A winter scene at The Stone Age Institute, which was built in 2003 and designed by the local architectural firm Kirkwood Design Studio. The entrance is a 35-foot stone tower modeled after prehistoric towers. *Courtesy of Kirkwood Design Studio*

Nick Toth and Kathy Schick in The Stone Age Institute library and great room, with replicas of skulls of extinct prehistoric carnivores from the Ice Age, between 50,000 and 25,000 years ago. From left: the American lion, the largest cat that ever existed (up to 1,000 pounds); the *Smilodon* or saber-tooth cat; and the cave bear.

From the Big Bang to the World Wide Web

13.7 billion years ago | 1 billion years | 100 million years | 10 million years | 1 million years | 100,000 years | 10,000 years | 1,000 years | 100 years | The last 10 years

Bloomington's The Stone Age Institute is creating an ambitious, multifaceted science program designed to explain the origins of everything!

by Jeremy Shere
Photography by Steve Raymer

The five great apes. From left: orangutan, gorilla, chimpanzee, bonobo (or 'pygmy chimpanzee'), and human. Humans are especially closely related to chimpanzees and bonobos (descending from a common ancestor perhaps 7 million years ago), and share almost 99 percent of our DNA code with these "cousin" species.

Where do we come from?

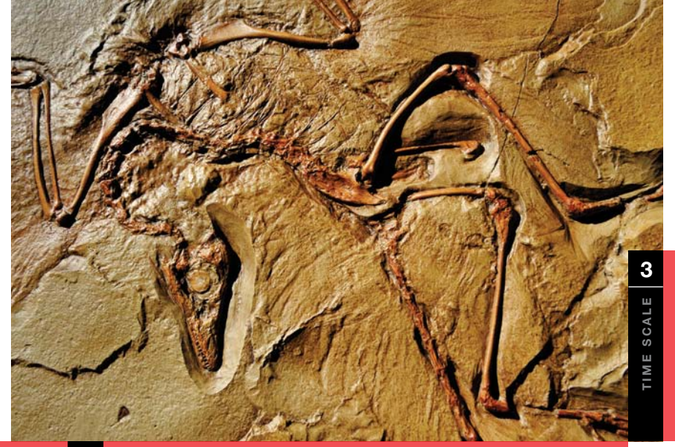
That's the question at the heart of "The Origins of Everything: From the Big Bang to the World Wide Web," a science outreach initiative headed by husband and wife team Kathy Schick and Nicholas Toth, IU professors of anthropology and cognitive science, and co-directors of The Stone Age Institute here in Bloomington. "Many people are interested in their ancestry," Schick says. "We're trying to provide the ultimate roots experience."

Set to premiere in the fall of 2010, the ambitious, multifaceted program—including an interactive website, a permanent exhibit at the Mathers Museum of World Cultures, a traveling exhibit throughout the United States and abroad, a book, and a song about evolution produced and performed by some of Bloomington's best musical talent, including Carrie Newcomer on lead vocals (and Toth on guitar)—explores 10 epochs, or "time scales," that together feature the 100 most significant events since the birth of the universe, nearly 14 billion years ago.

Starting with the Big Bang, the program moves through the entirety of evolutionary time, including the formation of galaxies, stars, and planets; the origins of life on Earth; the rise and fall of the dinosaurs; the evolution of mammals; and the rise of humans and advanced technology, culminating in the present-day information revolution.

Organizing the history of the universe into ten manageable segments is useful, Toth says, because the deluge of information about science available on the Internet and elsewhere can be overwhelming and make science seem overly difficult and remote from everyday life. "Our goal is to provide a framework for understanding and knowledge," he says. "Everything that happens builds on something that came before, so it's important that people see the big picture if they want to understand how the universe works and where it—and we—came from."

The program's ultimate goal, Schick says, is to remind people that all things—people, animals, plants, rocks, stars, even space—come from the same source. "It's easy to forget, but the chemicals necessary for life on Earth came from star dust," she says. "Ultimately, if you go back far enough, everything is connected."



One of the earliest birds, *Archaeopteryx*, had feathers (seen here as impressions in the limestone in which it was fossilized), but still retained ancestral reptilian features such as teeth. It lived about 150 million years ago in subtropical coastal areas of what is now Germany.

1 TIME SCALE

"From Nothing to Everything: The Origins of the Universe, the Solar System, the Earth, and Life"

(13.7–1 billion years ago)

Billions of years ago—13.7 billion, to be precise—the universe was compressed into a single, unimaginably dense pinprick. And then, for reasons unknown to science—BANG! That infinitesimally small point began to expand and become the universe we know. And it's been growing ever since.

"How and why the universe came into being and what existed before the Big Bang is one of the great mysteries of science," Schick says. "There are various theories and concepts, but we really don't know."

What scientists do know is that immediately after the Big Bang, the rapidly expanding universe consisted of a plasma soup of matter and antimatter particles battling for supremacy. As the infant universe continued to expand and cool, these elemental particles formed helium and hydrogen atoms that eventually came together to form gas clouds, which in turn coalesced to form stars. Gravity drew the stars together to form countless galaxies, one of which, the Milky Way, contained a medium-sized star in one of its spiral arms. Around this star, which we've named the Sun, planets formed, including our own, which came into being around 4.5 billion years ago. The Earth's surface and atmosphere evolved until the conditions were right for life to evolve in the ocean.

"Many people look at the stars at night and wonder how big the universe is and what it has to do with them," Toth says. "It has everything to do with us. When you gaze at the night sky you're literally seeing the universe evolving. And if not for the evolution of the universe, we wouldn't have a home."

2 TIME SCALE

"Animal House: the Cambrian Explosion of Animal Life and Its Aftershocks"

(1 billion to 100 million years ago)

For roughly 3.5 billion years, life on Earth was limited to the simplest creatures—primitive bacteria, other single-celled organisms, and then the earliest simple multicellular animals. Then, beginning around 540 million years ago, "there was an explosion of life, a rapid succession of events," Schick says, that involved the appearance of all the major phyla of animals seen today.

What enabled such a flowering after billions of years of relative stasis? During the earliest stages of its existence, the Earth underwent several deep freezes, known as "Snowball Earth." But after the last of these extreme ice ages, as the planet began to warm, single-celled creatures responded with a burst of evolutionary energy. Single-celled animals gave rise to multicellular organisms, which in turn begat primitive worms, jellyfish, anemones, sponges, brachiopods, sea mats, snails, and clams. Later, more complex animals such as crabs, spiders, and insects emerged, followed by our most ancient ancestors, chordates—the ancestors of creatures with backbones.

By 530 million years ago, the Earth—at least its wet parts—was teeming with complex life forms. The chordates would eventually lead to fish, then amphibians, and then reptiles.

But then, 250 million years ago, in what scientists call the Permian Extinction (or "The Great Dying"), more than 90 percent of all species on Earth disappeared. Scientists aren't sure what caused such a cataclysmic event but suspect that it involved some combination of environmental change due to massive volcanic eruptions, bombardment by one or more large asteroids, and changes in the chemical composition of seawater.

Whatever its causes, the Permian Extinction set the stage for the rise of the dinosaurs, small mammals, birds, and flowering plants.

3 TIME SCALE

"The Meek Inheritors [or One Extraterrestrial Impact Can Ruin Your Whole Day]: The Dinosaur Extinction and the Rise of Mammals"

(100 million to 10 million years ago)

Until their abrupt disappearance 65 million years ago, dinosaurs were one of the most successful types of animals in prehistory. T. rex, triceratops, velociraptor, and other reptilian dinosaurs familiar from the Jurassic Park movies roamed every continent, grew to enormous sizes, and kept our forebears—mammals—confined to small, niche habitats.

"The most interesting thing is that if you look at the fossil record, the world should still be dominated by dinosaurs," Toth says. "If not for something unexpected, they'd still be ruling like they did for 150 million years."

But something unexpected did happen—namely, an "Everest-sized" asteroid (or comet) slammed into Earth off the coast of Yucatan, Mexico. The impact caused global environmental chaos, causing massive flooding and an atmospheric blanket of ash that blocked out the sun and killed most plant life. Any plant-eating animals that survived the impact—and the carnivores that ate the herbivores—probably starved to death.

"It was a bad time to be a big-bodied dinosaur," Schick says, "but it opened the door for mammals."

Small and relatively insignificant until then, mammals took full advantage of the disappearance of their dinosaur overlords. During the next several million years, mammals and birds evolved into thousands of species, filling the ecological niches left empty when dinosaurs became extinct. By 50 million years ago, the major orders of mammals had arisen—marsupials (kangaroos, platypuses, and others), insect-eating creatures (moles, shrews, and hedgehogs), lagomorphs (hares and rabbits), carnivores (lions, tigers, bears, hyenas, and so on), rodents (mice, rats, chipmunks, etc.), primates (prosimians, monkeys, apes, and humans), and many others.

With the extinction of the dinosaurs and the rise of mammals, evolution started on a path leading directly to us. By 35 million years ago, the first monkeys appeared. Fast forward another 10 million years and apes appear, followed by primitive gorillas.

"One important lesson from this period is that evolution doesn't happen according to a predetermined plan," Schick says. "There's serendipity involved, unforeseen events that change the course of what comes next."

4 TIME SCALE

"Upstanding Apes: The Rise of Hominids, the Role of Rock, and Food for Thought"

(10 million to 1 million years ago)

"The story of the evolutionary origins of the cosmos, life, and humanity is the most profound and amazing story imaginable. Science, especially in the last century, is answering many of the questions of where we came from and how we got here."
Kathy Schick

Some time before 10 million years ago, Africa was covered almost entirely by dense forests populated by all manner of creatures, including many species of ancient apes.

But then, as it inevitably does, the climate changed. As the Earth cooled and became drier, African forests began to recede, giving way to savannahs and grasslands. Many species, including ape species, became extinct. But some, including our simian ancestors, responded to environmental change by evolving into something new: upright-walking apes.

Why did these creatures evolve to walk on two feet? Scientists aren't sure but suspect that bipedal locomotion allowed early humans to more efficiently carry food and possibly to feed on high bushes and lower branches of trees.

In any case, by five million years ago our ancestors, known as *Ardipithecus*, or "Ardi" (the first fossil evidence of which was just announced this past October), were hairy, upright-walking creatures with a grasping toe and a brain the size of modern apes. By four million years ago, they evolved into *Australopithecus* (including the famous fossil, "Lucy"). Zoom forward to two-and-a-half million years ago, though, and these creatures had begun doing something very un-ape-like: crafting stone tools—mainly sharpened stones used to butcher small animals and crack open bones to get at the protein-rich marrow inside.

The appearance of stone tools was hugely important in the evolution of early humans. It's no coincidence, Toth says, that "very soon after the emergence of stone tools, we get the expansion of the brain, reduction of jaws and teeth, and elongation of the legs and bodily proportions."

Over the next few million years, *Australopithecus* gave way to the first *Homo* species, our more immediate ancestors, whose brains were larger and tools more advanced. Well equipped to colonize new territory, our ancestors began to venture out of Africa and spread throughout Eurasia. By 1.7 million years ago, a species of hominid (or two-legged primate) called *Homo erectus* had come to dominate the human landscape. With their large brains—2/3 the size of modern human brains—and sophisticated tools, including large hand axes and cleavers, by about one million years ago, *Homo erectus* appears to have out-competed all other hominid forms. Soon, though, *Homo erectus* would be sent packing by an even bigger-brained human species: us.

5 TIME SCALE

"Becoming Human (or Just About): The Rise of Homo Sapiens and Our Neanderthal Cousins"

(1 million to 100,000 years ago)

For nearly one million years, *Homo erectus* spread throughout the Old World; fossil remains have been found in Africa, Europe, Indonesia, and China.

By half-a-million years ago, *Homo heidelbergensis*—hominids with large, modern human-size brains—had evolved from populations of *Homo erectus* in Europe and Africa. By 250,000 years ago, the famous Neanderthals (*Homo neandertalensis*), specially adapted to thrive during the ice age, had evolved and spread throughout Europe. And finally, a mere 200,000 years ago, modern humans, *Homo sapiens*—that is, you and I—came on the scene in Africa.

It's during this relatively recent epoch, Schick says, that we start "recognizing ourselves in prehistory." Both modern humans and Neanderthals had learned to control fire, to hunt with spears, and to craft elaborate, highly sophisticated stone tools.

We know how the story ends: Neanderthals died out as modern humans expanded beyond Africa and into Neanderthal territory. But it's worth asking: What exactly happened to the Neanderthals, who by all accounts had brains that were just as big, if not bigger, than *Homo sapiens*, and were exquisitely well adapted to their ice-age environment? Did our species wipe them out in a prolonged, bloody struggle over food and territory? Or, perhaps, did modern humans and Neanderthals interbreed?

The best evidence points to a more prosaic but logical conclusion: We simply out-competed Neanderthals. Although our brains weren't necessarily bigger, they were more agile and, significantly, had evolved the capacity for imagination and adaptability. Neanderthals, in contrast, were somewhat less adaptable—a disadvantage that gave modern humans a decisive edge. And so, well before the last ice age ended, Neanderthals became extinct. "Exactly why is up for controversy and conjecture," Schick says.

It's possible that Neanderthals and modern humans shared the same territory in relative peace for thousands of years. But our ability to live, hunt, and breed just about anywhere and our unique talent for inventing new ways to master a wide range of environments gave us a distinct advantage over our Neanderthal cousins. By 30,000 years ago, the last Neanderthals had disappeared, leaving *Homo sapiens* as the sole remaining humans on Earth.

6 TIME SCALE

"The Creative Explosion: The Rise of Symbolism, Language, Religion, Art, and Music"

(100,000 to 10,000 years ago)

Having emerged as the undisputed winners in the evolutionary race, what did humans do? We used our big brains to innovate and transform nature. As language continued to evolve, we invented new forms of communication. And, endowed with the imaginative prowess to invent entire worlds inside our minds, we began to paint, decorating the walls of caves with vibrant images of animals and people.

"Early human artwork, including cave painting and sculpture, is beautiful," Schick says. "When they look at it, most people feel instant identification and realize that these people were like me; they thought like I do, had a brain and feelings and emotions—things we think of as essential to humans."

Human culture didn't emerge all at once, of course. By 70,000 years ago, modern humans were crafting jewelry from shells, bones, and antlers, some of which were used for burial rites—the first evidence of which appears around the same time. The earliest signs of architecture—mammoth-bone huts—appear around 50,000 years ago.

It wasn't until 15,000 years later that prehistoric people began to make art, including sculpture and painting, and to play music. Around the same time, people began using needles and thread to fashion clothes.

"It's during this period that we really see prehistoric peoples inventing culture that we recognize as fully human and completely familiar," Toth says. "People lived very different lives than we do today, but how they perceived and interacted with the world is essentially the same as we do today."

Time Scale 4

The earliest known human technology, named the Oldowan, after the famous site of Olduvai Gorge in Tanzania, is characterized by simple stone tools made on cobbles. Oldowan sites are found as early as 2.6 million years ago. They are associated with the prehistoric human forms *Homo habilis* (left) and early *Homo erectus* (right), who had brains one-half to two-thirds the size of modern humans.

Time Scale 5

Around half-a-million years ago, prehistoric humans were making beautiful stone tools, including cleavers (top) and handaxes (bottom), as well as wooden spears. These types of tools, called Acheulean after a site in France, were made by *Homo heidelbergensis* from Africa (left) and Europe (right). These toolmakers had brains that overlapped in size with those of modern humans, but their faces were much more robust, with very prominent brow ridges above the eyes.

Time Scale 6

The Neanderthals (left), *Homo neandertalensis*, and modern humans (right), *Homo sapiens*, coexisted until the Neanderthals went extinct around 30,000 years ago. Modern humans ultimately developed new tools (lower right), including harpoons, fine spear points, blades, bone needles, and stone lamps, as wells as the earliest representational artwork.

Time Scale 7

After the retreat of the ice sheets about 10,000 years ago, human societies in many parts of the world became farmers during the "Neolithic Revolution." New tools included pottery, ground stone axes, grinding stones to process cereal crops, and other beautiful stone tools suggesting craft specialization.

7 TIME SCALE

"From Farm to City: The Neolithic and Urban Revolutions and Their Consequences"

(10,000 to 1,000 years ago)

Until around 10,000 years ago, prehistoric humans were nomadic Stone Age hunter-gatherers. Small clans of a few dozen individuals followed the animals they hunted, foraging roots, berries, and other wild plants along the way.

But then, as ice sheets began to recede throughout Europe and North America, something extraordinary happened: People stopped wandering, settled down in one spot, and began domesticating plants and animals. Independently, throughout the Near East, East Asia, Africa, and the Americas, agriculture was born.

It's unclear exactly how and why people moved from hunting and gathering to farming. It probably involved some combination of chance, optimal environmental conditions, and human ingenuity.

What archaeologists do know is that the rise of agriculture was a major turning point in human history. People went from living in small nomadic groups to inhabiting permanent settlements with relatively large populations. Before long, human society became more specialized; while farmers did the work of growing and producing food, others were freed to develop different skills, such as metal working, pottery making, weaving, and art.

By 5,500 years ago, agricultural settlements had given rise to written language and methods of counting, and to the first true cities and the trappings of advanced civilizations: kings and queens, priests, armies, taxes, traffic, and pollution.

"Once people had the ability to accumulate wealth, we immediately start seeing haves and have-nots in ancient societies," Toth says. "It's an almost inevitable consequence of any society where people gain power based on how much stuff they have."

Through the Bronze Age (5,000 years ago) and the Iron Age (3,500 years ago), human civilizations continued to develop, as carts, wagons, chariots, and other wheeled vehicles, and the first large ships, enabled travel and trade over long distances.

By 2,700 years ago, Greek civilization and its astonishing advances in science, philosophy, and politics had spread throughout the Mediterranean and much of Europe—a cultural transformation continued 700 years later by the Romans and their vast empire.

The fall of Rome's Western empire in 410 A.D. marked the onset of the so-called Dark Ages—an era when classical culture and learning gave way to superstition and the suppression of knowledge. But before long, humanity was poised to enter an entirely new, more enlightened age.

Nick Toth holds a specimen of "one of the world's strangest fossils"—*Dicranurus monstrosus*, a surreal trilobite with spiny horn-like structures, that lived in the seas of what is now North Africa about 400 million years ago. Such complex animal forms emerged after the Cambrian explosion.

8 TIME SCALE

"Ages of Enlightenment: From the Dark Ages of Superstition to the Scientific Revolution"

(1,000 to 100 years ago)

During the Dark Ages (from roughly the 5th through the 11th centuries, followed by the Middle Ages during the 12th through the 14th centuries), most people throughout Europe were ignorant of Greek and Roman triumphs in science, art, and literature. Illiteracy was the norm. Plague swept through cities and towns in deadly waves, killing off up to a third of the population of Europe. Science as we know it, at least in Europe, did not exist.

But by 650 years ago, thanks largely to the preservation of Greek and Roman thought by Arabian scholars, European thinkers re-embraced classical ideas and gave rise to the great flowering of culture known as the European Renaissance. Within a few hundred years, the world was utterly transformed by advances in printing, geography, art, science, and literature.

"So many things happened during this time period that set the world on a new course," Schick says. "There was a great stitching together of different parts of the world, or people being interconnected long before the Internet."

In a great creative burst throughout the 1400s and 1500s, technical innovations such as the printing press made books more widely available and encouraged literacy, while creative giants such as Michelangelo Buonarroti and Leonardo da Vinci achieved new heights in painting, sculpture, and architecture.

Around the same time, European explorers were "discovering" the Americas, Australia, and the Pacific Islands.

Perhaps most significantly for Schick and Toth, starting in the 16th and 17th centuries thinkers such as Nicolaus Copernicus and Galileo Galilei began to challenge prevailing notions about the natural world, most prominently the dogma that the planets, sun, and stars revolved around the Earth. (The Catholic Church persecuted Galileo for championing Copernicus' claim that the Earth circled the sun, finding him guilty of heresy and condemning him to a life sentence under house arrest.)

Most historians credit these figures with giving birth to modern science, paving the way for later revolutionary thinkers such as Isaac Newton, Charles Darwin, and many others whose work in mathematics, biology, chemistry, astronomy, physics, and economics fueled the Industrial Revolution. In rapid succession, technologies including steam-powered engines (used to power locomotives, ships, and other machines), the first airplanes, photography, the telegraph and telephone, radio, and electricity utterly transformed modern life.

9 TIME SCALE

"Modern Times: The Last Century, and Laying the Foundations of the World We Live In"

(100 to 10 years ago)

As impressive as human achievement was during the 15th through the 19th centuries, it in many ways pales in comparison to what we accomplished during the 20th, for both good and evil.

Beginning with Albert Einstein's $E=MC^2$, which revolutionized our understanding of the nature of time and space and paved the way for quantum mechanics (the study of atoms and subatomic particles), virtually every field of science experienced a creative explosion comparable to the evolution of art and literature during the Renaissance.

Advances in physics gave rise to rocketry, which in turn made possible satellite technology and space exploration, culminating in the first moon landing in 1969. Television, computers, and jet airplanes first emerged in the 1930s and have evolved at dizzying speed ever since. The atomic bomb made its violent debut in the early 1940s—a grim (if inevitable) development countered by the invention of antibiotics around the same time—a discovery that has since saved countless lives. A few years later, in 1953, James Watson and Francis Crick for the first time described the structure of DNA, pushing biology and medicine in new directions and giving rise to the science of genetic engineering.

And, finally, at the end of the 20th century, cell phones and the World Wide Web appeared, forever changing how we communicate.

Beyond technical and scientific innovations, Toth says, during the past several decades people have begun to "reflect on the antiquity of the human species, the earth, and the universe. And for the first time, we have the tools to explore these things. We're living in a magical time."

But, he adds, human progress hasn't been entirely beneficial. Rapidly growing human populations enabled by unchecked growth in agriculture and other industries are now putting enormous pressure on the environment, resulting in global problems that we're only now beginning to realize and attempting to solve.

10 TIME SCALE

"The Age of Connections: The Past Decade of Innovations and Their Implications"

(The last 10 years)

In the early years of the 21st century, we've continued to build on the achievements of the 20th. In just the past decade we've made great strides in astrophysics and space exploration (investigating dark matter and exploring Mars with mobile robots), digital communication (Google, GPS, the iPhone), medicine and biology (mapping the human genome, stem cell research), and engineering (nanotechnology).

But more than a century of burning fossil fuels to power our cars, homes, computers, and the thousands of other machines we rely on every day has resulted in daunting energy and environmental issues: namely, rapid depletion of fossil fuels and global warming caused by the buildup of carbon dioxide and other "greenhouse gasses" in the atmosphere.

"We'd better wake up pretty soon and realize the tenuousness of our place on this planet and the importance of our relationship with its resources and other species," Toth says.

But however daunting our 21st-century challenges, Toth and Schick are optimistic that the development of clean, renewable sources of energy can help us solve these problems and leave the world a better place than we found it.

"That's what our program is really about," Schick says, "having a sense of our place in the greater scheme of things. Humans have come a long, long way—we're no longer entirely at the mercy of nature. In many ways we control our own destinies, but nothing is guaranteed. If we want to continue thriving into the future, we have to work together to make smart choices about how we live in relation to the planet, and to the universe." ✲

Later Time Scale 7

During the last 5,000 years, some farming societies developed even more complex ways of living that we call "civilization." Many of these societies developed metallurgy and writing and built cities. The artifact examples here are from China and include a ritual cooking vessel (top), a musical bell, a dagger, and a drinking vessel, all in bronze, and an "oracle bone" with early Chinese characters engraved on a tortoise shell, used to divine the future.