Beyond us

Is a world without humans possible?

Valenti Rull

The potential annihilation of the human race is a topic that is often relegated to science fiction. Authors and filmmakers seem sometimes gleefully inventive when it comes to eradicating human civilization: deadly viruses in Terry Gilliam's *Twelve Monkeys* (1995); nefarious aliens in H.G. Wells's *War of the Worlds* (1898); scientific experiments gone wrong in Kurt Vonnegut's *Cat's Cradle* (1963); the degeneration of oil-addicted civilization in George Miller's *Mad Max* (1979); or a massive environmental catastrophe in Roland Emmerich's *The Day After Tomorrow* (2004). The theme that runs throughout all of these is that humanity, brave and indomitable, struggles onwards after the cataclysm; sometimes improving or sometimes, as in British science fiction

author Stephen Baxter's novel *Evolution* (2002), de-evolving into increasingly primitive species. Recently, however, the idea of a world devoid of humans after a global catastrophe has also been considered, with more or less detailed accounts on the potential ecological recovery of the biosphere (Holmes, 2006; Weisman, 2007).

None of the above—nor any other fictional accounts of how humanity might come to an end—has been taken seriously, in part because of an apparent lack of sound science underpinning such scenarios (Kilker, 2008; Pimm, 2008). Yet, the possible extinction of *Homo sapiens* should not remain the purview of fiction authors; indeed, one could think of potentially realistic scenarios that one way or another might lead to the disappearance of

humankind from Earth. The purpose of this essay is therefore to approach the topic rationally; in part because informed opinions need to be heard in modern societies, and scientists should take on this role to avoid the proliferation of pseudo-scientific 'truths'. The following is a personal view, its only aim being to stimulate a scientific debate.

A few decades ago, predictions of future scenarios, cataclysmic or otherwise, were considered unscientific because they were speculative and not testable by scientific methods. Today, science has learned to incorporate the future as a common time frame for predictive modelling, driven in part by uncertainty about the potential consequences of global climate change and the future developments and applications of genetic engineering. More generally, modern science increasingly uses modelling to generate workable hypotheses—which are ideally calibrated and validated against historical records—that can be tested by using current data and experimental investigations. One of the best examples is the Intergovernmental Panel on Climate Change, which guides actions in light of the potential consequences of global climate change (Solomon *et al*, 2007). Similarly, the future of the Earth's biosphere can now be addressed from a scientific perspective, as predictions about it are able to fulfil the main requirements of modern science: namely, the availability of falsifiable hypotheses and the methods to test them (Popper, 1959).

...the possible extinction of *Homo sapiens* should not remain the purview of fiction authors...

Based on the pictorial message engraved on the Pioneer plaques. Original plaques designed by L. Salzman Sagan.

When we think about the future, we usually imagine that humans—whom we envisage will look like us—will live in a world that is more or less different from our own, depending on the timescale involved. If we contemplate a world without humans, we usually assume that our demise has resulted from a global catastrophe. In other words, unless something very bad happens, we imagine that the future should include humans. However, there is little scientific support for such a view. In fact, our planet has been devoid of humans for almost its entire existence: *Homo sapiens* evolved around 200,000 years ago, which is a mere blink of the eye in terms of the Earth's own 3.5 billion year history (Schopf, 1999; Tattersall & Schwartz, 2009).

If we contemplate a world without humans, we usually assume that our demise has resulted from a global catastrophe

Therefore, the question is very real: will humankind persist or not? There is no *a priori* reason to believe that humans will fare any better than any of the other species in the fossil record that have come and gone throughout Earth's history. From a strictly biological point of view, humans are just one ephemeral animal among many in the history of the biosphere. In fact, the conscious or sub-conscious feeling that we are intrinsically special is founded in the Judaeo-Christian tradition, although evolutionary theory has already subdued this view to some extent (Stoneking, 2008). Nevertheless, humans are genuinely biologically and socially different to other animals. For example, our particular socio-cultural evolution has made us the most successful invading species, able to transform the environment to thwart competition from other species and to settle in even the most remote areas of the planet. Furthermore, the development of agriculture coupled with technological and biomedical development have enhanced wellbeing and life expectancy to the point where few other species can compete with our longevity, and our social constructs ensure that competition for food and other resources is regulated through the concept of trade. In principle, humans are more persistent than other species. But this comes at a price.

The same factors and activities that increase human fitness and persistence are often considered potentially fatal—on a global level—by catastrophists. They point out that the environmental effects of our success—pollution, ecological collapse and climate change, among others—might ultimately limit human population growth. Similarly, the successes of increased longevity and reduced morbidity could result in overpopulation, leading to starvation, poverty, disease, the exhaustion of natural resources, or war. Further increases in human fitness and health might, therefore, accelerate the deterioration of biodiversity and the Earth's carrying capacity. This is one of the reasons—in addition to simple curiosity and the human drive to explore the unknown—for space exploration. The hope is that it might one day be possible to relieve an overpopulated Earth by colonizing other planets such as Mars (Heppener, 2008). At present, however, insufficient technology and economic impediments remain the main constraints on developing a substantial space programme. Of course, even if we were successful in colonizing other planets, this would not immediately solve our climate and environmental issues, or the way in which we exploit resources; it would only transfer these problems.

There is no *a priori* reason to believe that humans will fare any better than any of the other species in the fossil record that have come and gone throughout Earth's history

Another concern about the future of humans is how evolution might yet change us, if at all. The current debate about the future evolution of humankind has focused on the relative impact of cultural compared with biological evolution. Since the invention of agriculture about 12,000 years ago, it has been socio-cultural evolution that has driven human development (Klüwer, 2008), and some have even claimed that cultural adaptation has replaced genetic adaptation in humans. Nevertheless, there is evidence that natural selection is still at work on us, mainly with regard to adaptations to environmental change (Stock, 2008). Furthermore, some have argued that we will not remain passive in this process. It has been suggested that at some point in

Further increases in human fitness and health might, therefore, accelerate the deterioration of biodiversity and the Earth's carrying capacity

the future, we will be able to direct our own biological evolution by means of sophisticated technological developments such as nanotechnology, psychopharmacology or genetic engineering (Hughes, 2008). Others have gone so far as to predict that we will be able to create artificial, synthetic and virtual organisms (Pearson, 2008), which might contribute to the problems of overpopulation, environmental degradation and the general collapse of human civilization.

Pessimistic predictions of an apocalyptic end to humanity are not only the stuff of biblical or science fiction, but are also the central tenet of many futurist propositions. In the past, it was almost always imagined that an apocalyptic war would instigate the end of humankind; nowadays, some view environmental deterioration and the exhaustion of natural resources as equally terrible menaces, and the present mercantilist economic system, sustainable or not, seems to support these concerns.

Of course, these dire predictions are nothing new. Early futurists, including the British biologist J.B.S. Haldane (1892–1964), put their hope in the use of scientific progress “for the better” by appealing to human nature (Haldane, 1927). This so-called techno-optimistic vision supposed that we could prevent future collapse through scientific endeavour. The opposing techno-pessimistic view held by other scholars of the time, such as Bertrand Russell (1872–1970), argued that because science and technology always benefit the dominant classes, they are insufficient to save the world from ruin (Russell, 1924). The modern equivalent of the techno-optimistic view is the idea that technological developments, especially stem-cell therapy and genetic manipulation, might be used for positive human enhancement.

However, this path to the future raises concerns about social justice and the further degradation of nature. In the present socio-political context, enhancements would probably only benefit—and be available to—a small portion of society. In addition, as discussed earlier, anything that increases human fitness also increases our competitiveness

and, therefore, our destructive capacity. This modern techno-pessimism is fuelled further by concerns about the market economy, which encroaches on many aspects of our lives. This mercantilism—as manifested in the quest for quick profits—is one more expression of humankind's narrow-mindedness and short-sightedness (Hanski, 2008), and it is largely responsible for the accelerating depletion of natural resources and the concomitant deterioration of the environment and biodiversity. Hence, in this context, it is doubtful that biomedical and technological improvements will contribute *per se* to a more 'humane' world. For that, we need a more 'humane' socio-economic system.

Such a 'partnership' approach to dealing with nature—as opposed to the current 'ownership' model adhered to in most developed societies—should be possible given that human development and conservation are not incompatible goals (Bruce, 2008). It would, however, require significant changes to be made to today's prevailing economic model and the direction of technological development. The question is whether the non-destructive coexistence of humans and other species could continue forever if humans themselves keep evolving. Evolutionary theory predicts that humans, like any other species, will either evolve into new species and/or will become extinct. Given the competitive nature and capacity of humans, a superior post-human species might eventually dominate our own or other species, just as *Homo sapiens* apparently dominated *Homo neanderthalensis* around 30,000 years ago (Finlayson, 2004).

In addition to being wiped out by catastrophic events, self-induced or otherwise, the possibility of the 'non-catastrophic' extinction of humankind must also be considered. Throughout history, five significant mass extinctions have occurred (Jablonski, 2001), but individual 'silent' extinctions have happened continuously. These, coupled with speciation, are the normal mode by which biodiversity turnover occurs and species fade away or evolve. In recent history, the extinction of various species has been commonly associated with the death of the last individual—as happened with the traveller pigeon, the Tasmanian wolf or the dodo—with the causes of extinction being habitat loss or degradation, environmental change, disease or human action.

Yet, extinction is a phenomenon that can occur through at least four modalities

Fig 1 | The four types of extinction discussed in the text. Species that disappear are shown in the lower part of the diagram (A, B, C, E, G) and emerging species are in the upper part (D, F, H, I). Extinction events are marked with an asterisk.

Another concern about the future of humans is how evolution might yet change us, if at all

(Fig 1). The most intuitive and commonly considered mode of extinction is the death of the last member of a species, as noted above. A second mode is hybridization, whereby two inter-fertile species become extinct because they have produced a new, dominant daughter species. The third is so-called cladogenesis, whereby a species diverges into two or more daughter species by allopatric speciation, rendering the original extinct (Delord, 2007). The fourth is anagenesis, which is the evolutionary modification of one species into another. Hybridization, cladogenesis and anagenesis are also called pseudo-extinction because part of the original gene pool is still present in the daughter species (van Valen, 1973). These four possibilities have been grouped into two categories based on the continuation, or not, of the phylogeny after extinction. Thus, the fatal death of a species is called phyletic extinction—there are no further branches in the phylogenetic tree beyond that species—whereas the other three are known as non-phyletic extinction types, as the branches of the tree continue (Raup & Stanley, 1971). In the case of humans, an abrupt, self-induced extinction would fall into the first category. On a less cataclysmic scale, hybridization, for example, might have accounted for the partial extinction of the Neanderthals, as some genetic interchange might have occurred between them and our ancestors (Stringer, 2002). Finally, the rise of one or

more post-human species by anagenesis or cladogenesis would be a natural evolutionary phenomenon, leading to our own bloodless extinction.

In the light of the evolutionary framework, even if we manage to preserve our planet and its biosphere in a more or less safe condition and if human evolution continues, the human nature—in a biological sense—might be lost naturally, sooner or later. The fossil record is brimming with examples of lineages that have experienced dramatic transformations into different morphologies and biological organizations, resulting in the appearance of new species, genera, families, and so on. In fact, this is ultimately what evolution is about. In terms of our own phylogeny, the change from quadruped ancestors into bipedal hominids took only a few million years (Richmond & Jungers, 2008; Tattersall & Schwartz, 2009), so the evolutionary change we might experience during the next, say, 5–10 million years could similarly lead to a very different animal to that which we currently call 'human'. Predictions about the nature and characteristics of a future species of humans, including their intelligence, is a fascinating issue but clearly belongs to the realm of fiction and, as such, is beyond the scope of this essay.

...the evolutionary change we might experience during the next, say, 5–10 million years could similarly lead to a very different animal to that which we currently call 'human'

A question that we might consider, however, is: if we are able to modify the natural course of evolution through technology, will we artificially prolong the human condition and thus delay our own 'natural' evolution or extinction? The potential process of governing our own evolutionary future through genetic manipulation has been called "enhancing evolution" (Harris, 2007), and it seems self-evident that the results of such intervention will depend on the dominant socio-economic and moral scenarios in which decisions are taken. As cultural changes occur much more rapidly than biological ones (Klüwer, 2008), predicting how we might best enhance evolution is extremely difficult. In the present state of knowledge, we cannot know if such procedures could perpetuate our species more or less unchanged; but, from an evolutionary perspective, this appears to be unlikely. Thus, the old human dream of immortality—in this context, as a species—seems hard to reconcile with evolutionary and ecological predictions.

No matter what the cause of our extinction might be, or the time-frame needed for it to occur, the idea of a planet without humans is worth considering from a scientific point of view. Biologically, there is nothing special that would either prevent us from going or cause us to go extinct. Indeed, we might fall foul of a self-induced global catastrophe, a natural mass extinction event, or simply by silent non-catastrophic or non-phyletic individual extinction. In any case, we might take some comfort from the fact that the biosphere rebounded from the 75% biodiversity loss at the Cretaceous–Tertiary boundary 65 million years ago, and even from the 90% loss during the Permian–Triassic mass extinction 250 million years ago (Courtyllot, 1999; Jablonski, 2001). Thus, even after the catastrophic disappearance of humans, the Earth would probably enjoy a full biotic recovery.

To provide firmer ground on which to consider these difficult questions about the future of humanity, the lessons learned from the fossil record and the available data about evolutionary trends in biodiversity should be used to model future scenarios for the

...as members of the Earth's biosphere, we might feel responsible for the future of all forms of life and should therefore be responsible for the future Earth as a whole...

biosphere. In this way, the cases discussed here and others could be simulated to derive robust hypotheses to be tested by future studies and observations. Such models ought to be able to simulate the evolutionary responses of organisms and biological systems to changing environmental and biotic factors. Moreover, ecological modelling could be used to simulate the effects of biotic interactions such as competence, predation or infectious diseases, as well as their potential evolutionary consequences. The coupling of both models would then provide potential scenarios for a future world with or without humans, considering both catastrophic and evolutionary human extinction. The most uncertain variable in these models would be the human capacity to modify the evolutionary process—both our own and that of the biosphere in general—although several outputs could be generated to obtain and evaluate a range of potential setups. At this moment in time, such a modelling approach might seem premature, but the effort is worth making—otherwise, unfounded fantasies will flourish and non-scientific explanations will take the lead. The aim is not to eradicate fiction, but rather to place science and science fiction in their correct contexts, both socially and professionally.

It is frequently said that our responsibility is to leave a safe, healthy planet to our descendants. Of course, this begs the question of whom we mean by "our descendants": our children? Our great great grandchildren? The next civilization? The next human species? The next species derived from humankind, whether it is human or not? All of these animals will be our descendants and the answer probably depends on our degree of selfishness, which is a matter of scale. As individuals, we are used to being concerned with the first options listed above but, as members of a given civilization, we might be also interested in "Humanity 2.0" (Chan, 2008) and, as a species, we could consider the health and welfare of the next human or post-human species. Finally, as members of the Earth's biosphere, we might feel responsible for the future of all forms of

life and should therefore be responsible for the future Earth as a whole, especially given that we have been one of the key agents of its current shaping.

The nature and attributes of an eventual non-human Earth will depend on how it arrives at that state—whether by human-induced disasters resulting in the eradication of humankind, or by evolution, with or without human intervention. Although we will not be around to see the final outcome of these processes, we can at least leave our thoughts and guesses to future generations to provide them with testable hypotheses, if they still practice science; or at least to make them laugh, if they still have emotions.

CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

ACKNOWLEDGEMENTS

This paper was written under the auspices of the BBVA Foundation (Biodiversity Conservation Program, project BIOCON 2004-90/05) and the Ministry of Science and Innovation of Spain (project CGL2006-0097/BOS).

REFERENCES

- Bruce D (2008) How sustainable are we? Facing the environmental impact of modern society. *EMBO Rep* 9: S37–S40
- Chan S (2008) Humanity 2.0? Enhancement, evolution and the possible futures of humanity. *EMBO Rep* 9: S70–S74
- Courtyllot V (1999) *Evolutionary Catastrophes: The Science of Mass Extinctions*. Cambridge, UK: Cambridge University Press
- Delord J (2007) The nature of extinction. *Stud Hist Philos Biol Biomed Sci* 38: 656–667
- Finlayson C (2004) *Neanderthals and Modern Humans*. Cambridge, UK: Cambridge University Press
- Haldane JBS (1927) The last judgment, a scientist's vision of the future of man. In *Possible Worlds and Other Essays*, pp 287–312. London, UK: Chatto & Windus
- Hanski I (2008) The world that became ruined. Our cognitive incapacity to perceive large-scale and long-term changes is a major obstacle to rational environmental policies. *EMBO Rep* 9: S34–S36
- Harris J (2007) *Enhancing Evolution*. Princeton, NJ, USA: Princeton University Press
- Heppener M (2008) Spaceward ho! The future of humans in space. *EMBO Rep* 9: S4–S12
- Holmes B (2006) Imagine earth without people. *New Sci* 2573: 36–41
- Hughes JJ (2008) Back to the future. Contemporary biopolitics in 1920s' British futurism. *EMBO Rep* 9: S59–S63
- Jablonski D (2001) Lessons from the past: evolutionary impacts of mass extinctions. *Proc Natl Acad Sci USA* 98: 5393–5398
- Kilker J (2008) Book review: the world without us, by Alan Weisman, New York: Thomas Dunne Books (St Martin's Press), 2007. 324 pp. *Sci Commun* 30: 288–291

...the old human dream of immortality—in this context, as a species—seems hard to reconcile with evolutionary and ecological predictions

- Klüwer J (2008) The socio-cultural evolution of our species. The history and possible future of human societies and civilizations. *EMBO Rep* **9**: S55–S58
- Pearson I (2008) The future of life. Creating natural, artificial, synthetic and virtual organisms. *EMBO Rep* **9**: S75–S77
- Pimm SL (2008) Imagine a better world. *Nature* **448**: 135–136
- Popper KR (1959) *The Logic of Scientific Discovery*. New York, NY, USA: Basic Books
- Raup DM, Stanley SM (1971) *Principles of Paleontology*. New York, NY, USA: W.H. Freeman
- Richmond BG, Jungers WL (2008) *Orrorin tugenensis* femoral morphology and the evolution of hominin bipedalism. *Science* **319**: 1662–1665
- Russell B (1924) *Icarus, or The Future of Science*. New York, NY, USA: E.P. Dutton & Co.
- Schopf JW (1999) *Cradle of Life: The Discovery of Earth's Earliest Fossils*. Princeton, NJ, USA: Princeton University Press
- Solomon S et al (2007) *Climate Change 2007: The Physical Science Basis*. Cambridge, UK: Cambridge University Press
- Stock JT (2008) Are humans still evolving? Technological advances and unique biological characteristics allow us to adapt to environmental stress. Has this stopped genetic evolution? *EMBO Rep* **9**: S51–S54
- Stoneking M (2008) Human origins. The molecular perspective. *EMBO Rep* **9**: S46–S50
- Stringer C (2002) Modern human origins: progress and prospects. *Philos Trans R Soc Lond B Biol Sci* **357**: 563–579
- Tattersall I, Schwartz JH (2009) Evolution of the genus *Homo*. *Annu Rev Earth Planet Sci* **37**: 67–92
- van Valen L (1973) A new evolutionary law. *Evolutionary Theory* **1**: 1–30
- Weisman A (2007) *The World Without Us*. New York, NY, USA: St Martin's

Valentí Rull is head of the Laboratory of Palynology and Paleoecology at the Botanic Institute of Barcelona, Spain.

E-mail: vrull@ibb.csic.es

Published online 16 October 2009

doi:10.1038/embor.2009.225