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Resurrecting the Woolly Mammoth: Science, Law, Ethics, Politics, and Religion

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I. INTRODUCTION

¶1 In April 1984, MIT's *Technology Review*, the nation's oldest journal of science and technology, reported something extraordinary. In an article entitled "Retrobreeding the Woolly Mammoth," author Diana ben-Aaron announced to the world that the grand, shaggy icon of the Pleistocene had been brought back to life after ten thousand years of extinction.[1] The miraculous feat had been accomplished, according to the article, by a Soviet-American pair (a miracle itself in the midst of the Cold War); Dr. Sverbighooze Nikhiphorovich Yasmilov, head of veterinary research at the University of Irkutsk, and Dr. James Creak of the Massachusetts Institute of Technology. Yasmilov had apparently recovered viable ova from a young mammoth found frozen in Siberia, and had sent them to Creak for testing, who in turn extracted the nuclear DNA, aligned it with similarly-prepared DNA from modern elephant sperm, and concluded that the genetic material was compatible. After several botched attempts, the pair were able to fuse sperm from an Asian elephant bull with eight of the recovered mammoth ova, and using Asian elephant cows as surrogate mothers, created the world's first elephant-mammoth hybrid, subsequently christened *Elephas pseudotherias*, or "mammontelephas."[2]

¶2 News of the mammontelephas spread quickly. The story was picked up by the *Chicago Tribune* and its syndicates, and ultimately appeared in over 350 newspapers across the United States.[3] Frantic phone calls from Europe confirmed *Elephas pseudotherias*' status as an international bio-engineered celebrity, to be surpassed only by the Roslin Institute's cloned sheep "Dolly" some 13 years later.[4] It took a letter from the editor in a later edition of *Technology Review* to explain to the world that Ms. ben-Aaron's piece was a parody, the result of an assignment for an undergraduate writing class, which was subsequently published in the magazine in celebration of

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1 Diana ben-Aaron, *Retrobreeding the Woolly Mammoth*, TECH. REV., Apr. 1984, at 85.

2 *Id.*

3 John I. Mattill, *Our Shaggy Elephant*, TECH. REV., Oct. 1984, at 4.

4 I. Wilmut, A.E. Schnicke, J. McWhir, A.J. Kind & K.H.S. Campbell, *Viable Offspring Derived from Fetal and Adult Mammalian Cells*, 385 NATURE 810 (1997); Elizabeth Farnsworth, *Online NewsHour: Cloning Mammals – February 24, 1997* <http://www.pbs.org/newshour/bb/science/jan-june97/cloning2_2-24.html>.

April Fool's Day.[5] Apparently, not everyone could take a joke—or, perhaps it was just that retrobreeding the mammoth was no laughing matter.

¶3 Diana ben-Aaron's mammontelephas was a sham, but the public and media response that it elicited was all too real. Hoax or no hoax, the very idea of bringing the mammoth back from its icy grave—even a hybrid containing only a half-complement of mammoth genes—struck a nerve and raised issues sufficiently sensitive to command international headlines. Accordingly, the misconstrued prank foreshadows what might happen should legitimate reports of the successful resurrection of a mammoth (or other prehistoric beast) make headlines again. More importantly, the turmoil created by the hoax provides an opportunity to explore the complex ethical, legal, moral, environmental, religious, and political issues that will most certainly arise in the event of a genuine resurrection *before* the deed is actually done, and ultimately allows us to consider whether the international community should allow it to happen at all, or whether instead the very idea of cloning or retrobreeding extinct animals should itself go the way of the mammoth.

¶4 Such discussion is perhaps more urgent than one might expect; for a lot has happened since that fateful day in 1996 when the Roslin Institute brought Dollyinto the world. Advances in mammalian somatic cell cloning have led to the repetition of the procedure in at least two other species.[6] To date, proposed legislation and the moral, ethical, and legal debate over such technology have focused on its potential application to human beings[7]—perhaps explaining the relatively muted response to the arrival of these other clones—but as the world keeps its watchful eye on human cloning, perfection of the procedure in other mammalian species is silently paving the way for the successful resurrection of the extinct. In 1996, for example, a team of Japanese scientists, led by veterinary reproductive biologist Kazufumi Goto and geneticist Akira Iritani, began a quest for frozen Siberian mammoth sperm and viable DNA from the nuclei of other mammoth cells. The team intends to recreate either an elephant-mammoth hybrid, or to clone a pure-blooded beast using nuclear transfer technology.[8] And the Japanese effort is not alone. An international team of paleontologists led by Siberian explorer Bernard Buigues, and funded in part by the Discovery Channel, entered the race in October 1999, after pulling the remains of a 23,000 year-old mammoth from the Siberian permafrost about 200 miles outside of the Russian city of Khatanga.[9] Buigues' team, which includes French, Dutch, Russian, and American scientists, plans to send the remains of the mammoth (named "Zharkov") to a cryogenics laboratory in the United States where the reproductive approaches originally contemplated by Goto and Iritani may be employed if the remains prove to contain viable genetic material.[10]

¶5 Should researchers ultimately follow through with such attempts, the world will find that there is very little law in place to stop, or even regulate them. Few, if any, countries have thought seriously about the myriad practical, ethical, moral, religious,

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5 Mattill, *supra* note 3.

6 Davor Solter, *Dolly* Is *a Clone—and No Longer Alone*, 394 NATURE 315 (1998).

7 *See* note 137 *infra.*

8 Richard Stone, *Cloning the Woolly Mammoth*, DISCOVER, Apr. 1999, at 58, 62.

9 Maggie Fox, *Mammoth Plucked Out of Ice in Siberia After 23,000 Years, It May Be Cloned*, SAN DIEGO UNION & TRIB., Oct. 21, 1999, at A9, *available in* 1999 WL 4091710.

10 *Id.*

and political implications of cloning animals, let alone "waking the dead". A society that chooses to undertake such a project will be confronted with issues ranging from animal rights, to environmental concerns, to the moral and religious implications of reversing the "natural" biological process of extinction. Current laws and policies, which were not designed to deal with such issues, may yield surprising or even alarming results when applied to the cloning of extinct animals.

¶6 Regretfully, though the ideas and techniques contemplated by Goto's and Buigues' teams are remarkably reminiscent of ben-Aaron's fantasy, the Associated Press and other news media have completely disregarded the campus prank, instead comparing the efforts to Michael Crichton's omni-popular novel, *Jurassic Park*, in which a brood of resurrected dinosaurs cloned from preserved DNA goes awry and wreaks havoc upon the guests of a prehistoric theme park.[11] It seems that awe and fear have already—perhaps inevitably—supplanted prudent reasoning, as is often the case when an idea from science fiction seeks to cross the evidently "forbidden" line into science fact. This rash sensationalism on the part of the media emphasizes the need for informed and careful forethought on the issue; for, if either team's efforts bear fruit, convincing the international community of the safety and potential benefits of the project will now undoubtedly be an uphill battle. Reasoned discourse on the ethical, legal, and social implications of the resurrection of an extinct animal is needed now to pave the way for public support to avoid a negative response by a misinformed public later.

¶7 This paper begins with an introduction to the woolly mammoth: its taxonomy, history, natural habitat, and a comparison of its biology and anatomy with that of living elephants. Part II examines the plausibility of the two approaches to resurrection originally proposed by Goto and Iritani. Finally, Part III focuses on the inevitable controversy that will surround any attempted resurrection once the necessary genetic material is acquired.

¶8 In the end, careful consideration of the arguments for and against resurrecting the mammoth leads to the conclusion that the potential benefits—particularly the knowledge that can be gained and the potential application of similar procedures to endangered species—can be made to outweigh the risks if researchers proceed with caution and act in compliance with certain ethical standards and procedural safeguards. This paper recommends what these standards and safeguards should be, and how the international community should proceed to ensure that the beneficial applications of the project are realized, and that the risks and abuses are kept to a minimum.

II. THE FAMILY TRUNK: TAXONOMY, ANATOMY, BIOLOGY, AND NATURAL HISTORY OF THE WOOLLY MAMMOTH

¶9 Woolly mammoths are classified in the order Proboscidea and in the family Elephantidae, which includes the two genera and species of living Proboscideans, *Elephas maximus* (the Asian or Indian elephant), and *Loxidonta africana* (the African elephant).[12] They are members of the extinct genus, *Mammuthus*, which appeared

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11 Tim Johnson, *Scientist Planning to Resurrect Woolly Mammoth is Not Joking*, JAPAN TIMES, Jan. 4, 1998 (visited Jun. 23, 1999) <http://trussel.com/prehist/news50.htm>; *Japanese Scientists Seek to Re-Create Woolly Mammoth*, ASSOCIATED PRESS, Aug. 19, 1996.

12 The Elephant Information Repository, *Stories & History* (visited Feb. 17, 2000) <http://elephant.elehost.com/About_Elephants/Stories/stories.html>; The Elephant Information Repository, *Evolution* (visited Feb. 17, 2000) <http://elephant.elehost.com/About_Elephants/Stories/Evolution/evolution.html>. *(footnote continued)*

in sub-Saharan Africa during the middle Pliocene epoch (approximately 3-4 million years ago) and included about 20 species, three of which lived on the mainland of the United States at the end of the Pleistocene epoch (50,000-10,000 years ago): *Mammuthus columbi* (the Columbian Mammoth), *Mammuthus jeffersonii* (Jefferson's Mammoth), and *Mammuthus primigenius* (the Woolly Mammoth).[13] The woolly mammoth is the youngest of the *Mammuthus* species, evolving in Eurasia between 500,000 and 120,000 years ago, and later migrating to the Americas across the Bering Strait.[14]

¶10 People often confuse mammoths with the much older and more primitive mastodonts (genus *Mammut*, also commonly, but erroneously, called "mastodons"), which first appeared by the early Miocene epoch (approximately 20 to 25 million years ago).[15] In fact, the family Mammutidae (which includes the mastodonts) diverged from its common ancestor with the family Elephantidae (which, again, includes the mammoths, Asian and African elephants) as early as 30 million years ago, making the mastodont only distantly related to the relatively young mammoth.[16] By contrast, the mammoth and both species of living elephant diverged from a common ancestor on the surviving branch of Proboscideans somewhere between three and five million years ago.[17] The mastodont, therefore, emerged, evolved and disappeared as a separate taxonomic family along a parallel, but unconnected evolutionary path.

¶11 Most relevant to this discussion is the relationship between the mammoth and the two surviving species of elephant. *Mammuthus*, including the woolly mammoth, seems to be more closely related to the Asian elephant than to the African elephant. *Loxodonta africana* probably branched off from the common ancestor of the family Elephantidae about three to four million years ago, while *Mammuthus* and the Asian elephant diverged from one another as many as one to two million years later.[18] Recent analysis of mammoth DNA taken from frozen Siberian specimens by Naoki

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At least one source has classified the forest-dwelling African pygmy elephant as a third living species, *Loxodonta cyclotis* (*see* Ivan T. Sanderson, *Elephants*, *in* 10 ENCYCLOPEDIA AMERICANA 210 (Int'l. ed. 1998)), but the current consensus is that this smaller variety of the African elephant is merely a subspecies, *Loxodonta africana cyclotis*, *see* PBS Online, *Nature: The Elephants of Africa* visited Feb. 17, 2000) <http://www.pbs.org/wnet/nature/elephants/html/intro.html>.

[13] The dates in this discussion have been pieced together from various sources, many of which conflict quite seriously. They therefore reflect best estimates, in most cases determined by the number of sources in agreement. The recentness of each of the sources has also been considered, though it appears that the precise origins and evolutionary relationships of the Proboscideans are still largely unknown. *See* GARY HAYNES, MAMMOTHS, MASTODONTS, AND ELEPHANTS: BIOLOGY, BEHAVIOR, AND THE FOSSIL RECORD 3, 5 (1991); Ulf Carlberg, *The Mammoth Saga* (visited Jun. 19, 1999) <http://www.nrm.se/virtexhi/mammsaga/mammut.html.en>; Illinois State Museum, *Mammoths* (visited Jun. 19, 1999) <http://www.museum.state.il.us/exhibits/larson/mammuthus.html>.

[14] Carlberg, *supra* note 13; Illinois State Museum, *supra* note 13.

[15] HAYNES, *supra* note 13, at 4.

[16] PETER D. WARD, THE CALL OF DISTANT MAMMOTHS: WHY THE ICE AGE MAMMALS DISAPPEARED 81 (1997).

[17] Stone, *supra* note 8, at 59; Grant Keddie, *Relationship Between Modern Elephants and Some of Their Ancestors*, DISCOVERY MAGAZINE (visited Apr. 24, 1999) <http://rbcm1.rbcm.gov.bc.ca/discover/ds24295/img_ds/chart.jpg>.

[18] Here, in particular, sources conflict on the precise dates of the emergence of the Elephantidae, and the divergence of the mammoths, African, and Asian elephants from each other. Richard Stone claims that the divergence occurred five million years ago, but Peter Ward proposes a divergence from a common ancestor as recently as three million years ago. Gary Haynes dates the emergence of each of the three genera at four million years ago (supported by references elsewhere in Stone's article that conflict to some degree with his date of five million years ago). *See* HAYNES, *supra* note 13, at 5, 8; WARD, *supra* note 16, at 81; Stone, *supra* note 8, at 59-60; Keddie, *supra* note 17.

Suzuki of the Jikea University School of Medicine seems to confirm that the mammoth is genetically closer to the Asian than to the African elephant.[19] Japanese geneticist, Tomoo Ozawa, who has performed separate genetic analysis on mammoth remains, has in turn concluded that the Asian elephant is more closely related to the extinct mammoth than it is to its living African counterpart.[20] Interestingly, despite its genetic similarity to the Asian elephant, the mammoth is believed to have had more chromosomes than either of the two living species, both of which have 56.[21]

¶12 Anatomical similarities support this proposed taxonomy, since the mammoth, for the most part, resembles the Asian elephant more than the African. Both the mammoth and Asian elephant, for example, have domed foreheads in profile, while the African has an angled forehead.[22] The head is carried above shoulder level in both of the former genera, while the African elephant's shoulders and back are the highest point in profile.[23] Female mammoths and female Asian elephants are also fairly similar in stature. The average shoulder height for a female woolly mammoth was approximately 230-250 centimeters, which is about the same as Asian females. African females are slightly larger, at 260-300 centimeters.[24]

¶13 All three genera have trunks that are fundamentally similar, though each features its own slight anatomical peculiarities. The Asian elephant, for example, features a single fingerlike projection at the anterior of the trunk's tip, whereas the mammoth had two such projections, one at the front and one at the back. The African elephant falls somewhere between, with a fingerlike projection at the front and a broader projection at the rear.[25] Overall, though, the profile of the mammoth, and of the woolly mammoth in particular, would have been quite similar to that of the Asian elephant, except that the mammoth's shoulders, spine, and thick mass of woolly hair would have created a larger hump.[26]

¶14 On the other hand, even the mammoth and Asian elephant possess certain anatomical differences that are quite striking. Mammoth limb bones, for example, were much greater in diameter than those of either Asian or African elephants, though they were similar in length.[27] This would have made the mammoth a much heavier creature than either of the modern elephants.[28] The skin of woolly mammoths, perhaps surprisingly, seems to have been thinner on average than that

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[19] *Nova: Mammoths of the Ice Age* (Nova Productions television broadcast, in association with WGBH, 1995) (transcript on file with Stanford Technology Law Review).

[20] Johnson, *supra* note 11.

[21] *Id.*; Elefant-Konsult, *The Absolut Elephant Homepage: Elephant Consultance, FAQ File* (visited Apr. 11, 1999) <http://www.elephant.se/main.htm>.

[22] HAYNES, *supra* note 13, at 12.

[23] *Id.*

[24] Mammoths, like modern elephants and most large mammals, however, exhibited a high degree of sexual dimorphism. The average shoulder height of a male woolly mammoth was a whopping 300-350 centimeters, while that of the male Asian elephant is a mere 250-275 centimeters. In this respect, the woolly mammoth more resembles the African elephant, which has an average male shoulder height of 310-350 centimeters. *Id.* at 12 and 15.

[25] *Id.* at 10.

[26] *Id.* at 12.

[27] *Id.* at 23.

[28] WARD, *supra* note 16, at 132.

of either species of modern elephant.[29] It was also almost entirely covered with a dense coat of woolen underfur (which, of course, gave the beast its common name), from which long, straight, coarse hairs emerged. The coat served to help maintain the animal's body temperature, a potentially important factor in its survival during the last Ice Age.[30] Modern elephant skin, by contrast, is relatively bare.

¶15 The ears of the woolly mammoth were also much smaller than those of either Asian or African elephants, and were shaped rather like the ears of humans, as compared to the ears of modern elephants, which are, quite astonishingly, shaped like maps of India and Africa, respectively.[31] The smaller size was almost certainly another adaptation to prevent heat loss from the extremities.[32] As for tusks, both male and female mammoths had them, but most female Asian elephants do not. Mammoth tusks were, further, more dense and elastic than those of modern elephants, and grew more spirally and in tighter curves.[33] Finally, the mammoth seems to have had a much larger heart than either of the two living species of elephant, another likely adaptation to the much colder Pleistocene climate in which the mammoth had to circulate greater quantities of blood in order to survive.[34]

¶16 Mammoths and modern elephants seem to have exhibited significant physiological differences as well. The gestation period of mammoths, for example, was probably quite a bit longer than that of the living taxa.[35] Further, the mammoth's larger weight and body mass, resulting in part from the thicker and denser bone composition, would have made it slower and dependent upon greater nutrient intake than the modern elephant.[36] Differences in dental structures, particularly in the molars, also suggest that mammoths had diets that were quite distinct from those of living taxa, though all three genera appear to have had similar digestive systems.[37] Finally, some studies of growth lines in the tusks of woolly mammoth remains suggest that sexual maturity was reached at age 18-20, compared with age 12-15 in modern species.[38]

¶17 Despite these rather significant differences, most paleontologists seem to agree that, on the whole, mammoths and modern elephants were very similar in anatomy, physiology, and behavior.[39] However, "even minor differences can be crucial in deciding which species survives and which goes extinct."[40] The short of it, of course, is that the mammoth did go all-but extinct at the end of the Pleistocene,

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29 HAYNES, *supra* note 13*,* at 32.

30 *Id.* at 32-33.

31 *Id.* at 35.

32 *Id.*

33 *Id.* at 41.

34 *Nova: Mammoths of the Ice Age*, *supra* note 19. For more detailed discussion of the anatomical similarities and differences between *Mammuthus*, *Loxodonta*, and *Elephas*, see HAYNES, *supra* note 13, at 10-47.

35 WARD, *supra* note 16, at 132.

36 *Id.*; HAYNES, *supra* note 13, at 87.

37 *Id.* at 87-88; WARD, *supra* note 16, at 132.

38 HAYNES, *supra* note 13*,* at 65, 328.

39 WARD, *supra* note 16, at 130.

40 *Id.* at 132.

approximately ten thousand years ago.[41] The last few holdouts of the species followed suit on Wrangel Island off the northern coast of Siberia approximately four thousand years ago (after the Egyptians built the pyramids at Giza, as many mammoth enthusiasts like to point out).[42] Why the mammoth met its demise when it did is "a rather famous scientific puzzle,"[43] but most scientists attribute its extinction to a combination of changes in the climate and ecosystem at the end of the Pleistocene, and improved hunting techniques and increased population sizes of Paleolithic peoples.[44] For our purposes, suffice it to say that *Mammuthus* most certainly died out for some reason, while *Elephas* and *Loxidonta* did not. As noted by anthropologist Gary Haynes:

> Those extinct forms—the genera *Mammuthus* and *Mammut*—were so similar to the modern elephants of Africa and Asia in terms of anatomy, ecology and behavior that it is sensible to discuss them together, and yet somehow there were sufficient differences among the proboscideans that while the majority were dying out, two species managed to survive the end of the Pleistocene.[45]

Which leads us to that irresistible "baited hook" of a question: Can the woolly mammoth be brought back from its frozen grave after thousands of years of extinction, and if it can, is the human race justified in reversing time and evolution to reunite it with the two surviving members of its family?

III. Science Fiction or Science Fact?: Can the Mammoth Be Resurrected?

> We are a long, long way from being able to reconstruct the DNA of extinct creatures, and in fact it may be impossible to resurrect the DNA of dinosaurs or other long-extinct forms. We have DNA for living creatures, including ourselves, and yet we cannot clone any living animal (from DNA alone). As for extinct taxa, it is unclear whether or not DNA actually can survive more than a few thousand years. No one has been able to demonstrate incontrovertibly, as of yet, that they can retrieve DNA from an extinct species.[46]

¶18 So wrote Montana State University paleontologist Jack Horner, but Kazufumi Goto and Akira Iritani believe otherwise. Since 1996 the Japanese team has braved the brutal Siberian wilderness more than once to pan for mammoth remains, determined to strike gold.[47] White frozen gold, actually—the preserved mammoth sperm that will, at least in theory, be the raw material for either of two proposed techniques to resurrect *Mammuthus primigenius*. Goto and Iritani believe that one of the two methods will work, because "no other scientist can deny [their] theory."[48]

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41 Illinois State Museum, *supra* note 13.

42 Stone, *supra* note 8, at 59; Ulf Carlberg, *The Extinction of the Mammoth* (visited Jun. 19, 1999) <http://www.nrm.se/virtexhi/mammsaga/dismamm.html.en>.

43 HAYNES, *supra* note 13, at viii.

44 Carlberg, *supra* note 42.

45 HAYNES, *supra* note 13, at vii.

46 Jack Horner, *Scientific American: Ask the Experts FAQ File* (visited Apr. 29, 1999) <http://www.sciam.com/askexpert/biology/biology1.html>.

47 Stone, *supra* note 8, at 59, 62-63; *Japanese Scientists Seek to Re-Create Woolly Mammoth*, *supra* note 11.

48 Johnson, *supra* note 11.

But is either of their planned approaches really grounded in sound scientific principles, or, as many skeptics submit, have the Japanese and international teams both seen one too many Steven Spielberg films?[49]

A. *Possible Scientific Approaches to Resurrecting the Mammoth*

¶19 THE HYBRID APPROACH: Goto's first proposed method (which is also being contemplated by Buigues' international team) is, in essence, the reverse of that suggested by Diana ben-Aaron in her April Fool's Day prank. The idea is relatively simple: find X-chromosome-bearing mammoth sperm with intact DNA and inject it into an Asian elephant egg to produce a hybrid mammoth-elephant embryo. The hybrid embryo, if viable, would be implanted into an adult female Asian elephant, which would then give birth to the first-ever half-extinct creature.[50] Only X-chromosome-bearing sperm would be used to ensure that the offspring was female.[51] Once the female hybrid reached sexual maturity, she would be impregnated with more X-chromosome-bearing mammoth sperm and so on, until a creature genetically close to *Mammuthus primigenius* was procured.[52] Each successive generation would be increasingly "woollier," increasingly less elephant, and increasingly more "mammoth."

¶20 THE CLONING APPROACH: Goto's second approach (also adopted by Buigues' team) involves the cloning of *Mammuthus primigenius* from ice-preserved somatic cells in a procedure similar to that used by Ian Wilmut at the Roslin Institute in 1996 to create another woolly marvel, the now illustrious magazine cover star, Dolly.[53] With Dolly, Wilmut and colleagues fused the nuclei of adult sheep mammary gland cells with enucleated sheep oocytes, thereby replacing the haploid genome of the egg cell with a fully-functional diploid copy of the adult sheep's genome.[54] Once fertilization mode was induced in the sample embryos through a shock of electricity, 29 of 277 successful fusions (11%) developed to the multi-cellular blastocyst stage. Only 1 of the 29 blastocysts (3%) successfully developed into a live lamb after implantation.[55] Dolly was the first clone ever produced using the nuclear DNA of a fully-differentiated adult somatic cell.[56]

¶21 Goto's team intends to employ the same nuclear transfer technique to resurrect a mammoth from intact DNA that it hopes to find preserved in the nucleus of a somatic cell from a frozen mammoth. Once the requisite genetic material is in hand, the team will fuse or inject the mammoth's genome into an enucleated Asian elephant egg, jolt it with electricity to induce fertilization mode, and implant the

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49 *Id.*

50 Stone, *supra* note 8, at 58.

51 *Id.*

52 Johnson, *supra* note 11.

53 Wilmut, *supra* note 4.

54 NATIONAL BIOETHICS ADVISORY COMM'N, CLONING HUMAN BEINGS 22 (June 1997).

55 *Id.*

56 Though no attempt was made at the time of nuclear transfer to document that the donor cells were fully differentiated, doubts that Dolly was derived from a fully-differentiated cell have been largely laid to rest by forensic DNA testing that has shown that she is indeed the direct descendant of a differentiated udder cell. In addition, adult somatic cell cloning has now been replicated in mice and in cows, confirming the scientific validity of the technique. Solter, *supra* note 6.

resulting embryo in an Asian elephant surrogate for gestation.[57] Fusion would be preferable to the injection approach, since it would transfer *all* the mammoth's cellular components into the elephant egg, including the mitochondria, which contain additional genes of their own.[58] The result would presumably be a purer mammoth than if only the mammoth cell's nucleus were transferred, since the additional DNA from the mitochondria (mt-DNA) would complete the transferred mammoth genome, while the former approach would leave part of the genome behind in the donor cell.

¶22 OTHER APPROACHES: Two other approaches not considered by Goto or the international team are worth mentioning briefly, though neither is feasible with current technology. The first of these is the precise approach described by ben-Aaron: to use preserved mammoth ova and elephant sperm to create a hybrid, or better still, to use both preserved mammoth ova and sperm to create a pure-blooded mammoth. This approach, however, is unlikely to succeed, since according to Goto's research to date, an egg cell killed by repeated freezing and thawing *never* yields a viable embryo, regardless of whether the sperm is living or dead.[59]

¶23 A second approach, which might be employed in the case where the DNA collected from mammoth remains is partly degraded, involves the use of polymerase chain reaction (PCR) technology and DNA sequencers to amplify and sequence fragments of the mammoth's DNA, with an ultimate goal of piecing a complete genome together.[60] If this "jigsaw puzzle" approach were successful, the complete sequence that resulted could be compared to the modern elephant's genome, and could perhaps some day be created from the latter by using germ line gene therapy to convert the elephant's DNA to the mammoth's, gene by gene. Though gene therapy of this magnitude is currently still the stuff of science fiction, it is likely to become increasingly feasible as biotechnology advances in the coming years.

B. *Problems, Obstacles, and the Feasibility of the Hybrid and Cloning Approaches*

¶24 THE SEARCH FOR VIABLE GENETIC MATERIAL: In getting the ball rolling for either the hybrid or cloning approach, researchers will first face the formidable task of finding a mammoth whose genetic material has remained intact over thousands of years, harbored still by the icy cuirass of the Siberian permafrost. For the hybrid approach, according to Goto, just finding sperm will be enough in itself, since sperm cells are "'very, very tough' in terms of their ability to withstand environmental stress"[61]—so tough, he believes, that the DNA contained within could remain functional and complete, even after millennia of freezing and thawing.

¶25 Goto's earlier research into the durability of sperm DNA was, in fact, the inspiration for the mammoth project in the first place.[62] In the early stages of his career as a veterinary reproductive biologist, while breeding cows to improve the

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57 Stone, *supra* note 8, at 58.

58 NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 20.

59 Johnson, *supra* note 11.

60 ARIZONA STATE UNIV. DEP'T OF BIOLOGY, *Chemical Synthesis, Sequencing, and Amplification of DNA* (last modified Aug. 19, 1998) <http://photoscience.la.asu.edu/photosyn/courses/BIO_343/lecture/DNAtech.html>.

61 Johnson, *supra* note 11.

62 Stone, *supra* note 8, at 59.

quality of Japan's beef, Goto discovered that sperm cells themselves are actually already dead at the moment of fertilization when oocytes envelop their DNA. The next step after this discovery was to determine how long a sperm cell could be dead before its DNA was no longer viable. Subsequent experiments proved that DNA in mouse and bull sperm remained intact even after dozens of freezings and thawings that destroyed the cells' membranes and stopped their metabolisms. Goto then injected the dead sperm into a cow egg and achieved cleavage, proving that sperm need not be alive to fertilize an oocyte and create a viable embryo.[63]

¶26 But alas, even if the results of Goto's bull sperm experiments are replicable with ten-thousand-year-old mammoth sperm, the team first has to find a mammoth carcass complete with testicles and sperm, not an easy task in light of the fact that only three whole-body specimens have officially been discovered in the last one hundred years.[64] Though smaller sections of mammoth flesh are discovered every year (e.g. a headless, but otherwise intact specimen discovered in Ust-Yansky in 1997),[65] even these are often lost to dogs, erosion, illegal ivory hunting, and scavenging by wild animals before scientists can get a look.[66] Those that do survive discovery by modern plunderers almost invariably appear to have been fed upon to some extent by scavengers before their carcasses froze thousands of years ago, and their soft tissues have slowly decayed as a result.[67] Finally, the barren, snow-covered Siberian landscape, where any intact specimen will most probably be found, is vast, sparsely populated, and difficult to navigate. This inaccessibility not only explains why so few intact specimens have been reported to date, but also acts as an additional obstacle that any research team will have to surmount before they can begin "panning" for mammoth sperm.[68]

¶27 Though early reports by the media claimed that "Zharkov," the mammoth excavated by Buigues' team, was nearly intact, Alexei Tikhonov of the Zoological Institute in St. Petersburg and other team members have asserted that the remains most likely include only mammoth wool, bones, and a small piece of skin.[69] Though a full analysis of the remains will not be conducted until April of 2000, the team's real contribution to the mammoth cloning effort seems to be the development of a technique that will enable a whole mammoth to be excavated in one piece, if an intact specimen is ever found.[70]

¶28 The discovery hurdle for the cloning approach is slightly lower, since the chances of finding some part of a mammoth intact are certainly greater than the chances of finding the testicles and sperm intact. Ideally, of course, Goto and others would like to find a frozen mammoth embryo with undifferentiated cells like the ones used to create clones decades before the arrival of Dolly; but since the chances of finding one are probably close to zero, scientists are hoping for the next best thing—preserved adult somatic cells with intact nuclei and unbroken DNA, or

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63 *Id.*

64 Johnson, *supra* note 11.

65 *Siberian Hunters Uncover Mammoth Remains*, 388 NATURE 510 (1997).

66 HAYNES, *supra* note 13, at 47.

67 *Id.* at 48.

68 *Id.* at 55.

69 Michael Steen, *Russian Says Mammoth Specimen Is Not Complete*, DESERET NEWS, Oct. 21, 1999, at A2.

70 *Id.*

even better, undifferentiated stem cells from the tissue of the testicles or ovaries, which give rise to sperm and eggs.[71] Stem cells would be a better option, since they are pluripotent or totipotent, capable of developing into many or all cell types, respectively; [72] but, of course, like the hybrid approach, this would require tissue from the mammoth's gonads, which a team of scientists is unlikely to come across.

¶29 The more realistic cloning approach would therefore employ differentiated adult somatic cells—those in which particular genes within the nucleus have been "activated" to perform a specific task (e.g. muscle cells, liver cells, and neurons)[73] and which comprise virtually every part of the mammoth's body. Differentiated cells are less desirable for cloning than stem cells since, unlike the latter, their genomes must be "reprogrammed" (i.e. the necessary genes must be "switched off and on" again to return the DNA to its original pluripotent or totipotent state) before they can develop into a new organism once injected into an enucleated egg. They are most likely the best that Goto, Buigues, or other scientists will have to work with, however, since they are present to some extent even in specimens that contain little flesh or blood. Cloning experiments from the 1970s all the way through Dolly have shown that genes contained in the nuclei of differentiated somatic cells can, in fact, be "reactivated by the cytoplasm of the egg and thus direct normal development . . . ."[74]

¶30 Of course, not just any adult somatic cell can serve as a donor in the cloning approach, since the DNA inside the cell's nucleus must also be intact. Unfortunately, in contrast with the DNA that would likely be present in a hard-to-find sperm cell, "the DNA recovered from [the somatic cells of] long-extinct creatures is severely degraded, and therefore unsuitable for any future reconstruction attempts."[75] The repeated freezing and thawing of mammoth remains in the Siberian permafrost only adds to the problem. Moreover, the only significant DNA that has been recovered from mammoths to date is a few short fragments of mitochondrial DNA, rather than the DNA of the nucleus required for nuclear transfer and cloning.[76] Thus, even in the somatic cell cloning approach, Goto and Buigues have a rather large obstacle to surmount before they can begin to clone the mammoth. Nevertheless, since even a single intact cell from anywhere on the mammoth's body can serve as the raw material for a cloning attempt, it seems at least possible that the hurdle can be overcome.

¶31 FERTILIZATION, CLEAVAGE, AND EX VIVO EMBRYONIC DEVELOPMENT: The hybrid approach presents an additional set of obstacles in the fertilization, cleavage, and pre-transfer embryonic development processes that the cloning approach avoids. For example, as mentioned briefly in the previous section, it is believed that the mammoth has more chromosomes than the Asian or African elephant, both of which have 56.[77] Though horses, which have 64 chromosomes, can successfully

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[71] Stone, *supra* note 8, at 62.

[72] Davor Solter & John Gearhart, *Putting Stem Cells to Work*, 283 SCIENCE 1468 (1999).

[73] NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 17.

[74] *Id.* at 18.

[75] Thomas Lindahl, *Scientific American: Ask the Experts FAQ File* (visited Apr. 29, 1999) <http://www.sciam.com/askexpert/biology/biology1.html>.

[76] *Id.*

[77] Johnson, *supra* note 11.

breed with donkeys, which have only 62,[78] few other cross-species fertilizations have proven successful where disparate numbers of chromosomes are involved. Goto and Iritani are encouraged by the fact that British scientists have successfully produced hybrid calves from Asian and African elephants, particularly in light of the recent confirmations that Asian elephants are genetically closer to woolly mammoths than they are to African elephants;[79] but this apparent genetic relatedness does not necessarily solve the problem of incongruous numbers of chromosomes, which may very well make the two species' DNA incompatible, causing developmental complications even before fertilization is complete.

¶32 Scientifically speaking, fertilization refers to the penetration of the secondary oocyte by the spermatozoon *and* the subsequent fusion of the male and female pronuclei (i.e. the haploid nuclear material in the head of the sperm and in the ovum, which fuse to reestablish diploidy).[80] In mammalian zygotes, this fusion—and, by extension, the process of fertilization itself—is not actually complete until *after* the pronuclei migrate toward the center of the egg and the chromosomes align themselves upon a single mitotic spindle, which mediates the first mitotic cleavage division of the zygote.[81] In other words, a true diploid nucleus in mammals is not formed in the zygote, but in the 2-cell stage instead, after the first cleavage has already occurred.[82] The fertilization process is, thus, longer and more complex in mammals than it is in other forms of life, reaching completion only after the zygote splits into an embryo. This may be important in the case of a disparate number of chromosomes in light of recent studies in mammals suggesting that the sperm-derived genome and egg-derived genome are functionally different, playing *complementary* roles during early development (a phenomenon known as "genetic imprinting").[83] If an unequal number of chromosomes align on the two sides of the mitotic spindle, for example, and the sperm- and egg-derived genomes play complementary roles in mediating the first mitotic division, it is conceivable that the extra chromosomes on the sperm side (i.e. those without complements on the egg side) will throw the heritable imprint "off-line," creating complications in the cleavage process, thereby disturbing fertilization before the pronuclei are actually fused.

¶33 Of course, even if the mammoth and Asian elephant had equal numbers of chromosomes, disparities between the two species' arrangements of genes in the genome could throw off the stability of the genetic imprint, disturbing fertilization and the development process. For example, it is known that disturbances in imprinting lead to growth abnormalities in mice and are associated with cancer and rare genetic conditions in human children.[84] On the other hand, as mentioned above, an unequal number of chromosomes does not seem to disturb the

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[78] Meredith Hodges, *Mule Facts* (visited Dec. 1, 1999) <http://www.willman.com/muletrainer/mulefact.htm#different>.

[79] Johnson, *supra* note 11.

[80] STEDMAN'S MEDICAL DICTIONARY 637, 1438 (Marjory Spraycar ed., 26th ed. 1995).

[81] Bruce Alberts, Dennis Bray, Julian Lewis, Martin Raff, Keith Roberts, & James D. Watson, MOLECULAR BIOLOGY OF THE CELL 1033 (3d ed. 1994); SCOTT F. GILBERT, DEVELOPMENTAL BIOLOGY 148 (4th ed. 1994).

[82] *Id.*

[83] *Id.*; NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 23.

[84] *Id.* at 23-24.

fertilization and development of mules, and placement of genes on the genome is evidently not a problem in cross-breeding the more distantly related *Loxodonta africana* with *Elephas maximus*. Nevertheless, the possibility of complications remains; for even if the sperm and egg genomes differ only slightly, far too little is known about the genetics of mammoths to predict with any certainty the outcome of an attempt at *in vitro* cross-fertilization.

¶34 Fertilization, moreover, is only the tip of a very large iceberg. As its definition suggests, it is really no more than a genetic "foot in the door." For example, in mammals, unlike most other categories of life, the embryonic genome is activated very early in development, usually between the late 1-cell (zygote) stage and the 16-cell stage, depending on the species.[85] This means that mRNA synthesis, or transcription, begins in the mammalian embryo almost immediately after fertilization is complete. Variances in the mammoth and elephant genomes may, therefore, express themselves at very early stages of embryonic development. Concurrent expression of two such distinct sets of genes may interfere with normal development and stop embryonic development in its tracks.

¶35 The cloning technique envisioned by the Japanese and international teams bypasses virtually all of the obstacles stemming from cross-species fertilization and genome conflict during embryonic development, since the enucleated recipient egg used to clone a mammoth would contain only the very small amounts of elephant DNA present in the egg's mitochondria. Any conflicts arising from this minor mismatch would most certainly be less significant than those in the hybrid approach, and could probably be eliminated, in any case, by fusing the entire donor cell of the mammoth (mitochondria and all) with the recipient egg. Thus, as before, the cloning approach appears to be the more promising one.

¶36 EMBRYONIC TRANSFER AND FETAL DEVELOPMENT: Both the hybrid and cloning approaches may face problems in embryo transfer from test tube (or other *ex vivo* medium) to the Asian elephant surrogate. Complications with subsequent fetal development in the womb may also be encountered, since "[t]he development of an organism is a complex orchestration of cell divisions, cell migrations, cell interactions, gene regulation, cell deaths, and differentiation[, and a]ny agent interfering with these processes can cause malformations in the embryo."[86]

¶37 In both approaches, for example, the early embryo could conceivably express mammoth proteins that cause the surrogate elephant's body to reject and abort it. Even in pure-blooded same-species embryo transfer—human test tube babies, for example—pregnancy is achieved no more than thirty percent of the time.[87] For that matter, up to two-thirds of embryos formed in *natural* human pregnancies fail to develop successfully to term, many of these expressing genetic abnormalities so early that they fail to implant successfully in the uterus.[88] The contemporaneous expression of potentially conflicting genomes can only compound what is, even naturally, an extremely delicate and complicated biological process.

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[85] In humans, for example, mRNA synthesis begins at the 4-cell stage, in mice at the 1- to 2-cell stage, and in cows and sheep at the 8- to 16-cell stage. GILBERT, *supra* note 81, at 481; NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 23.

[86] GILBERT, *supra* note 81, at 633.

[87] HARRISON'S PRINCIPLES OF INTERNAL MEDICINE 2109 (Anthony S. Fauci, Eugene Braunwald, Kurt J. Isselbacher, Jean D. Wilson, Joseph B. Martin, Dennis L. Kasper, Stephen L. Hauser & Dan L. Longo eds., 14th ed. 1998).

[88] GILBERT, *supra* note 81, at 633-34.

¶38 In the event that the hybrid or cloned mammoth embryo does successfully implant, the Asian elephant's anatomical variances from the woolly mammoth may still cause complications with *in vivo* fetal development. The mammoth genome (or mammoth half of the genome, in the case of the hybrid), for example, will code for thicker, denser bone composition than an ordinary Asian elephant fetus' genome would, making the fetus significantly larger and heavier than the elephant's womb was designed to support. The apparently similar body size and shape of the two species does not necessarily preclude such a scenario. On the contrary, there is a direct correlation between body size, weight, and length of gestation, such that a larger, heavier species like the mammoth would require more time to develop in the womb than the lighter and leaner elephant.[89] Since the *mother's* anatomy, biology, and genetics play an integral role in determining the gestational period and inducing labor,[90] it seems inevitable that the gestational period will be too short for a mammoth, or even a hybrid fetus, to develop fully to term, resulting in a premature birth.[91] This may be a major pitfall in either team's plan, as preterm mammals are often confronted with functional and structural immaturity of the organ systems, and "infants born before completion of the normal gestation period have higher morbidity and mortality rates than full-term infants."[92]

¶39 Moreover, as discussed in the previous section, the mammoth's larger size and heavier weight would increase nutritional requirements relative to the lighter Asian elephant fetus,[93] which may present another problem in the development of a mammoth or hybrid fetus. Maternal malnutrition is a factor commonly associated with prematurity and underdevelopment, and it is possible that the lack of a properly increased supply of nutrients to a more needy mammoth or hybrid fetus would yield similar results.[94] By the same token, since vigorous fetal growth in the latter part of pregnancy places heavy demands on the uteroplacental supply line, uteroplacental insufficiency might result from an inadequate "elephant" placenta (compared to a larger-than-normal fetus), leading to growth retardation in the mammoth or hybrid.[95]

¶40 FERTILITY AND REPRODUCTION: The hybrid approach carries with it a final and unique set of obstacles that make it highly undesirable. Even if all goes according to plan and a hybrid mammoth-elephant is born, it is quite possible that such a hybrid will be sterile. In the case of the mule, for example, the disparity in chromosomal numbers between horses and donkeys (which have 64 and 62, respectively) results in an offspring with 63 chromosomes, which interferes with the

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89 WARD, *supra* note 16, at 132.

90 Thomas R. Moore, *Pregnancy, Gestation*, in 7 ENCYCLOPEDIA OF HUMAN BIOLOGY 68 (Renato Dulbecco ed., 2d ed. 1997).

91 In humans, for example, infants born in multifetal pregnancies are more vulnerable to prematurity, early death, and disability than babies born in single deliveries. More than half of all multiple births, in fact, are low birth weight compared with six percent of singleton births, and complications rise precipitously with each additional fetus in the uterus, the most common negative effect being early gestational age at delivery. This suggests very strongly that the mother's body would not adapt or compensate very well for an abnormally heavy hybrid fetus. *Id.* at 72.

92 ROBBINS PATHOLOGIC BASIS OF DISEASE 432, 434-35 (Ramzi S. Cotran, Vinay Kumar & Stanley L. Robbins eds., 5th ed. 1994).

93 HAYNES, *supra* note 13, at 87; WARD, *supra* note 16, at 132.

94 ROBBINS PATHOLOGIC BASIS OF DISEASE, *supra* note 92, at 434.

95 *Id.* at 433.

process of meiosis, rendering the mule sterile.[96] Since this is not the case with the swamp buffalo and river buffalo, which can produce fertile offspring despite having a different number of chromosomes,[97] it is impossible to tell in advance which of the two paths the mammoth-elephant hybrid will follow. The existence of sterile hybrids, however, certainly points to infertility as another potential obstacle in any plan to impregnate successive generations of hybrids to create an increasingly pure-blooded beast. The cloning approach, of course, would avoid this obstacle.

¶41 Moreover, as mentioned in the previous section, studies of growth lines in the tusks of woolly mammoth remains suggest that sexual maturity was reached at age 18-20, compared with age 12-15 in modern Asian and African elephants.[98] Even if we adopt Goto and Iritani's optimistically low estimate of 10-15 years old for sexual maturity in a mammoth-elephant hybrid, it could take half a century or more to arrive at a near-pedigree specimen, particularly since gestation would last a minimum of 600 days for each successive offspring.[99] Again, using the cloning approach would avoid such a horrible inconvenience, as the first generation would already be a pure-blooded mammoth. Thus, for these reasons alone, the hybrid method would not be the method of choice, even if its success were a scientific guarantee.

¶42 PROBLEMS UNIQUE TO THE CLONING APPROACH: Though the cloning approach is by far the more preferable and feasible one, it does present its own set of obstacles that must be overcome if any team is to produce a woolly mammoth. Aside from the difficulty of finding the requisite somatic or stem cells intact, several scientific uncertainties still remain about cloning in general, and particularly somatic cell cloning.

¶43 First, though somatic cell cloning appears to be possible with sheep, mice, and cows, the process may not be reproducible with many other species.[100] As the National Bioethics Advisory Commission (NBAC) explains, the regulatory proteins of a differentiated donor nucleus must be replaced by those of the egg *before* embryonic gene activation ensues if it is to reactivate its genes in time to redirect development in the embryo.[101] As explained earlier in this section, different species of mammal undergo embryonic gene activation and transcription at different times, all of them earlier than in many non-mammalian species. In sheep and cows, such activation occurs in the 8- to 16-cell stage—relatively late in the development process—which is presumably one of the reasons why both make excellent candidates for somatic cloning.[102] Thus, gene activation occurs late enough in the development of sheep and cow embryos that the egg may replace the regulatory proteins of the donor nucleus with its own in time for reactivation of the nucleus to occur. In mice, embryonic gene activation occurs at the 1- to 2-cell stage,

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96 Hodges, *supra* note 78.

97 Stone, *supra* note 8, at 58.

98 HAYNES, *supra* note 13, at 328.

99 Stone, *supra* note 8, at 62.

100 *See id.*; NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 23.

101 *Id.*

102 GILBERT, *supra* note 81, at 481. A team of Japanese scientists at the Ishikawa Prefectural Livestock Research Center in Oshimizu, Japan, in fact successfully cloned twin calves using adult somatic cells on July 5, 1998, proving that the technique used to create Dolly is scientifically sound. *Mother of Cow Clones Dies*, ASSOCIATED PRESS, July 6, 1998 <http://abcnews.go.com/sections/science/DailyNews/calfclone 980706.html>.

making nuclear transfer in general much less successful in that species (though not impossible, as T. Wakayama and coworkers have successfully cloned mice from the nuclei of adult somatic cumulus cells).[103] Thus, if gene activation occurs late in the mammoth embryo, as it does for sheep and cows, the chances of successful nuclear fusion or transfer are high; but, if activation occurs earlier in development, as it does for mice and humans, successful nuclear transfer and the reprogramming of the undifferentiated nucleus may be more difficult to achieve.

¶44 On a similar note, the phenomenon of genetic imprinting, explained earlier in this section, could cause problems in the nuclear transfer or fusion process. To recapitulate, genetic imprinting refers to the nonequivalence of mammalian pronuclei, such that the sperm- and egg-derived genomes are functionally different, playing complementary roles during development.[104] When copies of both the paternal and maternal genomes are present in the embryo, development usually progresses normally, but when an imbalance between the two occurs (e.g. wholly maternally-derived embryos, as in "parthenogenesis"), instability of the heritable imprint contained in the chromosomes usually results, leading to fatal growth abnormalities.[105] In the case of nuclear transfer, the donor nucleus' preexisting diploid genome (whether taken from embryonic or adult somatic cells) may differ slightly from that created during natural fertilization by the fusion of sperm- and egg-derived haploid pronuclei, despite the fact that such preexisting nuclei were themselves once derived from precisely such a fusion. The result could be an imprint that is not stable enough to support normal development when used in a cloning experiment.[106] By the same token, mutations in the genomes of adult somatic cells, which inevitably occur over time as the cell repeatedly ages and divides, may cause serious genetic defects in an organism derived therefrom. Normally, such mutations occur only at the level of the individual cell and its progeny (e.g., an individual skin cell and the skin cells that it ultimately gives rise to); but if such a mutated cell's nucleus were to be transferred into an oocyte as the basis for a new somatically-cloned organism, the mistakes and alterations would be copied into every cell in the clone, possibly leading to developmental diseases or cancer.[107]

¶45 Finally, cellular aging itself, regardless of mutations in the genome, may lead to adverse consequences in the clone because of the progressive shortening of the telomeres, or ends of the chromosomes, in the adult donor cell.[108] With age, even normal adult cells lose their ability to replicate because of the shortening of the telomeres, and this may cause serious developmental problems in the clone that an older cell gives rise to. While it is thought that the egg environment has the potential to reset telomere length because of the presence of the enzyme telomerase,[109] recent studies of Dolly's telomeres suggest that this is, at least

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[103] NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 23; T. Wakayama, A.C.F. Perry, M. Zuccotti, K.R. Johnson & R. Yanagimachi, *Full-Term Development of Mice from Enucleated Oocytes Injected with Cumulus Cell Nuclei,* 394 NATURE 369 (1998).

[104] GILBERT, *supra* note 81, at 148.

[105] NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 23.

[106] *Id.*

[107] *Id.* at 24.

[108] *Id.*

[109] *Id.*

sometimes, not the case. It appears, in fact, that Dolly's telomeres are much shorter than those of age-matched non-clone controls, and instead are consistent with the age of her six-year-old progenitor's mammary tissue.[110] As the Roslin Institute concludes, "[f]ull restoration of telomere length did not occur because [Dolly was] produced without germline involvement."[111] Thus, depending on the age of the mammoth donor nucleus at the time of freezing, a clone's cells might reach a critical telomere length sooner than a naturally-born mammoth's would, perhaps even before a proper fetus could develop at all.

¶46 Many of these cloning-specific problems and obstacles will be avoided if researchers are lucky enough to find viable stem cells, but as mentioned, the chances of finding such cells with their DNA still intact seem quite slim. In any case, even with these added obstacles, somatic cell cloning seems to be a more realistic possibility than the hybrid approach. Dolly, Wakayama's cumulus-cell-cloned mice, and the Ishikawa Center's twin calves are, after all, living, breathing illustrations of the scientific possibility of creating a somatic clone. Since the technique works in several different species, the most difficult obstacle on the path of cloning the woolly mammoth may, in fact, be the initial discovery of a viable donor nucleus. Somatic cell cloning of the type used to create Dolly, in any case, is only a few years old, and technology is likely to improve dramatically in this field over the next several years, pushing Goto and Buigues' dreams of resurrecting a mammoth close enough to the border of science fact to warrant a discussion of whether the procedure, if scientifically possible, should be carried out.

IV. THE PROS AND CONS OF "PLAYING GOD": SHOULD THE MAMMOTH BE RESURRECTED?

> To those against it, cloning presents as much a moral problem as a technical problem. For them, cloning is an affront to religious sensibilities; it seems like "playing God," and interfering with the natural process. There are, of course, more logical objections, regarding susceptibility to disease, expense and diversity. Others are worried about the abuses of cloning. Cloning appears to be a powerful force that can be exploited to produce horrendous results.[112]

¶47 Take all of the fire, fury and emotion of the post-Dolly cloning controversy, add to it the eerie "sacrilege" of the return of the ten-thousand-year-old walking dead, and throw in the paranoia of a potential ecological, environmental, and evolutionary Armageddon, and one begins to get a feel for the societal hysteria that might ensue if a woolly mammoth were brought back to life. While some will find the idea of cloning a woolly mammoth or any other extinct creature awesome and worthy of every scientific effort, others will inevitably find it positively repugnant. Considering the worldwide reaction to the successful cloning of Dolly and the subsequent moratorium on human cloning that followed, there is little doubt that the Japanese team, Buigues' team, or anyone else who might attempt to resurrect the

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110 Paul Shiels, Alexander J. Kind, Keith H.S. Campbell, David Waddington, Ian Wilmut, Alan Colman & Angelika E. Schnieke, *Analysis of Telomere Lengths in Cloned Sheep*, 399 NATURE 316, 317 (1999).

111 *Id.*

112 Kayron Fatahalian, Bennett Scheider & Brandon Reavis, *Anti-Cloning Research; Conceiving a Clone* (visited May 2, 1999) <http://library.advanced.org/24355/data/reactions/cons.html>.

mammoth, will encounter serious opposition to the project if and when the procedure becomes a more certain scientific possibility.[113]

¶48 It would be wise, if at all possible, to establish some sort of global consensus on the issue before misconceptions and hype have an opportunity to replace informed thought and wise decision-making, as was largely the case with the immediate post-Dolly human cloning "crisis." Just as NBAC concluded upon careful consideration of that issue, "[t]he challenge to public policy [here] is to support the myriad beneficial applications of this new technology, while simultaneously guarding against its more questionable uses."[114] In order to achieve this rather lofty goal, the "beneficial" must first be distinguished from the "questionable," a challenge all its own. As is the case with any attempted categorization by a lone individual, some will have doubts, and others will strongly disagree with my view of the potential harms and benefits of resurrecting the mammoth. I will therefore attempt to be objective in identifying the issues and arguments, and save my own opinions and recommendations for the conclusion of this paper.

A. *Arguments In Favor of Resurrecting the Mammoth*

¶49 A MAMMOTH MILESTONE: The immediate argument in favor of cloning the mammoth is to do it simply because it has never been done before. From this point of view, the project can be rationalized as a scientific achievement, a milestone for humankind, not unlike the "small step/giant leap" of landing on the moon, climbing Mt. Everest, or making a genetic duplicate of a Scottish sheep, for that matter. Such activities bring meaning to life and humanity for some, providing a sense of accomplishment, achievement, and progress for the species as a whole. For others, resurrecting the extinct in particular would provide a feeling of timelessness and immortality—of mastery over nature. Such an accomplishment might also help restore confidence in the awe and wonder of science in the eyes of the general public.

¶50 RESEARCH, EDUCATION, AND LEISURE: By the same token, resurrecting a mammoth would provide scientists and curious tourists alike with a unique and unprecedented opportunity to view and study an extinct species firsthand. For the layperson, the mammoth would be an educational and entertaining attraction, a welcome addition to museums, zoos, and nature preserves. The Japanese team has, in fact, already proposed that the first resurrected beasts be released in a 160-square kilometer preserve called "Pleistocene Park," located near the renowned mammoth site, Duvannyi Yar in Siberia.[115] The site is already home to Yakutian horses, moose, reindeer, and a herd of bison that were reintroduced to the region in 1998

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113 President Clinton announced a five-year moratorium on human cloning and related research in 1997 consistent with a recommendation by NBAC. *See Cloning Moratorium* (National Public Radio broadcast, June 10, 1997) <http://www.npr.org/news/health/970610.cloning.html>. In 1998, the American Medical Association called for its own voluntary five-year moratorium on human cloning. *See* Joan Drummond, *AMA Recommends Voluntary Moratorium on Human Cloning* (Feb. 17, 1998) <http://www.ama-assn.org/ad-com/releases/1998/980218a.htm>. Further, in the United States, several federal bills were introduced to ban or regulate human cloning after Dolly. For a complete summary of proposed federal and state legislation, see Kenton Abel*, 1997 California Legislative Service 688 (West)—Human Cloning*, 13 BERKELEY TECH. L.J. 465, 466 nn.6 & 7 (1998). Other bills were introduced at both the state and federal levels after Chicago Physicist Richard Seed announced that he would attempt to clone a human being, but only the State of California has passed an anti-cloning bill to date. For discussion of action taken in Europe, see *id.* at 467 n.14.

114 NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 107.

115 Stone, *supra* note 8, at 63.

with the hopes that the animals will tear up the existing moss and shrubs to allow for return of the grasses that dominated during the Ice Age.[116]

¶51 For the scientist, the opportunity to study a mammoth firsthand would shed light on the many questions that remain about its anatomy, biology and behavior, and would also provide valuable insight into the ecosystems and environment of the Pleistocene. Even more exciting to some is the prospect of solving that "rather famous scientific puzzle"[117] of why the mammoths and mastodonts disappeared when they did, and why elephants did not. Goto and others are hopeful that comparing mammoth and elephant genes will help to resolve this hotly-debated age-old conundrum.[118]

¶52 INTRODUCING THE MAMMOTH BURGER: On the slightly less serious side, some have proposed that the mammoth, once resurrected, be farmed for its meat in the tradition of the hamburger, bison burger, and ostrich burger. Canadian science fiction writer Robert J. Sawyer has even written a television skit on the subject that proceeds as follows in the year 2020.

> (ROB): We're serving, for the first time in close to ten thousand years, fresh mammoth meat!
>
> (JAY): You've cloned mammoths?
>
> (ROB): Not exactly. Rather, I financed an expedition to Siberia to locate a frozen male mammoth with testes and sperm still intact. We finally found one, and we used that sperm to impregnate a modern elephant. By inbreeding the offspring, we were able to concentrate the mammoth genes; we've now got what's essentially almost all mammoth.
>
> (JAY): (DISGUSTED): And now you're going to eat it?
>
> (ROB): Only one; we've produced a whole herd. But, yes, we're going to eat one—it's a five-thousand-dollar-a-plate dinner. A century ago, there was a banquet in Russia where they served frozen ancient meat from a recovered mammoth carcass. *That* strikes me as disgusting; what we're doing is just animal husbandry . . . I created these animals, Mr. Ingram; they're my property to do with what I please.[119]

¶53 Though Sawyer's script was clearly intended to be humorous, it was also likely inspired by Goto's project and its international counterpart. The passage quoted above also brings to light one argument against resurrecting the mammoth, namely that the unfortunate clone and its progeny might be exploited and reduced to no more than an Ice Age commodity. This argument will be discussed in more detail below. For now, suffice it to say that farming the mammoth for its meat would presumably be a possibility, and for some, may be an argument in favor of resurrecting the beast. It is interesting to note that Goto began his career as a veterinary reproductive biologist using artificial insemination methods to develop

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116 *Id.*

117 HAYNES, *supra* note 13, at viii.

118 Johnson, *supra* note 11.

119 Robert J. Sawyer, *2020 Vision (Rehearsal Transcript): Resurrecting Mammoths* (broadcast Feb. 27, 1998) <http://www.sfwriter.com/20mammot.htm>.

Japanese beef with more marbling to compete with American steak, though this is probably no more than a coincidence.[120]

¶54 APPLICATION OF PROCEDURE TO ENDANGERED SPECIES: One compelling argument in favor of resurrecting the mammoth is that the project will contribute invaluable knowledge to the fields of conservation biology and veterinary reproductive biology, even if the project's immediate goal of creating a mammoth ultimately fails. Currently, conservation biologists fertilize the eggs of endangered species with frozen sperm to combat the difficulties of reproduction in captivity and to ultimately help preserve species in the wild. Species such as the red wolf, Eld's deer, black-footed ferret, and common marmoset have already benefited from such efforts.[121] Goto himself, in fact, spearheaded an emergency effort to rescue an endangered breed of cow from Kuchinoshima Island off the southern tip of Japan using such procedures in the early 1990s. His partner, Akira Iritani, is part of Kinki University's participation in the "Frozen Zoo" project, an international effort in which zoos exchange samples of frozen semen to assist one another in species conservation.[122] Meanwhile, the Wildlife Breeding Resource Center (WBRC) in Pelindaba, South Africa, has been employing similar technology to preserve endangered African species, and maintains the Genome Resource Bank for Africa, a frozen repository of sperm, egg cells, and embryos, which serves as a frozen fallback population to resurrect species in the event that the wild and captive populations die out.[123]

¶55 From a certain point of view, "re-creating a mammoth is not so far removed from what conservation biologists are doing regularly now [in the Frozen Zoo project and WBRC, i.e.,] using new reproductive technologies in the fight to save endangered species".[124] Technology similar to that proposed by Goto is, in fact, presently being employed in Japan in an effort to save the Japanese ibis, of which only two remain. The procedure involves the injection of Japanese ibis cells into the embryo of a closely-related ibis species. The hope is that a resulting hybrid can then be crossed again with cells from the Japanese ibis, creating successive generations of an increasingly purer species.[125]

¶56 Even more ambitious are attempts by several teams in several nations to *clone* endangered species. A Chinese team at the Chengdu Zoo, in conjunction with the Sichuan United University's biology department, for example, has successfully cloned an isolated gene of a Giant Panda. The goal, of course, is to employ such technology to clone the entire endangered animal, of which only one thousand still exist.[126] Still more remarkable is the attempt by a Thai team to resurrect an individual white elephant that died over a century ago. Scientists at Mahidol University in Bangkok intend to use genetic material from the preserved remains of a prized specimen owned by King Rama III (ruled 1824-51) to create a clone. White elephants are considered to be a symbol of luck in Thailand, and King

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120 Stone, *supra* note 8, at 58.

121 *Id.* at 62.

122 *Id.*

123 WildNet Africa, *Clone Rangers* (Dec. 1997/Jan. 1998) <http://www.wildnetafrica.com/wildlife articles/keepingtrack/1998/clonerangers.html>.

124 Stone, *supra* note 8, at 62.

125 WildNet Africa, *supra* note 123.

126 *Id.*

Rama's specimen allegedly possessed the finest characteristics of an adult male.[127] According to the team, the project was inspired by Goto's efforts to re-create the mammoth in Japan.[128]

¶57 Goto believes that the mammoth project will contribute essential knowledge and technology to the Frozen Zoo project and other global efforts to preserve rare, endangered, and extinct species, particularly since, in the case of the Frozen Zoo and Genome Resource Bank for Africa, it is still unknown how long the frozen DNA can remain intact. As he explains, "if we examine the state of frozen-preserved cells of ancient animals, this knowledge will help predict the fate of cells we started to preserve by freezing and improve the method of preservation."[129] Moreover, according to Kurt Benirschke, founder of the Center for Reproduction of Endangered Species at the San Diego Zoo, "there is no doubt that the cloning of endangered species is coming."[130] Though the high costs and general inefficiency of somatic cloning procedures (e.g. one of 277 fusions in the case of Dolly) currently make such a broad application economically infeasible, the mammoth project may lead to cheaper and more efficient technologies, which will enable zoos and conservationists to employ cloning techniques on a more regular basis. From this point of view, Goto's project represents a meritorious effort to understand the intricacies of cloning and *in vitro* fertilization from frozen genetic material, and an effort to overcome the many obstacles that currently litter the road to reproductive success for endangered species. The possibility always exists that such a project would also yield new technologies applicable to human *in vitro* fertilization or other reproductive procedures.

B. *Arguments Against Resurrecting the Mammoth*

¶58 INDUCING APATHY TOWARDS ENDANGERED SPECIES: One objection to the creation of frozen zoos, and by extension to any scientific endeavor that might facilitate their creation, is that such zoos could promote apathy, laziness, and irresponsibility when it comes to preserving endangered species. The fear is that people will begin to neglect the wild and captive populations of species and their ecosystems once frozen backup populations or convenient cloning opportunities become available. Basic economic principles dictate that more plentiful resources are valued less by society. In the case of endangered species, some might become apathetic about species which appear to abound in frozen repositories, or which appear to be easily replaced.

¶59 Moreover, cloning endangered species would only solve a small part of the larger problem of the negative effect of human activity on biodiversity; for, "even assuming that the formidable technical hurdles to widespread whole-organism cloning of a variety of endangered animal species could be overcome, 'cloning endangered species could distract people from saving habitats,' which are [sic] widely recognized as the summum bonum of biodiversity preservation."[131]

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127 *Thai Scientists to Clone Elephant,* ASSOCIATED PRESS, Jan. 2, 1999, *available in* 1999 WL 2227705.

128 *Id.*

129 Johnson, *supra* note 11.

130 Stone, *supra* note 8, at 62.

131 Robert F. Blomquist, *Legal Perspectives on Cloning: Cloning Endangered Animal Species?,* 32 VAL. U.L. REV. 383, 414 (1998) (quoting Michael Soule, emeritus population geneticist at the University of California, Santa Cruz).

Therefore, the application of improved frozen-material cloning techniques developed through projects like Goto's to endangered species may carry with it as many risks as benefits.

¶60 POTENTIAL APPLICATION TO PETS, HUMANS, AND PROTOHUMANS: Viewed more broadly, the endangered species applications and frozen mammoth cloning procedures suggest the frightening proposition that the techniques will be applied to long-dead pets, or even to human beings. The Thai white elephant project, which involves "selecting its target based on fitness and rare physical characteristics", is, from this viewpoint, only the beginning of an eerie, immoral, and sacrilegious future in which individuals could be plucked from the grave and cloned back to life based upon their characteristics, prestige, or lineage. References to such procedures abound in science fiction, from Mary Shelley's *Frankenstein*, to Ira Levin's *The Boys from Brazil*, but until the arrival of Dolly, few took the idea of cloning dead individuals seriously. The post-Dolly world, however, *is* a "brave new world" in which extraordinary applications not so far removed from the realm of science fiction appear to be possible.

¶61 Perhaps the most harmless of these budding cloning projects is the "Missyplicity Project," a private effort by wealthy dog owners who seek to preserve enough DNA from their beloved pet, Missy, to clone her once she passes on.[132] Harmless as it may seem, the project validates some critics' fears of a future of eugenics by cloning. Like the Thai white elephant project, the Missyplicity Project strives, in part, to "[r]eplicate specific, exceptional dogs of high societal value . . . ."[133] Interestingly, the Missyplicity Project has also tapped into the endangered species cloning movement, declaring as one of its goals to

> [e]nhance reproduction of endangered species, especially endangered canids. We intend to develop non-profit partnerships to provide technical know-how on canine reproduction (IVF and cloning) to organizations attempting to repopulate endangered canines, including numerous varieties of wolves, foxes, and wild dogs. The Missyplicity Project has already recruited the head of a major endangered species program to oversee this goal . . . .[134]

¶62 While some may be able to live with the idea of bringing dead pets back from the grave, the same can hardly be said when it comes to human beings—or their ancestors, for that matter. The question has been raised more than once, for example, whether the procedures used to clone or retrobreed a mammoth could also be used to resurrect the five-thousand-year-old "Ice Man" mummy that was discovered in the Italian Alps in 1992.[135] The Ice Man's DNA was, in fact, sufficiently intact to provide samples for comparisons to living humans (which revealed that the subject was most closely related to Icelanders, Germans, Danes, and other Northern Europeans), and there may have been enough material for a cloning experiment, using PCR and DNA sequencers to amplify and sequence the

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132 The Missyplicity Project Staff, *Introducing the Missyplicity Project* (visited May 25, 1999) <http://www.missyplicity.com/M2.Pages/M2.welcome.html>; Constance Holden, *Hello Missy*, 281 SCIENCE 1443 (1998).

133 The Missyplicity Project Staff, *Project Goals* (visited May 25, 1999) <http://www.missyplicity.com/M2.Pages/M2.goals.html>.

134 *Id.*

135 Stone, *supra* note 8, at 59.

surviving fragments of DNA.[136] On a similar note, in 1997, Svante Pääbo of the University of Munich and colleagues in Germany and the United States successfully extracted DNA from the right humerus of a Neanderthal for the first time[137]—again, possibly enough for cloning.

¶63 These reproductive technologies are even more feasible with modern human beings. It happens, in fact, on a daily basis to some degree in fertility clinics and sperm banks, where frozen human sperm are used regularly for *in vitro* fertilization. When the donor dies and his sperm is used to inseminate a living female, the result, quite obviously, is posthumous reproduction. While resurrecting a mammoth may not significantly affect these *in vitro* fertilization procedures, which are already practiced regularly on humans, it may introduce new technologies and procedures that allow for horrific ends. After all, "[a]n obvious extension to live human cloning is the possibility of cloning deceased or dying individuals. The creator of Dolly points out that the cloning of a dead person is not possible using NTT [nuclear transfer technology], as the cells used for implantation in the embryo must be alive."[138] But if the mammoth project achieves Goto's goals, the resulting increase in knowledge about the freezing and thawing of genetic material could one day help preserve the living cells of human donors for use in posthumous cloning of human beings. This, of course, raises all of the usual religious, ethical, and moral objections to human cloning that arise after every new advance in the field.

¶64 RELIGIOUS OBJECTIONS: Potential human application aside, the mammoth project is different from all cloning and artificial reproduction procedures to date in that the donor animal is extinct. This adds an extra repugnance for many who object to cloning in the first place, and is a potential decisive factor for others deliberating over which side of the cloning debate to join. Why would cloning an extinct or deceased individual be so objectionable to so many different groups and individuals? Aside from the fear of a sort of Hitleresque eugenics by cloning, as suggested by the "socially valuable" trait selection objectives of the Missyplicity and Thai white elephant projects, and by various works of popular culture,[139] many would object to resurrecting any dead or extinct being for religious reasons. Pope John Paul II, Chief Rabbi of Israel Meir Law, and representatives of Sunni Islam, for example, have all condemned any cloning of any life form on the grounds that it is prohibited by Judeo-Christian and Islamic Laws.[140] Moreover, a 1997 CNN poll found that 74% of 1,005 American adults surveyed believed that human cloning is

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[136] ARIZONA STATE UNIV. DEP'T OF BIOLOGY, *supra* note 60; *Relationship Between the "Ice Man" and the Modern Human* (visited May 5, 1999) <http://heg-school.awl.com/bc/companion/cmr2e/activity/PCR/PCR13.htm>.

[137] Archaeological Inst. of Am., *Neanderthal DNA*, 50 ARCHAEOLOGY 5 (Sept./Oct.1997) <http://www.archaeology.org/9709/newsbriefs/dna.html>.

[138] Paul Tully, Comment, *Dollywood Is Not Just a Theme Park in Tennessee Anymore: Unwarranted Prohibitory Human Cloning Legislation and Policy Guidelines for a Regulatory Approach to Cloning*, 31 J. MARSHALL L. REV. 1385, 1393 (1998).

[139] See, for example, Aldous Huxley's *Brave New World* (1932) and the popular film GATTACA (Columbia Pictures 1997) <http://www.spe.sony.com/Pictures/SonyMovies/movies/Gattaca/the_film.htm>. See also Ira Levin's *The Boys From Brazil* (1976), in which a surviving Nazi clones and resurrects a series of Adolf Hitlers from his preserved genetic material in an attempt to breed a new Aryan race. Realistically, of course, even if such procedures were scientifically feasible, it is widely accepted that genetics is only one determinant of personality and behavior. Even if a genetically-identical clone of Adolf Hitler were resurrected, therefore, unless every moment of Hitler's life were recreated for the clone, the resulting being would be very little, if at all, like the leader of Nazi Germany.

[140] Kayron Fatahalian, Bennett Scheider & Brandon Reavis, *Views: People and Organizations* (visited May 2, 1999) <http://library.thinkquest.org/24355/data/reactions/cloningviews.html>.

simply "against God's will."[141] For these people, cloning a dead or extinct creature represents a flat *reversal* of God's work and plans by reanimating that which He has chosen to put to rest. Finally, resurrecting the dead may suggest the coming of Armageddon. The Holy Bible abounds with imagery of the dead rising from their graves when the end of the world approaches, and members of certain religious groups might view the resurrection of extinct creatures as the beginning of Apocalypse.[142]

¶65 RESURRECTING THE DEAD OR EXTINCT IS UNNATURAL: Even for the non-religious, the idea of resurrecting what has long since died out may be objectionable because it seems eerie or contrary to the ordinary course of nature. The latter objection may depend on one's theory of why the mammoth went extinct in the first place. If it was due purely to over-hunting by humans, such objections might be unwarranted, as Goto's and Buigues' teams would simply be correcting what might be viewed as a human-induced wrong. But, if the mammoth's extinction was due to a combination of factors including changes in the climate and ecosystem at the end of the Pleistocene, as most scientists believe it was, then resurrecting the mammoth might be viewed as meddling in the affairs of nature and the natural progression of geology, meteorology, and evolution. In any case, as suggested in the first part of this paper, the mammoth did ultimately die out for some reason or another while the Asian and African elephant survived, and many might find the idea of bringing it back unsettling, at least until we know more about the reason for its extinction.

¶66 INTERFERENCE WITH THE DIGNITY OF LIFE: Viewed in the context of a laboratory experiment, the resurrection project raises the additional concern that any successfully cloned specimen will undoubtedly serve as a research subject for much if not all of its existence, as has Dolly at the Roslin Institute in Scotland. While this may be justified for some in the case of a single sheep on the grounds that it leads to important veterinary, medical, and agricultural advances (e.g. genetically-modified milk, production of proteins, and veterinary and human antibiotics and vaccines), using the sole representative of an entire species as a research subject may be viewed as unethical on the grounds that it trivializes and enslaves an entire form and expression of life. As one author explains:

> To the extent that animal cloning can be portrayed by its supporters as a "humane" and "non-painful" way to use animals for human purposes, little meaningful social opposition is likely to materialize to the whole-organism cloning of selected "domesticated" animals (like sheep, goats, cattle, and other animals with an agricultural genealogy). To the extent, however, that whole-body animal cloning is perceived by the public as interference with the life and dignity of "wild" animal species (like bears, wolves and salmon), social opposition is likely to be more problematic.[143]

¶67 With an extinct animal species, particularly one so majestic, grand, and well-known as the woolly mammoth, this opposition will only be magnified. The hope, of course, is that one mammoth will give rise to more, so that a population may eventually be maintained in a zoo, or perhaps even in the wild. At least in the

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141 Bruce A. Robinson, *Ethical Aspects of Human Cloning* (visited July 10, 1999) <http://www.religioustolerance.org/cloning.htm#comm>.

142 1 *Corinthians*, for example, reads: "In a moment, in the twinkling of an eye, at the last trump: for the trumpet shall sound, and the dead shall be raised incorruptible, and we shall be changed." 1 *Corinthians* 15:51-53.

143 Blomquist, *supra* note 131, at 401.

beginning, however, any successful hybrid or clone will be the prisoner and property of humankind, which, to some, will impugn the dignity of life.

¶68 UNACCEPTABLE COMMODIFICATION: By the same token, in the event that a population of mammoths is ever resurrected, some may fear that it will be commodified as a source of meat and ivory. Though some may consider the prospect of biting into a mammoth burger a palatable reason to proceed with cloning efforts, others will most certainly find this objectionable. The Church of Scotland's *Society, Religion and Technology Project*, for example (which includes the Roslin Institute's Ian Wilmut of Dolly fame) has extensively examined cloning issues, and the General Assembly of the Church passed a motion stating that the "application of animal cloning as a routine procedure in meat and milk production [is] an unacceptable commodification of animals."[144] Moreover, if a population of mammoths is ever released into the wild, the potential use of the mammoth as a food source might instantly throw it back into extinction. As a current illustration of this, many modern elephants are, in fact, killed regularly in poorer nations for their meat.[145]

¶69 Similarly, the economic appeal of the mammoth's tusks may be a concern. This is especially true in light of the fact that

> [t]he recovery of mammoth bones and ivory became an enormous commercial enterprise in the eighteenth and nineteenth centuries. In the nineteenth century, tens of thousands of kilograms of mammoth tusks were sold each year worldwide out of Siberia. The ivory from at least 46,000 individual mammoths had been sold in Russian Siberia by about 1913.[146]

The plight of modern elephants testifies to the potential dangers of bringing new (but, still precious and rare) sources of ivory into the world. For example, "[i]t is estimated that from 1973 to 1980 alone, two-thirds of all elephants in Kenya were killed for ivory."[147] And though the ivory trade was banned in 1989 when the Convention of International Trade in Endangered Species (CITES) listed the African elephant as an endangered species, "poaching continues because of the immense value of the tusks compared to the very low per-capita income in most regions native to elephants."[148] These unfortunate factors are certainly causes for concern about the prospect of bringing a new "marketable" species into the world. As one author attests sardonically to the difficulties of keeping even the world's modern elephant populations out of harm's way, "[p]erhaps we could best sustain the elephants by genetically altering them, making them tuskless and distasteful to our palate."[149] Needless to say, if all goes well, the end product of a resurrection project will be a genuine woolly mammoth—tusks, taste and all—and the concern that it will be viewed, at least by some, as a woolly gold mine or a gourmet meal seems to be a legitimate one.

¶70 POTENTIAL DISTURBANCE OF ECOSYSTEMS AND EVOLUTION: If mammoths are ever reintroduced into the wild, they will have to share their environment with

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144 Robinson, *supra* note 141.

145 WARD, *supra* note 16, at 184.

146 HAYNES, *supra* note 13, at 47.

147 WARD, *supra* note 16, at 212.

148 *Id.* at 213.

149 *Id.*

modern species of all sorts, from viruses and bacteria to large herbivores, carnivores, and humans. A complete and precise recreation of the Pleistocene will never be possible. Though the beast may fare well in a modern approximation of that environment, such as Goto's proposed "Pleistocene Park," any habitat in the modern world is linked to a delicate ecosystem that will not necessarily accommodate the introduction of a truly alien species. Particular ecological considerations, therefore, include "species composition, size of individuals, species diversity, total biomass . . . and natural selection dynamics."[150]

¶71 On the macro scale, for example, mammoths would require a large amount of food to nourish their large bodies, even more than modern elephants,[151] which would most certainly result in competition with any modern herbivores with similar diets in the habitat. This competition for food would place enormous stress on such modern species, and would likely lead to either a decline in that species' numbers, or a forced reliance on alternative food sources that might disturb a third species' diet, feeding habits, and population size. Either scenario, in turn, might lead to the decline of a carnivorous species that depends upon the modern herbivore as a food source, and so on all the way up and down the food chain. Similarly, though the healthy adult modern elephant has no predators other than humans,[152] a mammoth introduced into a habitat containing large carnivores such as wolves, bear, snow leopards, and mountain lions might provide a new food source for such carnivores, causing a sudden increase in the population sizes of the usual prey. Finally, the behavior and sheer size of mammoths could impact the ecosystem and food chain, assuming that their behavior would be similar to that of modern elephants, which "are inquisitive and exploratory animals [that] use their feet to manipulate [and trample] objects on the ground."[153] Changes in the environment caused by such trampling and exploration could affect the food sources and habitats of other species in the ecosystem.

¶72 On the micro scale, the reintroduction of a once-extinct species into the environment provides a new host organism for harmful viruses and bacteria that might mutate rapidly to adapt to it. These microorganisms could kill off a small population of mammoths rather quickly. Of course, in order to maximize the mammoth population's chances for survival, clones would have to be created from more than one donor, to introduce genetic diversity. As noted by Dr. Paul Bartels, head of the WBRC and Genome Resource Bank for Africa:

> People have this vision of a thousand copies of a single animal being made . . . . This would be really stupid. Take a black rhino, for example. What you might do is make five clones each of a number of rhino. And then you would recreate five populations of them as far apart as possible, so that if one population is wiped out for whatever reason, you would still have other populations.[154]

¶73 Even with such protections built in for a manmade mammoth population, however, the risk exists that mutated microorganisms might be harmful to other large mammals, potentially altering animal populations and disrupting the balance of

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150 Blomquist, *supra* note 131, at 407.

151 WARD, *supra* note 16, at 132.

152 *Id.*

153 HAYNES, *supra* note 13, at 157.

154 WildNet Africa, *supra* note 123.

the ecosystem. Such mutated viruses and bacteria could also spread to other ecosystems, infecting, for example, modern elephants and livestock, spelling disaster for human populations that depend upon livestock for their subsistence. Moreover, though the likelihood of such organisms infecting humans directly is small, recent outbreaks of trans-species pestilence such as Creutzfeldt-Jakob Disease in the United Kingdom (known in cattle as bovine spongiform encephalopathy (BSE) or "mad cow disease") and the so-called "chicken flu" in China serve as bitter reminders that it is within the realm of possibility.[155]

¶74 Any changes in the food chain and ecosystem brought about by the introduction of the mammoth would necessarily affect the course of evolution, as the survival of species depends upon the extent to which adaptations are suited to a particular environment. If the mammoth altered the environment in any significant way, individuals that were best suited to survive in the *altered* environment would survive, while individuals that would otherwise have been best suited to survive would perish. Ultimately, since humans would be responsible for the introduction of the mammoth into a particular ecosystem, they might also be responsible for altering the course of evolution and perhaps wiping out other species. As one author fears, "the human act of cloning competing, albeit endangered [or extinct], animals is problematic in Darwinian terms: to be cloned would tend to disrupt the evolutionary process of inclusive fitness and survival of the fittest, while creating unknown consequences on ecosystems as a whole."[156]

¶75 MAMMOTHS AND THE LAW: A final argument against resurrecting the woolly mammoth is that some might object to the procedure itself, or to the subsequent confinement and treatment of the resulting animal(s), on legal grounds. Of course, no laws currently exist that explicitly address the cloning or resurrection of extinct creatures, and any laws that did apply would differ from nation to nation, and from state to state if the procedure were undertaken in the United States. For the purposes of the following discussion, I will assume hypothetically that the procedure is performed in the United States.

¶76 Interestingly, in all of the dozens upon dozens of bills introduced at the State and Federal levels after the announcement of the cloning of Dolly the sheep, there are no bans or restrictions on the somatic cell cloning of animals.[157] Further, "the US-NBAC report flatly concludes that 'research on cloning animals . . . does not raise the issues implicated in attempting to use this technique for human cloning, and its continuation should only be subject to existing regulations regarding the humane use of animals and review by institution-based animal protection committees.'"[158] Perhaps the most relevant of such regulations is Chapter 54 of Title 7 of the United States Code, which mandates the humane treatment and handling of certain animals used for research or experimental purposes. Section 2132 of that Chapter defines "animal" as

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155 *See*, *e.g.*, Sean Henahan, *Mad Cow Disease: The BSE Epidemic in Great Britain* (visited July 17, 1999) <http://www.accessexcellence.org/WN/NM/madcow96.html>; *New Case of Chicken Flu Reported in Hong Kong*, NEWSWORLD ONLINE (Jan. 1, 1998) <http://newsworld.cbc.ca/archive/html/1998/01/01/chicken980101a.html>.

156 Blomquist, *supra* note 131, at 416.

157 *See* Stacy J. Ratner, Note, *Baa, Baa, Cloned Sheep, Have You Any Law? Legislative Responses to Animal Cloning in the European Union and United States,* 22 B.C. Int'l & Comp. L. Rev. 141, 150-52 (1999).

158 *Id.* at 151 (quoting NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at iii, iv).

> any live or dead dog, cat, monkey (nonhuman primate mammal), guinea pig, hamster, rabbit, or other such warm-blooded animal, as the Secretary may determine is being used, or is intended for use, for research, testing, experimentation, or exhibition purposes, or as a pet; but such term excludes horses not used for research purposes and other farm animals, such as, but not limited to livestock or poultry, used or intended for use as food or fiber, or livestock or poultry used or intended for use for improving animal nutrition, breeding, management, or production efficiency, or for improving the quality of food or fiber.[159]

¶77 Though the law clearly excludes all sheep, cows, and goats (the obvious first choice for cloning, as one author points out),[160] it might cover a woolly mammoth—even a dead one, according to the above definition—if the U.S. Secretary of Agriculture so decided. This, of course, would put the fate of the mammoth project and of the mammoth itself in the hands of a lone individual, who might be influenced by the current political views of the Agency or the politics of the nation as a whole. In short, under Chapter 54 it is anyone's guess whether cloning the mammoth would be banned completely on the grounds that it constitutes inhumane treatment of an animal, or allowed to proceed free of restrictions, on the grounds that a mammoth falls outside of the scope of the term "animal."

¶78 A more interesting legal consequence of cloning a mammoth or any other extinct species would be its presumed inclusion on the endangered species list the instant it emerges from the surrogate womb. Chapter 35 of Title 16 of the U.S. Code (the Endangered Species Act of 1973, as amended) assigns to the Secretary of the Interior the authority to determine whether a species is "endangered or threatened" based, among other things, upon "the present or threatened destruction, modification, or curtailment of its habitat or range; overutilization for commercial, recreational, scientific, or educational purposes . . . [or] other natural or manmade factors affecting its continued existence."[161] Since the same section mandates that "the Secretary shall make determinations required by subsection (a)(1) . . . solely on the basis of the best scientific and commercial data available to him,"[162] it seems that he or she would have no choice under the existing Act but to list the sole living representative of *Mammuthus primigenius* as an endangered species as soon as it came into the world, on the grounds of "overutilization for scientific or educational purposes" or "other manmade factors affecting its continued existence." It is unclear from the language and purpose of the Act what might happen after this point—in particular whether the study, research and future cloning of the sole mammoth subject would be prohibited as a threat to the existence of the species, or commended and allowed to proceed as an attempt to conserve it.

¶79 Myriad other federal agencies might also choose to involve themselves in regulating an attempt to resurrect the mammoth or the study and use of individual mammoths, including the Environmental Protection Agency (if it was determined that the procedure or resulting mammoth would somehow impact the environment), the Animal and Plant Health Inspection Service (APHIS) of the USDA (requiring minimum standards of care and treatment for most warm-

159 7 U.S.C. § 2132(g) (1999).

160 Ratner, *supra* note 157, at 151.

161 16 U.S.C. § 1533(a)(1) (1999).

162 *Id.* at § 1533(b)(1)(A).

blooded animals under the Animal Welfare Act),[163] the FDA (if the mammoth were ever used as a source of meat or as a transgenic "Pharm" animal for the production of proteins or drugs), and the United States Customs Service (if the animal or products derived from it were ever traded or imported across United States borders).[164] The states, for their part, might also pass their own laws regulating the cloning and/or subsequent use of a mammoth or other endangered species.

¶80 As mentioned, the laws governing and affecting an attempt to clone or otherwise resurrect the mammoth would vary from nation to nation,[165] but uncertainties as to which bodies and agencies, if any at all, govern which part of the process, would most certainly arise anywhere in the world. Further, since decisions concerning any project aimed at resurrecting the extinct would likely be viewed as properly requiring the input of all human beings as a unified species, it is likely that the United Nations or other international organizations would involve themselves in the legislative process. Such projects could, therefore, become entangled in a web of legal and political debates and power struggles, constituting, at least for some, another reason why such a project should itself go the way of the woolly mammoth.

V. CONCLUSION

¶81 The central dilemma in deciding if and how to regulate cloning is the same in the case of the mammoth as in the case of humans: "The challenge to public policy is to support the myriad beneficial applications of this new technology, while simultaneously guarding against its more questionable uses."[166]

¶82 At first glance, resurrecting an extinct species would seem to create more risks than benefits, and raise more objections than any government or society would care to address. A closer look at both sides of the equation, however, reveals that many of the benefits are too valuable and unique to refuse, and that many of the risks and objections can be minimized or eliminated if the project proceeds under carefully-constructed ethical guidelines and procedural safeguards. On the benefit side, the potential knowledge and insight into an extinct species and its habitat that could be gained from a successful resurrection is at once invaluable and exciting. The most compelling reason to proceed with the mammoth project, however, is its potential application to the conservation of the endangered and near-extinct species of our own time. The project offers the hope that we will someday be able to apply this new knowledge to aid in the creation of "frozen zoos" and in other efforts to preserve the diversity of life on earth, even in the event that the attempt to resurrect the mammoth itself ultimately fails.

¶83 While it is undoubtedly true that cloning and other assisted reproductive techniques are not, in themselves, solutions to the increasing problem of human-induced species extinction, they could help mitigate the ecological damage caused by

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[163] Animal and Plant Health Inspection Serv., UNITED STATES DEP'T OF AGRIC., *Animal Care* (visited July 25, 1999) <http://www.aphis.usda.gov/ac/awainfo.html>.

[164] *See*, *e.g.*, 16 U.S.C. §1531.

[165] The European Union, for example, unlike the United States, has recognized the inadequacy of existing law as it pertains to animal cloning, and has acknowledged a responsibility to react thoughtfully to changing technology by enacting new legislation that directly addresses the issue. The EU also recognizes that the concept of ethics should play a critical role in the development of animal cloning legislation, as well as human cloning legislation. *See generally* Ratner, *supra* note 157.

[166] NATIONAL BIOETHICS ADVISORY COMM'N, *supra* note 54, at 107.

the inexorable expansion of humankind into even the remotest of the world's habitats. As species are increasingly pushed out of their native ecosystems, successful reproduction becomes increasingly difficult for many of them, and humankind has a moral, ethical, and perhaps a legal duty to assist in their proliferation. The problem only worsens with the inevitable increase of the human population, and it would be an ignominy to reject a technology that could help save the many hundreds of species that currently face extinction.

¶84 Most of the other objections to cloning the woolly mammoth can be assuaged by maintaining the current moratorium on whole-body somatic human cloning, or by banning human cloning applications outright, consistent with whatever global consensus emerges on that issue. Concerns over the ecological and evolutionary effects of introducing a mammoth into a modern ecosystem can and should be addressed by keeping the subject in captivity until such time that the impact of its release into the wild can be better assessed.

¶85 While in captivity, every effort should be made to ensure that the animal is treated humanely, handled properly, and kept physically and emotionally healthy. An international review board comprising experts in the fields of ethics, law, and the biological and veterinary sciences should be established to ensure that the mammoth is treated properly, and that research and experiments maximize the benefits to humankind, while minimizing the risks of harm to the subject's physical and emotional well-being. Finally, all trade in mammoth meat and ivory should be strictly prohibited by international treaty or similar mechanism to prevent the commodification and trivialization of the mammoth's life.

¶86 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 potential harms and questionable applications.