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INCREASING STUDENT COMPREHENSION OF
EVOLUTION THROUGH LABORATORY INVESTIGATIONS
AND SIMULATIONS

presented by

STEVEN W. McCLINTOCK

has been accepted towards fulfillment
of the requirements for the

MS degree in INTERDEPARTMENTAL BIOLOGICAL SCIENCE

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INCREASING STUDENT COMPREHENSION OF EVOLUTION THROUGH LABORATORY INVESTIGATIONS AND SIMULATIONS

BY

STEVEN W. McCLINTOCK

A THESIS

Submitted to
Michigan State University
in Partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Interdepartmental Biological Sciences

2008

ABSTRACT

INCREASING STUDENT COMPREHENSION OF EVOLUTION THROUGH LABORATORY INVESTIGATIONS AND SIMULATIONS

By

Steven W. McClintock

In order to provide an opportunity for students to learn the concept of evolution an evolutionary unit of study was developed. It was designed to provide a hands on learning experience that would assist them in understanding the theory of evolution and the several lines of evidence that support it. By providing several laboratory experiences, simulations, and models students were able to gain an appreciation of the nature of science and an increased understanding of evolution. By utilizing humans as an example the theory of evolution was directly applicable to the students. The students worked in small and large groups, as well as individually, in order to collect and analyze their data. The activities designed for this unit improved the students understanding of the lines of evidence that support the theory of evolution.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr. Merle Heidemann and Dr. Ken Nadler for their guidance and instruction throughout my master's program. I would also like to express thanks to Dr. Chuck Elzinga for his many enlightening discussions, and for sharing his joy of the outdoors, getting lost and a love of fly fishing. I am in debt to Margaret Iding for all that she did for me. To my colleagues who assisted me completing my thesis: Jim Jakiemiec, the English teacher who proof read my papers, Kelly Hartley, the chemistry teacher, who provided his computer expertise and scientific knowledge whenever it was needed, and the school secretaries Gina Jenson, Alma Morales and Tammy Manne for all their help. I would also like to thank my classmates, especially Jen Baker and Amanda Whitfield. Amanda had to tolerate my sense of humor and inability to use a new computer for the summer of 2007 when we carried out our research on evolution. I would like to acknowledge the hard work and perseverance of my students as they performed their multitude of tasks for my research. I am also grateful that friends like Mark Zimmer were willing to assist me with my remodeling projects by moving maple bowling alley lanes. Finally, I would like to thank Floyd and Janet for their endurance in raising three kids and for helping us understand the importance of continuing our education. To the rest of my family, thank you, for their support as I completed my masters program, in particular my wife DeAnn, for all of her support and assistance.

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INTRODUCTION

The introduction of the new state science standards, (Appendix I, A) which have greater emphasis on evolution and the process of science, presented an opportunity to develop a lab-centered evolution unit. This unit gave my students the opportunity to develop hypotheses and make predictions about upcoming activities and witness the process of science first hand. When they finished with their investigation, they came to their own conclusions based on their outcomes. Through a lab-centered unit, with limited lectures and note taking, students should start to develop an understanding of evolutionary processes and improve on their test scores, as well as prepare for future merit tests required by the State of Michigan. Lawrence Scharmann (2005) stated that teachers should try to utilize lessons that involve student-centered activities. Massimo Pigliucci (2007) mentioned that lectures should play a smaller role in teaching. Instead, students should engage in open ended inquiry activities that stress how science functions rather than what science says. Robert Pennock (2007) of Michigan State University believes that there are no substitutes for hands on learning and lab activities. In these hands-on learning exercises, student are allowed to participate in the process of scientific discovery.

Knowing that faith and religion are strong components of the community of Kent City, Michigan, I utilized this research to gain a more comprehensive understanding of what my students thought of evolution and if their beliefs would inhibit them from learning how the theory has developed and understanding the research that supports it. My goal was to develop labs that would allow students to actively participate in the learning process and employ laboratory activities that stressed the nature of science and aided in developing life-long learners. When a concept that conflicts with personal belief systems exists, as it does with religion, it may take maturation of the learner to fully develop a respect and understanding of nature of science and evolution.

Evolution and science have been scrutinized, especially in recent political debates and with the release of Ben Stein's movie Expelled:No Intelligence Allowed. The attacks on science and in principal the theory of evolution are carried out from several different fronts. Evangelical ministers, such as D. James Kennedy and John Hagee, profess the evils of evolution and its negative impacts throughout history. In Darwinism Under the Microscope, D. James Kennedy stated "In the last few decades, every major pillar of the evolutionary faith has been collapsing all around us. And yet we have evolutionists today saying 'Evolution is a fact. It is not only a fact, it is a most thoroughly proven fact in all of science.' Nonsense. But the truth will win out, and I am sure the day will come when evolution will be recognized to be a pernicious and harmful theory, falsehood, deceit, and fairy tale that it really is." (Gills & Woodward, 2002) A student gave me Gills & Woodward, Darwinism Under the Microscope four or five years ago. She stated that this book would prove to me that evolution was false. In general, the authors of the book disguise Intelligent Design (ID) as a science that questions several aspects of current evolutionary research. By quoting literature from different scientists, philosophers, and mathematicians, they pose that if evolution is false, then ID must be correct. Michael J. Behe, Ph.D. , author of Darwin's Black Box, proclaims, in Darwinism Under the Microscope, that if the biological components of a cell are irreducibly complex molecular machines, then their existence can only be designed by an intelligent agent. He argues that he is not operating under religious ideas, but under the rules of science and is completely empirical (Gills & Woodward, 2002).

Many politicians throughout the state are introducing bills in state legislative bodies pushing for the theory of evolution to be either strongly questioned as a legitimate theory or stating that it should be taught along with other rival theories such as Intelligent

Design, Creationism or other types of theories. The Grand Rapids Press (GRP) recently covered two new bills, both known as the "Academic Freedom Law". They were introduced in the state House and Senate to address the ID/evolution debate. House Bill 6027 (2008) is sponsored by State Representatives Republican John Moolenaar of Midland, Fulton Sheen of Plainwell, and supported by Tom Pearce, Republican of Rockford, Dave Agema of Grandville, and Judy Emmons of Sheridan (GRP June 8, 2008). The lone Democratic sponsor is Representative Joel Sheltrown of West Branch. Senate Bill 1361 is sponsored by Republican Senators Bill Hardiman, of Kentwood, Wayne Kuipers of Holland, and Mark Jansen of Gaines Township. Bill Hardiman said that he was inspired by the documentary Expelled: No Intelligence Allowed, and believes that science teachers should have the freedom to teach and discuss ID. The bill states schools can not be prohibited from helping students understand, analyze, critique or review in an objective manner the strengths and weaknesses of scientific theories. Dave Agema believes that students should be allowed to think critically and should be able to see the facts, including alternative views of the theory of evolution. (GRP June 13, 2008)

Currently, this same "debate" is also taking place in 5 other states: Alabama, Florida, Louisiana, Missouri, and South Carolina. In Texas, the fight over science textbooks, the teaching of evolution, and the language that is used should make those involved in education concerned. The Texas Education Board will decide the curriculum for the next ten years and will be involved in the determination of the strength and weaknesses of evolutionary science. Glenn Branch of the National Center for Science Education warns that "what happens in Texas does not stay in Texas". Texas is one of the largest purchasers of textbooks in the nation and publishers try to appease Texas and often refuse to print different versions of the same text in order to reduce the cost of publishing text books (GRP June 8th, 2008).

In many political campaigns, the debate has come to the forefront. In the Michigan's Governor's race, in 2006, Dick DeVos, Republican candidate, told a reporter that he supports the teaching of "intelligent design" alongside evolution in public schools. DeVos stated "I would like to see the ideas of intelligent design that many scientists are now suggesting is a very viable alternative theory, and that theory, and others that would be considered credible would expose our students to more ideas , not less." (http://www.ncseweb.org/resources/news/2006/ MI/553_creationism)

In the Republican presidential debate, May 3, 2008, the candidates were asked if they disagreed with evolution, to which three of the ten responded yes. A fourth candidate said that he believes in evolution but feels God played a role. (http://pewforum.org/docs/?DocID=215) Bobby Jindal, Governor of Louisiana, a potential candidate for vice president ,running mate for John McCain, when questioned on the news show Face the Nation, Sunday June 15, 2008, stated he thought Intelligent Design should be taught in public schools, that students should look at the "evidence" for both and come to their own conclusions.

It's no wonder that students are confused by the topic of evolution or strongly believe it to be false. They are told by many in the public domain that it is incorrect or it is not the only theory of the origins of life and that it is filled with gaps. Public polls shed some light into what Americans believe about evolutionary sciences. According to The National Center for Science Education in a poll conducted by Gallup, 35% of those polled in November, 2004 thought that evolution was well supported and 35% said that it was not, while another 29% said they did not know enough about the topic to reply. In that same poll, 38% said they thought humans evolved over millions of years, guided by God, 13% had the opinion that humans evolved over millions of years in an unguided process and 45% had the view that God created humans in their present form within the last 10,000 years. In a June 2007, USA Today/Gallup poll, 18% thought humans evolved over millions of years as a definitely true statement, 35% thought it was probably true, while 16% thought it to be probably false and 28% thought it to be definitely false. When respondents were asked for their feelings on if Creationism- "the idea that God created humans pretty much in their present form within the last 10,000 years", 39% responded with definitely true, 27% thought it to be probably true, 16% said it was probably false and another 15% said that it was definitely false. Three percent of the people who were polled responded "unsure" to both of the previous questions. A Newsweek poll, conducted by the Princeton Survey, in late March 2007, found that 30% thought God guided the process of human origin and development, 13% thought that God played no part and 48% responded that God created humans in their present form. Nine percent were unsure of the how the process occurred. In the education of evolution and creation poll conducted by the Pew Research Center for the People and the Press Forum on Religion and Public Life survey found that a majority, 58%, favor the teaching of creationism along side of evolution in public schools. That same poll found that 51% thought that the decision to teach or not to teach creationism should be decided at the federal level, while 35% thought it should be a state right. (www pollingreport.com/science.html)

In <u>Evolution and Creationism in America's Classroom: A National Portrait</u>, a survey of high school biology teachers, between March 5 and May 1, 2007, found that these teachers on average allocated 13.7 hours of instruction toward evolution, with 59% of the teachers allowing between 3 and 15 hours of instructional time. Only 2% excluded the topic of evolution completely and another 17% excluded human evolution. Twenty three percent of the teachers who believed evolution to be a major unifying theme for biology dedicated 18.5 hours of instruction towards evolution. They also found that 25%

of the teachers who participated in the survey spent time on intelligent design or creationism. As in other national polls on evolution and intelligent design, they asked biology teachers about their own personal beliefs. When asked how humans evolved and developed, 28% thought that humans evolved over millions of years without divine intervention, 47% thought that humans evolved under the guidance of God over millions of years and only 16% believe that humans were created in our present form within the last 10,00 years. They found that the concept that was least accepted by teachers was that evolution was testable and humans evolved. They found that 37% responded in a manner that suggests evolution can not be scientifically tested. Over 30% responded in an unfavorable manner that humans are the product of millions of years of evolution. Many feel that the suggested solution to this dilemma, lack of teacher comprehension of evolution, is to increase teacher preparation and focus on certification standards for biology teachers. Winning court cases alone will not improve the science education of American youth. There should be standards in place that require biology teachers to take courses in evolutionary biology. (Berkman, Pacheco and Plutzer, 2008). Massimo Pigliucci (2007) insists that teachers should be mandated to continue their education and should consider teaching to be a life long learning experience. In order to keep up to date with recent findings, research and discoveries, teachers should take classes that emphasize evolution.

In an informal poll conducted March 24, 2005, by the National Science Teachers Association (http://www.nsta.org/about/pressroom.aspx?id=50377), 31% of the teachers feel pressured to teach Intelligent Design or creationism in their science classrooms. The pressure was applied by students and parents at nearly equal amounts. When they were asked if principals and superintendents were pressuring teachers to omit or deemphasize evolution only 5% and 3% respectively said that they did.

In the United States there have been several attempts at implementing some form of creationism or intelligent design instruction into the science class room. George J. Annas, (2005) broke the attempts of reducing or omitting evolutionary instruction, in public schools, into four waves. He described the first wave as an attempt at outlawing Darwin's theory of evolution all together. The court case that highlighted the first wave was the Scopes trial in which Clarance Darrow defended teacher John Thomas Scopes against prosecutor William Jennings Bryant. Scopes was convicted of violating the Tennessee law that prohibited any public school teacher from teaching theories that deny the divine creation of the bible. Upon appeal, the Tennessee Supreme court later threw out the case and ordered that Scopes was not to be tried again. The second wave was described as the development of creationism. This challenged the First Amendment prohibiting state established religion. In 1981, the state of Arkansas enacted a law that allowed for the balanced treatment of creation-science and evolution-science. It was overturned in court the next year.

As court cases related to teaching evolution in science classes were lost, the definitions used by opponents to evolutionary theory began to change in an attempt to distance themselves from any religious groups or deity. This was the framework for the third wave. The term Intelligent Design (ID) was strongly supported by the Discovery Institute as the new creation-science. The Discovery Institute is based in Seattle, Washington. The Discovery Institute's website states that "The point of view Discovery brings to its work includes a belief in God-given reason and the permanency of human natures..."(http://discovery.org/aboutFunctions.php). The goal of the Discovery Institute was to discredit evolutionary science by finding gaps in information or by misrepresenting current research and data. The Thomas Law Center defended the Dover School board after scouring the country looking for a school board who was willing to test the courts on ID. The Thomas Law Center located in Ann Arbor, Michigan (http://www.thomasmore.org/qry/page.taf?id=23) is a not-for-profit law firm dedicated to the defense and promotion of religious freedom of Christians . With the unifying of old earth and young earth creationists, Philip Johnson, a law professor, helped develop the Wedge Strategy, which was to provide scientific alternatives (ID) to evolution (Pennock, 2006). The first challenge to this new direction of attack on evolution occurred in Dover Pennsylvania, in Kitzmiller et al. v. Dover Area School District trial. The school board proposed making the book Of Pandas and People available to those students who were interested in reading the science of Intelligent Design. They also required ninth grade students to hear a statement, prior to instructions on evolution, that Darwin's theory is "not a fact" and has inexplicable "gaps" (http://www.msnbc.msn.com/id/10545387). The trial took six weeks, in which Judge John E. Jones III stated that "it is an interesting theological argument, but it is not science for several reasons... it relies on the same flawed arguments as creationism". According to Annas (2005), the fourth wave followed in which several states and school boards throughout the country began reversing previously made laws and mandates in favor of ID, due to the outcome of the Dover Case.

I would argue that the fifth wave is upon us. As the result of many court cases, the intelligent design movement, under the direction of the Discovery Institute of Seattle, has started to sway public opinion and is trying to write laws that may be able to pass the jurisdiction of the courts and the First Amendment. They are attempting to carry out scientific research that supports ID, and using mass media to get their information out. By publishing literature, hosting seminars, making appearances on televised programs they hope to promote that the "science" of ID becomes more popular. Finally, the Discovery Institute seeks to influence teacher training and challenge the legal status of teaching ID (http://www.antievolution.org/features/wedge.html). These efforts are taking place in many of the states House and Senate debates at this moment, including Michigan's, as previously mentioned.

THEORETICAL FRAMEWORK

Knowing the history, the politics, and the social views of evolution, it is no wonder that teachers and students are apprehensive about the nature of science and evolution, even though the theory of evolution is widely supported by multiple lines of evidence and overwhelmingly accepted by the scientific community. How do we convey this information to our students? Will increased efforts to teach evolution improve the student's ability to comprehend and understand the science of evolution?

To begin with, teachers should address the term "theory". The word is used differently within the scientific community and those of the general public. To some, theory is a term used to invoke negative connotations about scientific information, that confuse many people, including teachers and students. The term "theory" is often used to replace the word hypothesis, which can be defined as an educated guess or idea that may answer scientific questions. Many of my students respond to the word evolution with the statement "But it is only a theory". They don't understand that science defines a theory and how strongly a theory like evolution is supported by evidence. When Americans were polled, 75% responded that evolution is thought of as a theory because it has not yet been proven. (Morrison, 2005) Although evolutionary biology is a theory, it is not guesswork or unsupported by evidence. Scientists understand that a theory is a widely supported explanation of nature, based on facts and data derived from several fields of science (Cherif, Adams, and Loehr, 2001). There are 78 member societies of the American Institute of Biological sciences. The American Association for the Advancement of Science has members from many fields of science, all in support of evolution. Their members represent biological, physical, medical sciences as well as mathematics and many others. (Faber, 2003)

The Michigan Science Teachers Association (MSTA) and the National Science

Teachers Association (NSTA) have made statements that strongly support the teaching of evolution and the nature of science (http://www.nsta.org/about/positions/evolution.aspx). The MSTA position statement, which was adapted February 3, 2007, on Evolution Education and the Nature of Science states that:

> Scientists view and seek to explain the natural world through the empirical lens of science. The nature of scientific investigation is to ask a question and then work to find the answer. While philosophy and theology are valuable forms of human inquiry that also seek to explain our world, science is unique in its approach by relying exclusively upon empirical natural law (e.g., the laws of physics, chemistry, geology, etc.) in its explanation and not upon supernatural intervention or untestable conjecture. It is this testability that is a hallmark of the nature and process of science. Scientific hypotheses and theory must be testable against the natural world and therefore at least potentially falsifiable. Furthermore, any conclusions formulated from these tests are tentative pending new data to the contrary. As our scientific knowledge expands and provides us with better insights into the natural world, science is able to modify previous conclusions and theory to incorporate this new knowledge. Like all scientific theories, evolutionary theory is dynamic and will be modified as new information becomes available.....The scientific community's strong advocacy for the theory of evolution is a result of the preponderance of collaborating empirical data originating from virtually all disciplines of the physical and biological sciences. The scientific community regards evolutionary theory as on of the most robust and well-substantiated theories to date as evolutionary theory represents the convergence of corroborating evidence from independent lines of scientific investigation (http://www.msta-mich.org/downloads/about/2007-02-03.doc).

In biology, the underlying theme that is central to all life sciences is the theory of evolution (Faber, 2003). In "Nothing in Biology Makes Sense Except in The Light of Evolution" (1973) Theodosius Dobzhansky stated "Seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science. Without that light, it becomes a pile of sundry facts, some of them interesting or curious, but making no meaningful picture as a whole" (http://www.ncseweb.org/resources/articles/9256_cans_and_cants_of_teaching_ev_2_13_2001.asp). Unlike physical science that is searching for an underlying theme, biology has one, evolution. All of the biological sciences fit under the umbrella of evolutionary sciences (Faber, 2003). It is the mechanism for studying the many interesting questions that face biologists today (Rutledge and Warden, 2000).

Evolution explains how various organisms developed from common ancestors, through the process of natural selection acting on variations within populations leading to the development of new species. It is supported by many different lines of research and data, from the many variations of finches that Darwin discovered on Galapagos Island to the modern field of genetic technology. DNA has been used in determining if the extinct group of humans known as Neanderthal man are related to modern human or were they a distinct group of *Homo sapiens* that could not compete with modern *Homo sapiens sapiens*. Homologous structures and vestigial organs show the relationships that exist between species and demonstrate a linkage to ancestors from the past. Homologous structures of bat wings, whale fins, and human arms are very similar in design, thus giving evidence of a common ancestor that lived millions of years ago. The appendix, a vestigial organ, as well as many other useless organs, indicates that our ancestors may have used these structures and through the process of evolution we have lost the function of those organs. However, they have yet to lose the genetic material that leads to their development. When comparisons are made between the embryo development of different species, it becomes apparent that they develop in the same manner and utilize many of the same genes in the regulation and development of the embryo, thus demonstrating a common ancestry. The multitude of fossil finds throughout the world has indicated that there have been many changes in organisms over the 3.5 billion years of evolutionary history. When Donald Johansen discovered "Lucy," another critical piece of human evolution was brought to light. *Australopithecus afarensis*, in Johansen's scheme of thinking, should be linked by ancestry to *Homo habilis* and possibly modern humans, whereas Richard Leaky would disagree with him. (Edey et al, 1989) Although there is almost unanimous support for the theory of evolution, there can be controversy.

The controversy is not if evolution occurs, but with the details of how or when or what.

When teaching evolution, it is suggested that teachers do so in terms that make it easier to carry out instruction. The first guideline is to focus on the fundamentals, based on four factors: variations, inheritance, time, and selection. The second point to consider is what do you want your students to know and learn: plan out the concepts that you want to use to develop the students' understanding of evolution. And finally, find the resources that you will require to carry out your task.
(http://evolution.berkley.edu/evosite/Lessons/index.shtml)

By using humans as an example when teaching evolution, the students' curiosity will increase. By investigating lines of evidence, students will be able to make phylogenic trees of hominid evolution. This can be achieved by examining models of skulls of living hominids and their ancestors and by using molecular evidence of hominid evolution (Nelson, 2007). By having students measure variations, as well as exploring several lines of evidence, they will have an increased awareness of the nature of science. This provides testable questions that can be answered through investigations, as well as how evolutionary theory is supported (Flammer, 2006). Utilizing hominid skulls also helps to dispel myths such as humans evolved from monkeys or that there is no evidence for the theory of evolution. By comparing hominid skulls, students begin to realize that there are many differences between *Homo sapiens sapiens* and the other hominid skulls, but that they also share characteristics that link them together.

It is also suggested that students may become more interested in learning about evolution if they are aware of its importance to the biological sciences. Without the support and evidence gathered from evolution, doctors would have to continuously go back to square one when they are confronted by new viral or bacterial pathogens. Doctors would be unaware of how vaccinations and the development of antibodies could be used in combating many different ailments. The attempted management of the bird flu, HIV, or for that matter crop sciences and pest management all become unified under the science of evolution. There are many practical uses that are adapted from the research generated in biological science all unified by the theory of evolution (Nelson, 2007).

As we try to enlightening our students about the nature of science and the theory of evolution, we must do so with great care. It is inevitable that some, if not many of our students will be faced with conflict between their religious beliefs and the science that they are responsible for learning. We must take care to educate them in a manner that is respectful of their religious and social beliefs, being aware that at the same time there may be many different cultural and religious groups within a single classroom (Nelson, 2007).

It is important that students are aware of the differences in belief systems and that of science (Scharmann, 2005) . When students ask if I believe in evolution, they are stunned when I respond that I don't. Science is not about beliefs, but I agree that there is overwhelming evidence to support it, therefore evolution is a theory of science. Science addresses natural phenomena that can be empirically tested. There is no scientific means to study supernatural events and, in the process, science is not a fair democratic process but must pass the challenges of critical scientific scrutiny. As teachers, it is important to allow the students to negotiate through learning scientific explanations about the origin of life without convincing them to reject their religious beliefs. To help them through this process, a teacher could provide them with different ways in which others have resolved their personal views on evolution (Faber, 2003). Lee Meadows et al (2000) stress that changing personal views is very troublesome; students that are forced to change their views on religion may experience great anxiety and stress, which is a dangerous situation.

DEMOGRAPHICS

I teach for Kent City Community Schools which is located in northern Kent County, Michigan. The 2000 United States census showed 1,094 lived in the village of Kent City. It is described as a bedroom community in which the average travel to work is 22.2 miles. This conservative community is composed of 82.9% Caucasian and 11.9% Hispanic or Latino people. According to the United States Census Bureau, 79.7% were high school graduates, and only 7.4% had a bachelor's degree. The average for the United States is 24.4% with bachelors degree or higher. The median family income in Kent City was $42,375, below the United Sates average of $50,046 in 1999 dollars. There were 28 families, and 128 individuals that were listed below the poverty line. The community is composed of young families and individuals, the median age 28.1, with 66% of the people being 18 years old or over, and those under 5 years old make up 8.8% of the population (http://factfinder.census.gov/servlet/SAFFFacts?event=&geo_id=160). The community is home to many large orchards that are known for growing apples and cherries, as well as peaches and apricots. There are many small dairy and cattle farms found in the communities surrounding the the Village of Kent City.

In the 2007-2008 school year, there were 1,358 students that attended Kent City Community Schools (preschool-12), of which 20.76% received free lunch and another 8.69% received reduced lunch. The student body was composed of 90% Caucasian, 9% Hispanic, and the remaining students were identified as Asian, African American and Native American. All of the Asian students were foreign exchange students. There were 423 students who attended Kent City High School, for the 2007-2008 school year. The MEAP science scores for the 11th grade class of 2008, were as follows: 13.5% were given a score of level 4 (Apprentice), 13.5% received a level 3 (Basic), 65.2% received a level 2 (Met), and 7.9% earned a score of level 1 (Exceeded). The state averages were

25.0% at level 4, 15.2% at level 3, 54.4% at level 2, and 5.4% at level 1 (http://www.michigan.gov/mde/0,1607,7-140-22709_31168_40135---,00.html). According to an exit poll of graduating seniors in the class of 2008, 74% planned on acquiring a post secondary degree, 3% planned on attending a trade school, 9% planned to enter the military, and 14% planned on entering the workforce.

I have been employed by Kent City Community Schools for 16 years. I am one of three full time teachers that compose the high school science department. For the duration of this research project I taught 5 sections of biology. Students follow the sequence of classes: as freshmen they take Applied science, which consists of units covering space, weather, chemistry, geology, and rock cycles. They then take biology as sophomores and as juniors and seniors they have Anatomy and Physiology, Chemistry I and II, and Physics as optional classes. The largest biology class contained 26 students, and the smallest class had only 12 students. There were 98 students who participated in biology this year, of whom 46 were female. The majority of students were identified as Caucasian, while 8 were identified as Hispanic. Three Hispanic students were participants in the research project. Twelve students qualified for special education services, or assistance through a 504 plan, and an additional fourteen students were identified as needing academic support. These students participated in an academic support class for one hour per day in which a teacher assisted students in becoming more proficient in completing the needed tasks for their classes. Fifty-eight students participated my research, 30 females and 28 males. Of the 58 students, six were eligible for special education services or accommodations through a 504 plan, and four were placed into an academic support class.

IMPLEMENTATION

The implementation of the new state standards, which emphasized evolution to a greater degree, allowed me an opportunity to develop an evolution unit. The newly developed unit allowed students to learn evolutionary concepts through a hands on approach. The evolution unit utilized laboratory activities, which allowed students the opportunity to use the process of science in developing a scientific view of the origins of life and the process of evolution. The unit began with the history of life, which was followed by natural selection, and finally human evolution.

Parent consent forms (Appendix I, B) were sent out at the beginning of the 2007-2008 school year and were returned by October 31, 2007. The consent forms explained the purpose of the research project and asked them for permission to use their children's photograph and classwork in the research project. The student consent (Appendix I, C) forms were handed out in class after they were informed of the purpose of the research. The pre-survey was administered by Kelly Hartley, the chemistry teacher, the day the evolution unit began, April 14, 2008.

Students began the school year collecting and classifying insects. In doing so, they were introduced to classification and evolutionary principles from the beginning of the school year. Eventually, the students covered cells and organelles, and learned that the mitochondria and chloroplasts were similar to bacterial cells, thus providing more evidence supporting evolution.

After we studied genetics, we then began the evolution unit. In the genetics unit, students learned about the role of DNA in determining an individual's characteristics and how DNA is passed to the offspring through sexual and asexual reproduction. In the process of meiosis, genes and alleles are recombined creating new variations. Students became aware that there were many variations among individuals in the classroom. We looked for traits that could be observed easily by students. The students determined how many of their classmates had a widows peak, hitch hikers thumb, tongue rolling ability, ability to taste genetic taste papers, as well as many other characteristics.

This was followed by a study of the role of artificial selection in the development of food crops and pets, including the role artificial selection has played in developing chickens for the use in tying flies. I have a collection of chicken hackles and feathers, that span approximately sixty years of breeding. The feathers that my dad used in his youth, for tying flies, differ greatly from the quality of the feathers obtained from the chickens today.

I can directly demonstrate how mutations may affect an individual and can have positive, negative, or neutral affects on the individuals. I have a syndrome known as Poland's syndrome. It has caused my left hand to be much smaller than my right hand and I am also missing my pectoral major and minor muscles. My left hand becomes a unique teaching tool. I explain to the students that when I was growing up I loved to play sports, but it was very difficult shooting left handed lay ups, which exemplifies how mutations can be negative. They became curious and began asking questions. Inevitably someone asked if it is good for anything. This gave me the opportunity to demonstrate how I can get my left hand into tight spots and manipulate tools and small pieces of equipment easily. I also have the ability to grab pickles out of jars much easier than anyone else in the classroom. This was a trait that my grandmother and mother disliked. When I was young, I would pull pickles out of jars, contaminating the pickles for anyone else who wanted to eat them. All this information prepared the students for our last unit, which unified the entire year. We ended up where we began the year, with evolution. The evolution unit that I developed in the summer of 2007 is summarized in Table 1. The Simulating Radioactive Decay of Carbon ^{14} (Appendix II, A) and Human Evolution:

Hominid Skull Comparison (Appendix II, B) labs were the only labs that I have used in the past, both of which were altered for this project. I normally have great time constraints at the end of the year, which prevented me from implementing more labs. I was also pinched for time because of the five days lost to snow and ice during the winter.

Assignment	Days
Pre-survey	0.5
Pre-Test 14 The History of Life	0.5
Discussion on Science, Religion and Evolution	1.5
Simulating the Radioactive Decay of Carbon-14	1
Lecture on Using Radiometric dating	0.5
Discussion on evidence- fossils, pangea, age of rocks and fossil	1
Evolutionary Time Line	2
Lecture and review Time line, order of organims	1
Review for Test 14	1
Test 14 The History of Life	1
Pretest 15 Natural Selection and the Evidence for Evolution	0.5
A 19th Century Journey	1.5
Discussion Darwin/Wallace/Huxley and their thoughts of evoluti	1
Variations of Seeds within Species of Maple Trees	2
Review Variations and why do they think its important	1
Bead Bug Blitz	2
Lecture and Discussion of Natural Selection	1
Human Variations	2
Discussion on variations, sources and importance	0.5
Comparison of Homologous Structures	1
Different lines evidence	1
Molecular Sequencing of Amino Acids	0.5
Different lines of evidence continued	0.5
Clip Birds	2
Review 15	1
Test 15 Natural Selection and the Evidence for Evolution	1
Pretest 16 Human evolution	0.5
Chronology of Hominids	0.5
Fossil and Migration Patterns in Early Hominids	0.5
Pre Lab Skulls	0.5
Human Evolution: Hominid Skull Comparison	2.5
Lecture on evidence of human evolution and hominids	1
Lab Assessment	1
Review	1
Final Exam and Evolution Assessment	1

Table 1. Evolution Unit Lesson Plan

The unit began with a discussion of the difference between science and religion and how each is used to answer different types of question about our existence. We had an open discussion on belief systems and what different people believe. Many students asked why I don't teach creationism. They suggested that all ideas about the beginning of life should be discussed. My reply was that I teach science, not belief systems. The school could offer a class designed for religious studies, and if I were asked to teach it, I would teach all stories of Creationism from different religions and cultures. In general, the students want only their interpretation of Creationism to be taught alongside of evolution, not all the other religions. This provided me an opportunity to address the differences between science and religion. Science must be non-biased, supported by measurable and reproducible evidence, and independent of their religious beliefs. The basis for all scientific information is the data and evidence that supports it. In the discussion, I tried to convey that it became a personal process and that people combine their religious beliefs and the scientific world in some manner. But there are some people who reject either science or religion completely, in determining their own personal philosophy of the origins of life.

The students were asked to answer questions on pre-test and post-test and perform several tasks on the different laboratory activities. For each of the lab activities, they were given questions that had to be answered. Many of the activities had tables, charts, and graphs that had to be filled in as well. Even though the students worked with teams or partners on many of the lab activities, each student was responsible for his or her own answer sheets. Working with other students allowed them to share data and discuss results prior to turning in their work. The students were also asked to make comments about each lab and to rate them. They rated them from one to five, five being the lowest score and one being the highest score.

Review of Activities

Simulating the Radioactive Decay of Carbon-14 (APPENDIX II, A)

This activity allowed students to work on their graphing skills, a skill that the science department at Kent City has considered to be a weakness among the students taking science courses. Students worked individually on this activity to visualize how the half life of radioactive substances are used to determine the age of given artifacts and materials. They cut the red licorice, which represents the amount of C^{14}, in half by its length. The licorice was placed on graph paper and remained in place until the students can no longer cut their licorice in half. When all the licorice was cut, they then drew a curve demonstrating how radioactive substances decay at a constant rate. They got an image that allowed them to visualize what happens to the amount of C^{14} as it decays into N^{14}. The students were then asked to determine the age of given "fossils" by using the graph that they generated. As they cut the licorice it became apparent that at a certain point they would not have enough C^{14} remaining to accurately measure the age of a fossil.

Human Evolution: Hominid Skull Comparison (APPENDIX II, B)

A few years ago I had the opportunity to listen to Ginny Lambert, discuss using hominid skulls to teach evolution, at the Michigan Science Teachers Association conference. I was introduced to the thought of using these skulls to teach evolution of hominids. In this activity, students, working in teams, measured several different morphological characteristics of hominids skulls in order to compare them to each other. Their data allowed them to develop a phylogeny of hominids. By handling the skulls, students gained insights into Hominid evolution and in particular that of humans. The students learned the role that fossils play in assisting scientists in developing and modifying the theory of evolution. They began to see the different characteristics and how they were related from one specimen to another. The skulls have many characteristics that provided evidence as to how the hominids moved, their intelligence, and diet. By comparing the skulls of chimpanzees, gorillas, and humans, students recognized that the chimp skull shares many characteristics with those of the gorilla and human. When they were finished examining the skulls the teams were asked to develop phylogenic trees demonstrating that they comprehended the evolution of hominids. Much debate occurred as they began to place the skulls, in sequence from oldest to more recent species and tried to determine which species is the ancestor to the other species. The question that they asked most often was how correct their prediction was to the right answer. My reply was the scientific community debates how to interpret the data, but that the debate was in the details not about the theory of evolution.

Evolutionary Time Line (APPENDIX II, C)

This activity was adapted from the biology book that Kent City High School used, Biology: The Dynamics of Life published by Glencoe McGraw-Hill. The time line that is depicted in the book visually misrepresents the amount of time for each period of time for the history of the Earth. The time line is not uniformly scaled from the beginning of Earth to the present. The Precambrian is presented in a linear format that makes it appear shorter than it should be. To improve the student's perception of the geological time scale, they used a 5 meter length of cash register tape to make a time line that accurately represents the Earth's history. On the time line, the students labeled each era, period, and drew the major life forms that were present in each period. The students realized that the Earth is extremely old and that mammals have been the dominant life forms for a short length of time and humans are a new species, present on Earth only a sliver of time.

A 19th Century Journey (APPENDIX II, D)

The students mapped out Darwin's journey as he traveled on the HMS Beagle. His observations during that epic journey allowed him to develop his theory of evolution based on natural selection. As they mapped out his journey, it became evident that the journey was very long and allowed Darwin to visit many different countries and locations. The types of organisms that were collected and the number of variations made a strong impression on the young naturalist. The students read excerpts from his journal and draw pictures of the observations made by Charles Darwin. The students began to understand the importance of variations and the impact that islands have on speciation.

Variations of Seeds within Species of Maple Trees (APPENDIX II, E)

Several seeds were collected from four different species of maple trees. The students were given fifty seeds from one species of tree and asked to sort the seeds according to the overall length of the seed in millimeters. The seeds were then placed onto a graph, made on a piece of poster board and glued neatly in place. The mean, median and mode were determined for seeds plotted on the graph. When students looked at the seeds produced by maple trees, it became evident that there were not only variations between the several different species, but also within a species of Maple trees. This provided an excellent visual and allowed students to work on their graphing skills.

Bead Bug Blitz (APPENDIX II, F)

One of the most important concepts involved in the study of evolution is the role that variations within a species play in natural selection. Some variations give individuals advantages while others greatly impede their success and survival rates. In this activity, students gained a first hand experience in how variations that exist within a model population can play a role in the species' survival or extinction. The students were given a piece of cloth as a habitat and three different colored beads that represented the prey. Students acted as predators consuming the beads. The selection of the prey was determined by how quickly the students could visualize and grab a bead. Some of the variations were favored to survive based on their ability to camouflage into the environment. The surviving beads were allowed to reproduce prior to predation. After several seasons of predation and reproduction, the beads were placed in a different habitat and the process was repeated. The success and survival rates for the beads varied with each habitat. Natural selection acts on variations within a population or species. Those that were favored survived and reproduced, causing changes to take place in the species over time. Student realized selection pressures were pivotal in the ability of a species to survive and adapt or slip into extinction.

Human Variations (APPENDIX II, G)

This activity was an excellent extension to the genetics unit in which students determined the frequencies of phenotypes of their classmates. As a class, we determined the frequency of several characteristics such as tongue rolling ability, widows peak, the ability to taste genetic taste papers, or those with hitch hiker's thumb as well as many others. This activity allowed the students to move around and measure variations that exist within the human population. Working in teams of four, they measured the length of the arms, legs and hand spread of their classmates. The mean, median, and mode, for each class, were determined for the hand spread. The students developed hypotheses about the advantages and disadvantages of having different sized hand spreads. The teams of students were then asked to measure two variables of their choosing as long as it was appropriate for the class. This activity almost became a show and tell session. Students began to show each other their own weird little quirks and characteristics, such as very small hands or very long toes and digits. This activity reinforced the fact that there are many variations that exist in any given population and the basis for those variations was found in each individual's DNA.

Comparison of Homologous Structures (APPENDIX II, H)

From the beginning of the year, my students have heard that the bonobo (lesser chimpanzee) shares 97-98% of its DNA with humans, making it is our closest living relative. They have no conception of what that means, even though they have been told that the bonobo looks like and behaves like we do. The students were given photos of chimpanzee and human skeletons. They were asked to measure the length of the human arm and compare that to the length of the human leg and determine the ratio of arm to leg. They repeated the process for the chimpanzee arm and legs. They also measured the bones that compose the arms and legs of the two species and determined several different ratios between the bones to be used for comparisons. When they completed the task of measuring all of the bones they were asked to determine how anthropologists can distinguish bones of chimpanzees and humans and why this data could be useful if they were to discover fossilized remains of some extinct hominid. This activity made many of the students take notice of the similarities. They have hands and feet with toenails that are nearly identical in shape and structure. Is this by accident or due to common ancestry?

Molecular Sequencing of Amino Acids (APPENDIX II, I)

Students were given a table that listed the amino acid sequence for beta hemoglobin for several species of primates and one mystery animal that was later identified as a horse. Each student determined the number of differences between each species and used that information to develop a cladogram. They began to realize just how closely related chimpanzees, gorillas and humans are. Not only do chimpanzees, like the bonobo, share approximately 98 percent of their DNA with us, but also several skeletal, behavioral, social characteristics as well. This close relationship can be demonstrated by not only looking at the skeletal structure of each species, but by also comparing biochemistry between the species. The development of a cladogram helped students gain an insight into how anthropologists determine the evolutionary relationship that exists among organisms and the thought that all the primates found today have a common ancestor. This information became just one of the tools and pieces of evidence that are used to support the theory of evolution.

Clip Birds (APPENDIX II, J)

In this activity the students utilize a model that shows the concept of geographical reproductive isolation. The clip birds become segregated after a dispute and now are located in East and West Clip Land separated by a mountain. The students were separated up into two groups and were given clips of three different sizes, that are used as beaks. The clip birds must consume different types of foods on each side of the mountain. The energy requirements for survival and reproduction were predetermined by the teacher. The amount of food and its availability favored some clip birds while it selected against other individuals. As students proceeded through the lab, it became evident that natural selection acts on variations and will affect the survival rates of the clip birds. Some of the clip birds went into extinction while others survived and reproduced, thus demonstrating the role of reproduction and geographical isolation in the process of speciation.

Fossil and Migration Patterns in Early Hominids (APPENDIX II, K)

The students were given a list of coordinates for several sites from around the world where hominid fossils were discovered. They mapped the locations of the *Austalopithecines*, *Homo erectus*, *Homo sapiens neanderthalensis*, and *Homo sapiens sapiens*. As the students mapped locations of hominid fossils they began to realize that the oldest hominid finds were isolated in Africa. They then developed a hypothesis about the birthplace of hominids and how the hominids spread throughout the world. They noticed that in North and South America there were only *Homo sapiens sapiens* present.

Chronology of Hominids (APPENDIX II, L)

The students were given the dates of several hominid species and asked to make a time line of hominid evolution. Students recognized that the species *Homo sapiens sapiens* is a very recent development in hominid evolution. They noticed that there were several hominid fossils that date back millions of years. The common myth that humans evolved from monkey was dispelled. Many of the species of fossilized hominids were not known by the students. They began to ask question such as: What happened to Neanderthals and why did they go extinct? What was *Homo habilis* or *Homo erectus* as well as the other hominids? Finally, the time line they developed was used to make a phylogenic tree or cladogram showing the suspected relationships between the different species of hominids. Students began to hypothesize about the origin of modern humans and how they were related to the older hominids and other living primates.

Assessments

Evolution Pre-survey (APPENDIX III, A)

The Pre-survey consisted of two parts. The first portion was composed of fifteen statements that asked the students to comment on how strongly they agreed or disagreed with it. They could choose: 1 strongly disagree, 2 disagree, 3 neutral/no opinion, 4 agree, and 5 strongly agree. The second portion asked the students to comment on their beliefs and to answer questions that dealt with science and evolution.

Pre-test Chapter 14 The History of Life (APPENDIX III, B)

Chapter fourteen pre-test consisted of three short answers and six multiple choice items. The questions were associated with Earth history, carbon dating, and the history of life on planet Earth.

Test 14 The History of Life (APPENDIX III, C)

The test for chapter fourteen consisted of forty-one multiple choice and matching items. There were seven essay and short answer questions that ranged from two points to eight points. Some of the topics included fossils, radiometric dating, time line of Earth's history, and research on the origins of life. Some of the scientists that were mentioned included F. Redi, L. Pasteur, S. Miller and H. Urey, A. Oparin and S. Fox.

Pre-test Chapter 15 Natural Selection and the Evidence for Evolution (APPENDIX III, D)

Pre-test 15 consisted of ten short answer and essay questions. The questions focused on natural selection and variations, as well as evidence that supports the theory of evolution. The students were asked to comment on vestigial organs, analogous structures and embryology. They were asked to define convergent and divergent evolution and speciation.

Test Chapter 15 Natural Selection and the Evidence for Evolution (APPENDIX III, E)

There were 24 multiple choice items on test 15 and 10 essay questions. The multiple choice questions emphasized natural selection, evidence supporting evolution, and selection types either disruptive, stabilized, or directional. The essay questions ranged in point values from 3 to 6 points. Some of the questions concentrated on the Hardy-Weinberg Principal and genetic drift. There were questions on evidence supporting evolution, variations, and how speciation occurs.

Pre-test Chapter 16 Human evolution (APPENDIX III, F)

Pretest sixteen had seven short answer and essay questions that were related to hominids and human evolution. The students were asked to comment on evidence for human evolution, sources of variations in the human population as well as making statements on adaptations and why they were important to human evolution.

Hominid skulls pre-lab (APPENDIX III, G)

This assessment was also used as a pre-test for Hominid evolution. There were nine short answer and essay questions. The students were asked to comment on adaptations found on hominid skulls, including the importance of the slope of the forehead and the location of the foramen magnum. They were asked to discuss what they knew about different hominids, some of whom are still living and many of the extinct species.

Post-survey (APPENDIX III, H)

The post-survey was the same as the pre-survey. This was used to monitor any changes in opinions or knowledge of evolution and concepts and terms that are used in the discussion of evolution.

Evolution Lab Assessment (APPENDIX III, I)

There were twenty essay and short answer questions which focused on the lab activities that the students performed during the evolution unit. The questions were worth two to six points. There were four questions focused on adaptations and variations. The students were asked four questions that centered on Natural Selection. The questions revolved around selective pressures, extinction, and mutations. Four of the questions focused on evidence for evolution, including radiometric dating, evidence that results from fossils, and how relationships between species can be determined. Students responded to two questions about speciation and the role mountains play in it. The last six questions concentrated on human evolution and the evidence that supports it. The students were asked to respond to questions about hominids and human evolution. They were asked to compare and contrast hominid skulls in particular human, chimpanzee, and gorilla skulls. They were then asked to describe the pattern of hominid migration. The last four questions were opinion questions that asked the students to comment on the evolution unit and the labs.

Chapter 16 Test Human evolution (APPENDIX III, J)

Due to the lack of time, test sixteen was placed into the final exam. It consisted of forty-two matching and multiple choice items, questions thirteen to thirty-eight and questions one hundred and one to one hundred and sixteen. The questions focused on characteristics of human and chimpanzee skulls, and the different species of hominids.

Evolution Assessment and Final examination (APPENDIX III, J and K)

The final exam was composed of two parts. The first part had ten essay and short answer questions and the second portion was made of one hundred and sixteen multiple choice and matching items.

Evaluation

The students' final grades were the result of combining laboratory scores, test scores, and homework. On all the laboratory activities the students were graded on how well they performed the desired tasks. The lab assignments were graded on how well the students responded to the questions, did they provide evidence from their data, and throughly and properly explain their ideas. Many of the questions could be answered directly from the lab activity and the data that they collected. I looked to see if they had the data tables properly filled in and checked the graphs making sure they were properly designed and labeled.

On the pre and post-test essay answers, students were graded based on three components: Did they express their ideas in a manner that demonstrated knowledge of the topic? Did they provide a correct definition for the term or terms of the question and did they use them in the correct manner? Finally, did the students provide proper examples for their responses, demonstrating that they understood the context of the question? For a four point essay question, the students would need to define the terms properly and provide one or two examples to obtain the four points. If they provided just an example or just a definition they received two points. For the pre-tests and surveys, students received five points for making an effort on answering the questions. The test's format was multiple choice, matching terms, some short answer, and essay questions. The lab assessment and evolution unit assessment were written response questions only. The final exam for the class was made up of several multiple choice questions, some matching items and ten written response questions that were used as the evolution unit assessment.

RESULTS AND DATA

The students were given a pre-survey at the beginning of the unit and the same survey at the end of the unit. This information was used to determine if the students' perceptions and ideas about evolution changed after completing the unit. There were fifteen questions in which the students were asked to respond by indicating if they strongly disagreed, disagreed, had no opinion, agreed, or if they strongly agreed. The students were also asked to respond to ten short answer questions. (Tables 2 and 3)

Question	Survey Type	Strongly disagree	Disagree	Neutral/no opinion	Agree	Strongly agree	Total % Disagree	Total % Neutral/no opinion	Total % Agree
1. Variation exists within members of a population.	Pre-survey	0	2	19	18	19	3.45	32.76	63.79
	Post-survey	0	0	6	19	32	0.00	10.53	89.47
2. Artificial selection has been used by humans for thousands of years.	Pre-survey	3	12	24	13	5	25.86	41.38	31.03
	Post-survey	0	4	18	21	14	7.02	31.58	61.40
3. DNA mutations are always harmful.	Pre-survey	11	26	11	8	1	63.79	18.97	15.52
	Post-survey	26	20	7	3	1	80.70	12.28	7.02
4. Organisms are linked by a universal genetic code.	Pre-survey	2	7	11	30	8	15.52	18.97	65.52
	Post-survey	1	4	22	22	8	8.77	38.60	52.63
5. Most species on earth were created at the same time.	Pre-survey	17	19	8	10	4	62.07	13.79	24.14
	Post-survey	25	16	9	4	3	71.93	15.79	12.28
6. The earth is 6,000-10,000 years old.	Pre-survey	18	11	20	3	6	50.00	34.48	15.52
	Post-survey	32	11	8	4	1	75.44	14.04	8.77
7. The fossil record is incomplete, and thus provides poor evidence for the history of life on earth.	Pre-survey	5	19	14	17	3	41.38	24.14	34.48
	Post-survey	9	20	18	9	1	50.88	31.58	17.54

Table 2. Data Comparing responses for the pre-survey and the post-survey for question 1 through 7.

Question	Survey Type	Strongly disagree	Disagree	Neutral/no opinion	Agree	Strongly agree	Total % Disagree	Total % Neutral/no opinion	Total % Agree
8. New species discovered today have been on earth for thousands of years.	Pre-survey	2	9	20	20	7	18.97	34.48	46.55
	Post-survey	5	9	18	16	8	24.56	31.58	42.11
9. Humans as a population are perfectly adapted.	Pre-survey	8	22	14	11	3	51.72	24.14	24.14
	Post-survey	10	23	10	11	3	57.89	17.54	24.56
10. The fitness of an organism is the ability of an organism to survive and reproduce.	Pre-survey	0	2	8	39	9	3.45	13.79	82.76
	Post-survey	2	5	7	24	18	12.28	12.28	73.68
11. A theory is just a guess with little or no evidence to support it.	Pre-survey	12	22	6	11	7	58.62	10.34	31.03
	Post-survey	21	15	8	6	6	63.16	14.04	21.05
12. There is no evidence for evolution.	Pre-survey	6	17	19	10	6	39.66	32.76	27.59
	Post-survey	20	12	18	6	0	56.14	31.58	10.53
13. Evolution is not occurring in organisms today.	Pre-survey	12	26	17	2	1	65.52	29.31	5.17
	Post-survey	17	21	12	6	2	66.67	21.05	14.04
14. Evolution states that humans came from monkeys.	Pre-survey	5	6	12	23	12	18.97	20.69	63.34
	Post-survey	9	10	19	13	6	33.33	33.33	33.33
15. It is most likely that humans originated from Africa.	Pre-survey	13	8	23	9	5	36.21	39.66	24.14
	Post-survey	3	7	12	20	15	17.54	21.05	61.40

Table 3. Data Comparing responses for the pre-survey and the post-survey for question 8 through 15.

When the students were asked if variations exist within members of a population two students disagreed, nineteen students had no opinion, eighteen students agreed, and nineteen students strongly agreed. When asked the same question at the end of the unit thirty-two students replied that they strongly agreed, and nineteen agreed that variations do exist. No one disagreed about the existence of variations.

Prior to the unit twelve students disagreed and three strongly disagreed with the statement that humans have used artificial selection for thousands of years. Twenty four students had no opinion, thirteen agreed, and only five strongly agreed with the statement. The post-survey showed only four disagreed, eighteen had no opinion and twenty agreed with the statement. Fourteen students strongly agreed that humans have used artificial selection for thousands of years.

On the pre-survey eleven students strongly disagreed with the idea that mutations are always harmful. On the post survey, that number increased to twenty six individuals strongly disagreeing that mutations are always harmful. Prior to the unit, twenty-six disagreed that mutations were always harmful on both the pre and post-survey only one person strongly agreed with the statement.

The only question that showed a reversal of understanding occurred with question number four: Organisms are linked by a universal genetic code. Thirty-eight individuals, of which eight strongly agreed to question four. Nine total students disagreed, two of which strongly disagreed. The post-survey indicated that eight students strongly agreed with the thought of a universal genetic code, but only twenty-two agreed with the statement. Eleven students had no opinion and in the end twenty-two students were of no opinion.

When the students were asked if most species were created at the same time a total of thirty-six students disagreed, seventeen strongly, and fourteen students agreed, of which four strongly agreed. Eight students had no opinion, at the beginning, while only nine had no opinion in the end. On the post survey, a total of seven students were in agreement that most species were created at the same time, three strongly agreed, and forty one students disagreed with that statement. There was an increase of twelve students who strongly disagreed in the creation of species at the same time.

One of the misconceptions that emerges when teaching evolution involves the age of the Earth. When asked if the Earth is 6,000 to 10,000 years old, only a small number of students responded in a positive manner. Six students strongly agreed, and three students agreed with that statement, while twenty had no opinion. Twenty-nine students disagreed with the statement, while eighteen of the students strongly agreed, on the pre-survey. The number who had no opinion dropped to eight students and eleven disagreed. There was an increase of fourteen students who strongly disagreed to an "early Earth".

The second misconception with the theory of evolution involves the scientific evidence that has been gathered. Many students have the opinion that there is little fossil evidence supporting the theory of evolution. On the pre-survey twenty students responded that they agreed with the statement that there is poor evidence provided by the fossil record. Three of those students indicated that they were in strong agreement. Another fourteen students had no opinion and and twenty-four students disagreed with that statement. Only five students strongly disagreed with the question that the fossil record is incomplete. When the students were asked the same question on the post-survey, only ten students had a favorable view for a lack of fossil evidence for evolution, one strongly agreed. A total of twenty-nine disagreed that there is poor evidence supplied by the fossil record. This was an increase of five students.

"Newly discovered species have been on the Earth for thousands of years" when posed as a question showed little change in student responses between the pre and post survey. A total of eleven disagreed, two of them strongly, with the statement. There was an increase of three who were in strong disagreement and minimal changes occurred in those that agreed in some manner with that statement. When viewing humans, students were asked to reply to the statement: Humans as a population are perfectly adapted. There was an increase of three students from pre to post-survey that strongly disagreed with humans as perfectly adapted. At the beginning fourteen were of no opinion and fourteen total students were in agreement with humans being perfectly adapted. There was no change in the number of students who agreed and only ten had no opinion.

When asked as to identify the definition of fitness as the ability of an organism to survive and reproduce, there was an increase from nine to eighteen who strongly agreed with that principal. This gain was offset by an increase of five total students who viewed this as a negative.

Scientific terms are also difficult for students to grasp. The terms of theory, law and hypothesis proved to be troublesome for the entire year. When questioned on a theory as being just a guess with little evidence supporting it, eighteen students originally agreed with that statement, six were of no opinion, and thirty-three students disagreed with it. On the post survey there were noticeable gains in a healthier understanding of the term, theory. Overall, forty-six students disagreed with the thought of a theory being only a guess, of those twenty-one students were in strong disagreement.

Students also demonstrated a positive trend toward the understanding of evolutionary theory and the evidence that supports it. Originally, twenty-three students disagreed with the statement that there is no evidence for the theory of evolution. Only six were in strong disagreement. On the post survey that number increased to to thirty-two students, of which twenty strongly disagreed with the idea that evolution has no evidence. Six students indicated on the pre-survey that they strongly agreed with an unsupported theory of evolution and on the post survey no students were in strong agreement.

Continuing with thoughts on evolution, the students were asked to respond to the statement that evolution is not occurring in organisms today. There was no change in the total number of students who disagreed with that statement; there was a change from twelve to seventeen students that strongly disagreed with it when the pre and post-surveys were compared. Only three students had indicated on the pre-survey that they agreed with the idea that evolution is not occurring today and increased to eight students on the post-survey. On the pre-survey, seventeen students had no opinion or were neutral on the idea that evolution is not occurring today. On the post survey, the number dropped to twelve students who had no opinion or were neutral.

The last two questions on the survey pertained to human evolution. The first question was in response to the misconception that evolution states humans evolved from monkeys. On the pre survey twenty-three students were in agreement, and twelve students strongly agreed with the statement humans evolved from monkeys. Surprisingly, only twelve students had no opinion. The pre-survey also indicated that only eleven students disagreed with that thought, while only five strongly disagreed. On the post survey, sixteen fewer students agreed with that idea. Thirteen students agreed and six students strongly agreed with the statement. In the post survey, nineteen students, overall, disagreed that humans evolved from monkeys, which was an increase of eight students. Nineteen students had no opinion on humans evolving from monkeys; this was an increase of seven students.

The final question dealt with human origins. On the pre-survey thirteen students responded that they strongly disagreed with the statement that it is most likely humans originated from Africa, while another eight students simply disagreed. There were fourteen students, overall that responded positively to humans originating in Africa. The post-survey indicated that many students began to understand that humans originated in Africa. Thirty-five students agreed, in some manner with humans originating in Africa. That was an increase of twenty-one students. The number of students who replied that they strongly agreed increased from five students to fifteen students on the post-survey and a gain of eleven students who agreed with humans originating in Africa. The total number of students who disagreed, overall, with humans originating in Africa dropped by eleven students. Only three strongly disagreed with that statement.

The students were asked to respond to ten short answer questions based on content knowledge. Some of the questions simply asked them to define a term and other questions asked them for additional information by either explaining their answer or by giving examples.

Students were first asked what science is. On the pre-survey most of their responses were simple. They either gave a quick example or said that is was the study of "things. Some of the "things" included living animals, the study of living and nonliving things or the development of technology. Often students chose a field of science as the definition of science, mainly biology or living sciences. Other topics that students used were the study of the earth or space. One student stated "Science is life. It's how things live and adapt. How things were created. It's living and nonliving things. What elements make up something. It's everything in everyday life." Another student expressed science in the following way; The knowledge (and search of it) about everything related to nature, life chemistry...", Two students did not respond to the question and one student responded with "lies". Many of the responses were the same on the post-survey. One student answered the question with the statement "It is ideas and the quest to prove them". A few students expressed science as making observations and learning, the grouping of facts and unanswered questions. One of the better answers from the post-survey was as follows: "I think science is something that tests and discovers different things, about many things such as the universe, life, nature, water etc".

When the students were asked on the pre-survey what science is based on, many of the students responded that it is based on biological subjects, knowledge, "studying and learning for better understanding". Twenty-four students replied that it was based on the Earth, humans or some other object. Twenty-nine students included one or more of the following terms in their explanation; theories, laws, facts, observation, hypothesis or the results of experimentation. On the post-survey, fewer students responded with examples of objects such as the Earth or humans. Thirty students responded that science is based on terms used in science such as laws, theories, observations, hypothesis, etc. One student stated "science is based on "observations, facts, proven theories and opinions". Another student suggested that it is based on "theories and ideas, wonder and questions to find answers".

When asked to define a fact, the students had difficulty explaining and giving an example. They tended to do one or the other. Thirty-seven students used the word "proven" in the pre-survey while thirty-one students used the word "proven" in their explanation on the post-survey. One student mentioned that a fact is "Something that is true. Example: There is gravity on the Earth". Other statements were similar to the following "My hair is brown. A fact is something that can be proved [sic]." On the post-survey seven students responded that a fact is based on a proven law or theory or a proven hypothesis or question. On the pre-survey only two responded in that manner. On the post survey one student used his knowledge gained from the evolution unit when he stated; "A fact is something you know is true like humans have opposable thumbs thats' a fact [sic]".

Although on the opinion portion of post survey the students demonstrated that they understood what a theory was, they had difficulty explaining it in their own words. Pre-instruction eight students responded that it is not "completely proven" or it is "not 100% correct, and one person responded that it is an unproven law. Four students remarked that it is proven but there are still questions about the information. Seven students noted a theory as an educated guess. Only eight students commented that it is supported by facts, while on the post survey twenty students made statements that were more accurate. They made comments along the lines of a theory being a widely accepted idea, backed by many lines of information. One student explained that a theory is "facts and evidence from several places compiled together. While eight students simply stated that a theory is a proven hypothesis and supported by data.

On the pre-survey sixteen students differentiated a theory from a hypothesis with comments that suggest that a hypothesis is an educated guess and a theory is supported by evidence. Four students said that a theory is a fact and a hypothesis is an educated guess, and another seventeen students stated that a theory has more evidence than a hypothesis. Many comments were similar to: a "theory has been tested, where as a hypothesis is an educated guess" or a "theory has more evidence than a hypothesis". On the post-survey twenty-two students responded that a theory is well-supported and proven where as a hypothesis was defined as an educated guess. They made statements of a theory being widely supported and a hypothesis as an educated guess. "A theory is proven many times and supported by evidence" or that "a theory is different because it is backed by facts and research, where a hypothesis is just a "guess" were common statements that were noted on the post-survey. Nine students had the idea that a theory has more evidence that a hypothesis.

Students expressed many ideas as to why evolution is considered a theory. On the pre-survey nine students agreed that evolution is a theory because it is widely supported and accepted. The number of students who viewed evolution as a widely accepted theory increased to seventeen in the post-survey. Thirty-nine students on the pre-survey expressed the thought that evolution was a theory because of uncertainties, that it's not agreed upon or it can't be 100% proven. Prior to the evolution unit, three students stated that it was not 100% proven. That number increased to eleven students at the end of the unit. It was also suggested that evolution is not a fact or that no evidence exists for evolution. That number decreased to twenty-two in the post-survey from thirty-six on the pre-survey.

The last four questions asked for the opinions from the students regarding instructional techniques. Fifty seven students implied in some form that labs helped or assisted in their ability to learn. Many thought that hands on learning allowed them to focus or keep their attention and that it allowed them to see how science worked in the real world. This was noted on both the pre and post-surveys. On the post-survey two students stated that they did not like labs. One student actually thought that she preferred listening to me lecture over labs.

The last three questions dealt with their opinion on evolution, how life on Earth began, and if it should be taught in schools. The first of these questions asked the student: what is your opinion of evolution? On the pre-survey nine students did not have an opinion and one student did not respond. Twenty students said that they don't believe it and one student stated "that humans came from two people, Adam and Eve". One student wrote "It is not true, it should not be told the way it is". Another student said "I don't think people evolved (God Created) but I think the animals and plants are evolving. Some of the students believed that God started all life but that it has been evolving under his guidance. Three students were on the fence stating that there is evidence for evolution but there is room for error or that there is a 50% chance of evolution occurring. Eighteen students had a more positive view of evolution. The conflict of religion and evolution is displayed in the remarks of a student who wrote "I think there is some truth to it but I do believe in God". Surprisingly, only three students commented that man evolved from monkeys. One student commented "I believe evolution could have easily of [sic] happened. There are so many things around us that relate to it easily". On the post-survey seventeen students were absolute in their conviction that evolution is not true, that they believe in God. Five of those who disagreed with evolution stated that they understand the theory better or could state as this student did "I think it is false. I don't believe we are hominids adapting over millions of years". One student took the view of micro evolution when he/she wrote "I don't believe in it, [sic] species change but they don't become new species." Eight students either did not put a comment or responded that they had no opinion. Four students combined evolutionary theory with their religious beliefs. As one student put it "I believe God put us here to evolve and change". Seven students were confused as to what to think by making statements along the line of : "I am a Christian but there are scientific facts". This was indicated by one student writing "I'm a Christian, but kind of have a scientist mind, so I have no idea" The debate of evolution and religion is perplexing for some of my students. The post survey found that sixteen student were in agreement with the theory of evolution. One student reasoned "I think is [sic] good, because we can understand better about the species and their skulls." Another wrote that evolution "is true, it makes sense plus protocells [sic] and other test make it seem real".

Initial results from the pre-survey indicated that one student was unsure and twelve students responded that evolution should not be taught, due to religious conflicts and the fact that evolution is unproven. Four students commented that it should be taught but not forced, and one student remarked that it should be covered but not in depth. Some of the statements were as follows: "I think that it is important that we learn it but not to have it pressed upon us". Prior to the evolution unit, eight students were of the opinion that both sides or all theories should be presented, as represented by a student who wrote "all aspects of it and different ideas" or as another student said "Yes, it gives people more options to choose from as a base of religion or opinion". Twenty-four students said that they thought evolution should be taught in high schools prior to beginning the unit. In the post survey, eighteen students stated that they thought evolution should not be taught in public schools, which was an increase of six students. Twenty-seven students felt that evolution should be taught. Students commented that "it tells us how organisms have changed and are changing", "yes in science, it is something that the scientific community believes, its [sic] like teaching addition in math class", or "it is science and it shows where we came from". On the post survey two students thought it should be taught, but not pushed, and five said yes as long as it was taught with other theories. There was one student who wished to have the option of opting out of the evolution unit, and stated so on both the pre and post survey. Three students suggested that is good to know science even though it may conflict with the religious beliefs of some students.

The final question on the survey asked for their opinion on how life began on planet Earth. Thirty-two of the students said that God had placed life here, and five were not sure. Thirteen students indicated that life evolved and another five students said it evolved with God's involvement. Two students were not sure because there are many theories about how life began on Earth. The post survey found that thirty-one believed life originated through God, six students were not sure and three students had no response. Five students responded by using terms that were vague or joked by saying things like "Chuck Norris". Five students mixed their religious beliefs with those of evolution stating that God had a role in life starting then it evolved, and seven said life began through evolution. One student explains that "life began with lightning and rocks and all came together in a kind of storm with proteins."

Analysis of Laboratory Activities

The students worked with partners or in groups for several of the laboratory activities, but were responsible for turning in their own set of questions and data for each laboratory exercise. The grades for the laboratory exercises are shown in Table 4.

Name of Lab	Average Score	Average Rating	Missing labs
Simulating Radioactive Decay of Carbon-14	75	2.3	-1
Evolutionary Time Line	82	2.31	0
A 19th Century Journey	91	3.35	-2
Variations of Seeds within Species of Maple Trees	86	2.8	-2
Bead Bug Blitz	85	2.54	-1
Human Variations	81	N.A.	-1
Comparison of Homologous Structures	79	2.56	0
Molecular Sequencing of Amino Acids	81	3.22	-2
Clip bird	77	2.65	-4
Chronology of Hominids	97	2.33	-3
Fossil and Migration Patterns in Early Hominids	86	3.82	-6
Human Evolution: Hominid Skull Comparison	86	3.7	-2

Table 4. The average scores and student rating of labs and the number of students who failed to turn in their assignments (1=highest and 5= lowest score).

Simulating the Radioactive Decay of Carbon-14

Students worked alone in this activity, although many students assisted each other setting up their graphs. The average score for this activity was 75%. I had one student who failed to turn in this laboratory assignment. Students rated this a 2.3 out of a scale of five. After they turned it in, some students told me they read the scale wrong and thought five was the best score. I think this lab would have had a better rating than it received simply because they ate candy. Most people did well on this activity, although some failed to properly label their graphs or determine the intervals for the x and y axis. Students also had a problem answering question that entailed mathematical skills and interpreting graphs. One student commented that "I thought it showed half-life very well. It was a very easy lab [sic] taught a lot of info."

Evolutionary Time Line

This activity received an average rating of 2.31. This was one of the labs for which everyone turned in an assignment. The average grade was 82%. I was surprised as to how well this activity went. I had students, working in pairs, spread throughout my classroom, which is very large, in my storage areas, and out in the hallway. It took students two days to finish and some took three days to complete the task. Some students had difficulty in interpreting the time scale that we used. Many students commented throughout the day that this helped them put the time scale of the Earth's history into perspective. Because the book's image portrays the Precambrian as a shorter line than it should be, some students were confused by the fact that their time scale showed that the majority of Earth history is contained in the Precambrian. Many students who had a better understanding of math helped the other students figure out how to use the time scale.

A 19th Century Journey

Darwin's Journey rated 3.35, which was the third lowest rating (third highest score) of any of the laboratory activities. The students worked alone on this assignment. The students did not like this activity for two reasons. They disliked mapping out the points along the route of his journey, mainly do to the fact that the map was too small. Secondly, they did not appreciate having to draw the sights that Darwin saw on his voyage. On the other hand, the few artistic students liked the opportunity to draw in biology class. The average grade that the students received was 91%. Two students failed to turn in a worksheet for this activity.

Variations of Seeds within Species of Maple Trees

This rated 2.8 and had an average score of 86%. Many students found it boring to measure and glue seeds, but appreciated learning in this manner over lectures and notes. One student commented that "It's a lot better than worksheets" and another said "It showed the variation of all the seeds, but it was very slow and boring." The students worked with a partner during this laboratory. Many of the students made comments during this activity on all the variations in length of the seeds. It also gave them an excellent visual for graphing the seeds by length. It was easy to determine the mode and median for the data. Two students failed to turn in this assignment.

Bead Bug Blitz

On average, students earned an 85% and this activity received a rating of 2.54. This activity allowed for more student movement and a greater opportunity to actively participate working in teams of three. If students are working with a partner you may need to reduce the number of times the student feeds in each habitat due to time constraints. One student commented that "I liked it because it was easy to see the natural selection, but the beads were small. It was fun to be hands on." Some student thought it took too long, but overall students began to envision the role of natural selection on variations in the environment. Only one student failed to turn in this assignment.

Human Variations

The student rating and suggestion portion of this lab failed to be copied. The students seemed to enjoy this lab. We had already worked on some of the simple Mendelian inherited characteristics within each class. This gave them the opportunity to to work in teams of four. They measured hand spread, leg length, arm length and two variations of their choosing. The students were free to move about the room, and remained very active and on task. Several of my rambunctious students performed very well on this activity. The average score was 81%. There was one student who failed to turn in this assignment.

Comparison of Homologous Structures

This lab was an enjoyable exercise to observe. This was the first time many of my students began to recognize that chimpanzees and humans are similar in structure. This activity was a partner project. They made comments about the shape of the bones and noticed the finger nails and toe nails on the chimpanzee. The average grade was a 79% and the activity received a rating of 2.56. This was one of three labs in which all the students turned in their assignments. Many of the students thought the directions were easy to understand and follow. One student commented on the assignment "That I liked it because it was interesting to see the different measures from a human and a chimpanzee". other thought "It was fun learning about bones". Many of the students had difficulty with determining the ratios for the lengths of different bones.

Molecular Sequencing of Amino Acids

This activity did not rate very high with the students. It received a rating of 3.22, which was the fourth lowest rating overall. The average score earned by the students was 81%. There were two students who failed to turn in the assignment. Working on their own, students determined the number of amino acids that different primates shared with each other. This gave them an opportunity to make a cladogram using scientific data. Many thought this lab was boring and not fun, while some students thought it was interesting. One student remarked that "It's cool to compare species alike [sic]". One student suggested giving them pictures of each of the species used in the comparison.

Clip Birds

Although this lab had a rating of 2.65, there were four students who did not complete it and turn in their assignments. This activity required the students to work in two large groups. The average score was 77%. The competitive nature of the students is expressed in this activity. They were very aggressive in attempting to keep their clip bird alive and successfully reproducing by collecting enough calories. They were asked to make predictions before starting the laboratory and explain their thoughts. Many failed to follow those instructions which resulted in a lower score. The graphs that they made were of a higher quality than those they made in some of our previous experiments. They commented that the graphing confused them and that some found it boring. Those that found it enjoyable made comments similar to "It was fun using the clips to grab stuff especially when we had a time limit. One of my artistic students rated the activity a 1 commenting that "You had to pretend to be a funny looking bird".

Chronology of Hominids

This activity received a rating of 2.33 which was good for a worksheet type assignment. They worked alone and it was similar to traditional worksheet type assignments. The average grade was 97%. Some of the students completed the extra credit portion of this activity. There were three students who failed to turn this assignment in. Many commented that they liked it because it was short and easy to complete. There were only a few comments that were worth noting. One of those comments was "It was cool to see how we evolved through time". Another student remarked that "It helped put into perspective the time of evolution". The students worked in groups of three to six.

Fossil and Migration Patterns in Early Hominids

This assignment received the lowest rating of all the activities, 3.82, and it also had the highest number of students failing to turn in their assignments. The average score was an 86%. This was a fairly easy worksheet that the students completed on their own. The worksheet activities did not spark the interest in the students in the manner that I thought they would. Although it dealt with human evolution and migration, many students thought that putting dots on a map, again, was just no fun. One student gave it a rating of five, but scored it a "22,000, to [sic] many dots" and the only way to improve this assignment was to give "candy and pop". This sentiment was expressed by many other students in one form or another. One student liked it "because it was interesting find the countries on the map". I felt that the students began to understand that hominids migrated out of Africa throughout the entire world over a very long period of time.

Human Evolution: Hominid Skull Comparison

This was my favorite lab. Prior to beginning this activity I set the skulls out in front of the class for a couple of days to prompt student questions. They manipulated the jaws, looked at the characteristics and became curious as to what they are. Even though this laboratory exercise is time consuming, and involved a great amount of effort from the students, only two students failed to turn this lab in, one of whom simply quit coming to school by the last couple of weeks. The average grade for this assignment was 86% and it received the second lowest rating overall, of 3.7. Most students did not enjoy making all of the measurements. One student found it disgusting to handle all of the skulls even thought they were plastic replicas. One student commented that they "Liked seeing the different skulls". Many of the students mentioned that it was difficult making the measurements and that it was time consuming. Some of the other comments were: "It was scientific" and "I learned a lot about the differences between the skull but it took a long time to do". And finally one student stated "It was fun but really tough".

Analysis of Assessments

The students took three pre-tests and three post-tests. They received five points for attempting to answer questions on each pre-test. I gave the students two pre-tests on human evolution, covering different aspects of human evolution. The first one was given at the beginning of the unit and the second pre-test was given to the students prior to the hominid skull comparison activity. On all the pre-tests, the students performed poorly, averaging less than 26% on each pre-test. On the written response portion of the pre-tests students often left answers blank or simply responded with, "I don't know" or "IDK". See Table 5 for a comparison of pre-test and test scores, as well as the student scores for their assessments and final exam.

Unit	Pre-test Score %	Test	Average %	High score %	Low score %
Chapter 14 History of Life	26	Test 14	52	102	9
		Mc	50	93	12
		Essay	54	121	4
Chapter 15 Natural Selection And Evidence	14	Test 15	60	98	13
		Mc	59	96	25
		Essay	61	104	12
Chapter 16 Human Evolution	20	Test 16	65	93	38
Final Exam and Assessments		Lab assessment	74	98	34
		Exam	63	90	37
		Evol. Ass.	75	100	38
		Multiple Choice	59	87	34

Table 5. Average scores for pre-test, post-tests and assessments.

The average grade received for pre-test fourteen, The History of Life, was 26% (n=56). This was the only pre-test that I gave that was composed solely of multiple choice items. The average score for post test fourteen, The History of Life, was 52% (n=56). The high score was 102% and low score was 9%. The lowest score, for test 14, was recorded by a student who later dropped out of the class. When the test was analyzed by the type of question, the average score for multiple choice items was 50%. The high score was 93% and the low score was 12%. The average for the essay questions was 54%. The high score was 121%. This individual had a perfect score and completed all of the extra credit tasks on the test. The low score was 4%.

Pre-test and post-test for The History of Life were compared to each other with a Paired Student's t-Test. It was determined that at a 95% confidence interval the probability of the null hypothesis was 0.000. The null hypothesis was stated as there was no statistical difference between the pre-test and test for unit fourteen.

For pre-test on Natural Selection and the Evidence for Evolution, the students were given a questionnaire that was composed of essay questions and short answers. They did very poorly on the pre-test fifteen. The average score was 14% (n=56). The average score for post-test fifteen, Natural Selection and the Evidence for Evolution, was 60% (n=56) with a high score was 98% and a low score of 13%. When the test was analyzed by type of question the average score for the multiple choice items was 59% with a high score of 96% and a low score of 25%. The essay question average score was 61%. The high score for the essay portion of test fifteen was 104% and the low score was 12%. To determine if the students showed an increase in test scores a Paired Student's t-Test indicated that at a 95% confidence interval the probability of the null hypothesis being true was 0.000.

For test on Human evolution, the result were much the same as the previous two tests. Only forty seven students were used in the post analysis for this test due to the fact that there were several students that missed one or both of the pre-tests that were given for this unit. The pre-test scores were determined by adding the skull pre-lab and the pre-test sixteen together. The average score for the pre-test was determined to be 20%. Since the Human evolution test was added into the final exam, the questions for this chapter were scored independently of the final exam. The average score for the Human evolution test, which was composed of all multiple choice or matching items, was 65%. The high score was 93% and the low score was 38%. When the pre-test and test were compared for the Human evolution test, the Paired Student's t-Test indicated that at A 95% confidence interval the probability of the null hypothesis being true was 0.000.

The lab assessment was given to the students on Tuesday, which was the last day of class prior to the exams. The average score was 74%. The low score was 34% and the high score was 98%. The exams were scheduled to be taken Wednesday through Friday and lasted for one and half hours. The exam for this class consisted of a multiple choice and matching section and an essay portion, which had ten questions. This test covered the three sections of evolution. The essay portion of the test was called the evolution assessment. A portion of the multiple choice test was used as test sixteen, Human evolution.

The score for the exam was determined by adding the two portions of the exam together. The average was 63%. The high score was 90% and the low score was 37%. When the test was analyzed by the type of questions, the average for the multiple choice items was 59%. The high score was 87% and low score was 34%. The essay portion of the exam, evolution assessment, had an average score of 75%, with a high score of 100% and a low score of 38%.

The students' overall grade point average (GPA) was compared to their performance on the evolution unit. It was determined that four students performed at the same level as their GPA, thirty students performed at a higher level than their GPA, and twenty four students performed at a level below their GPA. The students' grade for each semester of science was averaged and compared to the grade they received in the fourth marking period of Biology. Eighteen students performed at level that was lower than

their science average grade, five students performed at the same level, and thirty-five recorded grades that were higher than their science grade average.

CONCLUSION

In the 2006-2007 school year, the science department at Kent City High School began to work on implementing the new state high school science expectations (Appendix I, A). The standards for biology had a greater emphasis on evolutionary concepts. The evolution unit at that time was lecture driven, with only two laboratory activities for the students. Also, the unit was rushed through at the end of the year. It was difficult for me to get my students interested in the topic and since there were many time constraints, the unit received very little attention on my part. The lack of hands on activities and the large amount of notes made it difficult to assist the students in understanding evolution. With this in mind, I began my research in the summer of 2007 with the plan to design an evolution unit that was lab driven, emphasizing activities to increase my students' understanding of the nature of science and the concept of evolution. I also planned to utilize the evolution unit to increase my awareness of what my students perception of evolution was and what their religious beliefs were. The community of Kent City has deeply embraced their mostly Judeo-Christian religious beliefs.

The student surveys indicated that many of them are deeply committed to their religious faith. Several students made comments on the survey that they believed God created the Universe, Earth and all that is on Earth, including Man. My goal was not, and should never be, to alter or change their perception of religion or a theology based belief system. My goal as a teacher was to present the theory of evolution in a manner that was respectful of their personal beliefs. I am also aware that I need to teach the nature of science and how science is based solely on evidence. Beliefs and personal bias have no place in properly conducted scientific research. When pre-survey and post-survey responses were compared, there was a large shift in their answers. There was a change of 30% from the pre-survey to the post survey when students were asked if humans have utilized artificial selection for thousands of years. When asked if humans originated in Africa, the pre-survey indicated that 24% of the students agreed with that statement. On the post survey 61% responded (correctly) that humans originated in Africa.

After completing their exams, I had the opportunity to discuss with two students, what they thought of the evolution unit. One of them said that she was confused. When I asked her what she found problematic about the evolution unit, she remarked that she understood the theory of evolution much better, but she was confused as what to believe, religion or science. I told her that is a problem that many people struggle with and that she will have to work it out and that many people find a way to make the two worlds fit together and others don't.

By making this a laboratory-focused unit that utilized humans as an example the students were allowed to view evolution from the perspective of scientists and as humans. We compared the human species with several of the other hominids and primate relatives that share our history and planet. The average rating for the laboratory activities was 2.87. The lower the score, the more the students liked the activity. The activities that scored the highest were those that allowed for the students to actively participate and engage in the activity. The highest rated activity was *Simulating Radioactive Decay of Carbon-14;* it received a rating of 2.3. The mapping worksheets received lower scores than the other activities. Although *Fossil Migration Patterns in Early Hominids* did achieve its goal of showing the students where hominids and humans evolved, it received a rating of 3.82. Six students failed to turn in their assignments, which was the highest recorded number during the revolution research. The average score for all of the activities was 84%. The highest average score, 97%, was recorded for the *Chronology of Hominid* activity. Although they enjoyed the radioactive decay exercise, the average score was only 75%. They had difficulties with the graphing and using mathematical equations.

One of the attributes of allowing students to work in a laboratory based setting is the amount of energy that the students put into the class. I found that behavior of the class overall was much better than when the students were asked to take notes and listen to lectures. Some of the students that were high maintenance and in need of constant attention became more focused and less distracting when we were engaging in the exercises. This occurred even though it was the end of the year in one of the warmest rooms in the high school. There is a greenhouse attached to the west wall of the classroom which generates a lot of heat in the classroom.

After examining all of the information and making observations during the teaching of the unit my plans are to change a few of the activities. I plan to continue implementing laboratory type activities throughout the year. There were several labs that I worked on that I just could not do because there was not enough time. In the beginning of the year, we began by classifying insects. The process of classification has been greatly influenced by evolutionary sciences.

Most of the labs will be used again without alteration. I plan on altering a *19th Century Journey* by giving the students the opportunity to view online images of the sights Darwin saw and then have them draw the images. The map that I used was too small, so I hope to provide large laminated world maps for their use when plotting the points, which should reduce some of the confusion that the students experienced in this activity.

I thought the Time Line activity worked very well. It allowed students to get a visual image of Earth's history. For next year my goal is to have my students use photos of several different fossils that can be viewed on the Internet and have them place them on their time lines. This will give them a better idea of what life forms lived in the past.

One of the suggestions that the students recommended for next year was to give the them photos of the different species of primates and hominids that were used in the activities. Many students wanted to know what each of the primates looked like while we were working on the *Molecular Sequencing of Amino Acids* worksheet. The images could also be used to enhance the *Human Evolution: Hominid Skull Comparison* laboratory. I also plan on improving the *Human Evolution* lab by giving the students laminated images of several different artifacts and fossilized remains of the different types of hominids. Many students were very curious about the different types of skulls and how each species survived.

For next year I am planning on using appropriate examples of evolution throughout the school year. I expect that this will increase my students' awareness of the theory of evolution and the multiple lines of evidence the support it. I plan on using a lab entitled *Creating Phylogenic Trees Using Caminicules* (APPENDIX IV, A) for the classification unit at the beginning of the year. This activity was adapted from Robert P. Gendron of Indiana University. He developed computer generated organisms that allow students to visualize how evolution results in the development of different species through natural selection. The students are given pictures of the organisms and asked to make a phylogenic tree, and then compare their tree to those of others. It permits students the opportunity to recognize that not all scientists interpret the information or sets of data in the same way, which leads to discussions on the nature of science. When more evidence or data are generated the view points of scientist may adjust to the new information.

The second unit explores the nature of science and biology. I plan on inserting the lab *Laetoli Footprints: Analyzing Fossilized Footprints* (APPENDIX IV, B) in this unit. This activity will allow the students to gather data on themselves and fellow classmates.

They will use the information to analyze foot length, stride length and height of modern man and compare those measurements to the Laetoli footprints to calculate early hominid height. This laboratory activity has many potential opportunities to use graphing as a learning tool. This was a weakness in the students who participated in my research project. This activity was adapted from Jennifer Johnson, and is available on line at www.indiana.edu/~ensiweb/lessons/footleng.html. In a June 2006 interview Louis J. Gross commented that students are not capable of carrying out basic quantitative research. They are not able to read, interpret, or produce graphs, even simple graphs (http://www.actionbioscience.org/education/gross.html). Graphing can be a powerful tool for summarizing complex information. The ability to make and utilize graphing skills may help students understand and interpret data and determine relationships. Even though graphing skills are an important principle in sciences many students lack essential graphing skills (Ozgun-Koca, 2001).

Prior to the evolution unit, I taught genetics. There are two short activities that I plan on using that use humans as their source of information. The first activity, *Genetic Evidence for Evolution: DNA analysis* (APPENDIX IV, C) will be used as an introductory lesson for DNA fingerprinting. The second activity will reinforce the genetic difference between people and the role mutations play in the survival of humans. The activity; *When Milk Makes You Sick* (APPENDIX IV, D), will allow students the opportunity to learn how some mutations have assisted in the survival of humans. They learn about the lactose tolerant gene and how this mutation allowed humans to use milk from other species as a food source. The allele is not equally distributed throughout the world. This activity was adapted from Therese Passerini. (www.indiana.edu/~ensiweb/lessons/tp.milk3.html)

Evolutionary science has been a hot topic since its conception. From its pre

Darwinian origins, many pieces of evidence have been discovered and brought to light, developing multiple lines of evidence for evolution. When Darwin wrote *On Origins of Species: by Means of Natural Selection* in 1859, the debate was brought to the forefront. In a debate between Thomas Huxley, "Darwin's Bulldog", and Bishop Samuel Wilberforce, Darwin's ideas were defended vigorously (Edey and Johanson, 1989). That debate rages on in the hallways of universities, schools, and in the public domain to this day, but does not exist among scientists. The perceptions that students bring into the classroom have been taught and embedded into their thought processes for most of their childhood is basically a non-scientific view of the world. Many science teachers avoid the conflict by not teaching evolution or lightly touching upon the topic, thus denying young students the opportunity of gaining any knowledge of the theory of evolution and the nature of science. In the process of education, our students need to increase their awareness of humans are and the importance of science in their lives. One way to achieve this goal is to incorporate evolution and the nature of science into your biology lesson plans.

APPENDIX I, A

Michigan Department of Education Biology Content Expectation: Unit 12 StatementB5.1 Theory of Evolution

Biology Content Expectation
Unit 12 StatementB5.1
Theory of Evolution

The theory of evolution provides a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms.

B5.1A

CODE	STATEMENT
B5.1A	Summarize the major concepts of natural selection (differential survival and reproduction of chance inherited variants, depending on environmental conditions).
B5.1B	Describe how natural selection provides a mechanism for evolution.
B5.1c	Summarize the relationships between present-day organisms and those that inhabited the Earth in the past (e.g., use fossil record, embryonic stages, homologous structures, chemical basis).
B5.1d	Explain how a new species or variety originates through the evolutionary process of natural selection.
B5.1e	Explain how natural selection leads to organisms that are well-suited for the environment (differential survival and reproduction of chance inherited variants, depending upon environmental conditions).
B5.1f	Explain, using examples, how the fossil record, comparative anatomy, and other evidence supports the theory of evolution.
B5.1g	Illustrate how genetic variation is preserved or eliminated from a population through natural selection (evolution) resulting in biodiversity.
B5.2x	Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descents branched.
B5.2a	Describe species as reproductively distinct groups of organisms that can be classified based on morphological, behavioral, and molecular similarities.
B5.2b	Explain that the degree of kinship between organisms or species can be estimated from the similarity of their DNA and protein sequences.
B5.2c	Trace the relationship between environmental changes and changes in the gene pool, such as genetic drift and isolation of subpopulations.
B5.r2d	Interpret a cladogram or phylogenetic tree showing evolutionary relationships among organisms. *(recommended)*

APPENDIX I, B
Parent Consent Form

Improving Student Comprehension of Evolution Concepts
Parent Consent and Student Assent Form

I am currently enrolled as a graduate student in Michigan State University's Department of Science and Mathematics Education (DSME). My thesis research is on improving student comprehension of evolution concepts. Some components of the unit are variation in organisms and populations, artificial and natural selection, the fossil record, and speciation.

Data for the study will be collected from standard student work generated in the course of teaching this unit such as pre and post tests, lab activities, and surveys. I am asking for your permission to include your child's data in my thesis. Your child's privacy is a foremost concern. During the study, I will collect and copy student work. These assignments will have the student's name removed prior to use in the study. All of the work being collected will be stored and locked in high school office vault until my thesis is finished and will be shredded after that time. In addition, your child's identity will not be attached to any data in my thesis paper or in any images used in the thesis presentation. Your child's privacy will be protected to the maximum extent allowable by law.

Participation in the study is completely voluntary. All students will be required to complete all of the given class assignments and activities. Once the unit is completed I plan to use the students work in my research. Students who do not participate in the study will not be penalized in any way. Students who participate in the study will not be given extra work to complete. You may request that your child's information not be included in this study at any time and your request will be honored. There are no known risks associated with participating in this study. Participation in this study may contribute to determining the best way to present evolution concepts to high school students.

Kelly Hartley, the chemistry teacher, will collect all of the consent forms and the pre-survey and post surveys that the students will be asked to answer. Mr. Hartley will have all he consent forms and surveys locked in the high school office vault until the unit is completed. If you are willing to allow your child to participate in the study, please complete the attached form and return it by October 31, 2007. Please seal it in the provided envelope with your child's name on the outside of the envelope. The envelopes will be stored in a locked cabinet and opened after the unit is completed. Any work from a student who is not to be included in the study will be shredded.

If you have any questions about the study, please contact me by e-mail at mcclints@kent-city.k12.mi.us or by phone at (616) 678-4210. Questions about the study may also be directed to Dr. Merle Heidemann at the DSME by e-mail at heidema2@msu.edu, by phone at (517) 432-2152, or by mail at 118 North Kedzie, East Lansing, Michigan 48824. If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Director of the Human Subject Protection Programs at Michigan State University, by phone at (517) 355-2180, by e-mail at irb@msu.edu, by fax at (517) 432-4503, or by mail at 202 Olds Hall, East Lansing, Michigan 48824.

Thank you,

Mr. Steven W. McClintock
Biology Teacher

Kent City High School

Parent/Guardian Consent Form

I voluntarily agree to allow ___________________________________ to participate in this study.

(print student name)

Please check all that apply.

_______ I give Mr. McClintock permission to use data generated from my child's work in biology class to be used in the thesis project. All data from my child will remain confidential.

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

_______ I give Mr. McClintock permission to use pictures of my child participating in various activities while in biology class. I intend on using the pictures on this thesis project. Your child's name will not be identified in these pictures.

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

____

____

(Parent/Guardian signature) (Date)

APPENDIX I, C
Student Consent Form

Student Consent Form

I , ___________________________________,voluntarily agree to participate in this study.

(print name)

Please check all that apply.

_______ I give Mr. McClintock permission to use data generated from my work in biology class to be used in the thesis project. All data from my work will remain confidential.

_______ I do not wish to have my work used in this thesis project. I acknowledge that my work will be graded in the same manner regardless of participation in the study.

_______ I give Mr. McClintock permission to use pictures of myself participating in various activities while in biology class. I understand that Mr. McClintock intends on using the pictures in this thesis project. Student's names will not be identified in these pictures.

_______ I do not wish to have my picture used at any time during this thesis project.

I voluntarily agree to participate in this thesis project.

____

(Student signature) (Date)

APPENDIX II, A

Simulating the Radioactive Decay of Carbon-14

Adapted from Ginny Lambert

Purpose: To understand the concepts of radioactive decay and half-life in the process of carbon dating.

Materials:
2 pieces of red licorice
1 plastic knife
1 piece of graph paper
1 red colored pencil
1 black colored pencil

Introduction: Imagine you discover a fossil in your backyard. Although fossils are interesting to look at, and a lot of information can be gathered just by observing a fossil, it is also useful to estimate how old the fossil is. All living things consume carbon-14, which is a radioactive version of carbon-12. Organic molecules, like proteins, carbohydrates, and lipids all contain carbon. All of us have carbon-14 in our bodies, and it is constantly decaying. Radioactive atoms change over time into other types of atoms. For instance, carbon-14 decays into nitrogen-14. Carbon-14 can be used to determine the age of anything that was once living or was made of organic material up to 50,000 years old! All radioactive materials have a half life, which is the amount of time it takes for half of a sample to decay. The half life of carbon-14 is 5,730 years, but other radioactive atoms exist with longer half-lives. The ratio of carbon-14 to carbon-12 in living things is relatively constant when the organism is alive. After death, the carbon-14 continues to decay, but the amount of carbon-12 remains the same. By measuring the amount of carbon-14 remaining in a fossil, a bone, or even a piece of cloth, the age of the artifact can be estimated. In this simulation, red licorice will be used to represent carbon-14. To simplify the graphing, we will assume the half-life is about 6,000 years.

Procedure:
1. Turn a piece of graph paper so that it is horizontal instead of vertical.
2. Label the x-axis number of years. The scale will be 500 years per line. You should label the axis up to 55,000 years.
3. Label the y-axis Percent of Carbon-14 remaining. Using the entire y-axis (from top to bottom), label from 0-100%.
4. Take both pieces of red licorice and lay them on the graph paper at time 0.
5. You need to cut the pieces of licorice so that they are the exact length of the y-axis.
6. Mark the top of the licorice at time 0.
7. Lay one piece of licorice on the y-axis, this piece will remain here until the end.
8. Measure the length of your other piece of licorice in centimeters. Record the number here: ___________
9. Using the knife, cut the other piece of licorice exactly in half.
10. Place the half piece of licorice on the 6,000 year point on the x-axis.
11. Draw a line at the top of the piece of licorice. This piece stays on the graph until the end.

12. Measure the length of the other half of licorice in centimeters. Record the number here: __________
13. Using the knife, cut the licorice exactly in half.
14. Place one of the halves of licorice on the 12,000 year point on the x-axis.
15. Draw a line at the top of the piece of licorice. This piece will also stay on the graph.
16. Continue cutting the licorice in half, placing the pieces on the graph every 6,000 years. Your challenge is to see how many times you can cut the licorice in half!
17. Once you can no longer cut the licorice in half, connect all of the points with a line graph, using the red colored pencil.
18. Above the red line, you need to draw a line from each of the intersects to the top of the graph, using a black colored pencil. This line represents nitrogen-14, one of the products of carbon-14 decay. Draw a red line down representing Carbon 14.
19. Once your graph is complete, all of the radioactive licorice may be consumed.

Questions and Analysis:

1. Based on what you have seen in your graph, fill in the chart below with the percent of carbon-14 remaining every 5,730 years.

Decay of Carbon-14

Years from present	0	5,730	11,460	17,190	22,920	28,650	34,380	40,110	45,840	51,570
% of original carbon14 left	100									

2. Describe the problems you had as you approached the last division you did with the licorice.

3. What do the black lines on your graph represent? Where did this element come from?

4. Carbon dating is generally useful for dating objects up to about 50,000 years old. Explain why this method is limited for objects older than 50,000 years and how do you think scientists can date older objects.

5. If a 42,000 year old piece of pottery was sold to a museum, how many half-lives has it existed for? ____________ If the original amount of carbon-14 was 1 kg, how much of the radioactive element is left today?
6. If you have a fossil with only 30% of the original radioactive carbon-14 remaining, how old is the fossil?

7. Ask the teacher for your fossils. You will be given 3 licorice fossils that you must date using your graph. Place your fossils on the graph and find where they intersect the curve and estimate the age of each fossil. Mark each fossil on your graph. Record the ages of the fossils below from youngest to oldest.

   Fossil 1 ______________

   Fossil 2 ______________

   Fossil 3 ______________

8. In 1991, a prehistoric man, Otzi, was discovered. The prehistoric man was frozen in time by glaciers. Carbon dating of the samples from the site established the time of Otzi's death at approximately 5,300 years ago. What percentage of the original carbon-14 in the body was remaining in 1991?

9. While studying the nature of past climates, scientists in 1998 pulled two ice cores from the bottom of a glacier. Trapped within the cores were insects and bark fragments from local trees. Carbon from organic material near the bottom of the cores dated to the coldest period of the last ice age. If those samples had 5.5 percent of their original carbon-14 remaining, approximately how many years ago did the glacier form?

10. The authenticity of the Shroud of Turin has long been debated. In 1988, scientists removed small samples for carbon dating. Three different labs analyzed the samples, and all three found that approximately 8 percent of the carbon-14 atoms had decayed. Using this information, how old is the shroud?

APPENDIX II, B

Human Evolution: Hominid Skull Comparison
Adapted from: Ginny Lambert & Mari Knutson
www.woodrow.org/teachers/bi/1995/hominoidscomp.html

Introduction: There have been many fossilized hominid skulls that have been collected from around the world. Three samples of living hominid skulls and several fossilized skulls have been sent to Kent City High School for evaluation and classification by a paleo-archaeological team. Working in groups, students will collect data by measuring the different skulls and interpret the data for presentation. This research will be tied to development of a hominid phylogeny and to the evolution of the modern hominids in particular humans.

Objectives:
1. To become familiar to the different tools and techniques used in paleoanthropological studies.
2. To analyze structural features features of the skulls and determine their importance in determining evolutionary relationships
3. To collect data by measuring and observing hominid skulls.
4. To use the data in analyzing and developing phylogenic trees showing evolutionary relationships between fossilized hominid skulls and living specimens of hominids.

Materials: Protractors, metric rulers, calipers, skulls (gorilla, chimpanzee, orangutan, several homo species: Homo sapiens steinheimensis, Homo habilis, Sinanthropus pekinensis, Homo sapiens sapiens (modern human), Homo sapiens sapiens (Cro-Magnon man), Homo sapiens neanderthalensis, Homo erectus, Australopithicus africanus)

Procedure:
1. The teacher will introduce morphological characteristics that will be used to examine the evolutionary relationships among primates that can be learned from the study of their skulls.
2. Work in teams of four to collect data and complete the Hominid Skulls Data Table. You will be given 7-10 minutes to make all measurements and record all the data. Consult the hominid skull comparison checklist for an explanation of each observation you will make.
3. For each measurement and observation that is made the team should come to a consensus on the data that is recorded. Any characteristic that can not be made due to missing or incomplete structures should be noted as not available (NA)- such as missing teeth or a partial skull lacking foramen magnum. This will avoid confusion when comparing data to skulls which are actually lacking a structure, like with the modern human skull.
4. Once the data chart is complete, work with your team to review and construct a phylogenic tree.
5. As you place the skulls in chronological order, generate a list of trends you observed in the skulls.
6. Research the characteristics and materials found with each fossil. Note the approximate date that the fossil lived, characteristics of the given hominid, what type of tools, specific types of material and types of artifacts that have been found

with each type of fossil.

7. Discuss with the class the theory of human evolution and the data that is used to support the theory.

Measurements

1. Width of cranium- Use the bow calipers and measure the widest portion of the cranium (ear to ear).
2. Length of cranium- Use bow calipers to measure from anterior to posterior of cranium. Place one end of the calipers on the most forward portion of the forehead and the other end of the calipers on the most posterior point of the skull. Make sure you are measuring the cranium. The brow ridge or the saggital crest should not be used in taking measurements
3. Maximum height- Measure from superior to inferior portion (foramen magnum) of the cranium. Place the bow calipers on the midpoint of the anterior of the foramen magnum and the other end of the calipers nearest the midline of the coronal and sagittal sutures on the top of the cranium. Make sure that you are measuring the cranium. Avoid the sagittal crest if present.
4. Determine cranial module- This provides a rough numerical value for the size of the cranium. Add the cranium height, width and length and divide by 3.
5. Post orbital constriction- Using the bow caliper measure across the cranium from behind the eye orbits on each side.
6. Angle of forehead- Place a protractor flat against the eye. Determine the angle of forehead by aligning a ruler so that it is parallel with the forehead. Place the ruler against the protractor to determine the angle of the forehead.
7. Facial angle- Place protractor along the jaw line and align a ruler so it is parallel with the face and record the angle.
8. Determine the angle and location of the foramen magnum. Place the protractor on the foramen magnum using a straight edge perpendicular to the foramen magnum to determine the angle.
9. Supraorbital browridge- Determine if it is present and if so determine if it is small, medium or large.
10. Facial prognathism- Measure the angle of the facial prognathism by placing a protractor onto the eye opening. Align a ruler parallel to a line from the front of the teeth of top jaw to the eye.
11. Shape of chin- Does the chin angle in or out.
12. Dental arcade- Is the jaw U or V shaped. U-shaped jaws are distinguished by the molars and premolars being parallel on each side of the jaw.
13. Dental formula- count the teeth on half of a jaw. Determine the number of incisors, canines, premolars and molars.
14. Angle of incisors. Do they angle in or out.
15. Canine diastema- Measure th gap between the upper canines and the incisors using the vernier calipers.
16. Upper Canine- Measure the length of the exposed upper canines using vernier calipers.
17. Lower Canine- Measure the length of the lower canine using vernier calipers.

SKULLS USED

A. Gorilla gorilla gorilla (male gorilla)

B. Pan troglodytes (male chimpanzee)

C. Pongo pygmaeus pygmaeus (male orangutan)

D. Homo sapiens steinheimensis

E. Homo habilis

F. Sinanthropus pekinensis (female)

G. Homo sapiens sapiens (modern human)

H. Homo sapiens sapiens (Cro-Magnon man)

I. Homo sapiens neanderthalensis (Neanderthal man)

J. Homo erectus (Peking man, Java man)

K. Australopithicus africanus

Names of team members

Name
Date
Hour

Working with your team answer the following questions:

1. What characteristics appear to change the most as you go from skulls that are least similar to modern human skulls to those that are the most similar to the modern human skull?

2. Using the cranial module measurement, please rank the skulls from the smallest to the largest. What does the cranial module indicate about hominid evolution?

3. What four features of a hominid skull indicate that it was bipedal?

4. Why was bipedalism such an important evolution step in hominid evolution?

5. What changes in the hominid skull appear to have occurred early on in hominid evolution?

6. What are the two most recent changes in hominids, resulting in the final appearance of the Homo sapiens sapiens skull?

7. What does the presence and size of the sagittal crest indicate about a hominid skull?

8. Describe the relationship between facial prognathism and the means of locomotion?

9. The location of the foramen magnum and the angle of the spinal cord is one of the more important parameters for studying the means of hominid movement. Why are these characteristics so useful for paleoanthropologists studying the locomotion of hominid fossils?

10. What is the significance of the angle of the forehead in hominid evolution?

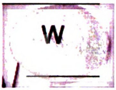
11. The dental formula and type of teeth play a significant role in diet. Try and predict what types of diets each hominid skulls studied would have been able to consume.

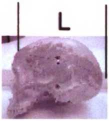
12. Please arrange the skulls from most recent to oldest. When you have completed placing them in order, try to make a phylogenic tree of human evolution. When complete, compare your tree to the other groups.

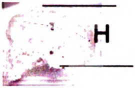
13. What evidence exists that indicates more than one species of a hominid existed on the planet at one time?

14. Based on your observation why would it be impossible for a human to evolve from chimps, gorilla or orangutans?

Skull Measurements



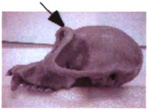




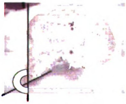
Post orbital costriction

Sagittal crest

Angle of forehead



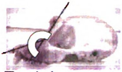
Supraorbital browridge



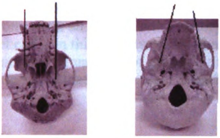
Angle of face

Foramen magnum

Skull Measurements (Continued)

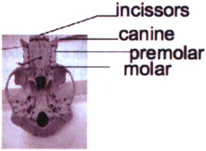


Facial prognathism



U-shaped jaw V-shaped jaw

Shape of dental arcade



Length of canine

Dental Formula

APPENDIX II, C

EVOLUTIONARY TIME LINE

Adapted from: Biology The Dynamics of Life
Glencoe McGraw-Hill

Purpose: Construct a time line that is a scale model of the Geological Time Scale. Use a scale in which one meter is equal to one billion years. Each millimeter equals one million years

Introduction: The geologic time that encompasses all of the Earth's history is a difficult concept for people to comprehend. In this activity, you will use a cash register tape to construct a scale to represent virtually all of geologic time. On the time line label each era, period, and life forms that were present in each period.

Materials and Equipment:

The following materials will be needed by each group of two students:

- A cash register tape measuring 5 meters, meter stick, calculator, Colored pencils,
- Evolutionary/Geologic Time line on pages 382 and 383.

1. Use a meter stick to draw a continuous line near the bottom edge of the 5m piece of cash register tape.
2. At the end of the strip place a vertical line and label it "The Present"
3. Measure a distance equal to 4.6 billion years ago. Draw a vertical line and label it "Earth's Beginning".
4. Use the time line found on pages 382 and 383 to plot the eras by making vertical line across the piece of paper.
5. Mark the periods with a shorter vertical line, and identify the life forms that would be present in each period.

EVOLUTIONARY TIME LINE

NAME________________________________

HOUR______

Questions:

1. What era was the longest? _____________The shortest?_____________
2. In which era did dinosaurs dominate? Which period did dinosaurs first appear?
3. When did mammals first appear in the fossil record?
4. When did humans evolve?
5. What marks the end of one era and the beginning of the next?
6. How does your geologic time scale differ from the one used in the textbook?
7. When did life first evolve?
8. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why.
9. What could be done to improve this activity?

APPENDIX II, D

A 19th Century Journey

Adapted from: Learning Evolution PBS
www.pbs.org/wgbh/evolution/educators/lessons/lesson2/act1.html

Introduction: Traveling in the 1830's was expensive and dangerous. Few people went very far from their homes. However, it was also a time of great discovery and colonization. At this time, a young man had just recently graduated from Cambridge University with a Bachelor's of Art degree. He was planning to follow in his father's footsteps and become a physician, but he could not stand the sight of blood. His interests extended beyond the arts to nature, including botany and geology. Eventually, he became a pastor in a small church so that he could also study natural history.

In 1831, this young man was invited to voyage on a ship called the Beagle to explore the shores of Chile, Peru, and island in the Pacific. He took the job as an unpaid naturalist and recorded his observations on his expedition.

Purpose: To map the journey of a young naturalist and identify key observations from the voyage and hypothesize what they mean.

Procedure:

1. Using the excerpts from <u>The Voyage of the Beagle</u> and a world map, plot the voyage. You should include the date at each location and number the locations in chronological order.
2. Connect the locations with a line, starting and ending in England.
3. When you are finished with your map, you should illustrate it. Use small pictures to illustrate the observations made on the voyage. If you do not have enough room on the map, you may draw on a separate piece of paper and number them to correspond to the map.
4. List at least 5 significant observations made on the journey in one column and write how the observations contribute to the development of natural selection.

5. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why?

6. What could be done to improve this activity?

Excerpts from *Voyage of the Beagle*
Adapted from www.literature.org

Devonport, England: 50° N, 4° W
December 27, 1831
After having been twice driven back by heavy southwestern gales, Her Majesty's ship Beagle, a ten-gun brig, under the command of Captain Fitz Roy, R.N., sailed from Devonport on the 27th of December, 1831. The object of the expedition was to complete the survey of Patagonia and Tierra del Fuego, commenced under Captain King in 1826 to 1830—to survey the shores of Chile, Peru, and of some islands in the pacific – and to carry a chain of chronometrical measurements round the World.

Cape Verde, Porto Praya: 14° N, 23° W
January 16, 1832
The neighbourhood of Porto Praya, viewed from the sea, wears a desolate aspect. The volcanic fires of a past age, and the scorching heat of a tropical sun, have in most places rendered the soil unfit for vegetation. The island would generally be considered as very uninteresting. A single green leaf can scarcely be discovered over wide tracts of the lava plains; yet flocks of goats, together with a few cows, contrive to exist. It rains very seldom, but during a short portion of the year heavy torrents fall, and immediately afterwards a light vegetation springs out of every crevice....

Rio de Janeiro, Brazil: 23° S, 43° W
July 5, 1832
In the morning we got under way, and stood out of the splendid harbour of Rio de Janeiro. In our passage to the Plata, we saw nothing particular, excepting on one day a great shoal of porpoises, many hundreds in number. As soon as we entered the estuary of the Plata, the weather was very unsettled. One dark night we were surrounded by numerous seals and penguins, which made such strange noises, that the officer on watch reported he could hear the cattle bellowing on shore. On a second night we witnessed a splendid scene of natural fireworks; the mast-head and yard-arm-ends shone with St. Elmo's light....

Tierra del Fuego, Argentina: 55° S, 73° W
December 17, 1832
Having now finished with Patagonia and the Falkland Islands, I will describe our first arrival in Tierra del Fuego. A little after noon we doubled Cape St. Diego, and entered the famous strait of Le Maire. We kept close to the Fuegian shore, but the outline of the rugged, inhospitable Statenland was visible amidst the clouds. In the afternoon we anchored in the Bay of Good Success. While entering we were saluted in a manner becoming the inhabitants of this savage land. The savages followed the ship, and just before dark we saw their fire, and again heard their wild cry. The harbour consists of a fine piece of water half surrounded by low rounded mountains of clay-slate, which are covered to the water's edge by one dense gloomy forest. A single glance at the landscape was sufficient to show me how widely different it was from anything I had ever beheld....

Maldonado, Uruguay: 34° S, 54° W
July 24, 1833
The Beagle sailed from Maldonado, and on August the 3rd she arrived off the mouth

of the Rio Negro. This is the principal river on the whole line of caost between the Strait of Magellan and the Plata. It enters the sea about three hundred miles south of the estuary of the Plata. About fifty years ago, under the old Spanish government, a small colony was established here; and it is still the most southern position (lat. 41°) on this eastern coast of America, inhabited by civilized man.

Buenos Aires, Argentina: 34° S, 59° W
August 24, 1833
The Beagle arrived here on the 24th of August, and a week afterwards sailed for the Plata. With Captain Fitz Roy's consent I was left behind, to travel by land to Buenos Ayres. I will here add some oberstvations, which were made during this visit and on a previous occasion, when the Beagle was employed in surveying the harbour.

The plain, at the distance of a few miles from the coast, belongs to the great Pampean formation, which consists in part of a reddish clay, and in part of a highly calcareous marly rock. Nearer the coast there are some plains formed from the wreck of the upper plain, and from mud, gravel, and sand thrown up by the sea during the slow elevation of the land, of which elevation we have evidence in upraised beds of recent shells, and in rounded pebbles of pumice scattered over the country. At Punta Alta we have a section of one of these later-formed little plains, which is highly interesting from the number and extraordinary character of the remains of gigantic land-animals embedded in it. I will here give only a brief outline of their nature.

First, parts of three heads and other bones of the Megatherium, the huge dimensions of which are expressed by its name. Secondly, the Megalonyx, a great allied animal. Thirdly, the Scelidotherium, also an allied animal, of which I obtained a nearly perfect skeleton. It must have been as large as a rhinoceros: in the structure of its head it comes, according to Mr. Owen, nearest to the Cape Anteater, but in some other respects it approaches to the armadillos. Fourthly, the Mylodon Darwinii, a closely related genus of little inferior size. Fifthly, another gigantic edental quadruped. Sixthly, a large animal, with an osseous coat in compartments, very like that on an armadillo. Seventhly, an extinct kind of horse, to which I shall have again to refer. Eighthly, a tooth of a Pachydermatous animal, probably the same with the Macrauchenia, a huge beast with a long neck like a camel, which I shall also refer again. Lastly, the Toxodon, perhaps one of the strangest animals ever discovered: in size it equaled an elephant or megatherium, but the structure of its teeth, as Mr. Owen states, proves indisputably that it was intimately related to the Gnawers, the order which, at the present day, includes most of the smallest quadrupeds.

The remains of these nine great quadrupeds, and many detached bones, were found embedded on the beach, within the space of about 200 yards square. It is a remarkable circumstance that so many different species should be found together; and it proves how numerous in kind the ancient inhabitant of this country must have been….
The remains at Punta Alta were embedded in stratified gravel and reddish mud, just such as the sea might now wash up on a shallow bank. They were associated with twenty-three species of shells, of which thirteen are recent and four others very closely related to recent forms….

Port St. Julian, Argentina: 49° S, 67° W
January 9, 1834
Everything in this southern continent has been effected on a grand scale: the land, from the Rio Plata to Tierra del Fuego, a distance of 1200 miles has been raised in mass (and in Patagonia to a height of between 300 and 400 feet), within the period of the now existing sea-shells. I have said that within the period of existing sea-shells, Patagonia has been upraised 300 to 400 feet: I may add that within the period when icebergs transported boulders over the upper plain of Santa Cruz, the elevation has been at least 1500 feet. Nor has Patagonia been affected only by upward movements: the extinct tertiary shells from Port St. Julian and Santa Cruz cannot have lived, according to Professor E. Forbes, in a greater depth of water than from 40 to 250 feet; but they are now covered with sea-deposited strata from 800 to 1000 feet in thickness: hence the bed of the sea, on which these shells once lived, must have sunk downwards several hundred feet, to allow the accumulation of the superincumbent strata. What a history of geological changes does the simply-constructed coast of Patagonia reveal!

Bay of S. Carlos, Chile: 42° S, 73° W
January 15, 1835
On January the 15th we sailed from Low's Harbour, and three days afterwards anchored a second time in the bay of S. Carlos in Chiloe. On the night of the 19th the volcano of Osorno was in action. At midnight the sentry observed something like a large star, which gradually increased in size till about three o'clock, when it presented a very magnificent spectacle….

Valdivia, Chile: 39° S, 73° W
February 20, 1835
This day has been memorable in the annals of Valdivia, for the most severe earthquake experienced by the oldest inhabitant. I happened to be on shore, and was lying down in the wood to rest myself. It came on suddenly, and lasted two minutes, but the time appeared much longer. The rocking of the ground was very sensible. The undulation appeared to my companion and myself to come from due east, whilst others thought they proceeded from southwest: this shows how difficult it sometimes is to perceive the directions of the vibrations. There was no difficulty in standing upright, but the motion made me almost giddy: it was something like the movement of a vessel in a little cross-ripple, or still more like that felt by a person skating over thin ice, which bends under the weight of his body. A bad earthquake at once destroys our oldest associations: the earth, the very emblem of solidity, has moved beneath our feet like a thin crust over a fluid….In the course of the evening there were many weaker shocks, which seemed to produce in the harbour the most complicated currents, and some of great strength.

Concepcion, Chile: 37° S, 73° W
March 4, 1835
We entered the harbour of Concepcion. While the ship was beating up to the anchorage, I landed on the island of Quiriquina. The mayor-domo of the estate quickly rode down to tell me the terrible news of the great earthquake of the 20th: -- "That not a house in Concepcion or Talcahuano (the port) was standing; that seventy villages were destroyed; and that a great wave had almost washed away the ruins of Talcahuano." During my walk round the island, I observed that numerous fragments

of rock, which, from the marine productions adhering to them, must recently have been lying in deep water, had been cast up high on the beach; one of these was six feet long, three broad, and two thick.

Galapagos Islands, Ecuador: 0° S, 90° W
September 15, 1835
This archipelago consists of ten principal islands, of which five exceed the others in size. They are situated under the Equator, and between the five and six hundred miles westward of the coast of America. They are all formed of volcanic rocks; a few fragments of granite curiously glazed and altered by the heat, can hardly be considered as an exception...

Considering that these islands are placed directly under the equator, the climate is far from being excessively hot; this seems chiefly caused by the singularly low temperature of the surrounding water, brought here by the great southern polar current. Excepting during one short season, very little rain falls, and even then it is irregular; but the clouds generally hang low. Hence, whilst the lower parts of the islands are very sterile, the upper parts at a height of a thousand feet and upwards, possess a damp climate and a tolerably luxuriant vegetation....

September 29th – We doubled the southwest extremity of Albemarle Island...

The rocks on the coast abounded with great black lizards, between three and four feet long; and on the hills, an ugly yellowish-brown species was equally common. The whole of this northern part of Albemarle Island is miserably sterile....

The natural history of these islands is eminently curious, and well deserves attention. Most of the organic productions are aboriginal creations, found nowhere else; there is even a difference between the inhabitants of the different islands;; yet all show a marked relationship with those of America, though separated from that continent by an open space of ocean, between 500 and 600 miles in width. The archipelago is a little world within itself, or rather a satellite attached to America....

....The remaining land-birds form a most singular group of finches, related to each other in the structure of their beaks, short tails, form of body and plumage: there are thirteen species, which Mr. Gould has divided into four sub-groups. All these species are peculiar to this archipelago; and so is the whole group, with the exception of one species of the sub-group Cactornis, lately brought from Bow Island, in the Low Archipelago. Of Cactornis, the two species may be often seen climbing about the flowers of the great cactus-trees; but all the other species of this group of finches, mingled together in flocks, feed on the dry and sterile ground of the lower districts. The males of all, or certainly of the greater number, are jet black; and the females (with perhaps one or two exceptions) are brown. The most curious fact is the perfect gradation in the size of the beaks in the different species of Geospiza, from one as large as that of a hawfinch to that of a chaffinch, and (if Mr. Gould is right in including his sub-group, Certhidea, in the main group) even to that of a warbler. Seeing this graduation and diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends.

I will first describe the habits of the large tortoises (Testudo nigra, formerly called Indica), which has been so frequently alluded to. These animals are found, I believe, on all the islands of the archipelago; certainly on the greater number. They frequent in preference the high damp parts, but they likewise live in the lower and arid districts. I have already shown, from the numbers which been caught in a single day, how very numerous they must be. Some grow to an immense size: Mr. Lawson, an Englishman, and vice-governor of the colony, told us that he had seen several so large, that it required six or eight men to lift them from the ground; and that some had afforded as much as two hundred pounds of meat. The old males are the largest, the females rarely growing to so great a size; the male can readily be distinguished from the female by the greater length of its tail. The tortoises which live on those islands where there is no water, or in the lower and arid parts of the others, feed chiefly on the succulent cactus. Those which frequent the higher and damp regions, eat the leaves of various trees, a kind of berry (called guayavita) which is acid and austere, and likewise a pale green filamentous lichen, that hangs from the boughs of trees....

I have not as yet noticed by far the most remarkable feature in the natural history of this archipelago; it is, that the different islands to a considerable extent are inhabited by a different set of beings.... I never dreamed that islands, about 50 or 60 miles apart, and most of them in sight of each other, formed of precisely the same rocks, placed under a quite similar climate, rising to a nearly equal height, would have been differently tenanted; but we shall soon see that this is the case...

Tahiti Island, French Polynesia: 17° S, 149° W
November 15, 1835

At daylight, Tahiti, an island which must for ever remain classical to the voyager in the South Sea, was in view. At a distance the appearance was not attractive. The luxuriant vegetation of the lower part could not yet be seen, and as the clouds rolled past, the wildest and most precipitous peaks showed themselves towards the centre of the island....

Sydney, Australia: 33° S, 151° E
January 12, 1836
Early in the morning a light air carried us towards the entrance of Port Jackson. Instead of beholding a verdant country, interspersed with fine houses, a straight line of yellowish cliff brought to our minds the coast of Patagonia. A solitary lighthouse, build of white stone, alone told us that we were near a great and populous city. Having entered the harbour, it appears fine and spacious, with cliff-formed shores of horizontally stratified sandstone. The nearly level country is covered with thin scrubby trees, bespeaking the curse of sterility. Proceeding further inland, the country improves: beautiful villas and nice cottages are here and there scattered along the beach.

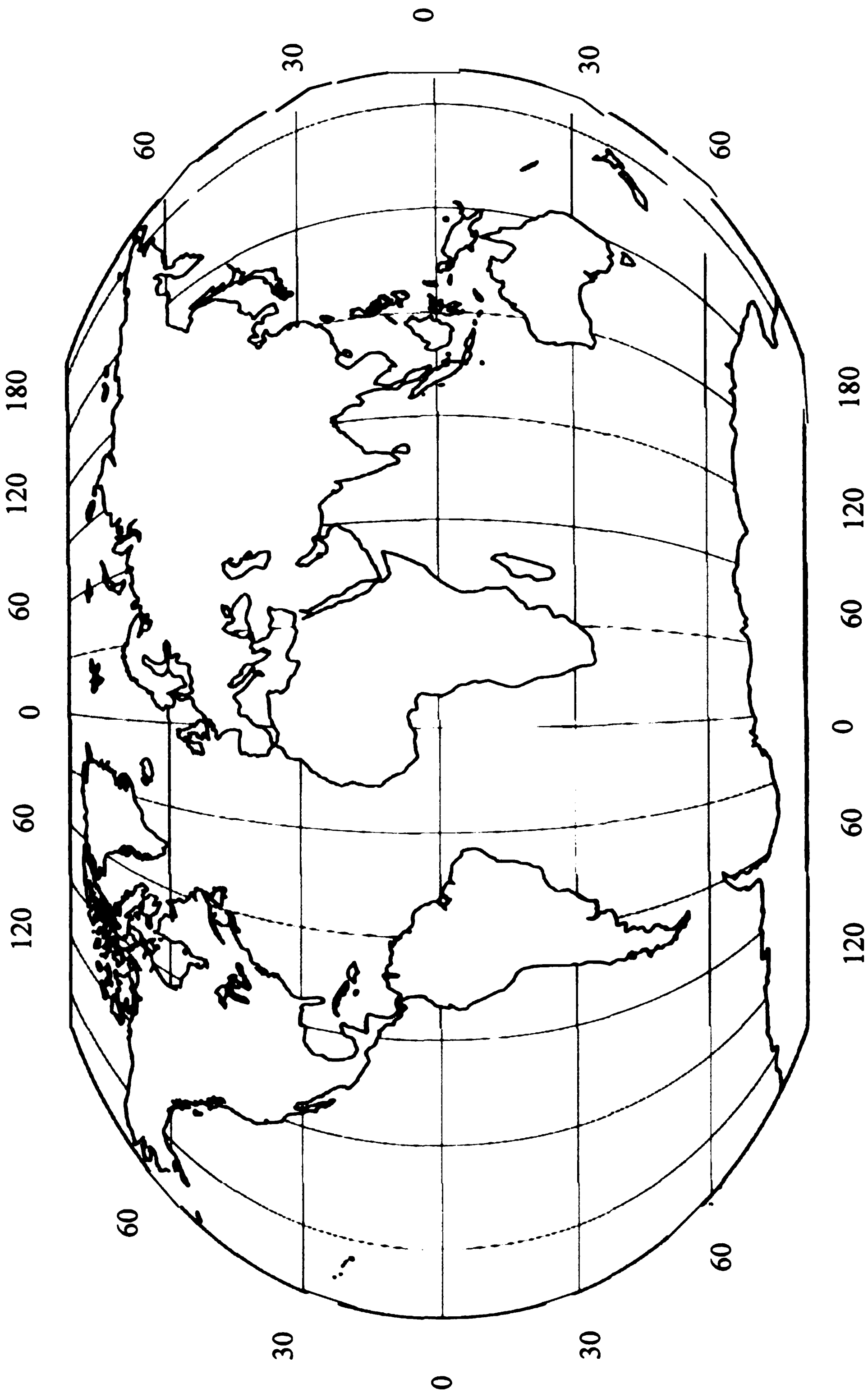
Cocos Islands: 12° S, 96° E
April 1, 1836
We arrived in view of the Keeling or Cocos Islands, situated in the Indian Ocean, and about six hundred miles distant from the coast of Sumatra. This is one of the lagoon-islands (or atolls) of coral formation, similar to those in the Low Archipelago which we passed near.....

Port Louis, Mauritius: 20° S, 57° E
May 9, 1836
We sailed from Port Louis, and calling at the Cape of Good Hope on the 8th of July we arrived off St. Helena. This island, the forbidding aspect of which has been so often described, rises abruptly like a huge black castle from the ocean.

Ascension: 8° S, 14° W
July 19, 1836
On the 19th of July we reached Ascension. Those who have beheld a volcanic island, situated under an arid climate, will at once be able to picture to themselves the appearance of Ascension. The will imagine smooth conical hills of a bright red colour, with their summits generally truncated, rising separately out of a level surface of black rugged lava.

Falmouth, England: 50° N, 5° W
October 2, 1836
....On the 2nd of October we made the shore, of England; and at Falmouth I left the Beagle, having lived on board the good little vessel nearly five years....

Figure 1. World map



APPENDIX II, E

Name________________________

Hour_____

Variations of Seeds within Species of Maple Trees

Adapted from Merle K. Heidemann

Science and Math Education Professor, Michigan State University

Introduction: Variations of individuals plays a critical role in the evolutionary process. When you look around the classroom and hallways there are many variations of characteristics that can be tested for. What role do these variations play in the evolution, survival or failure of a species. A common family of trees found in Michigan are the Maples. When looking at the seeds produced by maple trees it becomes evident that thee are variations between the several different species, but what about within a species of Maple trees. Your task today is to monitor the variations of the length of seeds from one species of Maple tree and to plot them onto graph.

Material: Metric ruler, 50 maple seeds of one species, poster board, digital camera, seeds from several different species of Maple trees.

Procedures:

1. Obtain the materials needed for this activity.
2. Measure the seed length, of 50 seeds, in centimeters.
3. Use a ruler to draw the x axis onto the poster board.
4. Leave enough space between the units on the x axis to place the seeds onto the poster board
5. Place the seeds neatly onto the poster board as if making a bar graph. Stack them one above the other horizontally.
6. Once you place the seed onto the poster board leave it in place.
7. Get a final tally for the number of seeds for each length recorded.
8. Take a digital photo of your poster board for a permanent record of your work, then answer the questions.

Questions:

1. Determine the mean, median and mode for seeds that you have measured and graphed.

2. What was the range for the length of the seeds measured.

3. Make a prediction on how the survival rates may be influenced by the length of the seed.

4. What other characteristics could you collect data on when looking at maple seeds?

5. How do the characteristics of your seeds compare to the seeds of other species of Maple seeds?

6. Design an experiment that involves Maple seeds that you and your partner could conduct in the classroom. You must set up, design and carry out your experiment.

7. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why?

8. What could be done to improve this activity?

APPENDIX II, F

Name________________________
Hour____

Bead Bug Blitz

Adapted from Merle K. Heidemann
Science and Math Education Professor, Michigan State University

Introduction: A population is a group of interbreeding organisms that exist within a known range. Natural variation exists among the organisms in a population, and selection pressures can cause certain individuals in a population to have an advantage over other individuals. A classic example of this is the peppered moths. There are two morphs of peppered moths, a light and a dark morph. Peppered moths live in England and rest on trees that are nearly the same color as the light morph peppered moth. Predators can easily find the dark morphs against the light background of the tree, so very few of the dark morphs survive to produce offspring. However, when the industrial revolution hit England, ash in the air from the coal-burning factories caused some of the lightly colored trees to become gray. In response, the light colored peppered moths were very easy to spot, so very few of the light morphs survived to reproduce. As a result, the dark peppered moths became more numerous because they had better camouflage and blended in with the darker trees. This example shows that populations can change over time as a result of selection pressures.

Purpose: To explain how genetic variation and environmental pressures contribute to the diversity of organisms and how natural selection acts on individuals, causing changes in populations over time.

Materials:
3 populations of colored beads (approximately 50 beads of each color)
2 fabric "habitats"
3 cups

Scenario: There exists a patch of land known as Multicolored Meadows. In the Meadows, there are small critters known as Beadbugs, who come in a variety of colors. The Meadow Muncher is a natural predator of Beadbugs. Today, you will become the Meadow Muncher and devour the tasty Beadbug in its natural habitat. You will be monitoring the different populations of Beadbugs for several generations to see if any change occurs.

Procedure: Read all directions before beginning!
1. Form a group of three.
2. Assign the following roles in your group: Meadow Muncher, Recorder, and Beadbug Reproduction Manager. You may swap duties when you change the habitat later.
3. Choose two types of habitats for your Beadbugs. The habitats come in the form of patterned material.
4. Choose three colors of beads to represent your Beadbugs. The colors should roughly match the colors of your first habitat. In other words, your beads should blend in.
5. Gather about 50 bead of each color and place each color into a separate cup.
6. Take all of your materials back to your lab station.
7. Lay down your first habitat and everyone but the Meadow Muncher should evenly

place 16 beads of each color on the fabric.

8. Record in your data table the number of beads of each color in Generation 1.
9. Now it is time for the Meadow Muncher to start catching Beadbugs, but there are some rules to follow:
    1. The Meadow Muncher can only pick up one bead at a time.
    2. The Muncher must take the first bead that he or she sees.
    3. After picking up a bead, the Muncher must look away before picking up another bead.
10. The Muncher must eat 24 beads.
11. After the feeding, the number of each color Beadbug must be counted and recorded in the data table.
12. Take the initial population and subtract the number eaten to find the number of survivors for each color.
13. The Beadbugs who survive get to reproduce. Each parent produces one offspring identical to itself. The Beadbug Reproduction Manager must double the number of survivors of each color and place the offspring in the habitat. For example, if 6 red Beadbugs survived, there would be 6 red offspring, for a total of 12 red Beadbugs at the beginning of the next generation.
14. Record the initial population for the next generation. This number should be two times the number of survivors from the previous generation.
15. Continue to eat, reproduce, and record the information for five generations of Beadbugs.
16. At the end of five generations, the Beadbugs are forced to move to a new habitat due to a drought. Move your Beadbug population to your other habitat.
17. Continue to use the same procedure for five generations on the new habitat.

First Round

Habitat Description ____

Gen.	Color:	Color:	Color:
1	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
2	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
3	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
4	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
5	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____

Second Round

Habitat Description ____

Gen.	Color:	Color:	Color:
1	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
2	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
3	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
4	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____
5	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____	Initial Population: ____ Number Eaten: ____ Survivors: ____

Questions and Analysis:

1. Did any specific color of Beadbug go extinct? If so, explain why extinction occurred using the concept of natural selection. If no extinction occurred, explain why all colors survived using the concept of natural selection.

2. Was there a change in the distribution of Beadbug colors when you switched habitats? Explain what this change in habitat represents in the real world.

3. If you started with a population of only green Beadbugs, would you see any change take place in this population over time? Why or why not?

4. If you only had green Beadbugs, explain whether or not this population would be able to adapt in the future if the organisms had to change habitats again.

5. Predict what the population of Beadbugs in the second habitat would look like in 10 generations. Explain why you think the population may or may not change.

6. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why?

7. What could be done to improve this activity?

APPENDIX II, G

Human Variations

Adapted from: Braun, S. and Young, J. (1989). Heath Biology Laboratory Investigations /www.ncsu.edu/scivis/lessons/variation/varlab2.html

Introduction: The human population exhibits countless variations that result in each individual being unique. Variations within a population provide the means for natural selection by affecting the survival rates and reproductive success of individuals within a population. In this lab we will determine the amount of variation that exists in our small population by measuring the spread of the hand, and the length of the arm and leg. You must also measure 2 other variations, on at least 10 people, to be determined by you and your partner. Working in groups of four you and your partners will measure hand spread, leg length, arm length and two other variables that will be determined by your group. You will then graph the hand spread data for classroom data and determine the mean, median and mode for the handspread data.

Materials: Meter stick, ruler, calipers, vernier calipers

Procedures:

1. To measure hand spread make a fist with your thumb and pinky sticking out from your fist.
2. Press your fingers down on a metric ruler with your thumb and pinky spread out as far as possible and record the data in the table below and on the board.
3. Measure the length of your leg by measuring from the outside of the ankle bone to the top of the hip bone.
4. Measure length of arm from the top of shoulder to the wrist.
5. You and your partners must make measurements of two other variations on 10 different people.

Hand Spread (cm)	Leg length (cm)	Arm length (cm)

Handspread Classroom Data

cm	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
# people															

Name	Variation 1	Variation 2
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

1. Compare the leg length to the arm length of the individuals that you collected data from. Why would this comparison be of interest to anthropologists?

2. What was the largest hand spread and smallest hand spread measured? What would be the advantages and disadvantages of large and small hand spread?

3. Why did your group select the two final variations to be measured?

4. Determine the mean, median and mode for the classroom data and tell me what this indicates about the data collected?

   Mean-

   Median-

   Mode-

5. What is the significance of having variations within a species such as humans (Homo sapiens sapiens)?

6. What is the source of the variations that you observed?

7. In your own words define variation.

8. Beside the variations that were observed today list at least 10 other characteristics that vary in human populations. Try to think of some that are internal rather than externally visible.

9.Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why.

10. What could be done to improve this activity?

APPENDIX II, H

Name_______________________________
Hour________

Comparison of Homologous Structures

Introduction: Chimpanzees and humans have several characteristics that are shared between the two species. When the bone structures of the two species are compared it becomes evident that there are similarities in structure, yet there remain differences between chimpanzees and humans. You and your partner will take measurements of the leg and arm bones of a chimpanzee and human and compare the two.

Materials: Photos of leg and arm bones from a chimpanzee and a human, metric ruler and skeletal models when possible.

Procedures:

1. Make all measurements in centimeters.
2. Measure the length of the human arm including the length of humerus, radius and ulna. Record in the table below.
3. Determine the ratio of the humerus to the total arm length.
4. Measure the length of the human leg including the femur, fibula and tibia. Record in table below.
5. Determine the ratio of the femur to the leg length.
6. Determine the ratio of the arm to the leg and record in the table below.
7. Repeat for the chimpanzee arm and leg.

Structure	Human	Chimpanzee
Arm length (cm)		
Humerus (cm)		
Radius (cm)		
Ulna (cm)		
Ratio of Humerus: Arm length		
Leg length (cm)		
Femur (cm)		
Fibula (cm)		
Tibia (cm)		
Ratio of Femur: Leg length		
Ratio of Arm length: Leg length		

Questions

1. What is a homologous structure?

2. Why is the comparison of homologous structures between different species useful?

3. Which organism has a smaller ratio of arm length: leg length? What does this indicate about how the animal walks? Why?

4. If you discovered an arm and leg bone from an unknown species of a hominid how could you determine if it was more human like or chimpanzee like?

5. Compare and contrast the bone and skeletal structures of the chimpanzee to that of a human. You may wish to view the photos of the chimpanzee and compare them to the skeleton in the front of the class.

6. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why?

7. What could be done to improve this activity?

Figure 2. CHIMPANZEE NEXT TO HUMAN LEG

Figure 3. HUMAN ARM AND LEG

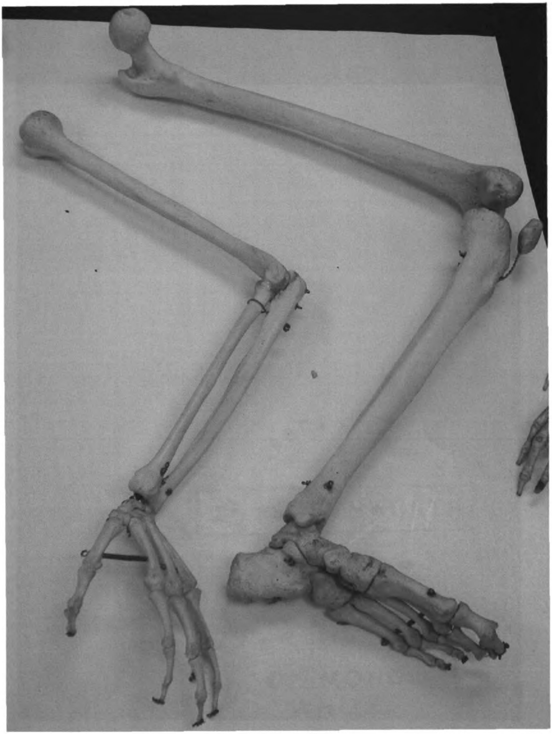


Figure 4. CHIMPANZEE ARM AND LEG

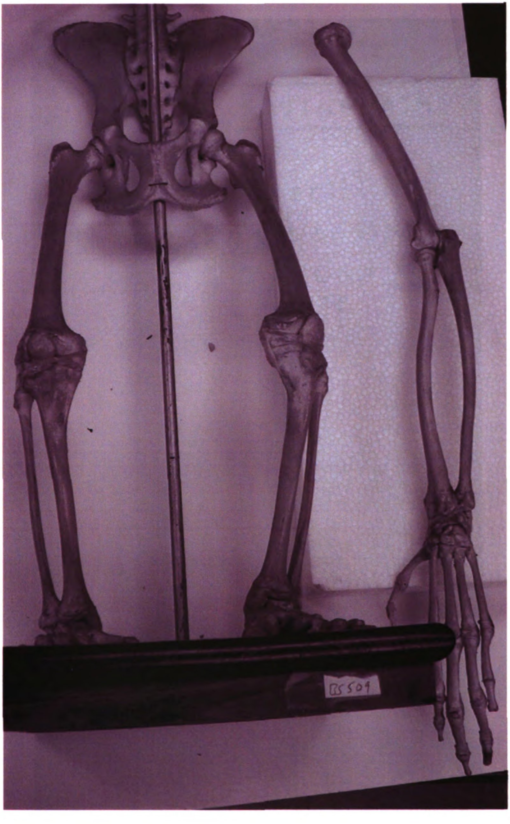


Figure 5. HUMAN AND CHIMPANZEE ARM

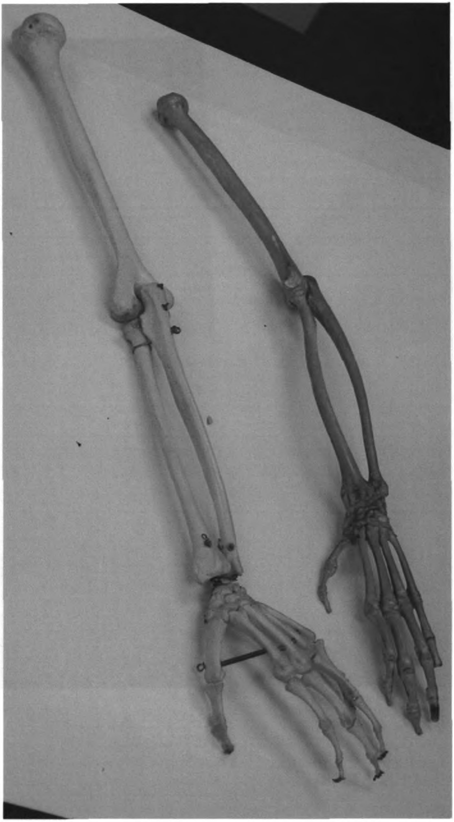
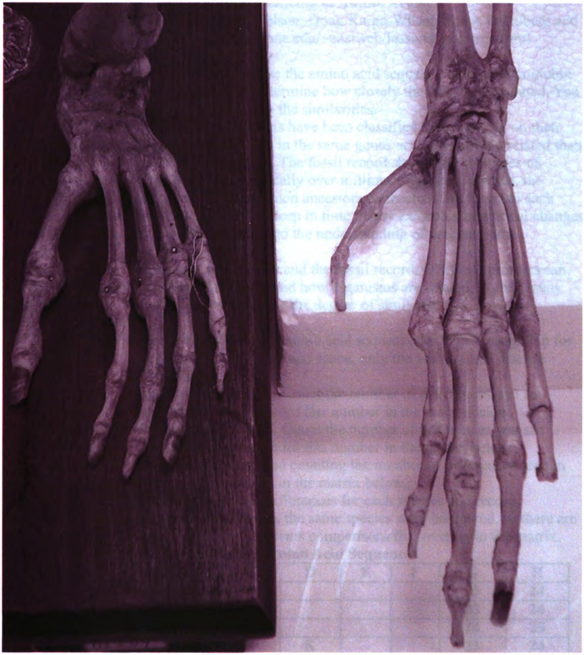


Figure 6. CHIMPANZEE FOOT AND HAND



APPENDIX II, I

Name________________________
Hour______

Molecular Sequencing of Amino Acids

Adapted from: Martin Nickels, Craig Nelson, Doug Karpa-Wilson, Steve Freedberg and Nathan Murphy http://www.indiana.edu/~ensiweb/lessons/mol.prim.html

Purpose: In this activity, you will analyze the amino acid sequence of beta hemoglobin molecules of eight different species to determine how closely the species are related. You will also construct a cladogram and graph the similarities.

Introduction: For many years, organisms have been classified based mainly on their visible characteristics. Organisms that are in the same genus are more closely related than all of the organisms in the same kingdom. The fossil record shows that the types of organisms on earth have changed dramatically over millions of years. However, the change is gradual, and indicates that common ancestors connect all life forms to each other. When tracing the flow of life back deep in time, many examples of gradual changes from earlier times can be seen. This leads to the understanding of descent with modification.

In addition to structural similarities and the fossil record, DNA and proteins can be used to determine patterns of ancestry and how organisms are related. In fact, many organic molecules can be used to determine the degree of similarity.

Procedure Part A:

1. On the Data Sheet you will find an amino acid sequence for beta hemoglobin for eight different species. To save time and space, only the amino acids that are different have been listed.
2. Compare species A with species B. Count the number of differences you see between the two sequences and record this number in the matrix below.
3. Compare species A with species C. Count the number of differences you see between the two sequences and record this number in the matrix below.
4. Continue comparing the species and counting the number of differences seen in each sequence and recording them in the matrix below.
5. Calculate the average number of differences for each species and record.

Note: The S in the matrix below means the same species were compared, so there are obviously no differences. The X represents comparisons that overlap in the matrix.

Part "A" Matrix: Differences Among Amino Acid Sequences

Species	A	B	C	D	E	F	G	H
A	**S**						**25**	**24**
B	**X**	**S**					**25**	**24**
C	**X**	**X**	**S**				**24**	**25**
D	**X**	**X**	**X**	**S**			**23**	**24**
E	**X**	**X**	**X**	**X**	**S**		**22**	**27**
F	**X**	**X**	**X**	**X**	**X**	**S**	**25**	**24**
G	**X**	**X**	**X**	**X**	**X**	**X**	**S**	**33**
H	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**S**
Averages	——						**24**	**26**

****Averages must be rounded to the nearest whole number.

Questions and Analysis for Part A:

1. What does the S represent in the matrix? In other words, what two species are being compared? How many differences would you expect for this comparison?

2. What two species are the most closely related? How can you tell?

3. What two species are the least closely related? How can you tell?

4. What is the general pattern of differences among the column averages as you move from left to right across the table? What does this suggest about the relationships of each species?

Part B

5. The first seven species in the data table and matrix are primates.
6. Label each of the species A-G with their names in the matrix according to the table below:

Species A	Human	Species E	Rhesus Monkey OWM
Species B	Chimp	Species F	Squirrel Monkey NWM
Species C	Gorilla	Species G	Lemur
Species D	Gibbon	Species H	Identified Later

Questions:

1. What two groups of primates is least similar to the others?

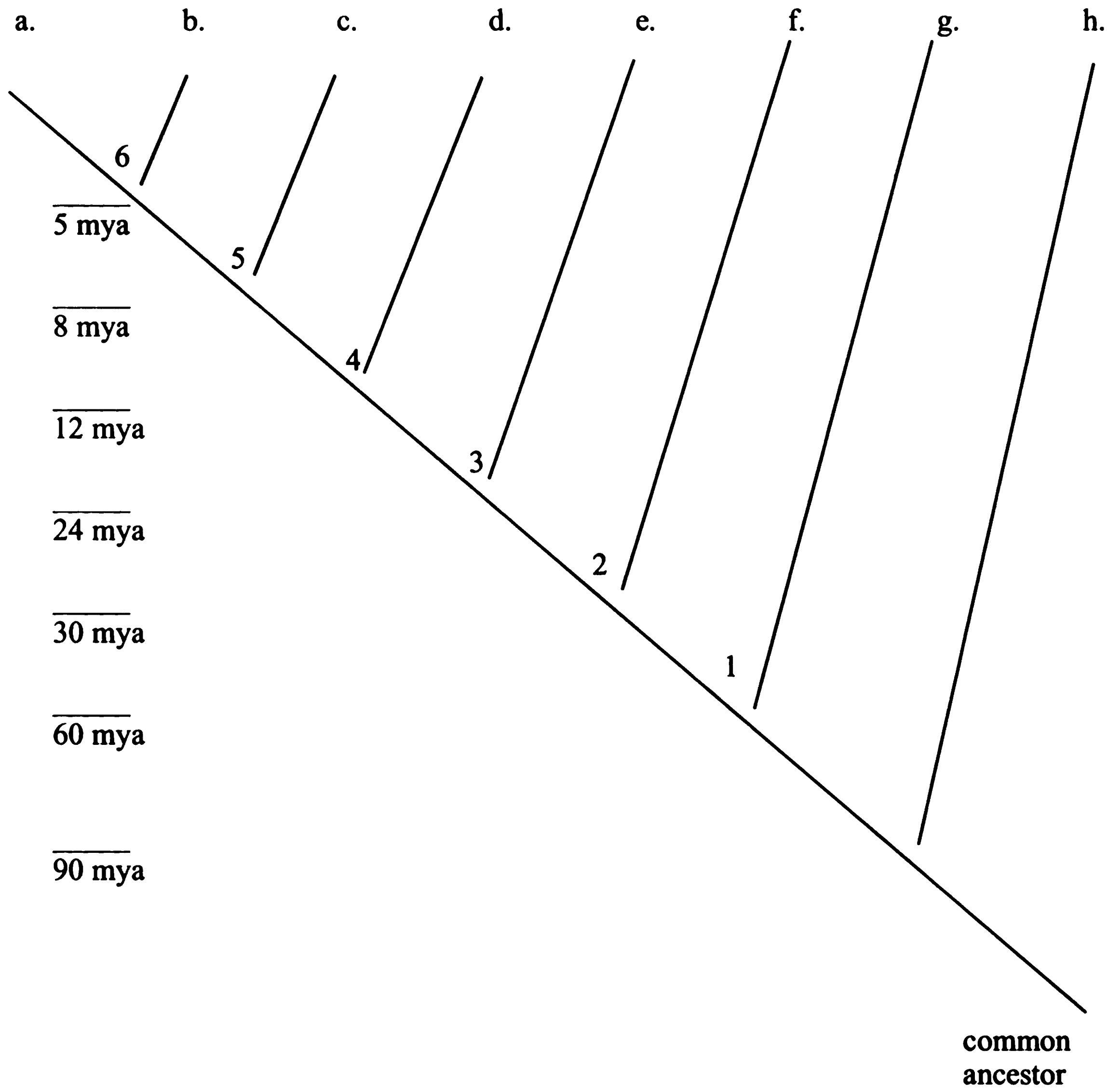
2. Are gorillas more similar to humans or to chimpanzees based on the sequence data? Why?

3. Explain what you think the similarities between the species indicate about a common ancestor?

Part C: Building a Cladogram

Cladistics is a classification scheme that assumes every group of organisms arose by branching off from a previous group. Each branch is called a clade. That clade includes any and all subsequent branching. One clade often includes many smaller clades. All the individuals within a clade share one or more selected traits. Each trait must be identical or very similar within a clade. However the traits appear to be modified from earlier forms of the trait. The simplest diagram showing the branches is based on the sequence of modifications and produces a cladogram.

Place the name of the species across the top from a. to h. On the left hand side place the average number of changes that occurs. You calculated averages in Table A.



4. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why.

5. What could be done to improve this activity?

Data Table: Comparison of the Amino Acids in the Beta Chain of the Hemoglobin Molecule in Eight Selected Species

Amino Acid Position	Species A	Species B	Species C	Species D	Species E	Species F	Species G	Species H
1	V	V	V	V	V	V	T	V
2	H	H	H	H	H	H	F	Q
4	T	T	T	T	T	T	T	S
5	P	P	P	P	P	G	P	G
6	E	E	E	E	E	D	E	E
8	K	K	K	K	K	K	N	K
9	S	S	S	S	N	A	G	A
10	A	A	A	A	A	A	H	A
12	T	T	T	T	T	T	T	L
13	A	A	A	A	T	A	S	A
16	G	G	G	G	G	G	G	D
20	V	V	V	V	L	V	V	V
21	D	D	D	D	D	E	E	E
22	E	E	E	E	E	D	K	E
33	V	V	V	V	L	V	V	V
43	E	E	E	E	E	E	E	D
50	T	T	T	T	S	T	S	N
52	D	D	D	D	D	D	D	G
54	V	V	V	V	V	V	I	V
56	G	G	G	G	G	N	G	G
69	G	G	G	G	G	G	S	H
70	A	A	A	A	A	A	A	S
72	S	S	S	S	S	S	S	G
73	D	D	D	D	D	D	E	E
75	L	L	L	L	L	L	L	V
76	A	A	A	A	N	A	H	H
87	T	T	T	Q	Q	Q	Q	A
94	D	D	D	D	D	D	V	D
95	K	K	K	K	K	K	A	K
104	R	R	K	R	K	R	K	R
112	C	C	C	C	C	C	I	V
116	H	H	H	H	H	H	H	R
120	K	K	K	K	K	K	N	K
121	E	E	E	E	E	E	D	D
123	T	T	T	T	T	T	S	T
125	P	P	P	Q	Q	Q	Q	E
126	V	V	V	V	V	V	T	L
129	A	A	A	A	A	A	A	S
130	Y	Y	Y	Y	Y	Y	F	Y
135	A	A	A	A	A	A	T	A

APPENDIX II, J

Clipbirds

Adapted from Al Janulaw and Judy Scotchmoor

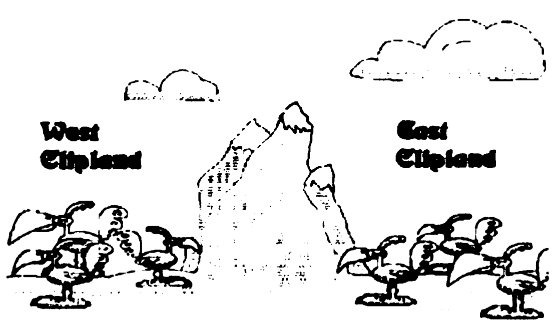
Overview: This activity will demonstrate how variation in bird beaks within a population varies from generation to generation based on the available food types.

Purpose: To show variation and natural selection within a population, adaptations that are advantageous persist in a population, and speciation requires reproductive isolation.

Introduction: Evolution is the result of natural selection acting upon variation within a population. Given a set of environmental circumstances, organisms with favorable traits have a selective advantage over individuals with less favorable traits. Selective advantage leads to speciation. It is important to understand that favored traits are only advantageous within a particular situation and may not aid in survival if the circumstances change. For Clipbirds, different types of food favor different beak sizes. One beak size may only be favorable over another beak size under specific conditions. When conditions change, the favored beak size may also change.

Materials per group:
3 bags filled with "food" for each season
10 large binder clips
10 medium binder clips
10 small binder clips
10 plastic cups

Scenario: In a land far, far away, there is an island known as Clipland. The island is inhabited by a large population of Clipbirds that feed on a variety of foods. The Clipbirds recently had a major disagreement about the mating season, and part of the population relocated to the other side of the mountain range that divides the island. The two populations now live separately because of their differences. Now, the two populations are known as the East and West Clipbirds.



Procedure:

1. The room will be divided in half, and you will be working with the people on your side of the room.
2. Before starting, predict which beak will be the most fit for survival for the three seasons described in Table 1. You should look at the energy values for each food type and at each of the birds energy requirements for survival and reproduction.
3. Choose six people to begin as the Clipbirds.
4. Two of the six people will be given large clips, two will be given medium clips, and the remaining two will be given small clips.
5. Each of the Clipbirds must also have a plastic cup that represents the stomach.
6. Spread out the food the first season in the pan provided.
7. Each Clipbird has different energy requirements to survive, and additional energy is needed to reproduce. See Table 2 for the caloric values of the food and Table 3 for the survival and reproduction energy needs for each bird type. Keep in mind there is competition between East and West Clipland to see which population will become the largest. When there is enough energy to reproduce, one offspring is made that is identical to the parent.
8. The entire population will have 30 seconds to eat all that they can, at the same time, but remember each of the various food types have a different caloric value.
9. To gather food, the "beaks" are opened, the food is grasped, the "beak" is closed, and the food is deposited in the stomach.
10. At the end of each feeding, the number of calories must be calculated and the fate of the bird must be recorded in Table 4. The number of birds that survive and the number of offspring for each season will be recorded. Students who were not part of the original six birds, will become the offspring for seasons 2 and 3. Birds that do not survive, are eliminated from the population, but may become offspring in future seasons.
11. After Season 1 is completed, return all of the food to the bag.
12. Pour the bag labeled Season 2 into the container and repeat steps 7-10.
13. At the end of Season 2, return all of the food to the bag.
14. Pour the bag labeled Season 3 into the container and repeat steps 7-10.
15. Record the initial populations and the end total population for East and West Clipland on the board for each season and each bird beak.

Table 1: Types and amounts of food available each season

Location	Season 1	Season 2	Season 3
East Clipland	4 cups popcorn 2 cups lima beans 50 marbles	1 cup popcorn 20 lima beans 50 marbles	100 marbles
West Clipland	4 cups popcorn 2 cups lima beans 50 marbles	4 cups popcorn 20 lima beans 5 marbles	6 cups of popcorn

Name________________________

Hour______

1. Predict which bird beak will be the most successful in each season, and explain why you think that way.

East Clipland Season 1:

East Clipland Season 2:

East Clipland Season 3:

West Clipland Season 1:

West Clipland Season 2:

West Clipland Season 3:

2. Based on your predictions, describe what you think the population on each side of the island will look like at the end of the third season. Explain why you think your predictions are likely.

East Clipland:

West Clipland:

Table 2: Food Values in Kilocalories

Food Type	Energy (Kilocalories)
Marblefruit (Marble)	10
Big Tootfruit (Lima beans)	5
Tiny Tootfruit (Popcorn)	2

Table 3: Kilocalories Needed for Survival and Reproduction

Type of beak	Kilocalories needed to survive	Kilocalories needed to reproduce
Large beak	100	200
Medium beak	60	120
Small beak	35	70

Table 4: Clipbird Population

Size	Season 1	Season 2	Season 3
Small	Initial Population _____ Survivors _____ Offspring _____ Total moving to Season 2 _____	Initial Population _____ Survivors _____ Offspring _____ Total moving to Season 3 _____	Initial Population _____ Survivors _____ Offspring _____ Total at end _____
Medium	Initial Population _____ Survivors _____ Offspring _____ Total moving to Season 2 _____	Initial Population _____ Survivors _____ Offspring _____ Total moving to Season 3 _____	Initial Population _____ Survivors _____ Offspring _____ Total at end _____
Large	Initial Population _____ Survivors _____ Offspring _____ Total moving to Season 2 _____	Initial Population _____ Survivors _____ Offspring _____ Total moving to Season 3 _____	Initial Population _____ Survivors _____ Offspring _____ Total at end _____

Questions and Analysis:

3. On a separate piece of paper, graph the initial populations and the end total population for the small, medium, and large beaks for each season and for both sides of the island. The seasons are on the x-axis and the number of birds should go on the y-axis. All of the information should be put on one graph.

4. What does the graph show is happening to the population of birds in East Clipland? Explain what you think caused the changes seen in the graph.

5. What does the graph show is happening to the population of birds in West Clipland? Explain what you think caused the changes seen in the graph.

6. Determine which beak size was the best adaptation for each of the seasons in East

Clipland.

Season 1 _______________

Season 2 ________________

Season 3 _______________

7. Compare your predictions with your results for East Clipland. Were the predictions the same as the results? Why or why not?

8. Determine which beak size was the best adaptation for each of the seasons in West Clipland.

Season 1 _______________

Season 2 ________________

Season 3 _______________

9. Compare your predictions with your results for West Clipland. Were the predictions the same as the results? Why or why not?

10. Define natural variation. Give at least two sources of natural variation found in this simulation.

11. Explain the role of the mountain range on the island. In other words, how does the mountain range effect the population of birds?

12. After three seasons, explain whether or not you think speciation is occurring between the two populations of clipbirds. Give evidence to support your claim.

13. What type of speciation do you think is occurring on Clipland? Explain your answer.

14. Rate this activity 1 2 3 4 5, 1 liked 5 disliked and please tell me why?

15. What could be done to improve this activity?

Chronology of Hominids
Adapted from: by Larry Flammer
http://www.indiana.edu/~ensiweb/lessons/chronlab.html

Introduction: As more discoveries are made, the fossil record for hominids is becoming more complete. Hominids include humans and their two-legged primate ancestors. With the addition of more information, the gaps in the fossil record are starting to show a more complete history of early man.

Purpose: To create a timeline of hominid fossils to show the changes in hominids over time.

Procedure:

1. Start with the oldest fossil in the chart below (*A. ramidus*), and draw a vertical line near the lower left corner on the chronology chart. The vertical line should start at 4.6 million years ago (mya) and end at 4.2 mya. Write the name of the fossil next to the vertical line.
2. For each of the remaining species, shift about a centimeter to the right each time and plot the vertical lines on the chronology chart.
3. Estimate as closely as possible the positions to plot which fall between the lines on the chronology chart.

Species/Sub-species	Lived... Years Ago
Homo sapiens	
Cro-Magnon.....................	50,000-10,000
Neanderthal......................	125,000-30,000
Archaic *H. sapiens*	700,000-250,000
Homo erectus	1.8 mya - 300,000
Homo habilis	2.5 mya – 1.5 mya
Australopithecus boisei	1.8 mya – 1.4 mya
A. robustus	2 mya – 1.5 mya
A africanus	3 mya – 2.3 mya
A. afarensis (Lucy)	3.9 mya – 3 mya
A. anamensis	4.5 mya – 3.0 mya
Ardipithecus ramidus	4.6 mya – 4.2 mya

Extended Chart—Extra Credit (You may tape extra sheets on the bottom of the chronology chart and plot the following for extra credit)

Chimpanzee	Line branched off about 7 mya
Gorilla	Line branched off about 10 mya
Ramapthithecus (in orangutan line)	Lived about 8 mya
Orangutan	Line branched off about 16 mya
Proconsul (very early hominid)	Lived about 20-18 mya
Aegyptopithecus (earliest known hominid)	Lived about 33 mya

Chronology Chart

MYA

Now --

.2 --

.4 --

.6 --

.8 --

1.0 --

1.2 --

1.4 --

1.6 --

1.8 --

2.0 --

2.2 --

2.4 --

2.6 --

2.8 --

3.0 --

3.2 --

3.4 --

3.6 --

3.8 --

4.0 --

4.2 --

4.4 --

4.6 --

4.8 --

5.0 --

APPENDIX II, L

Fossil and Migration Patterns in Early Hominids
Adapted from John Banister-Marx
www.teachersdomain.org/resources/tdc02/sci/life/evo/lp_humanevo/index.html

Introduction:

Discoveries of fossil hominids around the world have helped scientists to determine not only a likely origin for human species, but also a migration pattern throughout the world. Until the 1920's, Asia had been considered the birthplace of humans. Yet one man stood alone in his conviction that Asia was not the birthplace of humankind. Louis S. B. Leakey searched the weathered desert slopes of Olduvai Gorge for several decades, looking along what had been prehistoric shores of an ancient lake looking for hominid fossils. Eventually his efforts paid off when he confirmed finding early hominid fossil remains. Since then, other fossil hominids have been discovered throughout much of the world. It is the type, dates and distribution of these fossil specimens that gives us an indication of where humankind's earliest ancestors had migrated and originated.

Purpose:

Using knowledge of geography and mapping skills, students will determine the location of a sampling of fossil hominids to infer a continent of origin and a likely pattern of migration from that point of origin.

Procedure:

Examine the data below and plot each coordinate. Though this list is not an exhaustive list of all the fossil hominid discoveries, it is accurate in terms of general trends of distribution and density within given regions. Mark your map by using red numbers for Austalopithecines (1-10), blue numbers for Homo erectus (11-22), green numbers for Homo sapiens neanderthalensis, and black numbers for Homo sapiens sapiens. Write the numbers directly on your map using colored pencils.

Data:

The data below includes four pieces of information:

1. Fossil taxon and its age range in millions of years
2. Location in degrees east or west longitude and north or south latitude, and the name of site where fossil was found

Australopithecines (4.4-1.4 MYA) Fossils 1-10

1) 38°E, 1°S Chemeron	5) 36° E, 5° S Laetoli	9) 27° E, 27° S Swartkrans
2) 27°E, 27°S Sterfontein	6) 36° E, 7° N Omo	10) 38° E, 4° N Koobi-Fora
3) 43° E, 8°N Hadar	7) 26° E, 26° S Kromdrai	
4) 37° E, 4° S Olduvai	8) 28° E, 25°S Magapansgat	

Homo erectus (1.9-.3 MYA) Fossils 11-22

11) 112° E, 38° N Zhoukoudian	15) 38° E, 4° N Koobi-Fora	19) 27° E, 27° S Sterkfontein
12) 112° E, 8°S Modjokerto	16) 6° W, 35 ° N Sale	20) 43° E, 8° N Nhadar
13) 18° E, 18° N Yayo	17) 13° E, 47° N Mauer	21) 37° E, 4° S Olduvai
14) 7° W, 34° N Rabat	18) 27° E, 27° S Swartkrans	22) 36° E, 7° N Omo

Homo neanderthalensis (.13-.03 MYA) Fossils 23-44

23) 36° E, 33° N Amud	31) 11° E, 47° N Steinheim	39) 36° E, 35° N Tabun
24) 110° E, 7° S Solo	32) 7° E, 52° N Neanderthal	40) 24° E, 30° S Florisbad
25) 8° E, 32° S Saldanha	33) 34° E, 45° N Kiik-Koba	41) 138° E, 34° S Lake Mung0
26) 27° E, 32° S Broken Hill	34) 5° W, 32° N Jebel-Irhoud	42) 115° E, 1° N Niah
27) 68° E, 41° N Teshik Tash	35) 38° E, 50° N Sungir	43) 137° E, 38° N
28) 5° W, 35° N Gibraltar	36) 3° E, 43° N Lascaux	44) 112° E, 38° N Zhoukoudian
29) 44° E, 36° N Shanidar	37) 18° E, 48° N Predmost	
30) 2° W, 52° N Swanscombe	38) 70° E, 62° N	

Early modern *Homo sapiens* (.1-.02 MYA) Fossils 45-56

45) 75° W, 2° N Punin	49) 108° E, 27° N	53) 88° W, 32° N Natchez
46) 120° W, 44° N Marmes	50) 32° E, 27° S Border Cave	54) 102° W, 32° N Midland
47) 100° E, 54° N	51) 35° E, 32° Jebel Qafzeh	55) 81° W, 27° N Vero Beach
48) 70° E, 23° N	52) 44° W, 18° S Lagoa Santo	56) 99° W, 19° N Tepexpan

Questions

1. How many thousands of years ago is 1.3 million years? Or .02 million years?

2. Why have scientists concluded that Africa is the "birthplace" of hominids?

3. Find a fossil and write its type (taxon) and map coordinates for each of the following locations listed below.

Location	Coordinates	Fossil Type
China		
United States		
Mexico		
Australia		
Brazil		
Java		
Germany		
Ethiopia		
Iraq		
South Africa		

4. Which taxon seems to have the smallest range of distribution?

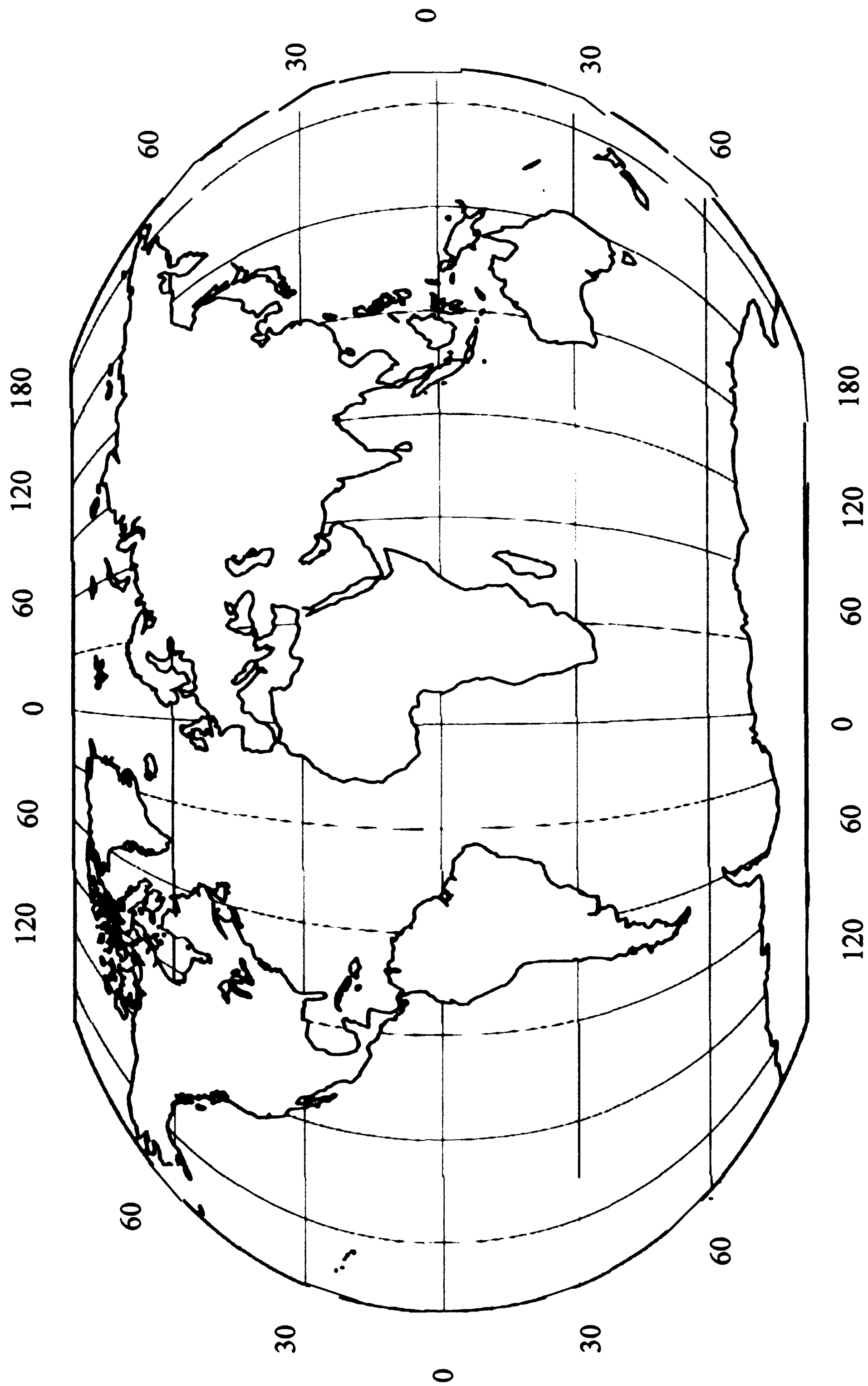
5. Which taxon seems to have the largest range of distribution?

6. Explain how you think that the hominids got to all of the different places.

7. In which area does Neanderthal seem to be most prominent?

8. Describe the overall pattern of hominid migration based on the data that you plotted.

Figure 7. World Map



APPENDIX III, A

Evolution Unit Pre-Survey

Answer the following questions on a scale of 1-5.

6. Strongly Disagree
7. Disagree
8. Neutral/No opinion
9. Agree
10. Strongly Agree

1. Variation exists within members of a population.
   1 2 3 4 5
2. Artificial selection has been used by humans for thousands of years.
   1 2 3 4 5
3. DNA mutations are always harmful.
   1 2 3 4 5
4. Organisms are linked by a universal genetic code.
   1 2 3 4 5
5. Most species on earth were created at the same time.
   1 2 3 4 5
6. The earth is 6,000-10,000 years old.
   1 2 3 4 5
7. The fossil record is incomplete, and thus provides poor evidence for the history of life on earth.
   1 2 3 4 5
8. New species discovered today have been on earth for thousands of years.
   1 2 3 4 5
9. Humans as a population are perfectly adapted.
   1 2 3 4 5
10. The fitness of an organism is the ability of an organism to survive and reproduce.
    1 2 3 4 5
11. A theory is just a guess with little or no evidence to support it.
    1 2 3 4 5
12. There is no evidence for evolution.
    1 2 3 4 5
13. Evolution is not occurring in organisms today.
    1 2 3 4 5
14. Evolution states that humans came from monkeys.
    1 2 3 4 5
15. It is most likely that humans originated from Africa.
    1 2 3 4 5

Open response questions

16. What is science?

17. What is science based on?

18. Explain what a fact is and give an example.

19. What is a scientific theory?

20. How is a theory different from a hypothesis?

21. Explain why evolution is considered a theory.

22. Do labs and activities enhance your learning Explain why or why not.

23. What is your opinion of evolution?

24. Do you think that evolution should be taught in schools? Why or why not?

25. How do you think life on earth originated? Explain your answer.

APPENDIX III, B

Chapter 14 pretest Name____________________________________
Hour______

1. How can the age of a fossil be determined?

2. What evidence is there of how the first cells may have formed and evolved?

3. What evidence is there for organisms that once lived on Earth?

4. How old is the Earth thought to be?
   a. 10,000 years
   b. 4.6 million years old
   c. 1 billion years old
   d. 4.6 billion years old

5. When did life on Earth evolve?
   a. 4.6 to 4.0 billion years ago
   b. 3.9 to 3.5 billion years ago
   a. 4.6 to 4.0 million years ago
   b. 3.9 to 3.5 thousand years ago

6. Which of the following choices place the eras in order from oldest to most recent.
   a. Mesozoic, Cenozoic, Paleozoic, Precambrian
   b. Precambrian, Paleozoic, Mesozoic, Cenozoic
   c. Cenozoic, Mesozoic, Paleozoic, Precambrian
   d. Paleozoic, Cenozoic, Precambrian, Mesozoic

7. Life evolved in the?
   a. Mesozoic
   b. Cenozoic
   c. Paleozoic
   d. Precambrian

8. Which of the following choices list the organisms in the proper order of appearance in the fossil
   record from the earliest appearing organisms to the most modern organisms.
   a. prokaryotes, eukaryotes, fish, land plants, amphibians, reptiles, mammals, birds, humans
   b. fish, prokaryotes, land plants, eukaryotes, amphibians, humans, reptiles, mammals, birds
   c. eukaryotes, prokaryotes, amphibians,birds reptiles, mammals, birds, land plants, humans
   d. humans, birds, mammals, reptiles, amphibians, land plants, fish, eukaryotes, prokaryotes
9. Primates evolved _______ years ago and modern humans evolved ________ years ago.

APPENDIX III, C

Test 14 THE HISTORY OF LIFE Name__________________

Multiple Choice Hour_____

Identify the letter of the choice that best completes the statement or answers the question.

1. Since the 1950s, experiments have been conducted that lead scientists to conclude that life may have originated _____.
a. spontaneously as originally thought
b. in small pools of water where amino acids could be concentrated
c. in other parts of the universe
d. when prokaryotes joined together to make the first eukaryotic cell

2. Before biogenesis became an accepted cornerstone of biology, ____was widely accepted.
a. living things could arise spontaneously from other things
b. Francesco Redi and Louis Pasteur would be unable to test the current beliefs
c. flies could be produced only from other flies
d. maggots were the immature offspring of flies

3. Humans are thought to have evolved during the _____ Era.
a. Cenozoic c. Mesozoic
b. Paleozoic d. Precambrian

4. The Geologic Time Scale begins at the formation of Earth approximately _____ years ago.
a. 4.6 thousand c. 46 million
b. 4.6 million d. 4.6 billion

5. Which of the following statements are true about fossils?
a. Fossils are usually found in sedimentary rock layers.
b. There are many different ways that fossils can be formed.
c. Fossil insects preserved in amber may contain ancient DNA.
d. all of these

6. Which of the following fossils are not found in sedimentary rock?
a. imprints c. amber
b. frozen mammoths d. petrified wood

7. While looking for fossils on an eroded hillside, you discover the fossil imprint of a fern frond and some fossil moss. In a layer just above, you find fossil coral and fish. Assuming the rock has not been disturbed, which of the following is the most probable conclusion?
a. The area had been a sea until recent times.
b. A forest had once grown there but had become submerged by water.
c. A sea replaced been replaced by the land in ancient times.
d. A saltwater sea had changed to a freshwater lake in ancient times.

8. This scientist was the first to teach spontaneous generation_____.
a. L. Pasteur
b. F. Redi
c. Aristotle
d. J. van Helmont

9. The first prokaryotes probably obtained their food _____.
a. through the synthesis of organic molecules from inorganic molecules
b. through a combination of photosynthesis and aerobic respiration
c. by eating carbohydrates formed by autotrophs
d. by consuming organic molecules available in their environment

10. Which group of organisms is believed to have been the earliest to evolve?
a. land plants
b. cyanobacteria
c. aquatic dinosaurs
d. mammals

11. A theory concerning the origin of life states that Earth's ancient atmosphere contained _____.
a. water vapor, methane, and ammonia
b. water vapor, oxygen, and hydrogen
c. methane, ammonia, and oxygen
d. methane, carbon dioxide, and oxygen

12. Which fact is the basis for using the fossil record as evidence that evolution has taken place?
a. In undisturbed layers of rock strata, the older fossils are found in the deeper layers.
b. There are fossils of all life-forms to be found in rock layers.
c. All fossils were formed at the same time.
d. Fossils have been shown to provide a complete record of human evolution.

13. Urey and Miller subjected water, ammonia, methane, and hydrogen to heating and cooling cycles and jolts of electricity in an attempt to _____.
a. determine how the dinosaurs became extinct
b. find out whether the conditions of ancient Earth could have formed complex organic compounds
c. determine the age of microfossils
d. find out how ozone forms in the atmosphere

14.__________ hypothesized, in the 1930's, that the early earth's environment may have allowed life to evolve. That the ammonia, methane, carbon dioxide, water vapor, heat, radiation, and lightning created a primordial soup in the early oceans leading to the first cells
a. Huxley
b. Oparin
c. Miller and Urey
d. Fox

15. Sidney Fox, in the 1950's, developed __________ by heating amino acids
a. prokaryotic cells
b. eukaryotic cells
c. autotrophic cells
d. protocells

16. The first cells were thought to be
a. autotrophic eukaryotes
b. autotrophic prokaryotes
c. heterotrophic eukaryotes
d. heterotrophic prokaryotes

17. How long ago is it thought that life first evolved on Earth?
a. 4.6 billion years ago
b. 3.5 billion years ago
c. 3.5 thousand years ago
d. 3.5 million years ago

18. Life first evolved during the ____________?
a. Mesozoic
b. Cenozoic
c. Paleozoic
d. Precambrian

19. Place the following eras in order from most recent to the oldest

a. Precambrian, Paleozoic, Mesozoic, Cenozoic
b. Cenozoic, Mesozoic, Paleozoic, Precambrian
c. Precambrian, Mesozoic, Cenozoic, Paleozoic
d. Paleozoic, Precambrian, Cenozoic, Paleozoic

20. Which of the following choices places the type of organism in the correct order of appearance in the fossil record from the earliest organisms to the most recent organisms.

a. eukaryotes, prokaryotes, invertebrates, fish, land plants, reptiles, dinosaurs, mammals, humans
b. invertebrates, eukaryotes, prokaryote, fish, land plants, reptiles, humans, dinosaurs, mammals
c. prokaryote, invertebrates, eukaryotes, fish, land plants, reptiles, dinosaurs, mammals, humans
d. prokaryotes, eukaryotes, invertebrates, fish, land plants, reptiles, dinosaurs, mammals, humans

21. Currently, scientist think primates evolved ___________ years ago and that modern human may have first appeared _________ years ago.

a. 30 million & 200,000
b. 1 million & 1,000
c. 30,000 & 3,000
d. 9,000 & 1,000

Matching

a. Precambrian
b. Cambrian
c. Ordovician
d. Silurian
e. Paleozoic Era
f. Devonian
g. Carboniferous- Penn and Miss.
h. Permian
i. Triassic
j. Jurassic
k. Mesozoic Era
l. Cretaceous
m. Cenozoic Era
n. Tertiary
o. Quaternary

22. Era dominated by marine organisms
23. Period when coal was produced, first seed plants and reptiles
24. Era dominated by dinosaurs
25. First dinosaurs and mammals
26. First placental animals
27. Flowering plants dominated, dinosaurs go extinct
28. Longest era, cells were thought to develop
29. First amphibians
30. Humans evolved in this period
31. First jawed fish and land plants
32. First invertebrates
33. Present era dominated by mammals and humans
34. First flowering plants and birds
35. First Vertebrates
36. Conifers dominate

a. Needham
b. Huxley
c. Spallanzani
d. Van Helmont
e. Leeuwenhoek

37. Discovered many microorganisms with microscopes
38. Used broth and glass jars boiled the broth then sealed the top by melting the glass- prevented broth from spoiling, disproving S.G.
39. boiled broth for ~10 minutes, sealed with cork- broth spoiled, supported S.G.
40. Biogenesis- life arises from other living things
41. Had a recipe for mice= rags + grain

Short Answer

42. How did Francesco Redi and Louis Pasteur support the concept of biogenesis with their experiments? Please draw out the experiments and explain the significance of each (8 points).
43. Discuss three types of fossils and how they are formed (2 points each). Extra credit - describe the other types of fossils

a.

b.

c.

44. Explain, in detail, how scientists determine the age of a fossil. We discussed two methods in class (8 points).
45. What signals the beginning and the end of an era (2 points)?
46. How were the first cells thought to have developed? Please give data that supports this theory (4 points)?

Essay

47. What information and data do scientists use to support the theory of evolution. We discussed several of them throughout chapter 14. Please explain them in detail and give examples to support your answer(8 points).

48. What are the three statements of the cell theory (2 points each)?

a.

b.

c.

APPENDIX III, D

Name________________________
Hour_____

Chapter 15 Pre-test

1. Who is the father of the modern theory of evolution?
2. Explain the concept of natural election.
4. What are the two main sources of variations within a population?
5. What is an adaptation?
6. Please give examples of adaptations and explain each one.
7. Compare and contrast artificial selection and natural selection.
8. Define speciation?
9. How does speciation occur?
10. Define the following terms and give examples for each.

a. Homologous structures

b. Vestigial organs

c. Analogous structures

d. Embryology

e. convergent evolution

f. divergent evolution

g. adaptive radiation

APPENDIX III, E

Test 15 **Name**________________________________

Multiple Choice **Hour**________

Identify the letter of the choice that best completes the statement or answers the question.

1. Hawaiian honeycreepers are a group of birds with similar body shape and size. However, they vary greatly in color and beak shape. Each species occupies its own niche and is adapted to the foods available in its niche. The evolution from a common ancestor to a variety of species is an example of _____.

a. adaptive radiation
b. cross-pollination
c. vegetative propagation
d. convergent evolution

2. Within a decade of the introduction of a new insecticide, nearly all of the descendants of the target pests were immune to the usual-sized dose. The most likely explanation for this immunity to the insecticide is that _____.

a. eating the insecticide caused the bugs to become resistant to it
b. eating the insecticide caused the bugs to become less resistant to it
c. it destroyed organisms that cause disease in the insects, thus allowing them to live longer
d. it selected random mutations that were present in the insect population and that provided immunity to the insecticide

3. Mutations such as polyploidy and crossing over provide the genetic basis for _____.

a. evolution
b. spontaneous generation
c. biogenesis
d. sexual reproduction

4. Structures that have a similar embryological origin and structure but are adapted for different purposes, such as a bat wing and a human arm and whale fin are called _____.

a. embryological structures
b. analogous structures
c. homologous structures
d. homozygous structures

5. Natural selection can best be defined as the _____.

a. survival of the biggest and strongest organisms in a population
b. elimination of the smallest organisms by the biggest organisms
c. survival and reproduction of the organisms that occupy the largest area
d. survival and reproduction of the organisms that are genetically best adapted to the environment

6. A pattern of evolution that results when two unrelated species begin to appear similar because of environmental conditions, such as birds, bats and bees, is _____.

a. disruptive selection
b. convergent evolution
c. directional selection
d. divergent evolution

7. The average individuals of a population are favored in _____ selection.

a. directional
b. stabilizing
c. disruptive
d. natural

8. In _____ selection, individuals with both extreme forms of a trait are at a selective advantage. The average organism is not selected for survival

a. directional
b. stabilizing
c. disruptive
d. natural

9. _____ selection favors one extreme form of a trait in a population, such as a larger beak in birds.

a. Directional
b. Stabilizing
c. Disruptive
d. Natural

10. What is the movement of genes into and out of a gene pool called?

a. random mating
b. nonrandom mating
c. migration
d. direct evolution

11. The variations needed for the origin of structural and physiological adaptations to occur are provided by _____.

a. mimicry
b. gradual changes
c. punctuated changes
d. mutations

12. A mechanism of Darwin's proposed theory is _____.

a. natural selection
b. evolution
c. variation
d. all of these

13. The founder of modern evolution theory is considered to be _____.

a. Charles Darwin
b. Alexander Oparin
c. Stephen Jay Gould
d. Lynn Margulis

14. Upon close examination of the skeleton of an adult python, a pelvic girdle and leg bones can be observed. These features are an example of _____.

a. artificial selection
b. homologous structures
c. vestigial structures
d. comparative embryology

15. The theory of continental drift hypothesizes that Africa and South America slowly drifted apart after once being a single landmass. The monkeys on the two continents, although similar, show numerous genetic differences. Which factor is probably the most important in maintaining these differences?

a. comparative anatomy
b. comparative embryology
c. geographic isolation
d. fossil records

16. When checking shell color for a species of snail found only in a remote area seldom visited by humans, scientists discovered the distribution of individuals that is shown in the graph in Figure 8. Based on the information shown in the graph, the snail population is undergoing _____.

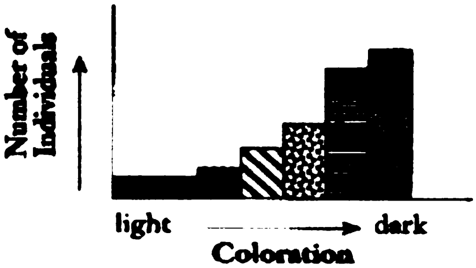


Figure 8. Coloration of snails

a. stabilizing selection
b. disruptive selection
c. artificial selection
d. directional selection

17. The flying squirrel of North America closely resembles the flying phalanger of Australia. They are similar in size and have long, bushy tails and skin folds that allow them to glide through the air. The squirrel is a placental mammal, while the phalanger is a marsupial. These close resemblances, even though genetically and geographically separated by great distances, can best be explained by _____.

a. convergent evolution
b. divergent evolution
c. spontaneous generation
d. vestigial structures

18. Which answer BEST shows an animal's adaptation to the tropical rain forest?

a. camouflage in a tree frog
b. the long neck of a giraffe
c. an elephant's long trunk
d. migration of birds in winter

19. Which of the following is <u>not</u> a factor that causes changes in the frequency of homozygous and heterozygous individuals in a population?

a. mutations
b. migration
c. random mating
d. genetic drift

20. Which combination of characteristics in a population would provide the <u>greatest</u> potential for evolutionary change?

a. small population, few mutations
b. small population, many mutations
c. large population, few mutations
d. large population, many mutations

21. Mutations occur because of _____.

a. the introduction of new variations from elsewhere
b. the introduction of new variations through mistakes in DNA replication
c. the chance survival and reproduction of new variations
d. change in allele or genotype frequencies

22. When one species is thought to evolve into two different species, as in the ground squirrels located at the Grand Canyon, ___________ evolution is said to have occurred.

a. convergent
b. divergent
c. extinctive
d. stabilized

23. In ____________ the changes in a species occurs slowly and over a long period of time, while in ____________ there is very little change over long periods of time followed by sudden change and development of species

a. punctuated, radiation
b. gradualism, rapid pace
c. punctuated, gradualism
d. gradualism, punctuated

24. Bacteria and viruses will demonstrate __________ changes in a very short period of time

a. no
b. rapid
c. slow
d. few

25. Why is the Hardy-Weinberg Principle useful when studying evolution?

Explain each rule of H-W Principle please tell me how the human population violates it. (3 points each).
a. Large populations-

b. No Mutations-

c. No Immigration-

d. Random mating-

e. No genotype more likely to survive-
26. The allele frequency for the pepper moth population prior to the industrial revolution was determined to be W=.8 (white allele) and the w= .2 (dark allele). After the industrial revolution the population frequency changed to W= .3 and w= .7. Why the did the frequencies change(6 points). Extra Credit- show me punnet squares that utilize this information.
Prior-

After industrial revolution-

27. Summarize Darwin's theory of evolution through natural selection. Also tell me what influenced his thinking when developing the theory of evolution (2 points each).
Theory-

Influences
a.

b.

c.

d.
Extra credit: Tell me about Malthus and Wallace

Malthus-

Wallace-

29. A study of the squirrel population in a large northern city revealed that many of the squirrels inhabited large park areas that were also populated by numerous squirrel predators. The graph in Figure 9 reflects the data collected in regard to color and number of squirrels. Explain why the light- and dark-colored squirrels might be selected for and the medium-colored squirrels selected against (3 points).

30. Define Speciation and Describe ways in which speciation is thought to occur. Give an example for each (3 points each).

Speciation-

a. Geographical Isolation-

b. Reproductive Isolation-

c. Change of chromosome number-

31. How can scientist use data on DNA or biochemicals produced by different species to determine how closely related they are to each other (6 points)?

32. What are the sources of variations within a population or species? Give examples of variations (at least 2) and describe the importance of variations as they relate to natural selection and evolution (6 points).
A. Sources-

B. Examples-

C. Importance-

33. Define the following terms, give examples of each, and tell me why they are considered important for the theory of evolution.

a. Homologous structures-

b. Vestigial organs-

c. Embryology-

d. Physical adaptations-

g. Fossils-

34. Define Adaptation and explain why they are important for survival of a species (4 points).

APPENDIX III, F

Pretest 16

Name________________________
Hour____

1. What is a Hominid?

2. What evidence is there for human evolution?

3. What adaptations do humans have and tell me why they are important?

a.

b.

c.

d.

e.

f.

4. What primate is our closest relative?

5. What are the sources of variation in the human population?

6. Where are the oldest hominid fossils found?

7. What vestigial organs do humans have and why are they used to study human evolution?

APPENDIX III, G

Skulls –Pre-lab questions

Name__________________

Hour____

1. What adaptations or changes have taken place in skulls of hominids over the millions of years they have walked on this planet?

2. What can you tell me about the following species:
   A. Australopithecus africanus-
   B. Homo erectus-
   C. Homo habilis-
   D. Homo sapiens neanderthalensis-
3. Homo sapiens sapiens -
4. Pongo pygmaeus pygmaeus (orangutang)-
5. Pan troglodytes (chimpanzee)-
6. Gorilla gorilla gorilla –
7. What is the foramen magnum and why is it important when studying hominid skulls?
8. What is the cranium module used to help determine?
9. Why is the slope of the forehead important when studying hominid skulls?

APPENDIX III, H

Evolution Unit Post-Survey

Answer the following questions on a scale of 1-5.

11. Strongly Disagree
12. Disagree
13. Neutral/No opinion
14. Agree
15. Strongly Agree

1. Variation exists within members of a population.
   1 2 3 4 5
2. Artificial selection has been used by humans for thousands of years.
   1 2 3 4 5
3. DNA mutations are always harmful.
   1 2 3 4 5
4. Organisms are linked by a universal genetic code.
   1 2 3 4 5
5. Most species on earth were created at the same time.
   1 2 3 4 5
6. The earth is 6,000-10,000 years old.
   1 2 3 4 5
7. The fossil record is incomplete, and thus provides poor evidence for the history of life on earth.
   1 2 3 4 5
8. New species discovered today have been on earth for thousands of years.
   1 2 3 4 5
9. Humans as a population are perfectly adapted.
   1 2 3 4 5
10. The fitness of an organism is the ability of an organism to survive and reproduce.
    1 2 3 4 5
11. A theory is just a guess with little or no evidence to support it.
    1 2 3 4 5
12. There is no evidence for evolution.
    1 2 3 4 5
13. Evolution is not occurring in organisms today.
    1 2 3 4 5
14. Evolution states that humans came from monkeys.
    1 2 3 4 5
15. It is most likely that humans originated from Africa.
    1 2 3 4 5

Open response questions

16. What is science?

17. What is science based on?

18. Explain what a fact is and give an example.

19. What is a scientific theory?

20. How is a theory different from a hypothesis?

21. Explain why evolution is considered a theory.

22. Do labs and activities enhance your learning Explain why or why not.

23. What is your opinion of evolution?

24. Do you think that evolution should be taught in schools? Why or why not?

25. How do you think life on earth originated? Explain your answer.

APPENDIX III, I

Lab Assessments

Variation and Adaptation

1. What is natural variation within a population (2 points)?
2. What is the significance of having variations within a species such as humans (4 points)?
3. What are the sources of natural variations (2 points)?
4. Explain how an adaptation increases the fitness of a population (4 points).

Natural Selection

5. Using the concept of natural selection, explain how extinction can occur (4 points).
6. Describe selection pressures in nature that could play a role in natural selection (4 points).
7. Are all genetic mutations negative? Why or why not (4 points)?
8. Explain why more offspring are produced than will survive (three points).

Evidence for Evolution

9. Describe a process that can be used to date fossils (5 points).
10. What can be learned from studying the fossil record (4 points)?
11. Why is the comparison of homologous structures between different species useful (4 points)?
12. Describe two ways in which scientists determine how closely two species are related (4 points).

Speciation

13. How can a mountain range effect a population of birds that has been separated (6 points)?

14. Explain how speciation can occur (3 points).

Human Evolution

15. What are hominids (2 points)?

16. What characteristics of hominid skulls make them useful in studying the evolution of hominids (6 points)?

17. What distinguishes a human skull from the other hominid skulls studied (4 points)?

18. Compare and contrast the chimp skull to both human and gorilla skulls (6 points).

19. What characteristics do chimpanzee skull share with early hominid skulls like Australopithecus (4 points)?

20. Describe the overall pattern of hominid migration. In other words, where were the first human ancestors found and where did they go (3 points)?

21. What did you like most about the evolution unit (2 points)?

22. What did you dislike most about the evolution unit (2 points)?

23. Which lab did you like the most (2 points)?

23. Which lab did you like the most (2 points)?

APPENDIX III, J

Final Exam 2008

a.	Speciation	g.	Founder effect
b.	Mimicry	h.	Emigration
c.	Natural Selection	i.	Immigration
d.	Analogous structures	j.	Gene pool
e.	Vestigial organs	k.	Genetic equilibrium
f.	Genetic drift	l.	Artificial selection

1. The best adapted organisms survive and reproduce
2. Genetic content of a population
3. To move out of a population or area
4. Small useless organs, tailbone wisdom teeth
5. Entering a new area
6. Different structures used to accomplish the same task
7. Man chooses who will reproduce, based on variations
8. The first organisms to arrive establish the genetics of the population, 7 toed cat
9. Development of species over time
10. When a population is at a constant, no change
11. A change in allele frequency
12. When an organism behaves or appears like other species

a. Human   b. Chimp

13. Large Facial prognathism
14. Flat Face
15. u shaped jaw
16. v-shaped jaw
17. foramen magnum at a ninety degree angle
18. arms are nearly as long as the legs.
19. large canine dystema
20. small canines
21. large canines
22. thumb that touches finger tips
23. large forehead
24. sloping forehead
25. large browridge
26. chin points outward
27. Large hips
28. flat, wide feet
29. walks hunched over
30. foramen magnum at an angle less than 90 degrees

a. Homo sapiens sapiens
b. Homo sapiens neanderthalensis
c. Homo erectus
d. Homo habilis
e. Australopithecus afracanus

31. 500 cc brain, human and apelike characteristics
32. 1500 cc brain, had art and finely made tools
33. 1000 cc brain, found in Europe, China, Africa, Island of Java
34. 1600 cc brain buried dead with artifacts died out approximately 35,000 years ago
35. 800 cc brain, possibly the first tool maker
36. approximately 1.5-2million years ago
37. approximately 2 million to 300,000 years ago
38. approximately 3 million years ago

Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

39. Select the group that best depicts the order that organisms were thought to appear on earth.
a. bacteria, eukaryotes, mammals, fish, land dinosaurs, plants, ,invertebrates, humans
b. eukaryotes ,bacteria, invertebrates, land plants, dinosaurs, fish, mammals, humans
c. humans, bacteria, eukaryotes, fish, land plants, invertebrates, dinosaurs, mammals,
d. bacteria, eukaryotes, invertebrates, fish, land plants, dinosaurs, mammals, humans

40. The primitive Earth atmosphere is hypothesized to have consisted mostly of _____.
a. oxygen, nitrogen, and water vapor
b. hydrogen, methane, ammonia, and water vapor
c. amino acids, ATP, carbohydrates, and oxygen
d. none of these

41. Which of the following fossils are not found in sedimentary rock?
a. imprints
b. frozen mammoths
c. amber
d. petrified wood

42. Life first evolved during the ____________.
a. Mesozoic
b. Paleozoic
c. Cenozoic
d. Precambrian

43. Place the following eras into the proper order from **oldest** to most recent.
a. Precambrian, Paleozoic, Mesozoic, Cenozoic
b. Paleozoic, Mesozoic, Precambrian, Cenozoic
c. Cenozoic, Mesozoic, Paleozoic, Precambrian
d. Mesozoic, Paleozoic, Precambrian, Cenozoic

44. Since the 1950s, experiments have been conducted that lead scientists to conclude that life may have originated _____.
a. spontaneously as originally thought
b. in small pools of water where amino acids could be concentrated
c. in other parts of the universe
d. when prokaryotes joined together to make the first eukaryotic cell

45. Which group of organisms is believed to have been the earliest to evolve?
a. land plants
b. cyanobacteria
c. aquatic dinosaurs
d. mammals

46. The first cells were thought to be _____________ cells.

a. autotrophic eukaryotes
b. autotrophic prokaryotes
c. heterotrophic eukaryotes
d. heterotrophic prokaryotes

47. Before biogenesis became an accepted cornerstone of biology, it was widely accepted that _____.

a. living things could arise spontaneously from other living things
b. Francesco Redi and Louis Pasteur would be unable to test the current beliefs
c. flies could be produced only from other flies
d. maggots were the immature offspring of flies

48. Humans are thought to have evolved during the _____ Era.

a. Cenozoic
b. Paleozoic
c. Mesozoic
d. Precambrian

49. Which event contributed most directly to the evidence of aerobic organisms?

a. an increase in the concentration of methane in the ancient atmosphere
b. a decrease in the sun's light intensity
c. the presence of organisms able to carry on photosynthesis
d. an increase in the number of organisms carrying on fermentation

50. The Geologic Time Scale begins at the formation of Earth approximately _____ years ago.

a. 4.6 thousand
b. 4.6 million
c. 46 million
d. 4.6 billion

51. The longest period of Earth history is __________________.

a. Cenozoic
b. Mesozoic
c. Precambrian
d. Paleozoic

52. Currently, scientist think primates evolved over __________ years ago and modern humans may have first appeared __________ years ago

a. 1 million & 1000
b. 30 million & 200,000
c. 100,000 & 20,000
d. 10,000 & 5,000

53. Which of the following statements are true about fossils?

a. Fossils are usually found in sedimentary rock layers.
b. There are many different ways that fossils can be formed.
c. Fossil insects preserved in amber may contain ancient DNA.
d. all of these

54. Scientists agree that two developments must have occurred for life to come into being: the formation of simple organic molecules important to life and _____.

a. development of prokaryotic cells in early oceans
b. organization of molecules into complex organic molecules
c. appearance of amino acids, monosaccharides, and lipids
d. an atmosphere rich in water vapor, oxygen, and ATP

55. The dinosaurs dominated the __________ era.

a. Cenozoic
b. Mesozoic
c. Precambrian
d. Paleozoic

56. Life was first thought to evolve on planet Earth ___________ years ago

a. 4.6 billion
b. 3.5 million
c. 3.5 billion
d. 1 million

57. In the 1950's, Sidney Fox developed _____________ by heating amino acids
a. protocells
b. autotrophic cells
c. eutrophic cells
d. prokaryotic cells

58. While looking for fossils on an eroded hillside, you discover fossil coral and fish in one layer. In a layer just above, you find the fossil imprint of a fern frond and some fossil moss. Assuming the rock has not been disturbed, which of the following is the most probable conclusion?
a. The area had been a sea until recent times.
b. A forest had once grown there but had become submerged by water.
c. A sea had been replaced by land in ancient times.
d. A saltwater sea had changed to a freshwater lake in ancient times.

59. ________________ discovered many single-celled organisms, leading many to think that spontaneous generation works on small organisms.
a. van Helmont
b. Huxley
c. Leeuwenhoek
d. Pasteur

60. Entire organisms, with even their most delicate parts intact, have been found preserved in _____.
a. igneous rock formations and ice
b. mineral deposits and metamorphic rock
c. amber and ice
d. amber and mineral deposits

61. According to one theory, the first prokaryotes probably obtained their food _____.
a. through the synthesis of organic molecules from inorganic molecules
b. through a combination of photosynthesis and aerobic respiration
c. by eating carbohydrates formed by autotrophs
d. by consuming organic molecules available in their environment

62. A clear fish imprint in a rock indicates that the rock is probably _____.
a. volcanic
b. sedimentary
c. metamorphic
d. igneous

63. The age of a fossil can most accurately be determined by ______________.
a. relative dating
b. ionic dating
c. elemental dating
d. radiometric dating

64. Marine organisms such as trilobites dominated the __________era.
a. Cenozoic
b. Mesozoic
c. Precambrian
d. Paleozoic

65. Which fact is the basis for using the fossil record as evidence that evolution has taken place?
a. In undisturbed layers of rock strata, the older fossils are found in the deeper layers.
b. There are fossils of all life-forms to be found in rock layers.
c. All fossils were formed at the same time.
d. Fossils have been shown to provide a complete record of human evolution.

66. _____________ hypothesized, in the 1930's that early earth's environment may have allowed life to evolve. that heat, methane, ammonia, carbon dioxide, water vapor, radiation, and lightning created a primordial soup in the early oceans leading to the first cells.
a. Miller
b. Huxley
c. Oparin
d. Fox

67. _________________ came up with the term biogenesis, life comes from life.

a. Huxley
b. Needham
c. Spallanzani
d. Pasteur

68. Urey and Miller subjected water, ammonia, methane, and hydrogen to heating and cooling cycles and jolts of electricity in an attempt to _____.

a. determine how the dinosaurs became extinct
b. find out whether the conditions of ancient Earth could have formed complex organic compounds
c. determine the age of microfossils
d. find out how ozone forms in the atmosphere

69. ____________ carried out research on spontaneous generation. His work supported this older thought in biology. He had a recipe for mice.

a. Redi
b. Pasteur
c. van Helmont
d. Huxley

70. __________ carried out research with s shaped flasks. He supplied evidence that clearly proved spontaneous generation was false.

a. Huxley
b. Pasteur
c. Redi
d. Aristotle

71. Redi carried out research on____________, disproving spontaneous generation for larger organisms.

a. life cycles of frogs
b. life cycles of flies
c. life cycles of pea plants
d. life cycles of dogs

72. Which statement would be considered false?

a. fossils appear to become more complex over time
b. There appear to be more organisms today than in the past
c. organisms appear to be less complex today than in the past
d. organisms appear to have gotten larger over time

73. Galapagos Island finches are a group of birds with similar body shape and size. However, they vary in color and beak shape. Each species occupies its own niche and is adapted to the foods available in its niche. The evolution from a common ancestor to a variety of species is an example of _____.

a. adaptive radiation
b. cross-pollination
c. vegetative propagation
d. convergent evolution

74. The Abert and Kaibab ground squirrel of North America closely resemble each other. They are two different species found on different sides of the Grand Canyon. The fossil record indicates that one species occupied the area in the past. What is thought to have occurred?

a. reproductive isolation
b. convergent evolution
c. geographical isolation
d. vestigial structures

75. Why is the Hardy-Weinberg Principle useful to biologists?

a. Determines why mutations occur
b. Determines why populations change
c. Determines how many people live in an area
d. Determines the death rate of populations

76. Survival and reproduction of the best adapted organisms is described as _______ .

a. artificial selection
b. natural selection
c. hybridization
d. survivalism

77. If the frequency of the black gene (B) is .2 and the frequency for white gene (b) is .8, what would the frequencies be for each genotype?

a. BB=.04, Bb=.16, bb=.64
b. BB=.4, Bb=.32, bb=.64
c. BB=.04, Bb=.32, bb=.64
d. BB=.04, Bb=.20, bb=.16

78. Mutations such as polyploidy and crossing over provide the genetic basis for _____.

a. evolution
b. spontaneous generation
c. biogenesis
d. sexual reproduction

79. When checking shell color for a species of trout found only in a remote area seldom visited by humans, scientists discovered the distribution of individuals that is shown in the graph in Figure 10. Based on the information shown in the graph, the snail population is undergoing _____.

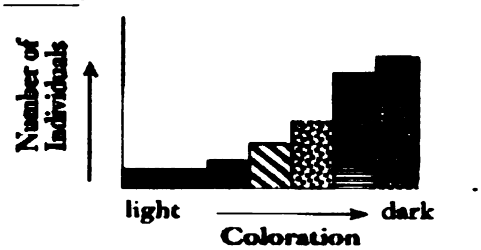


Figure 9. Coloration of snails

a. stabilizing selection
b. disruptive selection
c. artificial selection
d. directional selection

80. ____________ thought that the world's food supply for humans was limited and would lead to war and struggle for survival.

a. Wallace
b. Huxley
c. Darwin
d. Malthus

81. ______________ traveled the area of the Indonesian Islands. He collected 125,000 different species.

a. Wallace
b. Malthus
c. Huxley
d. Darwin

82. When organisms no longer mate and breed at the same time ______________ isolation has occurred. This is what may have resulted in the development of several species of frog all mating at different times of the years.

a. Geographical
b. Reproductive
c. Chromosomal
d. Vertical

83. Within a decade of the introduction of a new insecticide, nearly all of the descendants of the target pests were immune to the usual-sized dose. The most likely explanation for this immunity to the insecticide is that _____.

a. eating the insecticide caused the bugs to become resistant to it
b. eating the insecticide caused the bugs to become less resistant to it
c. it destroyed organisms that cause disease in the insects, thus allowing them to live longer
d. it selected random mutations that were present in the insect population and that provided immunity to the insecticide

84. Which of the following is <u>not</u> a factor that causes changes in the frequency of homozygous and heterozygous individuals in a population?

a. mutations
b. migration
c. random mating
d. genetic drift

85. Structures that have a similar embryological origin and structure but are adapted for different purposes, such as a bat wing and a human arm, are called _____.

a. embryological structures
b. analogous structures
c. homologous structures
d. homozygous structures

86. Luther Burbank used _________ in his plant breeding operation. He was able to create several new variations of plants.

a. outcrossing
b. inbreeding
c. artificial selection
d. natural selection

87. Natural selection can best be defined as the _____.

a. survival of the biggest and strongest organisms in a population
b. elimination of the smallest organisms by the biggest organisms
c. survival and reproduction of the organisms that occupy the largest area
d. survival and reproduction of the organisms that are genetically best adapted to the environment

88. A pattern of evolution that results when two unrelated species begin to appear similar because of environmental conditions is _____.

a. disruptive selection
b. convergent evolution
c. directional selection
d. divergent evolution

89. The average individuals of a population are favored in _____ selection.

a. directional
b. stabilizing
c. disruptive
d. natural

90. In _____ selection, individuals with both extreme forms of a trait are at a selective advantage.

a. directional
b. stabilizing
c. disruptive
d. natural

91. _____ selection favors one extreme form of a trait in a population.

a. Directional
b. Stabilizing
c. Disruptive
d. Natural

92. What is the movement of genes into and out of a gene pool called?

a. random mating
b. nonrandom mating
c. migration
d. direct evolution

93. Which answer BEST shows an animal's adaptation to the tropical rain forest?

a. camouflage in a tree frog
b. the long neck of a giraffe
c. an elephant's long trunk
d. migration of birds in winter

94. The variations needed for the origin of structural and physiological adaptations to occur are provided by _____.

a. mimicry
b. gradual changes
c. punctuated changes
d. mutations

95. A mechanism of Darwin's proposed theory is _____.

a. artificial selection
b. evolution
c. variation
d. all of these

96. The founder of modern evolution theory is considered to be _____.

a. Charles Darwin
b. Alexander Oparin
c. Stephen Jay Gould
d. Lynn Margulis

97. Mutations occur because of _____.

a. the introduction of new variations from elsewhere
b. the introduction of new variations through mistakes in DNA replication
c. the chance survival and reproduction of new variations
d. change in allele or genotype frequencies

98. Upon close examination of the skeleton of an adult python, a pelvic girdle and leg bones can be observed. These features are an example of _____.

a. artificial selection
b. homologous structures
c. vestigial structures
d. comparative embryology

99. Which combination of characteristics in a population would provide the <u>greatest</u> potential for evolutionary change?

a. small population, few mutations
b. small population, many mutations
c. large population, few mutations
d. large population, many mutations

100. The theory of continental drift hypothesizes that Africa and South America slowly drifted apart after once being a single landmass. The monkeys on the two continents, although similar, show numerous genetic differences. Which factor is probably the most important in maintaining these differences?

a. comparative anatomy
b. comparative embryology
c. geographic isolation
d. fossil records

101. The major anatomical difference between hominids and the apes is that the foramen magnum is _____ in hominids.

a. less developed
b. located at the bottom of the skull
c. thicker
d. all of these

102. As hominids evolved, they developed _____.

a. a good sense of smell and large lower vertebrae
b. good vision and large teeth
c. structures for walking in an upright bipedal motion
d. large teeth and a well-developed collar bone

103. Primates are adapted to live in trees because their eyes _____.
a. are in the front of their heads
b. detect color
c. see in stereovision
d. all of these

104. Evidence for the determination of bipedal locomotion in an animal could be found by an examination of the _____.
a. foramen magnum
b. upper arm and shoulder
c. finger (carpal)
d. jaw

105. According to the scientist the lesser chimp or bonobo share __________ of DNA with humans.
a. 47
b. 97
c. 100
d. 67

106. Primates evolved approximately _____.
a. 200 000 years ago
b. 2 million years ago
c. 8 million years ago
d. 65 million years ago

107. The ______________ had a very large saggital crest when compared to the other hominid skulls.
a. Gorilla
b. Chimpanzee
c. Homo habilis
d. Orangutan

108. The hominid that had the most advanced tool making abilities and spoken language was _____.
a. Homo sapiens sapiens
b. Homo sapiens neanderthalensis
c. *Purgatorius*
d. *Homo habilis*

109. The first hominids to make and use simple stone tools were _____.
a. *Homo sapiens*
b. *Homo habilis*
c. *Australopithecus afarensis*
d. *Australopithecus africanus*

110. Which factor may have played a large role in human evolution?
a. a geologic event that released much radiation into the environment, which in time resulted in an increased mutation rate
b. climatic changes that caused the rainforest to change into grasslands, forcing existing primates to search for new food sources
c. flooding due to melting glaciers causing primates to seek refuge in the trees
d. massive grassland fires that caused existing primates to flee to the mountains

111. Most early hominid fossils have been found in _____.
a. Egypt
b. France
c. Africa
d. North America

112. The jaw from the skull of the genus *Homo* and one from the genus *Australopithecus* are different, in that the jaw from the genus *Homo* would _____.
a. be much heavier with large teeth and well-defined canines
b. be smaller with smaller teeth and not so much definition of tooth type
c. be larger with a multitude of small teeth with well-defined canines
d. be smaller with larger teeth that were all about the same

113. Some primate skeletons were located in a cave in association with these things: a variety of tools, the charred bones of some animals they had cooked and eaten, and numerous paintings on the walls. Carbon-14 dating techniques determined that the bones and other artifacts were about 35 000 years old. The skeletal remains probably belonged to _____.

a. *afarensis*
b. *Homo habilis*
c. Homo sapiens sapiens
d. *Homo erectus*

114. The skulls and pelvic bones of australopithecines have structures that appear _____ those of chimpanzees and modern humans.

a. vestigial to
b. nothing like
c. intermediate between
d. identical to

115. Evidence that Homo erectus was more intelligent than its predecessors would include _____.

a. a small cranial capacity as indicated by their skeletal remains
b. involved messages they wrote on cave walls
c. signs of agriculture and tilled fields
d. tools such as hand axes that have been found near their fire pits

116. The _______________ had a very large brow ridge when compared to the other hominid skulls.

a. Chimpanzee
b. Gorilla
c. Homo habilis
d. Homo erectus

APPENDIX III, K

Name______________________

Hour______ **Date**______

Evolution Assessment

1. Give at least two examples of variations that exist within a population of organisms and tell me why they may be important.

2. Why are mutations in the gametes able to be passed from one generation to the next in organisms that sexually reproduce?

3. What is an adaptation?

4. Give three examples of a human adaptation and explain why the adaptation is useful.

5. Compare the differences and similarities between artificial selection and natural selection.

6. How does natural selection increase the fitness of a population?
7. What is a scientific theory?

8. What is necessary for an idea to become a theory?

9. What does the theory of evolution state?

10. Provide at least three pieces of evidence for evolution and describe each.

APPENDIX IV, A

Creating Phylogenic Trees using Caminalcules

Adapted from Robert P. Gendron
Indiana University
http://nsm1.nsm.iup.edu/rgendron/Caminalcules.shtml

Introduction: This exercise introduces the process of classification and the development of a Phylogenic tree based on the physical characteristics of Caminalcules. Caminalcules have an extensive fossil record that has been collected by many scientists throughout the world. You and your partner have been asked to assist in developing a Phylogenic tree based on the fossil evidence and several currently surviving species of Caminalcules. As you develop your Phylogenic tree please keep notes on the characteristics that you used to develop your tree. You will later be asked to compare your classification tree to those of other researchers in your classroom. Your notes will assist you in defending your Phylogenic tree. Please keep in mind that there may be many possible ways of developing a phylogenic tree for a given set of data.

About The Caminalcules:

The Caminalcules are artificial animals created by the late Professor Joseph Camin of the University of Kansas. They were developed to study how taxonomist classify real organisms.

Materials: Scissors, rulers, poster board, tape, Caminalcules

Procedures:

1. Cut out the 14 currently living species of Caminalcules and 57 fossilized species of Caminalcules.

2. Each Caminalcules is identified by a number, which corresponds to an individual species.

3. The number in parentheses indicates the age of the fossil which was determined by radiometric dating.

4. On poster board draw horizontal lines. Each line will represent 1 million years. On the bottom you will place the oldest specimen at 19 million years ago.

5. You should place the Caminalcules onto the poster board on the corresponding dates. Organisms that look alike should be placed above their ancestors to show the evolutionary lines of descent.

6. As you move upward, toward the present, attempt to determine the relationship of the newer species to the older species. Pay close attention to the characteristics that were used in determining the relationship from one species to the others.

7. Use horizontal lines to connect species of Caminalcule that are related. Be able to justify your reasoning for these relationships.

8. Compare your Phylogenic with others within the classroom. Openly discuss and share your ideas on each Phylogenic tree.

9. When finished answer the questions and turn in your phylogenic tree making sure to tape your Caminalcules to the poster board.

Questions

10. What does your phylogenic tree represent?

11. If two Caminalcules are related in your classification, or appear close together, what does that mean?

12. Which Caminalcule fossil is the oldest? What characteristics does it have?

13. Which Caminalcule is most closely related to number 9 and number 7 and why?

14. What may have occurred to number 34?

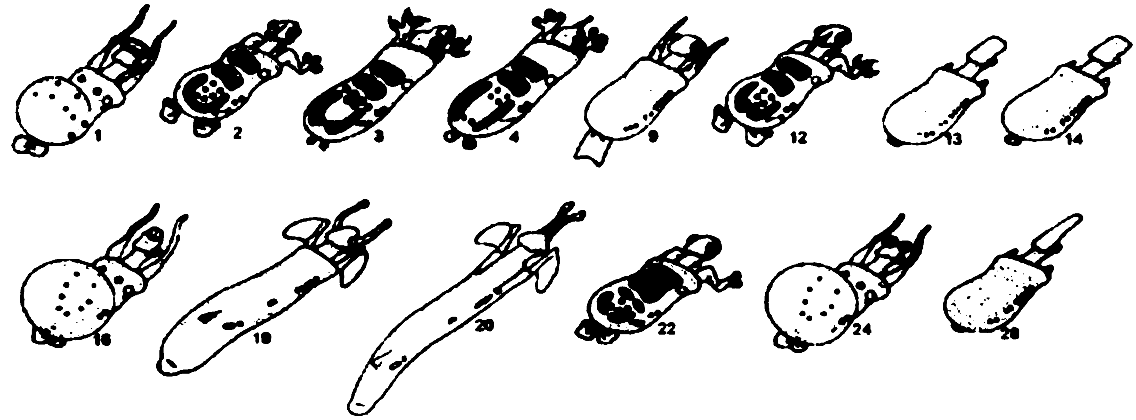
15. What is the common ancestor to number 20? Why do you think this?

16. If scientists wanted to test this hypothetical phylogenic tree, what other evidence could be used to analyze the relationships between Caminalcule ?

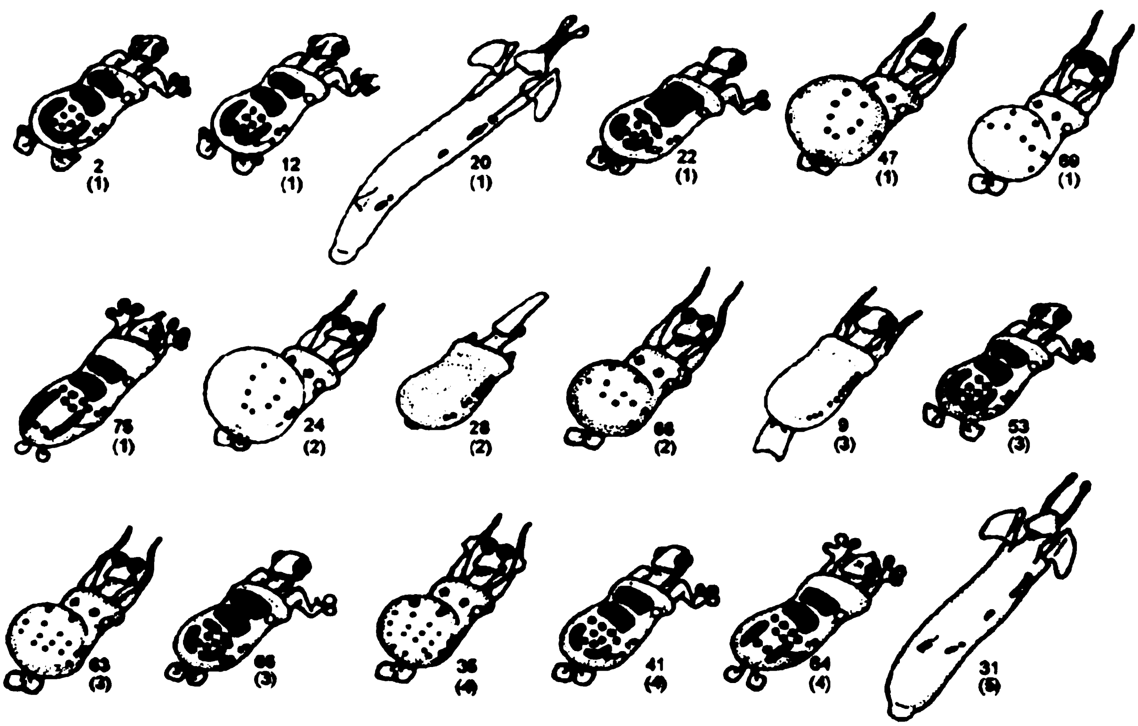
17. Are any of the Caminalcules dead end lineages or went extinct? What could have occurred to cause this extinction?

18. Write a paragraph explaining how you developed your phylogenic tree and what characteristics were used

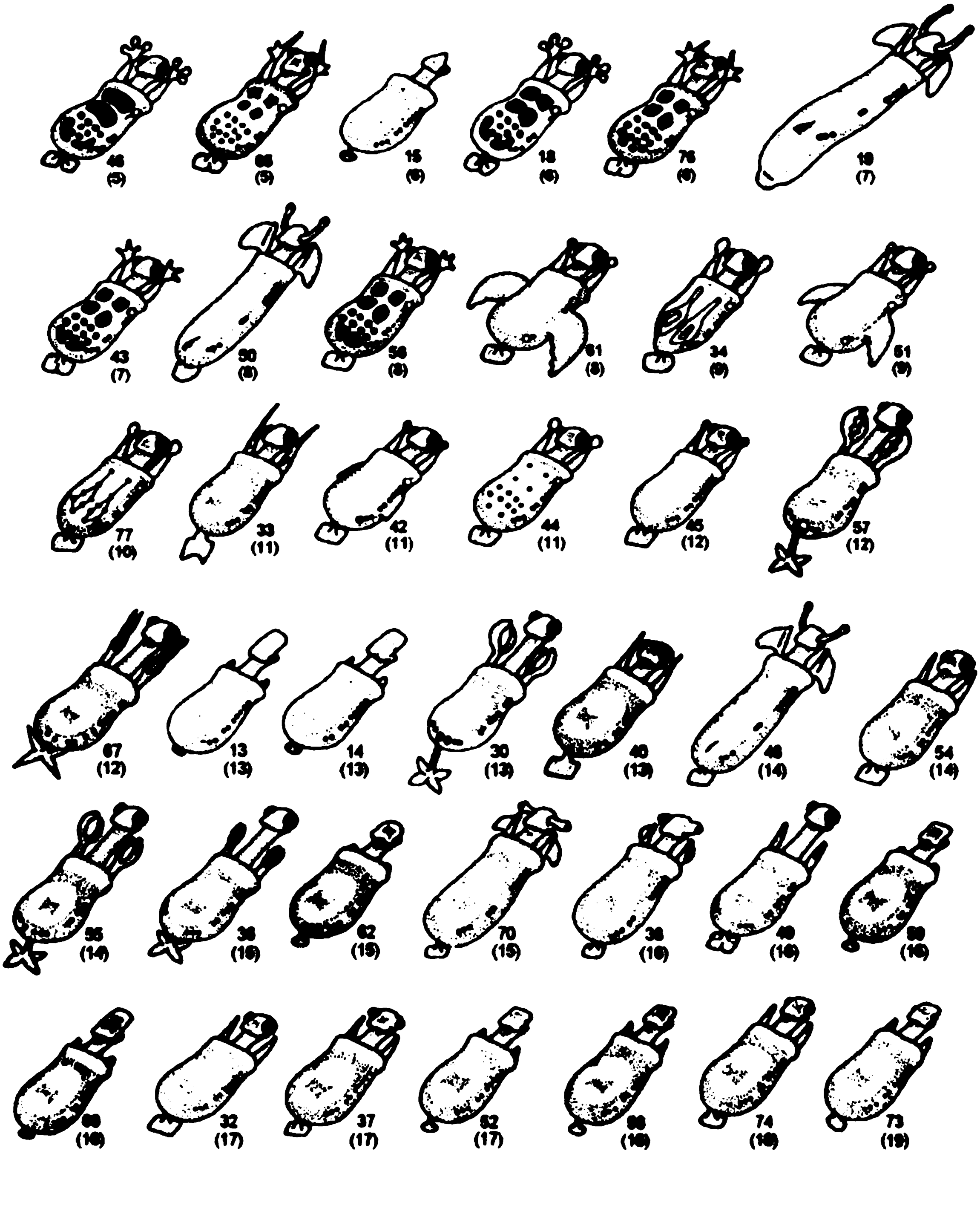
LIVING CAMINALCULES



FOSSIL CAMINALCULES
(numbers in parentheses indicate age in millions of years)



FOSSILS (continued)



APPENDIX IV, B

Laetoli Footprints: Analyzing Fossilized Footprints

Adapted from: Jennifer Johnson
www.indiana.edu/~ensiweb/lessons/footleng.html

Introduction: In 1976, a 3.6 million year old set of hominid footprints were discovered in Tanzania that were preserved by volcanic ash. They were discovered by Andrew Hill and a colleague when they were throwing elephant dung at each other. Hill dove out of the way and landed on the tracks. Since then, the footprints have provided insight into early bipedal ancestors of humans.

Purpose: To analyze foot length, stride length and height of modern man and compare these measurements to the Laetoli footprints to calculate early hominid height.

Procedure: You will gather a classroom set of data to determine if there is a relationship between foot length, leg length, and height. You will also measure your stride while walking and running.

1. Measure your foot length, leg length, and height in centimeters and record in the data table 1.
2. Graph the footprint size vs. height for the entire class. Footprint size on the x-axis and height on the y-axis.
3. Draw a line of best fit thru the data points on your graph.
4. Measure and mark off a distance of 2000 cm (20m).
5. Walk the length while counting the number of strides (Nw). Record Nw in the data table.
6. Run the length while counting the number of strides (Nr). Record the Nr in the data table.
7. Calculate the stride length (S) by dividing by the distance (2000 cm) by the number of strides (N).

   Sw = 2000cm ÷ Nw   Sr = 2000 cm ÷ Nr
8. Calculate the ratio of your stride length to leg length (S/L) and record in the data table.

   S/L = Sw ÷ Leg length
9. Calculate the ratio of stride length (S) to height (S/H) and record in the data table.

   S/H = Sw ÷ Height
10. Measure the footprint sizes from the model of the Laetoli footprints and record in Data Table 2.
11. Calculate the average size for the smaller individual and the average size for the larger individual. Record in Data Table 2.
12. Using the best fit line graph from the class data, determine how tall the individuals might have been based on their footprint size.

13. Measure the distances between the strides and calculate the average stride distance for each individual and record in Data Table 2.

Conclusions and Analysis

1. Do you see a pattern on the stride graphs? Explain your answer.

2. Determine if foot length can be used to predict height. To test this hypothesis, measure a person's foot length and use your graph to predict his or her height. Now, measure the height of that person. How close was your prediction to the actual height? Explain whether or not foot length can be used to predict height.

3. Paleontologists use the ratio of stride length divided by leg length (S/L) to tell whether a dinosaur is walking, trotting, or running. The following values are used to determine how a dinosaur might have been moving:

   Less than 2 = walking 2-2.9 = trotting More than 2.9 = running

   Examine the class data for the ratios of stride to leg length (Sw/L and Sr/L) to determine if the values used for dinosaurs also apply to people. If not, what values would change? Explain your answer.

4. If a person's footprints were discovered in someone's backyard, explain what information could be determined about the person who made the footprints? What information about the person could not be determined from the footprints?

5. Explain why you counted your strides over a 2,000 cm length rather than make only one stride measurement.

6. Below is a series of footprints found in the mud outside of school. Based on the measurements given, calculate the leg length and height of the person. Who do you think the footprint belongs to?

   Foot length = 29 cm   Stride length = 160 cm

   Estimate how tall the person is and what the person was doing when the footprints were made.

Class Data Table 1

Name	Foot Length	Leg Length	Height	Nw	Nr	Sw	Sr	Sw/L	Sr/L	Sw/H
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
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29										
30										
31										
32										
33										
34										
Averages										

Data Table 2:	Laetoli Footprints				
Small Footprint #	Size (cm)	Stride length	Large Footprint #	Size (cm)	Stride length
Average					

APPENDIX IV, C

Genetic Evidence for Evolution: DNA Analysis
Adapted from Heather Peterson,
High School Biology Teacher, Holt High School

Introduction: In today's entertainment world, watching CSI, Law & Order, etc. has provided many with an experience in what is suitable evidence in a court case. One of the most prominent evidences used in a courtroom is DNA evidence. Every person has their own set of DNA, and therefore it is considered to be be their genetic fingerprinting. This evidence is based on test that looks for unique features in the genetic code that identify an individuals genes. By comparing DNA sequences, a person can be identified by looking at these unique sequences. To find these sequences the DNA is digested (cut) by enzymes that look for a certain part of the genetic code. Every time the sequence of bases is discovered, by the enzymes, the DNA is cut again repeatedly, until many fragments are made. Then by comparing the amount of common fragments, an individual person can be identified, or in a paternity cases, relationships can be identified (the more DNA that is in common between two individuals the closer the relationship). These fragments are cut and sorted through a process known as gel electrophoresis. We can use this technology to not only compare individual people, but compare different species. By comparing these unique fragments of DNA in different species, we can determine how closely related the species may be. These Genetic relationships are just piece of evidence to show evolutionary relationships between different species. By understanding commonality of DNA between species we can understand how they may fall on a phylogenic tree. In this lab you will compare the DNA fingerprints of a chimpanzee and a gorilla to that of a human. From the data that you collect, you will be able to see how related chimps, gorillas and humans are, and how the three species exhibit close evolutionary relationships.

Objectives:

1. Compare the DNA of Chimpanzees, Gorilla, and Humans to determine their evolutionary relationship with one another.
2. Simulate how DNA el electrophoresis works, and how its application can be used.

Materials:

1. Chimpanzee DNA
2. Gorilla DNA
3. Human DNA
4. Ruler

Procedure:

1. On your lab table, you will see three different DNA sequences that contain both leading strand, and complementary strand. Each will be labeled according to its source.
2. The enzyme we will be using to "cut" the DNA is CCGG. At every location on the leading strand where you cross the CCGG sequence, draw a vertical line between the C and the G.
3. Once you have completed cutting the three DNA strands with the enzyme, count how many bases appear in each fragment. Record this value above the DNA

fragment.

4. On the "gel" provided, draw a horizontal; at every line that corresponds to your DNA fragment length (If you have a fragment of 7 base pairs, then on the gel next to line 7, draw a line).
5. For every duplicate you have of the same fragment length, increase the thickness of the horizontal line. This will allow you to distinguish if the DNA sequence had 1,2,3, etc. fragments of that length.
6. Complete this process for Chimpanzee, Gorilla, and Human.
7. Once completed compare the similarities in DNA fragment size between the three species and Answer the follow up questions provided.

Questions:

1. What is the purpose of DNA (2 pts)?

2. Which sized fragments moved farther up the gel (away from the insertion wells)? Why do you think this is? (2 points each)

3. According to the DNA evidence you have discovered in this lab, which species is more similar to human? State your evidence from this lab to support your answer (4 points).

4. If you looked at two DNA sequences from the same species (two humans, two chimps, etc.) would their DNA sequence be exactly the same (2 points)?

5. Draw a phylogenic tree of the three species that we have looked at in this lab, based upon the evidence we have found. What does this mean in terms of their evolutionary relationship (6 points)?

DNA fingerprints

1			
2			
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CHIMP

ATGATCCGGTATTCCGGTAACGTCCGGATGTCCGGATGCGTTGAAACCGGATC
TACTAGGCCATAAGGCCATTGCAGGCCTACAGGCCTACGCAACTTTGGCCTAG

GATCGTTCCGGATGGACCGGTCGATGGTCTAGTCGTACCGGAGCTAGCTACTG
CTAGCAAGGCCTACCTGGCCAGCTACCAGATCAGCATGGCCTCGATCGATGAC

ATGCTAATGTCCTAGGCATATCCGGGAGAACCTTTCGCCGGCTGATCGATCGAT
TACGATTACAGGATCCGTATAGGCCCTCTTGGAAAGCGGCCGACTAGCTAGCTA

GCTATCACCGGTAGTCGAATCGACCGGTCCGGATCGTAGCCGGTCGATGCTATA
CGATAGTGGCCATCAGCTTAGCTGGCCAGGCCTAGCATCGGCCAGCTACGATAT

TTATATATGCGCGCCGGATGTAACCGGATGCTAGCTAGCCATCTAGATCCGGAA
AATATATACGCGCGGCCTACATTGGCCTACGATCGATCGGTAGATCTAGGCCTT

GCTAGCTAGCTAGCTAGTAGCTACGAACTCCGGTAGTACTGTGACCGGTTATCG
CGATCGATCGATCGATGATCGATGCTTGAGGCCATCATGACACTGGCCAATAGC

TATGAGCGTCATCCGGTACCGGTATACCGGCGCTA
ATACTCGCAGTAGGCCATGGCCATATGGCCGCGAT

GORILLA

ATGATCCGGTATTCCGGTAACGTCCGGATGTCCGGATGCGTTGAAACCGGATC
TACTAGGCCATAAGGCCATTGCAGGCCTACAGGCCTACGCAACTTTGGCCTAG

GATCGTTCCGGATGGACCGGTCGATGGTCTAGTCGTACCGGTGCTAGCTACAG
CTAGCAAGGCCTACCTGGCCAGCTACCAGATCAGCATGGCCACGATCGATGTC

ATGCTAATGTCCTAGGCATATCCGGGAGAACCTGTCGCCGGCTGATCGATCGAT
TACGATTACAGGATCCGTATAGGCCCTCTTGGACAGCGGCCGACTAGCTAGCTA

GCTATCACCGGTAGTCGAATCGACCGGTCCGGATCGTAGCCGGTCGATGCTATA
CGATAGTGGCCATCAGCTTAGCTGGCCAGGCCTAGCATCGGCCAGCTACGATAT

TTATATATGCCGGCCGGATGTAACCGGATGCTAGCTAGCCATCTAGATCCGGAG
AATATATACGGCCGGCCTACATTGGCCTACGATCGATCGGTAGATCTAGGCCTC

CTATGTAGCTAGCTAGTAGTATCGTATTCCAGTAGTACTGTGACCGGTTATCGTA
GATACATCGATCGATCATCATAGCATAAGGTCATCATGACACTGGCCAATAGCT

TGAGCGTCATCCGGTACCGGTATACCGGCGCTA
ACTCGCAGTAGGCCATGGCCATATGGCCGCGAT

HUMAN

<u>ATGATCCGGTATTCCGGTAACGTCCGGATGTCCGGATGCGTTGAAACCGGATC</u>
TACTAGGCCATAAGGCCATTGCAGGCCTACAGGCCTACGCAACTTTGGCCTAG

<u>GATCGTTCCGGATGGACCGGTCGATGGTCTAGTCGTTTACGGCTATACCGGAGC</u>
CTAGCAAGGCCTACCTGGCCAGCTACCAGATCAGCAAATGCCGATATGGCCTCG

<u>TAGCTACTGATGCTAATGTCCTAGGCATATCCGGGAGAACCTTTCGCCGGCTGA</u>
ATCGATGACTACGATTACAGGATCCGTATAGGCCCTCTTGGAAAGCGGCCGACT

<u>TCGATCGATGCTATCACCGGTAGTCGAATCGACCGGTCCGGATCGTAGCCGGTC</u>
AGCTAGCTACGATAGTGGCCATCAGCTTAGCTGGCCAGGCCTAGCATCGGCCAG

<u>GATGCTATATTATATATGCGCGCCGGATGTAACCGGATGCTAGCTAGCCATCTA</u>
CTACGATATAATATATACGCGCGGCCTACATTGGCCTACGATCGATCGGTAGAT

<u>GATCCGGAAGCTAGCTAGCTAGCTAGTAGCTACGAACTCCGGTAGTACTGTGA</u>
CTAGGCCTTCGATCGATCGATCGATCATCGATGCTTGAGGCCATCAT GAC A CT

<u>CCGGTTATCGTATGAGCGTCATCCGGTACCGGTATACCGGCGCTATCGATCGCA</u>
GGCCAATAGCATACTCGCAGTAGGCCATGGCCATATGGCCGCGATAGCTAGCGT

<u>TTCGCCCGGCGATATCGGGTATAATTTACGACTTCGACATAGCGTACG</u>
AAGCGGGCCGCTATAGCCCATATTAAATGCTGAAGCTGTATCGCATGC

APPENDIX IV, D

When Milk Makes You Sick
Adapted from: Therese Passerini
www.indiana.edu/~ensiweb/lessons/tp.milk3.html

Introduction: According to statistics, approximately one third of all Americans feel ill after consuming milk and other dairy products. Parents constantly tell their children to drink their milk because milk "does a body good." It is well known that the calcium in milk helps to build strong teeth and bones. Overall, milk is a good source of nutrients, like calcium and protein.

Most animals stop drinking milk after they are weaned and their body chemistry changes so that they can no longer digest the sugar found in milk. Worldwide, this is also true for the human population. It is actually unusual for adults to be able to digest milk easily.

Lactose intolerance is the inability to breakdown the sugar found in milk. People who are unable to breakdown lactose are missing, or have a non-functioning enzyme called lactase. When lactose intolerant people consume milk, they often feel bloated and experience gas and diarrhea. As mentioned earlier, most adult animals are not able to breakdown lactose. Somewhere along the way, some adult humans might have developed a mutation that allows them to digest lactose as adults.

Purpose: To hypothesize where lactose tolerance might have developed and why, and to determine the mode of inheritance for the gene.

Part A: Pedigrees
You will make three pedigrees based on each of the scenarios below to determine how lactose intolerance is inherited. Fill in the circles or squares of individuals that are lactose intolerant.

Pedigree A
Mike and Donna Miller are both lactose tolerant. They have four children. Fred, Nick, and Linda are all lactose tolerant. Their daughter Jane is lactose intolerant. Draw the pedigree for this family below.

Pedigree B
Mary is married to John. Mary is lactose intolerant. They have five children. Ann, David, and Dan are lactose intolerant. Nancy and Scott are lactose tolerant.

Pedigree C
Joe and Lucy Anderson are both lactose intolerant. They have four children: Alicia, Eric, Ben, and Rodney and all of their children are lactose intolerant.

Analysis of Pedigrees:

1. Does it appear that lactose intolerance is an inherited characteristic? Explain your answer.

2. How can two parents who are both lactose tolerant produce children who are lactose intolerant? Explain your answer.

3. What is the most probable mode of inheritance for lactose intolerance? In other words, is lactose intolerance autosomal or sex-linked, and is it dominant or recessive. Give reasons for your choices.

4. Draw a Punnett square to support your mode of inheritance for lactose intolerance.

Part B: Populations and Lactose Intolerance

Graph the information in the charts below that provide percentages for lactose intolerant populations in different countries. You may use a bar graph. The x-axis should be the country of origin and the y-axis should be the percentage of lactose intolerance.

Percent of Lactose Intolerant People by Country

Country of Origin	Percent Lactose Intolerant	Country of Origin	Percent Lactose Intolerant
China	98	Iraq	71
Greenland	85	Russia	16
Mexico	53	Australia	20
Brazil	60	England	15
Italy	55	Kenya	88
South Africa	95	United States	30
India	60	Nigeria	22

Ethnicity in the United States also plays a part in lactose intolerance. Graph the information found in the table below in a bar graph. The ethnicity should go on the x-axis and the percent of intolerance should go on the y-axis.

Lactose Intolerance in the United States

Ethnicity	Percent Lactose Intolerant	Ethnicity	Percent Lactose Intolerant
African Americans	75	Eskimos	80
Asian Americans	90	Hispanic Americans	53
Caucasians	15	Native Americans	90

Questions and Analysis:

1. Formulate a hypothesis as to where lactose tolerance originated and explain why tolerance would occur here.

2. During the past 5,000 years agriculture has been important to human populations. In some isolated areas, crops did not perform as well or the climate did not permit growing crops year round. In these places, animals and their milk were the main food supply. Use your knowledge of evolution and natural selection to explain how some populations may have become lactose tolerant.

3. What would explain the statistics that approximately 30% of all Americans are lactose intolerant compared to other parts of the world where that number is more than 80%?

4. Compare the percentages of populations in African countries that are lactose intolerant. Form a hypothesis to explain why Nigeria is so different from the other African countries. You should include an explanation with your hypothesis.

5. Use the articles on lactose tolerance and evolution available in the classroom, to gather evidence to support your original hypothesis or formulate a new hypothesis. Write a paragraph about how scientists think lactose tolerance evolved.

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