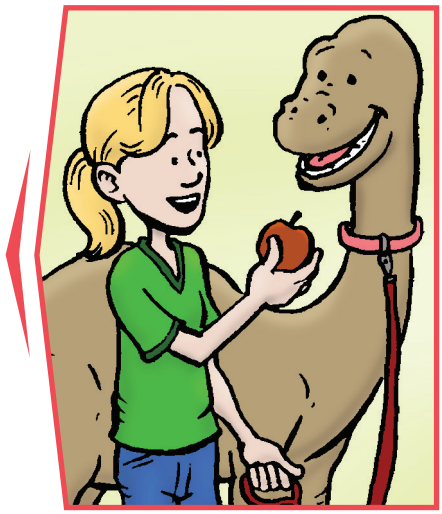
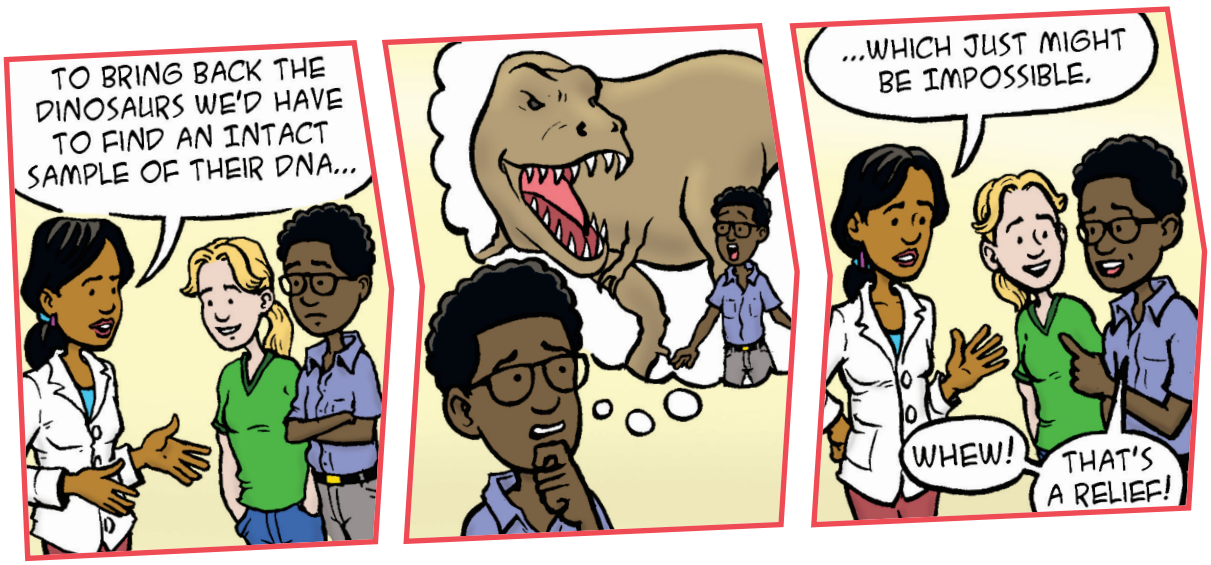
Chapter 1

Cloning Ancient Creatures



Is it possible to clone dinosaurs and other long-extinct creatures?



While dinosaurs are likely to stay extinct, there is a chance that scientists can clone other creatures if they can find viable DNA.

In science fiction, dinosaurs aren't always extinct. They roam around island amusement parks and generally terrorize the humans that get in their way. Most often, dinosaurs return to life in fictional universes such as that of the *Jurassic Park* franchise through cloning. This is a process through which geneticists can make clones, or copies, of long-dead organisms.

There is real science behind de-extinction, which is the term used to describe bringing extinct species back to life. Scientists have been successfully cloning both plants and animals for many years.

So why can't we visit a Tyrannosaurus rex at the zoo or take a tiny Compsognathus out for a walk? While making clones is a real scientific process, cloning long-extinct species is much harder than science fiction makes it seem.

WHAT IS A GENE, ANYWAY?

Before we can talk about clones, we have to talk about what makes us unique. Much of our characteristics are determined by genes. In humans, they help determine traits such as eye and hair color. Genes are like a microscopic blueprint for every living plant or animal, from a blue whale to a dandelion. And if you have a blueprint, you just might be able to build something.

Genes are composed of DNA, which is made of millions of molecules stored inside cells. DNA contains four basic building blocks called bases, and they are named adenine, guanine, cytosine, and thymine. These bases join together in pairs—adenine with thymine and guanine with cytosine. Each pair forms between two strands and looks similar to the rungs of a ladder. That DNA ladder is twisted into a shape called a double helix.

The tightly coiled strands of DNA inside a cell contain so much information that, despite their microscopic size, they would still stretch to more than 6 feet in length! All organisms have DNA, from bacteria to bison to blueberries. This gives every organism a unique set of instructions that determines what it becomes. If you were able to make a copy of an organism's DNA, you'd be able to build a new one with the exact characteristics as the original—a clone.

CLONING THE REAL WORLD

Cloning is the process of copying the DNA of one creature and using it to create a new, genetically identical being. In *Star Wars,* clones of Jango Fett are used to create the deadly clone trooper army. Here on Earth, we can find clones in a much less sinister place—the supermarket.

Even if we were able to bring a Tyrannosaurus Rex back to life, should we?

CLONE THYSELF

A newly discovered lizard in Vietnam reproduces without a mate. Leiolepis ngovantrii, like nearly 1 percent of all lizards, can spontaneously create offspring though parthenogenesis, which is reproduction without fertilization. The resulting lizards are all females and are clones of the original female parent. Parthenogenesis happens in many kinds of species, from aphids to sharks.

Have you ever wondered why most bananas look the same? That's because genetically, they are! The typical banana you can get at a grocery store is a variety called the Cavendish, and it's a clone. The original Cavendish banana was chosen for its taste, hardiness, and resistance to disease. It is grown all over the world. These traits made the Cavendish very attractive to banana growers, and as a result it has become the most popular banana.

Making a clone of a banana isn't hard to do. Growers take suckers, or offshoots, from adult plants and supply them with the nutrients they need to grow. Those suckers become adult plants that are genetically identical to the original plant.

> The next time you have a banana split, you can call it a clone split!

Clones are everywhere in nature. Some species even have the ability to clone themselves if the conditions are right. However, cloning animals is a lot more difficult and complicated than cloning plants. Animals don't have suckers or offshoots that can be trimmed and planted. But with a little help from science, it can still be done.

THE MOST FAMOUS CLONE

On July 5, 1996, Dolly the sheep was born at the Roslin Institute in Edinburgh, Scotland. Normally, the birth of a sheep is no cause for celebration in Scotland, but Dolly was different—she was the first animal clone created from an adult. This was the first time a copy of a fully grown and living animal had ever been made.

THE CAVENDISH IN DANGER

There's one major drawback to cloning bananas. Because the banana supply has no genetic diversity, all Cavendish bananas are susceptible to the same disease. A fungus called Tropical Race 4, which infects and kills banana plants, can be carried on a tiny amount of soil that could fit on the bottom of a farmer's shoe. So far, scientists have found no way of stopping its spread. This is what happened to the Cavendish's predecessor, the Gros Michel. It was wiped out by a strain of Tropical Race 4 in the 1960s. You can read more about this fungus here.

NPR doomed banana

Dolly was the clone of a six-year-old Finn Dorset sheep, and was the only lamb born out of more than 250 attempts. To create Dolly, scientists injected udder nuclei from the original sheep into the unfertilized egg cells of a second sheep. This is a process called nuclear transfer. These egg cells had their nuclei removed, and when they were exposed to electric pulses, the udder and egg cells joined. Once merged, the cells began to divide.

When scientists were sure that the cells were dividing properly, the egg cells were placed in a third, surrogate sheep, one with different coloring from the original donor sheep. That way scientists could tell just by looking that the surrogate sheep's DNA didn't end up in the cloned sheep's genetic makeup. After a normal 148-day gestation period, Dolly was born.

Since Dolly, many other animals have been cloned from adult cells, including cats, pigs, and horses. Cloning isn't done just to bring back the family cat or recreate the fastest race horse. Geneticists use clones to help understand how genes determine traits, as well as help discover more about genetic diseases so that scientists can develop treatments.

If scientists can clone animals from pretty much any adult cell, where are all the dinosaur clones? To create a clone, cells with intact DNA are needed. Obtaining DNA from living organisms is easy—there are billions of cells to choose from. But dinosaurs have been extinct for millions of years. How do we get viable, or intact, DNA from creatures that took their last breath long before humans even existed?

You can even pay to have your favorite pet cloned! The first cloned pet was a cat that was produced in 2004. The owner paid $50,000 for this service.

Cloning and Controversy

When Dolly was born, it caused a stir across the world. Some people feared that cloned animals meant that the cloning of human beings was right around the corner. Others believed the knowledge that cloning provided would save lives. This sparked a debate about the ethics of cloning. Watch a news report of the event here.

Retroreport Dolly

How Do We Know What Killed the Dinosaurs?

For years, geologists had evidence of a large meteorite hitting Earth around the time dinosaurs went extinct. Iridium, a metal that is rare on Earth but common in asteroids, was found across the world in layers of clay that were buried 65 million years ago. In 1991, researchers determined that a giant crater near the town of Chicxulub, Mexico, (pronounced CHEEK-she-loob), was created by a meteorite approximately 6 miles wide. It released as much energy as 100 trillion tons of TNT!

PS

photo credit: NASA Jet Propulsion Laboratory

Do you see the faint half circle in the upper left part of the peninsula? That's the edge of the crater!

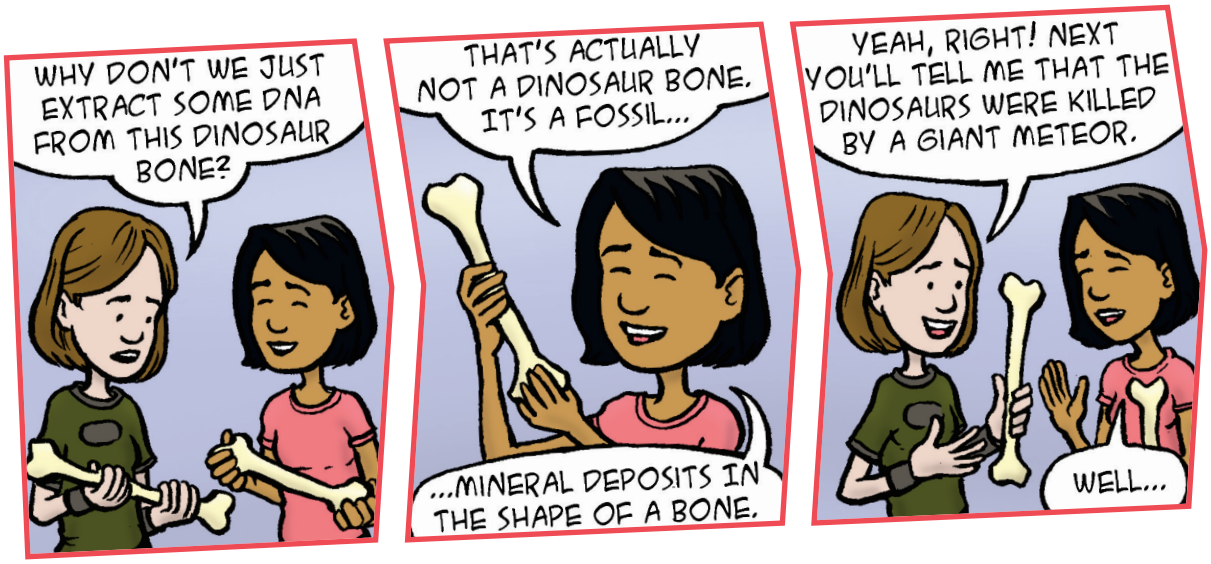
WHAT HAPPENED TO THE DINOSAURS?

About 65 million years ago, something big happened on Earth. A huge meteorite struck our planet, sending dust and debris high into the atmosphere. This dust blocked the sun and caused temperatures around the globe to drop. Climate change at this scale caused a massive extinction of plant species. Without a food source, herbivores began to die off as well. The carnivores that ate the herbivores soon followed.

Scientists estimate that in the wake of the impact, between 50 and 90 percent of all species on Earth went extinct within about 30,000 years. Dinosaurs, the largest and most dominant animals at the time, all but disappeared from the planet. Now, all we have left of dinosaurs are their fossils.

One of the most important tools for paleontologists are fossils. When plants and animals die, the natural process of decay sets in. Soft tissues, such as organs and skin, quickly rot, while harder, denser materials, such as teeth and bone, remain behind. Those harder remains can slowly disappear as well, unless something rare happens.

Animals whose remains are buried beneath sediment in lakes, rivers, oceans, and streams decay much more slowly. During the course of many years, the sediment can harden into stone, encasing the remaining bones and teeth. As more and more sediment piles on the stone that holds the skeleton, the pressure increases. Water is forced into the spaces with the bones, which are slowly dissolved and carried away.



This leaves a hole in the stone that keeps the same shape as the bone that it once held. As more water seeps into the stone, minerals are deposited in the spaces, creating a cast of the skeleton. It is these casts that we call fossils. Although they are the same size and shape of the bones and look like bones, fossils are not actually bone.

While fossils can tell us a lot about the animals and plants that once lived, the process of fossilization removes pretty much any trace of organic material, such as cells. This means no DNA, because it disappeared millions of years before scientists could get there to keep it safe.

Unfortunately, fossils aren't going to help us clone a dinosaur, but this isn't necessarily the end of any chance to bring back extinct animals. In the *Jurassic Park* franchise, scientists didn't use fossils to resurrect the dinosaurs. They used dinosaur DNA from a completely different place—inside the stomachs of ancient mosquitos trapped inside amber.

Creatures trapped in amber are beautifully preserved specimens ready for eager scientists to unlock their secrets.

DINOSAURS FROM AMBER?

Amber is tree sap, a substance sticky enough to trap insects and even small animals as it slowly flows from trees. The sap hardens into a shiny, sometimes transparent mass that allows whatever might be stuck inside to be seen. On very rare occasions, prehistoric creatures are found inside amber, protected for millions of years from the effects of air and moisture.

In the fictional *Jurassic Park* world, scientists find fragments of dinosaur DNA locked inside amber by drilling into and extracting a preserved mosquito whose last meal was dinosaur blood. Once they find the DNA, the scientists are able to put it back together and fill in missing parts by using DNA from amphibians. With a complete genome, they're able to start building dinosaurs from scratch, including the terrible Tyrannosaurus rex and the intelligent but deadly velociraptor.

In the 1990s, real scientists tried just such a method, and were unable to find any intact dinosaur DNA—or any DNA at all—from insects trapped in amber. They hadn't really expected to. Why not? DNA is extremely fragile. While the cell is alive, DNA is constantly checked and repaired to keep the cell functioning correctly. If it's not cared for, DNA can cause changes to the cell that can hurt the entire organism.

When a plant or animal dies, its body begins to decompose very quickly. The cells making up that creature die, and are unable to keep DNA intact. The genetic material begins to fragment, or break down.

The rate at which DNA decays varies, depending on how the organism dies, but scientists generally think that DNA has a half-life of about 500 years. This means that after about 500 years, half of the genetic material will be un-readable.

DNA AND CANCER?

When a cell reproduces, or divides, mistakes can be made in the copying of DNA. These are sometimes called mutations. Most mutations never harm us. In fact, they are a natural part of life. Usually, cells repair any errors in their genes. Sometimes, if the mutation is extreme enough, the cell can no longer follow the instructions of its genes and can grow out of control. The resulting disease is what we call cancer.

Eventually, all of the DNA breaks down, just as most organic material does. By the time people started to learn what dinosaurs were, their genes were long gone—even those trapped in amber.

> DNA that survives for millions of years just isn't likely.

Bringing back animals that have been gone for millions of years is very unlikely. We just don't have intact DNA. But the story might be different for more recently extinct animals whose DNA might still be viable. The remains of a well-preserved, un-fossilized animal just might have enough intact DNA to make a clone. One possibility is the woolly mammoth.

WHEN THE MAMMOTHS ROAMED

Extinction is a regular occurrence on Earth. In tracing the fossil record, scientists can see that millions of species have come and gone since life began on this planet. Today, many animals are endangered and facing extinction, and others are already gone. Species such as the passenger pigeon and the Tasmanian tiger have disappeared due to overhunting and loss of habitat caused by humans.

A group of scientists at the Long Now Foundation's revive-and-restore project believe that de-extinction is possible for many kinds of plants and animals. They help to restore sensitive environments and recreate ecosystems as they may have existed years ago. One of their first projects is to bring back the woolly mammoth.

Famous Extinct Animals

The passenger pigeon and Tasmanian tiger are two of the most famous extinct animals. The passenger pigeon was once one of the most common birds in North America, gathering in flocks of millions. Overhunting and loss of environment led to their extinction, and the last passenger pigeon died in captivity in 1914. The Tasmanian tiger was actually a marsupial that resembled a dog with stripes. After the species was hunted to extinction, the last specimen died in an Australian zoo in 1936. What can people do to prevent the extinction of other species?

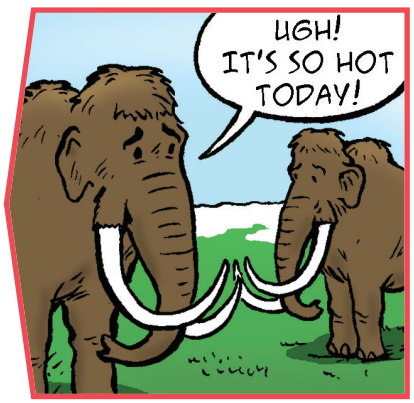
Watch an exhibit of the passenger pigeon here.

Manitoba Museum passenger pigeon

About 10,000 years ago, Earth went through another significant change in its climate—the planet warmed from an ice age. The frozen tundra of North America and Asia was home to steppe bison, saber-toothed cats, and herds of woolly mammoths.

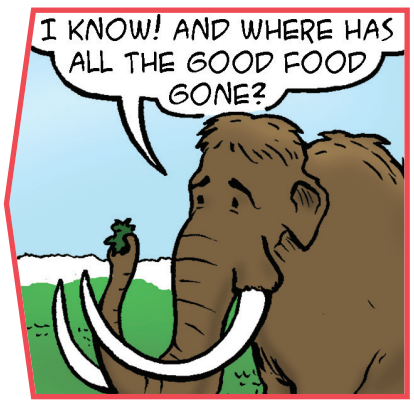
Woolly mammoths were large, standing about 10 feet tall and weighing about 6 tons when fully grown. Adapted for colder environments, they had thick, hairy coats and thick layers of fat that protected them from freezing temperatures.

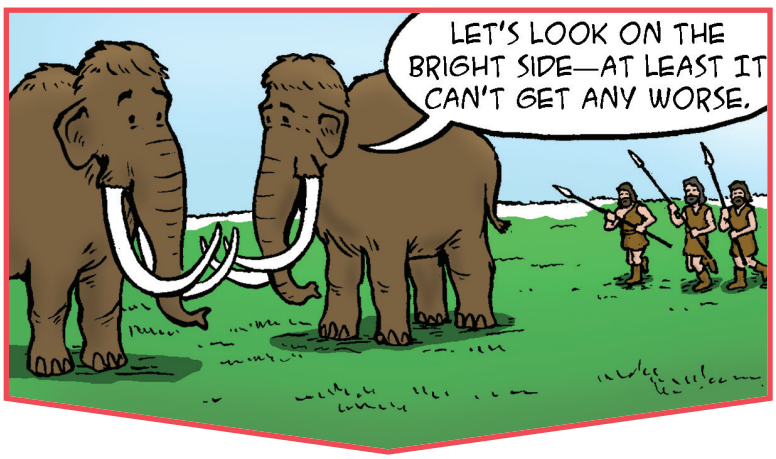
At that time, creatures better suited for life during an ice age began dying off. Animals that lived in warmer areas moved further north into a warming Arctic, increasing the competition for food and space to live. Just as when the dinosaurs died out, a changing Earth threatened their existence.



> However, mammoths had to face an additional danger the dinosaurs never had to deal with–humans.

Prehistoric hunters preyed upon the large mammals, using them for food, clothing, and even shelter.





The last woolly mammoths disappeared about 4,000 years ago from Wrangel Island, a cold and remote place off the northern coast of Siberia.

FINDING A MAMMOTH

For the most part, remains of woolly mammoths are, like the dinosaurs, fossilized. But not all of them. Recently, inhabitants of Siberia came across remains of animals poking out of the permafrost. These creatures had been hidden and frozen for thousands of years, but are now uncovered due to a warming environment.

At the time of death, these animals were likely covered quickly by mud or water, keeping them away from the open air. The cold climate in which mammoths lived and died provided an excellent opportunity to preserve their bodies and slow the decay of organic material. These are not fossils—some of them are intact animals with bones, teeth, hair, and even organs.

> Some of these beasts are so well preserved that scientists have even recovered samples of their blood.

As the ground begins to thaw and expose these mammoths to moisture, air, and sunlight for the first time in thousands of years, they begin to decompose very quickly. When they are found, scientists rush to the scene to try to preserve them as quickly and carefully as possible. And, sometimes, the efforts pay off. Even though these mammoths have been dead for thousands of years, they are so well preserved that some of their tissue can be recovered by scientists to extract actual mammoth DNA.

WRANGEL ISLAND BEAUTY

Wrangel Island is a place of few humans and many more species of animals than is usual for places in the Arctic region. You can see photographs of this beautiful area at this website.

PS

UNESCO Wrangel Island

GENETICALLY ENGINEERING A WOOLLY MAMMOTH

In order to clone any animal, a complete genome is needed. As we've learned, DNA is so delicate that even well-preserved DNA can become so fragmented that it's unusable. But, sometimes, if they find a DNA fragment large enough to use, scientists can fill in the gaps of the creature's genetic code with a close genetic relative of the deceased animal.

By recovering as many woolly mammoth remains as possible, scientists have the chance to collect lots of woolly mammoth DNA. Then they can look to modern elephants to help rebuild the genome.

Woolly mammoths and Asian elephants last shared a common ancestor between 2.5 and 5 million years ago. As their populations separated, mammoths adapted to colder climates while Asian elephants evolved to live in warmer environments.

Because they are closely related, mammoths and Asian elephants share many similar traits in their DNA. This is extremely helpful for geneticists. Recovered DNA is a bit of a mess—fragments that were once arranged in incredibly long and complex strands are now jumbled together in pieces.

By comparing fragments of woolly mammoth DNA to an intact Asian elephant genome, geneticists can determine where in their DNA the two species are similar, and where they are different. Matching pieces of mammoth DNA to elephant DNA creates a kind of map for a mammoth. And once there's a map, there's a path to follow.

Assembling the Puzzle

Have you ever tried to put together a jigsaw puzzle? Working with fragmented DNA is a little bit like working on a huge puzzle without knowing what the final picture looks like. It helps to know what the picture is before you start assembling the puzzle so you know where the pieces go when you find them. Asian elephants can help geneticists assemble a picture of mammoth DNA in a similar way.

TURNING ELEPHANTS INTO MAMMOTHS

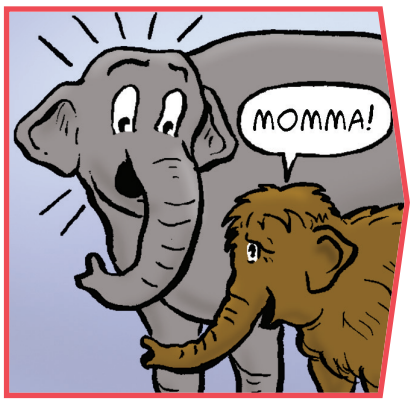
With this mix of mammoth and elephant DNA, scientists aren't trying to build a mammoth genome from scratch. Instead, they are using the blueprint for a woolly mammoth to edit an Asian elephant's DNA to be as much like a mammoth as possible. By removing an unwanted trait from the elephant DNA and replacing it with the desired mammoth trait, a very mammoth-like genome might be constructed. Once completed, cloning would be done in much the same way scientists cloned a sheep to make Dolly—nuclear transfer.

Using an Asian elephant as a surrogate, geneticists, biologists, paleontologists, and the whole world would have to wait between 18 and 22 months for a very mammoth-like animal to be born. Maybe someday, many of these animals could be born and set free.

Would this creature truly be a mammoth? Creating an animal with both mammoth and elephant genes wouldn't be an elephant or a clone of a mammoth. It would be a kind of hybrid, or a combination of two species, with as many mammoth traits as possible.

SCI-FI FACT

Scientists also use the process of nuclear transfer to examine complex human diseases and look for treatments.



Pleistocene Park

The Pleistocene Epoch was a time period that existed from 2.5 million years ago until 11,000 years ago. It was a time of large mammals, such as mammoths and mastodons, as well as woolly rhinoceroses and giant ground sloths. The last ice age occurred during the Pleistocene, and its end marked the extinction of many plants and animals that lived and thrived in a colder environment. Now, a group of people in Siberia is working to re-establish a Pleistocene environment in today's world.

You can look at Pleistocene Park here.

Pleistocene Park Science Magazine

All animals are born with inherent traits, or instincts. These are things that they simply know how to do without having to be taught. Animals also learn things from their parents and through interactions with other members of their species. Without adult mammoths around to raise and teach this new hybrid animal, it might not be a true woolly mammoth.

Would this mammoth-like baby know how to act and behave like a mammoth? An elephant that is genetically engineered to look like a mammoth might have the physical characteristics necessary to live in a colder environment, but scientists won't really know whether it could learn to survive away from its Asian elephant relatives until one is created and set loose. Fortunately, there's a nature preserve called Pleistocene Park that's ready for when extinct species of the frozen north are brought back to life as hybrids.

Pleistocene Park, named for the Pleistocene Epoch, is a nature preserve in northern Siberia. Its land has been set aside to recreate the environment that once existed there 30,000 years ago.

Russian scientist Sergey Zimov has been working to return a section of the Siberian tundra back to the type of ecosystem that existed when woolly mammoths and woolly rhinos roamed. He believes that bringing large herbivores back to Siberia could help slow climate change and the melting of the permafrost.

By digging for grasses and other plants, large mammals such as horses and bison expose the soil to colder temperatures because they are uncovering ground that is usually insulated by snow and therefore maintaining the permafrost. Returning mammoth-like creatures to the tundra could help protect and preserve a rapidly changing environment.

DE-EXTINCTION AND ETHICS

Bringing back dinosaurs is most likely to remain science fiction, but returning more recently extinct plants and animals is coming closer to science fact. Researchers are working on tools and techniques that will help determine the genome for animals such as the woolly mammoth and the passenger pigeon. Their goal is to provide a way to return very close approximations of these creatures to their former habitats. But is this ethical?

Many species became extinct due to human actions. Some people argue that we have a responsibility to return species to their environment if we can, especially if we were responsible for their decline in the first place. However, many of these habitats have changed. Other plants and animals have filled in the gaps in the ecosystem left behind by these extinct creatures.

The re-introduction of extinct species might have unintended consequences on the environments we have today. What do you think?

KEY QUESTIONS

- **What are some of the benefits to cloning? What are some of the drawbacks?**
- **What are some of the reasons people are interested in bringing back species that have been extinct for many years?**
- **What are some of the ethical issues involved in cloning and de-extinction?**

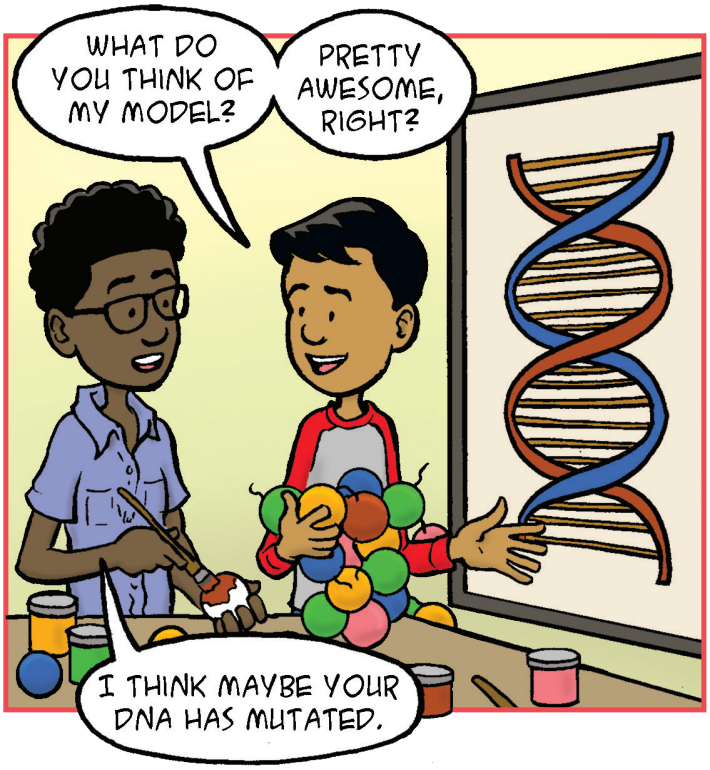
You might be able to visit Pleistocene Park someday and see a herd of woolly mammoths lumbering across the grasslands of northern Siberia.

Inquire & Investigate

MAKE A DOUBLE HELIX

In 1953, James Watson and Frances Crick used models discovered by Rosalind Franklin to determine the chemical structure of DNA—a twisted ladder shape called a double helix. The sides of the ladder are made of sugars and phosphates, while the rungs are made of base pairs. Together, they form the structure that passes genetic information from one generation to the next!

- **Create a model of the structure of DNA.**
  - What type of supplies will you use for the four bases (cytosine, guanine, thymine, and adenine)?
  - How will you attach the pairs together (cytosine goes with guanine, thymine goes with adenine)?
  - How will you create the outside of the ladder structure?
  - How will you set it up to maintain a twist?



To investigate further, consider that if you stretched out a single strand of your DNA, it would reach nearly 6 feet in length. How long would your model need to be to accurately represent the length of a DNA model?

DE-EXTINCTION—YOU CHOOSE

Extinction is part of evolution. Species that are not able to adapt to changes in their environment can disappear from Earth forever. In recent history, humanity has played a larger role in the extinction of species, from overhunting and overfishing to destroying habitats and environments. With the science of de-extinction getting closer to reality, what would you bring back, and why?

- **Do some research and find creatures that are near extinction or recently extinct.** Choose the one you think is the best candidate for de-extinction. Consider the following questions.
  - Why did you choose your animal?
  - When, why, and how did your animal go extinct?
  - Was this extinction caused by humans?
  - What could have been done to avoid its extinction?
  - Does your animal have any close relatives that still exist?
  - Where would this formerly extinct creature live? Does its old habitat still exist?
  - What effects might it have on other species?
- **Print or create a picture of your animal, and include your answers from the questions above to make an infographic.** An infographic combines pictures and information together in a way that is informative and interesting to look at! Don't forget to present and discuss your infographic with others!

Inquire & Investigate

VOCAB LAB

Write down what you think each of the following words means. What root words can you find for help?

extinct, **cloning**, **DNA**, **parthenogenesis**, **ethics**, **paleontologist**, **genome**, **mutation**, **half-life**, **permafrost**, and **ethical**.

Compare your definitions with those of your friends or classmates. Did you all come up with the same meanings? Turn to the text and glossary if you need help.

To investigate further, research an endangered species that could go extinct in your lifetime. Answer the same questions and compare and discuss your answers with others.