Big History: The Emergence of an Interdisciplinary Science?

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Synopsis

'Big history' is a fresh approach to history that places human history within the wider framework of the history of the universe. In addition to telling the story of how everything has come to be the way it is now, big history allows students from many different disciplines to become scientifically literate within a short period of time. A brief overview of the approach taken by the course I have developed at the University of Amsterdam is placed with the wider context of the emerging field of big history. Based on energy and complexity studies, over the past twelve years major theoretical advances have been made that are now turning big history from a multidisciplinary into a truly interdisciplinary approach.

Introduction

'Big history' is a fresh approach to history, in which human history is placed against the background of a coherent overview of the entire known past, from the beginning of the universe to life on Earth today. It thus deals with the origins of the universe; the emergence and development of galaxies, including our own Milky Way; the formation of the solar system; and the emergence and development of life on Earth as part of geological and climatological change. Next, the rise of early humans is discussed, followed by an overview of human history located in this overarching context.

I have been teaching big history at the University of Amsterdam for fourteen years. Following the British/American/Australian historian David Christian's pioneering initiative at Macquarie University in 1989, a big history course has been run in Amsterdam every year since 1994, for students from all departments, who follow the course as an elective module. From the very beginning, the big history course has been very popular, and in fact I now teach three different courses, two at the University of Amsterdam and one at Eindhoven University of Technology. Every year, hundreds of students have successfully completed these courses. At the University of Amsterdam, most students come from the social sciences and humanities, which reflects the general composition of the student population. At Eindhoven University of Technology, students from all departments take part.

The Amsterdam big history course consists of a series of twenty-four lectures given by specialists ranging from astronomers to social scientists. They offer the latest views of what has been happening in their various fields explained in a language that all students are able to understand. As a result, we find psychology students engaged in hot discussions with biology students about how the universe might have evolved. History students become familiar with
Darwin's theory of evolution, while science students gain knowledge about human history over the past four million years. In so doing, the big history approach offers a grand tour of all the major scientific paradigms, from big bang cosmology, to the theory of biological evolution (human history itself does not yet have a general paradigm!). After having completed the big history course, our students have become scientifically literate to at least some extent, and our approach is clearly raising interest in science among a good many students who otherwise would perhaps not have become involved in these subjects, had they been offered separately. In particular, the coherent format of the big history approach, reuniting all the sciences into one narrative, helps students understand why science might be important for achieving a better understanding of why everything has become the way it is.

Today, there are a great many complaints about students losing interest in science. Yet in our big history courses we experience exactly the opposite. One way of stimulating an interest in science could therefore be to introduce big history courses in universities and secondary schools, and perhaps even at primary level. Teaching big history in primary schools may sound a little optimistic, yet in the Netherlands the primary-school teacher Jos Werkhoven has already successfully developed a big history course called 'Life lines', meant for children between eight and twelve years old, while David Christian and colleagues is now writing a big history coursebook for secondary schools.

From a Multidisciplinary to an Interdisciplinary Approach

The big history course started as a multidisciplinary project. Based on David Christian's programme in Australia, we began planning our course in 1993. The organisers were the sociologist Johan Goudsblom and myself (trained as a biochemist, cultural anthropologist and social historian), and in composing the preliminary lecture series we invited a number of key lecturers to take part. Most notably the positive response from the natural sciences was overwhelming: not only were astronomers, geologists and biologists willing to lecture for free (we had no budget at all in those days), they also offered us generous help in structuring the course as well as vital support in getting it established. This latter aspect was by far the largest problem at the time, since we had to convince the university management, split across the many rival departments, that the course was a good idea. Only a successful appeal to top management allowed us to get the big history course off the ground. Fortunately, more or less at the same time the Institute of Interdisciplinary Education was founded, thanks to the efforts of other academics. This institute is not located within any existing department; now called the Institute for Interdisciplinary Studies, it has proved to be a safe haven for big history up until today.

The big history course has been a tremendous source of education not only for students but also for the organisers. Suddenly we found ourselves in contact with a great variety of prominent scholars, ranging from astronomers to sociologists, who were very sympathetic to the project and who freely offered us their latest knowledge. Yet in order to be able to discuss the contents of all their different lectures in a fruitful way, I needed to gain good overviews myself of all the fields involved, which required many years of intensive reading on a wide variety of subjects.

Since the course was new and experimental, there was of course considerable room for improvement. Achieving a certain degree of coherence was not a major issue for the natural science portion of the course up to the emergence of humans, since in the natural sciences dominant historical paradigms exist that are accepted by most scholars: astrophysicists share the 'big bang' paradigm, geologists have plate tectonics, and biologists agree on natural selection. In each discipline there are controversies, of course, yet the core issues are usually not under attack (at least not all the time). As a result, it was fairly easy to transform this part of the course into a reasonably integrated whole. In human history, by contrast, no single paradigm exists that would unite even most historians. As a consequence, it has been much more difficult to find suitable speakers for this section, while those who do participate are sometimes less willing to reflect
upon their place within the grand scheme. Over the course of time I have therefore found myself doing an increasing number of the human history lectures. Many of the discussions among the organisers and the invited speakers have taken place informally after the lectures while sharing a few drinks. This has been a wonderful way to achieve greater coherence. In this way and over many years, our big history courses have been evolving into a more integrated enterprise.

While structuring the first big history programme, I realised that by doing so I was actually structuring big history itself. This exciting insight led to my 1996 book The Structure of Big History. I wrote that book believing I was the first to have formulated such an approach to all of history. A few years later, however, I discovered that the Austrian philosopher Erich Jantsch had got there first, with his analysis The Self-Organizing Universe of 1980. In this much neglected classic, Jantsch looked at all of history in terms of what he called 'process structures'. The honour of being the first to design a general structure for big history should therefore go to Erich Jantsch.

In my book I proposed to use the term 'regime' for all more-or-less structured processes that make up big history. I defined a regime in its most general sense as 'a more or less regular but ultimately unstable pattern that has a certain temporal permanence', a definition which can be applied to human cultures, human and non-human physiology, non-human nature, as well as to organic and inorganic phenomena at all levels of complexity. By defining 'regime' in this way, human cultural regimes thus became a subcategory of regimes in general, and the approach allowed me to look systematically at interactions among different regimes which together produce big history. I later recognised that my 'regimes' are very similar to Jantsch's 'process structures', if not the same (interestingly, when things became very complicated, Jantsch himself often used the term 'regime' instead). Subsequently, I systematised the most important regimes in big history with emphasis on human history, since this was the only discipline which was still lacking a central paradigm in Thomas Kuhn's sense. By formulating this general approach for all of history, the multidisciplinary enterprise began to turn into an interdisciplinary approach, and the first contours of a general theory of big history began to emerge.

A Short History of Big History

While running our big history courses in the 1990s, both David Christian and I thought we were designing an entirely new way of looking at the past. Yet more recently, my research into the history of big history has revealed that this was not the case at all. In addition to discovering Jantsch's work, I found that during the nineteenth century major such efforts had already been made, most notably by Alexander von Humboldt with his book series Kosmos (1845–59), and also by the Scottish publisher Robert Chambers with his anonymously published Vestiges of the Natural History of Creation of 1844. Widely read and enormously influential, these books were translated into many languages. These studies very much paved the way for Darwin's theory of evolution, by allowing a much longer time-span for natural history than was accepted in the versions of history inspired by Christian teachings.

In the early nineteenth century, many of these scholars were multidisciplinary, or perhaps even interdisciplinary, but without knowing it, because at the time of course these terms did not yet exist. Alexander von Humboldt, for instance, called himself a 'naturalist', yet he was interested in subjects ranging from the sky to human history, while the 'naturalist' Charles Darwin was as good a geologist as he was a biologist. Over the course of the nineteenth century, however, the growing body of scientific knowledge led to the ever greater differentiation of academic studies. While more and more specialisations were defined, academic knowledge became more compartmentalised, which resulted in the disciplines with which we are all familiar today. In the real world, everything has remained connected with everything else. As a result of the ongoing 'disciplinification' of universities, however, this important insight, familiar
enough to Alexander von Humboldt, was lost.

It would take until the 1980s before a few dedicated scholars again began looking at the past as a whole. This was probably no coincidence. By the middle of the 1970s, the current scientific paradigms of the history of the universe, the solar system, the Earth and life had all become accepted within mainstream science. As a result, some innovative US scholars, including the geologist Preston Cloud at the University of Minnesota, the biologist Siegfried Kutter at Evergreen State College in Washington State, and the astronomers George Field and Eric Chaisson at Harvard University, started synthesising this knowledge. They offered university courses and wrote books on the science-based history of everything, with emphasis on their own specialisations. Then, a few years later, the historians David Christian and John Mears (Southern Methodist University, Dallas, USA) began designing their 'big history' courses.

Over the same period, the call for interdisciplinary approaches became stronger. Scholars became increasingly aware of the fact that although universities had undergone a process of 'disciplinification', the world out there had not. It was increasingly recognised that our world was more complex than had been realised before, and that the application of a variety of disciplinary approaches to tackle single problems could be quite successful. This recognition appears to have been caused partly by the fact that the world was becoming more complex as a result of human action. But there may have been more to it than that.

As I see it, the call for interdisciplinarity may also have been an unplanned effect of the Apollo moon flights of the late 1960s and early 1970s. The views of the Earth as seen from space, most notably the so-called 'Earthrise' photo made by the astronauts of Apollo 8 from lunar orbit, had an enormous impact in this respect. On the Earthrise photo, the Earth is seen rising above a stark and forbidding grey lunar landscape. This was the first time that human beings had watched the Earth from a distance as a blue and white ball swinging through space. It is well known that the images of the seemingly fragile 'Spaceship Earth' provided an enormous impetus to the fledgling environmental movement. It may well be, however, that the Spaceship Earth pictures also stimulated the upsurge of interest in interdisciplinary studies, since scholars could suddenly see for themselves that in reality everything is interconnected.

The early nineteenth-century all-round scientific pioneers had one major advantage: they were not yet much hindered by institutional boundaries. More recent generations of students of nature and human life, by contrast, have had to deal with universities parcelled up into a great many disciplines. Today, as a result of decades of efforts to promote interdisciplinary studies, it is perhaps not longer so difficult to engage in such projects. Nevertheless, even in the present time, interdisciplinary studies in the form of theoretically-integrated approaches are still rare.

The Emergence of a General Theory of Big History

Let me return to my own approach to big history. A number of years after finishing The Structure of Big History, I began to see that regimes could not only be very useful for structuring big history, but also for explaining it. Over the course of about five years, the elaboration of these insights led me to a new theoretical approach. As a result, the big history approach is now becoming more of an interdisciplinary project.

A major stimulus came from the work of the US astrophysicist Eric Chaisson. Around 1980, together with the astronomer George Field, Chaisson had started teaching a course at Harvard University called 'Cosmic evolution'. This was big history from an astronomical point of view, and being natural scientists, they paid relatively minor attention to human history. Over the course of time, Chaisson developed a general approach to cosmic evolution based on thermodynamics and complexity studies, which he summarised in his groundbreaking book Cosmic Evolution: The Rise of Complexity in Nature, published in 2001.
Summarising Chaisson's approach in only a few sentences of course cannot possibly do full justice to his book. Yet the following may be a fair summary of his main argument. First of all, big history is the story of the rise and demise of complexity at all scales, ranging from galaxy clusters to the tiniest particles. This may well be the shortest possible description of big history. As a result, the explanation of history boils down to the question of how to explain the emergence and disintegration of all these forms of complexity. From a scientific point of view, the most general answer to this question is that complexity can emerge when energy flows through matter – this is just as much the case for stars as for ourselves – but after having emerged, it all depends: Rocks swinging through virtually empty space do not need any additional energy flows to maintain their structures, since they are close to thermodynamic equilibrium. Yet a great many other forms of complexity, ranging from stars to life-forms, are not close to thermodynamic equilibrium, and can be said to consist of dynamic steady states. All of these regimes of matter need an energy flow to maintain their complexity. If this sounds austere, one need look no further than oneself. Clearly, human beings can only maintain their complexity by harvesting matter and energy on a regular basis while getting rid of unwanted forms of disorder, also known as entropy. This is not only the case for humans but applies to all life-forms.

Three general types of complexity can be discerned: physical inanimate nature, life, and culture. The first level of complexity, lifeless nature, ranges from nuclei to entire galaxies. All of this inanimate matter organises itself entirely thanks to the fundamental forces of nature. Although the resulting structures can be exquisite, in contrast to life, inanimate complexity does not make use of any information for its own formation or sustenance.

The second fundamental level of complexity is life. In terms of mass, life is a rather marginal phenomenon. Yet the complexity of life is far greater than anything attained by lifeless matter. In contrast to the inanimate universe, life seeks to maintain the conditions suitable for its own existence by actively harvesting matter and energy flows with the aid of special mechanisms, which are maintained by using information stored in large molecules (mostly DNA). Over the past four billion years or so, both the energy flows and the energy levels on the surface of our home planet have been suitable for the emergence and continued existence of biological complexity. This fact is related to the special position of the Earth within the solar system: neither too close to the Sun, in which case it would become too hot, nor too far away to make it too cold. Although from a terrestrial point of view life can operate under an impressive range of conditions, ranging from hot geysers to arctic environments, from a universal point of view this range is still fairly limited. As soon as living things stop harvesting matter and energy on a regular basis, they will die, and their matter will return to lower levels of complexity (unless it is consumed by other life-forms).

The third fundamental level of complexity emerged when living beings started to organise themselves with the aid of information stored in nerve and brain cells. The emergence of these brainy animals was a new strategy for obtaining ever greater matter and energy flows for survival and reproduction, while seeking not to become a matter and energy source for others. This suggests that the evolution of brains and intelligence may have been almost inevitable, given the long-term continuity of the rather mild temperatures and pressures on our planet.

In order to quantify these energy flows through matter, Eric Chaisson defined the 'free energy rate density', the amount of energy per second that flows through a certain amount of matter. Chaisson next showed that there is a clear correlation between the observed levels of complexity (more or less intuitively defined) and his calculated free energy rate densities. In general, life is far more complex than lifeless matter, and it is also able to generate far larger energy flows per unit mass. This may appear counterintuitive, yet the results of Chaisson's calculations leave no doubt that stars produce far less energy per unit of mass and time than living things. Although stars deliver huge energy outputs, they are so heavy that the resulting energy flow per unit of
mass is substantially smaller than that of even a simple bacterium. While humans may appear to be vanishingly small compared to most other aspects of big history, according to Chaisson human brains have generated the largest free energy rate densities on a continuous basis in the known universe.

I became acquainted with Chaisson's approach in the year 2000, thanks to his willingness to come over and lecture in our Amsterdam big history course. Subsequently, our small group of 'big historians' began to discuss his approach, while David Christian incorporated part of it into his book *Maps of Time: An Introduction to Big History* of 2004.

**The Goldilocks Principle**

As Eric Chaisson noted but did not elaborate, complexity emerges when the circumstances, most notably the energy flows and levels (including temperature, pressure and radiation) are right, while complexity is destroyed when the circumstances are not right, namely when for instance the energy flows and/or energy levels become either too high or too low for that particular type of complexity to survive. For example, without a sufficient energy flow, no biological regime, human life included, will continue to exist. Yet if an organism experiences energy flows that are too large, such as elevated temperatures, it will succumb to them. This is also the case for lifeless regimes, such as rocks, planets or stars, although our rocks swinging through space, or even entire galaxies, may continue to exist for long periods of time without any additional energy flow. Yet in the very long run these structures too will slowly but surely degrade, not least because their building blocks, the nuclear particles, are thought to be unstable over extremely long periods of time. In other words, all relatively stable 'steady-state' matter regimes are characterised by certain circumstances, certain bandwidths of energy levels and flows, within which they can emerge and continue to exist. In a reference to a popular Anglo-Saxon children's story, I call this the 'Goldilocks principle'.

For those readers who are not familiar with this story: Goldilocks is a little girl who happens to wander into a house in a forest where three bears live: mama bear, papa bear and little bear. The bear family is, however, not at home. Goldilocks, hungry and adventurous as she is, tries out the porridge bowls on the counter-top. She finds that the porridge in the biggest bowl is too hot; the middle-sized bowl is too cold, but the little bowl is just right. Then she tries out the chairs: the biggest one is too hard; the middle-sized one is too soft; and the little one is just right. And so it goes on until the bears come home and don't like what they see. As a result, Goldilocks has to flee.

The Goldilocks principle derived from this story points to the fact that the circumstances must be right for any type of complexity to form or continue to exist. For instance, we humans cannot live below or above certain temperatures, while our needs also include a sufficient air pressure as well as a regular water supply. These are some of the Goldilocks circumstances that make our complexity possible. The Goldilocks requirements for stars, however, are very different. As a result of gravity, these huge balls consisting of mostly hydrogen and helium create so much pressure in their interiors that nuclear fusion processes ignite, thereby converting hydrogen into heavier (and thus more complex) helium while producing energy in the form of radiation. These stellar Goldilocks circumstances are very hard to reproduce on Earth, which explains why it is so hard to develop nuclear fusion as a way of generating electricity, while it is a great deal easier to make a thermonuclear bomb. The Goldilocks principle also helps to explain why there is no life on the surface of the Sun, let alone in its interior. While all of this may well appear obvious, surprisingly, perhaps, no one yet appears to have systematically elaborated the significance of these ideas for big history.

In sum: in order to understand the rise and demise of complexity we must not only look at
energy flows through matter but we must also systematically examine the Goldilocks circumstances prevailing. In my new book *Big History and the Future of Humanity*, to be published in 2010 by Wiley-Blackwell, I claim that the 'energy-flows-through-matter' approach combined with the Goldilocks principle provides a first outline of a historical theory of everything, including human history. While this theory cannot explain all the details, it does lend some structure to, and provides explanations for, what has happened in big history.

All Goldilocks circumstances are characterised by a certain bandwidth. Stellar nuclear fusion, for instance, is possible at temperatures over ten million degrees Kelvin, while its upper limit is only posed by the size stars can attain. By contrast, humans unprotected by clothes or other inventions are only able to live within a rather restricted range of temperatures, possibly between fifteen and thirty-five degrees Celsius. In the natural sciences, these bandwidths are known as the upper and lower boundary conditions, outside of which that particular type of complexity will decay.

Not only do life and human societies need certain very specific Goldilocks circumstances within which they can exist, they also create some Goldilocks circumstances themselves that help them to survive, and which may make life difficult for other life-forms. These Goldilocks circumstances can be social and material in nature. Take for example traffic rules. These social regulations can be seen as defining human behaviour in a way that creates Goldilocks circumstances allowing all participants to reach their destinations relatively efficiently while preserving both their own complexity and the complexity of others. Material Goldilocks circumstances created by humans include clothes and housing, to name a few.

The term Goldilocks circumstances can thus be seen as a convenient shorthand concept for characterising a great many different situations in which greater complexity has emerged and has continued to exist, both in space and over time. Because I am following a new, rather unbeaten, track, right now I can only sketch the contours of this approach. Yet I believe, perhaps overly boldly, that this approach constitutes an entirely interdisciplinary research agenda, which, if pursued, would allow scholars ranging from astronomers to historians and anthropologists to collaborate in unprecedented ways while speaking a mutually intelligible language. This may sound idealistic, yet in actual practice this process has already begun.15

**Complexity in Big History**

In this article, I cannot possibly summarise the history of the universe with the aid of the terms outlined above. In the concluding pages of this paper, I restrict myself therefore to a few observations. Today, the known universe mostly consists of islands of relatively basic forms of complexity (galaxies) surrounded by almost empty space, in which there is hardly any complexity at all. Virtually all the galactic complexity, mostly stars, comes in the form of self-regulating but non-adaptive regimes. Yet even within the galaxies, most space is still rather empty. This high degree of emptiness makes possible the emergence of greater complexity, because it functions as an entropy sink. Had the universe not been mostly empty, greater complexity would not have emerged.

Life as we know it is powered either by sunlight or by energy emanating from within the Earth. This means that all life-forms, that is complex adaptive regimes, are powered by complex non-adaptive regimes. It may well be that the first life-forms emerged as a result of energy flows from within the Earth generated by nuclear fission and perhaps also by the original accretion heat. Yet over time, as these energy flows from within decreased in intensity, life became more dependent on solar energy from outside, which is thought to have increased by about twenty-five per cent over the past 4.6 billion years.

As James Lovelock has argued with his Gaia hypothesis, it may well be that life has created
conditions favourable to its own continued existence. In terms of the process of natural selection or, as some prefer, non-random elimination, this makes perfect sense. As I see it, surely any organism that created and maintained Goldilocks circumstances favouring its continued existence (or at least not hampering its survival) would have had an easier time surviving than life-forms producing circumstances damaging to their existence. Yet what may be Goldilocks circumstances for one species may well be unfavourable circumstances for another, which, as a result, might be eliminated. The overall result of this process would be a biosphere occupied by species that are not diminishing their own chances for survival to the extent that they go extinct (at least in the short term), while they may actually be improving them. As a result of cosmic influences, the changing condition of the Earth's surface through plate tectonics, and the dynamics of biological evolution interacting with the biosphere, Gaia keeps changing.

Many animals have created what I call forms of 'constructed complexity'. These are mostly means for protecting their own complexity or the complexity of stored matter and energy, such as nests, holes, beehives, etc., as well as devices for harvesting matter and energy such as spider-webs. Any type of constructed complexity can only emerge when there is a sufficient energy flow available, which is usually the bodily energy expended by the animals making it. These types of constructed complexity may not need energy flows for their continued existence for as long as they are not disturbed by outside events. Yet such disturbances are common, of course, and as a result the animals usually have to spend energy maintaining these forms of complexity.

Today, humans have created by far the most constructed complexity on this planet. A major distinction between the ways humans and other animals have constructed complexity is that as early as perhaps three and a half million years ago, humans started using tools to create complexity (or to destroy it). Moreover, in contrast to other animals, over the course of time humans have also learned to employ external energy sources for doing so, first of all through fire control. This allowed humans to expand the range of constructed complexity far beyond anything other animals have achieved, for example with pottery and cooking, and even by changing the complexity of entire landscapes through burning. Fire control also helped humans to increase their destructive capabilities. Subsequent external energy sources included animal power as well as the energy that could be harvested from wind and water flows. It is only very recently that humans have begun using fossil fuels for such purposes.

The agrarian revolution, which took off about ten thousand years ago, can be seen as a process involving two types of complex adaptive systems, humans on the one hand and plants and animals on the other, mutually adapting to each other under human dominance, with the human aim of harvesting increasing amounts of matter and energy from the biosphere within a certain area. This process began about ten thousand years ago and is still continuing today, with the result that humans may now control between twenty-five and forty per cent of the energy flows within the web of life.

The subsequent process of state formation and development, starting between about six and five thousand years ago, can be seen as the institutionalisation of inequality among humans by social means. Within the emerging states, increasing numbers of humans derived their basic matter and energy flows no longer from working the land but from other humans. And since these matter and energy exchanges have always been based on the power and dependency relations prevailing, they have usually been unequal. As a result, to our knowledge there have been no states in human history in which humans have lived based on a more or less equal exchange of matter and energy anything like what was observed to be the situation among certain groups of hunter-gatherers in the very recent past.

State formation may have happened as a result of the fact that by practising agriculture, humans became tied to the land, while it also led to population growth. Among agrarian societies, it is profitable to have a considerable number of children – they are productive at an
early age at the same time as, with luck, providing your retirement fund. Furthermore, as Robert Carneiro pointed out, the first states all emerged within very restricted ecological conditions, usually river valleys surrounded by deserts. These were, apparently, the Goldilocks circumstances for state formation. As a result of the emergence of states, humans learned to adapt to one another as part of an unequal power structure. These social structures were, of course, never completely uncontested. In addition, states as a whole and their neighbours in whatever form of societal development can be seen as complex adaptive systems in continuous need of adapting to one another depending on their power resources, ranging from attempts at complete destruction of neighbours to almost complete submission to them.

For thousands of years, humans have been constructing forms of complexity using external energy sources to perform certain tasks, ranging from treadmills, wind- and watermills, to steam engines, electric motors, jet engines and moon rockets. This has been a unique human achievement: to my knowledge, in nature no examples exist of animals constructing forms of complexity that employ external energy sources to perform tasks. This has allowed humans to expand their constructive and destructive capabilities way beyond anything other life-forms have achieved, as well as to adapt nature to their wishes and desires for as long as there is sufficient matter and energy available, and while there is also enough space to get rid of the inevitable entropy that comes as a result of these efforts. All such human enterprises can be seen as efforts to produce certain Goldilocks circumstances for themselves, while sometimes seeking to destroy those of others, if not their entire complexity.

As a result of the process of non-random elimination, in biological nature Gaia has produced a global trash recycling regime that allows life to deal with its entropy problem. Humans are now making some efforts to do this too, but as yet we do not appear to have found a lasting solution to this problem. At the same time, both matter (in the form of important natural resources) and energy may well become scarce in the near future. These may well be the most important issues facing humanity today. Are we able to adapt ourselves sufficiently to the changing circumstances we have brought about by our collective actions and maintain our complexity with the aid of different matter and energy sources, or will humanity be eliminated by Gaia as a result of a failure to do so? In sum: are humans perhaps genetically hard-wired by Darwin's process of natural selection to always harvest a little more matter and energy to overcome the lean times, and if so, will we be able through our culturally acquired capacities to counter this genetic tendency?

In our big history courses, we will of course not be able to resolve any of these issues. And given the space limitations of this article I have not been able either to elaborate any of the cultural mechanisms that have contributed to the current situation. Yet I feel strongly that this emerging interdisciplinary theory of history greatly helps to summarise big history in a simple way that has not yet been done before, while explaining not only how everything has come about but also what the major aspects are of issues that may threaten our common future. While not all of my guest teachers have embraced this approach, natural scientists in particular have begun incorporating it in their lectures. In my own teaching, I use this theory as my main focus, and I feel that most of my students not only grasp it, but actually find it very useful. It is in this way that big history in Amsterdam is turning from a multidisciplinary into an avowedly interdisciplinary enterprise.

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Notes


2 For more information on the history of the University of Amsterdam course, see F. Spier: 'The small history of the big history course at the University of Amsterdam', http://worldhistoryconnected.press.uiuc.edu/2.2/spier.html.

3 For more information on Jos Werkhoven's course, see www.dearend.nl (in Dutch).

4 F. Spier: The Structure of Big History: From the Big Bang until Today; 1996, Amsterdam, Amsterdam University Press.


6 F. Spier: The Structure of Big History, p. 14 (see Note 4).

7 Although there has been a great deal of discussion of the meaning of the term 'interdisciplinarity', no general agreement has yet been reached. The most basic definition appears to be 'the application of different disciplines to address a given problem', which I would call a weak definition. My preferred definition is the much stronger and more challenging formulation: 'research or study that integrates concepts from different disciplines resulting in a synthesised or co-ordinated coherent whole'. One of the earliest widely known studies of interdisciplinary approaches was L. Apostel et al.: Interdisciplinarity: Problems of Teaching and Research in Universities; 1972, Washington, DC, OECD, the result of a seminar on interdisciplinarity hosted by the Organization for Economic Cooperation and Development (OECD) and held in Nice, France in September 1970. This report, which uses the strong definition of interdisciplinarity, surveys the experiences and problems of university programmes in institutions worldwide in engaging with the concept. See also J. T. Klein: Interdisciplinarity: History, Theory, and Practice; 1990, Detroit, MI, Wayne State University Press.


10 For an excellent exploration of the fate of the universe over a very long timescale, see F. Adams and G. Laughlin: The Five Ages of the Universe: Inside the Physics of Eternity; 1999.
New York, NY, Free Press.

11 I am certainly not the first to employ the term 'Goldilocks principle'. Over the past ten years, a number of scientists have also begun using it.


13 Although the process of 'cold fusion' has not yet been completely ruled out, it has been very largely discredited.

14 The idea of calling this the Goldilocks principle was first suggested to me by David Christian in March of 2003, while commenting on the first draft of what would later become my article 'How big history works', published in 2005. In the mean time, the term Goldilocks principle has become more popular. In addition to the authors mentioned elsewhere in this paper, a number of scientists including Vaclav Smil (Energy: A Beginner's Guide; 2006, Oxford, OneWorld Publications) and Paul Davies (The Goldilocks Enigma; 2006, London, Allen Lane) have taken up the term. For Davies, though, it is only another way of stating the anthropic principle first formulated by Brandon Carter in 1973 and elaborated by John Barrow and Frank Tipler (The Anthropic Cosmological Principle; 1986, Oxford, Oxford University Press). In his book Humanity: The Chimpanzees Who Would be Ants (2007, Santa Margarita, CA, Collins Foundation Press), the US astronomer Russ Genet mentions the term Goldilocks principle as 'one of the general laws of the Universe' (p. 24), using it in his description of cosmic history but, strangely, not for human history, which is the main thrust of his book.

15 For instance, in 2004 two astronomers, Eric Chaisson and Tom Gehrels, took part in a big history panel during the Annual Conference of the Historical Society in Boothbay, Maine. In Russia, interdisciplinary conferences on big history have been organised in Belgorod (2004) and Dubna (2005). In Amsterdam in 2004, we organised a day conference on this theme with contributions from scholars ranging from an astronomer to a sociologist. In March of 2008, I attended the Santa Fe Institute Workshop on 'Complex adaptive systems in history' in Waikiki, Hawaii. These have been among the liveliest and cheeriest scholarly meetings I have ever attended.


17 This was essentially the central question raised in the famous report The Limits to Growth commissioned by the Club of Rome (D. H. Meadows, D. L. Meadows, J. Randers and W. W. Behrens III: The Limits to Growth: A Report for the Club of Rome Project on the Predicament of Mankind; 1972, New York, NY, Universe Books.

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