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DNA and Genetics

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What's the Big Idea about Genetics?

This text is provided courtesy of OLogy, the American Museum of Natural History's website for kids.

Illustrations Credit: Kelvin Chan/AMNH

Genetics Is Where It All Begins

Some scientists are curious about basic questions of life: Where did it come from? Why is it so varied? Why do children look like their parents?

To answer these questions, they study a type of biology called GENetics (juh-net-icks). "Gen" means beginning.

Genetics is the science of genes and how traits are passed on from one generation to the next.

People who study genes are geneticists (juh-net-i-sists).

Every Living Thing Has DNA

Credit: courtesy of AMNH Department of Library Services K4508 [starfish], AMNH [ladybug], courtesy of AMNH Department of Library Services PK241 [perch fish] (top image); AMNH (bottom image)

DNA is an amazing chemical present in every cell. It contains all the information cells need to make a fish a fish, or you YOU.

All humans start out as a single cell and grow into trillions of cells. DNA tells the single cell to divide into two cells, then four, then eight — until a whole body forms. It controls the growth of EVERYTHING, from your head to your toes.

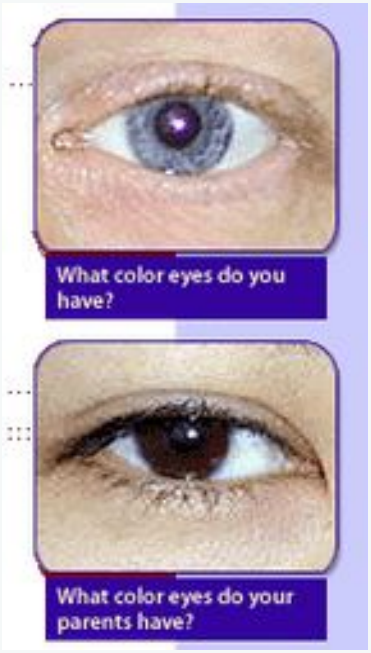
DNA also influences many individual traits, such as whether you are a boy or a girl and whether you are tall or short.

Genes Are Made of DNA

Where do traits, such as eye color and shape, come from? Why do you look more like your relatives than other people? The parts of your cells that determine these traits are called genes.

In the past, no one knew what genes were. In the 20th century, scientists figured out that they were actually made of DNA.

Genes come in pairs. You get half of your genes from your mother and the other half from your father.



Photos Credit: AMNH

We Gather Clues about Life by Studying Genes

As we discover more about how genes work, we will be able to understand how cells build complex organisms — like humans.

Today, scientists are studying human genes to learn about traits and diseases. There are so many genes in humans — at least 30,000 of them — that it will take a long time to study every one in detail and find out what it does.

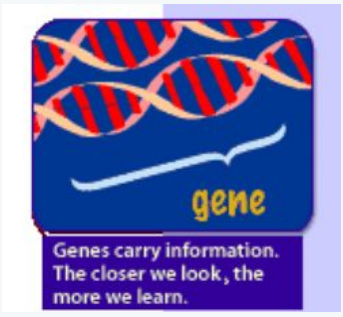


Illustration Credit: Kelvin Chan

A Genome Is All the DNA in a Cell, Including All the Genes

Recently, new technology has enabled scientists to look closely at the entire human genome.

They have also been able to describe the whole genomes of other animals, including those of bacteria, worms, flies, and mice. The science of genomics asks questions about all of these genes at once. Scientists can also compare genomes of different animals and figure out how they are similar and different.

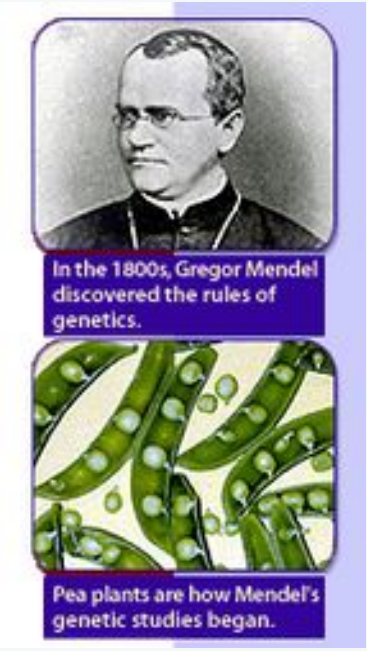
Credit: AMNH (top image); courtesy of Flybase (bottom image)

Why Isn't the Study of Genes Called Genealogy?

Well, the name was already taken.

Genealogy is the study of family origins. It is how people trace their ancestry and create a family tree. It's not a biological science.

Genealogy has been around for a long, long time — before we discovered genes.



Photos Credit: AMNH

The science of genetics began in the 1800s when Gregor Mendel figured out how traits are inherited by studying peas. Since scientists identified genes in the mid-1900s, the field of genetics has grown by leaps and bounds.

A Sheep Named Dolly

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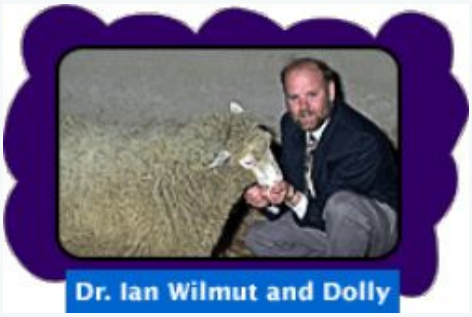


Photo Credit: courtesy of the Roslin Institute

In 1997, a 7-month-old sheep named Dolly became a celebrity. Dr. Ian Wilmut, a Scottish scientist, announced to the world that he had created her using a procedure called cloning. Cloning is a method that scientists use to produce a genetic copy of another individual. In other words, Dolly was a clone of her mother.

Well, actually, Dolly had three mothers. One mother gave Dolly her DNA, one mother supplied an egg, and the third mother, her surrogate mother, gave birth to her.

Normally, an animal gets half of its DNA from its mother and half from its father. Dolly was an identical twin of the mother who gave her her DNA. But Dolly was six years younger.

However, Dolly and her mother were not identical in every way. Since Dolly and her "DNA mother" had different experiences, they were different in many ways. Like human twins, clones have unique personalities.

It took scientists 277 tries to succeed in cloning Dolly. To make her, Dr. Wilmut used a complicated method called "nuclear transfer." In this method, scientists remove a nucleus from one cell and transfer, or move, it to a different cell.

Photo Credit: courtesy of the Roslin Institute

Why Clone?

This text is provided courtesy of OLogy, the American Museum of Natural History's website for kids.

What Other Animals Have Been Cloned?

Illustration Credit: Clay Meyer

Cows

Some cows produce much more milk than others. By cloning these cows, farmers could make milk more quickly and cheaply.

Illustration Credit: Clay Meyer

Mice

Scientists use special mice to study diseases like cancer. Cloning them could help scientists research how diseases progress.

Illustration Credit: Clay Meyer

Monkeys

To develop new medicines for humans, scientists use animals that are as identical as possible. Cloned monkeys could help improve the development of these medicines.

Why Clone a Sheep?

There's no sheep shortage, but scientists are able to create sheep whose milk contains medicine. If scientists can then clone these special sheep, it may be possible to produce more medicine at a faster rate.

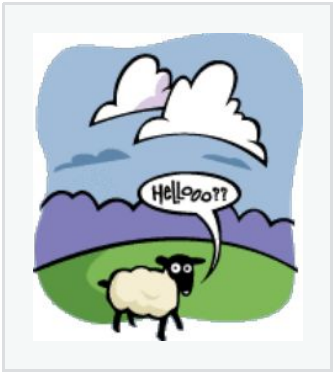


Illustration Credit: Clay Meyer

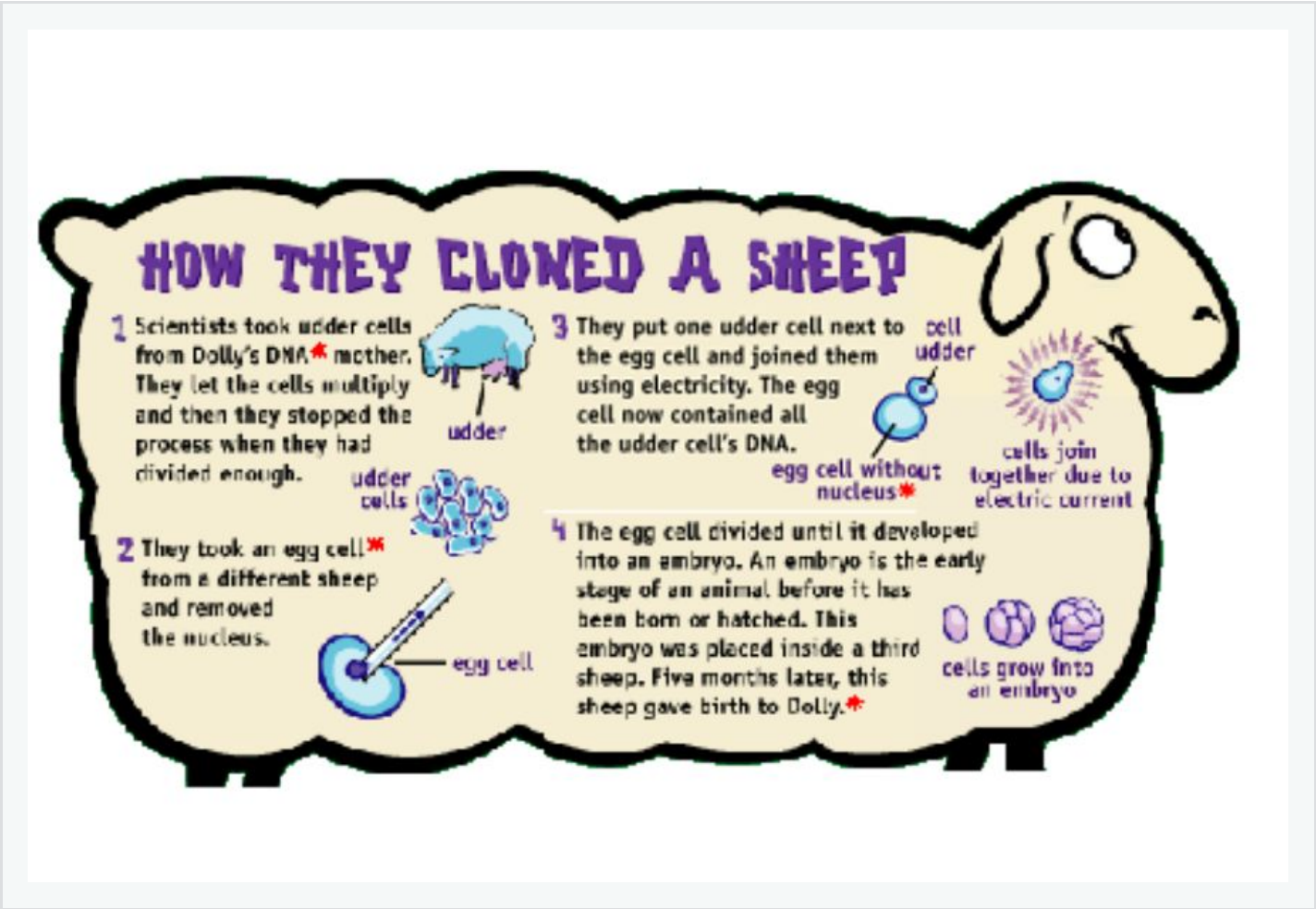
Can Cloning Bring Back Extinct Dinosaurs?

Illustration Credit: Clay Meyer

Cloning anything is tricky. You need very special conditions, and most importantly, you need DNA. In the movie *Jurassic Park*, a scientist brings extinct dinosaurs back to life by cloning DNA found in ancient dinosaur blood. *T. rex*, one of the last large dinosaurs to roam the earth, lived 65 million years ago. We've never found well-preserved DNA this old. And we probably never will.

How They Cloned A Sheep

This text is provided courtesy of the American Museum of Natural History.



The Human Genome Project

By American Museum of Natural History

This text is provided courtesy of OLogy, the American Museum of Natural History's website for kids.

What's a Genome, Anyway?

A genome is the name for all the DNA and genes in a cell. Every kind of plant and animal has a different genome. There's a chicken genome, a celery genome, and, of course, a human genome. To understand the genome, scientists need to unlock the secrets of DNA.

During the 1950s, scientists James Watson and Francis Crick discovered that DNA is shaped like a twisted ladder, made of four chemicals called bases. These bases are identified by the letters **A**, **T**,**C**, and **G**. Most genes, which are sections of DNA, are made of at least 1,000 of these base pairs.

The entire human genome is made of more than 3 billion base pairs.

If each A, T, C, and G were a letter or number in a phone book, they would fill 140 big city phone books, which is as tall as a 40-foot building.

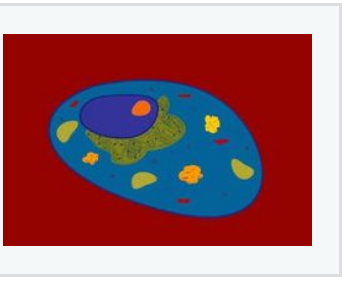


Image credits: Kelvin Chan.

Have you ever wondered what our muscles, blood, bones, and bodies are made of? They are made of cells! Cells are the building blocks of all life. Some living things, such as protozoa, are made of only one cell. The human body, on the other hand, contains trillions of cells. The cell's nucleus is the control center of all genetic information.

Image credits: Kelvin Chan.

All the DNA in a cell is called a genome. Your body contains trillions of copies of the human genome -- one in each of your trillions of cells. A genome contains all the genes that tell the cells how to grow. In fact, all animals, plants, viruses, and bacteria have a genome. However, the genomes' sizes and structures vary among different living creatures.

Image credits: Kelvin Chan; Kevin Chan.

Saying "deoxyribonucleic acid" is a real mouthful. Luckily, you can call it DNA for short. DNA is found in all living things, including YOU! DNA is in every cell of your body and is shaped like a long, twisted ladder. The steps of this "ladder" are made of only four building blocks, called bases. These bases are known by the letters A, C, G, and T.

What is the Human Genome Project?

The goal of the Human Genome Project is to determine the order of the base pairs in the entire human genome. Remember, there are more than 3 billion base pairs.

Because DNA is super long, thousands of scientists in labs all over the world split up the work. In June of 2000, after about ten years of hard work, scientists completed a rough draft of the human genome. And, in February 2001, they discovered that humans have 30,000 genes.

The work isn't over yet! . . .

Image credits: Kelvin Chan.

Many scientists have joined forces on the Human Genome Project. Their goal is to figure out the order of all "DNA letters" (bases) in our genome. Since the human genome is more than 3 billion "letters" long, this is an insanely huge job! By learning about our genome, scientists will better understand how our bodies work and how diseases develop.

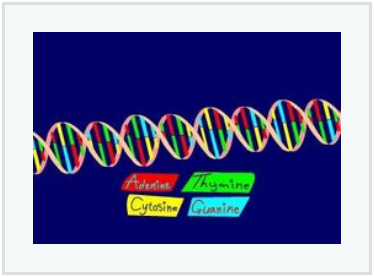


Image credits: Kelvin Chan.

DNA is shaped like a long twisted ladder, and pairs of bases form the ladder's steps. Bases are known by the letters A, T, C, and G. It's the DNA alphabet soup! In DNA, bases only pair in two ways: T only pairs with A, and G only pairs with C. When a cell "reads" a long string of these letters (genes), it gets information on how to grow and develop.

What Does it Mean to Me?

Toby: Hi, I'm Toby. Joining us now is genome expert Georgia Dunston, who is the Acting Director of the National Human Genome Center at Howard University.

Georgia: Thanks, I'm glad to be here.

Toby: So, Georgia, nobody sequenced my DNA for the Human Genome Project. Does this mean that our genomes are exactly the same?

Georgia: No. Unless you are an identical twin, you have a unique genome. But even so, humans are 99.9% the same genetically. Since we're all so alike, information from even one human

genome relates to all of us. Your friends may have different color skin or eyes, but you have thousands of more things in common.

Toby: How will the Human Genome Project affect kids' lives in the future?

Georgia: Our knowledge about the human genome will help us figure out what causes some diseases, such as cancer or diabetes. Sometimes, small changes in the gene sequence can mean the difference between health and illness.

By understanding our genes, we will be better able to diagnose and maybe even prevent many diseases in you, your kids, and your grandkids.

Toby: Wow! Thanks for stopping by.

Georgia: My pleasure. Remember, the most exciting discoveries are yet to come! So stay involved. We all need to be thinking about this—now and in the future.

Meet the Ologist: Rob DeSalle

By American Museum of Natural History

This text is provided courtesy of OLogy, the American Museum of Natural History's website for kids.

Do other species, like chimpanzees, have similar DNA to humans?

Rob Said: Yes, this similarity is very interesting. We're 98% identical genetically with chimps.

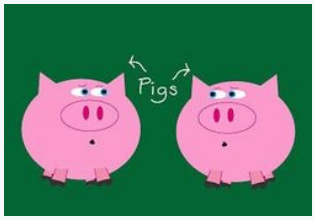


Image credits: Kelvin Chan.

Clones are plants and animals that have more than just their looks in common; they also have the exact same DNA sequence. Identical twins are natural clones. They look alike because they have the same genes and identical DNA. Today, scientists can even create clones from the cells of an adult animal. These clones are genetically the same as the adult -- only much younger.

If you compare a human and a mouse, 90% of the genes are similar.

If you compare a human and a fruit fly, 52% of the genes are similar.

If you compare a human and a roundworm, 35% of the genes are similar.

And if you compare a human and bacteria, about 9% of the genes are similar.

Were you interested in science as a kid?

Rob Said: Actually, I had no interest in biology whatsoever until I started my senior year in high school. I had a teacher who made me keep a physics laboratory notebook much like a scientist would. He essentially made me see the value of keeping track of what I did in the lab. This teacher connected what we did in class and in the lab to the notebook. Because I organized what I learned, it became my own work. I think that's what got me interested in science.

What's special about doing research in a museum?

Rob Said: The Museum is a special place because it not only has exhibitions, but also an enormous collection of specimens collected from all over the world. The Museum also has very modern research equipment. It's great to be able to study different animals—and how they're related—in one place.

How has technology changed lab work?

Rob Said: Because genetics is so high-tech, the new machinery that we have in the lab becomes very important. I think in the next few years, we're going to see a shift in what happens in the

lab. When I started in the lab about 25 years ago, I spent most of my time doing things by hand. With new machinery, people can spend less time generating the data by hand and more time thinking about it.

Image credits: montage of Silver sword, AMNH and Bald Eagle, courtesy of AMNH, Department of Library Services 1118.

Thousands of plants and animal species may be in danger of becoming extinct and disappearing forever. Some endangered species include giant pandas, tigers, and the silver sword plant, which is found only on the Hawaiian islands. Many species are threatened because of human actions. But by creating laws to preserve natural habitats, we may be able to save some of them.

New technology opens up new possibilities.

What do you think about cloning a pet?

Rob Said: Cloning is a really interesting and important subject to think about.

We have the responsibility to think about the natural world. Does cloning pets have an effect on the natural world? It might. Will cloning human beings have an effect on the natural world? I think it probably will. Will cloning endangered species have an effect? Yes, but maybe it's a positive effect. So I think we need to look at the effects of our actions.

These are questions everybody needs to consider. But in order to weigh in on the decisions, people need to be informed about what's going on.

How did you become interested in genetics?

Rob Said: When I went to college, I had an interest in science, and I got a job at the Field Museum in Chicago. Every morning I'd walk by an exhibition of the narwhal, an Arctic whale, and I became very attached to him. Narwhals are really cool animals.

At that time, I'd really never been out of Illinois. These creatures were from faraway places, the North Atlantic and Greenland and Iceland. I decided I wanted to understand them. So I went to talk to my advisor in college, and I said, "I want to work on narwhals." My advisor was a microbiologist. He looked at me and said, "Forget about the narwhals for now. Learn some genetics and come back to the narwhals." So I went back to the Field Museum and started doing genetics.

Image credits: Kelvin Chan.

Genetics is the study of how traits are passed from one generation to another. Traits such as eye color and nose shape are transferred from parents to their kids through genes. Our genes carry information that affects our health, our appearance, and even our personality.

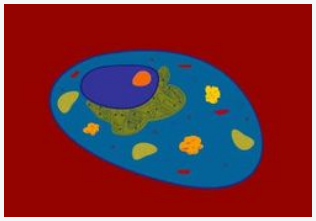


Image credits: Kelvin Chan.

Have you ever wondered what our muscles, blood, bones, and bodies are made of? They are made of cells! Cells are the building blocks of all life. Some living things, such as protozoa, are made of only one cell. The human body, on the other hand, contains trillions of cells. The cell's nucleus is the control center of all genetic information.

Do all species of plants and animals have the same amount of DNA?

Rob Said: No, there are very, very different amounts of DNA in things. But just because you have more DNA doesn't mean you're better, or you're more advanced. Certain species of amoebas, for instance, have much, much more DNA per cell than humans do. In essence, it's how genes are used that determines how complex living things are.

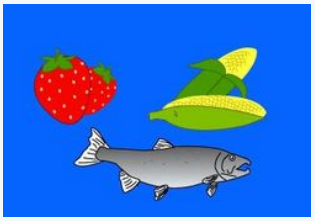


Image credits: Kelvin Chan.

Scientists figured out a way to take genes from one species and stick them inside the DNA of another species. When a plant's DNA is changed, it develops different traits. This technology can create insect-resistant corn and tomatoes that stay fresh for longer periods of time. But critics call these new products "Frankenfood" and say that gene-switching is harmful.

Now, if you want to talk about numbers of genes, it becomes a little bit more important. For example, yeast, the organisms that you put in bread to make it rise, have about 6,000 genes. Drosophila, the fruit flies you might see flying around fruit, have about 13-14,000 genes. Humans have about 30,000.

Image credits: courtesy of USGS.

The only way to learn about life that went extinct thousands, millions, and billions of years ago is to study the fossils they left behind in rocks. Fossils are the key to understanding what organisms lived on Earth long before modern humans appeared. Fossils are like windows to the past.

Interestingly, we don't have that many more genes than flies or even yeast. So it's really how an organism uses those genes that determines how complex an organism is.

How do you decide what to research?

Rob Said: Science is really about exploring what's unknown. And there are a lot of unknowns. In school, you learn mostly about the questions that have been answered already. But the really exciting stuff happens when you try to figure out problems that haven't been solved. These become great research topics.

Image credits: Kelvin Chan.

Have you ever wondered why you look like your parents, grandparents, or siblings? It's because of your genes -- the instructions for making you. Genes are sections of DNA, which is found in every cell in your body. You inherited half your genes from your mother and half from your father. Your parents got their genes from your grandparents. And so on. . .

What's important to consider about genetically modified food?

Rob Said: You need to make your own list of pros and cons.

As a biologist, I'm concerned about the effect of technology on the

environment. When food is genetically modified, part of the natural world is changed. We need to look carefully at what effects this can have.

On the other hand, there will be 9 billion people on the Earth in the next 30 years. That's a lot of people to feed. Genetic modifications is probably one of the few ways we can produce enough food.

It's a very complicated issue. Think about it.

What's it like to work on a Museum exhibition?

Rob Said: Working on Museum exhibitions gives scientists a chance to share ideas with a large audience. It's great to be a part of creating something that reaches a quarter of a million people. Many people have become scientists because of a visit to a museum.

It's challenging to create an exhibition with a science like genomics. Explaining the science is difficult, and we also have to think of really special, interesting ways to display things. With a science like paleontology, the display is much easier—the fossils tell the story. We don't have specimens like that in genomics, so we really have to use our imaginations.

Image credits: courtesy of NASA; Rosamond Kinzler: AMNH.

The Earth is our home. So far, it's the only place that we know of that has life. Everywhere you look on Earth there is life. This is possible because Earth has lots of water. It's also just the right distance from the Sun. Some people call Earth the "Goldilocks planet." It's not too hot (like Venus), and not too cold (like Mars), it's just right!

What's the Museum's new exhibition on genomics about?

Rob Said: We are in the midst of a scientific revolution that will affect the future of medicine, agriculture, and biology. In our exhibition, I tried to focus on a few basic ideas.

I would like people to understand that we are more than our genes. Genes are involved in how we behave, but the environment in which we live also influences who we are.

Also, I think it's important to realize that while each person is unique at the genetic level, we also have a great deal in common with each other—no matter what the race, creed, or color.

I think people should be informed about what's going on in the scientific world. Our future depends on the decisions we make today.

How did you become interested in studying fruit flies in Hawaii?

Rob Said: When I went to graduate school at Washington University in St. Louis, I thought I wanted to work on human genetics. I talked to one of the guys in the biology department, and he gave me some advice: work somewhere fun.

Besides having a lot of white sand and sun, the Hawaiian Islands are the most isolated, relatively large area of land on Earth.

A lot of people think that fruit flies were blown to Hawaii in tropical storms from other places. When they arrived there, they adapted and changed. So the Hawaiian Islands are a wonderful, natural laboratory for studying variation and adaptation.

The Adventures of George Amato, DNA Detective

By American Museum of Natural History

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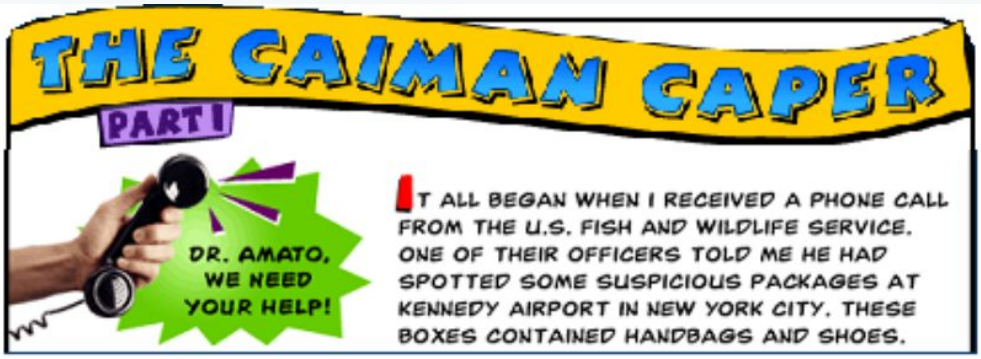

By looking at the pattern on the reptile skins, the officer had a hunch they were made from Yacaré caiman, a relative of the crocodile and alligator.

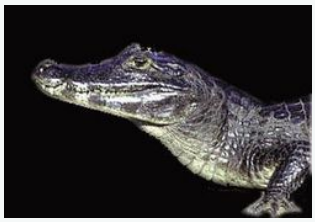

Image credits: courtesy of Santos Breyer, the Crocodilian Photo Gallery; George Amato: courtesy of Denis Finnin.

That toothy grin might make you think this is a crocodile or an alligator. But the Yacaré caiman is neither. Caimans are closely related to alligators, but you wont run into one in a Louisiana swamp. Caimans live in South America. All six types of caiman are protected, which means that they may disappear from the planet forever unless we help them.

My blood started to boil. "But the Yacaré caiman is a protected species," I said into the phone. "Bringing skins of that animal into the U.S. is against the law!"

"Exactly!" said the guy at the U.S. Fish and Wildlife Service. "That's why the officer seized the shoes and handbags from the reptile skin importer."

"So, what's the problem?" I asked.

"The importer said it was not a protected caiman," he said.

The importer claimed that it's impossible to tell the difference between caimans just by comparing skin patterns. This disagreement went to court. And that's where I came to the rescue.

First I took samples of the reptile skins to my lab at the American Museum of Natural History. There I used some high-tech machines to separate the DNA from everything else.

Then I made lots of copies of the DNA, so it was easier to study.

Next I used a machine to figure out the DNA's sequence, which looks like a long string of letters. Every animal species has its own DNA pattern.

Geneticists can match DNA patterns the same way police match fingerprints.

Finally I compared this skin's sequence with other crocodilian sequences in our DNA computer library. It was a perfect match to the Yacaré caiman! Those shoes and handbags were definitely made from a legally protected species.

I gave this report to the judge. Based on the DNA evidence, the judge agreed that the skins were illegal. The skins were taken away and the importer had to pay a fine.

Image credits: Kelvin Chan; Kevin Chan.

Saying "deoxyribonucleic acid" is a real mouthful. Luckily, you can call it DNA for short. DNA is found in all living things, including YOU! DNA is in every cell of your body and is shaped like a long, twisted ladder. The steps of this "ladder" are made of only four building blocks, called bases. These bases are known by the letters A, C, G, and T.