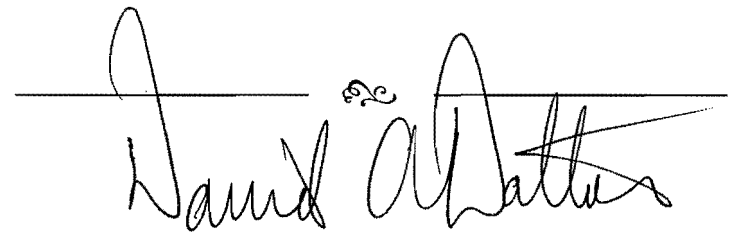


THE NATURAL WORLD OF
LEWIS AND CLARK


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CHAPTER 1



Mega-expectations

It is hard to appreciate fully just how little early Americans knew about the country west of the Mississippi. Thomas Jefferson was arguably the greatest intellectual on the continent, yet even he had almost no idea what was out there. It is instructive to examine some particular points where Jefferson went astray.

Jefferson believed that the West probably still contained many of the great mammals of the Pleistocene epoch, including mammoths, giant ground sloths, and perhaps others. He believed this because many mammoth bones had been found in the East—especially in Kentucky at a place called Big Bone Lick. Meriwether Lewis visited Big Bone Lick as he passed through Cincinnati on his way to St. Louis on September 28, 1803, at which time he collected some mammoth fossils and shipped them to Jefferson.

Jefferson was an avid collector of fossils, many of which he displayed at Monticello. He also came into possession of some fossil bones of a giant ground sloth from present-day West Virginia and

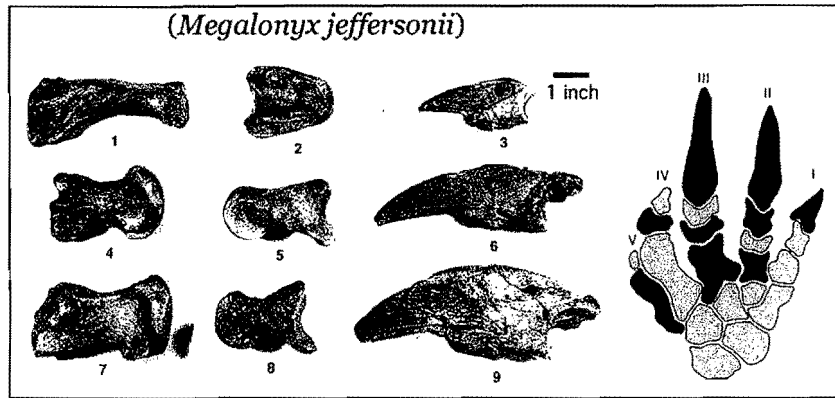


Fig. 1.1. Modern photograph of the hand bones of the *Megalonyx* that were described by Jefferson. Courtesy of Academy of Natural Sciences.

subsequently wrote one of the first technical papers in North America in the field of paleontology in 1799 (fig. 1.1).¹ He called the beast a “Great-Claw,” or *Megalonyx*, which he estimated to be at least three times larger than an African lion. Jefferson went into considerable detail to describe the dimensions of these bones. For instance, the “Great-Claw” itself was 7.5 inches long (as opposed to 1.4 inches for a lion’s claw), and the diameter at the middle of the femur was 4.25 inches, whereas the lion comes in at only 1.15 inches. Jefferson speculated that such a creature could easily dine on mammoths in the way that he imagined that modern African lions might prey on elephants. Not only was Jefferson one of the first paleontologists, but he was also an ecologist, as evidenced by his concern about the fate of *Megalonyx*. He noted:

1. Jefferson, “A Memoir of the Discovery of Certain Bones of a Quadruped of the Clawed Type in the Western Parts of Virginia.” Despite its antiquity, this article is readily available online at many libraries. It makes for some entertaining reading.

In fine, the bones exist: therefore the animal has existed. The movements of nature are in a never ending circle. The animal species which has once been put into a train of motion, is still probably moving in that train. For if one link in nature’s chain might be lost, another and another might be lost, till this whole system of things should vanish by piece-meal. . . . If this animal then has once existed, it is probable on this general view of the movements of nature that he still exists.

Jefferson later instructed Lewis to be on the lookout for such unusual creatures but did not mention them by name. Instead, the charge was to look for “the animals of the country generally, & especially those not known in the U.S. the remains and accounts of any which may [be] deemed rare or extinct.”² But Lewis and Clark were about twelve thousand years too late, for reasons we will examine shortly.

Jefferson also had peculiar ideas of what the western Indians might be like. He was familiar with a popular legend of the time that held that a band of Welshmen with Viking roots settled in North America in the twelfth century. There are many fragments of stories from early Europeans—mostly secondhand hearsay—that described encounters with white Indians who spoke Welsh. In particular, the Mandan, who were unusually fair-skinned and with whom Lewis and Clark spent their winter in North Dakota, were often mentioned as likely candidates for this distinction. If this sounds too bizarre to be true, that’s because it is just that—too bizarre. Lewis and Clark found no evidence for it. However, the legend is still with us today and has a few fringe advocates even in academe. It is a myth that just won’t die, though the evidence is woefully thin.

2. Reuben G. Thwaites, *Original Journals of the Lewis and Clark Expedition*, 7:249.

Jefferson also held out the possibility that Lewis and Clark might encounter a long-lost tribe of Israelites in the guise of American Indians. This belief persists today as part of the teachings of the Mormon Church. Recent DNA evidence has debunked this bizarre theory, but there are still a few believers.³ So, no Welshmen and no Israelites—unless you want to include Lewis, who was in fact of Welsh descent.

Jefferson also assumed that the climate west of the Mississippi was similar to that in Kentucky and Virginia, that is, temperate with ample rainfall and thus suitable to agriculture. This was a myth that was long in dying, dragging out after the Civil War in the misguided belief that “rain follows the plow” and perhaps even contributing to hardships of the Dust Bowl on the Great Plains in the 1930s.

Before the Expedition, no one understood the major geographical features of the West. Jefferson believed that all the great rivers of the West—including the Columbia, Colorado, Rio Grande, and Missouri—arose from a single “height of land” and that it might be possible to completely traverse the continent with only a brief portage across the mountains. He believed this in part because he was aware that Alexander Mackenzie, a fur trader with the North West Company, succeeded in crossing virtually all of Canada by river in 1793. He went up the Peace River from the east and made a brief portage of only seven hundred yards, at which point he was able to eventually connect to the Fraser River, which drains into the Pacific. The elevation at the portage was only three thousand feet.⁴ This remarkable feat is less famous than the later Lewis and Clark Expedition in part because Mackenzie had no interest in science or

3. See Simon G. Southerton, *Losing a Lost Tribe: Native Americans, DNA, and the Mormon Church*.

4. Stephen Ambrose, *Undaunted Courage: Meriwether Lewis, Thomas Jefferson, and the Opening of the American West*, 73.

ethnology and so had less impact. His interest was strictly commercial, and in this sense he was phenomenally successful, eventually becoming one of the wealthiest men in England (and a knight). But he rarely wrote of the plants and animals he encountered, and when he did it was with very little insight. For instance, he referred to mountain goats as “small white buffalo” and freely admitted,

I do not possess the science of the naturalist; and even if the qualifications of that character had been attained by me, its curious spirit would not have been gratified. I could not stop to dig into the earth, over whose surface I was compelled to pass with rapid steps; nor could I turn aside to collect plants which nature might have scattered on the way, when my thoughts were anxiously employed in making provision for the day that was passing over me.⁵

Nevertheless, Mackenzie’s explorations were key in establishing a British presence and claim to ownership in western Canada. In this regard, Mackenzie played a similar role to that of Lewis and Clark’s advancement of American interests to the south. Even though Mackenzie’s adventure took place in 1793, it was not until 1801 that a book on the subject, *Voyages from Montréal*, was published. Jefferson got his hands on one of the first copies, which set him into a frenzy of activity to get his own expedition off the ground.

It was quite reasonable to assume—as apparently Jefferson did—that the Appalachians in Virginia were perhaps the highest mountains on the continent. The highest point in Virginia is Mount Rogers at 5,729 feet. Even though some high mountains such as Mount Hood (11,235 feet) in Oregon and Mount Rainier (14,410 feet) in Washington had been sighted and named thirteen years earlier on

5. Mackenzie, *Journal of the Voyage to the Pacific*, 49.

Captain George Vancouver's remarkable expedition to the western coast, the scale of these mountains was not widely appreciated until later. Lewis and Clark saw these and other high mountains of the Cascade Range, but they almost invariably misidentified them. For instance, they were actually looking at Mount St. Helens (not Mount Rainier) when on November 4, 1805, Ordway, a sergeant who also kept a dairy during the Expedition, wrote that they "discovered a high round mountain Some distance back from the River on the Stard Side which is called mount rainy." The highest point that Lewis and Clark actually set foot on was probably Saddle Mountain (8,225 feet) as they entered the Bitterroot Valley during their tortuous crossing of the Rocky Mountains.

It is clear that Jefferson had some pretty strange ideas in spite of the fact that he was certainly a genius and had the largest library in the world on the subject of the geography of North America. The fact is, nobody really knew what to expect. If such an expedition were to be launched today, Jefferson might tell Lewis to be on the lookout for Bigfoot, space aliens, and weapons of mass destruction. They could be there, and as any good scientist can tell you, "absence of evidence is not evidence of absence."

There are numerous interesting biological issues surrounding the question of the missing mammoths and other large mammals—henceforth referred to as the megafauna that are defined as animals weighing more than one hundred pounds. The big mammals had not been gone long—only something like twelve thousand years, which puts them squarely at the end of the Pleistocene epoch. The bones of the megafauna that have been found are not fossilized in the sense that dinosaur bones are. The bones have simply been preserved more or less intact, usually in caves or buried in mud or permafrost. There are even cases of mummified remains of complete skeletons, flesh, skin, hair, and dung.

The diversity and size of the megafauna are absolutely astounding. Jefferson's *Megalonyx* was an impressive beast that probably weighed in around eight hundred pounds, but that animal had plenty of large cousins, including about thirty-four genera of other ground sloths in the Americas. The biggest was *Megatherium* (literally, "great beast"), which may have topped eight thousand pounds—a bulk that puts it in the range of a modern African elephant.

Ground sloths, mastodons, and mammoths are only the beginning of a very strange assortment of beasts. Beavers back then were approximately the size of bears (four to five hundred pounds). Lewis and Clark often spotted California condors along the Columbia River, but they missed out on their giant ancestors—the teratorns, which were giant vultures with wingspans of up to sixteen feet in North America and perhaps twenty-five feet in South America (fig. 1.2). Nevertheless, the condor is an impressive bird, as Clark noted on February 16, 1806: "I believe this to be the largest Bird of North America.⁶ it was not in good order and yet it wayed 25 lbs had it have been so it might very well have weighed 10 lbs. more or 35 lbs. between the extremities of the wings it measured 9 feet 2 Inches." That is a big bird, but still far short of the teratorns.⁷ The glyptodont—a type of giant armadillo—weighed in around three thousand pounds and had an armored shell two inches thick. Other examples include fossil rhinos, horses, and camels such as those found in ash beds in Nebraska in which the bones are still articulated and joined together

6. He was correct.

7. A recent study has suggested that the reason the condor persisted into modern times is that its food base included large marine mammals that survived the Pleistocene extinctions. In contrast, the teratorns were restricted to the land animals that of course largely disappeared. See Kena Fox-Dobbs et al., "Dietary Controls on Extinction versus Survival among Avian Megafauna in the Late Pleistocene."



Fig. 1.2. Typical examples of the North American megafauna of the Late Pleistocene. *Left to right*: teratorn vulture (flying, *Teratornis*), mammoth (*Mammuthus*), musk ox (background, *Ovibos*), ancient bison (*Bison*), saber-toothed cat (*Smilodon*), dire wolf (*Canis*), horse (background, *Equus*), giant ground sloth (*Megatherium*), giant armadillo (*Glyptodon*), and camel (background, *Camelops*). Copyright 2000 Yale Peabody Museum and Rudolph Zallinger.

in the proper order. Some specimens contained unborn young and stomach contents, thus giving paleontologists an opportunity to reconstruct the life appearance and habits of these ancient species with great accuracy.

North America lost thirty-three of its forty-seven genera of megafauna in the Late Pleistocene. Meanwhile, South America lost fifty of its fifty-nine genera of megafauna. In many regards, the changes that took place in the few thousand years before Lewis and Clark were more severe than the changes that have taken place since. It must have been quite a sight to see the North American plains filled

with camels, ground sloths, and mammoths instead of cows and wheat fields.

Since organic remains, and not just mineralized fossils, of these mammals have been found, it has been possible to apply techniques in modern molecular biology to great effect. For instance, the sequence of mammoth mitochondrial DNA is now known in its entirety. It may even be possible to obtain something approaching a complete nuclear genomic sequence for mammoths, thus raising the possibility of a new field called "paleogenomics."⁸ This would be invaluable for studying population genetics of Pleistocene mammals and plants and might even shed light on causes of their extinction. However, reconstructing a complete, living mammoth using DNA sequence is not practical, and thus a "Pleistocene Park" scenario with living mammoths is unlikely.

The power of ancient DNA studies was demonstrated recently by scientists who reconstructed the diet of giant sloths from Nevada by analyzing the DNA in vegetable remnants in their dung. This group used the PCR technique to sequence a short section of the rubisco gene (*rbcL*)—a key gene in all plants that allows them to photosynthesize. They could then match up the DNA sequence with known sequences in extant plants to determine what the sloths were eating (table 1.1). The older ones (28,500 years ago) were eating mostly pine, mulberry, and capers, whereas their descendants from 11,000 years ago ate mostly mints, sunflowers, and saltbush. It is clear that these animals were herbivores with a wide-ranging palette and not carnivores, as Jefferson once thought. The "Great-Claw" threw him off.

8. See H. N. Poinar et al., "Metagenomics to Paleogenomics: Large-Scale Sequencing of Mammoth DNA."

Table 1.1. Plant species eaten by giant ground sloths from Nebraska 11,000 to 28,500 years ago		
Family	Number of genera	Representative genera
Sunflower	9	<i>Achillea, Lactuca</i>
Mustard	8	<i>Brassica</i>
Rose	7	not given
Mint	4	not given
Grass	3	<i>Stipa, Karroochloa</i>
Caper	2	not given
Saltbush	2	<i>Atriplex, Grayia</i>
Willow	2	<i>Salix, Populus</i>
Agave	1	<i>Yucca</i>
Nolina	1	<i>Nolina</i>
Grape	1	<i>Vitis</i>
Mulberry	1	<i>Morus</i>
Pine	1	<i>Pinus</i>
Creosote bush	1	<i>Larrea</i>
Milkweed	1	not given

Source: M. Hofreiter et al., "A Molecular Analysis of Ground Sloth Diet through the Last Glaciation."
 Note: The identification is based on DNA sequences from chloroplast DNA isolated from dung.

So what happened to all these animals? The short answer is humans ate them. Climate change may have also been a factor, but there is good evidence that we—or, more precisely, those early humans who walked across the land bridge over the Bering Strait about thirteen thousand years ago—did it. The case for this theory was put forth

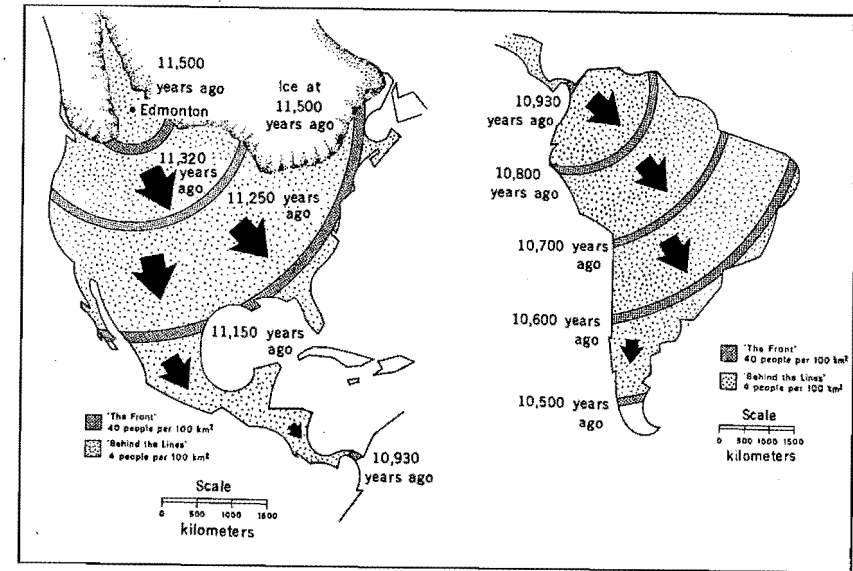


Fig. 1.3. The wavelike sweep of human migration into the Americas. From Paul S. Martin, "The Discovery of America," 972. Reprinted with permission. Copyright 1973 American Association for the Advancement of Science.

in 1973 by Paul Martin, a geology professor at the University of Arizona (fig. 1.3).⁹ Since that time, the story has been clouded a bit by evidence suggesting a limited human presence somewhat earlier and perhaps a role for climate change. The issue is far from settled. There are many adamant voices that argue either for or against the role of humans in the extinctions, but the case that Martin made is still largely intact with considerable fossil and paleoanthropological evidence to back it up.

According to the "overkill" hypothesis that Martin put forth, early humans found a huge surplus of naive, inexperienced animals that

9. See Paul S. Martin, "The Discovery of America."

had never seen humans and were thus easy prey. Why should a three thousand-pound ground sloth be concerned by the proximity of a feeble one hundred-pound human? Martin called them “ambulatory pin cushions” and even went so far as to suggest that adolescent humans might have amused themselves by using them just for target practice.¹⁰ The humans wiped out the megafauna before there was time for the animals to learn or evolve appropriate defenses. The hunters rode their success in a line of death first through North America and then South America, wiping out the local populations of large animals as they marched south in search of continued abundance of game. The leading front of this wave could have supported a dense population of humans (one person per square mile) that migrated at perhaps about ten miles per year. Martin estimated that, from a starting population of only one hundred humans, it would have taken only about seventeen generations to saturate the hemisphere. Local extinctions would have occurred within a decade of the wave hitting any particular area.

Some of the more compelling evidence that humans were primarily responsible for the disappearance of the megafauna includes: (1) the paleological record that shows a correlation between the arrival of humans and extinction of the megafauna; (2) the fact that the megafauna had been around for tens of millions of years over various climate changes and then vanished nearly overnight—mere decades, if we believe Martin; and (3) the fact that the only large animals that did survive beyond human arrival are those that avoided humans either by being nocturnal, arboreal, alpine, or deep-forest dwellers. This last point argues especially compellingly against the climate-change theory. Last, recent sophisticated computer models based on human

10. See Paul S. Martin, *Twilight of the Mammoths: Ice Age Extinctions and the Rewilding of America*.

hunting and growth rates have correctly predicted the extinction or survival of thirty-two out of forty-one prey species without invoking climate-change effects.¹¹ Readers interested in exploring further the issue of extinction of the megafauna should refer to Martin’s 2006 book, *Twilight of the Mammoths: Ice Age Extinctions and the Rewilding of America*. Regardless of the cause—hunting (“overkill”), climate change (“overchill”), or disease (“overill”)—the fact remains undisputed that the megafauna did go extinct around this time, and thus the ecosystems of the American West changed radically only a few thousand years before Lewis and Clark’s arrival.

Ecosystems left in the wake of these changes had much less diversity than the original ones. There are many studies in modern ecology demonstrating that the removal of just a few keystone species may result in the catastrophic collapse of species diversity.¹² Let’s take just one case illustrating some likely ecological consequences of extinctions. Consider the case of the gomphotheres—a group of elephant-like creatures that roamed Central America and South America in the Pleistocene.¹³ There are at least thirty-seven extant plant species that were probably highly dependent on the extinct megafauna, such as gomphotheres, for distribution of their fruit. The large and hard-skinned fruits were simply too tough for any smaller animal to crack open, much less carry off to a new site. Consequently, the abundance of these plants in modern neotropical forests and grasslands has been greatly reduced to the point that some plants appear to reproduce hardly at all, putting their future in doubt.

11. See John Alroy, “A Multispecies Overkill Simulation of the End-Pleistocene Megafaunal Mass Extinction.”

12. See, for instance, R. T. Paine, “Intertidal Community Structure: Experimental Studies on the Relationship between a Dominant Competitor and Its Principal Predator.”

13. See Daniel H. Janzen and Paul S. Martin, “Neotropical Anachronisms: The Fruits the Gomphotheres Ate.”



Fig. 1.4. Lewis sitting in a garden in St. Louis preparing a letter to Jefferson in which he describes the samples of Osage orange that he was sending. Lewis's letter of March 26, 1804, begins: "Dear Sir: I send you herewith enclosed some slips of the great Osages Plums and Apples." From Jackson, *Letters of the Lewis and Clark Expedition*, 170. Artwork by Michael Haynes (<http://www.mhaynesart.com/home.html>).

Early in their journeys, Lewis and Clark ran across one such plant that appears to have lost its dispersers when the megafauna were wiped out. While still camped at Camp Dubois near St. Louis, Lewis observed Osage orange (*Maclura pomifera*) blooming and sent cuttings and seeds back to Jefferson (fig. 1.4). These may be the first objects returned to Jefferson by the Expedition.¹⁴ Several impressive Osage orange trees still survive in Philadelphia that were started

14. Moulton, *Journals of the Expedition*, 2:210.



Fig. 1.5. Osage orange tree planted at St. Peter's Church (formerly the garden of Bernard McMahan; see Chapter 2) in Philadelphia. This tree, along with several similar ones in the background, is reputed to have been planted from seeds or cuttings sent back by Lewis. Photo by author.

from these same specimens (fig. 1.5). Offspring of the Philadelphia Osage orange trees eventually even made it to England, thanks to the efforts of David Douglas, the famous naturalist sent to North America by the Horticultural Society of London (later named the Royal Horticultural Society) to collect plants for English gardens. In 1823 Douglas visited Bernard McMahan's garden in Philadelphia, where he observed several Osage orange trees with a "height of about seventeen feet, bushy and rugged."¹⁵ He obtained fruits from one of McMahan's fellow nurserymen, David Landreth, and carried

15. Douglas, *Journal Kept by David Douglas during His Travels in North America, 1823-1827*, 8.

them back to England for propagation. It is almost certain that this fruit came from plants that were descendants of cuttings sent back by Lewis.

Lewis wrote to Jefferson on March 26, 1804, that “so much do the savages esteem the wood of this tree for the purpose of making their bows, that they travel many hundreds miles in quest of it.”¹⁶ A local tribe of Indians known as the Spiroan Indians flourished in the area around A.D. 500–1300. This tribe was fortunate enough to control this restricted resource and consequently was very prosperous by local standards.¹⁷

Although Paul Cutright credits Lewis and Clark with introducing Osage orange to science, the tree had been encountered earlier by French explorers who named it *bois d’arc* (“bowwood”).¹⁸ This name may have been corrupted over time to the familiar “Ozark” to indicate the hills of Missouri and Arkansas where Osage orange grows, although there are alternative explanations for the origin of “Ozark.”¹⁹

The fruits of Osage orange are so tough and large (two to three pounds) that hardly anything can eat them (fig. 1.6). In fact, Osage orange is probably the best example in North America of a fruit that now lacks its dispersers due to the disappearance of the megafauna.²⁰ By the time Europeans arrived, this species was clinging to a range restricted to a small area near where Arkansas, Texas, and Oklahoma meet. The actual range may have been so small as to be limited to

16. Donald Jackson, *Letters of the Lewis and Clark Expedition with Related Documents, 1783–1854*, 170.

17. Frank F. Schambach, “Osage Orange Bows, Indian Horses, and the Blackland Prairie of Northeastern Texas,” 212.

18. Paul Cutright, *Lewis and Clark: Pioneering Naturalists*, 41.

19. See Richard Rhodes, *The Ozarks*.

20. Connie Barlow, *The Ghosts of Evolution: Nonsensical Fruit, Missing Partners, and Other Ecological Anachronisms*, 120.

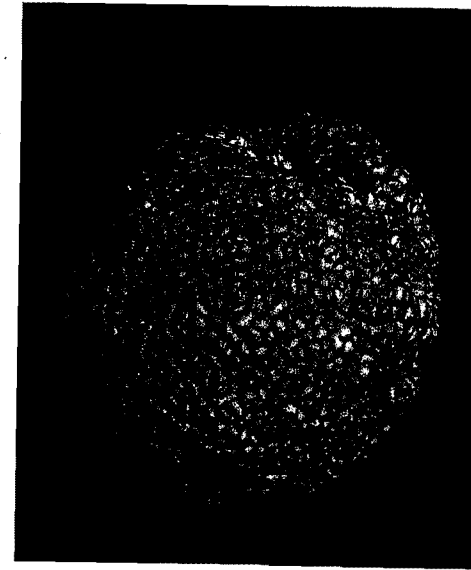


Fig. 1.6. Fruit of the Osage orange (*Maclura pomifera*). Photo by Steven J. Baskauf (<http://bioimages.vanderbilt.edu>).

just one watershed (the Bois d’Arc Creek). Yet fossil evidence indicates that this species ranged as far north as southern Ontario during the Pleistocene epoch. The thick pulp of the fruit repels rodents who might be tempted by the deeply embedded seeds. There are simply no extant animals who show any inclination to eat it.

Maclura is in the mulberry family (Moraceae) and has relatives from other parts of the world that are dispersed by extant megafauna. For example, *Treculia africana*, commonly known as African breadfruit, produces fruit with a diameter up to ten inches and is a favorite food of elephants. Similar examples can be found in other members of the Moraceae in Asia. The megafaunal traits of *Maclura* are so extreme that one wonders how it has managed to survive at all. Certainly, several other species of *Maclura* from North America did not survive the Pleistocene extinctions. Connie Barlow suggests that “root suckering, apomixis [nonsexual seed production] and the exceptional resistance to wood rot and termites are compensatory

life history traits that could have held extinction at bay for thirteen thousand years."²¹ Lewis and Clark were too late to help the ground sloths and mammoths, but they arrived just in time to start the process of pulling *Maclura* back from the brink of oblivion.

Why were the Pleistocene mammals so big? For that matter, why too the dinosaurs? There are several ways to answer that question. Generally speaking, the size of an animal increases with the landmass of the area they inhabit. A recent survey of the top terrestrial herbivores and carnivores over the past sixty-five thousand years confirmed this trend and also established a clear ranking of body sizes as follows: ectothermic (that is, cold-blooded) herbivore > endothermic (warm-blooded) herbivore > ectothermic carnivore > endothermic carnivore (fig. 1.7).

This ranking is due in part to the greater amount of food available to herbivores. A larger food base can support a larger body mass. Ectotherms are also favored for food caloric reasons, since they have a much lower energy requirement (per pound of body mass) than do endotherms. The logical extension of this argument is that an animal tends to be as big as its food base will allow. A larger landmass allows for larger home ranges of individuals, ergo more food and a larger animal. Other factors include a sort of ecological arms race in which herbivores tend to evolve larger body sizes in order to fend off would-be predators. Who would really want to tangle with an eight thousand-pound giant ground sloth or a twelve thousand-pound mammoth? Predators simply did not have the food base to get ahead in such a showdown. The ultimate mammalian expression of this battle was the case of the rhinoceros-like *Indricotherium* from Asia (alas, extinct for thirty million years) that stood sixteen feet high at the shoulders and weighed up to seventy thousand pounds.

21. Ibid.

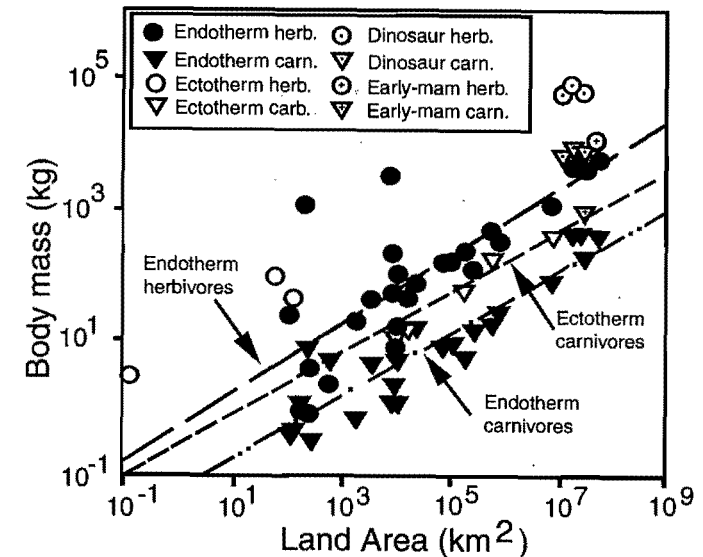


Fig. 1.7. Body masses of various animals (extinct or not) as a function of land area inhabited. The North American megafauna are evident as a cluster near the top right. From Gary P. Burness, Jared Diamond, and Timothy Flannery, "Dinosaurs, Dragons, and Dwarfs: The Evolution of Maximal Body Size," 14520. Reprinted with permission. Copyright 2001 National Academy of Sciences, USA.

The correlation between landmass and body size also explains many cases of small body size, in particular the numerous cases of dwarfism in animals that have become confined to islands. A classic case can be found on Wrangell Island in the Siberian Arctic. Rising sea levels separated this island from the mainland about twelve thousand years ago. The local mammoth population found itself stranded on a small landmass for which it was poorly suited. Evolution quickly (five thousand years is quick for evolution) remedied this imbalance by selecting for a size reduction of greater than 50 percent. Humans

are not immune to this law of landmass and body size, as recently demonstrated by the discovery of prehistoric three-foot-tall humans who evolved on the small Indonesian island of Flores.²² There are many other similar cases to be found in biology textbooks. On the other hand, North America is a large area, so it is to be expected that its animals would also be large.

Another likely factor in the large size of the megafauna was the need to keep warm, a particularly important factor during the ice ages. Large size in animals means a larger volume-to-surface-area ratio and hence an advantage in conserving heat. The relationships between body mass and structure or function are termed *allometrics*, a fascinating and vibrant field of biological inquiry beyond the scope of this discussion.

It has also been suggested that the evolution of large size in mammals was driven by increases in the concentration of oxygen in the atmosphere.²³ In the past 205 million years, the levels of oxygen in the atmosphere have increased from about 10 percent (by volume) to the current level of 21 percent. This correlates nicely with an increase in the body mass of mammals over geologic time and may be a consequence of the high energy demands of mammalian life history and the fact that larger animals require higher ambient oxygen levels to sustain maximal metabolic rates. Mammals in particular would have benefited from this higher level of oxygen because of the inherent inefficiency of oxygen transfer to the fetus as a consequence of placental reproduction.

22. See P. T. Brown et al., "A New Small-Bodied Hominid from the Late Pleistocene of Flores, Indonesia."

23. See Paul G. Falkowski et al., "The Risk of Oxygen over the Past 205 Million Years and the Evolution of Large Placental Mammals."

Last, what about those dinosaurs? Why were many of them so much bigger than even the Pleistocene megafauna? Ectothermy goes a good ways toward explaining this phenomenon if you are willing to accept that dinosaurs were cold-blooded, but many scientists now think dinosaurs may have been warm-blooded. An alternative explanation argues that some dinosaurs had a substantially larger plant-food base due to an elevated concentration of CO₂ in the atmosphere. Plants presumably responded with increased photosynthesis and productivity. More food, bigger animals. Determining the concentration of CO₂ in the long-ago atmosphere is a daunting task, but creditable reports estimate the level could have been >2,000 ppm (parts per million) from sixty to fifty-two million years ago, which compares to the current level of around 370 ppm.²⁴ If such high levels were present earlier, during the reign of dinosaurs, then dino-plants would have had prolific productivity.

So if big worked in the Pleistocene and before, why is small better now? Answer: us again, at least in some cases. Humans are a powerful selective force for small size in animals. Smaller sizes lead to shorter life cycles and earlier sexual maturity, which results in an improved ability to withstand the pressure of heavy predation. As an example, consider the case of the Atlantic cod, which has decreased markedly both in age and in size at maturation during the past three decades alone due to heavy fishing pressure by humans.²⁵ This rapid change apparently represents a true evolutionary adjustment, not just direct selection in which the bigger fish are removed.

24. See Paul N. Pearson and Martin R. Palmer, "Atmospheric Carbon Dioxide Concentrations over the Past 60 Million Years."

25. See S. Barot et al., "Long-Term Trend in the Maturation Reaction Norm of Two Cod Stocks."

Let's go back to the story of the disappearing giant sloths. Although many genera of sloths did disappear,²⁶ we do have two that managed to endure: *Bradypus*, the three-toed sloth, and *Choloepus*, the two-toed sloth. These animals have the traits that are typical of survivors of the megafaunal extinction: small body size (twenty pounds at best) and a habitat (treetops) that keeps them well separated from humans. About the only time that modern sloths come down from their tree perch is to defecate.

There are many other examples of the move toward smaller size and quicker maturity in response to human predation. Even the mighty bison underwent considerable dwarfing between 11,000 B.P. and 4,000 B.P. as the species readjusted to a new environment that included continuous hunting by Indians.²⁷ Quicker-maturing individuals were favored in the scheme of evolution since they could outreproduce larger, slow-to-mature individuals. Also, small animals were more agile and could get out of harm's way faster. Finally, it is reasonable to imagine that early humans (as with modern ones) would have been looking for the largest trophy to fill their pot or hang on the wall.

The bison story is a complicated one with many twists. Their near extirpation in the 1800s is usually seen as white man's folly, but it can also be seen as an unavoidable continuation of the forces that wiped out the megafauna. Even without the interference of white hunters in the 1800s, the bison might have been doomed anyway. The reintroduction of the horse into America by the Spaniards in the 1500s had shifted the equilibrium between the Indians and the bison. It is

26. The exact number is hard to pin down, but one source estimates that, worldwide, thirty-five genera of sloths disappeared (<http://www.sloth-world.org/Sloth-FAQ.html>).

27. Jerry N. McDonald, *North American Bison: Their Classification and Evolution*, 250.

at least feasible that the bison would have disappeared if this experiment had been allowed to run its course for a few more centuries.²⁸

What might have been the fate of the Lewis and Clark Expedition if the megafauna had still been there? There are many scenarios, and I seriously invite you to suggest your own. The only way for the megafauna to still be around is if the Indians had never shown up. If you take the Indians out of the picture, then a lot of things would have been different for Lewis and Clark. They would have had plenty to eat, what with all those slow and naive ground sloths ambling around, so easy to kill. They were good enough woodsmen that they probably could have dealt with the weather and built their own shelters for the severe winters on the Great Plains. But the Corps of Discovery was highly dependent on the Indians for information on which rivers to follow and where to cross the mountains. Plus, the Indians provided them with horses, which were indispensable for hauling their supplies over the mountains. Without the Indians, the Expedition may have been defeated by the maze of mountains in Montana and Idaho. Or they might have wandered off course and ended up a long way from their goal. That is what happened to Mackenzie the first time he tried to cross Canada. His goal was the Pacific Ocean, but through a slight miscalculation he ended up at the Arctic Ocean instead. He had to try again later after he had brushed up on his navigational skills back in London.

The point of all this is that the ecosystems that Lewis and Clark found were far from free from human interference. In fact, the "natural" system had been replaced with one shaped largely by humans. The extinction of the megafauna literally opened the door for other

28. Dan Flores, "Bison Ecology and Bison Diplomacy: The Southern Plains from 1800 to 1850," 465.

mammals that had evolved to cope with humans in Asia to move in for the first time. These included practically all the big mammals that Lewis and Clark saw: elk, moose, plains bison, and grizzly bear. According to one view, the bison on the Great Plains were just a "weed species" that moved into the void left by the extinction of the megafauna.²⁹ There are no known fossils of grizzly bears in the contiguous United States before thirteen thousand years ago. Recent evidence from mitochondrial DNA from permafrost-preserved bears in Alaska has confirmed that these bears did not have a long history of isolation from the founding Asian population.³⁰ The grizzlies moved in to take over the ecological niche left open by the demise of the short-faced bear, which was about twice the weight of a modern grizzly. A bear of such dimensions would have been a formidable adversary when met on the open prairie with the limited firepower possessed by Lewis and Clark. Indeed, such encounters would likely have an outcome much less favorable than that described by Lewis on May 5, 1805:

Capt. Clark and Drewyer killed the largest brown bear this evening which we have yet seen. it was a most tremendous looking animal, and extremely hard to kill notwithstanding he had five balls through his lungs and five others in various parts he swam more than half the distance across the river to a sandbar & it was at least twenty minutes before he died; he did not attempt to attack, but fled and made the most tremendous roaring from the moment he was shot.

29. Ibid.

30. See Jennifer A. Leonard, Robert K. Wayne, and Alan Cooper, "Population Genetics of Ice Age Brown Bears."

The next day, Lewis wrote further about their bear problems:

I find that the curiosity of our party is pretty well satisfied with respect to this animal, the formidable appearance of the male bear killed on the 5th added to the difficulty with which they die when even shot through the vital parts, has staggered the resolution several of them, others however seem keen for action with the bear; I expect these gentlemen will give us some amusement shortly as they soon begin now to copulate.

His prediction proved true. only a few days later, May 11:

About 5 P.M. my attention was struck by one of the Party running at a distance towards us and making signs and hallowing as if in distress. I ordered the perogues to put to, and waited until he arrived; I now found that it was Bratton. . . . [H]e arrived so much out of breath that it was several minutes before he could tell what had happened; . . . he had shot a brown bear which immediately turned on him and pursued him a considerable distance but he had wounded it so badly that it could not overtake him; I immediately turned out with seven of the party in quest of this monster, we at length found his trail and pursued him about a mile by the blood through very thick brush of rosebushes and the large leafed willow; We finally found him concealed in some very thick brush and shot him through the skull with two balls; we proceeded [to] dress him as soon as possible, we found him in good order; it was a monstrous beast, not quite so large as that we killed a few days past but in all other respects much the same the hair is remarkably long, fine, and rich, tho' he appears partially to have discharged his winter coat; we now found that Bratton had shot him through the center of the lungs, notwithstanding which he had pursued him near half a mile and had returned more than double that

distance and with his talons had prepared himself a bed in the earth about 2 feet deep and five long and was perfectly alive when we found him which could not have been less than two hours after he received the wound; these bears, being so hard to die, reather intimatedates us all; I must confess that I do not like the gentlemen and had rather fight two Indians than one bear.

Several themes thus emerge from these issues that are worth keeping in mind when considering the long-term view of nature in the West. The first is that prior to Lewis and Clark there was an astounding lack of understanding about what was out there with respect to both natural history and geography. The second, and perhaps more profound, concept is that nature is highly dynamic. Certainly, things have changed a lot since Lewis and Clark came through, but there were other equally dramatic changes much earlier that humans had a major hand in. The concept of the American West as unspoiled paradise prior to the 1800s is attractive, but it is misguided when viewed in a larger perspective of geologic time. Last, these pre-Euro-American changes raise complex questions for modern conservation biology and attempts to restore ecosystems in the West. Exactly how far back should we attempt to set the clock?

CHAPTER 2



Flagship Species

Lewis and Clark discovered several new plants that stand out as particularly appropriate icons of the Expedition. Chief among these is certainly the two genera, *Lewisia* and *Clarkia*, that were named after the captains.¹ Following close behind is *Calochortus elegans* (cat's ear or elegant mariposa lily), which qualifies as symbolic because it represented a new genus that contains some of the most strikingly beautiful and varied plants in the West. Finally can be added *Philadelphus lewisii* (Lewis's mock orange) and *Mimulus lewisii* (Lewis's monkey-flower), partly for aesthetic reasons, but also because of the use of Lewis's name for the specific epithet *lewisii*. The events surrounding the origin of these names involve not only Lewis and Clark but also several other figures of historical note, especially Frederick Pursh

1. Strictly speaking, only Lewis bore the official rank of captain, but he always referred to Clark by that rank, and the two men shared command on an equal footing. When Lewis recruited Clark for the Expedition, he offered Clark a commission as captain. Despite the support of Jefferson, Congress provided the official commission of only second lieutenant to the disappointment of both men.