The Field Museum Education Department Presents

The Daniel F. and Ada L. Rice DNA Discovery Center

EDUCATOR GUIDE & WALKING MAP

The Field Museum’s Education Department develops educator guides to provide detailed information on field trip planning, alignment with Illinois State Learning Standards, as well as hands-on classroom activity ideas to do before and after your visit to the Museum.

This exhibition is generously supported by the Daniel F. and Ada L. Rice Foundation. We gratefully acknowledge The Pritzker Foundation’s generous support of the Pritzker Laboratory for Molecular Systematics and Evolution. We express our appreciation to Misty and Lewis Gruber for establishing an endowment in support of research in the Pritzker Laboratory.
The Daniel F. and Ada L. Rice DNA Discovery Center Educator Guide

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Teacher’s Note

Science can be a tough subject to teach. Science is always changing and it is sometimes difficult to keep pace with the advancements and breakthroughs in such a fluid field. Science textbooks from years past are obsolete, yet some teachers, parents/caregivers and school communities find it challenging to constantly update and renovate science curricula.

Science can also create controversy in the classroom. For example, think back to when Christopher Columbus claimed that the earth was flat. It was heresy to believe anything else; it was not until brave navigators set off to challenge this claim and determined that indeed they did not fall off the earth into the great abyss that other ideas about the Earth were entertained. Scientific discovery taught us that the earth is a sphere. Charles Darwin’s scientific breakthrough of the theory of evolution through natural selection still stirs up debates amongst many people, even though there is ample proof to support such theories. Scientific history is full of numerous examples of controversy behind the discovery – it is this very curiosity that continues to keep scientific investigation alive.

Today’s classrooms are filled with a myriad of students that come from a variety of backgrounds, values, and beliefs—therefore it is important that educators be sensitive to these beliefs but also challenge students to explore and ask questions about the world we live. Teaching about DNA and the discoveries that have been made using DNA technology is no different. Scientists today, continue to debate and challenge the latest breakthrough findings and question the results proving old common beliefs wrong. This educator guide will provide you an opportunity to explore some examples of such controversy that will prove to be helpful in the classroom and begin discussing these topics in science, specific to the DNA Lab at the Museum.
Introduction and Key Concepts

DNA has been in the forefront of scientific research for quite some time. People are often introduced to DNA through the breakthroughs that have been made in human genealogy, criminology and forensics. Forensics, although it is extremely important and very flashy with the urban CSI television series, it is only a small part of what makes up the study of DNA. The Daniel F. and Ada L. Rice DNA Discovery Center will allow visitors to learn about the groundbreaking research that is being conducted in at The Field Museum’s Pritzker Molecular Laboratory for Molecular Systematics and Evolution, a lab in which DNA research is conducted every day.

The Daniel F. and Ada L. Rice DNA Discovery Center is broken into key sections for individual study to understand the complexities of DNA.

- An introductory DNA overview video
- A three-dimensional interactive model of a cell, detailing where DNA is found and highlighting differences between eukaryotic animal and plant cells
- A three-dimensional interactive model of DNA
- A gel processing video
- A DNA analysis interactive
- An interactive touch screen relative to Field Museum research
- An opportunity to ask a scientist(s) questions about their current research
- A viewing area for visitors to observe scientists working on the lab on their cutting-edge genetic research

It is important that students have some understanding of a few key concepts prior to visiting the exhibition in order to make their field trip as educational and focused as possible. Allow ample time for reflection and discussion in the exhibition to bridge possible concerns and basic understanding of key concepts prior to moving onto the next destination and/or lesson.

- Every living thing is made up of cells. Plants, fungi, and animals are made up of many cells. Some organisms, such as some bacteria are comprised of only a single cell.

- Cells contain organelles that do specific jobs that carry out the cells’ necessary functions. Cells contain an organelle called a nucleus which contains the DNA. In eukaryotic cells, DNA can be found in the mitochondria. Certain plastids, called chloroplasts, conduct photosynthesis, others store starch.

- DNA is the molecule that contains an individual organism’s “blueprint.” It is also the molecule that connects all living things on earth to each other.

- DNA is a molecule that has a unique molecular structure that allows scientists to analyze it with advanced technology. The information scientists get from studying DNA allows them to find similarities and differences amongst organisms that were never before known. The research also allows scientists to trace an organism’s ancestry and find its evolutionary relationship to other species.

- The Daniel F. and Ada L. Rice DNA Discovery Center allows teachers and students to be apart of groundbreaking research being done at the Museum, and it will also allow all visitors to learn about the diversity of projects that are currently underway in numerous countries around the world on multiple topics.

Special Teacher Note: The Daniel F. and Ada L. Rice DNA Discovery Center offers a unique opportunity for students to ask a scientist a question while the scientists are conducting research in the lab. This is a great opportunity for students, prior to their field trip to formulate some questions that would be appropriate to ask the scientists. The scientists will only be available at certain times throughout the day, check with the museum for availability.
Illinois Learning Standards (ILS)

Use of the materials in this educator guide in combination with a field trip to The Daniel F. and Ada L. Rice DNA Discovery Center will help you structure learning experiences that correspond to the following Illinois Learning Standards. This exhibition, although suitable for all grade levels, closely corresponds to the concepts studied in middle school and high school. Teachers will need to identify descriptors and benchmarks to link their lesson plans, larger units of study, and to specific subject areas. For more information on the Illinois State Standards visit www.isbe.state.il.us/ils/.

**English Language Arts**

*State Goal 1:* Read with understanding and fluency.

*State Goal 3:* Write to communicate for a variety of purposes.

*State Goal 4:* Listen and speak effectively in a variety of situations.

*State Goal 5:* Use the language arts to acquire, asses and communicate information.

**Mathematics**

*State Goal 6:* Demonstrate and apply a knowledge and sense of numbers, including numeration and operations patterns, ratios and proportions.

*State Goal 7:* Estimate, make and use measurements of objects, quantities and relationships and determine acceptable levels of accuracy.

*State Goal 8:* Use algebraic and analytical methods to identify and describe patterns and relationships in data, solve problems and predict results.

*State Goal 10:* Collect, organize and analyze data using statistical methods; predict results; and interpret uncertainty, using concepts and probability.

**Science**

*State Goal 11:* Understand the process of scientific inquiry and technological design to investigate questions, conduct experiments and solve problems.

*State Goal 12:* Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space science.

*State Goal 13:* Understand the relationship among science, technology and society in historical and contemporary contexts.

**Social Science**

*State Goal 16:* Understand events, trends, individuals and movements shaping the history of Illinois, the United States and other nations.

**Physical Development and Health**

*State Goal 22:* Understand principles of health promotion and the prevention and treatment of illness and injury.
Words to Know

**Allele:** One of two or more alternative forms of a gene or genetic marker.

**Base:** A subunit of nucleic acid. It is the portion of a nucleotide that makes it an A, G, T, and C.

**Base Pair:** Two complimentary bases held together by chemical bonds. Base pairing occurs between A and T and between G and C.

**Capillary Electrophoresis:** A method used to separate DNA fragments of different sizes using a liquid polymer inside of a very narrow length of tubing.

**Cell:** The basic building block of an organism.

**Chromosome:** The physical structure that contains a continuous piece of DNA and the genes for which the DNA code is located.

**Cladogram:** A branching, treelike diagram in which the endpoints of the branches represent a taxonomic group, such as a species or a population. A cladogram is used to illustrate genetic relationships and show points at which various species have diverged from common ancestral forms.

**Clone:** An organism that has the exact same genetic material as another organism.

**Cloning:** Using molecular technologies to make a copy of an organism or segment of DNA.

**Denaturation:** A change in a protein or nucleic acid caused by heat or chemicals. In PCR (polymerase chain reaction) it refers to the separation of double-stranded DNA into single-stranded DNA by heat.

**DNA:** *(deoxyribonucleic acid)* A chemical substance that contains instructions for the function of cells and the development of an organism.

- **Adenine "A" (AD-uh-neen):** One of the four building blocks of DNA. It always pairs with thymine.
- **Cytosine "C" (SYT-uh-seen):** One of the four building blocks of DNA. It always pairs with guanine.
- **Guanine "G" (GWAN-een):** One of the four building blocks of DNA. It always pairs with cytosine.
- **Thymine "T" (THY-meen):** One of the four building blocks of DNA. It always pairs with adenine.

**DNA Amplification:** The process of making numerous copies of a particular region of DNA using the polymerase chain reaction (PCR).
Words to Know (continued)

**DNA Polymerase:** An enzyme that assists in creating a new DNA strand from an existing template.

**DNA Replication:** The process of copying a new double-stranded DNA molecule from an existing double-stranded DNA molecule.

**Double Helix:** The shape of a DNA molecule. The helix looks like a ladder that has been twisted. The “rails” on the ladder are the backbone and are made up of sugar and phosphate molecules. The “rungs” are formed by bonds between the nitrogenous bases.

**Electropherogram:** A representation of alleles or a sequence of bases in the form of peaks after separation by electrophoresis and detection by a DNA Analyzer.

**Electrophoresis:** The technique used to separate molecules by their rate of movement in an electric field. When electrophoresing DNA, fragments are separated according to size.

**Enzyme:** A protein that speeds up specific reactions, which is not changed or consumed in the process. A biological catalyst.

**Eukaryote/Eukaryotic:** A cell that contains a nucleus and various organelles. Plants, animals, fungi, algae and protists are eukaryotic.

**Gene:** A section of DNA that forms the basic unit of inheritance.

**Genetic Engineering:** A technique that directly alters an organism’s DNA; alters the structure of a DNA molecule by substituting genes from other DNA molecules (often from different organisms).

**Genetics:** The study of genes, DNA, and heredity.

**Genome:** The total genetic makeup of an organism.

**Heredity:** The passing of traits from parent to offspring.

**Microsatellite:** Any of numerous short segments of DNA that are distributed throughout the genome, that consist of repeated sequences of usually two to five nucleotides, and that are often useful markers in studies of parentage because they tend to vary from one individual to another.

**Mitochondrial DNA:** *(mDNA)* The small circular DNA molecules found in mitochondria.

**Mutation:** Changes to the base pair sequence of genetic material. Mutations can be caused by copying errors in the genetic material during cell division, by exposure to ultraviolet or ionizing radiation, chemical mutagens, or viruses.

**Nucleus:** An organelle found in the vast majority of eukaryotic cells. It contains most of the cell’s genome.
Words to Know (continued)

**Polymerase Chain Reaction:** (PCR) A process that creates millions of copies of a desired DNA sequence.

**Prokaryote:** A cell that does not have a nucleus or any other organelles. Bacteria are prokaryotes.

**Protein:** A class of biological molecules made up of amino acids; proteins provide much of the organisms function and structure.

**Recombination:** The process by which genetic material is broken and joined to other genetic material.

**Restriction Enzyme:** An enzyme that cuts DNA at specific locations determined by the DNA sequence.

**Trait:** A characteristic or property of an organism.
DNA Lab Equipment you will see at the Museum!

*The Daniel F. and Ada L. Rice DNA Discovery Center* is equipped with brand new state of the art equipment that means the scientists can conduct research faster and more precisely.

**Applied Biosystems 3730 DNA Analyzer** – A DNA Analyzer is an instrument used to read pieces of DNA that are labeled with a fluorescent dye.

DNA Analyzers are able to read as many as 384 fluorescently labeled samples in a run and perform as many as 24 runs a day. These perform the size separation and peak reading, resulting in an electropherogram.

A simple DNA Analyzer will have one or more lasers that emit at a wavelength that is absorbed by the fluorescent dye that has been attached to the DNA strand of interest. It will then have one or more optical detectors that can detect the wavelength at which the dye fluoresces. The presence or absence of a strand of DNA is then detected by monitoring the output of the detector. Since shorter strands of DNA move through the polymer matrix faster they are detected sooner and there is then a direct correlation between length of DNA strand and time at the detector. This relationship is then used to determine the actual DNA sequence.

**Autoclave** – An autoclave is a device that uses pressure and heat to sterilize equipment.

**Bench Top Centrifuge** – A bench top centrifuge is a piece of equipment driven by a motor that puts an object in rotation around a fixed axis, applying force perpendicular to the axis. Centripetal acceleration is used to separate substances of greater and lesser density.

**Computers** – The computers in the DNA lab are used to run some of the equipment, they are also used to analyze and store the scientists’ data.

**Fume Hood** – A fume hood is a large piece of equipment common to laboratories designed to limit a person’s exposure to hazardous and unpleasant fumes.

**Gel Imaging System** – A gel imaging system allows scientists to permanently preserve the results of their DNA and protein electrophoresis experiments by photographing the actual gels. It can be broken down into three parts.

1) A UV light source enables the user to visualize their bands on a gel, as their bands have been “stained” with a chemical that fluoresces in UV light.
2) The camera takes a picture of that gel while it is being illuminated on the UV light box, recording the gel image.
3) The camera sends the digital photo to the gel imaging system’s computer, where it can be saved, printed, labeled, and adjusted for clarity, among many other features the software provides.
part one: introduction

DNA Lab Equipment you will see at the Museum! (continued)

**Gel rigs, molds and power sources** – Gels are used for many things in the lab.
1) check for the existence of DNA in a prepared extraction
2) determine the size of a DNA fragment
3) verify if an amplification worked
4) cut a band out of the gel and purify it for an amplification product.

**Large Refrigerated Centrifuge** – The large refrigerated centrifuge is used specifically to precipitate DNA out of solution for sequencing. At lower temperatures more DNA will precipitate out of solution.

**Ovens** – The ovens are used to keep some of the samples at a constant temperature as required by some of the labs protocols.

**Pipettes** – Pipettes are laboratory instruments used to transport a measured amount of liquid. Pipettes are used in chemistry and molecular biology research. A pipette works by creating a vacuum above the liquid-holding chamber and selectively releasing this vacuum to draw up and dispense liquid. Pipettes that dispense between 1 and 1000 μl are termed micropipettes, while macropipettes dispense a greater volume of liquid.

**Refrigerator** – The refrigerator is used to store some of the chemical reagents, as well as a temporary storage facility for some of the DNA tissue samples that are currently being analyzed.

**Spectrophotometer** – The spectrophotometer is an instrument used to determine the intensity of various wavelengths in a spectrum of light. It is used to help scientists determine how much DNA they have in a sample.

**Speed-Vac** – A speed-vac is a centrifuge with a vacuum that also provides heat, in order to dry down samples by means of evaporating liquid.

**Thermal Cycler** – The Thermal cycler (also known as a PCR machine or DNA amplifier) is an apparatus used for polymerase chain reaction, PCR. The device has a thermal block with holes where tubes with the PCR reaction mixtures can be inserted. The cycler then raises and lowers the temperature of the block in discrete, pre-programmed steps.

**Vacuum /filter plate system** – This system is one of the many ways scientists can isolate and purify the DNA created from the polymerase chain reaction (PCR). By placing the DNA sample onto a filter, and sucking the sample by using the vacuum it allows smaller components of a reaction to go through the filter, leaving the scientist with a pure sample on the filter.

**Vortexes** – Instrument used to mix samples/reactions by agitating them. Vortexes also help bring DNA into solution when used in conjunction with the vacuum/filter plate system.

**Water Bath or Incubator** – An apparatus in which environmental conditions, such as temperature and humidity, can be controlled, often used for growing bacterial cultures, hatching eggs artificially, or providing suitable conditions for a chemical or biological reaction.
DNA Lab Equipment you will see at the Museum! (continued)

- **-20 Freezer** – The -20 freezer is another place for temporary storage for DNA tissue samples that are currently being analyzed in the lab.

- **-80 Freezer** – The -80 freezer is another storage facility for permanent/long term storage of DNA samples. This freezer is also used for storage of other DNA lab related items that require sub-zero storage.

**Cryogenics Facility** – The cryogenics facility, although not seen on exhibit is an important component of The Pritzker Laboratory. It contains liquid nitrogen fueled freezers that can reach temperatures far below -80°C. These freezers serve as permanent tissue and DNA storage.
An Introduction to DNA

Living things are formed from cells. Some living things are made up of one cell—while others, like humans are comprised of 50 to 100 TRILLION cells. These cells contain genetic instructions stored as DNA. DNA is found in every living thing from the largest of mammals to the smallest of bacteria. DNA is the substance of genes, the units of inheritance that transmit information from parents to offspring.

Genetic instructions provide all of the necessary information for a living organism to develop and survive. DNA resides in the nucleus of every cell. These instructions tell the cell what role it will play in the body. The instructions come in the form of a molecule of DNA. DNA encodes a detailed set of plans, “a blueprint” for building different parts of the cell. Each cell uses instructions only from parts of the total DNA makeup. For example, an optical cell uses DNA that specifies the structure and function of the eye; where as a cardiac cell uses DNA that deals with the heart. Therefore, during development a cell reads only the part of the DNA that it needs.

DNA is found in a cell’s nucleus and mitochondria:

The bodies of all multicellular organisms on Earth are made of complex cells. Most DNA is contained in the large nucleus, the control center of the cell.

The DNA molecule is extremely long, and in order to condense it, it must be wound tightly and packaged as a chromosome. Humans have two sets of 23 chromosomes in every cell nucleus—one set is inherited from each parent.
Examples of other chromosome numbers:

- Alligator: 2 sets of 16 – 32 chromosomes
- Apple: 2 sets of 17 – 34 chromosomes
- Camel: 2 sets of 35 – 70 chromosomes
- Fruit Flies: 2 sets of 4 – 8 chromosomes
- King Crab: 2 sets of 104 – 208 chromosomes
- Petunia: 2 sets of 7 – 14 chromosomes
- Porcupine: 2 sets of 17 – 34 chromosomes
- Tomato: 2 sets of 12 – 24 chromosomes

Each DNA molecule that forms a chromosome contains regions called genes, which guide the production of one particular component of an organism. A set of human chromosomes contains one copy of each of the 30,000 genes in the human genome. Each nucleus in our cells contains an entire set of chromosomes.

Genes provide the instructions for producing all the biological components of organisms. Genes govern metabolic processes, as well as specifying physical characteristics. Traits such as an individual’s height or skin tone require the actions of many genes working together.

Humans share 100% of the same genes, it is the actual nucleotide sequences that make up any individual organism's genome that are not entirely identical. Therefore, each person is unique. Although the DNA of any two people on earth is 99.9% identical, it is the little differences that can have a big effect on how the genes are expressed.

The DNA molecule comes in the form of a twisted ladder shape called a double helix. The ladder's rungs are built with the four nucleotides: A, C, T and G. The four nucleotides are called adenine (A), thymine (T), guanine (G), and cytosine (C). These four nucleotides are all that's needed to write a code that describes an entire organism's body plan. These instructions are read as a string of A's, C's, G's, and T's such as TGCCATTCA. Just as there are 26 letters in the alphabet, there are only four letters in the alphabet of DNA.

If this sounds too simple, remember that Morse code uses only four symbols (dot, dash, short spaces and long spaces), and a person could spell out an entire library worth of books with Morse code!

**FOR EXAMPLE:**

<table>
<thead>
<tr>
<th>One DNA strand (one half of the ladder) could be made of the letters:</th>
<th>GTGACCTCGAAGTGCTGACTCATTTGA</th>
</tr>
</thead>
<tbody>
<tr>
<td>The letters make “words”</td>
<td>GTG ACC TCG AAG TGC TGA CTC ATT TGA</td>
</tr>
<tr>
<td>The “words” make “sentences” which create useful instructions</td>
<td>“GTG ACC TCG AAG” “TGC TGA CTC ATT TGA”</td>
</tr>
</tbody>
</table>
Studying DNA

How do scientists obtain the DNA of the organisms they are studying? More importantly, what do they do with the information once they have it? Inside the DNA lab at The Field Museum there are numerous projects going on. Some scientists have traveled to the rainforests of South America to study bats, while others have focused their attention on lichens from Sweden. In both cases, these scientists collect the DNA of their target species, analyze the DNA, and use this analysis to understand which species are related, how species evolved, and how particular species fit into overarching trees of life. Scientists have done this analysis in the past using the physical traits of organisms as the primary mean of classification, among other techniques. But now, DNA analysis allows scientists to map relatedness among species at the molecular level, often resulting in dramatic changes in how we previously had classified organisms.

Dr. Kevin Feldheim, The Pritzker Lab manager, focuses his attention on lemon sharks in the Bahamas. Throughout the following explanation of DNA analysis, Dr. Feldheim’s research will serve as an example for each of the five DNA analysis steps.

It is important to note that the techniques used in The Field Museum’s DNA lab may be different from other techniques, especially those used at the high school level. Since the study of DNA is constantly changing, so are the techniques used to work with DNA.
**Part One: Introduction**

**DNA Analysis in 5 Steps**

1. **Collect**

First scientists must find the organism that they are interested in studying and collect a sample. Since the scientists are studying the relationships between organisms (whether individuals or species), numerous individuals are sampled. DNA is found in nearly every cell of an organism, therefore most parts of the organism can be used.

When Dr. Feldheim was in the field capturing lemon sharks for his research, he and his team set out long nets in coastal areas off of Bimini (an island of the Bahamas). The nets were set out at night and the team checked the nets every 15-minutes, or until they heard splashing. Nets are used only to capture newborn and juvenile sharks. Adult sharks were captured using long line fishing. Once the team caught the sharks, they would take physical measurements. Three measurements were taken: a) pre-caudal length (PCL) from the snout to a pre-caudal pit just before the tail b) fork length – from snout to the fork in the shark’s tail and c) total length – tip to tip. The sharks’ sex were also determined as well as their weight.

A small clip from their fin, about 1/3 the size of a pencil eraser was also taken. All sharks heal extremely fast, and only a small scar is left from the clip. In one study done by Dr. Feldheim, over 900 sharks were caught, tagged, clipped and used for his research. The small bit of shark tissue contains more than enough DNA for the team to conduct their research back at the Museum.

Learn more about Dr. Feldheim and his research by visiting The Year of Biodiversity and Conservation, Meet the Scientist http://www.fieldmuseum.org/biodiversity/scientist_profiles/scientist_feldheim.html

Once enough samples have been collected, the team stores each sample in test tubes that are stored in tanks that are cooled by liquid nitrogen. Since DNA will eventually degrade in the open air, it is important to store samples at ultra cold temperatures (for example, in liquid nitrogen at -196°C) where DNA can essentially last forever.
Part One: Introduction

DNA Analysis in 5 Steps (continued)

2 Extract

The extraction of DNA from a cell is the second step in this procedure. In order for scientists to study DNA it must be isolated or separated from the other contents in the cell. This is especially true because some of the other components of the cell (certain enzymes, for example) will break DNA down and render it useless for scientific study. DNA is freed by breaking membranes through the use of mechanical agitation, chemicals, heat and spinning in a centrifuge.

By adding salt, proteins will precipitate out of solution. Alcohol is then added to the supernatant and the DNA comes out of solution. The DNA resembles a cloudy opaque material and is spun down to the bottom of the tube.

The technique used by Dr. Feldheim and his team to extract the lemon shark DNA from his tissue samples is called “salting out,” this similar to the technique explained above.
To better “see” the genes, scientists make millions of copies of the extracted DNA using a Polymerase Chain Reaction or a PCR. Before the reaction can take place, the scientist will need to identify what part or parts of the DNA they need to copy. Since a strand of DNA contains millions of base pairs, the scientist only makes copies of a specific area they are interested in. This process can be done by researching the gene to determine what primers they will need to use in the amplification process. Primers are short strands of DNA that act as a starting place for DNA synthesis and once added, will bind their complementary regions on the extracted DNA. Primers are typically ordered from biological supply company.

The extracted DNA, the pre-determined primers, the four nucleotides (Gs, As, Ts, and Cs), and an enzyme are added to a vial to begin the PCR. The PCR process takes 1.5 to 3 hours, and begins by heating the solution in order to “unzip” the DNA. After the DNA unzips – the solution is cooled and the primers bond with their complementary base pairs on the target DNA.

In the next phase of the reaction, the solution is heated to the temperature at which the enzyme works optimally a second time only this time the enzyme works to create another double-stranded copy of the target DNA.

The solution contains many copies of the primers and millions of nucleotides in order to undergo many cycles of amplification. With each cycle the number of copies of the target DNA doubles. After 25 cycles there are more than 33 million copies of the target region of DNA!

Dr. Feldheim's research focuses on microsatellites located within the lemon sharks DNA. Microsatellites are portions of the DNA, which usually do not code for anything and are formed from a repeating pattern of nucleotides. For example, GTGTGTGTGTGT. In some microsatellites, the repeated unit (e.g. GT) may occur four times in a row, in others it may be twelve, or even thirty-three. In organisms such as lemon sharks, each individual animal will have two copies of any particular microsatellite segment, one from each parent. A mother might have a genotype of 6 repeats and 12 repeats, a father might have 20 repeats and 9 repeats while their first born baby shark might have repeats of 6 (inherited from mom) and 9 (inherited from dad). Therefore it is possible to determine the shark’s parents from this type of genetic analysis.
Once the copies are made, it is time to decode the sequence of its chemical components. A DNA Analyzer reads the components in a section of DNA.

Once a piece of DNA is amplified, it can be directly run on the DNA Analyzer. Alternatively, to find the sequence of Gs, As, Ts and Cs in the stretch of DNA, scientists perform a DNA sequencing reaction on the amplified DNA. This process is very similar to a PCR (polymerase chain reaction) except that the Gs, As, Ts and Cs are labeled with different fluorescent tags. All A’s are green, T’s are red, C’s are blue, and G’s are yellow. The DNA Analyzer is able to differentiate between the colors.

The analyzer that is used at the Field Museum is called an Applied Biosystems 3730 DNA Analyzer that uses capillary electrophoresis technology. The analyzer reads the components in a section of DNA by attaching a fluorescent tag to each base so that a laser can see the different colors. The DNA analyzer produces an electropherogram. An electropherogram is a representation of the sequence of bases in the form of peaks.

Dr. Feldheim uses the data from the DNA analyzer to determine how many repeats are on the microsatellite he was studying from a certain shark.
Now that all the work has been done, what is done with all the information? Most of the scientists working in the Field Museum’s DNA lab are using DNA to find relationships between the organisms they are studying. By studying an organism’s DNA they can determine how organisms mate, where they migrate, and how they are related to other organisms in their population. They use these data to find similarities and differences that can only be discovered through DNA analysis. Their data can also be used to help conservation efforts to preserve the species that they are studying.

Dr. Feldheim has been researching lemon sharks for years, and has identified a pattern over a two-year period where these sharks have continued to return to the same lagoon (The North Sound Nursery of Bimini) to give birth to their offspring, and where these baby sharks remain for a period of time to grow. It is important to conserve and provide protection of these unique locations to ensure safe guarding shark nurseries for future generations.
DNA Overview Video

Have students watch the six-minute introductory video to gain a better understanding of what is being studied and accomplished in the laboratory here at the Field Museum.

DNA is the molecule that connects all living things on earth. This fairly simple molecule is responsible for making unique individuals, but it is also responsible for connecting us to other organisms - both living and extinct. Therefore, this relatively simple molecule, with an alphabet of only four letters, is responsible for the incredible diversity of life on earth. Through exciting breakthroughs in DNA technology, scientists can trace our ancestry back much further than our great-great grandparents or even back to prehistoric times, but all the way back to the origin of life on earth.

Guiding Questions for the Overview Video

1. Why do we resemble our biological parents?
2. What is the immense family tree called?
3. What is the shape of DNA called?
4. The “words” that DNA creates are really called what?
5. What do genes do?
6. When do mistakes occur in inheritance?
7. What are these mistakes called?
8. How do new species evolve?
9. How do scientists know if different species are closely related?
10. What is the goal of The Field Museum scientists’ Tree of Life?

Answers to the Guiding Questions

1. We resemble our parents because we have inherited their DNA.
2. The Tree of Life
3. The shape of DNA is called a double helix
4. The “words” are considered genes.
5. Genes contain the instructions for how an organism looks and functions. Genes are responsible for an organism’s traits.
6. Mistakes can occur when chromosomes copy themselves during the inheritance process.
7. Mistakes are called mutations.
8. New species arise during the process of evolution, when separated populations begin to accumulate genetic differences.
9. If the sequences of DNA are similar, scientists can determine how closely related the species are.
10. Scientists at the Field Museum and many other organizations are working to create branches of the Tree of Life to show relationships among all the species on Earth.
Three Dimensional Interactive Cell Model

Cells are a starting point for studying living things and for understanding the study of DNA. All living organisms are made up of cells. Cells contain all of the biological equipment necessary to keep an organism alive. Eukaryotic cells are made up of components called organelles, and each cell is specialized for a certain function.

In the Daniel F. and Ada L. Rice DNA Discovery Center, students will be introduced to a plant cell and an animal cell. Plant cells are easier to identify because they have a protective structure called a cell wall made of cellulose. Plants have a cell wall; animals do not. Plants also have organelles called chloroplasts and large water-filled vacuoles. Prior to visiting the exhibition it would be beneficial for students to be able to compare plant and animal cells, and be able to identify and describe the cells’ organelles.

- Cell Membrane
- Cell Wall
- Cytoplasm
- Nucleus
- Ribosomes
- Golgi Apparatus
- Smooth Endoplasmic Reticulum
- Rough Endoplasmic Reticulum
- Mitochondria
- Lysosome
- Centrioles
- Vacuoles
- Chloroplast

Guiding Questions

1. Where is the majority of DNA found in the cell?
2. Where else in the cell can DNA be found?
3. What does the term “permeable” mean, and how does it pertain to the cell membrane?
4. Aside from a cell membrane, what else does a plant cell contain that provides additional structure to plants?
5. What is translation? Where does it occur?
6. What are the tiny organelles called that are involved in making proteins?
7. What is the organelle called is involved in packaging proteins and other substances the cells needs to survive?

Answers to Guiding Questions

1. The Nucleus
2. Mitochondria, plastids in plants (chloroplasts for example)
3. Permeable means that something can pass through; it pertains to the cell membrane which allows waste material to leave the cell, and allows nutrients and water to enter the cell.
4. A cell wall
5. Translation is the process of making proteins from an RNA sequence, and it takes place in the Rough Endoplasmic Reticulum
6. Ribosomes
7. The Golgi Apparatus
Three Dimensional Interactive Cell Model (continued)

**Pre-visit Activities**

- Have students in groups of two create organelle flashcards. On one side illustrate an organelle, on the other side, ask the other student to write a detailed description about the organelle. Have the students quiz each other using their flashcards.

- Present the following question to the students, “What are the benefits of living organisms being comprised of numerous tiny cells instead of one gigantic cell?”

- Have students visit the following website, created by other students, to learn about the cell and visualize each of the organelles: [http://sun.menloschool.org/~cweaver/cells/](http://sun.menloschool.org/~cweaver/cells/)

**Post Visit Activities**

- Have students compare a cell and its’ organelles to something larger - for example a city, a prison, a school, a mall etc.

- Have students create their own three dimensional cell model that they can present to the class. Students should be encouraged to use their creativity to make their models. Items such as play dough, candy, jell-o and craft store products are some examples of materials that could be used.

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To preserve tissue samples for DNA analysis, samples are stored in tubes at extremely low temperatures.
DNA is one of the most important molecules ever discovered. It is the molecule that connects all living things on Earth. DNA has the potential to unlock many secrets about life, answer questions about our ancestry, prevent and solve crimes, cure and treat diseases, prevent food shortages as well as shed new light on solving our current global warming and climate changes. For such an important molecule, it has a relatively simple structure.

DNA (deoxyribonucleic acid) consists of only six different molecules:

- a sugar (called deoxyribose)
- a phosphate
- four nitrogenous bases
  - Adenine (A)
  - Thymine (T)
  - Cytosine (C)
  - Guanine (G)

The six molecules connect together through bonds and repeat in a very long sequence resulting in DNA’s trademark double helix. The double helix resembles a long twisting ladder.

The double-stranded DNA molecule consists of a sugar–phosphate backbone (rails of the ladder). In the interior of the latter are pairs of nitrogenous bases (the rungs), holding the two strands together by hydrogen bonds.

Remember, in the double helix, adenine (A) can pair only with thymine (T), and guanine (G) can pair only with cytosine (C). As a cell divides (we refer to this as mitosis), the two strands of the double helix separate, and each side serves as a template for the new complementary strands.

Guiding Questions for the Three Dimensional DNA Model

1. What does DNA stand for?
2. DNA is composed of 6 different things. What are they?
3. What are the 4 bases called?
4. How do the bases pair together?
5. Where is DNA located?
6. What is the structure of DNA called?

Answers to Guiding Questions

1. deoxyribonucleic acid
2. a sugar, a phosphate and 4 nitrogenous bases
3. nitrogenous bases
4. Adenine pairs with Thymine; Cytosine pairs with Guanine
5. inside the cells of an organism’s body (nucleus, mitochondria, plastids – in plants).
6. double helix
Three Dimensional Interactive DNA Model (continued)

**Pre-visit Activities**

- Have students visit the following websites to see various DNA models. What do all the models have in common? What does the shape of DNA remind you of? Why do you think that shape is helpful for the DNA molecule?
  - [http://genomics.energy.gov/gallery/basic_genomics/gallery-01.html](http://genomics.energy.gov/gallery/basic_genomics/gallery-01.html)
  - [http://www.genetics.gsk.com/kids/dna01.htm](http://www.genetics.gsk.com/kids/dna01.htm)
  - [http://www.umass.edu/molvis/tutorials/dna/dnapairs.htm](http://www.umass.edu/molvis/tutorials/dna/dnapairs.htm)

- Have students break up into groups to research the one following scientists. Ask the groups to articulate why it was so important to know the structure of DNA, and how each of the scientists contributed to our understanding of DNA.
  - Erwin Chargaff
  - Linus Pauling
  - Maurice Wilkins
  - Rosalind Franklin
  - James Watson
  - Francis Crick

Ask each group to give an oral presentation of their findings in class prior to visiting the *Daniel F. and Ada L. Rice DNA Discovery Center*. In class, introduce students to the web site: [http://www.dnai.org/a/index.html](http://www.dnai.org/a/index.html) As a class, click on “code” and then click on “Finding the Structure.” You will take the class through the discovery of DNA through this interactive, which will help connect all the research done by each individual scientist and their discoveries.

**Post Visit Activities**


2. Test your skills on the structure of DNA by visiting the tutorial at [http://learn.genetics.utah.edu/units/basics/builddna/](http://learn.genetics.utah.edu/units/basics/builddna/).
In order for scientists to make great discoveries and unlock clues about the interrelationships between organisms, they first need to analyze the DNA. The process of DNA analysis is the same whether it is a lemon shark from the Bahamas, a brown bird wrasse from Hawaii or some oyster mushrooms from Michigan.

Although collecting a tissue sample from a shark maybe a bit trickier than getting a sample from a mushroom, the end result will be a series of A’s, T’s, G’s and C’s that scientists will use to answer questions about that particular organism.

In the lab, scientists are conducting real science and DNA analysis on innovative research from around the world. Most students, even adults are familiar with DNA analysis through a technique called gel electrophoresis, in which DNA is collected, extracted and then put into a gel to separate out through the electrophoresis process. In the DNA Lab, Field Museum scientists behind the glass are very familiar with the technique of sequencing DNA, but with the ever-changing technology available for studying DNA—it is critical that The Field Museum scientists have access to the most state-of-the-art technology and information to conduct their research and share their findings with the scientific communities around the world. Several Field Museum scientists spend months in the field collecting data, and publish in scientific journals.

To make the process of DNA analysis easier to understand, it has been broken down into 5 steps.

- Step 1 Collect
- Step 2 Extract
- Step 3 Amplify
- Step 4 Sequence
- Step 5 Analyze

Guiding Questions for DNA Analysis

1. How do Field Museum scientists procure their DNA samples that are analyzed here in the lab?
2. Why is it important to store DNA in a cold environment?
3. What is the second step in DNA analysis?
4. What needs to be done in order to extract the DNA out of the sample?
5. What is the third step in DNA analysis?
6. Why do scientists need to make so many copies of the section of DNA that they want to research?
7. During PCR, heat causes hydrogen bonds to break between the base pairs, and the DNA separates into its two complementary strands. Primers mark the starting line for the section to be copied. What takes places to make the complement strand?
8. What is the fourth step in DNA analysis?
9. What do the different color bands that are produced by the genetic analyzer represent?
10. What are some examples of questions that scientists can answer with their research in DNA analysis?

** If possible, ask the scientist any questions you might have about DNA!
** Take the time to watch the gel processing video; it will give you insight into the many genetic techniques that go into analyzing DNA.
DNA Analysis—Lab Rail Section (continued)

Answers to the Guiding Questions

1. Samples are collected in natural habitats and from specimens in the museum collections.
2. Because DNA decomposes rapidly in open air, DNA can last for an extremely long time if kept in very frigid conditions.
3. Extract.
4. The sample must be chopped up and heated along with chemicals to break apart cell membranes, other chemicals are added to separate the cellular debris from the DNA.
5. Amplification.
6. Because extracted DNA is difficult to see (there are too few copies of any particular gene region for the scientists to study).
7. An enzyme called polymerase attaches bases to their complement on the strand.
8. Sequencing
9. Each color represents one of the four nitrogenous bases. Each base is identified by a certain color.
10. How many species of venomous fish exist?
    What impact does a mountain range have on mammal evolution?
    How are all birds related?

Pre-visit Activities

1. In class, ask students to visit the following web site: http://learn.genetics.utah.edu/units/biotech/gel/. This website will give students an opportunity to perform gel electrophoresis, this is one way scientists can analyze DNA. The scientists at the Field Museum use a much more sophisticated process, but the objectives and outcomes are still the same.

2. In class, ask students to visit the following web site: http://www.dnai.org/b/index.html click on techniques, click on sorting and sequencing, then on cycle sequencing for an in-depth tutorial on how the scientists at The Field Museum sequence DNA on a daily basis.

3. In order for students to understand the amplification process have the students learn about it by visiting the following web site: http://www.dnai.org/b/index.html, click on techniques, then amplifying, and finally on PCR animation to get an overview.

4. After students have some background information on what is being done in the lab, have them formulate a question and bring it with them to the Daniel F. and Ada L. Rice DNA Discovery Center. At certain times throughout the day, scientists will be available to answer questions visitors may have.
Post Visit Activities

1. Before leaving the Daniel F. and Ada L. DNA Discovery Center exhibition, have the students look at the section about projects currently being conducted at The Field Museum. Ask the students to choose one organism and write down the name and location where that organism is found. Once the students return to the classroom, or home, ask the students to conduct some research about that particular organism and draw their own conclusions about WHY it would be important to learn about that organism's DNA. Ask the students to present their findings to the class.

2. Extract some DNA in your own classroom. Visit the following website for helpful instructions: http://learn.genetics.utah.edu/units/activities/extraction/.

3. Ask students to visit the following website to find out about cladistics and constructing trees that illustrate the relationships between species. http://evolution.berkeley.edu/evolibrary/article/0_0_0/phylogenetics_05

Many of the scientists that work at The Field Museum are interested in finding relationships between organisms and their ancestors. Their interest is similar to individuals creating their own family tree. After gaining an understanding of cladistics, visit the Tree of Life website, http://tolweb.org/tree/phylogeny.html. Ask students what are the major goals of the Tree of Life? Why is Dr. Shannon Hackett, a scientist here at the Field Museum intricately involved in the creation of a large-scale cooperative effort to determine the evolutionary relationships among all major groups of birds?
EVOLVING PLANET and DNA

The Daniel F. and Ada L. Rice DNA Discovery Center exhibition is not very large. It is therefore important to make connections to other exhibits using DNA as a basis for further discovery throughout the museum. Although teachers are encouraged to make their own connections, here are a few suggested exhibitions and activities for students to complete while studying DNA at the Field.

EVOLVING PLANET (Located on the Upper Level in the northeast corner)

Evolving Planet explores the history of life on Earth as revealed through the process of evolution. Since evolution is closely tied to DNA, Evolving Planet is a strongly recommended exhibition to visit.

Before students enter Evolving Planet, a few basic concepts about evolution should be discussed. The exhibition is 27,000 square feet so being sure to identify specific destinations in the exhibition to focus on with your students. An educator guide is available to download at http://www.fieldmuseum.org/evolvingplanet/educational_3.asp.

1. In order to understand evolution, it is necessary to view populations as a collection of individuals, each harboring a different set of traits.
2. When a population is evolving, the ratio of different genetic types is changing.
3. Individual organisms do not evolve: they retain the same genes throughout their life.
4. Genes change as a result of mutations or other processes. Individuals better suited to the environment survive and reproduce, passing their traits to the next generation. Over time, populations change, or evolve.
5. Evolution is not progress. Populations are adapted to their current surroundings, but those surroundings can change, leading to a change in the population’s adaptations.

DNA can tell us how closely related species are on the evolutionary tree of life. Genes (the carriers of inheritable characteristics) are the source of the random variation upon which natural selection operates. Mutations cause variation. Additional variations are the results of the parents’ chromosomes being copied and shuffled like a deck of cards, in a process called recombination.

It is important to know that genetic variation is not directed by a goal.

Giraffes did not grow long necks because they wanted to reach higher. A genetic mutation occurred that created slightly longer-necked giraffes. Longer necked giraffes were able to reach leaves that were farther away and not available to other organisms. This trait was more favorable, and the long-necked giraffes survived in greater numbers than the shorter-necked giraffes, and passed that trait onto their offspring. Over time, longer-necked giraffes became more numerous in the population.

Once students have an understanding of evolution in relation to DNA, ask the students to walk through the exhibition with the following guiding questions.

“Nothing in biology makes sense except in the light of evolution.”
— Theodosius Dobzhansky
Guiding Questions

1. Evolving Planet discusses the six mass extinctions that have occurred throughout Earth’s history. While you are walking through the exhibition, stop at the mass extinctions, hypothesize and write down two possible adaptations that certain organisms may have possessed that allowed them to survive. It will be important to note when the extinctions occurred as well as the climate and habitats that the organisms thrived in.

2. Within the entrance to the Evolving Planet exhibition you will encounter a brief discussion of evolution and the concept of a scientific theory. What evidence supports the theory of evolution?

3. In the Precambrian sections of the exhibition, you will encounter two different cell models: a prokaryotic cell and a eukaryotic cell. What is the major difference between a prokaryotic cell and a eukaryotic cell?

4. What is an example of a prokaryote?

5. In eukaryotes, where in the cell, besides the nucleus, is DNA found? Where is DNA found in prokaryotes?

6. How is sex related to evolution? What are the pros and cons of asexual reproduction? What are the pros and cons of sexual reproduction?

7. Watch the video on natural selection in the Precambrian section. What is natural selection? Give an example of natural selection (not from the video). Check out the What is an Animal? exhibition for some ideas, or look at some of the organisms in Evolving Planet.

8. At the end of the Precambrian section, note the label that discusses Charles Darwin. What is Charles Darwin’s theory of natural selection? What organisms did he study to come to his conclusions?

9. As you enter the Silurian and Devonian periods, look for a family tree, or cladogram, of plants. What is a cladogram? Draw an example.

10. Along with the fossils of early plants, locate and watch the video “How did pollen and seeds let plants live high and dry?” Account for the evolution of pollen. What evolved? How did this evolutionary event lead to greater genetic diversity?

11. Just before Mass Extinction #2, look for the case that contains the fish Tiktaalik. Why is this organism considered a “missing link?” What does this organism have that humans also have?

12. Why is the amniotic egg a key to the diversity of tetrapods? What characteristics does the egg have that made/make it so successful?

13. What are synapsids?

14. What do the first mammals resemble? What characteristics are unique to mammals?

15. Watch the video on phylogeny that’s located in the Triassic section. What is phylogeny? How do we know where mammals come from? How could the study of DNA help with this kind of research?

16. In the Dinosaur Hall, enjoy the large dinosaurs and prehistoric plants. Choose either a dinosaur or plant and describe its characteristics. Why was it successful in its environment? What made it unique? Hypothesize about why it is not living today? What is its closest relative?
17. Watch the video on coevolution that’s located in the Dinosaur Hall. What is coevolution? Aside from plants and insects, what are some other examples of coevolution?

18. Watch the video on convergent evolution that’s located in the Tertiary section. How is it possible for two different organisms to have similar traits? Aside from the saber-toothed mammals, what is another example of convergent evolution?

19. Find the Neanderthal skeleton in the section on human evolution. How do Neanderthals differ from our own species, Homo sapiens?

20. In the exhibitions section on human evolution, you will find a display called Useful to Useless. What surprises you?

21. Watch the video on mitochondrial DNA extraction located within the section on human evolution.
   a. Why was mitochondrial DNA used for this study?
   b. What was the outcome of this study?

22. Watch the video on biogeography that’s located in the Quaternary section. What are some ways species can become separated and then over time evolve into different species? Aside from the lemurs of Madagascar, think of some other organisms that this could have happened to and why. Be creative—it doesn’t have to be correct.

23. After learning about the current research being conducted in the DNA lab, and after reading about Mass Extinction #6 – the current mass extinction that is going on right now—how can the research being done in the DNA lab help curb the extinctions occurring now? Watch the video next to the Mass Extinction #6.
WHAT IS AN ANIMAL? Exhibition (Located on the Main Level in the southwest corner)

There is no better place in The Field Museum for students to witness the awesome power of natural selection and evolution than in the What is an Animal? exhibition. Through the study of genetics and the new breakthroughs occurring in the Daniel F. and Ada L. Rice DNA Discovery Center it is possible to determine how animals are related to each other and what our common ancestors are—that’s right, humans are mammals! Looking at the myriad of animals inside this exhibition, it is incredible to think that all animals evolved from a common form. Be sure to stop near the exit of the exhibition to discuss with your students the actual numbers of species of life. This example will demonstrate where mammals “humans” fall in the big picture of all life on earth, note insects!

>> Use the following questions to guide the students through the large exhibit.

**Shallow Coastal Oceans**

1. In the shallow coastal oceans there are numerous types of animals with different types of adaptations. What accounts for the vast number of species in this ecosystem?

2. What type of adaptations/traits do shallow coastal ocean dwellers have that make them successful in this ecosystem?

**Open Ocean — Sunlight Zone**

3. What type of adaptations or traits do sunlight zone dwellers have that make them successful in this ecosystem?

**Open Ocean - Twilight Zone**

4. What type of adaptations/traits do twilight zone dwellers have that make them successful in this ecosystem?

**Open Ocean — Deep Zone**

5. What type of adaptations/traits do deep zone dwellers have that make them successful in this ecosystem?

6. Explain why the number of species decreases as the well as the amount of variation within a species.

**Animal Senses**

7. How is electrical sensing a useful trait for animals? Please give 2 – 3 examples of animals that use this technique and why.

8. What are 5 means/techniques/abilities animals have to sense their surroundings?
   a.
   b.
   c.
   d.
   e.
9. How do males ensure that they will pass on their DNA through the mating game? Give 4 examples.
   a. 
   b. 
   c. 
   d. 

**Reproduction**

10. How do animal moms (and sometimes dads) ensure that their young live and thrive to pass on their traits? Give 3 examples.
    a. 
    b. 
    c. 

11. Why do animals have sex? Why is sex good for genetic variation?
12. What are some unusual ways animals accomplish gene recombination?
13. Aside from sexual reproduction, what are some other ways animals can reproduce? What are the pros and cons of these types of reproduction?

**Eating**

14. What are 5 unique adaptations/tools that animals have that make eating possible?
    a. 
    b. 
    c. 
    d. 
    e. 

**Not being eaten**

15. What are 10 adaptations that animals have that protects them from being eaten by other animals?
    a. 
    b. 
    c. 
    d. 
    e. 
    f. 
    g. 
    h. 
    i. 
    j.
Movement

16. What are 4 different adaptations that animals have that provides them with the ability to move?
   a. 
   b. 
   c. 
   d. 

Classification

Animals are classified into different groups based on shared similarities. What are the similarities that place animals in the following specific groups:

17. Echinoderms
18. Chordates
19. Mollusks
20. Arthropods
21. Porifera
22. Cnidaria
23. Worms
24. Which group of animals contains the most number of species?
25. Do you think that with the advancements in DNA technology, that animals could be regrouped based on their DNA sequencing? Why or why not?

>> Students will now be leaving the What is an Animal? exhibition and should proceed into the Animal Hall, starting with the Red Fox case.

Variation

26. Explain the coat color differences of the Red Fox. Why are they all called Red Foxes if they don’t have a red coat?
27. Why are the thin horn sheep and big horn sheep in different subspecies? What is a subspecies?
28. How does geographic variation result in bears with different looking coats?
29. Compare and contrast natural selection and artificial selection in pigeons.

>> Have students finish this activity at the animal case called Madagascar.

Madagascar

30. Why is Madagascar considered such a unique place?
31. Why is Madagascar a place that should be protected?
32. In your opinion, how can DNA technology prove useful in preserving a place such as Madagascar?
Prior to having students visit the Plants of the World exhibition, hand out a copy of the cladogram of embryophytes, taken from the Tree of Life web site, that illustrates the relationships between some of the plants.

Using the excerpt from the Tree of Life web site, have the students visit the Plants of the World exhibition and find the items listed below. On a separate sheet a paper, have the students create a couple of hypothesis about how plants are grouped in the following manner. What similarities do the plants placed closest together share? What differences do the plants placed furthest away have? (Items that are marked with the “†” are extinct and are not found in the exhibit.)

Questions for Plants of the World

1. How are liverworts and mosses similar? In your opinion, do you think that these groups are in the correct spot on the cladogram? (These specimens are located in the very back of the exhibit)
2. How are horsetails and ferns related? (These specimens are located in the Seedless Flowerless Plants section)
3. Why do you think seed plants are completely separated from the other types of plants on this particular cladogram?
4. How does the cladogram directly relate to the work that the scientists are currently doing in the DNA Lab?

Additional Plants of the World Activity

In the back of the Plants of the World Hall, on the south wall, there is a television monitor that showcases some of the work that is done at The Field Museum.

>> Watch the video clip called Genetic Biodiversity, which highlights Dr. Kevin Feldheim's research.

1. What does Dr. Feldheim discuss in the video clip? What is so groundbreaking about the two frogs that are highlighted in the video clip?

>> Then watch the video clip called Tree of Life, which highlights Dr. Shannon Hackett and her involvement with the Tree of Life.

2. What does the Tree of Life illustrate and why is it important to DNA?
WORLD OF BIRDS  *(Located on the Main Level in the northwest corner, across from SUE.)*

To begin this activity, go to the entrance of Nature Walk and walk through to The World of Birds exhibition.

Examine the Tree of Life diagram taken from Dr. Shannon Hackett’s groundbreaking research (found on the next page). As you may notice, birds are broken down into numerous categories. In this exercise you will be looking at birds from three major groups: *Palaeognathae*, *Galloanserae* and *Neoaves*.

Since you do not have the DNA technology that our scientists have, you will need to look at the birds in the exhibit as scientists of the past have—by concentrating on their visible traits (phenotypes). Take some time documenting with cameras or by sketching and drawing some interesting species variations.

**Your assignment!**

Look at Dr. Hackett’s Tree of Life. The birds located at the very bottom of the page (from Kiwis down through Ostriches) are considered *Palaeognathae*. The birds located just above them (from Pheasants, Quail, Guineafowl through Ducks, Geese, Other Waterfowl and Screamers) are considered *Galloanseraes*. The rest of the birds on the page are considered *Neoaves* (Passerines through Grebes).

Choose four birds from the Palaeognathae group, and fill out the form on the attached page. Write out the name of the bird you have chosen, write down the physical characteristics and sketch that bird to the best of your abilities. Then study their similarities and decide if their placement on the Tree of Life would be considered accurate if they were being grouped solely on their physical characteristics.

Now repeat the exercise using 2 birds from the Galloanseraes, and 8 birds from the Neoaves. Once you have finished, answer the questions that follow.
Passerines
Parrots
Falcons
Seriema
Puffbirds, Jacamars
Barbets, Honeyguides, Woodpeckers
Kingfishers, Rollers, Bee-eaters, Motmots, Todies
Hornbills
Hoopoe, Wood Hoopoes
Trogons
Cuckoo-rollers
Owls
Mousebirds
New World Vultures
Hawks, Eagles, Secretary-bird
Plains wanderer
Seedsnipes
Jacanas, Painted snipes
Turnstones
Buttonquail
Gulls, Crab Plover
Thick-knees, Plovers, Oystercatchers, Sandpipers
Hammerkop
Shoebill
Pelicans
Heron
Ibis
Anhingas, Frigatebirds, Cormorants, Gannets
Storks
Penguins
Albatrosses, Shearwaters, Petrels
Loons
Turacos
Rails, Finfoots
Cranes, Limpkin, Trumpeters
Cuckoos
Bustards
Hummingbirds
Swifts
Owlet-nightjar
Frogmouths
Nightjars
Oilbird
Potoos
Sunbittern, Kagu
Pigeons, Doves
Mesites
Tropicbirds
Hoatzin
Sandgrouse
Flamingos
Grebes
Pheasants, Quail, Guineafowl
Curassows, Chachalacas, Guans
Megapodes
Ducks, Geese, Other Waterfowl, Screamers
Kiwis
Cassowaries, Emu
Tinamous
Rheas
Ostriches
<table>
<thead>
<tr>
<th>Name of Bird</th>
<th>Physical Traits</th>
<th>What is this bird's closest relative?</th>
<th>Do you agree with the bird's position on the Tree?</th>
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<td><strong>PALAEOGNATHAE</strong> (Kiwis — Ostriches)</td>
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<td><strong>GALLOANSERAE</strong> (Pheasants — Screamers)</td>
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<td><strong>NEOAVES</strong> (Passerines — Grebes)</td>
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Discussion Questions

1. After looking solely at the birds’ characteristics, did you classify birds in the same way as the, Tree of Life, diagram? Why or why not?

2. Scientists have recently discovered that birds once thought to be closely related are in fact not as closely related to each other. Why do you think this is causing controversy within the scientific community?

3. Scientists have also made discoveries linking birds to dinosaurs, how do we know this is true?

4. If you had just spent many years of your life classifying birds based solely on their physical traits, and a molecular scientist, such as the Field Museum’s Dr. Shannon Hackett, brought forth DNA evidence that contradicted your taxonomy, how would that make you feel?

5. Why is it important for scientists to share their research with Museum visitors?

Specimens collected in natural habitats are often added to the vast collections at The Field Museum where scientists can study their physical and genetic makeup long into the future.

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Recommended Websites

DNA Game
http://nobelprize.org/educational_games/medicine/dna_double_helix/dnahelix.html

Polymerase Chain Reaction website
http://highered.mcgraw-hill.com/olc/dl/120078/micro15.swf

DNA interactive
www.dna.org/b/index.html

Polymerase Chain Reaction
www.sumanasinc.com/webcontent/animations/content/pcr.html

Genome sequencing
http://www.laskerfoundation.org/rprimers/gnn/wagn/gsequencing.html

The American Museum of Natural History – The Gene Scene
http://www.amnh.org/ology/genetics/aroundtheworld/index.html

The University of Utah – Gel Electrophoresis Lab simulation
http://learn.genetics.utah.edu/units/biotech/gel/

The University of Illinois at Urbana-Champaign – Molecular Biology Cyberlab, Gel Electrophoresis of DNA
http://www.life.uiuc.edu/molbio/geldigest/electro.html

GlaxoSmithKline – Kids Genetics
http://www.genetics.gsk.com/kids/dna01.htm

US Department of Energy Genome Programs – Basic Genetic images
http://genomics.energy.gov/gallery/basic_genomics/gallery-01.html

Animal and Plant Cell diagrams
http://www.cellsalive.com/cells/cell_model.htm

University of Wisconsin – typical animal cell, learning activity
http://www.wisc-online.com/objects/index_tj.asp?objID=AP11403

John Kyrk Cell Biology Animation
http://www.johnkyrk.com/

Tree of Life Web Project
http://tolweb.org/tree/phylogeny.html

University of California Berkeley - Understanding evolutionary trees.
http://evolution.berkeley.edu/evolibrary/article/phylogenetics_01
Recommended Websites

The Field Museum Research and Collections

The Pritzker Laboratory for Molecular Systematics and Evolution
http://www.fieldmuseum.org/research_collections/pritzker_lab/pritzker/index.html

Evolving Planet
http://www.fieldmuseum.org/evolvingplanet/

Biodiversity and Conservation
http://www.fieldmuseum.org/biodiversity/interactive/work.html

Darwin Exhibition
http://www.fieldmuseum.org/darwin/

Dinosaurs: Ancient Fossils, New Discoveries
http://www.fieldmuseum.org/dinosaurs/

Gregor Mendel: Planting the Seeds of Genetics
http://www.fieldmuseum.org/mendel/

Harris Loan DNA Box rental information
http://fm1.fieldmuseum.org/helc/

Educator Guides
http://www.fieldmuseum.org/education/edu_guides.htm

Field Trip registration information
http://www.fieldmuseum.org/education/registration.htm
Recommended Books for Educators


Recommended Books for Students


Recommended DVDs/Videos


Cracking the Ocean Code, Discovery Communications, Inc. 2005.

DNA and the Evidence for Evolution, Films for the Humanities and Sciences, 1981.


Greatest Discoveries with Bill Nye Genetics, Discovery School. 2005.