EMBO reports

viewpoint

'Finitics'

A plea for biological realism

Ladislav Kováč

The history of human thought can be separated into two periods: before Darwin (BD) and after Darwin (AD). The former period covers 150,000 years of the existence of modern humans; the latter a thousand times less. Yet, as this paper argues, the burden of pre-Darwinian thinking continues to prevent us from realistically appreciating the present evolutionary stage of the human species. Therefore, I suggest that it might be time to substitute our current illusions, either about a bright future or imminent doomsday for humanity, with a radical Darwinian alternative.

Before Charles Darwin (1809–1882) published his theory of evolution in *The Origin of Species* in 1859, humans explained the existence, order and purpose of all things in nature by either natural or supernatural design. The fundamental tenet of Darwin's theory and the foundation of AD thought is the universality of Darwinian dynamics: complexity is steadily increasing and new knowledge is accumulating in the universe by uncorrelated variations and selection from the variants. However, selection—or, in the more precise words of the evolutionary biologist Ernst Mayr (1904–2005), non-random elimination—needs time to be effective.

A second Darwinian insight is the assertion—which Darwin adopted from British economist Thomas Malthus (1766–1834)—that life is subject to the law of exponential growth: the rate of change of a variable Q is a linear function of its present quantity: $dQ/dt = kQ$; $Q = ce^{kt}$ (Fig 1A). The population of any species would literally explode if its dynamics were not 'moderated' by the incessant 'struggle for existence' of each individual organism. Our ancestors were unlikely to encounter any exponential processes in their individual lifetimes, and so the human mind has been shaped to be successful by making linear extrapolations. Even a biologist who inoculates a culture with *Escherichia coli* and harvests a few grams of bacterial biomass after growth overnight might find it hard to conceive that, if the exponential proliferation of the bacterial culture continued unfettered for another 36 h, its mass would amount to the mass of the Earth.

Indeed, it has only been in the AD era that we have been able to observe exponential proliferation—most notably, that of the human population itself (Kremmer, 1993). According to calculations by the biophysicist Hans von Foerster and co-workers, the growth of the human population has been more than exponential: since antiquity, it has followed a hyperbolic curve, which is expressed as $dQ/dt = kQ^2$; $Q = 1/k(t_m - t)$ (von Foerster *et al*, 1960). Although the doubling time during exponential growth is a constant, hyperbolic growth is characterized by the fact that every doubling of a variable halves the doubling time (Fig 1B). Hyperbolic growth is linked to the mathematical notion of singularity: a point at which the rate of change becomes infinite and the quantity itself becomes infinite at a finite time t_m. Von Foerster and colleagues extrapolated the hyperbolic curve of human population growth and indicated that the population should reach infinity and the doubling time zero on Friday 13 November 2026: a date they dramatically called "doomsday" (von Foerster *et al*, 1960). In fact, the rate of growth of the human population achieved a maximum during the mid-1970s, subsequently transitioned from hyperbolic to exponential and is now slowing down. This unexpected change has been called the demographic transition.

…it might be time to substitute our current illusions, either about a bright future or imminent doomsday for humanity, with a radical Darwinian alternative

The sphere of scientific knowledge is another example of expansion; it has been increasing exponentially since about 1750 (Price de Solla, 1963). Although some scientific disciplines might have slowed down or even ceased growing, new ones join the fray while others continue to grow exponentially or even transit to hyperbolic expansion. The same observation pertains to some advanced technologies, which has prompted the American inventor and futurist Raymond Kurzweil to assert that "the singularity is near" (Kurzweil, 2005). In Kurzweil's view, the twenty-first century will see about a thousand-times greater technological progress than the twentieth century. Humanity is supposed to reach the technological singularity, which he defines as a uniquely rapid and profound technological change—a "rupture in the fabric of human history"—somewhere during the middle of the twenty-first century. In a review of Kurzweil's book, *The Singularity is Near: When Humans Transcend Biology,* Australian physicist and cosmologist Paul Davies objected to what he called wild ideas: "The key point about exponential growth is that it never lasts. The conditions for runaway expansion are always peculiar and temporary (with the possible exception of the expanding Universe)" (Davies, 2006).

At first glance, the human demographic transition seems to support Davies' objection, yet it presents biologists with an enigma: how is it possible that *Homo sapiens,* the most successful mammalian species on Earth, has

©2008 EUROPEAN MOLECULAR BIOLOGY ORGANIZATION

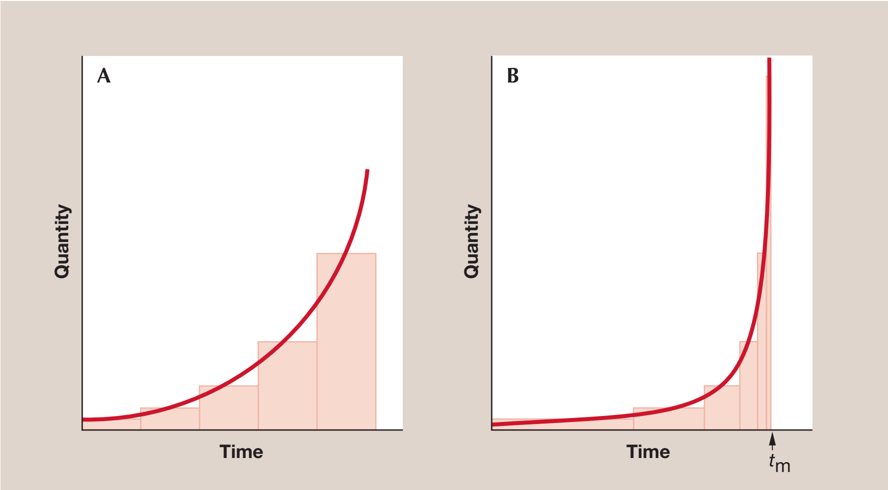

Fig 1 | Different time-course of exponential and hyperbolic dynamics. (**A**) Exponential and (**B**) hyperbolic growth. The doubling time in exponential growth is constant. In hyperbolic growth, the doubling time halves at every doubling of a variable, until, at the singularity (t_m), the doubling time becomes zero and the variable infinite.

'voluntarily' decided to limit or halt its proliferation, thus disobeying the first and most powerful biological imperative? This phenomenon was not anticipated by Darwin and might even be used as an argument against Darwinian theory; however, its analysis might allow for a rigorous Darwinian view of human evolutionary destiny.

Modern humans live in environments for which they have not been selected. Various metabolic, physiological and cognitive functions, which once were instrumental for our ancestors to survive in the African savanna, have lost their adaptive qualification. In analogy with the term exaptation, we might thus use the neologism 'disaptation' to describe the change of evolutionary meaning of these functions.

> **Avoiding pain and seeking pleasure, by a runaway process of emotional evolution, might have made humans a unique hedonotropic species...**

With the emergence of self-consciousness as a specific human trait, emotions—the principal motivational drivers in animals—started to be consciously experienced as pleasure or pain and might have become the main arbiters of subsequent evolution. Our forbears evolved to appreciate sweet taste as pleasurable because sweetness was a sign for precious and scarce food. But, even as food has become abundant, we continue to crave sweet things, which has become a cause of obesity and other related health problems. Similarly, evolution has vested sex with irresistible pleasure to make the reproductive drive more powerful; but this hypertrophy of pleasure has inadvertently led to the contemporary detachment of sexual practices from reproduction. Humans display the most bizarre behaviours, including artistic creations, scientific tournaments—displays at conferences, in the media or citation policies, for example—or sporting achievements, in order to override competitors and win the hearts of the opposite sex. Men in particular could disseminate their genes far more effectively by queueing up at sperm banks. Avoiding pain and seeking pleasure, by a runaway process of emotional evolution, might have made humans a unique hedonotropic species—one which seeks to amplify sensations they experience as pleasant—and might thus have become the main driver of subsequent cultural evolution.

The presumed units of cultural evolution are memes, which parasitize human hedonotropy and assemble to form ideologies, institutions, material and symbolic artefacts. Memes reinforce themselves and thrive, irrespective of their adverse effects on the Darwinian fitness of human individuals or populations, by exploiting the avoidance of pain and longing for pleasure. In principle, highly virulent memes might reduce the number of their human hosts to almost zero while they are still positively selected for—the drop in population numbers in parallel with the expansion of the entertainment business in some consumer societies is such an example. Ceaseless hedonic trade-offs mean that 'natural' pleasures can be replaced with ever more sophisticated artificial ones. This would explain the demographic transition in countries where low birth rates—at or below the level of replacement—correlate with the average 'living standard': that is, with pleasures and delights provided by the entertainment industry that are available to the majority of the population.

The same factors that curb the exponential growth of the human population also seem to support and drive vigorous and apparently limitless expansions in cultural evolution. Cultural evolution is the evolution of artefaction, which has been advancing by a ratchet-like process of inventing ever more sophisticated artefacts. The development of scientific instruments is a telling example. The discovery of the structure of DNA and the deciphering of the genetic code allowed the invention of DNA sequencing, which has been improving exponentially since the 1970s owing to ever more efficient techniques. We have not only seen an exponential increase in the number of sequences, but also an exponential decrease in the cost per base pair and the resources required: energy, time and material (Shendure *et al*, 2004). These examples support a more general observation that resources, which have always been the limiting factor of biological evolution, are not necessarily limiting cultural evolution. There is no sign that a technological transition—analogous to the population transition—is looming in the near future.

It also means that the rate of usable energy consumption and thus energy dissipation, which has been increasing since the early days of the industrial revolution, might slow down—as is already the case in some developed countries—halt or even decrease without affecting cultural evolution. In fact, it is not the absolute quantity of energy dissipation that will change exponentially or even hyperbolically, but its specific values, the density of energy fluxes.

The American astrophysicist Eric Chaisson argues that a variable, which he called the

©2008 EUROPEAN MOLECULAR BIOLOGY ORGANIZATION

free energy rate density—which might be expressed as $J\,s^{-1}\,kg^{-1}$—has been increasing in a nonlinear manner not only in biological evolution, but also in the entire universe (Chaisson, 2001). Chaisson, who uses this variable to characterize the complexity of a system—biologically or otherwise—argues that evolution has led to ever more complex systems, organisms, organs and regulatory networks. We can also see this trend, for example, in the evolution of present-day computers: the greater the number of transistors per chip—which, according to Moore's famous law, doubles every 18 months—the greater the free energy rate density.

The nonlinear rise in energy flow density is just one specific example of the trend of universal densification, which has become the most conspicuous feature of our time. The density of news on television, the internet and in newspapers; of data from scientific research; of goods on the market; and, generally, of events to which an individual is exposed every day—and with it the density of emotional experiences—is increasing. This densification is accompanied by ephemerization: everything lasts just a short time; banalization: everything becomes commonplace; and trivialization: anything, or any person, becomes insignificant and cursory. Cultural evolution is becoming similar to the early phase of biological evolution, when nearly the only measure of fitness was growth rate and when selection meant the "survival of the fastest" (Kacser & Beeby, 1984). "Time-based competition"—the drive behind innovations—is the main feature of today's market economy (Blackburn, 1991). The 'struggle for life' is assuming a 'struggle for attention': in an abundance of goods, data and toys, the 'evolutionary fitness' of any of these items is determined by the publicity it enjoys, which one might also describe as 'survival of the loudest'.

The unconstrained exponential dynamics of memes seems to be driven not only by hedonotropy, which might be human-specific, but also by something called 'sensory adaptation', which should be given the less ambiguous name of 'sensory accommodation'. Biological sensing systems are designed to respond to changes of incoming stimuli, rather than to the magnitude of a stimulus. If a signal's intensity is low, a biological sensor will respond to even negligible changes. If the intensity remains unchanged, the sensor stops responding to the signal. Human vision, for example, operates over a 1×10^{11}-fold range of light levels, from about 1×10^{-6} candela per m^2 in darkness to 1×10^{5} in full sunlight. Sensory accommodation has been described in virtually all sensory modalities of animals. Even chemotactic *E. coli* exhibit a similar sensory accommodation: they sense and adapt to ligand concentrations that range over five orders of magnitude.

Sensory accommodation has its counterpart in emotional accommodation: once a need or demand is satisfied, another one appears. The large increases of real-term income in the developed world during the past 50 years have yielded no accompanying change in reported life satisfaction (Easterlin, 1995). Studies on consumers' happiness show that new things delight us, but only for a short time: the pleasure of acquiring something new quickly loses its effect as it becomes familiar (Wexler, 2006). This observation—that improved life circumstances quickly cease to provide increased satisfaction—has been called the

©2008 EUROPEAN MOLECULAR BIOLOGY ORGANIZATION

hedonic treadmill (Brickman & Campbell, 1971). Repeating delights must be furnished in ever-larger doses in order to experience pleasure at all: the hedonic thresholds are steadily increasing.

[Evolution] is advancing towards a point in time at which some variables of evolutionary dynamics, including knowledge, will become infinite

At the same time, improving life circumstances have steadily reduced the intensity and frequency of pain that we are experiencing, and accordingly the threshold for pain might be decreasing. According to the Italian political scientist Giovanni Sartori, people in developed countries are characterized by "spineless softness" (Sartori, 2002). However, the unwillingness to act resolutely might not reflect sentimentality and all-embracing compassion, but rather self-centred hypersensitivity to any discomfort. The slightest sign of insecurity or of endangering the incessant flow of delight might provoke panic and aggression.

All these developments lead to an inevitable conclusion: the technological singularity, as envisaged by Kurzweil, is not a phantasm, but a real attractor of the contemporary dynamics of human civilization. Kurzweil adopted the term technological singularity from the American mathematician and computer scientist Vernor Vinge—who had adopted it from the mathematicians Stanislaw Ulam (1909–1984) and John von Neumann (1903–1957). Vinge conceived the singularity as a threshold after which cultural evolution, owing to the progress of computer technology, would produce a superhuman intelligence. He borrowed the term from the physics of black holes: just as our model of physics breaks down when it tries to model a black hole, our model of the world breaks down when it tries to model a future dominated by entities more intelligent than humans. Our present intelligence simply does not have the capacity to grasp a world with an intelligence that would transcend us—much like a dung-beetle trying to understand the world of humans.

This reservation notwithstanding, Kurzweil has attempted to depict the world behind the technological singularity. Humanity will merge with computational technology; the world will soon be populated by computational hybrids having at their core the minds and, poetically, the 'hearts and souls' of humans. The hybrid intelligence will become trillions of times more powerful than that of contemporary humans. The new species would do away with human frailties and live forever. Within the next few centuries, the entire universe will be taken over by an omniscient superintelligence. Various brands of transhumanists, extropians and singularitarians believe that the technological singularity will be achieved thanks not only to the unrestrained progress of computer technology, but also to similar progress in genetics, nanotechnology and robotics (GNR).

These are no longer the fantasies of science-fiction writers, but assessments by serious scientists, mostly physicists and computer scientists. A biologist might be amazed when reading an essay by the American physicist Freeman Dyson on "our biotech future" (Dyson, 2007). In his view, the tools of genetic engineering will soon become accessible to ordinary people; domesticated biotechnology in the hands of housewives and children will furnish an explosion of diversity of new living creatures; designing genomes will become a new art form as creative as painting or sculpture. The final step will be biotech games, designed in a manner similar to computer games for children down to kindergarten age, but played with real eggs and seeds rather than with images on a screen. "Playing such games, kids will acquire an intimate feeling for the organisms that they are growing." Dyson hopes that ethical progress will keep pace with science, making possible a future of universal prosperity and cooperation. Others are not so 'optimistic': "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; it is going to be like giving a powerful chemistry set to a child for its third birthday" (Pearson, 2008).

Dyson's speculations actually reflect ambitions that had previously been expressed by competent biologists. Long before the era of genetic engineering, biologists considered the possibility of changing heredity not by slow and blind breeding, but by quick and premeditated interventions. The only thing that they got wrong was assessing when such technologies would be available (Hughes, 2008). British biochemist and geneticist J.B.S. Haldane (1892–1864) pointed out in 1963 in a speech about *Biological possibilities for the human species in the next ten thousand years*: "It may take a thousand years or so before we have a knowledge of human genetics even as full as our present very incomplete knowledge of organic chemistry. Till then we can hardly hope to do much for our evolution" (Haldane, 1963). Half a century ago, the assessment was not in thousands, but in millions of years: French writer Anatole France (1844–1924) wrote in 1895 in his book *The Garden of Epicuros*: "When biology will be constituted, that is in some millions of years...". It is the year 2008, the replacement of 'wrong' genes with 'desirable' ones, and the creation of completely novel organisms, is becoming an engineering programme. As the American geneticist J. Craig Venter put it: "We now know we can create a synthetic organism. It's not a question of 'if', or 'how', but 'when', and in this regard, think weeks and months, not years" (Venter, 2007).

...the life of an individual, group or species assumes meaning and dignity from its temporariness

British biologist Julian Huxley (1887–1975), who introduced the term 'transhumanism' in 1957, envisioned a new philosophy based on the tenet that humans have the duty and the destiny to 'take charge' of evolution by transcending their biological limitations. The famous last sentence from Richard Dawkins' book *The Selfish Gene* reiterates this challenge: "We, alone on earth, can rebel against the tyranny of the selfish replicators" (Dawkins, 1976). This conviction dates back to the French philosopher Nicolas de Caritat, Marquis de Condorcet (1743–1794), who stated that the perfectability of man is unlimited, and seems to resound in countless sermons of contemporary neo-Enlightenment scientists, including biologists. Edward O. Wilson wrote that we are "the first truly free species" that is about "to decommission natural selection, the force that made us [...] the legacy of the Enlightenment is the belief that entirely on our own we can know, and in knowing, understand, and in understanding, choose wisely" (Wilson, 1998).

In his review of Wilson's book, Robert May commented: "I would like to share his

 ©2008 EUROPEAN MOLECULAR BIOLOGY ORGANIZATION

optimism, but I cannot […] I fear that inflexibility of human institutions, rooted in the past evolutionary history of our species, will ineluctably continue to put their emphasis on the interests of individuals and of the short term" (May, 1998). But it is not only the inflexibility of institutions that is important here; the basic flaw of neo-Enlightenment biologists—staunch adherents of Darwin—is, *horribile dictu*, their sticking to and perpetuation of pre-Darwinian thinking.

First, who are the 'we' that Dawkins and Wilson are talking about? Is it the scientists who would "rebel against their selfish genes"? If the number of scientists on Earth were one-hundred million—the present number is far less—this would still be only 1.6% of the human population. Politicians? The horizon of the average politician seems to be limited by the next election term. Would it be the general public who could advance us the next step of evolution? Polls in the USA—the scientifically and technologically most advanced nation on Earth—disclosed that less than 50% of adults know that the Earth orbits the Sun once a year and only 9% understand what a molecule is. Various surveys reveal that 94% of American adults believe in God, 89% in Heaven, 73% in the Devil and Hell, 36% in ghosts, 37% accept astrology and 23% believe in reincarnation. Only 9% of Americans accept that humans developed over millions of years without divine participation, 40% understand evolution as a process guided by God and 47% are convinced that God created humans within the past 10,000 years (Augustine, 1998; Taylor, 1998; Robinson, 2000). Similar surveys in other countries would probably reveal similar results (Kováč, 2003).

Second, what does it mean to 'choose wisely'? For J. Craig Venter, a 'wise choice' is to engineer a synthetic organism with higher photosynthetic efficiency than extant plants in order to convert sunlight and carbon dioxide into fuel. A 'wise choice' for a bioterrorist would obviously be something quite different. Would it be a 'wise choice' to 'eradicate' schizophrenia by replacing 'the genes for schizophrenia' by their 'sound' alleles, even if we know that 28 of the 76 genes that have been linked to schizophrenia have undergone positive selection during human evolution and are closely linked to cognitive abilities involved in complex thought (Crespi *et al*, 2007)? It is feasible that different 'schizophrenic' alleles or variation in their penetrance determine whether an individual would be mentally ill or a creative artist or scientist. As the concept of genetic networks is replacing the 'one gene, one disease' doctrine of 'genes for...' it becomes clear that making 'wise choices' becomes increasingly difficult.

According to Dyson (2007), Darwinian selection was just an interlude in biological evolution and now, after three billion years, it is over. He claims that we are entering into a period of a true 'intelligent design'; by transferring genes easily from microbes to plants and animals we are moving rapidly into the post-Darwinian era, when species other than our own will no longer exist. In fact, however, it is the essence of any evolution that it is not deterministic; by its very definition, a new evolutionary phenomenon is unforeseeable. With regard to genes and memes, everything that can be done will be done, by humans and, eventually, by robots. Yet, the Darwinian principle of uncorrelated variations, of trials and failures, will continue to hold; it is the only way that evolution can proceed. The only thing that will change is that there will be not enough time for selection—evolution will take a form of paravolution: random drifts and explosions in multivariable space—a process uncontrolled, and uncontrollable.

If evolution, in its present-day form as cultural evolution, is heading towards the singularity, it is, in fact, heading to the mathematical singularity and not only to the technological singularity of superhuman intelligence. It is advancing towards a point in time at which some variables of evolutionary dynamics, including knowledge, will become infinite. Still, what does 'infinite' mean? Edwin T. Jaynes (2003), referring to the nineteenth century mathematician Carl Friedrich Gauss (1777–1855), emphasized that an infinite set cannot be said to have any 'existence' and mathematical properties at all; infinite sets only arise as well-defined and well-behaved limits of finite sets. Infinity is not just an invention of mathematicians, but also a fundamentally misleading and delusional concept of human thought, specifically of Western religion and philosophy with its obvious corollary: immortality. The German philosopher Oswald Spengler (1880–1936) saw the essence of Western culture in the 'Faustian' longing for infinity and boundlessness (Spengler, 1962). This is a universal aspect of human hedonotropy, as aptly noticed by the German philosopher Friedrich Nietzsche (1844–1900): "Woe implores: Go! But all joy wants eternity..." (Nietzsche, 1978).

Time and time again, the meaning of human life, fulfilment and optimism have been inseparably linked with the notion of eternity and immortality throughout the BD era. Without it, life and the universe as a whole would be pointless, meaningless and filled with despair. The British philosopher Bertrand Russell (1872–1970), a sober and atheistic thinker, proclaimed in 1903 that as "all the labors of the ages, all the devotion, all the inspiration, all the noonday brightness of human genius, are destined to extinction in the vast death of the solar system [...] only within the scaffolding of these truths, only on the firm foundation of unyielding despair, can the soul's habitation henceforth be safely built" (Russell, 1976). A recent article by cosmologists, which describes the fate of life in the expanding universe ends by saying: "The picture we have painted here is not optimistic [...] We can take solace from two facts. The constraints we provide here are ultimate constraints on eternal life, which may be of more philosophical than practical interest. The actual time frames of interest, which limit the longevity of civilization on physical grounds, are extremely long, in excess of 10^{50}–10^{100} years" (Krauss & Starkman, 2000).

Consequent Darwinian thinking should take species extinction as a fact of evolution. The traditional faith in eternity, including its secular version of the unrestricted improvement of human things, has been persevering as a gigantic metaphor of the biological imperative of survival. AD evolutionists should point out that the life of an individual, group or species assumes meaning and dignity from its temporariness. By contrast, immortality as the eternal return of all possible delights would be a true inferno. The philosophical and theological eschatology of the pre-Darwinian era was a doctrine of 'last things' or 'end times': death, judgement, heaven and hell. A new, naturalized, Darwinian eschatology could be named 'finitics'.

REFERENCES
Augustine N (1998) What we don't know does hurt us. How scientific illiteracy hobbles society. *Science* **27:** 1640–1641
Blackburn JD (ed) (1991) *Time-Based Competition*. Boston, MA, USA: Irvin
Brickman P, Campbell DT (1971) Hedonic relativism and planning the good society. In *Adaptation-Level Theory*, MH Appley (ed), pp 287–301. New York, NY, USA: Academic

©2008 EUROPEAN MOLECULAR BIOLOGY ORGANIZATION

Chaisson EJ (2001) *Cosmic Evolution: The Rise of Complexity in Nature*. Cambridge, MA, USA: Harvard University Press
Crespi B, Summers K, Dorus S (2007) Adaptive evolution of genes underlying schizophrenia. *Proc R Soc Lond B Biol Sci* **274:** 2801–2810
Davies P (2006) When computers take over. *Nature* **440:** 421–422
Dawkins R (1976) *The Selfish Gene*. Oxford, UK: Oxford University Press
Dyson F (2007) Our biotech future. *New York Rev Books* **54(12)**
Easterlin RA (1995) Will raising the incomes of all increase the happiness of all? *J Econ Behav Org* **27:** 35–47
Haldane JBS (1963) Biological possibilities for the human species in the next ten thousand years. In *Man and His Future*, G Wolstenholme (ed). Boston, MA, USA: Little, Brown & Co
Hughes JJ (2008) Back to the future. *EMBO Rep* **9 (Suppl):** 59–63
Jaynes ET (2003) *Probability Theory: The Logic of Science*. Cambridge, UK: Cambridge University Press
Kacser H, Beeby R (1984) Evolution of catalytic proteins. *J Mol Evol* **20:** 38–51
Kováč L (2003) Science and September 11th: a lesson of relevance. *World Futures* **59:** 319–334
Krauss LM, Starkman GD (2000) Life, the universe, and nothing: life and death in an ever-expanding universe. *Astrophys J* **531:** 22–30
Kremmer M (1993) Population growth and technological change: one million BC to 1990. *Q J Econ* **108:** 681–716
Kurzweil R (2005) *The Singularity is Near: When Humans Transcend Biology*. New York, NY, USA: Viking
May RM (1998) An attempt to link sciences and humanities. *Sci Amer* **278:** 97–98
Nietzsche F (1978) *Thus Spoke Zarathustra*. New York, NY, USA: Penguin
Pearson I (2008) The future of life. *EMBO Rep* **9 (Suppl):** 75–77
Price de Solla DJ (1963) *Little Science, Big Science*. New York, NY, USA: Columbia University Press
Robinson BA (2000) Public beliefs about evolution and creation. http://www.religioustolerance.org/ev_publi.htm
Russell B (1976) A free man's worship. In *The Collected Papers of Bertrand Russell*, vol. 12. London, UK: Routledge
Sartori G (2002) *Pluralismo, Multiculturalismo e Estranei*. Milan, Italy: Rizzoli
Shendure J, Mitra RD, Varma C, Church GM (2004) Advanced sequencing technologies: methods and goals. *Nat Rev Genet* **5:** 335–344
Spengler O (1962) *The Decline of the West*. New York, NY, USA: Alfred A. Knopf
Taylor H (1998) *Large Majority of People Believe They will go to Heaven; Only One in Fifty Thinks They will go to Hell*. Rochester, NY, USA: Harris Interactive. www.harrisinteractive.com/
Venter JC (2007) Changing one species to another. *Edge*. www.edge.org
von Foerster H, Mora P, Amiot L (1960) Doomsday: Friday, 13 November, AD 2026. *Science* **132:** 1291–1295
Wexler BE (2006) *Brain and Culture: Neurobiology, Ideology, and Social Change*. Cambridge, MA, USA: Bradford Books
Wilson EO (1998) *Consilience: The Unity of Knowledge*. New York, NY, USA: Knopf

Ladislav Kováč is Professor of Biochemistry at Comenius University, Bratislava, Slovakia.
E-mail: kovacl@fns.uniba.sk

doi:10.1038/embor.2008.138
Published online 18 July 2008

©2008 EUROPEAN MOLECULAR BIOLOGY ORGANIZATION