Once data were collected, students were responsible for typing up a formal lab report on their experience (Appendix E-III.). A summary of student research from this project can be found in Appendix I.

Although running labs for these experiments was a lot of work, it was one of the more rewarding things I've ever done in my teaching career. At times I thought that all science classes should be run in this way, with students doing research. However, the success of these research projects probably had a lot to do with what preceded it: proper training.

EVALUATION OF NEW LABS, ACTIVITIES, AND TECHNIQUES

Two primary methods of evaluating the new genetics units were used. These involved getting student impressions of each new activity through activity assessments (Appendix J), and pre- and post-testing to evaluate the effectiveness of the unit in teaching new content and reviewing previously learned concepts (Appendix K). Students and parents were informed of the data I would be collecting, and that these evaluations and assessments had no effect on their grade for the class. Forty-nine students returned permission slips (Appendix L) with parent signatures, agreeing to be part of the study. Three students returned the letter denying permission to use their data, which would not have significantly altered the results.

One goal of the new unit was to increase student interest in genetics. To measure this, students filled out activity assessments (Appendix J) following each new lab or activity indicating their interest level and perception of its effectiveness. In this assessment, students ranked four statements from 1-5 based on how much they agreed or disagreed with the statement. The rubric for these assessments is shown below.

Rubric for responding to statements:

5 agree very much
4 agree
3 neither agree or disagree
2 disagree
1 disagree very much

The results of each survey were averaged for each statement. Students showed an average positive response for every new activity taught in this unit. The average

responses are shown below along with a summary of student impressions and personal observations.

The Yeast Life Cycle (n=48):

I found this activity both interesting and fun.	3.94
The activity taught me a new concept or skill.	4.16
The activity helped reinforce the concepts being taught in class.	4.06
I recommend this activity be taught in the future.	4.20

When asked what they liked most about this activity, answers were varied. Many liked the idea of doing lab work on a more regular basis and dedicating lecture time to something that was more applied. Others enjoyed using the microscope, watching yeast grow, learning more about yeast, transferring yeast between different media, looking at contaminants, and working in groups. Some students felt the lab activities were repetitive and lost interest. However, most negative comments about this lab were regarding the lab notebook. They seemed to enjoy the lab, but not the work associated with it.

> What did you like most about the activity?
> "It was cool because I liked looking through the microscopes and seeing the cells. I felt like a real scientist!"
>
> "I thought it was interesting to learn about yeast. I didn't really care much at first, but now I find it pretty interesting. I didn't realize the life cycle of yeast cells could be so complex."
>
> "I liked getting to work with the yeast and doing my own experiments, rather than reading about some dead guy who did the same thing."
>
> "The thing that I liked most about this activity is that you could work with other people, so that they could help you and you could help them and learning more about yeast."
>
> "Observing the changes in my yeast cells day by day and how different types of yeast agar had different effects."

"I liked seeing the yeast grow so fast."

"I liked seeing the yeast colonies get bigger every day and looking at them under the microscope."

"Hands-on work makes it easier to remember the skills."

"It was good to work in a group. I learned a lot from it."

"I liked using the microscope because it gave me practice. Before I couldn't find anything under it but now I can. This activity also gave me a chance to work with 2 other people as a group."

"I liked the hands-on experiment part. How we actually got to do things."

"looking in the microscope."

"the transferring of yeast from different agar types."

"I liked learning about the yeast life cycle, growing habits, etc."

"I learned how to keep good notes to keep organized and how to do things on the agar and how you had to be careful."

<u>What did you like least about the activity?</u>
"All the analysis questions to go with it."

"having to keep detailed records of our experiences, procedures used and analyzing questions."

"the writing you had to write a lot."

"Not being able to fill in the labs in the packet and having to do everything by hand."

"Well the analysis was the part I liked the least, but we might not understand it as well if it was gone."

"Writing all the stuff down."

Lab Notebook (n=47):

I found this activity both interesting and fun.	3.30
The activity taught me a new concept or skill.	3.76
The activity helped reinforce the concepts being taught in class.	4.00
I recommend this activity be taught in the future.	3.71

The lab notebook received the lowest positive response of any new activity. This was expected because of the time and effort on the students' part. It was a big part of their grade, and many students who received low scores wrote negative remarks. The highest score on the lab notebook (4.00) was for reinforcing concepts taught in class. I think many students realized that although they did not necessarily enjoy keeping a lab notebook, it was a good learning tool. Many of the other student comments admitted that it did keep them organized and prepared for lab, as well as helping to increase comprehension of the material. In addition, the notebook forced students to be more observant. They knew observations would be a big part of the grade, and students became better at describing what they saw and labeling their sketches in detail. Although there is no data relating the lab notebook to performance, I am convinced that it made a significant difference in student test scores.

What did you like most about this activity?

"Observing my yeast cells daily and noticing changes."

"...writing down directions so I didn't get confused and forgot some parts."

"Looking and understanding the yeast and writing out what I saw."

"Being organized and learning how to be more detailizing."

"I liked how it was easy to do. You gave us a specific way to put in info."

"Having the information organized and all together."

"It helped me stay organized."

"It was easy to keep my data in a notebook."

"It let me keep track of my lab info."

What did you like least about this activity?
"The fact that I got an 58%."

"All the procedures to write down."

"Writing so much."

"Not being able to write in the packets and copying out all of the procedures into my notebook."

"Having to follow the pattern and be organized."

"all of the writing we had to do."

One student made a suggestion on this assessment that was quite interesting. "At the end your could have everyone do their own experiments for fun, just to see what comes up. To use everything we learned." Ironically, this was the same idea I had after two years of working with yeast.

Simulating a Two-Factor Cross (n=46):

I found this activity both interesting and fun.	4.02
The activity taught me a new concept or skill.	3.85
The activity helped reinforce the concepts being taught in class.	4.10
I recommend this activity be taught in the future.	4.20

This activity provided a good introduction to probability. Students had mastered the punnett square; and this activity helped them to realize the significance of the ratios they love to work out. Most students enjoyed it because it was hands-on and quite simple. Most of the negative comments were due to the repetition required in collecting data. However, I think most students realized that the repetition was a key component of the lesson.

What did you like most about this activity?
"It made me better understand how they cross and why they look the way they do."

"I thought it was interesting to see how the process is so random."

"Once we started, it made a lot of sense. It was easy."

"It was hands on and it proved what we were talking about."

"It was fun."

"It visually shows possible outcomes."

"I like how it was set up kind of like a game."

"It was not complicated and was easy to understand."

What did you like least about the activity?
"The fact that we had to do it 64 times."

"It was sort of boring doing that over and over. If that is the only way to find the offspring, then it's fine."

"It got boring when you kept dumping bingo chips on the table."

"The big punnett squares were hard to find genotypic ratios."

"I had to think."

UV Lethality and Mutagenesis Lab (n=48):

I found this activity both interesting and fun.	4.06
The activity taught me a new concept or skill.	4.02
The activity helped reinforce the concepts being taught in class.	4.13
I recommend this activity be taught in the future.	4.31

Students enjoyed this lab. They felt like they were doing something rather technical, and that made them feel good. Sterilizing hockey sticks was a hit, as well as working with radiation to produce mutant yeast. Most negative comments were related to the work necessary to analyze the results (surprise, surprise).

What did you like most about the activity?
"We got to make mutant yeast!"

"U.V. exposure on the yeast."

"Using the goggle cabinet and the sterilization of the glass hockey sticks."

"I liked when we got to stick that hockey stick thingy in the fire."

"I thought it was cool when we sterilized the yeast spreader."

"Lighting the glass hockey sticks on fire."

"We got to work with new concepts. Lighting the alcohol to sterilize it."

"Exposing the yeast to radiation."

"It was fun and we could play with radiation and fire."

What did you like least about the activity?
"I liked this activity a lot, but I guess counting the mutant cells."

"The graphing because it took a while but it was worth it."

"Counting all the cells."

"We didn't do the activity very long it was short."

DNA Fingerprinting Simulation (n=49):

I found this activity both interesting and fun.	4.21
The activity taught me a new concept or skill.	4.27
The activity helped reinforce the concepts being taught in class.	4.31
I recommend this activity be taught in the future.	4.29

Like most dry-labs, students seem to like the fact that this was hands-on. This simulation may be the most popular "dry-lab" I've ever taught, having received the highest average response of any new part of the genetics units. Most students have heard about DNA fingerprinting, but really have no idea how it is done. Not

surprisingly, most negative comments related to the repetition and work necessary to get the end result.

What did you like most about the activity?
"It was just fun to do it because it involved DNA and other people's DNA."

"It was fun and interesting and I enjoyed comparing my DNA sequences with my friends."

"That it visually showed this concept."

"I liked seeing who was the closest to the criminal."

"Taking DNA fingerprinting one step at a time."

"It was almost like the real thing and I wondered how they do that."

"It helped me understand more about the concept, and what I was doing."

What did you like least about the activity?
"Copying the long chain of DNA on adding paper."

"The amount of time it took to get all these results."

"How long the DNA strands had to be."

"Copying all the letters over and over again."

Designing a Controlled Experiment (n=47):

I found this activity both interesting and fun.	4.06
The activity taught me a new concept or skill.	4.02
The activity helped reinforce the concepts being taught in class.	3.98
I recommend this activity be taught in the future.	4.23

Students seemed to enjoy the freedom of designing their own labs, as well as having more time in the lab. The most difficult part for most groups was getting started. Many negative remarks related to needing more time or wanting to do more trials. Some students also disliked any work (writing) associated with the activity.

What did you like most about the activity?
"We were able to create an experiment on our own."

"I liked that we got to design our own experiment on what we wanted to do."

"My partner and I got to be in charge of what we were doing."

"I liked making the plates up."

"Getting to plan our own experiment."

"I liked how we were in control of the experiment and we decided what to do and how to do it."

"Having some choices and being able to be creative."

"Doing the experiment ourselves it helped me more on my creative, and descriptive skill."

"The independence we are given."

"The freedom of design we got, it wasn't defined too much."

What did you like least about the activity?
"We could only try once."

"I wish we started a few weeks earlier and had time to develop a better project."

"Coming up with the experiment."

"Writing clear procedures."

Formal Lab Report (n=48):

I found this activity both interesting and fun.	3.96
The activity taught me a new concept or skill.	4.12
The activity helped reinforce the concepts being taught in class.	4.08
I recommend this activity be taught in the future.	4.31

I was surprised that responses were as high as they were for this activity, which most students saw as "work" needed to get credit for their time in lab. They may have equated this assessment with designing the experiments. Many students did enjoy the

fact that this project seemed like less "work" than other projects I've assigned this year. Other student responses were quite varied. The negative comments should not surprise you.

> What did you like most about the activity?
> "I understood what I did in lab better because I had a chance to write it out and look over my info."
>
> "I liked to put raw data into more usable information."
>
> "Being able to have the teacher correct it before its due."
>
> "It was very independent, we got to choose what we wanted to do. Not what the teacher told us to do."
>
> "This was our own experiment we were writing about."
>
> "I liked that we were allowed to work in groups for the experiment and on the procedure, but we all had to work on our own to finish up the project. I liked this because this practiced group skills, but then everyone had to carry their own weight too. I also liked how we got to pick our group."
>
> "This was our experiment."
>
> What did you like least about the activity?
> "Doing the graphs."
>
> "I did not like writing the whole lab out."
>
> "All of the typing."

Taking Notes (n=49):

Students completed a separate survey on taking notes in biology. They responded to each of the statements in Table 6 using the same rubric from the activity assessments. Average responses are also summarized in Table 6.

Overall, students strongly agreed with every statement in this survey. Students often complain about taking notes, and every year I try different methods of making note-taking more relevant. Most students feel that taking notes from lectures helps

Table 6: Average Student Responses on Note-Taking Survey

Taking notes in biology helps me to understand the concepts in the book.	4.30
The notes we take in class are helpful in studying for tests.	4.51
Taking notes on a prepared outline is easier than on notebook paper.	4.57
The notes taken on outlines are more accurate than notes taken by myself on notebook paper.	4.36
Taking notes on an outline allows me to listen more carefully to the lecture.	4.12
Taking notes on an outline allows me more time to ask questions.	4.22
Taking notes on an outline allows me to get more understanding from the lecture.	4.12
I recommend that you use note outlines in the future.	4.48

tremendously in learning the material, and they are big fans of using the note outlines. This survey shows that students feel this approach helps them to learn more from lecture. Students were asked to write one comment regarding note-taking in biology. A summary of these comments is presented below.

Positive Comments:

"Taking notes on the outline form is a lot easier than having to take notes its easier to listen and pay attention. And much easier to study for my test."

"It's easier to use the 'fill in the blank' outlines because I find when I'm studying at home for a test, its easier to find information from the outline than helplessly searching in the book. The notebook paper notes are very frustrating. I can't keep up when I'm writing so it's hard to get it all down."

"Note taking is easier to understand when it's done on an outline, important information is often bulleted or italicized to make studying easier."

"I think that when we take notes on a plain piece of paper we lose lecture time."

"I think note-taking helps greatly to understand the information given in class."

"It is way better using an outline than taking my own notes because I know what I'm studying is the correct information."

"I like the outline because it gives me more time to think."

"The outlines are sooo much easier. On paper, I never know what to write down. Outlines only, please."

"I study most from notes and it enforces what we read."

"Notes are very helpful for studying. DO NOT GET RID OF THEM!"

"I think notetaking helps me study more for tests than the book helps me study."

"I like them because I can listen to you talk more so I get a better understanding."

"I remember long note-taking in 5th grade. We were always writing. I hated it. I couldn't get all of the stuff because she was going so fast. I like this better because I have time to learn what I am writing."

"Outline notes take less time and I can listen more than write."

Negative Comments:
"I understand more when we take notes on notebook paper."

"I learn what I am writing when I use notebook paper, but half of the time I don't write them down. I get behind."

"I like the notes where we write them out because writing helps to remember. Filling them out is easier and it doesn't take much time to get the same point across."

In summary, the activity assessments provided useful information that will help in modifying this unit further. Most students were very cooperative in filling these out and took time to provide valuable written comments.

EVALUATION OF EFFECTIVENESS OF UNIT

Pre-tests and post-tests (Appendix S) were given to determine the effectiveness the new genetics units. These tests consisted of short answer questions that required a one or two sentence response. Due to the length of the tests, they were administered over a two-day period. The tests did not count toward their grade, but students were given homework credit for responding to the majority of the questions. These tests were scored according to the following rubric:

Scoring Rubric for Genetics Pre/Post Test:

0 No response, or response is inaccurate and irrelevant.

1 Response may include information that relates to the question, but does not provide an answer to the question.

2 Response answers only a portion of the question and/or lacks accuracy and clarity.

3 Response is mostly accurate or answers a majority of the question without detail. Needs clarification.

4 Response provides a complete and accurate answer to the question without detail or the use of examples.

5 Response provides a clear, complete, and detailed answer to the question, using examples when appropriate.

A comparison of pre-test and post-test results for each student (n=49) is found in Appendices M and N, and summarized in Tables 7 and 8. The average gain on the review topics was 32.9% with a standard deviation of 9.7. The average gain on the genetics topics was 39.2% with a standard deviation of 15.3. In order to determine if these differences were significant, I ran a student t-test for each set of data. The null hypothesis would predict that the average gains on each test would be close to zero.

The resulting t with >40 df for the review topics was 23.78. The resulting t with >40 df for the genetics topics was 17.97. The null hypothesis is rejected at the 0.001 significance level for both sets of scores. Therefore, the new units taught not only had a positive impact on student learning in genetics, but in related biology topics as well.

Table 7: Summary of Pretest and Posttest Data from Review Topics:

	Pretest	Posttest	Gain
High Score	55.6	95.6	51.1
Low Score	14.4	31.1	11.1
Mean Score	34.0	66.8	32.9
Median Score	33.3	64.4	35.6
Mode Score	41.1	60.0	37.8
Standard Deviation	10.5	15.2	9.68

Table 8: Summary of Pretest and Posttest Data from Genetics Topics:

	Pretest	Posttest	Gain
High Score	52.0	92.0	75.0
Low Score	0.00	17.0	8.00
Mean Score	20.9	60.2	39.2
Median Score	21.0	61.0	39.0
Mode Score	24.0	55.0	37.0
Standard Deviation	9.39	18.7	15.3

DISCUSSION AND CONCLUSION

Addressing the Problem:

The problem identified in the introduction had many layers. First was the need to restructure the sequence of topics taught in biology so that they could be finished successfully within one school year. In addition, I wanted students to focus on a single group of organisms each quarter to create a more thematic approach to teaching and learning biology. Given this, I developed a new approach to teaching genetics using "wet" labs with yeast that were more process-oriented and investigative. The study was based on using the mutant yeast developed through the GENE project at Kansas State University (now available through Carolina Biological Supply).

The design of the new genetics unit met the criteria set forth in the introduction. Students have done more labwork in genetics than ever before. In addition, the labwork was investigative in nature compared to the cookbook-style labs students do in the first semester. Students felt like researchers working in lab on a long-term project. I believe these long-term labs force students to think more than when they engage in a one-hour activity where they could easily go through the motions and be done for the day. Students understood that what they did in class today would affect weeks of labwork. The lab notebook forced students to plan for each day of lab and made them think about the observations being made. In addition, because *The Yeast Life Cycle* was treated as its own unit, students knew that every part of the lab was to be mastered for a test. Ultimately, I believe the yeast labs were key to the development of students' understanding of basic genetics.

Fungi are no longer neglected in the biology curriculum. In years prior to implementing the new approach, we may have dealt with fungi for one or two days. Now, students talk about yeast all the time, and have the opportunity to observe molds and other fungi that contaminate their plates. Students took it upon themselves to prepare wet-mount slides of these contaminants and saw the filaments that characterize most other fungi. The fact that students did these extra activities reflects their interest toward labwork. In working with yeast, students learned a lot of interesting things about an organism they had heard of, but knew very little about. They learned the importance of these microorganisms to humans both scientifically and economically.

Meeting the Objectives:

In the introduction, I listed five performance objectives to be tested. The biggest challenge of this unit was getting students to become proficient with sterile technique in a large group setting. The other challenge was to have students learn genetics from these experiences. The unit was taught and modified for two years before I felt it was effective in meeting the five objectives. In the third year, students exceeded my expectations for each objective. A review of these objectives follows.

Objective 1: Raise student interest in genetics.

The interest surveys for each lab activity showed that in general, students enjoyed the new activities and labs that were part of this unit. Although I have no data for years prior to teaching a lab-based genetics unit, I strongly believe that I have accomplished this objective. The yeast labs provided students with an experience they'll never forget. Students had fun. They talked about the yeast as if it were their pet. Many students

would check on their yeast cultures the moment they entered the classroom. Some students even wrote poems about yeast that are now framed and displayed in my classroom. They told their friends about the labs and who then came in after school to help prepare media and pour plates. I have never seen enthusiasm of this nature in my freshman biology classes.

Objective 2: Improve student competency in genetics.

A comparison of pre-test and post-test results in genetics clearly shows that this was accomplished. On average, students increased their performance on the test by nearly 40% in areas related to genetics. On the pre-test, students seemed to recognize some of the material, but couldn't formulate accurate answers. In addition, it was evident that students had many misconceptions concerning genetics. Answers that were somewhat accurate were often lacking clarity or examples. On the post-test, students often relied on their experiences from the yeast-based labs. I believe these labs provided students with examples to be remembered for a long time. Having the experience of actually *doing* genetics should help retention of the material as opposed to learning content through rote memorization and simulations.

Objective 3: Refine and improve laboratory skills of students by teaching sterile technique used in culturing microorganisms (yeast).

The success students had in carrying out lab procedures and collecting data demonstrates that they met this objective. It was obvious that they came to understand how easily contamination could occur. On lab days, students often compared plates between groups and took pride in good technique. Occasionally, students would joke about having a "yeast infection". Students came to the conclusion that bacterial infections, when isolated, did not usually interfere with their work. However, mold

contamination could be devastating. Seeing an occasional mold provided a great review of fungi. Students were reminded that most fungi grow filaments, which are capable of growing across the surface of the agar, unlike the unicellular yeast and bacterial colonies.

Objective 4: Get students to think in a scientific manner.

This objective was most clearly illustrated in the lab activity *Designing a Controlled Experiment* and in the lab reports students generated based on this experience. By developing their own experiments, students had to think and work like a scientist. After brainstorming with their partners, students developed a hypothesis and submitted research proposals that were sound. Most of the research proposals were denied on the first attempt, usually for lack of detail and the inclusion of more than one variable. They learned that experiments must be simple *in design*, but are not necessarily simple *to design*. Although most groups experienced success with their experiments, it was easy for them to identify flaws in their experimental design. They realized that it is hard to control variables when working with living organisms. I believe these experiences clearly demonstrate scientific thinking.

Objective 5: Increase overall competency in other areas of biology.

This objective became the one I was most interested in. It seemed that improving student success in the labs and in genetics involved reviewing a lot of basic ideas in biology. On average, students increased their performance on the review portion of the post-test by over 32%. I think the genetics unit provided a format where students could apply the information they learned in previous units. They realized the importance of these concepts in doing applied labwork, and how they helped to explain observations

being made in lab. Students became more confident working in lab because they really began to understand the organism they were working with. This allowed them to focus more on learning from these laboratory experiences.

Personal Impressions of Student Learning through the Lab-Based Approach

During this study, I was able to make observations that are not reflected in the data. In the first few days of working with yeast, students did not seem all that interested. To them, yeast were boring in comparison with plants and the other microbes we had already studied. When students first saw them under the microscope, they were not very impressed. Yeast didn't look interesting or seem to do much of anything. Students probably wondered why I was so excited about working with these organisms.

Within the first week of doing yeast labs, most students began to share my enthusiasm. They began wondering about the "stuff" growing on the plates, and were amazed at how fast it could grow. It wasn't long before the majority of students experienced some form of contamination on their plates. I could see them really thinking about how the contamination might have occurred. Students began to take real ownership in their work. They would come into class and immediately go to the incubator to check their cultures, whether we were doing lab work that day or not.

In general, students reflected this positive attitude in all activity assessments. Although most students gave high ratings to the yeast labs, there were a handful of students that disliked them. Most of the negative comments in these assessments stemmed from the work associated with the labs. Many students did not enjoy follow-up exercises to the yeast labs, such as the lab notebook, the graphing and analysis, or the

formal lab report. Once these students realized how much work it was to complete the lab and receive credit, they complained about the work. I took these complaints as a sign that the new approach was working. The biggest problem in previous years was student comprehension of the concepts demonstrated in the lab. Students probably had more fun during these years because it was more of a break from doing a lot of "work" (the student definition of work being something that involves time, writing, or thinking). I had hoped students would get a deeper understanding of genetics through the lab during these two years, but I didn't make them as responsible for learning the details of the lab. Students during the 1999-2000 school year had more mixed impressions. In general, they thought it was fun and interesting, but also realized it was a lot of work. To some students, anything involving work cannot possibly be fun. There were a handful of students that felt this way, and they were upset about low grades on the lab notebook and formal lab reports. As an educator, I believe it is impossible to please everyone, and high standards for achievement must be set in order for all students to learn and be challenged.

My experiences show that students need direction in the lab if there is specific content to be addressed. In the 1997-1999 school years, I took an open-ended approach to *The Yeast Life-Cycle* lab. I wanted students to explore their interests and experience genetics through a more investigative approach during our time in lab. Procedurally, the lab was not open-ended. However, without classtime to discuss results, it was largely up to the student to construct the meaning and draw the appropriate relationships with the Mendelian principles being tackled in the book. The problem with this approach was that students realized the content emphasized on the test was in the book,

and they began to view the lab as just "fun-time". I think they learned a lot about culturing microorganisms these two years, but gained less in their understanding of genetics.

Personally, I believe students must first understand basic concepts and skills for open-ended investigations to work, and that specific criteria need to be set for investigations. A strong scoring rubric is necessary to distribute grades in a fair manner. In order to have students invest their efforts in an open-ended investigation, I coupled the lab *Designing a Controlled Experiment* with writing a formal lab report. This way, students had freedom to explore their interests, but there was a common end result expected from each student. Just like *The Yeast Life Cycle* lab, I felt *Designing a Controlled Experiment* taught students valuable skills that were absent from our curriculum.

Looking at the progression of the three yeast labs taught, I think signs of a constructivist approach are evident. In the high school, time is not a luxury. I believe it is unrealistic to expect students to "discover" concepts through inquiry and expect them all to reach the same end result. However, I think the sequencing of the yeast labs reflected a constructivist approach as a whole. In the yeast life cycle lab, students were directed through predetermined procedures with the expectation of learning very specific content and developing certain skills. This lab relied on a lot of modeling from the teacher.

With *UV Lethality and Mutagenesis*, students were provided less direction. As a class, we designed the experimental setup and assigned data to be collected by each student. The expectation was that students already knew the basic techniques about

growing yeast. As a teacher, I was coaching more during this time and becoming a resource person. In the follow up to this activity, questions were more open-ended, and required basic application of laboratory principles. Although there were no correct answers, students were expected to justify their responses with concrete observations from the lab. In addition, students practiced analyzing quantitative data, something that is not a common practice in freshman biology. Students did simple calculations and graphing to represent their lab data.

Finally, in *Designing a Controlled Experiment* students used what they learned about culturing yeast and collecting and analyzing quantitative data to embark on their own investigations. Students applied concepts to construct new meaning as an extension of what they had learned. Students used me as a resource to design good experiments, but I let them carry out the experiments for themselves. In the end, I learned as much from their experimentation as they did.

The future of lab-based genetics:

Although a working plan is now in place for teaching lab-based genetics, the unit will continue to evolve. I may explore other yeast-based genetics labs, and I've thought about teaching other subject areas using microorganisms. This year, I had two independent study students who studied algae. They isolated pure cultures of a variety of algal species from local lakes, ponds, and aquariums according to the procedure in an "Amateur Scientist" article from Scientific American (Carlson, 1998). I thought in the future this may be an interesting way for students to study both classification and plants early in the year (theme 1).

This year I helped a fellow biology teacher implement *The Yeast Life Cycle* lab. He thoroughly enjoyed it, commenting on the value of the labs and high student interest. There are a total of six biology teachers in my high school, and a second one has expressed interest in trying the labs next year. Changes planned for this lab for next year will include having students use innoculating loops for their manipulations. This should save a lot of time by eliminating the need to sterilize toothpicks everyday.

Through student research, I've learned that the *UV Lethality and Mutagenesis* lab is in need of revision. Results for this lab have occasionally been inconsistent; it seems this is primarily due to placement of petri dishes in the goggle cabinet. Student lab reports showed that lethality in the cabinet varies with both vertical and horizontal position. As written, my procedure did not specify where in the goggle cabinet to place petri dishes for radiation exposures. This may or may not be changed for next year. Although results could be improved by giving students more specific directions, I think it was a valuable experience to let students discover this for themselves.

Most of the new pedagogical techniques employed in the genetics unit will definitely be used again. I've already written note outlines for the majority of the other units in freshman biology. The lab notebook and writing formal lab reports will become standard projects for the second semester of freshman biology, although their format may be modified slightly. Many students thought that requirements for these projects were too vague. I wanted them to be somewhat open-ended, but I will make minor adjustments to address these concerns. I strongly believe these two projects do a lot to progress student thinking. I think it is critical to give freshman this opportunity to apply

themselves, because within a short period they will have decided what track they are part of in high school.

Final Thoughts

Incorporating yeast culturing into the freshman biology program has resulted in more change than I had anticipated. I did not change one unit, but an entire marking period. This resulted in a significantly different approach to teaching the second semester of the course for me. Overall, I believe it really benefited students, often in ways that I could not have foreseen. Students in my class had a unique experience compared with their peers at this high school. They became more active participants in the learning process by asking questions and seeking the solutions themselves. They applied what they learned in the first semester, and really began to master key concepts for the first time. They also constructed new knowledge through their research. They designed experiments to test their own hypotheses and were eager to share this information with the class. These experiments became a valuable learning experience for me as well. After three years of teaching and modifying labs and activities related to this unit, I have an approach that I believe in.

Incorporating yeast culturing into the freshman biology program has been by far the most drastic change in my approach to teaching that I have ever made. It has also been the most rewarding. As a result, this genetics unit is the best-planned quarter in my new thematic approach to biology. I must thank the Division of Science and Mathematics Education for offering a strong program that led me to this end result.

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APPENDICES

APPENDIX A

TEACHER INFORMATION: YEAST LABS

These yeast experiments have been modified from the GENE project at Kansas State University. For information on yeast experiments and materials, you may visit their web site at www.phys.ksu.edu/gene/.

Obtaining Yeast Strains:

Yeast strains and supplies for genetics experiments are now available from Carolina Biological Supply. Yeast can be stored in the refrigerator for up to 9 months. Before using the yeast, they should be subcultured on YED agar plates and be allowed to grow up overnight at 30°C.

Preparing Media:

The following recipes are for preparing 100 mL of medium which is enough to pour 4 standard 100 x 15 mm plates. Mix ingredients together in a flask and bring to a boil on a hot plate with frequent stirring to dissolve the agar. A magnetic stirrer makes this much easier. Flasks must be carefully monitored to prevent a boil-over. Do not overfill flasks (I usually mix 600 mL of medium in a 1000 mL flask). Sterilize mixtures in an autoclave or pressure cooker for at least 15 minutes at 15 psi. Pour plates when flasks are cool enough to hold with your bare hands. After the agar has set, store petri dishes upside-down until ready to use. You may want to rebag and refrigerate plates if they will not be used immediately.

YED agar:
1 gram yeast extract
2 grams anhydrous dextrose
2 grams agar
100 mL water

YEKAC agar:
1 gram potassium acetate
0.25 grams yeast extract
2 grams agar
100 mL water

MV agar: Purchase from Carolina Biological Supply.

Glass Hockeysticks:

Prepare several small glass hockeysticks for spreading yeast suspensions on agar by bending approximately 3 cm of a glass rod at a right angle. To avoid flaming in alcohol, autoclave glass rods in a beaker covered with aluminum foil. Students can remove glass rods as they are needed from a "sterile" beaker and then return them in a "used" beaker.

Preparing Yeast Suspensions:

With a sterile toothpick, scrape a small "pin-head" amount of yeast from a subcultured plate of yeast and suspend in 35 mL of sterile water. This suspension should be slightly turbid, and contains approximately 1 x 10^6 cells/mL. Using a sterile pipette, transfer 0.1 mL of this suspension into a flask containing 100 mL of sterile water. This suspension contains approximately 1 X 10^3 cells/mL. When students pipette 0.1 mL of this suspension onto their plates, it should contain 200-500 cells which works well for most radiation experiments.

Exposing Plates to UV-C Radiation (Mutagenesis):

Goggle cabinets with germicidal lamps are a good source of UV-C radiation. Petri dishes can sit on goggle racks during exposures. Make sure to remove the lids before exposing plates, as this will filter out most of the radiation. In addition, placement in the goggle cabinet is very important. For consistent results, use the same shelf and keep horizontal position controlled.

I found it useful to hook up a switch to the electrical cord so that the germicidal lamb can be turned on and off quickly and easily. Your will also need some way of timing the exposures.

Exposing plates to UV-A Radiation (Photoreactivation):

UV-A exposures can be done using sunlight or a standard 40-watt fluorescent bulb. The light should be allowed to pas through a sheet of glass before exposing the plates. This will filter out most of the more harmful UV-B and UV-C radiation.

APPENDIX B

Student Interest Survey

For each of the following statements circle Y (yes), N (no), or U (undecided). Follow up each question with a brief explanation of your response.

Y N U Do you enjoy school?

Y N U Do you like science?

Y N U Do you like biology?

Y N U Is science your favorite subject? List your 3 favorite subjects.

Y N U Are you taking Geophysical Science next year? If not, what are you taking?

Y N U Do you plan on taking more than two years of science?

Y N U Do you plan on attending college? Explain your plans.

Y N U Do you plan on going into a science-related career?

THE YEAST LIFE CYCLE

An Introduction to Genetics

DAY 1: Innoculating Petri Dish with Mutant Yeast Cells

Purpose:

To transfer yeast strains HBT and HA2 onto nutrient rich YED agar.

Background:

In order to observe the complete yeast life cycle, we will be starting with haploid yeast strains of opposite mating type. Both strains are mutant forms of *Saccharomyces cerevisiae*, common bakers and brewers yeast. Before mating these yeast cells, healthy colonies will be grown up on your petri dishes using agar that is rich in nutrients. These nutrients include the sugar dextrose as a food source, and an extract of yeast that will provide other essential vitamins and minerals.

In the study of genetics, scientists often use mutants with observable differences. Colonies of these mutant yeast strains have noticeably different colors. By crossing parent strains and observing the offspring, we will be able to explore genetics is a similar way that Mendel did with his pea plants. However, the short generation time of yeast will allow us to do this in a short period of time (about 2 weeks).

Procedure:

1. Label the bottom of a nutrient-rich YED plate as shown on the following page.

2. Use a sterile toothpick to gently scrape a small amount of growth from a colony of HA2 yeast. Spread the yeast cells out as thin as possible on the YED agar above your HA2 label. Discard the toothpick.

3. Use another sterile toothpick to transfer HBT yeast in the same way above the HBT label. Discard the toothpick.

4. Make sure your petri dish is labeled with your group name and hour, and then store it in the incubator with the agar side up.

LABELING THE PETRI DISH

Observations:

1. Describe the appearance of each parent colony. Make sure to note the color and record the name of each.

Analysis:

1. Why is it necessary to use sterile toothpicks to transfer yeast colonies?

2. What does it mean to "innoculate" a medium?

3. What type of agar was used to grow colonies on? What is in this agar?

4. Why are we storing our petri dishes in the incubator? Why do we store petri dishes with the agar side up?

5. What are "mutants"? Why do scientists use mutants to study genetics?

DAY 2: Mating Mutant Haploid Yeast Strains

Purpose:

To mate the haploid yeast cells and make observations of the original haploid cells.

Background:

The haploid yeast strains (HBT and HA2) living on the nutrient agar are of opposite mating type (like male and female). When mixed together they will transform from the usual circular-shaped cells to pear-shaped cells called "schmoos", which are yeast cells getting ready to mate. Schmoos mate through conjugation, which simply means they join together to form a diploid cell. Conjugation produces diploid cells called zygotes, which look like peanuts. As these zygotes grow they will divide through budding, which produces more circular shaped cells. (review life cycle from handouts)

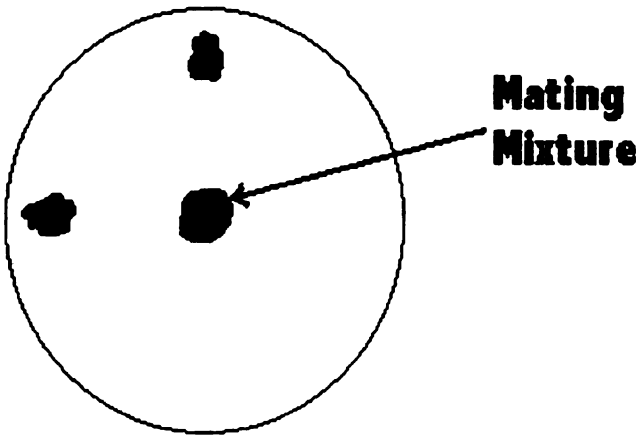
Procedure:

1. Draw a sketch of the colonies on your petri dish in your lab notebooks. Describe the appearance of these colonies and label your sketch with the date and agar type.

2. Use a sterile toothpick to gently scrape a portion of the HBT colony and transfer it the center of the plate. Discard this toothpick.

3. Use another sterile toothpick to transfer a small portion of the HA2 colony to the center of the plate. Use this toothpick to mix the two strains of yeast together, and then carefully spread this mixture out in the center of the plate. Be careful not to tear the surface of the agar. Discard the toothpick.

YOUR PLATE SHOULD NOW LOOK LIKE THIS:



4. Make a wet-mount slide from each of the haploid parent strains (HA2 or HBT) and focus the cells under high power. Sketch about 10 of these cells as microscopic observations for day 2 in your lab notebook.

5. Place the plate back into the incubator (agar side up).

Observations:

1. Sketch of plates prepared on Day 1.

2. Microscopic observations of the HA2 and HBT parent strains from Day 1 plates. Draw at least 10 cells, and provide a written description of your observations.

Questions:

1. Do HA2 and HBT yeast strains appear different under the microscope?

2. Why will HA2 and HBT mate when mixed together?

Day 3: Observing Zygotes from the Mating Mixture

Purpose: To observe schmoos, zygotes, and budding zygotes as evidence that mating occurred.

Background:

By now, most of the haploid cells have formed schmoos and conjugated (they have mated). The end result of mating is a diploid zygote with two sets of chromosomes. Remember, the mutant haploids each had a single defective gene. Now, each diploid cell should carry at least one good copy of each gene. You will not be able to distinguish these diploid cells under the microscope, they look pretty much just like haploid cells. However, you should be able to find some zygotes and budding zygotes left over from mating. You may even be able to find a schmoo.

Procedure:

1. Make observations of your YED plates and record in your lab notebook for day 3 observations.

2. Make a wet-mount slide of the prepared "Mating Mixture" and observe under high power. Look for haploid "schmoos" preparing to mate, and diploid zygotes and budding zygotes. Sketch about 10 cells of the mating mixture in your lab notebooks for day 3 observations.

3. Place YED plates back in the incubator.

Observations:

1. Sketch of plates prepared on Day 2.

2. Microscopic observations of the mating mixture. Draw at least 10 cells. Label unbudded zygotes, budding zygotes, and "schmoos". Describe all observations in words.

APPENDIX C-I.

Questions:

1. What is a yeast "schmoo"? Are schmoos diploid or haploid?

2. What is a zygote? Are zygotes diploid or haploid?

3. How can you tell the difference between haploid and diploid budding yeasts?

4. How do yeast reproduce asexually? Sexually? Describe each process.

DAY 4: Selecting the Diploids

Purpose:

To isolate a pure culture of diploid cells by transferring the mating mixture onto media unsuitable for growth of mutant haploids.

Background:

To observe the diploid phase of the yeast life cycle, we need to eliminate the haploid cells that did not mate. These haploid cells lack the ability to produce a nutrient that is essential to their survival. Haploid HBT cells are unable to produce tryptophan and HA2 cells are unable to produce adenine. These cells grew on the YED agar because it contained these nutrients.

Today we will transfer our mating mixture to a new medium which lacks both tryptophan and adenine. Unfortunately, neither HBT or HA2 cells will survive under these harsh conditions. However, the diploid cells will because they have one good copy of the gene for making both adenine and tryptophan.

Procedure:

1. Make observations of your YED plate in your lab notebook for day 4. Label your drawing and describe all forms of growth.

2. Label a MV plate using your YED plate as a guide. Make sure to change the date and agar type (from YED to MV).

3. Make a copy (replica) of your YED plate by transferring the HBT cells, HA2 cells, and mating mixtures onto the MV plate. Use a separate, sterile toothpick to transfer each strain, and then discard the toothpick.

4. Put the MV plate in the incubator (agar side up) to let the diploid cells grow. Store your YED plate in the designated spot on the counter.

Observations:

1. Sketch of plates prepared on Day 3.

Questions:

1. What color is the colony that grew from the mating mixture? Is this colony haploid or diploid?

2. Why did we transfer the colonies to a new petri dish? (What will this accomplish?)

3. Why are the haploid mutants (parents) unable to survive on MV agar? Why are diploids able to survive?

DAY 5: Preparing Diploids for Sporulation

Purpose:

To transfer diploid cells from MV agar to nutrient-rich YED agar.

Background:

The diploid cells growing on our MV plates are not flourishing because the nutrients are poor. Before we proceed with the life cycle, we want cells that are growing and dividing rapidly. These more vigorous cells will be easier to work with during the next phase of the lab.

Procedure:

1. Make observations of your MV plate in your lab notebook. Label your drawing and describe all forms of growth.

2. Make a wet-mount slide of the diploid cells growing on the MV plate and look at them through the microscope. Draw about ten of these cells in your lab notebook for microscopic observations.

3. Using a sterile toothpick, transfer cells from the mating mixture on your MV plates to a fresh plate with YED medium. Discard the toothpick.

4. Label the plate with your name, hour, date, YED, and "Diploids".

Observations:

1. Sketch of MV plates prepared on Day 4.

2. Microscopic observations of diploid yeast cells. Make sure to label and describe your observations. Draw at least 10 cells.

Questions:

1. How well did the parent strains grow on MV agar? Explain.

2. How well did the diploid cells grow on MV agar? Explain.

3. What color is the diploid yeast colony growing on MV agar? Explain.

4. How does the appearance of the diploid cells compare to that of the haploids?

5. Why are we transferring the diploid cells back to YED agar?

DAY 6: Sporulating the Diploids (Meiosis)

Purpose:

To transfer diploid cells to a sporulation medium (YEKAC).

Background:

At this point, you have seen half of the yeast life cycle: mating between two haploid cells to produce diploid cells. The diploid cells are stable, and will continue to grow and divide as long as food, nutrients, and space are provided. The other half of the life cycle involves meiosis of the diploid cells to produce haploid cells once again. In yeast, this is the process of sporulation. When environmental conditions are not as favorable for growth and reproduction, diploid yeast cells sporulate, forming four haploid spore cells. These spores can remain dormant for long periods of time, until conditions improve.

In order to sporulate our diploid cells, we will transfer them to YEKAC medium. This medium does not contain nitrogen (important for making proteins) and only a poor food source (acetate). Diploid cells will not grow well on YEKAC. In a short period of time, they will sporulate and go dormant. A single sporulating diploid cell will produce four haploid spores enclosed in a sac called an ascus.

Procedure:

1. Draw a sketch of the YED plate you prepared on Day 5. Make sure to record the color of your diploid colony.

2. Use a sterile toothpick to transfer freshly grown diploid cells from your YED plate to a YEKAC plate. Spread them out in at least 3 long streaks. Label this plate with your name, hour, date, and "YEKAC".

3. Incubate the YEKAC plate for at least three days.

Observations:

1. Sketch YED plates prepared on Day 5.

Questions:

1. Why did we transfer our colonies to a new media (YEKAC)?

2. What causes a yeast cell to "sporulate"?

3. What process produces the haploid yeast spores? How many spores are produced from a single cell?

4. How is YEKAC agar different from YED?

DAY 7: Observation of Asci and Germination of Haploid Spores

Purpose:

To look for asci on YEKAC plates and spread asci onto fresh YED plates for germination.

Background:

The sporulating diploids produce an ascus containing four haploid ascospores (spores). These look like lumpy cells which are actually spores contained within a membrane. After observing the asci, you will germinate these spores and grow fresh haploid colonies. We are interested in seeing what phenotypes (red or white) show up in this generation of haploids.

Procedure:

1. Make observations of your Day 6 YEKAC plate in your lab notebook. Label your drawing and describe all forms of growth.

2. Make a wet-mount slide from yeast growing on the YEKAC plate and examine it with a microscope. Look for the lumpy asci that include two, three, or four round spores within a membrane. These are the asci containing ascospores. They should all have four spores, but not all develop. Record microscopic observations in your lab notebook.

3. Transfer asci from the YEKAC plate to a new YED plate

Observations:

1. Sketch of YEKAC plates from Day 6.

2. Microscope observations: Look for asci containing spores. Draw at least 10 asci or cells.

Questions:

1. Why did yeast cells on the YEKAC medium form spores? What process formed these spores?

2. What will happen to the spores that get transferred to a YED plate?

3. Why is it necessary to spread out the yeast asci in the "zigzag" manner described in the procedure? (What will this accomplish?)

4. What will we be interested in looking for in the next day of lab?

Day 8: Observing Phenotypes of Germinating Haploid Spores.

Purpose:

To look for different colors among the individual colonies growing on the YED plate from the germination of haploid spores.

Background:

When you put spores back onto YED growth medium, they germinate, begin budding, and grow into colonies. Since some will be of opposite mating type, they may also mate. Therefore, the colonies that grow may be either haploid or diploid cells and either pink or cream colored.

Procedure:

1. Look for different colors among the colonies. Can you find both phenotypes (pink and cream colored) of the original haploid parent strains?

2. Draw and label a sketch of this plate in your lab notebook for day 8 observations.

3. Observe the plates of your classmates and record observations in your lab notebook.

Observations:

1. Sketch of YED plates prepared on Day 7.

2. Observations of YED plates from your classmates.

Questions:

1. Are the individual colonies growing on your YED plate haploid, diploid, or both? Explain.

2. What phenotypes showed up on your YED plate? How abundant were each of the phenotypes? Explain using your knowledge of genetics.

3. Describe three things that you learned from this lab.

UV LETHALITY AND MUTAGENESIS IN YEAST

Purpose:

To explore the effects of UV-C radiation on living cells.

Background:

In the previous lab we worked with two mutant strains of yeast to observe the yeast life-cycle and some basic genetics. Remember, mutants are organisms that carry mutations, or DNA that has been altered. Geneticists often experiment with mutant organisms because they have differences that are easy to trace. In order to cause mutations in an organism, scientists often expose cells to substances called mutagens, which cause damage to DNA. This process is known as mutagenesis. Most often, mutations are lethal and result in cell death. However, surviving organisms that carry mutations are valuable to the scientist for studying the genes that have been altered. Mutants that are physically different, like our red mutant yeasts, are useful in doing crosses like Mendel did and learn more about gene transmission and expression.

In this experiment you will spread a dilute suspension of red mutant yeast (HA2) on nutrient-rich YED plates and expose them to the germicidal lamp in our goggle cabinet for various lengths of time. The germicidal lamp is a source of UV-C radiation, which is quite lethal to living cells. We will be looking for the survival rate at different exposure times, and the numbers of these survivors that are mutants. The mutation we will be looking for causes red mutant yeast to mutate back to the wild-type cream color.

Procedure:

DAY 1: Exposing Cells to UV-C radiation.

We will divide the classroom in half to do two replicates of this experiment. Each half of the class will divide into 6 groups of 2-3 students. Each group will prepare one plate of cells and do an exposure. In addition, each half of the class will need to prepare a single control plate that receives no UV-C exposure.

1. Divide your groups to complete UV exposures of 0, 15, 30, 45, 60, 75, 90 and 105 seconds. Label your petri dish with your group's names, hour, date, and the exposure time.

2. Pipette 0.1 mL of the prepared yeast suspension onto your YED plate. Using a sterile glass hockeystick, spread the suspension evenly over the surface of the agar without spreading it completely to the edge.

3. Remove the lid of your petri dish and invert it. Carefully place both halves of your petri dish on the shelves in the goggle cabinet and lock the door. Expose the plate for the appropriate time. Remove the dishes immediately and replace the lids.

4. Store the plates in the incubator to let the surviving colonies grow up.

DAY 2: Collecting the Data

1. Count Surviving Colonies: Place the clear acetate grids under your petri dish to help in counting the number of surviving colonies. Each group member should do this and record their number in the GROUP DATA TABLE. Then, average the colony counts for your group.

2. Count Mutant Colonies: The yeast cells added to these plates were red mutants. White colonies that grew up were started by a single cell that mutated back to its wild-type color. Count these white colonies in the same way and average your numbers. Record information in TABLE 1.

TABLE 1: GROUP DATA (exposure = _____ sec):

Colony Types:	Count 1	Count 2	Count 3	Colony size (ave)
Surviving (all colonies)				
Mutant (only white)				

3. Combine your group's data with the rest of the class by completing data tables 2 and 3. Average the colony sizes for each exposure time and use these averages for your analysis.

TABLE 2: Class Data – Surviving Colonies

Exposure (sec)	Group 1	Group 2	Colony size (ave)
0 sec (control)			
15 sec			
30 sec			
45 sec			
60 sec			
75 sec			
90 sec			
105 sec			

TABLE 3: Class Data – Mutant Colonies

Exposure (sec)	Group 1	Group 2	Colony size (ave)
0 sec (control)			
15 sec			
30 sec			
45 sec			
60 sec			
75 sec			
90 sec			
105 sec			

Analysis of Data:

Complete items 1-4 and the questions that follow on a separate sheet of paper. All work must be shown for calculations and results must be organized in a data table. Graphs should be large enough to cover one full sheet of graph paper. Make sure to label both axis.

1. Calculate the surviving percent for each exposure time. Summarize calculations in a data table.

$$\text{Surviving Percent} = \frac{\text{Number of surviving colonies on Exposed Plate}}{\text{Number of surviving colonies on Control Plate}} \times 100\%$$

2. Prepare a graph of the survival data. Plot the surviving percent against the UV exposure time.

3. Calculate the percent of white mutants in the surviving colonies for each exposure time. Show calculations and organize results in a data table.

4. Prepare a graph of the mutant data. Plot the percent of white mutants in the surviving colonies against the UV exposure time.

Questions:

1. If you were a scientist trying to create new strains of mutant yeast by using UV radiation as a mutagen, what exposure times might you choose? Explain your answer.

2. The red yeast in this experiment were themselves mutants. The red color results from their inability to produce adenine. In general, are mutations most often good or bad? Describe at least one benefit and one harmful effect of mutations.

3. Ozone is a chemical substance (O_3) in our atmosphere that filters out most of the harmful ultraviolet radiation from the sun. Human activity, such as the use of aerosols, coolants, and solvents, has a devastating effect on the ozone layer. Why is it important to regulate the use of these materials? How do you think UV radiation might affect human cells?

4. Vitamin D is important in the absorption of calcium ions from the foods we eat. Calcium is an important mineral needed for building strong teeth and bones. Exposure to sunlight allows our body to produce vitamin D naturally in our skin. Is sunlight good or bad for you? Explain. Describe how one might balance the risks and benefits of sunlinght.

APPENDIX C-II.

Survival Data:

Exposure (sec)	Group 1	Group 2	Average number of surviving colonies
0 sec (control)			
15 sec			
30 sec			
45 sec			
60 sec			
75 sec			
90 sec			
105 sec			

Mutant Data:

Exposure (sec)	Group 1	Group 2	Average number of mutant colonies
0 sec (control)			
15 sec			
30 sec			
45 sec			
60 sec			
75 sec			
90 sec			
105 sec			

APPENDIX C-II.

Surviving Percents:

Exposure (sec)	Calculations	Surviving Percent
0 sec (control)		
15 sec		
30 sec		
45 sec		
60 sec		
75 sec		
90 sec		
105 sec		

Percent of Mutants in Surviving Colonies:

Exposure (sec)	Calculations	Surviving Percent
0 sec (control)		
15 sec		
30 sec		
45 sec		
60 sec		
75 sec		
90 sec		
105 sec		

APPENDIX C-III.

PHOTOREACTIVATION
REPAIR OF ULTRAVIOLET DAMAGE

Purpose:

To design an experiment that demonstrates the phenomenon of "photoreactivation".

Background:

In the previous experiment (UV Lethality and Mutagenesis), we exposed yeast cells to UV-C radiation in the goggle cabinet. This demonstrated that UV-C radiation is quite lethal to living cells, killing large numbers upon exposure. The exposure also damaged the DNA, or caused mutations, in many of the surviving colonies. These mutations were seen as a change in the color of the colonies.

When DNA is damaged in any way, mechanisms within the cell try to repair the damage. One such repair mechanism in yeast involves the enzyme " photolyase", which uses the energy from sunlight to repair the damage. In the Mutagenesis Lab, irradiated cells were not exposed to sunlight, so this repair mechanism was shut down.

Procedure:

Your lab group will design its own "photoreactivation" experiment and write a formal lab report. In order to do this, you will need to refer back to the Mutagenesis lab for ideas concerning set-up and exposure times. The goal is to design an experiment that effectively demonstrates the phenomenon of "photoreactivation". Rather than using sunlight to activate the photolyase enzyme, we will be using fluorescent lights.

<u>Parameters for experiments:</u>

1. Each group will get 6 nutrient-rich YED plates to experiment with. Make sure to use at least one for a control.

2. Two yeast suspensions will be available for spreading colonies on your plates. One will be roughly the same concentration as the suspension from the Mutagenesis lab (approx. 2000-3000 cells per milliliter water). The other will be 10X more concentrated if you prefer a larger colony size. You may use both suspensions in

your experiment if you like. Data can then be compared by either multiplying or dividing by "10".

3. All materials from the Mutagenesis lab will be available. Feel free to bring in other materials, or ask if you need other items from the lab.

4. You will have one day to "set-up" and expose your plates. After colonies have grown up, you will have one day to collect the data and begin your analysis.

Grading:

You will be graded on the lab report you generate from this experiment. The format for this lab report is outlined below. A rough draft of items I.-V. must be completed before running your lab.

I. TITLE: Write a catchy title for your lab.
II. PURPOSE: Write a brief statement explaining the reason for this experiment.
III. HYPOTHESIS: Generate an educated guess about the outcome of your lab.
IV. MATERIALS: List all of the materials to be used in your lab.
V. PROCEDURE: Write a step-by-step procedure to be followed in running your experiment. It may be helpful to make drawings of your setup.
VI. DATA: Data collected in the lab is to be organized neatly in a data table.
VII. ANALYSIS: Summarize the results of your experiment. Determine a measure of "photoreactivation" and summarize this for each setup.
VIII. CONCLUSION: Does the data support or reject your hypothesis? Explain. How could your experiment be improved?

DESIGNING A CONTROLLED EXPERIMENT

Purpose:

Students will work in a group to design a controlled experiment using microorganisms. Data will be collected and analyzed, and presented in a formal lab report (Note: Each student is responsible for generating their own lab report). If time permits, presentations of the data will be given to the class.

Suggestions for Reseach:

1. Photoreactivation: Read the handout regarding this phenomenon. Design an experiment to test the hypothesis that yeast cells need sunlight to repair DNA damage from ultraviolet radiation.
2. UV Lethality or Mutagenesis: Design an experiment that might improve this lab or increase its consistency. You may want to test the effect of exposing cells with lids on the plate, variation in the height of plates in the cabinet, effect of exposure on different types of organisms, effects of continuous exposures vs. fragmented exposures, or how to limit contamination in this experiment. You may also want to test the effects of radiation on different types of yeast cells (HA2, HBT, diploid mutants, wild yeast, yeast spores)
3. Test the effects of growth in different liquid growth mediums. Add different substances to the medium, vary the concentration of nutrients, or test growth in different foods or different environments. Doing an experiment of this kind may require more preparation time.

Parameters for the experiment:

1. Groups must use at least one of the following yeast types:
   HA2, HBT, diploid mutant yeast, wild bakers yeast, yeast spores
2. Individual cells should be pipetted onto agar from suspension.
3. Each group will use a maximum of six petri dishes. YED plates will be available for growing yeast. Any special growth mediums will need to be prepared by students and poured after school.
4. Groups must get a research proposal approved by Mr. Hudecek before beginning their experiments.
5. Each group can expect up to three days for planning, and up to five days to carry out the experiment. Basic lab equipment will be available, but feel free to bring in other materials you may need.

Format for Research Proposal:

1. Identify names of all persons in the group.
2. State the purpose or intent of your study.
3. Clearly state a hypothesis with a single variable.
4. Describe an experimental setup that would provide data either supporting or rejecting the hypothesis.
5. List all materials you would need provided for the experiment, along with materials you might need to bring yourself.
6. Formulate a timeline for setting up your experiment and collecting data. This timeline should not exceed 5 days of actual lab work, however data may be collected after this time.

APPENDIX D-I.

Name _____ hour _____ date _____

SIMULATING A TWO-FACTOR CROSS

A. Determining the Expected Outcome

Gregor Mendel investigated heredity by crossing garden pea plants. He determined that heredity is determined by factors (genes) that are passed on from generation to generation. All individuals have two copies (diploid number) of each factor, one received from each parent. These factors exist in various forms known as alleles. The combination of alleles (genotype) determines an organisms outward appearance (phenotype). Mendel's Principal of Dominance states that some alleles mask the expression of others.

Mendel's pea plants were an excellent choice for studying heredity because they possessed several traits that varied. In this activity, we will study two such traits. The first trait will be seed shape. Mendel's pea plants showed either round or wrinkled seed shape, and it was determined that round seeds are dominant over wrinkled seeds. The second trait is seed color. Mendel determined that yellow seeds are dominant over green seeds.

Round seeds (R) are dominant over wrinkled seeds (r)
Yellow seeds (Y) are dominant over green seeds (y)

1. This can be verified by crossing purebred round, yellow seeds with purebred green, wrinkled seeds. Predict the outcome of such a cross:
   a. How many genotypes would show up in the offspring from this cross? _____

   b. What is(are) the genotype(s)? _____

   c. What would be the phenotype(s) of these offspring?

      _____

2. Heterozygotes from such a cross are known as hybrids. Work out a Punnett square that represents a cross between hybrids from the previous cross (RrYy x RrYy).

3. Use the results from your punnett square to fill in TABLE 1. Multiply the number of each outcome by 4 to make a prediction for 64 offspring. (our Punnett square reveals the prediction for 16 offspring)

TABLE 1: Expected Outcome (RrYy x RrYy)

Phenotype	Genotype	Number expected for 16 offspring	Number expected for 64 offspring
Round, yellow seeds	RRYY RrYy RRYy RrYY		
Round, green seeds	RRyy Rryy		
Wrinkled, yellow seeds	rrYY rrYy		
Wrinkled, green seeds	rryy		

4. What is the expected phenotypic ratio for this cross?

   _____

5. Determine the probability of getting each of the following phenotypes from such a cross. Express probabilities as a fraction.

   Round yellow seeds _____

   Round green seeds _____

   Wrinkled yellow seeds _____

   Wrinkled green seeds _____

B. Determining the Observed Outcome

Remember, a Punnett square only helps in determining the expected outcome of a cross. In reality, the outcome depends on chance. In order to see what real data might look like, we will simulate this two-factor cross by tossing bingo chips.

Procedure:

1. Work with a partner. Each student will need one dixie cup and two bingo chips. Make sure to grab one bingo chip of each type. One should be labeled R/r and the other Y/y. You will represent one parent, and your partner will represent the other. (Realize we are only simulating the mating of peas)

2. Both partners place the bingo chips into the dixie cups and hold your hands over the mouth of the cup. Shake it so the chips are tossed around, and empty them onto your desk. Record the genotype from this cross by scoring a mark in TABLE 2 (Toss Results).

3. Repeat step 2 sixty-three more times.

TABLE 2: Observed Outcome (RrYy x RrYy)

Phenotype	Genotype	Toss Results	Total Number Observed
Round, yellow seeds	RRYY RrYy RRYy RrYY		
Round, green seeds	RRyy Rryy		
Wrinkled, yellow seeds	rrYY rrYy		
Wrinkled, green seeds	rryy		

C. Combining Class Data

1. All class data will be combined on the markerboard. Draw a data table of your own that summarizes the class totals for the simulation.

D. Questions

1. In your simulation, why might your actual experimental values (observed outcome) be different from your expected values?

2. Why do you think it is helpful to conduct a large number of trials when simulating genetics crosses? Would this be important in doing real crosses (with peas)?

3. How is an understanding of genetics useful to an animal or plant breeder?

4. Is it possible for two organisms to have different phenotypes but the same genotype? Explain your answer.

5. Is it possible for two organisms to have different genotypes but the same phenotype? Explain your answer.

6. How could a guinea-pig breeder determine whether a rough-coated guinea pig is homozygous or heterozygous for this trait?

7. In dogs, wire-hair is due to a dominant gene W. Two wire-hair dogs were mated and produced a puppy with smooth hair. What were the genotypes of the two parent dogs?

DNA FINGERPRINTING SIMULATION

Background:

YOU have been accused of a terrible crime. Someone has broken into Mr. Hudecek's household and changed student grades on his computer. The computer shows that you got an A+ on a quiz that Mr. Hudecek claims was impossible. A list of all suspects has been turned over to the authorities, who believe it was a group effort. They intend to prosecute everyone involved to the fullest extent of the law.

Fortunately, the perpetrator(s) cut themselves when breaking in through the window. DNA was isolated from blood samples taken at the scene of the crime. This DNA was used to make a DNA fingerprint of this dangerous criminal. In order to clear your name, you must complete a DNA fingerprint for yourself.

Procedure:

DAY 1: Preparing a DNA Sample

1. Obtain a 1.5 meter piece of adding machine tape. This will represent your DNA. This piece of DNA contains 10 genes. The sequence for these genes are listed below:

Gene 1: A T T C G T A G G C G T A A G A C C

Gene 2: G G T T A C G T T A C A A T C C G G T A C

Gene 3: T A C C G G A T T C T C T C C G G A

Gene 4: G G A T C C G G T A C G C A T G C T T C C G G T

Gene 5: T C G C A A C C G G A G

Gene 6: G A T A C C G G A T G A A C C

Gene 7: T A C C G G A A G C A T T A C C G G T C C

Gene 8: G G T A C C G G A T T A

Gene 9: T T A C C G G A C T A G A G T C A T C C G G C C

Gene 10: G G A T C C G G A T C G C G T

2. Copy the sequence for Gene 1 (and ONLY gene 1) down the left-hand side of your tape. Print these letters no larger that you would naturally on notebook paper, and don't leave much space between them. You need to fit many letters on this tape!

3. Between our genes, DNA contains "junk" made of repeated sequences of base pairs that differ in length from one person to the next. Differences in these repeated sequences makes each of our DNA fingerprints unique. Choose one letter (A, T, G, or C) for your repeated sequence, and roll two die to determine how many bases you have between Gene 1 and Gene 2. Fill in the number of repeated bases specified by your roll.

4. Continue to copy you gene sequences down the left-hand side of your tape. Between each gene, choose different letters for your repeated sequence. Continue to roll the die to determine the number of repeats.

5. When finished copying 10 genes and 10 sets of junk, copy the complimentary base sequence down the right-hand side of your tape. Now your DNA sample is complete.

DAY 2: Preparing the DNA Fingerprint

1. DNA is cut into fragments using restriction enzymes. The restriction enzyme we will use is called HaeIII. This enzyme cuts DNA wherever the sequence CCGG exists. Specifically, it cuts between the C and G (CC/GG). Cut your DNA strand into fragments wherever this sequence can be found. Hint: Every gene gets cut at least once.

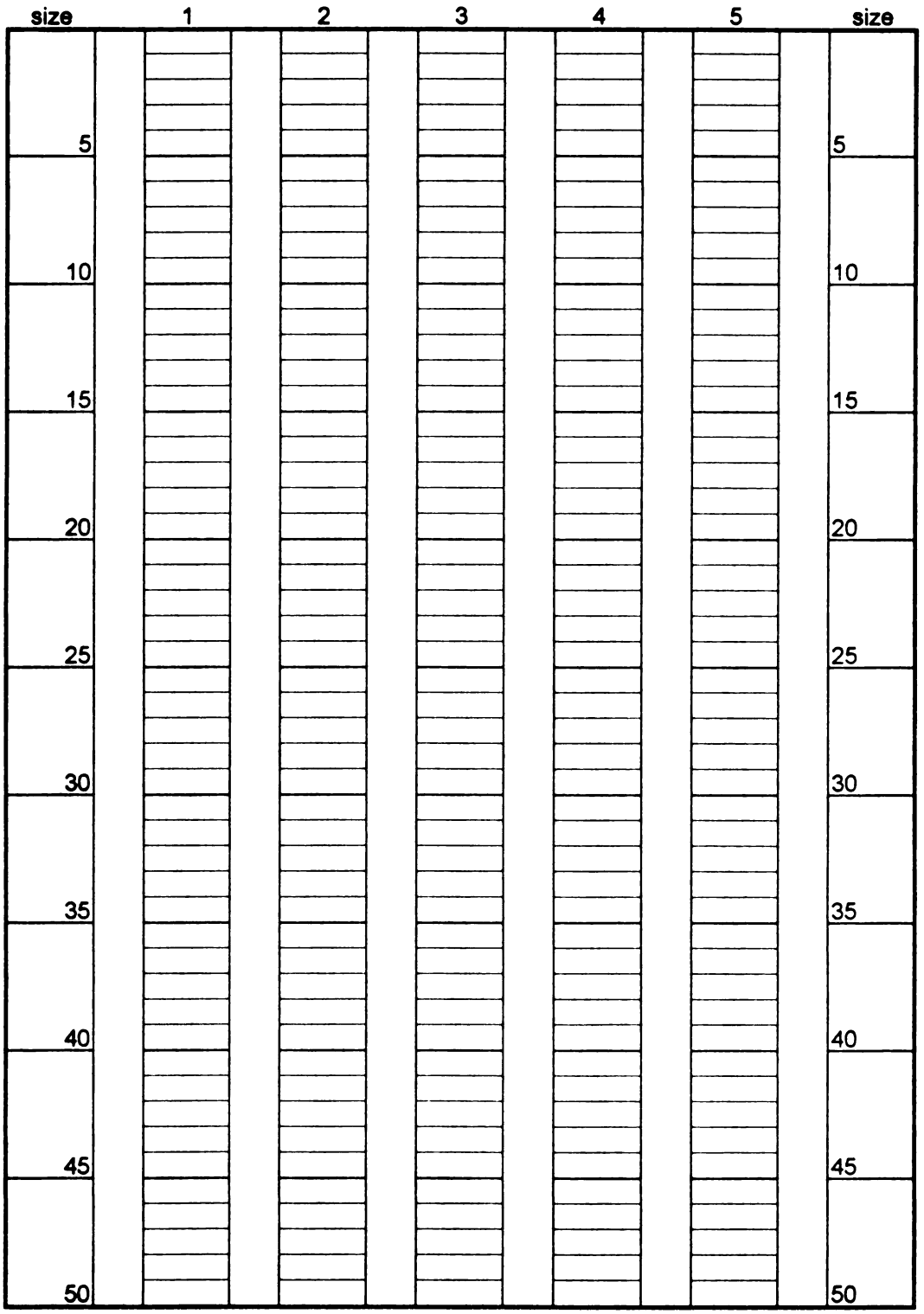
2. These DNA fragments are then separated according to size by electrophoresis. Remember, in electrophoresis, larger fragments move more slowly through a gel than small ones. Count the number of bases in each of your DNA fragments.

3. Choose lane 1, 2, 3, or 4 on the "DNA ELECTROPHORESIS GEL" handout. Write your name at the bottom of a lane, and shade in the appropriate boxes for your DNA sample.

4. Compare your DNA fingerprint with that of your partners and of the alleged criminal in lane 5.

APPENDIX D-II.

DNA ELECTROPHORESIS GEL



APPENDIX D-II.

QUESTIONS

1. Does your DNA fingerprint clear your name? Is it identical to anyone else in your group?

2. How is your DNA similar to the DNA of other people? How is it different?

3. What is "junk" DNA? How is this junk important for DNA fingerprinting?

4. How are restriction enzymes used in DNA fingerprinting?

5. In your own words, explain how electrophoresis works. Name one other possible use for electrophoresis?

6. How can DNA fingerprinting be useful in solving crimes?

7. Real human DNA contains approximately 100,000 genes. In addition, different alleles exist for each gene (our gene sequences are not always identical to everyone else). In real DNA fingerprinting, several restriction enzymes are used. Reflect on how powerful you believe DNA fingerprinting to be. Do you think mistakes can be made? Explain.

APPENDIX E-I.

LABORATORY NOTEBOOK: A GENETICS PROJECT

Hudecek, 2000

Project Description:

The project for this quarter will involve organizing and maintaining a laboratory notebook for genetics. Students will be responsible for writing procedures, recording observations, and completing a lab analysis for ongoing laboratory activities in genetics. Most of these labs involve culturing mutant colonies of common baker's yeast.

Format for Lab Notebook:

Students will need an 80-page spiral notebook. The pages of this notebook need to be numbered 1-80 in the upper right-hand corner. Leave the first two pages blank for a table of contents. The pages that follow will document all lab procedures and results for the quarter. Each of these pages should document the date that the information was entered in the upper left-hand corner.

Each student will be issued a procedure manual for the genetics labs. These manuals are to be returned in good shape at the end of each lab. Students are not to write in these manuals. The manuals will provide the student with the information needed to complete the laboratory notebook.

Format for Lab Entries:

Each day of lab is to be documented according to the following format:

1. Title: Centered at the top of the page.
2. Objective: Write out objectives (goals) to be accomplished on that day of lab. Objectives are to be written in complete sentences.
3. Procedure: Write a detailed step-by-step description of the work to be done for that day.
4. Observations: Record the observations specified by the lab manual. This usually includes both drawings and written descriptions. Make sure to label all observations as asked.
5. Lab Analysis: Answer all questions from the lab manual for that day. Answers are to be written in complete sentences.

6. Daily Progress Report: Comment on that day's lab experience. Problems that were encountered should be addressed, along with suggestions for improvement.

Grading:

Lab Notebooks will be collected near the end of the marking period and are worth 100 points. Grades will be assigned according to the following breakdown:

A. Format followed..... 10 points
   (title page, page numbers, dates, objectives, etc.)
B. Content:
   Procedures.....20 points
   Observations .....20 points
   Lab Analysis.....30 points
   Daily Progress Report.....5 points
C. Overall Neatness/Appearance .....10 points
D. Return of Lab Manuals in acceptable condition.....5 points

9-1 NOTES: MENDELIAN GENETICS, PART I

A. Background Vocabulary

1. Heredity:

2. Genetics:

B. Early Ideas About Heredity

1. Characteristics of parents are _____ into their offspring. " _____ "
2. Traits:

3. Example:

C. *Gregor Mendel*, the "_____ of Genetics" (born _____)

1. Mendel was an Austrian monk who had control of the _____.
2. Mendel learned the _____ mechanisms of the _____ plant.
   a. Under normal circumstances, pea flowers produce seeds by _____ , where_____ produced by a plant fertilizes _____ cells in the same flower.
   b. Self-pollinating plants produce _____ with the same _____ as the parent plant. (purebreds)

c. Mendel learned to _____ pea plants by transferring _____ from one plant to another. This allowed Mendel to cross plants with different _____.

D. Mendel's Pea Plants

1. Purebreds:

2. Mendel studied ____ different traits of his pea plants. Each trait had _____ differing characters (see page 183).

Example: Trait -
Characters -

E. Mendel's Crosses

1. Monohybrid Cross – Mendel crossed plants with different _____ for a single _____.

Example:

2. These crosses produced organisms known as _____.
3. Results of cross:

Example:

F. Mendel's Conclusions:

1. Individual _____ control each trait of a living organism, and these factors do not _____ with one another.
   a. These factors that control traits are known as _____. A gene is a segment of _____ that codes for a particular _____.
   b. Contrasting forms of a gene are known as _____.
2. Principle of Dominance: Some factors (_____) are _____ whereas others are _____.
   a. REVIEW: You receive ____ copies of every gene, one from your _____ and one from your _____. These genes are located on _____.
   b. _____ alleles are always expressed, even if present with the contrasting _____ allele.
   c. _____ alleles are only expressed if paired with another recessive allele.

9-2 NOTES: Applying Mendel's Principles

G. Test Crosses

1. Test crosses are used to determine the _____ of an unknown parent.

2. Test crosses are done by crossing the unknown individual that is dominant with a _____ individual.
3. If any of the offspring from a test cross show the _____ phenotype, the parent was _____. Otherwise, the unknown parent was _____.
4. Example:

   In mice, running (R) is dominant over waltzing (r). When a running mouse is crossed with a waltzing mouse, nine offspring are running and two are waltzing.

   a. What was the genotype of the unknown parent? _____
   b. What would the genotype be if all offspring were running? _____

H. Probability Defined

1. Probability is the _____ or _____ that a particular event will occur.
2. Probability = _____
3. Examples:
   a. Probability of flipping heads on a coin = _____.
   b. Probability of rolling a "3" on a die = _____.

APPENDIX E-II.

I. Rules of Probability

1. You will get closer to the _____ outcome with a _____ number of trials.
2. _____ events do not affect _____ outcomes. Each trial is _____ of the others.

J. The Product Rule:

Examples:

1. What is the probability of flipping heads 5 times in a row?

2. What is the probability of rolling a "5" three times in a row?

3. What is the probability of getting the following genotypes from this cross: AaBbCc X AaBbCc

a. aabbcc? _____

b. AaBbCc? _____

c. AABbcc? _____

MODERN GENETICS

NOTES, Part I: Genes and Chromosomes

A. Chromosome Theory of Heredity (Walter Sutton, 1902)

1. _____ are located on chromosomes.
2. Genes occupy a _____ place on a chromosome.
3. A gene may exist in several forms, or _____, and each chromosome contains _____ copy of each gene.

B. Gene Linkage

1. Linked genes are located on the same _____.
2. Linked genes are _____ together. (do NOT undergo _____)
3. Morgan's Fruit Flies – an early example (pg. 207)
   a. gray-bodies and normal wings usually inherited together.
   b. Black-bodies and short wings usually inherited together.
4. "Packages" of genes that are inherited together are known as _____. These "packages" are _____.

C. Linked Genes are not always inherited together.

1. REVIEW: during meiosis, portions of DNA on homologous chromosomes may be exchanged. This is known as _____.
2. This produces _____, or individuals with new combinations of _____.

3. Crossing-over breaks apart genes in a

   _____.

D. Gene Mapping

1. Crossing-over is more common when genes are located_____ on a chromosome.
2. Crossing-over is _____ between genes that are in close proximity to one another on a chromosome.
3. The _____ of crossing-over can be used to construct a gene map.
4. What does a gene map show?

E. Sex Linkage

1. Sex chromosomes – a single pair of chromosomes which are not _____ (they do not match).
   a. all humans have _____ pairs of chromosomes, one of these is a pair of sex chromosomes.
   b. Females have two " _____" sex chromosomes.
   c. Males have an "_____" and a "_____" sex chromosome. The "____" chromosome is smaller, containing fewer genes.
2. Genes located on the sex chromosomes are said to be

   _____.

3. Result of sex linkage: many recessive alleles for genes on the sex chromosomes are seen more often in _____, which have only one copy of the gene.

F. Mutations

1. Mutations are a change in the _____ of an organism.
2. Mutations may result from:
   a. mistakes in _____.
   b. Exposure to _____ - substances that cause mutations.
      Examples: _____

G. Gene Interactions

1. Mendel's principle of dominance is not always observed.
2. **Dominance** (review) – one allele masks the other in _____.
   a. the dominant gene is usually _____ whereas the recessive allele is not.
3. **Incomplete dominance** – Heterozygotes show a _____ phenotype which is _____ between parent phenotypes.
   a. Ex. Parents: Red flowers X White flowers (both purebreds)
      Offspring: _____
4. **Codominance** – heterozygotes express both alleles and both _____ show up in the offspring.
   a. Ex. Parents: Red hair X White hair (both purebreds)
      Offspring: _____

5. **Polygenic Inheritance** – many traits, especially in humans, are controlled by more than a single gene.
   a. Ex: _____

NOTES, Part II: Genetic Technology

H. Breeding Strategies

1. Farmers have increased the productivity of domesticated plants and animals over time through breeding strategies.
2. **Selective Breeding** – only breed those individuals with _____ characteristics.
   a. **inbreeding** – crossing individuals with similar characteristics
      1) used to maintain a stock of similar organisms
      2) risk: _____
      3) example: _____
   b. **hybridization** – crossing dissimilar individuals
      1) hybrids are often hardier than either parent, a phenomenon known as _____.
      2) example: _____

I. Mutagenesis

1. **Mutagenesis** involves using _____ to increase the mutation rate.

2. On occasion, mutations may produce _____ characteristics.
3. Mutants are often studied by _____.

J. DNA Sequencing – (review from Ch. 7)

1. reading the sequence of DNA bases (_____ method)

2. **Human Genome Project** – the worldwide effort by scientists to sequence the entire human genome.

K. Transgenic Organisms

1. **Transgenic** organisms contain _____ from other organisms.
2. DNA is cut in very specific locations by _____ enzymes. These enzymes have many other applications.
3. _____ DNA contains genetic information from two different species.

L. DNA Fingerprinting

1. This technique can be used for _____.
2. Based on the fact that humans have large amounts of "_____" DNA between functional genes. This DNA is made of _____ sequences that code for _____.
3. This "_____" varies from one person to the next. Functional genes vary little.

4. DNA samples are cut with _____ enzymes and separated by _____, producing a distinct pattern of bands.

M. Cloning

1. What is cloning?

2. Why clone?

3. Risks of Cloning:

N. Ethical Considerations (notes on class discussion)

APPENDIX E-IV.

FORMAL LAB REPORT

In order to document the experiment you designed and its results, you will be writing a formal lab report. Although experiments were designed by the group, each individual is responsible for submitting a unique lab report.

FORMAT:

The format for this lab report is outlined below. A rough draft of items I.-V. must be completed before running your experiment. You should work with your lab partners to develop the procedure, but type up your own version for the lab report.

I. TITLE: Write a catchy and descriptive title for your lab.

II. PURPOSE: Write a brief statement explaining the goal of your research.

III. HYPOTHESIS: Generate an educated guess about the outcome of your experiment.

IV. MATERIALS: List all of the materials to be used in your experiment.

V. PROCEDURE: Write a step-by-step procedure that could be followed by another student to replicate your experiment. It may be helpful to make drawings of your setup.

VI. DATA: Neatly organize the raw data from your experiment in a data table of your design.

VII. ANALYSIS: Summarize the results of your experiment. Compare your data both qualitatively and quantitatively. Show all calculations and graphing.

VIII. CONCLUSION: Does the data support or reject your hypothesis? Explain. How could your experiment be improved?

GRADING:

Projects will be graded on the effort put into designing the experiment and writing the lab report. Lab reports should follow the proper format and be typed. Emphasis will be placed on the clarity of your lab procedures, effort spent on presenting and analyzing data, and the accuracy of your conclusion.

APPENDIX F

STUDENT SURVEY: TAKING NOTES IN BIOLOGY

Respond to each statement using the rubric below.

5 agree very much
4 agree
3 neither agree or disagree
2 disagree
1 disagree very much

1 2 3 4 5	Taking notes in biology helps me to understand the concepts in the book.
1 2 3 4 5	The notes we take in class are helpful in studying for tests.
1 2 3 4 5	Taking notes on a prepared outline is easier than on notebook paper.
1 2 3 4 5	The notes taken on outlines are more accurate than notes taken by myself on notebook paper.
1 2 3 4 5	Taking notes on an outline allows me to listen more carefully to the lecture.
1 2 3 4 5	Taking notes on an outline allows me more time to ask questions.
1 2 3 4 5	Taking notes on an outline allows me to get more understanding from the lecture.
1 2 3 4 5	I recommend that you use note outlines in the future.

Comments regarding note-taking:

APPENDIX G

NOTES: YEAST LIFE CYCLE

A. Yeast – unicellular fungi we will use to investigate genetics.

1. Asexual Reproduction – Yeast reproduce asexually through a special form of cell division known as "budding".

Yeast cells grow a "bud" on their side. When this bud is large enough, the nucleus divides (mitosis) and one is transferred into the bud. Finally, the new cell will separate from the parent cell.

2. Sexual Reproduction – Occurs between haploid cells of opposite mating types (+, –)

Haploid cells

Haploid "schmoos"

Diploid zygote

Budding zygote

Diploids

Budding diploids

B. Haploid Strains of Yeast for Lab

1. HBT: creamy-white color
2. HA2: pinkish-red color
3. These strains are of opposite mating type.

C. Growing Yeast in Lab
   1. Innoculate – To transfer a pure culture (one species or strain) onto a sterile growth medium.
   2. YED agar – nutrient-rich growth medium for yeast.
      a. Yeast Extract – provides vitamins and minerals.
      b. Dextrose (glucose) – a simple sugar, the preferred food of yeast.
      c. Agar – provides a semisolid support for ingredients and yeast.

D. Mutants are organisms that have been genetically modified (DNA changed in some way).

E. Our Mutants:
   1. HBT (white):
      a. Do not carry the gene for making tryptophan (amino acid).
      b. HBT cells need to get tryptophan from their environment in order to survive.
      c. YED agar contains tryptophan.
   2. HA2 (red):
      a. Lack the gene for making adenine (nitrogenous base).
      b. HA2 cells need adenine to survive.
      c. YED agar contains adenine.
   3. Diploid cells from mating mixture:
      a. Diploid cells contain two copies of every gene.

b. Our diploid yeast cells contain 1 good copy of the gene for making tryptophan (from HA2 parent) and adenine (from HBT parent), and 2 copies of all other genes (one from each parent).
c. These diploid cells can make their own tryptophan and adenine.

F. Replica Plating:
1. Transfer cells from each colony onto a new plate.
2. Day 4 procedure: transfer cells from YED to MV agar.
   a. MV agar contains no tryptophan or adenine.
   b. Only diploids will survive on MV
3. Day 5 procedure: transfer diploids from MV to YED agar.
   a. This generates an actively growing diploid colony.
4. Day 6 procedure: transfer cells from YED to YEKAC agar.
   a. YEKAC agar substitutes dextrose with potassium acetate, which is a low quality food. It also has no nitrogen, and contains only ¼ the yeast extract of YED.
   b. Yeast cells placed on YEKAC will form spores through meiosis (sporulation). This reduces the chromosome number from diploid to haploid.
   c. Sporulation of a single diploid cell results in the formation of a single ascus containing 4 haploid spores. The spores will remain dormant until conditions improve.
   d. Diagram:

   e. When conditions improve, the ascus will break, schmooing will occur, and conjugation will form diploid zygotes.

APPENDIX H

Lab Schedule for Implementing *The Yeast Life Cycle* Lab

Hudecek, 2000

Day 1: Getting Ready (No Lab)

Students receive all lab materials and groups are formed. Notes on the yeast life cycle are started in lab notebooks. Topics include yeast, asexual reproduction and budding (review mitosis), sexual reproduction in yeast, a description of the haploid strains to be used in lab, and basic techniques on growing yeast in the lab. Students are expected to have prelab complete for next day's procedure.

Day 2: Innoculating Petri Dishes. (15 minutes lab per group on rotation)

Students complete day 1 of the procedure from the lab manual. Groups of students each spend about 15 minutes in lab as they are rotated through three lab stations. In the first station, students practice their technique of scraping plain agar with toothpicks. In station two they label a YED agar plate, and in station three they innoculate plates with the haploid yeast strains HA2 and HBT. Downtime for students not in lab is spent working on prelab for the next day or answering analysis questions for this day.

Day 3: Mating haploid strains of yeast. (Full hour of lab for all groups)

All students spend the full hour in lab as they complete day 2 of the procedure from the lab manual. Students observe phenotypes of each haploid yeast strain (HA2 is red, HBT is white) Students make macroscopic and microscopic observations of their haploid colonies in their notebooks. Sterile toothpicks are used to prepare a mating mixture in the center of the petri dish. Extra time is used on lab notebook.

Day 4: Observing Zygotes in the Mating Mixture (All groups in lab last 20 minutes of class)

Notes are continued in the lab notebooks. Topics include genotype vs. phenotype, mutants, mutations found in HA2 and HBT yeast strains, gene combinations of mating mixture, and the technique of replica plating. Students get back into lab during last half of hour to make observations of plates and prepare wet mounts of mating mixtures to look for schmoos, zygotes, and budding zygotes.

Day 5: Selecting diploid cells (15 minutes lab, beginning of hour)

Students spend 15-20 minutes in lab making observations of YED plates and then prepare a replica plate on MV agar. The difference between haploid and diploid is emphasized. Only diploids will be able to survive on MV agar. The remainder of classtime is used to answer questions and finish notebook entries for the week.

Day 6: Preparing for Sporulation (20 minutes lab at end of hour)

Notes on yeast are continued in lab notebooks. Topics include a review of the entire lab to date, and the purpose of MV and YEKAC agar. Sporulation is discussed and meiosis is reviewed. Students make further drawings of this phase of the yeast life cycle. The last 20 minutes of class are spent in lab making final observations of MV plates and transferring yeast onto YEKAC agar. Wet-mount slides are prepared of the mating mixtures for microscopic observations.

Day 7: Meiosis of Diploids through Sporulation (15 minutes lab time)

Lab procedures and sporulation (through meiosis) are briefly reviewed and students spend about 15 minutes in lab transferring the mating mixture from MV to YEKAC agar. Time is provided to complete analysis in class. Notebooks will be spot checked tomorrow.

Day 8,9: (No Lab)

No lab is performed on these days. Time is used to check lab notebooks, a review of lab to date, completing prelab for last two days, and a quiz and a discussion of the quiz over the lab up to this point.

Day 10: Observing Asci and Germination of Haploid Spores

This is a full day of lab for all students. Observations of YEKAC plates are made, and students prepare wet-mounts to look for asci and spores. Using the zig-zag technique, students transfer spores from YEKAC to YED in an attempt to isolate individual haploid spores.

Day 11, 12: Observing phenotypes of germinating haploid spores

Students make final observations for yeast lab by observing all YED plates prepared by the class. They are looking for the original red and white phenotypes from the haploid strains we started with. Comparisons with other groups are made and the class has a final discussion of the results.

APPENDIX I

SUMMARY OF STUDENT RESEARCH
from *Designing a Controlled Experiment (2000).*

Student Research during the 1999-2000 school year focused on one of three areas: Lethality and mutagenesis involving UV-C radiation, photoreactivation, or yeast growth. A summary of student experiments and results follows.

1. Experiments Involving UV-C Radiation.

Many students chose to modify or improve the Lethality and Mutagenesis Lab by looking for what may have been hidden variables in the procedure. Other students tried survival experiments comparing two different kinds of yeast. These experiments proved to be very interesting. A summary of some of the more interesting experiments designed by students follows:

Summary of UV experiments Designed by Students:
Survival of cells vs. spores
Survival of diploids vs. haploids
Survival of wild vs. mutant yeast
Survival rates as a function of vertical position in goggle cabinet
Survival rates as a function of horizontal position in cabinet
Survival rates with lids on petri dishes compared to lids off petri dishes
Survival rates for continuous exposures vs. fragmented exposures

Results from these experiments showed that:

- Position in the goggle cabinet is a big factor in survival. Petri dishes placed lower in the goggle cabinet during an exposure have considerably fewer survivors. Also, the center of the cabinet turned out to be much more lethal than the sides.

- Mutant yeast could better survive radiation exposures that the wild strain of baker's yeast. However, when I think about how these mutants were probably made, it seems to make sense.

- It was shown that diploids survive UV-C radiation better than haploids.

- Also a continuous exposure of 50 seconds is much more lethal than five interrupted 10 second exposures.

2. Photoreactivation Experiments

Some students chose to test the hypothesis that sunlight helps yeast to repair ultraviolet damage to DNA. These experiments involved using UV-C radiation from the goggle cabinets as well as UV-A radiation from fluorescent bulbs. A typical experiment involved exposing yeast cells on YED agar to radiation in the goggle cabinet for a given amount of time. Then, some plates were wrapped with aluminum foil to prevent any light from reaching the cells. Other plates were given UV-A exposures under a fluorescent light hood. Survival and Mutant data were then compared to control plates receiving no radiation to calculate the surviving percentages in each treatment. Results on this experiment were varied. Most showed little or no difference in survivorship.

3. Growth Experiments

Students wanting to do something different chose to test the growth rate of yeast in different environments, or to compare the growth of two types of yeast. Most students grew yeast in liquid cultures, and pipetted diluted suspensions onto YED plates to measure the population size. Most growth experiments were completed over a four-day period. The first day they prepared any media that needed sterilization. On the second day, these liquid media were innoculated with the yeast of their choice, and the initial population size was measured by pipetting a certain dilution onto a YED plate. On the second and third days, students did serial dilutions of their cultures and pipetted these onto YED plates to measure the population growth. This became sort of a guessing

game because each group could only use one YED plate to measure the population size on a given day. On the first day most students had hundreds of colonies to count, on the second day it was typical for students to have thousands of colonies, and by day 3 many students were unable to count individual colonies. This surprised students because they were diluting the suspensions more and more each day. What a good review of exponential growth! After the data was collected, students multiplied the number of colonies by the dilution factors used on that day in order to generate a population curve in each treatment. Examples of experiments designed include testing growth in different types of food and at different temperatures. It was shown that yeast grow better in baby food media prepared with a fruit than with a vegetable. Also, yeast growing in media containing 5% ethanol seemed to grow very little. Refrigeration of the growth media also greatly slows down the growth rate.

A few groups designed heat experiments that were rather interesting. They were interested in the maximum temperature yeast could survive in. One experiment involved heating up a dilute yeast suspension and measuring the population size at various temperatures. Most groups doing these experiments found that most yeast will die off somewhere between 50-60°C. Another group did a heat experiment comparing the survival of spores verses live yeast cells. Their results showed that spores had better survival rates at elevated temperatures.

APPENDIX J

ACTIVITY ASSESSENT

Hudecek, 2000.

Name of Activity: _____ Date: _____

Respond to each statement using the rubric below.

5 agree very much
4 agree
3 neither agree or disagree
2 disagree
1 disagree very much

1 2 3 4 5 I found this activity both interesting and fun.

1 2 3 4 5 The activity taught me a new concept or skill.

1 2 3 4 5 The activity helped reinforce the concepts being taught in class.

1 2 3 4 5 I recommend this activity be taught in the future.

What did you like most about the activity?

What did you like least about the activity?

What might improve the activity?

APPENDIX K

GENETICS PRE/POST TEST

A. REVIEW TOPICS:

1. A petri dish with nutrient-rich agar is innoculated with a pure culture of yeast. Within a few days, a healthy colony has grown up.
   a. What conditions are necessary to get these results?

   b. Describe the pattern of growth rates over these first few days.

   c. What causes the colony to stop growing after a few days?

   d. What would happen if a bacterium was introduced on the same petri dish with the yeast? Explain your answer.

2. a. What is the purpose of respiration and fermentation?

   b. What is the difference between respiration and fermentation?

   c. Under what conditions would colonies of yeast ferment? Respire?

3. a. What is DNA?

   b. Describe specifically what cells do with their DNA.

   c. What problems could arise if mistakes occurred during DNA replication?

4. a. What might slow down the growth of cells on a petri dish?

   b. What might a unicellular organism do when conditions suddenly become unsuitable for growth?

   c. Describe how both mitosis and meiosis are important in a population of organisms.

5. a. What characteristics place yeast into the fungi kingdom?

   b. In what ways are yeast different from other fungi?

   c. How can yeast be useful in science? In other areas?

6. a. Describe the setup necessary for a controlled experiment.

b. Describe a possible experiment to test the following hypothesis: *Bacterium A* causes disease in mice that have not reached reproductive age. (3 pts)

B. TOPICS IN GENETICS:

1. Laboratory Skills

a. Describe three things important to sterile technique in culturing microorganisms.

b. Describe three ways of manipulating microorganisms grown on agar.

c. Describe three reasons working with microorganisms is advantageous for a researcher in biology.

2. Classical Genetics

a. What is genetics? Give two examples of what you believe genetics involves.

b. What is a "gene"? How do genes determine the characteristics of an organism?

c. Explain how traits from parents are passed on to their offspring.

d. A white chicken is mated with a black chicken and all of the offspring are white in color. How is this possible?

e. Two black chickens are mated and the offspring contain both white and black chickens. Explain how this is possible.

f. Farmers often plant "hybrids". These plants tend to produce higher yields than purebred crop plants. What is the difference between a purebred and a hybrid?

g. Describe two factors that determine an organisms outward appearance?

h. Purebred mice that are black are crossed with hybrid mice that are also black. If black is dominant over brown, describe the results of this cross. (Assume fur color is controlled by one gene)

i. Purebred tall pea plants are crossed with purebred short pea plants. If tall is dominant over short, describe the genotype and phenotype of the offspring. Also describe the second generation of offspring produced when these plants self-pollinate.

3. Modern Genetics

a. Farmer Bob has 5 chickens and would like to raise more so he can sell meat and eggs. Describe how he might become most successful in this venture.

b. The human genome project is aimed at sequencing all of the genetic information possessed by humans. Describe one possible benefit and risk involved in this project.

c. What is a "mutant" organism?

e. How might a cell's DNA be altered or damaged? Explain.

f. How might an organism with altered DNA be useful in scientific research?

h. Explain how mutations could be both good and bad.

i. What is DNA fingerprinting? What characteristics of DNA make this possible?

j. How is DNA fingerprinting done? Summarize the process.

APPENDIX L

Date: March 14, 2000

To: Students and Parents of Mr. Hudecek's Biology class

From: Mr. Hudecek

RE: Collection of Data for Master's Thesis

Dear Students and Parents,

During the next few months, we will be studying two units on genetics, just as we normally do at this time of the year. The first of these units will cover classical genetics and the second will cover modern genetics. As part of my masters's program through Michigan State University, I have designed a more lab-based approach to teaching these units. These labs involve growing mutant strains of yeast in the lab, which are then used as the organism of study for our investigations. These labs have been taught and modified during the 1998 and 1999 school year, and I am now ready to teach the final version of this unit.

In order to evaluate the effectiveness of this unit, I will be collecting pre and post-test data from the students. These tests will cover fundamental concepts in genetics, as well as a review of other topics that I believe the labs will reinforce. In addition, student surveys will be given to measure attitude and interest toward this approach. These tests and surveys will be a required part of the course for all students. With your permission, I would also like to use data from these assessments for my master's thesis.

Please fill out the bottom portion of this letter and return it to me by March 17. I am asking your permission to use the data from your son or daughter's tests and surveys related to the genetics unit for my thesis. There is no penalty for denying permission to use your data. Names will not be used in the thesis, and your decision will not affect your son or daughter's grade in any way. In addition, you may request that I don't use the data at any time during the study. Thank you for your time and cooperation.

Sincerely,

Josef J. Hudecek

_____ I give Mr. Hudecek permission to use data collected from my pre/post-test assessments and student surveys in his Master's Thesis. I understand that

Mr. Hudecek will maintain my confidentiality in doing so, and I may change my decision on this at any time during the unit.

_____ I do not wish for Mr. Hudecek to use data from my tests and surveys as part of his Master's thesis. I understand that there is no penalty for choosing to do so.

Student signature _____ date _____

Parent/Guardian signature _____ date _____

APPENDIX M

Pre/Posttest Scores on Review Topics:

Student	Pretest	Posttest	Gain
1	20.0	57.8	37.8
2	18.9	63.3	44.4
3	46.7	84.4	37.7
4	25.6	66.7	41.1
5	30.0	71.1	41.1
6	27.8	45.6	17.8
7	16.7	36.7	20.0
8	25.6	62.2	36.6
9	41.1	92.2	51.1
10	28.9	40.0	11.1
11	36.7	52.2	15.5
12	35.6	66.7	31.1
13	46.7	95.6	48.9
14	22.2	60.0	37.8
15	43.3	91.1	47.8
16	55.6	92.2	36.6
17	41.1	56.7	15.6
18	26.7	67.8	41.1
19	38.9	65.6	26.7
20	26.7	57.8	31.1
21	14.4	31.1	16.7
22	26.7	56.7	30.0
23	22.2	60.0	37.8
24	36.7	61.1	24.4
25	47.8	88.9	41.1
26	46.7	83.3	36.6
27	28.9	64.4	35.5
28	54.4	90.0	35.6
29	37.8	67.8	30.0
30	15.6	53.3	37.7
31	25.6	62.2	36.6
32	37.8	51.1	13.3
33	47.8	75.6	27.8
34	21.1	55.6	34.5

35	27.8	67.8	40.0
36	50.0	80.0	30.0
37	41.1	72.2	31.1
38	26.7	63.3	36.6
39	24.4	58.9	34.5
40	33.3	64.4	31.1
41	27.8	64.4	36.6
42	44.4	83.3	38.9
43	41.1	80.0	38.9
44	32.2	68.9	36.7
45	37.8	54.4	16.6
46	36.7	60.0	23.3
47	47.8	95.6	47.8
48	33.3	58.9	25.6
49	41.1	76.7	35.6

Summary Pre/Posttest Scores on Review Topics:

Score	Pretest	Posttest	Gain
High Score	55.6	95.6	51.1
Low Score	14.4	31.1	11.1
Mean Score	34.0	66.8	32.9
Median Score	33.3	64.4	35.6
Mode Score	41.1	60.0	37.8
Standard Deviation	10.5	15.1	9.7

APPENDIX N

Pretest/Posttest Scores on Genetics Topics:

Student	Pretest	Posttest	Gain
1	12	37	25
2	24	47	23
3	24	92	68
4	14	45	31
5	21	58	37
6	13	61	48
7	5	21	16
8	9	50	41
9	31	70	39
10	12	35	23
11	25	53	28
12	21	71	50
13	21	83	62
14	10	38	28
15	28	74	46
16	31	87	56
17	15	72	57
18	26	55	29
19	20	66	46
20	27	68	41
21	9	17	8
22	11	44	33
23	11	19	8
24	18	67	49
25	32	90	58
26	26	55	29
27	17	58	41
28	24	85	61
29	0	75	75
30	24	34	10
31	11	41	30
32	34	51	17
33	52	91	39
34	17	43	26

35	24	52	28
36	38	73	35
37	22	71	49
38	24	67	43
39	17	55	38
40	20	55	35
41	27	67	40
42	26	85	59
43	17	73	56
44	26	63	37
45	27	64	37
46	7	59	52
47	32	87	55
48	17	55	38
49	27	70	43

Summary of Pre/Posttest Scores on Genetics Topics:

Score	Pretest	Posttest	Gain
High Score	52.0	92.0	75.0
Low Score	0.0	17.0	8.0
Mean Score	20.9	60.2	39.2
Median Score	21.0	61.0	39.0
Mode Score	24.0	55.0	37.0
Standard Deviation	9.4	18.7	15.3