Civilizing Earth

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ABSTRACT: *This essay explores a strategy for the creation of consilience among the sciences of nature and humanity. The relatively new discipline of* Earth System Science *provides the overall framework. This field seeks a top-down system's approach to this planet, embracing the full span of geological history. The ultimate goal of the proposed undertaking is to combine two mathematical models, one representing Earth history and dynamics and the other for the* process of civilisation, *in Elias's sense – that is, the dynamics of the 'world of humanity', from the origins up to its present state. As neither of these models is available at present, all I can do here is to help and prepare the ground for their construction. Some implications for our worldview are briefly discussed.* [1] [#N1]

KEYWORDS: *Earth System Science, civilising process.*

Ever since C. P. Snow (1959) eloquently exposed the breakdown in communication between the sciences and the humanities, this problem has stood out as a traumatic violation of our intellectual integrity. Intuitively, we are aware of a fundamental unity between the worlds of nature and humanity. Yet we are left in doubt as to the proper connection. In this essay I regard the world of humanity (including all its implements, symbols and paraphernalia) as an emergent property of System Earth.

Following the seminal publication by sociologist Norbert Elias (2000 [1939]), I shall use the term *civilising process* to indicate the dynamics of the 'world of humanity', from the origins up to its present state. Note that Elias's use of 'civilisation' corresponds to the value-free requirements of science and differs from vernacular parlance. The integrated study of the planet Earth as a whole is known as *Earth System Science*; this field is concerned with global dynamics as it developed through geological time (that is, 46 million centuries). It came to fruition following the advent of plate tectonics in the late 1960s.

While plate tectonics concentrates on the solid earth (or 'geosphere'), Earth System Science encompasses the interactions between the geosphere, the hydrosphere (mainly the world ocean), the atmosphere and the biosphere. Solar radiation and heat production by radioactive decay in the deep Earth are the main energy sources driving these complex dynamics. Major topics in Earth System Science are long-term changes in tectonic regimes and continental masses, the global cycling of chemical elements, oxygenation of the atmosphere and the oceans, global climate dynamics, and patterns of global biodiversity. The origin of life and biological evolution are understood as emergent features of Earth system dynamics. Progress depends on the spectacular increase in sophistication by which the geological record can be interpreted. The general approach is to quantify the results of this fieldwork and to integrate them into mathematical models. On the outside, the ambition of Earth System Science may seem far-fetched. But by now, fifty years after the emergence of plate tectonics, it has become a major focus within the natural sciences.

To epitomise the outcome of Earth System Science so far, the metaphor of a *ratchet* springs to the mind, an asymmetrical cogwheel-and-click that can only turn in one direction (Fig. 1). Ratchets are used in clockworks, jacks, rattles and mechanical toy trains. I use the term to denote irreversible, accumulative developments in complex systems. The ratchet, of course, is no more than a mechanical metaphor. In contrast to ratchets, real systems tend to lose information, and their development is unpredictable. The Earth, for example, is known to have passed through a number of deep crises, when the planet seemed to return to earlier stages of its development. Time and again, however, the system veered back with a surprising speed and subsequently followed a different course from before. On such occasions, it seems as if a global memory was in operation. The ratcheting behaviour is documented for many phenomena, including biological evolution, mineral diversity (from a dozen minerals in the original dust cloud from which solar system emerged to more than 4,300 in the present Earth), atmospheric oxygen levels (from 0 to 21 per cent), as well as the complexity of global geochemical pathways and their regulation. Overall, environmental diversification and differentiation appear to have been on the increase, from the origin of the Earth up to the present day.

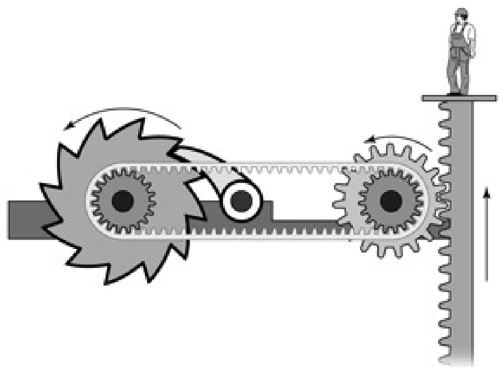

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Fig. 1 A ratchet.

The cogwheel on the left can only turn to the left, lifting up the technician into the sky. (I use the word ratchet metaphorically to characterise complex systems exhibiting an irreversible, accumulative development.)

The incorporation of the civilising process into Earth System Science seems a logical step that would help in bridging the gap between Snow's two cultures, and in deepening our understanding of a sustainable development. A serious impediment to this endeavour is the widespread reluctance in the humanities to address *big history*, which is advocated by Christian, Spier and others (Christian 2004; Spier (2010). 'We have seen enough of the great narratives' is the complaint: 'History is contingent, and it is silly to even try and understand its workings.' The situation reminds me of my own field of interest, geology, prior to the advent of plate tectonics, when a global view was missing. As long as we interpreted the rock record in detail it revealed its chaotic side, while the emergent large-scale patterns of change only became apparent with the overview.

Since the goal of integrating the process of civilisation into Earth System Science is out of reach at present, I can at least try and prepare the ground for it to be realised. As a geologist outsider to the study of civilisation, I do not pretend to contribute anything original to this subject. Instead, I summarise relevant ideas by four insiders (Frans de Waal, Anton Pannekoek, Norbert Elias, and Johan Goudsblom) who approach the process of civilisation from very different angles, all unrelated to Earth System Science. I realise that the resulting overview is very incomplete. For example, I had to leave out the research on fossil hominids, as well as neurological insights. Despite these shortcomings I was surprised to discover that, despite some personal biases of the authors, these ideas are highly complementary and consistent. I shall suggest that, together, they may form a suitable starting point for a connection with Earth System Science.

Biological roots

To begin with, it is useful to remember how trivial we are from the perspective of the giant tree of evolution. All we are talking about is an insignificant tip of a minor branch and a couple of million years on a time scale of, say, 3.7 billion. Our closest relatives in the animal world are the chimpanzees and the bonobos. Those two primate species separated about 2.5 million years ago, while it was some 7 million years ago when our ancestors split up from the common branch of the pedigree. The other apes, the gorillas and the orang-utans, are slightly further away from us.

Is it vanity to think that something extraordinary must have happened on that single human lineage of a few million years? We know that the ratchet of evolution that produced the overall tree of life has been propelled according to the Darwinian principles, for all those billions of years. Who are we to believe that we are the exception to this ancient rule?

Frans de Waal is among the scientists who actually study our cousins, the chimpanzees and bonobos. Through this recent research we have become acquainted with fighting, courting, grooming, teasing and laughing whiz kids, who support each other with endearing fidelity, but are also capable of swindle, treason, repression and murder. Do not think that these primates live carelessly, or that they simply follow their instincts. Their communities can only hold out because they are endowed with subtle networks of unwritten laws regulating hierarchical and sexual relationships as well as feeding habits. It is because the community members intimately know one another that steady relationships may emerge, but also antipathies and conflicts that need to be settled time and again.

Of course, natural selection plays a role, but the complexity of the primate world leaves ample room for generosity, empathy and care for the weak. No wonder that de Waal's position is far removed from genetic determinism. Animals (and humans in particular) do not follow automatically the behavioural patters prescribed by their genetically programmed instincts; their behaviour *emerges* within the social context from a combination of natural tendencies, intelligence and experience. It is impossible to decide from this mixture what is inborn and what not.

Curiously, Charles Darwin himself was well aware of this ambiguity. It was his epigones who stressed the idea of a cultural varnish. But we now know that primates recognise and greet each other and that they are sharply aware of their past. They can think ahead and are capable of planning (of travel routes, for example). They can make tools, may live in caves, and all the time make clever decisions. In one word, de Waal believes that primates are cultural beings, just like we are. The communities of many animals, and in particular of chimpanzees and bonobos, undergo *learning* processes, through which experiences are transmitted from one individual to the other and to posterity. This is why with time the behaviour of a community, or even an entire species, may change while its genetic constitution remains the same.

By introducing the concept of culture into biological theory, de Waal facilitates the debate between biology and the social sciences. Human communities (and with them the communities of all kinds of apes) not only transmit information to their offspring through the genetic pathway, but also distribute their acquired knowledge among their members. And as this latter method does not depend on the tedious process of reproduction it can be extremely rapid and can only materialise if it works out to the advantage of an entire community.

There is one snag to de Waal's approach. Because he rigorously limits himself to biology, he tends to trivialise the obvious differences between our nearest cousins and us, although he believes that the genetic programming of our behaviour is even looser than for the other primates. When this became clearly apparent at a recent meeting on this subject, I overheard a sociologist mumble that he would like a chimpanzee to give the next lecture, so that we could become acquainted with his views on humans. There *is* a gap between the chimps and us, and we must account for it.

Pannekoek's theory of anthropogenesis

My compatriot Antonie Pannekoek (1873–1960) was a world-renowned astronomer and on top of that he used to be widely known for his contribution to 'council communism', his own, very idiosyncratic brand of Marxism. In astronomy, intelligence, strict logic and disinterested observation provide a constant stream of new insights in the dynamics of the Universe. Would an equally deep scientific understanding allow the unbridled social and economic forces to be rationalised and controlled, so that they could work out to the advantage of all humanity? To answer this question, Pannekoek looked for a field where the natural and social sciences were connected and so he settled on *anthropogenesis,* the origin of man, as one of his favoured subjects (Pannekoek, 1909, 1953). This work is almost entirely forgotten, and therefore it is my privilege to briefly re-introduce Pannekoek's point of view.

Thus, Pannekoek was specifically interested in the mechanisms by which civilisation emerged from biological principles, and how it subsequently propelled humanity further and further away from its animal origins. To do this, he concentrated on three different characteristics of humans – *the production of tools, abstract thought and speech*.

When Pannekoek wrote his studies in the first half of the twentieth century, it was well known that rudiments of these properties already occur in the other primates. For Pannekoek this was no problem: it only proved how closely related we are to these animals. To him, the difference was in the degree in which human and animal communities rely on these faculties. Furthermore, none of these three attributes could have developed all by itself. They are interactive, and always need each other, he argued. When the development of one of them lagged behind, the other two would come to a standstill as well. Thus, in human communities, the use of specially produced tools, abstract thought and speech form a kind of trinity, a coupled system.

What is so special about the production of tools? For the sake of orientation, just consider an animal with no special aptitude for tool use, a lion for instance, or a hare. No doubt its behaviour is largely determined by its physiology, the organisation of the body. A lion trusts its claws and jaws to catch a prey. It smells an antelope and steals up on it with its supple legs. A hare uses its long ears to sense the approach of an enemy from a distance, and its hind legs are like springs that can bring it into safety. The point to make is that in natural selection animals compete with their organs – and that these are component parts of their body. The most fitting organs survive, while the others disappear, together with the individuals and species to which they are attached.

For a human this is all different. To defend himself or to attack his prey he takes a tool in his hand – a spear or a knife. For as long as the action lasts, the hand and the tool become a single, organised whole, capable of purposeful action. From a functional point of view, you may compare this combination with an animal's organ. The difference is that, when the action is over, the human can put his tool aside and do something else, while the animal remains stuck with his organs. The human tool is not part of the body and it can easily be exchanged for another one, without any harm done to the individual. *Humans are animals with exchangeable organs*.

The consequences of this new principle are pivotal. The tools not only give more freedom to their proprietors, but they also can be easily *improved* upon. Their replacement also implies their *differentiation* over time and their *adaptability* to an increasing variety of functions. This offers us humans the possibility of adapting to many different environments and of spreading all over the world (today even into outer space). In contrast, the animal species remain tied to the limitations of their particular niche. The ease by which the tools can be differentiated and improved upon has created an immense array of new means that allow humans to exploit their environment. This has always been the specialty of humanity – to become increasingly dependent on a steadily expanding arsenal of artificial resources. This discovery set into motion a cumulative, irreversible development – a ratchet – slow at first and then faster and faster. The reason why natural, Darwinian evolution has to be measured in millions of years is that the information that specifies the properties of the organs is in the genes, the DNA, so that it often takes many generations for major changes and adaptations to realise (for a contrasting view, see Ryan 2011). By contrast, for a tool to improve we need little more than a good idea. This implies that the breakthrough of organised tool use was explosive by comparison and soon took over the momentum of biological evolution. *From then on, the focus of natural selection shifted away from the body to the artefacts and tools*. However hard the life of our early ancestors may have been, there is no doubt that as time went on, they gradually alleviated the constraints of biological evolution. The wild, natural environment was gradually incorporated into the human organisation and transformed into a civilising domain.

Thought

Even in Pannekoek's days it was well understood that thinking is a widespread feature in the animal world. Whenever the animal is confronted with a dilemma and challenged to reach a decision, it is forced to make a mental representation of the outcomes of its possible responses before it can select the most appropriate action. But usually foresight and planning are of limited use. Animal behaviour is largely prescribed by the organisation of the body, so that most of the activity automatically emerges in response to incoming information. Just consider lions and hares that start pondering when they perceive their prey or their enemy. And when you see a trout shooting through the water, or a seagull elegantly manoeuvring against the storm, you understand that in such animals the incoming stimuli, the subsequent avalanche of mental perceptions, and the following responses form almost continuous chains. This is because the range of possible responses is limited in most animals.

In humans these chains are broken and the reactions delayed. Observation and action are divorced. The observations take place, but remain unused and are added to an existing reservoir. Human activities appear autonomous creations, emerging spontaneously from the stored information. A sensory impulse evokes a series of mental perceptions; the chain is formed, but at the free end, where it is broken, the thought is reflected. The mind shoots to and fro along the broken chain and the mental perceptions themselves become objects of observation. Connections are formed with other chains, until huge networks of associations emerge. Thus, in contrast to what happens in the animals, the human mind is continuously forced to make detours, and many detours are possible. Just as in the animals, the mind represents the results of all possible actions and compares them. The action is delayed until a choice has been made. But the number of possible actions is infinitely greater. It causes the postponement of activities to be vastly extended. This is why a high degree of independence, a relative *autonomy* of thought could emerge.

It is reasonable to assume that it was the ongoing amplification of tool use that caused the chains of mental perceptions to break with ever increasing frequency. Whereas animals usually come into action soon after an appropriate sensory impulse, humans were forced to make much longer detours in their minds. Before they could bring their plans into practice they had to fetch, or even invent and produce the appropriate tools. This invention and production of tools caused a further separation between the primary impulse and the subsequent action. New chains and connections were constantly added to the existing networks of the mind and the tools; some were strengthened by repeated success, whereas others faded away. The eventual autonomy of thought implied that some mental activities became divorced altogether from the practice of tool use. People began to indulge in abstract speculations, games and the intricacies of social relationships. They became more and more conscious of themselves and of the world around them. According to Pannekoek (1953), it was the steady expansion of thinking capacity that forced the brain to enlarge during the earlier stages of civilisation. Once the brain could accommodate the full range of mental activities required for a human individual, its further growth came to a standstill. It was at this stage that civilisation began to supersede biological evolution.

Speech, the organ of human community life

The systematic dependence on tools caused the perceptual chains to be more and more disconnected from the sensory impulses that brought them about. The disconnected chains now became isolated mental entities, ready for subsequent processing. But how were our ancestors able to handle such vague mental isolates? They needed a minimum of substance at least, an identity, in order for the mind to observe them. This is exactly what humans have been doing all the time: out of a nebulous mass of internal representations the mind isolated the essence and gave it a label – a name. The name referred to a *concept*, and concepts are abstractions. They refer to what a number of separate representations have in common. The names provide these concepts with identities, so that the mind can handle them. From now on, an external stimulus is no longer required to recall an impression in the past; it is enough to mention the appropriate name. Eventually, the human mind even became capable of dealing with concepts that did not refer to any concrete reality. Words like truth, virtue, or energy could – and still can – evoke clear representations in the mind. We know what we mean, although these concepts only exist as their names. Just consider what happens while you read this essay. Your thinking is little more than a play of abstractions, words and symbols. The names and words are combined into sentences where they form the exchangeable parts. You read, think and draw your conclusions, but it may take long before the practical consequences of your effort are put into practice. Some of our detours may last for more than a lifetime.

When speech emerged, the emotional utterances of our ancestors were gradually converted into formal communications evoking similar linguistic acts. Hence, information and experience of great refinement could rapidly spread through the spirit of many. Indeed, speech is not only the carrier of thoughts, but also the instrument of human communication. Pannekoek could conclude that humanity would never have emerged in the absence of intense community life inherited from the primate ancestors. Therefore, the first human communities could build on from the rich tradition of group behaviour and mutual solidarity that already had evolved in their animal ancestors. It is striking to what extent his argument is compatible with the more recent research by de Waal. De Waal made us aware of rudimentary cultural evolution among the chimpanzees and bonobos.

Pannekoek’s emphasis on speech and communication as a vehicle of cultural evolution has profound implications that are easily overlooked. He was fully aware of the total dependence of individuals on the communities to which they belong, and realised that the process of civilisation primarily proceeds at the social level of organisation. Individuals may make promising discoveries and entertain the deepest of thoughts, but if at some point their community does not embrace these findings, the effort is wasted and leaves no trace on the ratchet of civilisation.

In conclusion, Pannekoek argued that the three attributes that he considered as basically human – tool use, abstract thought and speech – are inextricably connected. In the absence of one of these faculties, humans would never have emerged. They elicited and maintained each other; they worked together as an autocatalytic engine that gained force with time, and increasingly liberated humanity from the constraints of animal life. It is interesting to note that ongoing comparative research on chimpanzee and human infants essentially supports Pannekoek's more intuitive vision on communication (Tomasello, 1999, 2008, 2009). The difference is that, according to Tomasello, it is the evolutionary refinement in the communicative skills of young humans that triggered the process of civilisation, whereas Pannekoek takes the view that, in order to be sustained, improvements in communication (speech) depend on concomitant tool use and thought.

The theory of civilisation by Norbert Elias

Not unlike Anton Pannekoek, Norbert Elias (1897–1990) dreamt of a sociology raised to the level of the natural sciences. The question was what magic principle could clarify the immense history of humanity and the overwhelming diversity of all its manifestations.

To solve this crucial problem, Elias took refuge in a method frequently applied in the natural sciences, although he likely arrived at this trick by mere intuition. The first biochemists for instance were confronted with a dazzling variety of phenomena. They wished to unravel the workings of all living organisms at the molecular scale, from bacteria to humans, whales and sequoia trees. Clearly, they would never be able to unravel the biochemistry of millions of different species. Yet they found a way out. They selected just one organism that was easy to handle experimentally, and simply assumed that all the rest would be more or less the same. Nature always repeats itself, was their motto. And so it came that *Escherichia coli*, a simple bacterium in our intestines, became the *model system* by which the biochemistry of all life was studied. And it worked! We now know that most of the principles underlying the molecular machinery of *E. coli* are common to all of life (apart from significant differences of course). This is how *E. coli* became the key to understanding our own molecular underpinnings.

So, what was to become the *E. coli* of humanity? Elias looked for a fragment of history that could be studied in relative isolation, that was far enough back in the past to study objectively, and that was well documented (Elias 2000). After a long search, he chose a neat little subject – the transformation of etiquette in Western European post-medieval courts. The documentation was excellent, as he had manners books at his disposal from about 1350 onwards. As he found out, the changes in etiquette over that period had been dramatic. Elias discovered that in the early days of this period even sophisticated people had little objection to urinating in the corner of the room, blowing their noses on the tablecloth during dinner, and eating with their hands from a common bowl. In the manners books they were warned not to put a piece of food back into the bowl after an oral try-out. In a general sense, the relationships among people were rude and far more impassioned than today, varying between extreme warmth and acute violence. Step by step, the passions had been curtailed, relationships formalised and table manners introduced.

How could these changes be explained? Elias argued that they were associated with profound modifications of the power structure in society. In early medieval times the elite was made up of more or less isolated warlords. Inside their own territory they could do as they liked and give free rein to their impulses. But as competition among them increased, they became entangled in hierarchical relationships and complex networks of social connections. Eventually, the most powerful ruler acquired the monopoly of violence, while the lower echelons were subjected to an existence in courts of increasing sophistication. In these new environments, intrigue replaced immediate violence and etiquette had to be mastered for the sake of success. Thus, new compulsions emerged that first were imposed from outside, but soon became internalised as self-restraint. New, psychological thresholds of shame and repugnance emerged that suppressed the original, more direct impulses.

This model system allowed Elias to study in detail how the civilising process manifested itself both in the human individuals and in society at large and showed how these two levels of organisation were connected. He also demonstrated in detail how new patterns of self-restraint spread from the courts, where they had their origins, through society at large. Particularly revealing is his analysis of changes in eating habits as they disseminated through Western society over the centuries. At first, symbolising the suppression of violence, the knife was converted from a weapon into a food-cutting device. Then the spoon, and at long last the fork interposed between the eaters and their meals.

Elias was able to draw yet another major conclusion from the study of his model system. He showed the process of civilisation was of such magnitude that individual people could hardly influence its course. It just occurred, and people were largely unconscious of the huge transformations in which they were entangled.

Elias and Pannekoek

The connection with Pannekoek's theory of anthropogenesis springs to the mind. Independently, these two authors discovered the same, fundamental principle of societal development. According to both theories, tools interposed between the immediate impulse and the following action. If the tools forced the actions to make detours, the mind had to make detours as well. The immediate impulse was suppressed, while the existing chain of perceptions in the mind was severed and replaced by new, internalised ones that allowed the tool to be properly handled. The entire process critically depended on the continued emergence of new sets of concepts and networks of communication. And it was propelled by changing patterns of power distribution, both in relation with nature and civilisation.

But there were also significant differences. With some exaggeration one might see Pannekoek's humans as bloodless productive robots, whereas Elias painted a more comprehensive, lively and realistic picture. Because Elias's process of civilisation encompasses the whole gamut of human activities, it is the model of preference. On the other hand, it was Pannekoek who made the connection with biology. Furthermore, his earliest publication on the subject came out in 1909, well before *The Civilizing Process* by Elias in 1939.

The big picture

After completing the study of his model system, Elias went on to investigate many other sociological phenomena in order to verify whether his theory of civilisation was more generally applicable. Arts, sport, leisure, science, democracy ... the diversity of his subjects is amazing. By the end of his life, in the 1980s, he extended the chronological scope of his work considerably. Overall, the results of these studies strongly suggested that the basic principles of his theory are universal and apply to the entire development of humanity, from its origins up to the present day. With the research of biologists like Frans de Waal in mind, we may even include the burgeoning civilisations in animals, the apes in particular, because there, too, cultural rules suppress instinctive impulses, forcing action, mind and communication to follow commensurate detours.

If indeed Elias's theory of civilisation is generally applicable, it may help to improve our understanding of human development as a whole. As it turns out, the ratchet of civilisation did not work in a gradual way, but developments were punctuated and stepwise. Reconstructing the story of civilisation is like reading a book with a series of consecutive chapters.

Although this large-scale pattern has been recognised for a long time, I should like to refer here to a recent analysis of this phenomenon by the University of Amsterdam sociologist Johan Goudsblom (Goudsblom and de Vries, 2002; Goudsblom, this issue). What makes his study particularly relevant for this essay, is that it takes Elias's theory of civilisation as its starting point. Goudsblom distinguishes between three successive 'social-ecological *regimes*' where domination of fire, production by agriculture and animal husbandry, and industrial production occupy a central position. This succession appears to be universal and roughly repeats itself all over the globe. It has all the characteristics of an emergent pattern that only becomes apparent in the long view, an astounding order allowing us to take in one glance an overview of the major stages in the global process of civilisation. In agreement with the civilisation theory, Goudsblom does not regard these regimes as solely reflecting political relationships or, as Marxists would have it, productive constellations, but also 'the complex of regulations, habits and sanctions (both positive and negative) by which people try to regulate the relationships among each other and with their environment' (Goudsblom, 2002). Within a regime, all these factors are roughly geared to one another, so that a stable whole emerges, capable of maintaining itself for a longer period of time. The transition to the next regime may then be relatively sudden. For those who find it hard to believe in such patterning, it may be helpful to note that in geology and Earth System Science a similar succession of stasis and change is found to characterise the history of this planet as a whole (Westbroek, 1991).

Goudsblom devoted a detailed study to his first regime, characterised by the domestication of fire. He showed that this ability definitively separated the human lineage from its animal ancestry. The technology alone demanded a very drastic repression of prevailing impulses. Almost unsurmountable fears had to be overcome, while very complex behavioural patterns had to be established. As the maintenance of fire depended on close collaborations between community members, one can envisage profound alterations in social structures and in the behaviour of individuals. This breakthrough in the process of civilisation could only take place because the domination of fire opened fabulous new opportunities. It immediately turned the balance of power in favour of the humans, at the expense of even the biggest of animals. Food could be cooked, forests burned, and game driven up to be hunted. Major waves of migration from Africa over large extents of the globe followed in consequence. These people lived as hunters and gatherers, and for their mental orientation they had to rely on a kaleidoscopic variety of world views, collectively known as *animism*. The time when the domestication of fire became implemented is at present uncertain: estimates vary between 1.8 million and 250,000 years.

The next phase, of *agrarianisation*, took shape about 10,000 years ago. It was under this regime that the *geocentric* world view would culminate. The third regime, of *industrialisation* (with *modernism* as the dominating worldview), emerged by the end of the eighteenth century, while a new world view may have appeared only a few decades ago, in response to the first view of the Earth from deep space. Goudsblom discerns the first signs of an associated, fourth regime, emerging in response to to-day's ominous predictions of global environmental change. Novel societal structures would further the implementation of a sustainable development. The idea of a smooth transition into a forthcoming, sustainable regime is widely discussed at present.

Discussion

The foregoing arguments may now be summarised as follows:

1. Civilisation is not limited to humanity, but it already occurs in the animal world, in particular in the great apes (de Waal).
2. Broadly speaking, the human process of civilisation is ratchet-wise or accumulative; in chimpanzees and bonobos, acquired cultural skills are insufficiently maintained to be perpetuated over long periods of time.
3. Perpetuation of the process of civilisation requires an intimate coupling of tool use, thought and communication. A delay in one of these activities holds up the entire process. This autocatalytic mechanism implies that immediate impulses for the satisfaction of particular societal and personal needs are systematically suppressed and diverted along alternative and ultimately more satisfactory routes (Pannekoek and Elias).
4. In the long term, the civilising process unavoidably results in a distinct sequence of adaptive reorganisations, culminating in stable regimes of production, societal structure and world views – that is, the domestication of fire, agrarianisation and industrialisation (Goudsblom).

On the face of it, this hypothetical scenario appears to be internally consistent. Intuitively, we may also feel that the connection beween civilisation and the rest of Earth history is feasible, at least in principle. But intuitions are unreliable and a round of rigorous testing and falsification is mandatory. For this to be realised, concept-derived mathematical modelling, combined with empirical research, is the method of choice. To practitioners of the human sciences it may seem a long shot to express the basic mechanisms underlying the process of civilisation in terms of mathematical formulations. But there is little reason for hesitation, because in essence modelling is like riding a bicycle: it brings you further ahead with less effort. Essentially, the modelling is no more than a formalisation of basic scientific procedures. In so far as our scenario for civilisation is concerned, it would greatly facilitate the detection and correction of internal inconsistencies, as well as the validation and falsification of these ideas by comparison of model outcomes with the real world.

In Earth System Science, mathematical modelling has now become an indispensable tool. It is routinely applied in studies on a wide variety of aspects of Earth history, such as the global cycling of chemical elements, plate tectonics, ocean and atmospheric currents, and the organisation of biological systems (for the latter subject, see Kooijman, 2000). However, a comprehensive model of Earth system dynamics over the full range of geological time is not yet available (Westbroek, 2009). Such a fabrication would be a key tool for bringing the human and natural sciences in line. A promising long-term strategy for the realisation of the latter endeavour would be to insert a future civilisation model into one for Earth dynamics as a whole. Again, this construct could subsequently be improved upon by real-world observation.

Obviously, we cannot know whether this modelling exercise will meet with success before the work has been done. The challenge is gargantuan, but the probable benefits are worth the effort. Already, one general implication seems inescapable. One can anticipate that the joining of a civilisation model with a more general model for Earth dynamics would reveal a complex hierarchical relationship. In the introduction, I epitomised Earth history as a ratcheting, accumulative development, an immense planetary odyssey, unpredictable in its course, but nevertheless bringing about an overall long-term differentiation and complexification. It is important to realise that early in Earth history this differentiation must have been purely physical and chemical. The agglomeration of the early Earth as a separate component of the solar system; the segregation of the moon; the subsequent differentiation between the core, the mantle, the crust, the hydrosphere and the atmosphere; the emergence of initial tectonic regimes, which in turn gave rise to a steadily proliferating spectrum of minerals and rock-types; all these early differentiation steps took place in the absence of life, independently of Darwinian mechanisms. The first living systems must have emerged locally out of complexifying elaborations of geochemical fluxes. This event marked the origin of miniature self-replicating organisations – the first cells – that would soon spread out over the entire planetary surface and increasingly modify previously existing mechanisms of Earth dynamics. Life, indeed, represents an immense geological force (Westbroek, 1991), and biological evolution is known to have increasingly amplified the rate of differentiation in the planetary dynamics. Thus, life cannot be considered as an autonomous process adapting to the physical and chemical constraints imposed by the Earth system. Instead, biology is part and parcel of the ratcheting Earth, or, to put it more bluntly, an emergent property of the planet that speeds up the rate of its differentiation.

The process of civilisation stands out as the subsequent major revolution in earth dynamics. In the last per mill (1 ‰) of Earth history, complexity locally increased to the point where the ratcheting became more and more independent of tedious Darwinian mechanisms. The new principle proliferated slowly at first, but then at a rapidly increasing rate, until at present it is modifying the dynamics of the outer Earth. Its differentiating effect on the planet (to be expressed in tools, thoughts, means of communication and institutions) was immense. Thus, from the point of view of Earth System Science, the process of civilisation is not the privilege of humanity, but an emergent property of Earth dynamics. Primarily, it is the Earth that civilises, and not us. Consequently, the civilising process cannot be divorced from the chemical, physiological and biological factors governing Earth dynamics. Thus, like biological evolution, the civilising process represents an emergent property of planetary dynamics that amplifies and speeds up the ratchet of the Earth's differentiation.

What causes complexification and differentiation to proceed through Earth history remains a mystery, although explanations have been proposed (see for example Spier, 2010, Wright, 2001). Darwinian principles of biological evolution are an obvious candidate, but they do not stand on their own. Rather, biological evolution should be regarded as an emergent property of the overarching ratcheting entity, the Earth.

These considerations may have important implications for our worldview. Sigmund Freud spoke of three anxieties [*Kränkungen*] that shook the self-confidence of humanity: the realisation that the Earth is not the centre of the universe; the descent of humanity from the animal world; and his own observation that conscious thinking is only a minor component of our information processing system. We may now add a fourth anxiety to the list: the Earth, and not humanity, is the primary agent of civilisation. In the 1950s, Pannekoek could still claim that our descendents are destined to master the Earth. By contrast, Earth System Science reveals that we are entangled in a larger, autonomous process, civilisation, which in turn is enmeshed in the vagaries of a complexifying planet. Ultimately, we have no choice but to accommodate to the vicissitudes of this planetary odyssey, like surfers amid the ocean waves. To some it may look as if this awareness forms a last and definitive blow to the anthropocentric worldview of the Middle Ages. But anthropocentrism is still in charge. While we tend to protect ourselves from the savage world by spinning cocoons around our personal lives, our 'civilised' society seems to opt for ignorance. Obsessed with personality, we endulge in our twittering global village. We are like goldfish in an aquarium, imagining that they are in charge of the ocean at large.

A growing chorus of philosophers and opinion makers is claiming that, since the ideologies of the twentieth century melted away, we are in need of a new 'big story'. This is exactly what the fundamental sciences provide. The vision inspired by Earth System Science may seem scary at first; but it is a liberating experience to leave our cocoons, become aware of the immeasurable depth our our roots, and orient our lives in agreement with the real world. We should not forget that, when the Apollo 8 astronauts observed the Earth from deep space, it was the Earth seeing herself for the first time in 4.6 billion years – through our eyes.

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Biography

Peter Westbroek (1937) studied geology and did his PhD on fossil brachiopod palaeobiology at Leiden University (the Netherlands). He then had a post-doctoral position at Queen's University in Belfast where he began biochemical research on biomineralization. In 1970 he was able to start a small group in the Department of Biochemistry in Leiden, with research on calcification in the coccolithophore *Emiliania* *huxleyi*', 'immunology of fossil macromolecules' and 'bacterial manganese and iron oxidation'. Peter Westbroek gave regular lecture courses on the influence of biological systems on Earth dynamics, and wrote the book *Life as a Geological Force* (New York, W. W. Norton, 1982, translated into 5 languages). He directed the 'Global Emiliania Modelling Initiative' (GEM), an international and interdisciplinary project on the climatic effects of marine phytoplankton. Westbroek is emeritus professor of Geophysiology in Leiden University, is member of the Royal Netherlands Academy of Arts and Sciences, and occupied the Chaire Européenne du Collège de France in 1996—7. He was the first recipient of the 'Vladimir I. Vernadsky Medal' of the European Geophysical Society in 2003. In 2009, he published *Terre ! Des menaces globales à l'espoir planétaire* (Paris: Le Seuil). This book shows how the long view of fundamental research brings admiration for our planet and helps to overcome our fears. A revised Dutch version is almost finished and will be followed with a further update in English.

Notes

1. This is an edited version of Chapter 9 in P. Westbroek, 2009. Terre! Des menaces globales à l'espoir planétaire. Seuil. A thoroughly edited English version of this book is in preparation. [#N1-ptr1]

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