

BRINGING BACK WOOLLY MAMMOTHS?

A CASE STUDY

CREATED BY:

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ISU BIOETHICS WORKSHOP 2009

BACKGROUND INFORMATION:

taken from the

Mammoth Genome Project

Pennsylvania State University

<http://rw.mammoth.psu.edu/index.html>

<http://rw.mammoth.psu.edu/society.html>

Mammoths and society

Mammoths played an important role for humans during the Pleistocene epoch, 1.8 million to 10,000 years ago. They provided the hunter/gatherers with much-needed meat, skins, and building materials for their huts. As mammoths were likely plentiful, with a population size of several million during the early and mid Pleistocene, the impact of hunting is believed to have been small during that period. On the other hand, human hunting may have been an important factor during the final stages of the mammoths' existence in the late Pleistocene (20,000 to 10,000 years ago). Still, the impact may not have been large, given the enormous amount of meat coming from a 6 to 8 ton animal, which would have fed 400 people for several weeks. Also, preservation of meat was not an issue for humans living in the ice age, who had access to natural forms of refrigeration. Mammoths might therefore have played a role in human survival similar to today's farm animals. The appreciation of the Stone Age people is reflected in many pieces of art, such as cave paintings and ivory carvings. It might also explain why people living today still care about mammoths.

A hairy relative of elephants

Woolly mammoths were a species of elephant that populated much of Eurasia and North America until about 10,000 years ago. Along with their living relatives, the African and Indian elephant species, mammoths originated in Africa millions of years ago. Within the last several hundred thousand years, mammoths adapted to the numerous ice age periods in the northern hemisphere by evolving several traits that are specific to woolly mammoths. These traits include the shape and size of their bodies, the thick hair coat, the enormous tusks, and a 2-inch layer of insulating fat tissue.

Lessons from the mammoth genome

The Mammoth Genome Project discussed here is the first to decipher the genome of an extinct animal. Our data allow a view back in time as far as 60,000 years and describe the genetic

changes that occurred in mammoths. Our analyses show that the rate of evolution within the three lineages of elephants (mammoth, Indian elephant and African elephant) since they separated about 6 million years ago is only half of that between humans and chimpanzees. Our study also identified changes in proteins that occurred only in mammoths, but not in any of the other 50 mammalian genomes sequenced so far. Since proteins are a main contributor to an animal's physical traits, it is possible that these differences helped mammoths to survive in their harsh environment.

Biology of extinction

The broader implications of our research involve studying genomes of extinct animals and asking specific questions about their life styles. In general, our work shows that it is possible to open a window to the past and study animals that are long gone at the same level of genetic detail as when examining modern species. The lessons being learned from studying extinct species can help us to understand the processes that are driving today's endangered species toward possible extinction.

The Center for Comparative Genomics and Bioinformatics

The Mammoth Genome Project is being conducted at the Center for Comparative Genomics and Bioinformatics at the Pennsylvania State University. The team has already completed a first phase of the project, where the genome was read at single-fold coverage. We are currently working on a high-resolution sequence of the genome, which has more than 4 billion base pairs.

ACTIVITY:

Students will be divided into groups. Each group will represent a different interest group that is petitioning the United States Department of Pre-historic Recovery (USDPR – established 2150) concerning their interest in regenerating mammoths. For the purpose of this case study, you should consider yourself to be a member and advocate of the group to which you have been assigned and do your best to adequately and persuasively represent the interest of your group. This is a *role-playing exercise*. Regardless of whether or not you actually agree with the position to which you have been assigned, you should do your best to accurately represent the point of view of your group.

ACTIVITY SCHEDULE:

- 1) Read your article and look for information that will support your position.
- 2) Working with your group decide:
 - a. The information you will present – remember you want to support your argument.
 - b. Which group members will present the different pieces of information.
- 3) Write your argument out in a short one page essay, which will be handed in.
- 4) Each group will be given 3-5 minutes to present their case to the USDPR.

INTEREST GROUPS:

1. **Mammoth Information** (You are neutral, you are just informational)
 - a. “Shivers of Delight at Mammoth Find”, “Woolly Mammoth”, and “About Mammoths”
 - b. “Mammoths: Resurrecting Extinct Megafauna”

2. **Against cloning a mammoth**
 - a. “Making a Mammoth Mistake” and “Cloning the Mammoth”
 - b. “Cloning the Woolly Mammoth and Other Extinct Animals”
 - c. “Bring Back the Woolly Mammoth?” and “Regenerating a Mammoth for \$10 Million”

3. **For cloning a mammoth**
 - a. “Woolly Mammoth Resurrection, ‘Jurassic Park’ Planned”
 - b. “Resurrection of Mammoths Possible”
 - c. “Woolly Mammoth Genome Sequenced”

GROUP 1: MAMMOTH INFORMATION

Shivers of Delight at Mammoth Find

Luke Harding in Moscow | July 12, 2007

<http://www.brisbanetimes.com.au/news/world/shivers-of-delight-at-mammoth-find/2007/07/11/1183833598302.html>

Close up it looks suspiciously like a small and unremarkable Asian elephant. But scientists are hailing the sensational discovery of a perfectly preserved baby woolly mammoth, which died around 10,000 years ago and was found in the frozen tundra of northern Russia.

Experts said the six-month-old female calf was a rare complete specimen. The animal's trunk and eyes are intact. It even has fur.

A reindeer herder, Yuri Khudi, stumbled across the carcass in May near the Yuribei River in Russia's Yamal-Nenets autonomous district, in a virtually inaccessible part of north-western Siberia.

Extinct woolly mammoths - and giant tusks - have turned up in Siberia for centuries. But it is unusual for a complete example to be recovered. The last major find was in 1997 when a family in the neighbouring Taymyr Peninsula came across a tusk attached to what turned out to be a 20,380-year-old mammoth carcass.

The latest Siberian specimen - 130 centimetres tall, and 50 kilograms - appears to have died just as the species was heading for extinction during the last Ice Age. It is being sent to Japan for further tests.

"The mammoth has no defects except that its tail was a bit off," Alexei Tikhonov, one of group of international experts who examined the mammoth last week in the Arctic town of Salekhard. He added: "In terms of its state of preservation, this is the world's most valuable discovery."

Global warming has made it easier for woolly mammoth hunters to hack the animal out of Russia's thawing permafrost. An entire mammoth industry has sprung up around the far eastern frontier town of Yakutsk.

Many examples are simply sold on the blackmarket - and can be seen in Russian souvenir shops, next to unhappy-looking stuffed brown bears.

Mammoths first appeared around 4.8 million years ago. Most died out 12,000 years ago at the end of the Pleistocene era.

GROUP 1: MAMMOTH INFORMATION

Guardian News & Media: About Mammoths

http://www.ucmp.berkeley.edu/mammal/mammoth/about_mammoths.html

Mammoths were first described by German scientist Johann Friedrich Blumenback in 1799. He gave the name *Elephas primigenius* to elephant-like bones that had been found in Europe. Both Blumenbach and Baron Georges Cuvier of France concluded, independently, that the bones belonged to an extinct species. The bones belonged to the woolly mammoth, later considered to be a distinct genus, and so renamed *Mammuthus primigenius*.

Mammoth evolution

Mammoths stem from an ancestral species called *M. africanavus*, the African mammoth. These mammoths lived in northern Africa and disappeared about 3 or 4 million years ago. Descendants of these mammoths moved north and eventually covered most of Eurasia. These were *M. meridionalis*, the “southern mammoths.”

In the early Pleistocene, about 1.8 million years ago, *M. meridionalis* took advantage of low sea levels (during an Ice Age) and crossed into North America via a temporary land bridge across the Bering Strait. The southern mammoth then radiated throughout North America. In the Middle Pleistocene, a new North American species evolved, the imperial mammoth, *M. imperator* (though some question whether *M. imperator* is a legitimate genus). Then, in the Late Pleistocene, the Columbian mammoth, *M. columbi* (also known as the Jefferson mammoth, *M. jeffersoni*), appeared. Its range covered the present United States and as far south as Nicaragua and Honduras.

Back in Eurasia, another species of mammoth, the steppe mammoth (*M. trogontherii*), lived from 200,000 to 135,000 years ago. And later in the Pleistocene, the woolly mammoth (*M. primigenius*), which incidentally was the smallest of the mammoths, made its debut.

With the advent of another Ice Age and low sea levels lasting from 35,000 to 18,000 years ago, woolly mammoths were able to enter North America via a new land corridor across the Bering Strait. Woolly mammoths’ southern migration extended as far south as present-day Kansas.

Dwarf forms of mammoth are known from fossils found on islands: *M. exilis* from California’s Channel Islands stood only about four to six feet at the shoulder.

Many believe that mammoths disappeared because of a change in climate, disease, hunting by humans, or perhaps some combination of these. It is still something of a mystery.

Something to chew on

If mammoths were similar to elephants in their eating habits, they were very remarkable beasts. Consider the following facts about modern elephants:

Spend 16 to 18 hours a day either feeding or moving toward a source of food or water.

Consume between 130 to 660 pounds (60 to 300 kg) of food each day.
Drink between 16 to 40 gallons (60 to 160 l) of water per day.
Produce between 310 to 400 pounds (140 to 180 kg) of dung per day.

Since most mammoths were larger than modern elephants, these numbers must have been higher for mammoths!

From the preserved dung of Columbian mammoths found in a Utah cave, a mammoth's diet consisted primarily of grasses, sedges, and rushes. Just 5% included saltbush wood and fruits, cactus fragments, sagebrush wood, water birch, and blue spruce. So, though primarily a grazer, the Columbian mammoth did a bit of browsing as well.

GROUP 1: MAMMOTH INFORMATION

Woolly Mammoth

<http://www.bbc.co.uk/nature/wildfacts/factfiles/458.shtml>

Scientific name

Mammuthus primigenius

Meaning of scientific name

From the old Russian word "mammut" for the animals - possibly meaning "earth mole" as they believed the animals to live underground and die on contact with the light (explaining why they were always found dead and half-buried).

Statistics

Males 3m tall, females 2.75m tall.

Physical Description

Woolly mammoths are well known through bones, frozen carcasses from the permafrost of Siberia, and through ancient art. They were built like elephants but with tiny ears and short tails to prevent heat loss, and a thick coat of dark brown hair - up to a meter long on the underbelly. The long hairs were probably shed in the summer. They had trunks with 2 'fingers' at the end to help them pluck grass. The males had longer, more spirally-shaped and more heavily built tusks than the females. Both sexes appear to have had 'humps' of hair and fat behind their heads making the shoulders seem taller than the pelvis, although front and back legs are actually about the same length.

Distribution

The woolly mammoth is known from bones and frozen carcasses from Ireland to the east coast of North America with the best preserved carcasses in Siberia.

Habitat

They lived on the 'mammoth steppe' - the plains of northern Europe and North America.

Diet

Mammoths were herbivorous, grazing and browsing grasses, sedges and twigs.

Behavior

Mammoths are thought to have behaved very like modern elephants, with herds made up of females and their young - led by a matriarch. They may have bred more seasonally than tropical elephants do today, and may well have needed to migrate in search of food and water during the winter months.

Conservation status

Extinct.

Notes

Mammoth bones have been known in Europe since at least the 15th century, but for hundreds of years they were thought to be the bones of giants. Around 300 years ago they were identified as belonging to elephants but this caused more confusion - what were they doing in such a cold climate? Eventually, with the discovery of the remains of dinosaurs and the extinct animals of South America, it was realized that animals had lived in the past which were different from those which are seen around today, and the famous anatomist Georges Cuvier correctly proposed that the mammoth bones were those of an extinct form of elephant.

History

They lived 135,000-11,000 years ago. DNA analysis has confirmed that mammoths are very closely related to our living elephants. The woolly mammoth evolved from earlier mammoths, which had adapted to the cooling climate in Northern Europe, and lived alongside other species in North America as well. It was the last species to become extinct, and is the only one for which we have frozen carcasses.

Closest relative

Modern elephants.

GROUP 1: MAMMOTH INFORMATION

Mammoths: Resurrecting Extinct Megafauna

<http://www.actionbioscience.org/biotech/agenbroad.html?print>

Larry D. Agenbroad

An ActionBioscience.org original article

Approximately 11,000 years ago 76 percent of North American megafauna (those animals weighing more than 100 pounds) became extinct, though the causes of the extinction are still unknown. Perhaps the most readily recognizable member of that group is the mammoth.

Mammoths are members of the family Elephantidae. Their closest living relatives are the African elephants (*Loxodonta africana* and *Loxodonta cyclotis*) and the Asian elephant (*Elephas maximus*). Elephantidae appeared in North Africa nearly 3.5 million years ago and migrated to Europe, Asia, and ultimately to North America.

There were several species of mammoths in North America: pygmy forms (*Mammuthus exilis*) inhabiting islands off the coast of California; large, temperate grassland forms (*Mammuthus columbi*); and sub-Arctic denizens (*Mammuthus primigenius*), known as woolly mammoths. Woolly mammoths have been preserved in the permafrost zones of the Arctic regions—especially Siberia and Alaska—presenting the possibility of creating a living reproduction of an extinct animal through cloning.

The cloning question

The recovery of the Jarkov Mammoth from the permafrost of the Taimyr Peninsula, Siberia, was featured in the Discovery Channel's television documentary "Raising the Mammoth." A portion of the program was devoted to the possibility of cloning a woolly mammoth, if high-quality DNA could be recovered from the carcass. That concept caught the imagination of people of all ages worldwide. The response was a large number of questions and comments, both pro and con, on the possibility, feasibility, and consequences of such an endeavor.

The DNA recovered from the Jarkov Mammoth was of insufficient quantity and quality to allow any further experiments with that individual. Another mammoth, known as the Fishhook Mammoth, also from the Taimyr Peninsula, provided better DNA but was still unsuitable for a cloning process. Many researchers feel there will never be a good enough DNA sample preserved in animals frozen under natural conditions because of the degrading effects of freeze-thaw cycles and microbes in the soil. On the other hand, there are many frozen specimens within the permafrost regions of the northern hemisphere, and one of them may produce satisfactory DNA.^{1,2}

The controversy

Almost instantaneously, opposition to a possible cloning project began. The arguments fell into several categories: (1) legality of cloning, (2) morality, (3) feasibility, and (4) potential of success. These will be addressed briefly here.

Legality

One of the first items to surface on the Internet was a legal brief from the Stanford University Law School, San Jose, California.³ This treatise covers many aspects of potentially cloning a mammoth, but it basically concludes there is no legal barrier, nationally or internationally, to prevent such an experiment.

Morality

The question of the morality of such a project was addressed in the legal brief mentioned above, but it was encountered most commonly in emails, letters, articles, and verbal exchanges. These reactions fell into several general groupings (and miscellaneous others):

- (a) These animals are extinct. Are we playing God by trying to resurrect them?
- (b) Cloning will create monsters that will destroy life as we know it.
- (c) There are no modern environments suitable for these creatures.
- (d) It would be inhumane.
- (e) Such an endeavor would release a plague of unknown diseases on Earth.

The counterpoints to these arguments are as follows:

- (a) Mammoths are extinct, yet some remnant populations survived to at least 3700 years ago on a small island in the Arctic Ocean.⁴ There is also evidence that mammoths were extant on St. Paul Island, in the Alaskan Pribilof Islands, until as late as 7980 years ago.⁵ How did two populations of insular mammoths survive the extinction of continental mammoths? There is compelling evidence that humans had a role in mammoth extinction, at least in North America. If humans were instrumental in mammoth extinction, perhaps human technology would compensate by allowing them to once again walk the Earth.
- (b) If such a project, however conceived, were successful, the result would not be some monster out of Jurassic Park. It would be similar to an elephant, although hairier. Initially, it would look and act like a juvenile elephant, needing to be nurtured, guided, and taught by the surrogate elephant mother that carried it in the womb.
- (c) Many people, including some of the Siberian expedition team, claim it would be impossible to replicate the environment of the woolly mammoth, and therefore cloning would be a disservice to the restored mammoth. We do not actually know what the environmental conditions were where the woolly mammoth lived; in fact, finding out is one of the research goals of restoring the extinct animal. Most experts agree that the woolly mammoth lived in a cold, dry grassland called the Mammoth Steppe.⁶ Many of the plants found in the digestive tract of the frozen mammoths still grow in Siberia today. Even if there is no remnant of the mammoth's environment, we have expert nutritionists on hand who could create "mammoth chow" (in very large bags, of course). In Sakha (or Yakutia) land has been set aside for a Pleistocene Park where muskoxen, bison, and Przewalski's horses have been reintroduced alongside the native animals such as bears, wolves, and reindeer. The only missing megafauna are woolly mammoths, woolly rhinos, and cave lions. Russian scientists have stated they would welcome clones to the park.

- (d) We have been besieged by people who say, “it is not humane to clone a mammoth,” “it will be treated just like a laboratory rat,” “why don’t you use the research expertise for projects that benefit humans, like the recent cloning of five piglets to supply heart valves?” But is it humane to clone creatures that will be butchered for their body parts, to be used as spares for humans?
- (e) As for loosing plagues on the Earth, there are hundreds of frozen, extinct animals that are defrosted by natural means each year. To our knowledge there have been no recorded maladies or plagues from such natural events.

Feasibility

Experts in the cloning field have claimed that if DNA of suitable quality and quantity is recovered, there will be little difficulty in producing a clone. The cloning potential lies in two differing methodologies:

- (1) Sex cells. A Japanese team of researchers headed by Drs. K. Goto and A. Iritani has attempted several expeditions to collect sex cells (eggs or sperm) from frozen mammoths in Siberia. To date, these attempts have failed. (Note: Even if successful, this method would produce a hybrid offspring, 50 percent *Mammuthus* and 50 percent *Elephas*.)
- (2) Body cells. As with Dolly, the cloned sheep, it is not necessary to have sexual reproduction to obtain a clone. In this technique, the egg of an Asian elephant would have the nucleus destroyed and replaced with the nucleus of a mammoth specimen. If successful, the resulting clone would be genetically pure mammoth.

Possibilities of success

The technology of cloning is new and its potential mostly unrealized, but there are reasons to be optimistic:

There have been many recent cloning successes: sheep, calves, kittens, monkeys, guars, mouflon sheep, the Arabian oryx, the African quagga, and others.

Successful cloning of an extinct species may lead to techniques and procedures to save currently endangered species. Examples include the Japanese ibis, the Chinese giant panda, the Australian hairy nosed wombat, and others.

There may even be successes with recently extinct animals such as the New Zealand moa and the Tasmanian thylacine, or marsupial wolf.

There is also the possibility of creating a frozen zoo for sperm, eggs, and cells of endangered species.

I’ll conclude with a statement by Salsberg: “With these procedural and ethical standards and safeguards in place, it is my belief that the benefits of resurrecting the mammoth can be fully realized, while minimizing or completely avoiding most, if not all, of the project’s harms and questionable applications.”³

A different perspective

A very different perspective, at least from the view of a North American, is shown by the following analogy: It can be demonstrated that humans had a hand in the North American extinction of the mammoths (and possibly other Pleistocene megafauna). There are numerous mammoth kill sites as evidence (although too few in the view of Grayson and Meltzer,^{7,8} who were rebutted by Fiedel and Haynes⁹).

Leaving that argument to stand, consider the following: In prehistoric and protohistoric North America there were many wolves (*Canis lupis*) and grizzly bears (*Ursus horribilis*). With the expansion of European settlers as farmers and ranchers, these carnivores were exterminated, or at least removed from large regions of western North America, often with the aid of national governments. Now, in the late 20th and early 21st centuries, wolves and grizzly bears are being reintroduced to former ranges, in spite of the opposition of farmers and ranchers, with the support and protection of national governments.

Conclusion: If two carnivores were exterminated from areas of western North America by humans and are now being reintroduced to old ranges, is there a moral, legal, ethical, or environmental difference from the proposed reintroduction (albeit by cloning) of an extinct herbivore (mammoth), which can be demonstrated to have been driven to extinction (at least in part) by humans?

GROUP 2: AGAINST CLONING A MAMMOTH

Making A Mammoth Mistake

<http://www.respect-authority.com/2008/11/making-a-mammoth-mistake>

Perhaps inspired by *Ice Age*'s amiable Manny the Mammoth, scientists said this week that they're once again looking into the ability to regenerate a living mammoth using DNA. Well, DNA and \$10 million.

Apparently a team of scientists stumbled across a large swath of mammoth hair, from which they were able to extract a significant portion of the mammoth genome. By filling in the gaps from the animal's nearest genetic neighbor – in this case, an elephant – scientists postulate that they would be able to create a living, breathing mammoth.

Considering how easy *Jurassic Park*'s tutorial video made it look (“Hi! I’m Mr. DNA!”), I frankly wasn’t prepared for the sophistication of the science involved in this process. And in part, the scientific procedure was immediately irrelevant for me because before we consider *how* to reproduce a mammoth, or any other long-extinct species, I feel it might be in our best interest to consider *why* we would ever want to.

For me personally, there’s very little in mammoth existence that I find compelling, and certainly nothing so compelling that an elephant can’t do the trick. They’re big, they have trunks, they eat peanuts, and run from mice – what else could we want? Moreover, the notion that scientists would create mammoths for the express purpose of restoring their place in the wild is both shortsighted and completely idealistic. We have no idea how mammoths would cope with species that exist today, or the environment of the 21st century. Nor would we ever find out, because any genetically created mammoth would find its permanent home in the local zoo or museum way before the Great Outdoors.

Science these days is chock full of these “We can, but should we?” moments, and this one’s a perfect example. Did *no one* see *Jurassic Park*?! Recreating extinct species is little more than a recipe for disaster – and disaster means destruction, death and Jeff Goldblum’s acting. While regenerated mammoths sound like little more than an oversized and pointless eyesore, applying the same technology to other species – dinosaurs, Neanderthals – opens the door to much more serious threats: losing our place in the food chain, or *actual* Geico cavemen.

Listen scientists, I say we hold on to the \$10 million, as well as our tentative grip on world order, instead.

GROUP 2: AGAINST CLONING A MAMMOTH

Cloning the Mammoth?

05/07/2009

http://blogs.discovery.com/animal_news/2009/05/cloning-the-mammoth.html

The discovery of the best-preserved mammoth ever found ranks as one of the coolest science finds of all time. But seriously folks, am I the only one who wonders what the heck they are thinking when talking about cloning the mammoth?

In 2007, a one-month old baby mammoth was found frozen in a Siberian swamp, and University of Michigan paleontologists, including Professor Daniel Fisher, are studying her. They know she lived more than 10,000 years ago and died in a mud pit. Named Lyuba, the mammoth has its skin, bones, and organs almost fully intact. She even has mother's milk in her tummy.

Scientists have already decoded 70% of the woolly mammoth's genome, and with the discovery of Lyuba, they most certainly can finish the job. Cloning a mammal is no simple feat, but it can be done. Since 1996 when Dolly the sheep was cloned from somatic, or non germ-line cells, scientists have since cloned several animals, including a domestic sheep, rabbit, cat, dog, mouse, goat, mule, horse, pig, and camel. Only a handful of wildlife species have been cloned and most have not survived long due to succumbing quickly to disease or illness. A water buffalo died after five days due to a lung infection. The endangered ox-like Gaur died of dysentery 48 hours after birth. A cloned moufflon sheep survived longer, as did a cloned rhesus monkey, Tetra. But for every cloned animal that survived were many more that died early, or had tumors or subtle genetic abnormalities.

But no one has ever successfully cloned an extinct animal. And scientists have long debated the possible problems with cloning extinct, endangered or rare species.

Maybe Jurassic Park is etched too deeply in my mind, but it seems like the massive beast of a woolly mammoth would not be the ideal candidate for cloning. What if they have very bad tempers?

Besides the fact that we have no idea what their temperament may be, we don't know what their dietary needs might be, whether they have any co-evolved intestinal microorganisms that have since gone extinct and whether they could even survive in today's non-Ice Age world. Bringing back a species that is long since extinct, like the woolly mammoth, is surely more ecologically problematic than attempts to restore presently endangered species, or recently extinct species like the Tasmanian tiger. It's not like we're going to have herds of cloned mammoths anytime soon, given the long arduous task any animal cloning involves but the question remains – if one does successfully clone the mammoth, where will it go? We could put the mammoth in a zoo or a pen, and study it like a lab rat. And that's probably what would happen. Is that ethical? Then again, we will certainly never know the answers to these fascinating scientific questions if nobody tries. What do you think about cloning long extinct species?

GROUP 2: AGAINST CLONING A MAMMOTH

Cloning the Woolly Mammoth and Other Extinct Animals

By Allen Butler

[http://www.associatedcontent.com/pop_print.shtml?content_type=article&content_type_id=17821\](http://www.associatedcontent.com/pop_print.shtml?content_type=article&content_type_id=17821)

In the fall of 2005 an international team of scientists hailing from the United States, Canada, the UK and Germany successfully decoded 1% of a strand of DNA of the woolly mammoth that has been extinct for 10,000 years. Using an excellently preserved 27,000 year old specimen this team hopes to fully decode the woolly mammoth's DNA within a year.

The announcement created a great buzz around the idea of cloning the long extinct species. For the first time in history the idea of cloning an extinct species actually seems plausible and in fact nearly a reality.

In the early 1990's the possibility of cloning extinct animals was popularized by the Michael Crichton novel and later Stephen Spielberg movie Jurassic Park. In this story dinosaurs are cloned using DNA taken from ancient mosquitoes embalmed in amber. Being an adventure story things ultimately end up badly for everyone involved when surprisingly enough the dinosaurs escape.

Scientists today are not talking about cloning dinosaurs, however, which is still a remote possibility but rather woolly mammoths. Instead of a "Jurassic Park" many mammoth clone advocates wish to create a Pleistocene Park that would recreate the Ice Age conditions in which the woolly mammoth thrived.

The Woolly Mammoth

Woolly mammoths have long captured the popular imagination. Unlike dinosaurs, they once coexisted with man and were even hunted by man. It is widely believed that man was the ultimate cause of extinction of the woolly mammoth, an event that occurred about 10,000 years ago although recent evidence has shown that some mammoths survived in isolated pockets another 2,000 years or more.

For centuries man's primary knowledge of the mammoth came from its tusks. Like its closest modern relative, the African elephant, a mammoth's tusks are made of ivory. For hundreds of years and perhaps more residents of the harsh climates of Siberia mined the tundra permafrost for mammoth tusks, the ivory from which was sold around the world. This trade continued until at least the 1930's.

Although mammoth tusks had been harvested for generation after generation in Russia, it was not until the 18th and 19th centuries that the woolly mammoth first began to be understood. In 1799 an ivory hunter by the name of Shumakov happened upon a massive dark shape encased in ice. Over several years he continued returning to the site, until finally in 1803 the ice had completely melted and revealed a nearly perfectly preserved woolly mammoth specimen, the first to be scientifically studied.

Weighing over seven tons, the woolly mammoth stood twelve feet tall and higher. Larger than its modern day descendants (African and Indian elephants), it was also covered in thick, shaggy hair (from which it gains the moniker 'woolly' mammoth). Its exact origins are unknown, although it is speculated that it first developed in Africa about 1.5 million years ago. It then spread out to cover almost the entire globe, until it died out about 10,000 years ago at the end of the last Ice Age.

Because of such excellently preserved specimens as that found by Shumakov in 1799, much is known about the woolly mammoth, more than is known about most other extinct species of its era and prior. This is also the reason that scientists have turned to the mammoth rather than the much older dinosaur as being the first extinct species to be brought back to life.

The Mammoth Creation Project

Although it was only nearing the end of 2005 that the first results of the mammoth DNA decoding process were released to the general public, the idea of cloning woolly mammoths has been around for several years.

The Mammoth Creation Project is a Japanese organization that has long sought to bring this Ice Age giant back to life. Rather than begin with a look into the actual genetic code of the mammoth, the concept behind the Mammoth Creation Project is quite simple: find a well-preserved mammoth specimen, extract sperm from it and use this sperm to impregnate a modern elephant.

Although this would not actually recreate a woolly mammoth, it would create a creature very close to the mammoth. This new half mammoth-half elephant would then itself be impregnated by more frozen mammoth sperm, making its off-spring would be 75% mammoth and so on until within fifty years it is speculated we would have a creature that is 88% mammoth.

Most of the scientific community has been rather skeptical about the Mammoth Creation Project. The possibility of finding sperm preserved enough to use in this process is slim if there is any at all, and the process defined would not in fact bring about an actual mammoth, but something similar to a mammoth.

Pleistocene Park

Besides scientific skepticism of the work of the Mammoth Creation Project, scientists have also chastised the idea of cloning mammoths on ethical grounds. For one thing, the environment of the woolly mammoth no longer exists. Mammoths could not survive in modern climes. At best they would be isolated to small parks, little better than the island home of Michael Crichton's Jurassic Park.

Advocates of the Mammoth Creation Project, however, say that bringing mammoths back to life will allow us to better understand them, how they live and how they died. As for the environment of the mammoth, Mammoth Creation Project scientists believe that there are still parts of the Siberian tundra that reflect the ancient habitat of the mammoth.

Some scientists actually seek to recreate the Pleistocene environment. Russian scientist Sergey Zimov is very interested in recreating the landscape of 10,000 years ago. In a large swath of land in northern Siberia he and a team of colleagues are making an attempt to create an actual Pleistocene Park that would accurately reflect this lost world.

The team has begun with introducing animals that would have thrived during the Pleistocene period, hoping that these animals will assist in the recreation of the Ice Age ecosystem. For Zimov though, the goal is not to create a home for modern day mammoth clones but rather to investigate further the cause of the mammoth's extinction and whether or not it is truly human caused.

The Future of the Mammoth

As of today, it is unknown whether we will ever see the woolly mammoth once again walk the earth. As cloning technology continues to advance and our capability of studying these ancient beasts continues to increase the possibility becomes greater and greater. Even if we have the technology, however, the ethical questions remain unanswered. Is it right to bring back an animal that has been extinct for 10,000 years? This is a question that is still under debate.

GROUP 2: AGAINST CLONING A MAMMOTH

Bring Back the Woolly Mammoth?

November 23, 2008

<http://www.nytimes.com/2008/11/23/opinion/23sun3-3.html?scp=2&sq=&st=nyt>

A new research report suggests that scientists may be able to recreate an extinct woolly mammoth from its long-frozen DNA. The most gung-ho scientists think it could be done in a decade or two for as little as \$10 million. The deeper question is should we try?

Michael Crichton warned us in his novel “Jurassic Park” about the dangers of tinkering with extinct species (and populating a theme park with dinosaurs).

That sort of improbable disaster is not what gives us pause. There is little doubt that it would be fun to see a living, breathing woolly mammoth — a shaggy, elephantine creature with long curved tusks who reminds us more of a very large, cuddly stuffed animal than of a T. rex. We’re just not sure that it would be all that much fun for the mammoth.

The first mammoth would be a lonely zoo freak, vulnerable to diseases unknown to its ancestors. To live a full and rewarding life, it would need other mammoths to hang out with, a mate to produce a family and a suitable place to live. The sort of environment it is used to — the frigid wastes of Siberia and North America — are disappearing all too fast.

No one is quite sure why the woolly mammoths died out toward the end of the last ice age, some 10,000 years ago. Theories include warmer temperatures that gradually displaced the plants on which they fed, over hunting by primitive man, an accumulation of harmful genetic mutations, widespread disease, or an asteroid or comet colliding with Earth and disrupting the climate. If scientists do bring back a few mammoths, we suspect our warming world won’t look any more hospitable than the one that did them in.

GROUP 2: AGAINST CLONING A MAMMOTH

Regenerating a Mammoth for \$10 Million

November 18, 2008

http://www.nytimes.com/2008/11/20/science/20mammoth.html?pagewanted=1&_r=1

Scientists are talking for the first time about the old idea of resurrecting extinct species as if this staple of science fiction is a realistic possibility, saying that a living mammoth could perhaps be regenerated for as little as \$10 million.

The same technology could be applied to any other extinct species from which one can obtain hair, horn, hooves, fur or feathers, and which went extinct within the last 60,000 years, the effective age limit for DNA.

Though the stuffed animals in natural history museums are not likely to burst into life again, these old collections are full of items that may contain ancient DNA that can be decoded by the new generation of DNA sequencing machines.

If the genome of an extinct species can be reconstructed, biologists can work out the exact DNA differences with the genome of its nearest living relative. There are talks on how to modify the DNA in an elephant's egg so that after each round of changes it would progressively resemble the DNA in a mammoth egg. The final-stage egg could then be brought to term in an elephant mother, and mammoths might once again roam the Siberian steppes.

The same would be technically possible with Neanderthals, whose full genome is expected to be recovered shortly, but there would be several ethical issues in modifying modern human DNA to that of another human species.

A scientific team headed by Stephan C. Schuster and Webb Miller at Pennsylvania State University reports in Thursday's issue of *Nature* that it has recovered a large fraction of the mammoth genome from clumps of mammoth hair. Mammoths, ice-age relatives of the elephant, were hunted by the modern humans who first learned to inhabit Siberia some 22,000 years ago. The mammoths fell extinct in both their Siberian and North American homelands toward the end of the last ice age, some 10,000 years ago.

Dr. Schuster and Dr. Miller said there was no technical obstacle to decoding the full mammoth genome, which they believe could be achieved for a further \$2 million. They have already been able to calculate that the mammoth's genes differ at some 400,000 sites on its genome from that of the African elephant.

There is no present way to synthesize a genome-size chunk of mammoth DNA, let alone to develop it into a whole animal. But Dr. Schuster said a shortcut would be to modify the genome of an elephant's cell at the 400,000 or more sites necessary to make it resemble a mammoth's genome. The cell could be converted into an embryo and brought to term by an elephant, a project he estimated would cost some \$10 million. "This is something that could work, though it will be tedious and expensive," he said.

There have been several Russian attempts to cultivate eggs from frozen mammoths that look so perfectly preserved in ice. But the perfection is deceiving since the DNA is always degraded and no viable cells remain. Even a genome-based approach would have been judged entirely impossible a few years ago and is far from reality even now.

Still, several technical barriers have fallen in surprising ways. One barrier was that ancient DNA is always shredded into tiny pieces, seemingly impossible to analyze. But a new generation of DNA decoding machines use tiny pieces as their starting point. Dr. Schuster's laboratory has two, known as 454 machines, each of which costs \$500,000.

Another problem has been that ancient DNA in bone, the usual source, is heavily contaminated with bacterial DNA. Dr. Schuster has found that hair is a much purer source of the host's DNA, with the keratin serving to seal it in and largely exclude bacteria.

A third issue is that the DNA of living cells can be modified only very laboriously and usually at one site at a time. Dr. Schuster said he had been in discussion with George Church, a well-known genome technologist at Harvard Medical School, about a new method Dr. Church has invented for modifying some 50,000 genomic sites at a time.

The method has not yet been published, and until other scientists can assess it they are likely to view genome engineering on such a scale as being implausible. Rudolph Jaenisch, a biologist at the Whitehead Institute in Cambridge, said the proposal to resurrect a mammoth was "a wishful-thinking experiment with no realistic chance for success."

Dr. Church, however, said that there had recently been enormous technical improvements in decoding genomes and that he expected similar improvements in genome engineering. In his new method, some 50,000 corrective DNA sequences are injected into a cell at one time. In the laboratory, the cell would then be grown and tested and its descendants subjected to further rounds of DNA modification until judged close enough to that of the ancient species. In the case of resurrecting the mammoth, Dr. Church said, the process would begin by taking a skin cell from an elephant and converting it to the embryonic state with a method developed last year by Dr. Shinya Yamanaka for reprogramming cells.

Asked if the mammoth project might indeed happen, Dr. Church said that "there is some enthusiasm for it," although making zoos better did not outrank fixing the energy crisis on his priority list.

Dr. Schuster believes that museums could prove gold mines of ancient DNA because any animal remains containing keratin, from hooves to feathers, could hold enough DNA for the full genome to be recovered by the new sequencing machines.

The full genome of the Neanderthal, an ancient human species probably driven to extinction by the first modern humans that entered Europe some 45,000 years ago, is expected to be recovered shortly. If the mammoth can be resurrected, the same would be technically possible for Neanderthals.

But the process of genetically engineering a human genome into the Neanderthal version would probably raise many objections, as would several other aspects of such a project. “Catholic teaching opposes all human cloning, and all production of human beings in the laboratory, so I do not see how any of this could be ethically acceptable in humans,” said Richard Doerflinger, an official with the United States Conference of Catholic Bishops.

Dr. Church said there might be an alternative approach that would “alarm a minimal number of people.” The workaround would be to modify not a human genome but that of the chimpanzee, which is some 98 percent similar to that of people. The chimp’s genome would be progressively modified until close enough to that of Neanderthals, and the embryo brought to term in a chimpanzee.

“The big issue would be whether enough people felt that a chimp-Neanderthal hybrid would be acceptable, and that would be broadly discussed before anyone started to work on it,” Dr. Church said.

GROUP 3: FOR CLONING A MAMMOTH

Woolly Mammoth Resurrection, "Jurassic Park" Planned

Stefan Lovgren

National Geographic News

April 8, 2005

http://news.nationalgeographic.com/news/2005/04/0408_050408_woollymammoth_2.html

A team of Japanese genetic scientists aims to bring woolly mammoths back to life and create a Jurassic Park-style refuge for resurrected species. The effort has garnered new attention as a frozen mammoth is drawing crowds at the 2005 World Exposition in Aichi, Japan.

The team of scientists, which is not associated with the exhibit, wants to do more than just put a carcass on display. They aim to revive the Ice Age plant-eaters, 10,000 years after they went extinct.

Their plan: to retrieve sperm from a mammoth frozen in tundra, use it to impregnate an elephant, and then raise the offspring in a safari park in the Siberian wild.

"If we create a mammoth, we will know much more about these animals, their history, and why they went extinct," said Kazufumi Goto, head scientist at the Mammoth Creation Project. The venture is privately funded and includes researchers from various institutions in Japan.

Many mammoth experts scoff at the idea, calling it scientifically impossible and even morally irresponsible.

"DNA preserved in ancient tissues is fragmented into thousands of tiny pieces nowhere near sufficiently preserved to drive the development of a baby mammoth," said Adrian Lister, a paleontologist at University College London in England.

Furthermore, Lister added, "the natural habitat of the mammoth no longer exists. We would be creating an animal as a theme park attraction. Is this ethical?"

Ice Age Giants

Mammoths first appeared in Africa about four million years ago, then migrated north and dispersed widely across Europe and Asia.

At first a fairly generalized elephant species, mammoths evolved into several specialized species adapted to their environments. The hardy woolly mammoths, for instance, thrived in the cold of Ice Age Siberia.

In carvings and cave paintings, Ice Age humans immortalized the giant beasts, which stood about 11 feet (3.4 meters) tall at the shoulder and weighed about seven tons.

"It is hard to imagine that woolly mammoths browsed around the places where we live now, and our ancestors saw them, lived with them, and even hunted them," said Andrei Sher, a paleontologist and mammoth expert at the Severtsov Institute of Ecology and Evolution in Moscow, Russia.

At the end of the last ice age, about 10,000 years ago, woolly mammoths dwindled to extinction as warming weather diminished their food sources, most scientists believe.

There are believed to be ten million mammoths buried in permanently frozen soil in Siberia. Because of the sparse human population in the region, though, only about a hundred specimens have been discovered, including two dozen complete skeletons. Only a handful of complete carcasses have been found.

In 2002 hunters stumbled across the mammoth now on display in Japan. After a period of relatively warm weather, the head of the beast had been left protruding through the snow and ice cover.

Viable DNA?

The scientists with the Mammoth Creation Project are hoping to find a mammoth that is sufficiently well preserved in the ice to enable them to extract sperm DNA from the frozen remains.

They will then inject the sperm DNA into a female elephant, the mammoth's modern-day counterpart. By repeating the procedure with offspring, scientists say, they could produce a creature that is 88 percent mammoth within 50 years.

"This is possible with modern technology we already have," said Akira Iritani, who is chairman of the genetic engineering department at Kinki University in Japan and a member of the Mammoth Creation Project.

In 1986 Iritani's lab successfully fertilized rabbit eggs artificially, employing a technique now used in humans. In 1990 his colleague Goto, the Mammoth Creation Project head scientist, pioneered a breeding plan to save a native Japanese cow species by injecting dead sperm cells into mature eggs.

The current challenge, however, is finding viable woolly mammoth DNA. The DNA in mammoth remains found to date has been unusable, damaged by time and climate changes. "From a geologist's point of view, the preservation of viable sperm is very unlikely, and this is so far confirmed by the poor condition of cells in the mammoth carcasses," said Sher, the Russian paleontologist.

Current Siberian permafrost temperatures are 10 to 18 degrees Fahrenheit (minus 12 to 8 degrees Celsius), which may not be cold enough for DNA survival.

Sperm is not the only possible DNA source, and mammoth-elephant crossbreeding isn't the only potential way to resurrect the woolly mammoth.

An alternative method would be to clone a mammoth from DNA found in mammoth muscles or skin. To do this, however, scientists would need preserved cells with some unbroken strands of DNA.

"There is no evidence this exists, and even if it did, it is very unlikely to be preserved without significant errors having accumulated—probably leading to birth defects," said Lister, the London paleontologist.

Safari Park

The Japanese scientists, however, are not deterred.

Iritani is planning a summer expedition to Siberia to search for more carcasses. His team has already picked out a home for living mammoths in northern Siberia. The preserve, dubbed Pleistocene Park, could feature not only mammoths, but also extinct species of deer, woolly rhinoceroses, and even saber-toothed cats, he said.

"This is an extension of my work for the past 20 years in trying to save endangered species," Iritani said.

Other scientists are less enthusiastic about the project.

"Even if the cloning experiment is successful, they are not reconstructing the past but rather creating a new mammoth-like creature," said Anatoly Lozhkin, an Ice Age expert at the Northeast Interdisciplinary Scientific Research Institute in Magadan, Russia.

"Scientists are always able to learn from every experiment, but I am not sure that cloning a mammoth will help us significantly move forward our understanding of the animal or the conditions under which it lived," Lozhkin said.

GROUP 3: FOR CLONING A MAMMOTH

Resurrection of Mammoths Possible

By Margaret Munro

Canwest News Service

NOVEMBER 20, 2008

<http://www.canada.com/Resurrection+mammoths+possible+Researchers/976676/story.html>

The genetic blueprint for the woolly mammoth has been unveiled, fuelling speculation that extinct creatures, or their look-alikes, might one day walk the Earth again.

An international team has sequenced the nearly complete mammoth genome using hair samples from the shaggy beasts that had been frozen in the Siberian permafrost. The team, led by Stephan Schuster and Webb Miller at the Pennsylvania State University, describe the feat - which makes the mammoth the first extinct creature to be sequenced - in Thursday's issue of the journal Nature.

Resurrecting the iconic creature would not be easy, but scientists say genetic and reproductive technology is advancing so quickly that the idea of bringing the mammoth back to life is not as implausible as it sounds. As a first step they say mammoth look-alikes could be genetically engineered by adding genes for giant tusks and shaggy coats to modern-day elephants.

"For all practical purposes you could certainly have something that looked like a mammoth," says geneticist Hendrik Poinar, at McMaster University in Hamilton, who would like to see more debate about the ethics of resurrecting extinct animals. "There need to be rules in place."

Poinar says it may not be long before someone tries to build a theme park based on the Pleistocene era, which ended about 10,000 years ago.

"The Pleistocene Park would be a big money maker," with "the woolly mammoth ride" and "the sabre-toothed tiger run," Poinar said in an interview.

He chuckles at the possibilities, but says boundaries need to be put in place, as the technology is moving ahead so fast.

Not only are genetic blueprints for extinct animals spewing out of gene sequencing machines, but European researchers are now working on the genome for humans' closest relative, the Neanderthal, which could be published next year.

Gene sequencing is many times cheaper and faster than it was a decade ago and has transformed the task of reading a mammal's genetic blueprint from a years-long, multimillion-dollar endeavour to one that can be done in a lab within a few months.

Schuster and Poinar demonstrated the power of the "high-throughput" sequencing technology in 2006 when they made international headlines for sequencing the first chunk of the mammoth genome - 13 million base pairs, or biochemical units, of the sequence. The scientists then went

their separate ways, with Schuster's team carrying on to sequence the rest of the mammoth genome, which contains more than four billion base pairs.

Schuster's team used DNA extracted from the hairs of two mammoths that had been buried in the Siberian permafrost - one for 20,000 years and the second for at least 60,000 years. By using hair, Schuster says they avoided problems that have bedeviled the sequencing of ancient DNA from bones. He says DNA from bacteria and fungi can more easily be removed from hair, which encases and protects the ancient DNA like "a biological plastic."

Mammoths, which used to roam northern Europe and North America, are thought to have died off at the end of the last ice age because of environment changes and the arrival of big game hunters in North America, or a combination of both.

The genome is not much to look at - page after page of biochemical shorthand for the long strands of DNA found inside mammoth cells. But it speaks volumes to the scientists, who say it appears woolly mammoths had low genetic diversity. "Individual woolly mammoths were so genetically similar to one another that they may have been especially susceptible to being wiped out by a disease, by a change in the climate, or by humans," says Schuster.

Poinar's team in Hamilton has been charting the evolution and fate of the different mammoth subspecies using small chunks of their DNA and says he is looking forward to exploring this week's "data dump" by Schuster's team, which is posting the genome online. It will take time to make sense of it all, says Poinar.

But the scientists say it should not be too long before they identify genes the mammoth shared with its modern elephant cousins, and the genes that set them apart. By isolating the genes for distinctive features - like tusks and shaggy coats - Poinar and other geneticists say it should be possible to genetically engineer a "hybrid" that looks like a mammoth.

Poinar is not suggesting it should be done. "There is no other reason to do it other than for the 'Ooh Ahh'," he says. But that wow factor could be a powerful motivator, he says, noting that there is currently nothing to prevent the patenting of genes from extinct organisms, or putting look-alike creatures in amusement parks.

GROUP 3: FOR CLONING A MAMMOTH

Woolly Mammoth Genome Sequenced

By Thomas Claburn, Information Week

Nov. 19, 2008

<http://www.informationweek.com/story/showArticle.jhtml?articleID=212100912>

Just in time for global warming, scientists have sequenced the genome of the extinct woolly mammoth, last seen roaming the Earth about 10,000 years ago.

Just in time for global warming, scientists have sequenced the genome of the extinct woolly mammoth, last seen roaming the Earth about 10,000 years ago and in cudgel-and-sandals films like *10,000 BC*.

"Previous studies on extinct organisms have generated only small amounts of data," said Stephan C. Schuster, the Penn State University biochemistry professor who co-authored the new research, in a statement. "Our data set is 100 times more extensive than any other published data set for an extinct species, demonstrating that ancient DNA studies can be brought up to the same level as modern genome projects."

Schuster told The Associated Press that eventually it should be possible to re-create any extinct creature that lived within the last 100,000 years, given suitable genetic material.

That appears to preclude the sort of dinosaur theme park depicted in the film *Jurassic Park* -- the Jurassic period spanned from about 206 million to 144 million years ago.

However, Pleistocene Park has potential -- think saber-toothed tigers, giant ground sloths, and Neanderthal tour guides.

"[B]y deciphering this genome we could, in theory, generate data that one day may help other researchers to bring the woolly mammoth back to life by inserting the uniquely mammoth DNA sequences into the genome of the modern-day elephant," Schuster said in a statement. "This would allow scientists to retrieve the genetic information that was believed to have been lost when the mammoth died out, as well as to bring back an extinct species that modern humans have missed meeting by only a few thousand years."

For ancient humans, meeting a woolly mammoth may have been a real treat: According to the Mammoth Genome Project, "the enormous amount of meat coming from a six- to eight-ton animal ... would have fed 400 people for several weeks."

The natural refrigeration available when mammoth was "what's for dinner" may have made it possible to keep mammoth meat fresh for several weeks. Unfortunately, experiments suggest chilled mammoth meat probably smelled and tasted like Limburger cheese. Of course, hygiene standards, not to mention dietary options, were different then.

Before any of this happens, however the researchers -- from Penn State, the Severtsov Institute of Ecology and Evolution, the Zoological Institute in Russia, the University of California, the Broad Institute, Roche Diagnostics, and the Sperling Foundation -- have further work to do.

The genome data set now consists of 4 billion DNA bases, but Schuster and his colleagues believe that only 3.3 billion of them belong in the mammoth genome. The extra DNA bases could belong to bacteria, fungi, or something else that might have contaminated the genetic sample, comprised of hairs from a frozen mammoth recovered from the Siberian permafrost.

So the scientists have to clean up their genomic data. If and when tomorrow's aspiring P.T. Barnum decides to revive the species for science or showmanship, he won't want his woolly mammoth to have, say, a mushroom for a head.

To help arrive at a functional woolly mammoth genome, the researchers at the Broad Institute of MIT and Harvard are sequencing the genome of the African elephant for comparison.

"Only after the genome of the African elephant has been completed will we be able to make a final assessment about how much of the full woolly-mammoth genome we have sequenced," said Webb Miller, a professor of biology, computer science, and engineering at Penn State, in a statement.

This work, however, awaits further funding.