Case Study:
Should We Bring Back the Woolly Mammoth?

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ISU Bioethics Workshop 2009.
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Under revision by Clark Wolf, April 2016.

Background: Researchers have discovered remains of *woolly mammoths*, revealed because of the retreat of ancient ice in polar regions of the globe. These remains are very well preserved because they have been frozen since the death of the animals. One benefit we gain from these discoveries is, simply, a better understanding of Pleistocene life. But scientists have also been working to piece together a complete model of the mammoth genome.

This opens the possibility that scientists might be able to use this mammoth DNA to produce a new mammoth, using *somatic cell nuclear transfer*. If a complete mammoth genome could be found, then some hope that we might be able to *clone* a mammoth by inserting mammoth DNA into an egg cell taken from a modern elephant. Scientists would first remove the elephant DNA from the egg cell, and then insert the mammoth DNA in its place. The fertile cell could then be implanted in an elephant, where it would—scientists hope—develop and grow until its birth. Other scientists hope that we might gain information about the mammoth genome so that we could re-assemble a working copy, which could, once again, be used to clone a mammoth.

QUESTION: Should we do this?

Class Activity:

1) Show the following video in class: **Video on Mammoth Cloning from Discovery Magazine: http://news.discovery.com/animals/videos/are-we-finally-ready-to-clone-a-mammoth-video.htm**

Additional Teacher Resource: http://rw.mammoth.psu.edu/society.html

2) Reading Assignment: Everyone should read the articles on pp. 5-8, which provide background on mammoths and mammoth cloning.

3) Divide the class into four groups. Members of each group should think of themselves as representatives of a different interest group, to give testimony at a hearing held by the *United States Department of Pre-historic Recovery* (USDPR – fictionally established in 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.

4) Read the material associated with your assigned group, and then brainstorm arguments in support of the position of the group to which you have been assigned. It might help to make bullet points identifying different arguments, to be presented by different group members. Feel free to do some additional web research to find updated sources and materials on this topic!

Note: Materials included in your packet are *relevant* to the case you will need to make on behalf of your group, but you should use it to spur your own thinking. Create your *own* arguments on behalf of your group.

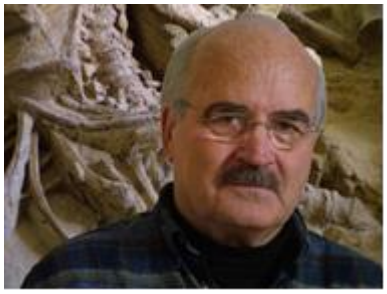
5) Your group will have 5-10 minutes to present your case to the USDPR, after which representatives from other groups will have an opportunity to ask questions or raise challenges.

PRESENTATION RULES:

*****Every group member should be involved to present one part of the case.
*You should not read your presentation (except perhaps very short quotations). Make the case in your own words.
*In your presentation, you should take on your role as a member of your assigned group. This means that instead of saying "This group holds that…" you should use the first person mode: "We believe that…"

Interest Groups:

Group I: Scientists In Favor of Mammoth Cloning: As representatives of this group, you should argue in favor of the project to clone a mammoth. Your reading, by Dr. Larry D. Agenbroad, a professor of geology at Northern Arizona University, addresses objections people have offered against mammoth cloning, but also provides positive arguments in favor of the proposal. Dr. Agenbroad has led mammoth excavations and made discoveries around the world. Most recently, his discovery of a woolly mammoth in Siberia was featured in a documentary for the Discovery Channel.



In his article, Dr. Agenbroad responds to 5 challenges concerning the morality of cloning extinct animals: (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 to bring a mammoth into the world through cloning. (e) Such an endeavor could release a plague of unknown diseases on Earth.

As representatives of this group, you should explain the arguments in favor of cloning a mammoth, and respond to concerns like those addressed by Dr. Agenbroad.

Group 2: Citizens Concerned about Cloning: (Note: CCC is a fictional organization created for this case study.) Citizens Concerned about Cloning is an organization that debates key controversies dealing with genetics and the use and manipulation of DNA in our world. These are people who generally feel that the science dealing with genetics have a very wide "gray area" and believe that we need to conduct more research before moving forward with cloning of endangered or extinct animals. Major arguments from this group are: (a) Our money is best used somewhere else (b) There are unforeseen side effects (c) Their natural environment does not exist anymore. As a representative of this group, you are a concerned citizen opposed to the project of mammoth cloning. (d)

Readings for this group include "Making a Mammoth Mistake" and "Cloning the Mammoth" Pg. 13-14"Cloning the Woolly Mammoth and Other Extinct Animals" Pg. 15-17

Group 3: Lobby of Science Enthusiasts In Favor of Mammoth Cloning: As a representative of this group, you are enthusiastically in favor of mammoth cloning, which may yield unknown benefits for science and for the environment. Using these techniques, we can bring back other extinct species, repairing some of the damage we have inflicted on global biodiversity. Overall, you should argue, the scientific benefits of this project completely outweigh the concerns of naysayers. Besides: cloning a mammoth would be *way cool!*

Readings: a. "Woolly Mammoth Resurrection, "Jurassic Park" Planned Pg. 18-20 b. "Resurrection of Mammoths Possible" Pg. 21-22 c. "Woolly Mammoth Genome Sequenced" Pg. 23-24

Group 4: Environmentalists and Animal Welfare Activists Against Mammoth Cloning: As a representative of this group, you are adamantly opposed to mammoth cloning. Reintroducing a species that has been extinct for so long could have unknown environmental effects, and is simply not worth it. Rather than spending this money to produce an individual animal, we should instead use it to protect vanishing species and restore damaged environmental systems. Reintroducing a mammoth would, in addition, be cruel to the animal produced: it would be lonely—the sole member of its species in existence—and it would be unhappy because the world has changed since mammoths roamed here, and there is no longer an environmental niche for mammoths.

Readings: a. "Bring Back the Woolly Mammoth?" and "Regenerating a Mammoth for $10 Million" Pg. 25-29

READING FOR EVERYONE:

Please read the following articles for background information on the Wooly Mammoth.

Mammoths, Gene Sequencing, Cloning, and Reintroduction of Extinct Species (Clark Wolf, June 2015)

Wooly mammoths looked like huge hairy elephants. They were a staple food source for some early human peoples, but they have been extinct for a long time. Mammoths lived from about 5 million years ago until about 4,300 years ago. There are different theories about why they went extinct, but it is possible that some mammoth populations were driven to extinction by human hunting. Near complete mammoth remains have been discovered in permafrost in several different places, but some of the best preserved specimens come from the Yakutia region in Siberia.

Some mammoth remains were well preserved. It is reported that ancient frozen mammoth meat was even served as an entrée for the New York *Explorers Club* in 1951. More importantly, mammoth remains contain DNA. In May 2015, scientists reported that they have managed to *sequence* the full genome from two different mammoths. (Cite: Palkoploulou, E. et al. 2015. "Complete Genomes Reveal Signatures of Demographic and Genetic Declines in the Woolly Mammoth. *Current Biology*. 25(10):1395-1400. 18 May 2015.)

Several different groups of scientists have considered the possibility that we might be able to re-produce mammoths from the recovered materials. One proposed method would involve sperm from a discovered mammoth. It might be possible to use this sperm to impregnate a modern female elephant, to produce offspring that would be mammoth-elephant hybrid. But there is reason to doubt that ancient mammoth sperm would be well enough preserved. And even if it were, there are additional reasons to doubt that such sperm would be compatible, and could be used to impregnate an elephant.

Another proposal would use mammoth DNA to *clone* a mammoth. Cloning has been already been successful in several mammal species. To clone a modern animal, scientists remove an egg cell from a living female animal. The nucleus of an egg cell contains half of the full compliment of DNA, to be combined with other DNA contained in the sperm. When scientists clone animals, they first remove the nucleus of the egg cell, and replace it with the full DNA from the animal to be cloned. Many different cells can be used as the source of this DNA. Once the DNA has been injected into the egg cell, it receives an electric shock to jump-start the process of cell division.

How could this technique be used to clone an extinct mammoth? One possibility is that scientists might find intact DNA in a recovered mammoth cell. If they do, they might be able to implant that DNA in an egg cell from an Asian elephant—a cell from which the nucleus has been removed. That cell could then be jump-started, then implanted for

gestation in a modern female elephant. If an animal developed from this embryo, it would have nuclear DNA from a mammoth. But other DNA in the cytoplasm of the cell—the area of the cell surrounding the nucleus, would still have mitochondrial DNA from a modern elephant.

Another possibility is that scientists might be able to use the information from the mammoth genome sequence, to put together a new genome that would have the same sequence. *That* DNA might then be implanted in a the denucleated egg from a modern elephant, to produce a cloned mammoth embryo.

There is yet another possible method that might be used to produce a mammoth: existing elephants could be modified, using genetic engineering. By making gradual changes in the elephant genome, elephants might be changed so that they are progressively more mammoth-like. In the end, after many small changes have been made, it might be possible to produce a true mammoth. New genetic engineering technologies make it easier and easier to make specific changes in DNA. These new techniques are already being used to adjust mammoth DNA.

The Ethical Question: Should we Produce a Cloned Mammoth?

Using these techniques, it may eventually become possible to produce a live mammoth. Should we do it? People disagree about whether it would be a good idea. Who will be responsible for the animal that might be produced? What kind of life would it have? What would we gain from reintroducing the mammoth? Some researchers imagine that we might reintroduce herds of mammoth to repopulate the tundra. Would reintroducing the mammoth undermine efforts to protect or reintroduce other species that are not yet extinct?

Shivers of Delight at Mammoth Find **Luke Harding, 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. (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.

Woolly Mammoth *Mammuthus primigenius*

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

Mammoths were closely related to modern day elephants.

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.

Pronunciation of scientific name: MAM-oth

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.

Readings for Group 1:

Mammoths: Resurrecting Extinct Megafauna

http://www.actionbioscience.org/biotech/agenbroad.html?print
Larry D. Agenbroad An ActionBioscience.org original article

The Woolly Mammoth at the Royal BC Museum, Victoria, British Columbia. Source: Wikimedia Commons.

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 Pribolofs, 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 Sahka (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.

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.
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 Haynes[9]).

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?

Larry D. Agenbroad, Ph.D., is director of the Mammoth Site of Hot Springs, South Dakota, and professor emeritus at Northern Arizona University. He has been actively researching the Quaternary period (2 million years ago to the present) since 1966, conducting geological, archaeological, hydrological, and paleontological research in the United States, Mexico, and Siberia. His work on Pleistocene fauna includes the Paleo-Indian Hudson-Meng Bison Kill Site, mammoth kill sites, continental North American mammoths, pygmy mammoths of the California Channel Islands, and mammoths of the Taimyr Peninsula of Siberia. He also studies the geology, archaeology, and paleontology of the Colorado Plateau. He has coauthored and edited several books as well as numerous professional presentations and publications. http://www.mammothsite.com/history.html

Group 2 Against Cloning

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.

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?

Cloning the Woolly Mammoth and Other Extinct Animals

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

By Allen Butler

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 3: Scientists and Science Enthusiasts For Mammoth Cloning.

Woolly Mammoth Resurrection, "Jurassic Park" Planned

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

Stefan Lovgren for National Geographic News April 8, 2005

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?"

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. 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.

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.

Resurrection of Mammoths Possible

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

BY MARGARET MUNRO, CANWEST NEWS SERVICE, NOVEMBER 20, 2008

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 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 bedevilled 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.

Woolly Mammoth Genome Sequenced

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.

By Thomas Claburn, Information Week Nov. 19, 2008
URL: 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 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.

Group 4: Environmentalists and Animal Welfare Supporters Against Mammoth Cloning

Bring Back the Woolly Mammoth?

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

November 23, 2008

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.

Regenerating a Mammoth for $10 Million

http://www.nytimes.com/2008/11/20/science/20mammoth.html?pagewanted=1&_r=1
November 18, 2008

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.

The quest is to clone a mammoth. The question is: should we do it?

After the dramatic display of a frozen carcass in Japan, the ethics of reviving an extinct species are under intense scrutiny

Robin McKie Saturday 13 July 2013 19.06 EDT Last modified on Wednesday 21 May 2014 20.31 EDT

http://www.theguardian.com/science/2013/jul/14/wooly-mammoth-extinct-cloning-dna

The idea would make headlines around the world and bring tears of joy to the planet's journalists. An adorable baby woolly mammoth, tottering on its newborn legs, is introduced to the media. Cloned from a few cells scraped from the permafrost of Siberia, the little creature provides the latest proof of the might of modern science and demonstrates the fact that extinction has at long last lost its sting.

It is a fascinating prospect, one that was raised again last week when the most recently discovered carcass of a mammoth was revealed to the public in Yokohama, Japan.

The female, thought to have been around 50 when she died, had lain frozen in the ground for tens of thousands of years. Yet she still had hair, muscle tissue, and possibly blood. Samples have now been sent to South Korea, where scientists say they are planning to use them to clone a mammoth, though the proposal is considered to be highly controversial.

"The hunt for mammoth corpses has been transformed in recent years," said Professor Adrian Lister, of the Natural History Museum, London, and one of the advisers for the museum's current "Extinction" exhibition. "We have found as many mammoths in the past five years as we did in the previous 50, partly because global warming is melting the Siberian permafrost and is revealing more and more bodies and partly because local people realise it is a lucrative business. Mammoth ivory is viewed as a legal and ethically acceptable alternative to elephant tusks.

"The only trouble is that every time a new well-preserved mammoth is found, people also repeat the claim that we will soon be able to clone them, and I very much doubt that we will."

Mammoths ranged from the British Isles to eastern Asia and northern America until they disappeared around 10,000 years ago, though one small population was recently found to have survived to around 4,000 years ago on the Russian island of Wrangel.

Hunting by cavemen or climate change, or a combination of the two, are generally blamed for their demise. Now some scientists are talking openly of bringing them back to life. Yokohama mammoth samples have been sent to the private laboratory of the disgraced South Korean cloning expert Hwang Woo-suk, who is co-operating with Russian scientists with the specific aim of recreating mammoths. Similarly, Semyon Grigoriev, who led the team that excavated the mammoth, has speculated that fluid found near the creature may be blood that contains intact cells which could be used to bring about their resurrection. "This find gives us a really good chance of finding living cells, which can help us implement this project to clone a mammoth," said Grigoriev.

The idea gathers little support from scientists such as Lister, however. "I very much doubt if the idea of cloning a mammoth is feasible," he said, a point that was backed by the molecular biologist Professor Michael Hofreiter, of York University.

"There are two ways that you could try to clone a mammoth," said Hofreiter. "The first is straightforward. You could simply look through the bodies we dig up in the Arctic to see if we could find one that had a cell that still contained a nucleus with a complete, viable genome in it.

"Then, employing the cloning techniques that were used to create Dolly the Sheep, we could put that nucleus inside an elephant embryo and then implant it into a female elephant, who would later give birth to a mammoth.

"The problem is that these creatures died many thousand years ago, when their DNA would have started to degrade, so the chances of finding an entire viable mammoth genome are essentially zero," he said.

There is another approach, however. Scientists could use the scraps of DNA they do find in preserved bodies to build up a map of a mammoth's genome. "Then you would use the same techniques that are employed in creating transgenic mice to make stretches of DNA – using your map as a guide – that you would then put into the embryo of an Asian elephant embryo which is the closest living relative of a mammoth," said Hofreiter.

"Bit by bit, you would continue with this process with separate pieces of mammoth DNA until you had completely replaced the DNA in your elephant embryo with mammoth DNA. You would now have an embryo with a mammoth genome it. This would then be placed in a female elephant in whom the embryo would develop to birth."

There are many difficulties with this approach, however. "A key point to remember is that elephants and mammoths each have about 4 billion DNA bases in their genomes," said Hofreiter. "However, the maximum size of the DNA section you can add is about 1 million bases. So you would have to repeat the process sequentially 4,000 times – without mishap – to create your mammoth embryo. The chances of that happening are also essentially zero." On top of these problems there is the simple issue of differences in proteins that exist between the Asian elephant that would be used as a surrogate mother and the mammoth embryo you have created. "It is quite possible that these differences would be big enough to make the embryo incompatible with the elephant. It is a further factor to suggest that mammoth cloning is not going to happen for a very long time indeed." For good measure, there are other concerns that make the idea of cloning animals such as the mammoth controversial, added Lister.

In particular, there is the question of the ethics involved. "Mammoths were very similar to elephants, we believe," he said. "In other words, they were highly social, intelligent creatures. What right have we got to recreate one or two and then keep them in solitary confinement at zoos or research facilities? I have problems with those who think this is not a real issue."

Several other concerns also trouble scientists. Species are now being wiped off the planet at a staggering rate. The WWF has suggested a figure of around 10,000 species a year, for example, though these figures are disputed by other scientists.

The crucial point is that resources are desperately needed to help slow down the rate at which animals and plants are being rendered extinct. As a result, the idea of investing large amounts of money on reviving special interest species while the natural world is dwindling as the climate changes and human populations soar is leaving many scientists uncomfortable.

"We shouldn't be piling our cash into projects that could resurrect an already extinct large mammal," said Lister. "We should be trying to help those who are now hovering at the edge of extinction today. That would be the best way to invest our money in conservation."

Washington Post: Can scientists bring mammoths back to life by cloning?

By Jackson Landers February 9, 2015

http://www.washingtonpost.com/national/health-science/can-scientists-bring-mammoths-back-to-life-by-cloning/2015/02/06/2a825c8c-80ae-11e4-81fd-8c4814dfa9d7_story.html

When Dolly the sheep was cloned from the mammary cell of a Finn-Dorset sheep in 1996, the public imagined growing identical copies of all sorts of animals. The process, known as somatic cloning, tempted us with the idea that if we could obtain just a single working nucleus from any cell, we could reproduce the entire animal.

Scientists' minds jumped quickly to woolly mammoths, which became extinct 4,000 years ago. The frozen carcasses that occasionally emerge from the Earth's melting permafrost offer a trove of well-preserved soft tissue and hair. The University of Pennsylvania has made major progress reconstructing the mammoth's genome. Two groups of scientists have announced plans to clone the mammoth. They're pursuing cloning to broaden our scientific understanding of the animals and hoping that putting mammoths back into certain Arctic habitats could help those ecosystems to function better after the relatively brief interval since they disappeared.

Frozen mammoths appear to provide all of the raw material necessary for rebuilding a living animal. In some cases, entire organs are intact. Blood, eyes and digestive matter have been found. But this isn't the same as having well-preserved tissue on a cellular and molecular level.

Some groups of scientists, including one led by Akira Iritani of Kyoto University and another at South Korea's Sooam Biotech Research Center (in partnership with Russia's North-Eastern Federal University) hope to extract functional cells from a frozen mammoth and use the genetic material in those cells to begin cloning.

Unless an organism contains some type of antifreeze, the freezing process tends to destroy cells. A steak in your freezer may look like a perfect slab of muscle and fat, but if you were to look at it under a microscope, you would see that as water within the tissue freezes, it expands and tears apart cell walls and other fine structures. Attempts at somatic cloning of mammalian cells that have been frozen for years have failed, with one possible exception.

Researchers at Japan's Riken Center for Developmental Biology claimed in 2008 that they had cloned mice from the brain cells of animals that had been frozen for 16 years. However, according to Teruhiko Wakayama, who conducted most of that work, no other laboratory has replicated those supposed results. If an extraordinary scientific claim cannot be replicated, that can be a warning sign that the research may have been flawed.

There is a substantial difference between 16 years ago and the Pleistocene epoch. Freezing a body does not halt change or decay. Enzymes in animals' bodies normally begin breaking down tissue soon after death. This enzyme activity isn't gentle on cell structures, but it is what makes aged beef more tender.

Freezing dramatically slows the action of these enzymes, but it does not stop it entirely. You probably wouldn't notice a steak's getting more tender after a year in the freezer. Give it a few thousand years, though, and the texture may improve. The cumulative effects of normal background radiation also gradually damages the DNA in frozen tissue.

George Church doesn't believe that the viable cells or nuclei sought by the Japanese and South Korean teams will be found in any frozen mammoth. A professor of genetics at Harvard Medical School and a vocal advocate for bringing extinct animals back to life, Church thinks that the route to a mammoth will have to be found elsewhere.

"Ten thousand years of radiation. In a frozen specimen that has no metabolism going on, it's accumulating and breaking into bits," he said. "That DNA will never function again. Their goal is a mammoth. Our goal is testing genes."

Other approaches: Skepticism about the cloning projects may be warranted. The Sooam Biotech Research Center is led by Hwang Woo-suk, a scientist who was first lauded for his breakthrough work in somatic cloning, including creating the world's first cloned dog — a service that the center advertises on its Web site.

In 2009, he was convicted of fraud for faking research into the cloning of human stem cells. Yoshiki Sasai, deputy director of the Riken Center, was embroiled in a similar fraud case and was found last summer to have failed to exercise oversight over Riken Center researchers who faked stem cell research. He committed suicide in August.

Church's efforts at Harvard appear more modest than the South Korean and Japanese projects. He hopes to identify mammoth genes associated with adaptation to cold weather and insert them into the nuclei of elephant cells. In fact, he asserts that this has already taken place.

"We have functioning elephant cells with mammoth DNA in them right now," Church said in an e-mail. "No failures so far as I know . . . We have CRISPR [a method of genetic manipulation] working in elephant cells and have made 14 changes in the genome fairly easily so far. Focusing on cold-resistance initially (blood, subcutaneous fat, woolly hair and external ear size)."

However, Church has not published this research in a journal. It is unusual for a scientist to publicly make such an extraordinary claim without providing evidence that can be evaluated for accuracy by their peers.

Others are taking a different route. By reconstructing the mammoth genome through a mosaic of samples, scientists might be able to engineer a cell nucleus and then use the somatic cloning method that led to Dolly the sheep.

What scientists have been able to get out of frozen mammoths is partial DNA. No single cell has given up a complete genome on its own, but by analyzing different samples from various mammoths, scientists with Pennsylvania State University's Mammoth Genome Project appear close to publishing a complete woolly mammoth genome. In a separate effort, Kevin Campbell of the University of Manitoba has used a fragment of DNA to replicate the oxygen-bearing hemoglobin that mammoths used to make.

The best source of mammoth DNA has not been the famed soft-tissue remnants but rather the hair. Each hair cell contains a complete genome encased in a protective coating.

Mammoths, like humans, were full of bacteria and viruses. The digestive tracts of the specimens that have been unearthed are filled with genetic material from plants they were eating. Contemporary and modern pollen may have dropped onto them. A frozen mammoth contains a lot of DNA other than mammoth DNA.

Part of the challenge of reconstructing the mammoth's genome has been sorting out this contamination. Scientists can wash and bleach mammoth hair in a manner not unlike the methods used by a good hairdresser. It is comparatively easy to remove contaminating DNA from hair as opposed to other cell types.

Packing an artificially reconstructed genome into the nucleus of a mammal's cell and making it function has never been done, and it would be a feat worthy of a Nobel Prize. With enough time and money, it may be possible to use a polymerase chain reaction (a way of copying small parts of DNA) to make millions of copies of Penn State's genome and place them into a modern elephant's living cell. Then scientists could prompt cell division and start growing a line of woolly mammoth cells. If they got that far, it isn't a stretch to suggest that they could fuse nuclei from those cells into elephant egg cells, stimulate them with an electrical current and start making blastocysts (very early-stage embryos), in much the same way that Dolly the sheep and many other mammals have been cloned.

SOURCES:

http://www.npr.org/2015/05/09/404661850/if-science-could-clone-a-mammoth-could-it-save-an-elephant

Excerpt: Interview with Beth Shapiro, author of *How to Clone a Mammoth.*

On techniques that could bring the mammoth back: Anyone who is determined to go out there and find a living mammoth cell is going to be sorely disappointed. There are other ways that we can do this though — not by cloning a mammoth but by editing the genome sequence of an elephant cell in a dish in a lab, using new genome editing technology, and swapping out bits of elephant sequence for the mammoth version of sequences that we think are important in making a mammoth look and act more like a mammoth than like an elephant. And this technology is possible for today.

Until we figure out how to meet the physical and psychological needs of elephants in captivity, they shouldn't be in captivity at all, much less being used to make mammoths. If we were to put that all aside, I don't want to see mammoths come back — it's never going to be possible to create a species that is 100 percent identical. But what if we could use this technology not to bring back mammoths but to save elephants?

What if we could use this technology to make elephants slightly better adapted to cooler climates, the type of place that mammoths used to live? We could then create more space for them. ... Mammoths and elephants have approximately 99 percent identical genomes. If we are talking about changing a few genes here and there to make them better adapted to living in the cold, I think we are talking about preserving elephants.

On the risk of releasing genetically engineered elephants: We don't know what's going to happen when we start messing around with reprogramming the genetic code to create Chihuahuas or Great Danes. And we don't seem to fear that. There's something more natural than going in and targeting a very specific gene that we have some idea of what it does. ...

I think that the key use of this technology ... is to protect species and populations that are alive today. Take, for example, the black-footed ferrets that are living across the plains of North America. Black footed ferrets nearly went extinct a couple decades ago because of extermination programs. Today, black-footed ferrets are threatened by a disease. What if we could use this same technology that we're talking about to go back in time, to sequence DNA of ferrets in museums somewhere that are decades or centuries or even thousands of years old, and find genetic diversity in those that we could then inject in the populations today that have no genetic diversity?

Maybe we could use this technology to give those populations a little bit of a genetic booster shot and maybe a fighting a chance against the diseases that are killing them. We're facing a crisis — a conservation, biodiversity crisis. This technology might be a very powerful new weapon in our arsenal against what's going on today. I don't think we should dismiss it out of fear**.**