EMBO
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introduction

The future of our species

Will there be a sustainable evolution of humanity in the twenty-first century?

Andrew Moore

We start this special issue of *EMBO reports* with the most 'distant' prospect for humanity: space travel to other stars and planets. "Curiosity is probably the best [explanation]: exploration is, metaphorically speaking, in our genes," writes Marc Heppener about why humans want to leave the Earth and reach out into space. This curiosity is unlikely to change, no matter how much we evolve in the meantime: we want to know how the Earth and our neighbouring planets were created, and, ultimately, whether we are alone in the universe. With current technology, Mars is the most likely destination: it would take a minimum of 520 days for a manned mission to Mars, including one month spent on the Martian surface. If we want to travel to our nearest star, which is Alpha Centauri, we will need to devise ways in which to extend the human lifespan and overcome space-flight boredom, or develop artificial hibernation.

Only time will tell whether any of this is feasible. Yet, in the time that it would take us to send even a small group of humans to Mars, the surface of our planet could change beyond all recognition—because of us. We face a range of pressing biological problems that will test our ingenuity to its limits, but we also face the problem of managing our own technological progress and socio-cultural evolution. More than ever before, our survival and well-being depend on the generation of new wisdom through transdisciplinary approaches that involve the natural sciences, social sciences and humanities. In the articles that follow, the experience of a broad range of professionals from these areas is brought to bear on the question of the future of our species.

As we enter the twenty-first century, infectious diseases account for 32% of deaths worldwide and 68% of deaths in Africa. Although disease prevention and treatment do not require 'rocket science', this situation has barely changed and is not likely to improve in the near future. Even the cynical economics of fighting diseases—that is, a demonstrable net economic pay-off through increased productivity—has not spurred governments on to greater action to combat infectious diseases. As Peter Ndeboc Fonkwo asserts, simple and relatively cheap measures such as washing hands, cleaning and disinfecting surfaces, correct food handing and preparation, immunization, correct use of antibiotics and safe sexual habits, can notably reduce the prevalence of infectious diseases, and lead to tangible economic benefits for both developing and industrialized countries. Much of what prevents this is poverty itself, and the lack of education and infrastructure that accompanies it.

But there is more to come: during the past 20 years, 16 new diseases have emerged, and five serious infectious diseases are making a comeback, including multidrug-resistant tuberculosis. Julian Davies continues to argue for greater wisdom in the use of existing antibiotics and greater research into new ones. By the 1970s, through (imprudent) use of antibiotics, we thought that we had gained the upper hand over infectious diseases. Today, we are witnessing a 'veritable pandemic' of microbial transfer of antibiotic-resistance genes to human pathogens. The burden to the US healthcare system in 2005 was US$10 billion owing to methicillin-resistant *Staphylococcus aureus* (MRSA) infections alone—not a bad reason to invest in improved antibiotic strategies. However, funds are not limitless, and hence prioritization in addressing infectious diseases is crucial. Gérard Krause proposes a rational prioritization system that should allow better decision-making in the allocation of funds for research on, and treatment of, a battery of infectious viral, bacterial and parasitic diseases.

We can put figures to the cost of healthcare, but what of the price of the environment, our fellow inhabitants of Earth and natural resources? Chris Thomas and colleagues leave us in no doubt that when the chips are down, the damage caused by wealthy nations is paid for by poorer ones. Worse still, the poorest nations—which contribute the smallest fraction of anthropogenic carbon dioxide to the atmosphere—experience the greatest changes as a result of global warming. There is no international agreement on how to compensate those who lose out in this monstrous and unsustainable exploitation of the planet. The headline-making disappearance of coral reefs, which could affect the livelihoods of between 500 and 600 million people worldwide, either directly or indirectly, is mirrored by disastrous losses of land species: up to 25% are condemned to extinction by 2050, assuming a mid-range global temperature rise, if Thomas *et al* are correct.

Our current and potential future impacts on the natural world are increasing rapidly; however, not so our perception of the world, which remains comparatively limited, argues Ilkka Hanski. The cumulative environmental consequences of burning fossil fuels are on a scale comparable

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with the asteroid impact that caused the demise of the dinosaurs. We could avert tragedy by imagining that we have 30% less of the world to exploit, but much depends on how—not only technically but also philosophically—we view our relationship with the Earth and life on the planet. Donald Bruce presents a reflection on the different models of how to treat nature as represented in society today, and asks how sustainable we are. We can 'control and exploit', 'use and take care of', 'partner and respect', or 'maintain in a technical sense', or we can combine all four approaches. The last strategy embodies mutual responsibility, concern for biodiversity and "much technical ingenuity". Bruce suggests that we follow this fifth way of 'stewardship and relationship' in order to avert further environmental decay with unforeseeable consequences.

However, we might also notice the benefits to the human race of a warming world, and the long-term environmental and financial dangers of current strategies that are intended to put a brake on global warming. Global warming is not bad news for all of us, as Thomas Gale Moore points out. Moreover, given that we do need to control emissions to some extent, a worldwide carbon tax is—according to Moore—the only efficient way in which to deal with this problem. We should use the most efficient and cheapest strategy for reducing greenhouse-gas releases; anything else would merely impoverish much of the world.

We have reached a turning point in the sojourn of humanity on this planet, at which our technological, social and economic evolutions have clearly taken the upper hand in determining our future. Yet, what of biological evolution itself? Are we still evolving in strict Darwinian terms? Mark Stoneking takes us back to the beginnings of our species, to answer the question of where we came from. The facts that the modern human lineage diverged from African apes around 5–7 million years ago, and that modern humans radiated in waves from Africa between 1.5 million and 50,000 years ago, are now beyond serious contention. Recent advances in molecular genetics have provided invaluable information for clarifying who our closest relatives are, and—for example—also indicate that in Europe, *Homo sapiens sapiens* interbred to a small extent with *Homo sapiens neanderthalis*.

Jay T. Stock presents some examples of the more recent biological evolution of modern humans, such as the division between populations possessing and lacking the lactase gene, and jaw size and dentition, which have changed as our more refined diet has made lighter work for our chewing apparatus. Today, we might have reached an all-time 'go-slow' in genetic evolution—as implied by our relative genetic unity across populations, which is greater than most other species—but our evolution in cultural and technological terms is ever accelerating.

Unlike biological evolution, sociocultural evolution has Lamarckian traits: adaptations arising during the lifetime of an individual can be passed on to the next generation, as Jürgen Klüver reminds us. Nevertheless, social roles in a societal system "become the equivalent of genes in a genetic system." The rate of evolution of these social elements of heredity depends on the extent of creative freedom within a society. Klüver therefore concludes that humanity will probably evolve socioculturally to a convergence around Western culture, with local variations. The extent to which we evolve biologically will depend on how well our technological adaptability helps us to master an environment that is moving away from a period of relative stability and towards new challenges that could put all of the species on this planet under new selection pressures.

And so we enter the realm of futurism. James J. Hughes provides a 'biofuturistic' perspective by taking us back to England in the 1920s. He synthesizes predictions of whether we can surpass our 'humanity' and become post-humans, or how we might change our 'human nature' for the better and become more environmentally responsible. Bio-optimists, then and now, see a bright future if we can use technology to enhance our "moral sense and our capacity for social responsibility". It is therefore appropriate that the discussion of human enhancement encompasses current biomedical technologies and their possible development into enhancement technologies.

The final section of this special issue starts with an authoritative insight from Fulvio Mavilio and Giuliana Ferrari into what is currently—and what might soon become—possible in gene and stem-cell therapy, though with a sober recognition of the failures and difficulties. The initial success in treating severe combined immunodeficiency (SCID) patients, for example, has been undermined by leukaemia in two patients that resulted from the uncontrolled insertion of the viral vector into the host genome. The precise repair of genetic defects has major hurdles to overcome in the next years. The increasing focus on 'safety first' creates enormous challenges for medical research, and "some promising technologies might become too difficult to develop and to translate into effective therapies".

This makes the issue of enhancement seem distant. Yet, as Sarah Chan points out, we have been 'enhancing' our abilities since the invention of simple tools. Would genetic enhancement be anything more than a 'natural' progression, she asks? Moreover, could it be viewed as an expression of our humanity, rather than—as opponents claim—a 'dehumanizing' concept? After all, enhancement is, by definition, something that is good for us and that we think is good for us. Chan claims that the moral distinction, for the individual, between correcting short-sightedness by biological intervention and improving visual acuity to above average does not exist. Current physical limitations that we consider to be normal, such as our running speed, are only 'natural' or 'normal' in the context of one human generation and its culture.

Ian Pearson foresees that we will, indeed, surpass our current biological limitations with new biological, artificial and mixed carbon/silicon-based technologies. The creation of sentient beings with the ability to react and adapt is not limited to biology: soon we will have to face the reality that certain computer-based entities and their software could become sentient. Pearson sees the potential for new life forms, including human ones—through the integration of, or collaboration with, electronic systems—to expand exponentially through the mixing of electronics, synthetic and real biology. However, as he surmises, "we will almost certainly gain the required technology many years before we reach the level of cultural sophistication that would ensure the power is wielded with appropriate wisdom."

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This last sentiment could be held high as the unifying concern about our future on Earth—a small planet at the outer edge of a galaxy that we know as the Milky Way, which will, based on the predicted life-span of the Sun, theoretically be habitable for another 5 billion years. Humans might have the intelligence to change the environment and their place in it more profoundly than any other species, and we might even be able, one day, to enhance this prodigious intelligence further or to reach out to the stars. But what use, if our wisdom and common sense regarding the use of natural resources do not improve? Our ancestors who left Africa 100,000 years ago were surely closer to nature and understood it in ways that most modern humans no longer do. As we evolve into and out of the twenty-first century, we would do well to apply our new-found insights into the working of the living and non-living systems of the Earth in order to improve our sustainability. This knowledge, after all, is not of itself wisdom; rather, wisdom embodies the judgement of how best to use the knowledge. Let us hope that humanity can agree on the answer to this question soon, for the sake of the human race, our fellow organisms and the Earth itself.

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