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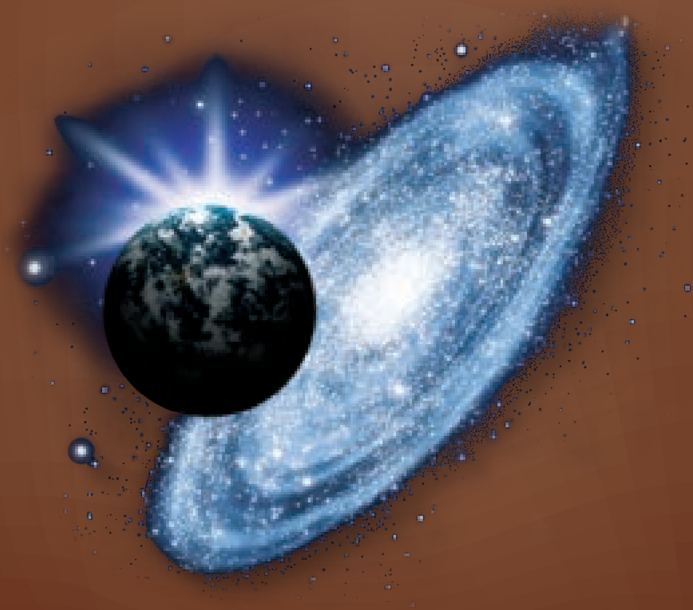
Big History: The Big Bang, Life on Earth, and the Rise of Humanity

Course Guidebook

Professor David Christian
San Diego State University



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Professor David Christian is Professor of History at San Diego State University, where he teaches courses on big history, world environmental history, Russian history, and the history of Inner Eurasia. From 1975 to 2000, he taught Russian history, European history, and world history at Macquarie University in Sydney.

Professor Christian was born in New York and grew up in Nigeria and Britain. He completed his B.A. in History at Oxford University, his M.A. in Russian History at The University of Western Ontario, and his D.Phil. in 19th-Century Russian History at Oxford University. As a graduate student, he spent a year in Leningrad (now St. Petersburg) during the Brezhnev era.

In the late 1980s, Professor Christian developed an interest in understanding the past on very large scales. With the help of colleagues in astronomy, geology, biology, anthropology, and prehistory, he began an experimental history course that started with the origins of the Universe and ended in the present day. Within two years, after his students persuaded him that it was a shame not to deal with the future after studying 13 billion years of history in 13 weeks, he introduced a final lecture on prospects for the future. In 1992, he wrote an article describing this approach as “big history.” The label seems to have stuck, as similar courses have independently appeared elsewhere, and there are now several courses in big history at European, Russian, Australian, and North American universities.

In addition, Professor Christian has written on the social and material history of 19th-century Russian peasantry, in particular on aspects of diet and the role of alcohol. In 1990, he completed a study of the role of vodka in Russian social, political, and economic life. Professor Christian’s recent publications include: *Imperial and Soviet Russia: Power, Privilege and the Challenge of*

Modernity (Macmillan/St. Martin's, 1997); *A History of Russia, Central Asia and Mongolia, Vol. 1: Inner Eurasia from Prehistory to the Mongol Empire* in *The Blackwell History of the World* (Blackwell, 1998); *Maps of Time: An Introduction to Big History* (University of California Press, 2004), which won the 2005 World History Association Book Prize and has been translated into Spanish and Chinese; and *This Fleeting World: A Short History of Humanity* (Berkshire Publishing, 2007).

Professor Christian is a member of the Australian Academy of the Humanities and the Royal Holland Society of Sciences and Humanities. He is Affiliates Chair for the World History Association and was one of the editors of the *Berkshire Encyclopedia of World History*. He also participated in the creation of the world history website World History for Us All (http://worldhistoryforusall.sdsu.edu/dev/default.htm). ■

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SUPPLEMENTAL MATERIAL

Big History: The Big Bang, Life on Earth, and the Rise of Humanity

Scope:

Big history surveys the past at all possible scales, from conventional history, to the much larger scales of biology and geology, to the universal scales of cosmology. It weaves a single story, stretching from the origins of the Universe to the present day and beyond, using accounts of the past developed within scholarly disciplines that are usually studied quite separately. Human history is seen as part of the history of our Earth and biosphere, and the Earth's history, in turn, is seen as part of the history of the Universe. In this way, the different disciplines that make up this large story can be used to illuminate each other. The unified account of the past assembled in this way can help us understand our own place within the Universe. Like traditional creation stories, big history provides a map of our place in space and time; but it does so using the insights and knowledge of modern science.

At first, the sheer scale of big history may seem unfamiliar—after all, historians usually focus on human societies, particularly those that had states and left documentary records. Until the mid-20th century, "history," in the sense of a chronologically structured account of the past, meant "human history" because we could only date those parts of the past for which we had written records. Since World War II, however, new dating techniques have allowed us to determine absolute dates for events before the appearance of written records or even of human beings. Radiometric dating techniques, based on the regular breakdown of radioactive materials, were at the heart of this chronometric revolution. These new chronometric techniques have transformed our ideas of the past, enabling us for the first time to construct a well-structured, scientifically rigorous history extending back to the origins of the Universe!

Telling this story is the daunting challenge taken up by big history; however, we have so much knowledge today that no single individual can be an expert on it all. Thus, you will not find in this course detailed analyses of the functioning of DNA, the causes of the French Revolution, the myths of ancient Greece, or the artistic innovations of the Renaissance—plenty of other courses offer more detailed accounts of such topics. What you *will* find is an attempt to weave stories told within many different historical disciplines into a larger story so that, instead of focusing on the details of each period or discipline, we can see the larger patterns that link all parts of the past. I am a historian, so this course inevitably reflects the expertise and biases of a historian. The same tale can also be told, with varying emphases, by astronomers and geologists. But at the heart of any such account is a core story, one that enables us to see the underlying unity of modern knowledge.

The first modern courses in big history appeared in the 1970s and 1980s. I began teaching big history in 1989; in 1991, I published an article in which (somewhat whimsically) I coined the term "big history." Though far from ideal, the name seems to have stuck, which is why we use it here in this course.

The unifying theme adopted in this course is the idea of increasing complexity. Though most of the Universe still consists of simple empty space, during almost 14 billion years new forms of complexity have appeared in pockets, including stars, all the chemical elements, planets, living organisms, and human societies. Each of these new forms of complexity has its own distinctive "emergent" properties, which is why each of them tends to be studied within a different scholarly discipline.

The introductory lectures describe the origins and aims of big history, the vast scale of the modern creation story, the central idea of complexity, and the large body of scientific evidence on which this account of big history is based. Eight major thresholds of increasing complexity provide the basic framework for this course.

The first threshold we cross is the creation of the Universe itself about 13.7 billion years ago during the big bang. This group of lectures summarizes some of the main insights of modern cosmology. We move from cosmology to astronomy in the second threshold with the creation of stars, which were the first really complex objects to appear in our Universe as well as the source of energy and raw materials for later forms of complexity. The third threshold is the creation of the chemical elements, which laid the foundations for the new forms of complexity studied within the discipline of chemistry. In the fourth threshold, where we cross from chemistry to geology, we zoom in on our own tiny corner of the Universe: the solar system and the creation of the planets, including Earth.

Earth provided an ideal environment for the fifth threshold, which takes us from geology to biology and describes the appearance of life; we survey the history of life on Earth and the evolution of our own species. The sixth threshold in this course is the appearance of human beings between 200,000 and 300,000 years ago, leading us from biology to history and marking the beginning of the first of three major eras of human history. The seventh threshold is the appearance of agriculture about 10,000 to 11,000 years ago, which supported larger and denser populations and made possible the creation of more complex human societies. Finally, the eighth threshold concerns the modern world within the last few centuries; during this period, the pace of innovation increased, creating human societies vastly more complex and integrated than those of the Agrarian era.

The final lectures of the course will peer into the future, and the course will end with a discussion of the place of human beings within the Universe.

I hope you will find the sheer scale of the course exhilarating, and I hope you will be persuaded—as I am—that each of the different time scales surveyed in this course has something important to teach us about our distinctive place within the Universe. ■

The Structure of the Course

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What Is Big History?

Lecture 1

Big history assembles accounts of the past from many different disciplines into a single, coherent account of the past.

In this lecture, I introduce myself and describe how I began teaching such a course. Then I discuss what big history is and some of the challenges it poses. I end by describing the structure of this course. I will begin by describing my own path to "big history." My own, somewhat confused background is relevant here. I was born in Brooklyn, lived as a child in Nigeria, went to school and university in England, married in Canada, studied as a graduate student in Russia during the Brezhnev years, then taught Russian and Soviet history at Macquarie University in Sydney, Australia, for 25 years before coming to the U.S. in 2001. That background may explain my interest in global approaches to the past!

The French Annales School of historiography insisted on seeing history within a larger spatial and temporal context. It had an immense impact on historians of my generation. The leading *annaliste*, Fernand Braudel, famously argued that historians needed to explore the past at multiple scales, including what he called the "*longue durée,*" or very large time scales. Only at these scales could you tackle the history of important but often neglected features of life such as diets, which seemed to change hardly at all at smaller scales. To fully understand the past, he argued, you had to see it at multiple scales.

These ideas encouraged me to undertake research on the daily life of 19^{th}-century Russian peasants, and led to a study on the vital role of vodka in 19^{th}-century Russia. As a history teacher, I was also concerned about the *significance* of history. Why did we always seem to be teaching fragments of the past rather than trying to convey a sense of the past as a whole? In the 1980s, I took up these twin challenges in the most ambitious way I could imagine, by creating a history course that began at the beginning—with the origins of the Universe.

I began teaching big history with a wonderful team of astronomers, geologists, biologists, anthropologists, and historians. Such courses are rare, so we made up the rules as we went along. We soon found that big history was exhilarating for both teachers and students because it allowed us to explore fundamental questions about the meaning of history and our place in the cosmos.

In 1992, I wrote an article on the course using the whimsical label "big history." It's not the ideal label but … it seems to have stuck! Since then, I've discovered that in the U.S., the rapidly emerging field of "world history" is also aiming at a larger vision of the past. So, big history can be thought of as an expansion of the world history approach to the past.

Threshold 6 is the creation of our own species, *Homo sapiens*, about 250,000 years ago.

Because of its large scale and the many disciplines it touches on, many will find this vision of the past unfamiliar. We do not try to cover everything! Instead, we will focus on large patterns of change. This means familiar historical topics, such as the French Revolution or the Renaissance, may seem to sail past in a blur. Though we will touch on many disciplines, from cosmology to biology to history, my expertise is as a historian. So this is not the course in which to study the specialist details in each discipline. Others are better qualified to explain the intricacies of DNA or the nuances of Confucian philosophy. Instead, you will find an attempt to link the insights of these different disciplines into a single, coherent vision of the past, in which each discipline can provide its own distinctive illumination.

Though such courses are unusual today, they belong to a long and ancient tradition. Though it uses modern, scientific information, big history has many similarities with traditional creation stories. These also used the best available information to construct credible and powerful stories that gave people a sense of their bearings in space and time. Similar attempts to map space and time have been made within all the great religious and cultural traditions. This was the aim of Christian writers such as Augustine (354–430 C.E.), who constructed a universal history that began about 6,000 years ago and would shape Christian historiography for more than 1,000 years. H. G. Wells's *Outline of History*, published just after WWI, is perhaps the most famous 20th-century attempt at a universal account of the past.

Despite this long tradition of "universal histories," modern education focuses on specialized knowledge, which inevitably leads to a fragmented vision of reality. Erwin Schrödinger (1887–1961), one of the pioneers of quantum physics, wrote a famous book on the nature of life in which he argued that it was vital for scholars to cross discipline boundaries, despite the risks this involved, if we are to move toward a more unified understanding of reality. That is the spirit in which I have approached this course.

What follows counts as just one attempt to tell the story of big history. There are other courses in big history taught by geologists and astronomers, and their emphases differ. However, historians may be in a particularly good position to tell such stories because historians are used to dealing with phenomena of extraordinary complexity, and they are also used to weaving stories from complex information.

This course is organized around the central idea of eight thresholds of increasing complexity. These eight thresholds provide the scaffolding for this course. Threshold 1 is the creation of our Universe about 13 billion years ago. Threshold 2 is the creation of the first complex objects, stars, more than 12 billion years ago. Threshold 3 is the creation inside dying stars of the chemical elements that allowed the formation of chemically complex entities, including planets and living organisms. Threshold 4 is the creation of planets, such as our Earth, bodies that are more chemically complex than the Sun. This group of lectures also surveys the history of our home planet.

Threshold 5 is the creation and evolution of life on Earth from about 3.8 billion years ago. This group of lectures also surveys the evolution of our own ancestors, the hominines, from about 6 million years ago.

Threshold 6 is the creation of our own species, *Homo sapiens*, about 250,000 years ago. This section of the course discusses what makes us so distinctive and describes the Paleolithic era of human history.

Threshold 7 is the appearance of agriculture (about 11,000 years ago). Agriculture accelerated the pace of change, leading to the emergence of larger and more complex societies and introducing the Agrarian era of human history.

Threshold 8 is the "Modern Revolution," the vast social, economic, and cultural transformations of recent centuries that introduced the Modern era of human history and created today's world.

The concluding parts of the course look to the future of humans, of the Earth, and of the Universe. They also offer an overview of the entire course.

Here are some of my more important objectives in this course.

- I hope you will find this huge journey exhilarating.

- I hope you will gain a clear understanding of the overall shape of this modern origin story.

- I hope you will gain a better sense of the underlying unity of modern knowledge. ■

Essential Reading

Christian, "The Case for 'Big History.'"

———, *Maps of Time,* Introduction.

Supplementary Reading

Christian, "World History in Context."

Questions to Consider

1. What are the main difficulties we face in trying to construct a “modern creation story”?

2. How can big history help us to better understand who and what we are?

Moving across Multiple Scales

Lecture 2

Tigers are dangerous; galaxies are not. Bump into a tiger, you have to be able to understand it, you have to be able to deal with it. Bump into a galaxy and, quite frankly, you're not going to need to deal with it. Either it's going to obliterate you and all of us, or it's not.

We saw that big history surveys the past at many different scales. Indeed, one of the unifying ideas of big history and one source of its intellectual power is the idea that what we see at any one scale illuminates what we see at other scales. That makes it very different from most history courses, which normally concern themselves with scales of a few decades to a few centuries. So big history requires an understanding of large spatial and temporal scales. But how can we possibly grasp how big (or how old) our solar system is—or the entire Universe? This lecture tries to help you deal with multiple scales in both space and time.

Understanding such scales is both difficult and extremely important. There's a biological reason why it's difficult. Our brains evolved to deal with the scales familiar in our daily lives, the "biological scale." Tigers are dangerous; galaxies are not! So we're not really designed by nature to grasp larger spatial or chronological scales. As Stephen Jay Gould writes: "An abstract, intellectual understanding of deep time comes easily enough—I know how many zeroes to place after the 10 when I mean billions. Getting it into the gut is quite another matter" (Gould, *Time's Arrow, Time's Cycle*, p. 3).

But getting a feeling for these large scales is important. Like ants on an elephant, we can see only the wrinkles up close. If we don't stand back, we'll never see the elephant. Each scale within big history brings new things into focus, even if it also hides other things. Though we can never really grasp the largest scales, like geologists and astronomers, we can find ways of dealing with them. The rest of this lecture starts the process of helping you become more comfortable with large scales.

To get a sense of spatial scales, let's go on a journey through the solar system. We begin with the human scale, then widen the lens. On April 12, 1961, at 9:07 am Kazakhstan local time, Yuri Gagarin blasts off aboard a Vostok 1 rocket from the Baikonur Cosmodrome to become the first human being to enter space.

We can picture the lift-off because we're still at the human scale. Almost 6 miles up we see Baikonur as if from an international jet. That's a view familiar to many of us. Gagarin reached 188 miles, close to the orbit of the International Space Station (220 miles). From here you can see large, clearly geographical features—seas and mountains—and also the Earth's curvature. But you can no longer see Baikonur. From 6,000 miles up we can see the Earth as a ball drifting in space. The first pictures of Earth from space had a powerful impact because they reminded people of the Earth's fragility and isolation.

Courtesy NASA.

Neil Armstrong became the first man on the moon.

What does the Earth look like from the Moon? Neil Armstrong landed on the Moon at 10:56 pm (EDT) on July 20, 1969, becoming the first human to step onto another world. As he stepped on the Moon his interest was focused (naturally) on whether he was stepping into quicksand; yet he was also aware of the momentousness of the occasion. He was thinking at multiple scales.

So far, no human has traveled further—though two human-made objects, the Voyager satellites, have now passed the outer planets of our solar system. To appreciate the scale of the solar system, imagine flying in a modern passenger jet at roughly 550 mph. To cross the continental U.S., it takes about 5 hours. To reach the Moon, it would take 18 days. To reach the Sun, it would take 20 years; to reach Jupiter, about 82 years; and about 750 years to reach Pluto, at the edge of our solar system. These are distances our minds can no longer grasp.

Stellar scales take us to entirely new orders of magnitude. How long would it take to reach the nearest star, Alpha Centauri, which is about 4.3 light years, or 25 trillion (25,000,000,000,000) miles away? The answer is about 5 million years. Cosmologically, that's a walk next door!

How many of these stellar neighbors do we have? There are about 100 billion stars in our stellar "city," the Milky Way. Most are separated by a plane flight of at least 5 million years. How many galactic "cities" are there in our Universe? About 100 billion. This means, as Cesare Emiliani writes, that there are "about as many stars in the Universe as there are sand grains in all the deserts and beaches of the Earth" (Emiliani, *The Scientific Companion*, p. 9). Another way of appreciating these different spatial scales is by going to one of the many "Powers of 10" websites. These offer images of the Universe at different scales, from the very large to the very small.

There are about 100 billion stars in our stellar "city," the Milky Way.

The temporal scales of the modern creation story are equally daunting. But they are not unique. Almost 2,500 years ago, the Buddha described even larger time periods in a delightful parable about how long it would take to wear down an entire mountain just by dragging a silken cloth across it. Our modern time scale, with a Universe just over 13 billion years old, seems modest in comparison. We can grasp it more easily if we shrink it one billion times, so that the whole history of the Universe can fit into just 13 years. On this scale, our Earth would have been formed about 5 years ago. The first multi-celled organisms would have evolved about 7 months ago. After flourishing for several weeks, the dinosaurs would have been wiped out by an asteroid impact about three weeks ago. The first hominines would have appeared about three days ago, and our own species just 53 minutes ago. The first agriculturalists would have flourished about 5 minutes ago, and the first Agrarian civilizations would have appeared just 3 minutes ago. Modern industrial societies would have existed for just six seconds.

At first sight, these huge scales may seem to deprive human history of any significance. But we will see in the next lecture that this is not quite the end of the story. By some criteria, such as that of "complexity," we humans and our history are significant even on cosmological scales. The French philosopher Pascal wrote: "For what is Man in nature? A nothingness in respect to infinity, a whole in respect to nothingness, a median between nothing and everything" (Delsemme, *Our Cosmic Origins*, p. 1). ■

Essential Reading

Christian, *Maps of Time*, chap. 2, 53–55; app. 1.

———, "World History in Context."

Supplementary Reading

Calder, *Timescale*.

Delsemme, *Our Cosmic Origins*, Introduction.

Gould, *Time's Arrow, Time's Cycle*.

Kelley, *The Home Planet*.

Power of 10 Websites

http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

http://www.powersof10.com/

http://www.wordwizz.com/pwrsof10.htm

Questions to Consider

1. Do the huge spatial and temporal scales of modern cosmology diminish the significance of human beings?

2. Is it possible that, by placing humans in a larger context, they can help to illuminate the nature and meaning of human history?

Simplicity and Complexity

Lecture 3

You could study the properties of hydrogen and the properties of oxygen as long as you liked without being able to predict the properties of water, which is what you get when you combine two hydrogen atoms and an oxygen atom in a very specific way.

What thematic coherence can we possibly find across all the scales and disciplines included within big history? This lecture discusses the unifying idea of increasing complexity. We must begin by exploring what we mean by "complexity."

Here are some basic properties of complex entities. Complex things, like stars, planets, or living organisms, consist of diverse components bound into larger structures. These structures display "emergent" properties: features that are not present in the components from which they are constructed, but appear only when those components are assembled in specific ways. For example, the properties of water are not apparent in its component atoms, hydrogen and oxygen. They emerge only from a particular arrangement of those atoms. Emergent properties can appear magical because they do not reside in particular things but only in particular arrangements of those things. The idea of "emergence" is present in many different religious and scholarly traditions.

Complex entities have a certain stability. Molecules or stars survive for billions of years; butterflies survive for just a few days. But eventually they all break down. Energy flows are needed to bind simple components into more complex structures. Without these flows the structures break down. We study complex things because we are complex. But there are also good biological reasons for our fascination. To survive, we must be good at detecting complex patterns in our surroundings (such as tigers or tax inspectors!).

Over 13 billion years, the upper level of complexity appears to have increased. Intuitively, this is reasonably clear. The early Universe consisted of little more than hydrogen and helium; today's Universe contains many more interesting objects, such as ourselves! There may be more rigorous ways of demonstrating that complexity has increased. Astronomer Eric Chaisson (who teaches an astronomer's version of big history in Boston) argues that if it takes energy flows to sustain complexity, we ought to be able to measure levels of complexity by estimating the size of those energy flows in different complex entities. To test this idea, Chaisson has estimated the amount of energy (in ergs) flowing through a given amount of mass (in grams) in a given amount of time (seconds) within several complex entities. He finds that these energy flows increase significantly as we move from stars to planets to living organisms to modern human society.

Complexity ought to be decreasing, not increasing!

Chaisson's results suggest conclusions of fundamental importance for big history. Most of the Universe has remained simple. Yet the upper level of complexity has increased. Chaisson's calculations suggest that living organisms are more complex than stars, and modern human societies may be among the most complex things we know. Perhaps we are not as insignificant as the previous lecture might have suggested. However, more complex objects also appear to be rarer and more fragile than simpler objects. Stars, for example, are more common and survive longer than butterflies. The simplest thing of all—the vacuum—is more common than either!

Curiously, the idea that complexity has increased may seem to contradict one of the most fundamental laws of physics: the second law of thermodynamics. The laws of thermodynamics describe the relationship between energy and work (the ability to make things happen, to cause change). The first law states that the total amount of energy available in any closed system (such as the Universe) is fixed. Yet at any particular point in the Universe, the form, distribution, and intensity of energy can change. This matters because work can be done only when energy is distributed unevenly, so that it can flow from one level to another: from the top to the bottom of a waterfall, or from the boiler to the condenser of a steam engine.

However, as energy flows its distribution evens out, thereby reducing the capacity of energy to perform work. Like a battery, electrons flow from one terminal to the other until the distribution of electrons has evened out, and we say the battery has "run down." Energy has not disappeared; it is simply distributed more evenly so it cannot flow or do work. The level of simplicity or disorder (known as "entropy") has increased.

The second law of thermodynamics was formulated by a German physicist, Rudolf Clausius (1822–1888). It generalizes these principles, stating that differences in energy levels tend to diminish as work is done, so that entropy increases. Applied to the Universe as a whole, the second law of thermodynamics implies that energy flows ought to decrease over time.

As Stuart Kauffman puts it:

> The consequence of the second law is that … order—the most unlikely of the arrangements—tends to disappear. … It follows that the maintenance of order requires that some form of work be done on the system. In the absence of work, order disappears. Hence we come to our current sense that an incoherent collapse of order is the natural state of things. (Kauffman, *At Home in the Universe*, pp. 9–10)

Complexity ought to be decreasing, not increasing!

How can the upper levels of complexity increase if energy flows in the Universe are constantly being run down? There have been several attempts to solve this apparent paradox. Nobel Prize–winning chemist Ilya Prigogine (1917–2003) suggested there may exist a spontaneous tendency toward "self-organization" wherever there are large energy flows. As yet, though, it has been impossible to identify such laws.

A simpler answer is that even if energy differentials are diminishing over the entire Universe, they may increase locally. For example, gravity packs energy and matter into smaller spaces, thereby creating the local differentials in density and temperature from which stars are built. In turn, the heat generated in stars creates new energy flows within their hinterlands. This is why planets are good places for complex beings such as us. (*Inside* stars, however, the energy flows may be too intense for the building of new forms of complexity.)

Eric Chaisson has suggested a third possible source of free energy (or "negentropy"). The expansion of the Universe itself may constantly create new energy imbalances, ensuring that work can always be done somewhere in the Universe! These conclusions do not contradict the second law of thermodynamics because in the long run local energy flows diminish energy differentials in the Universe as a whole.

Wherever there are local energy gradients allowing energy to flow, it is possible, in principle, for complex entities to appear. The rest of this course will trace the astonishing creative process of increasing complexity, a process eventually leading to modern human societies, one of the most complex entities we know of. In the next lecture we ask: How do we know these things? Why should we trust the claims made by modern scientific accounts of the past? ■

Essential Reading

Chaisson, *Cosmic Evolution*, Prologue and Introduction.

Christian, *Maps of Time*, app. 2.

Supplementary Reading

Christian, "World History in Context."

Spier, *The Structure of Big History*.

Questions to Consider

1. What properties are shared by all complex entities?

2. Does the idea that modern human society may be among the most complex things you know alter your idea of the place of humans within the Universe?

Evidence and the Nature of Science

Lecture 4

The second position we'll describe as "relativism." And it goes something like this. We can never really know if what anyone says is true or not. We can't even know whether to trust our own senses, because they may be conveying inaccurate impressions about the real world.

In this lecture we ask: Why should we trust the claims of modern science (including the modern scientific discipline of history)? We discuss the nature of truth, in particular "scientific truth." We illustrate the discussion by surveying the evolution of modern techniques for dating events in the past.

Whatever society you live in, you need to ask the same fundamental question: Why should I believe the stories the experts tell me? The idea of "truth" is explored in the branch of philosophy known as "epistemology."

In principle, there are two extreme positions one can adopt to the idea of "truth." "There is a real world out there and with a bit of effort we can get real knowledge of that world." This is epistemological "absolutism." "We can never really know if what anyone says is true or not because even our senses can deceive us." This is epistemological "relativism." (Descartes [1596–1650] famously asked how you could prove that all the impressions you had about the world were not placed there by an evil demon.)

In practice neither position is tolerable in its extreme forms. Extreme relativism is intolerable because, as I live my life, I have to act, and to do that I need to trust some statements about the world I live in. Extreme absolutism is intolerable because we all know that some information is unreliable and our senses sometimes deceive us. So the real question is: How do I decide what claims about reality to trust?

To the question of trust, there are also two broad types of answers. The first is to trust authority. We trust a priest, or a sacred text such as the Koran, or the president of the U.S., or a scientist. Every time we fly in a plane we place our trust in those who built it, maintained it, and fly it. Or we can decide to trust no claims unless they are based on strong evidence. Descartes famously decided to distrust everything for which he did not have firm evidence, and concluded that the only thing of which he could be certain was that he was thinking, so therefore he must exist: "*Cogito ergo sum*." In practice, life is too short to get direct evidence about everything, so we always have to rely on both evidence and authority.

Modern science bases its claims as much as possible on evidence. This rule applies to all modern scholarship, from historical scholarship to geology or astronomy. In this sense all historical disciplines, from cosmology to human history, can be described as "scientific." Even if you cannot always check out the evidence yourself, you must be assured that the evidence is available so that, if you had the time, you could check it yourself. All scientific scholarship makes some concessions to relativism. As in a court of law, we know that the evidence is rarely perfect, so there is always the possibility of error. Yet modern science does not believe that all stories are equal. The story based on good evidence should always be preferred to the story based on none. As in a court of law, claims based on no evidence will be thrown out. Science has this advantage over the courts of law, that it can change its mind so it can evolve and improve. Over time, the story should slowly get more trustworthy, as more evidence accumulates. In summary, scientists are generally confident that they are on the right track because their claims rest on a vast amount of carefully tested evidence accumulated over many centuries and subjected to multiple tests. That is why in this course we will discuss evidence a lot.

The rest of the lecture will illustrate these features of modern science by surveying the evolution of "chronometry," the techniques used to date past events. To construct a well-structured account of the past, we must be able to assign dates to past events. How? In societies without writing, history depended on oral traditions. But oral tradition tends to lose precision within a few generations of the present.

The first "chronometric" revolution was the appearance of writing, about 5,000 years ago. Written documents made it possible to assign objective dates to events many generations earlier. But written documents also