Humanity does not steer, but should enjoy the ride

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Can a discussion of whether or how humanity should steer its own future development claim scientific rigour? Clearly not: firstly, the future evolution of a system as complex as human civilisation is unpredictable, and secondly the question introduces the value judgement of what goal one sees humanity as striving towards.

A number of different goals are on offer at present, notably including the reorganisation of society along the lines found in the religious texts of ancient, preindustrial societies, the continued favouring of Enlightenment concepts of growth and progress in technology and the economy, and the overturning of those same concepts in pursuit of a new order of society whose principal characteristic is sustainability at an industrial level but without further growth. Any consideration of the human future must accept that these three broad views of what is most desirable for humanity – return to a preindustrial state, continuation of growth, or halting of growth at close to its present level – will continue to be represented by different groups within society. Civilisation will therefore develop in a direction which represents the balance of power between these three forces. We are looking at an evolving system, not one controlled from any one point according to some master plan.

But having said that, it is still possible to consider how life and civilisation have evolved in the past, and thence project their continuation into the future if the pattern of the past is assumed to be a reliable guide. This will be found to favour the growth and progress model.

First it will be necessary to ask whether progress in a broad sense is in fact meaningful. A simple graphical model based on nested shells is offered in an attempt to reconcile the concept of progress with the scientific demand for rigorous understanding of evolutionary changes. This then sets up the context for our speculations about the future course of the human species, and about what if any steering can be applied to that course.

The Question of Evolutionary Progress

Human civilisation is a direct outgrowth of biological change on Earth over the past several billion years, with humanity one species among an estimated 30 million species alive today. Our present-day society is based on the principles of growth and progress in many different areas – science, technology, the arts, politics, economics, population, geographical spread, personal and collective material wealth – but is complex enough and diverse enough that its development continues to be a form of evolution. In order to decide whether human society can make meaningful progress, therefore, the controversial question of whether the evolution of life in general can or can not be described as progressive must be faced.

Biologist Stephen Jay Gould is well known for arguing that biological progress is not a valid concept. In 1994 he wrote:

> "I [...] wish to argue that our conventional desire to view history as progressive, and to see humans as predictably dominant, has grossly distorted our interpretation of life's pathway by falsely placing in the center of things a relatively minor phenomenon that arises only as a side consequence of a physically constrained starting point." (Stephen Jay Gould, "The Evolution of Life on the Earth", *Scientific American*, special issue "Life in the Universe", October 1994, p.62-69, on p.65.)

The constrained starting point he refers to is that of the necessarily minimal complexity of life at its time of origin. Over the aeons species occasionally populate regions of greater complexity through the random walk of evolutionary change. The extreme of biological complexity on Earth – "if we wish, albeit parochially, to honor neural architecture as a primary criterion" – is currently occupied by *Homo sapiens*, but the most salient and enduring feature of terrestrial life is "the stability of its bacterial mode from the beginning of the fossil record until today and, with little doubt, into all future time so long as the earth endures".

I propose that in his zeal for placing our species in its proper scientific perspective Gould has made three mistakes: he assumes in this article that biological complexity can be represented by a continuous scale, showing it as such in the accompanying diagrams, he limits himself to a purely terrestrial perspective, ignoring the possibilities for life beyond Earth itself, and he misses the significance of neural architecture as an enabler of hitherto impossible types of evolutionary change.

These mistakes are corrected by Richard Dawkins in the final chapter of his popular book *River Out of Eden* (Weidenfeld and Nicolson, 1995). Dawkins describes how stars occasionally explode as supernovas, and then points out that there is another type of explosion that a star can produce: instead of going supernova it can "go information". As the energy from such a star flows through the surface environment of an orbiting planet it can power an "information bomb", in which chemical replicators on that planet undergo exponential growth into a huge variety of complex life forms, whose DNA encodes ever increasing amounts of organised information.

This is, however, not a smooth, continuous process. When a giant star explodes, it does so because its internal state reaches critical levels of pressure and temperature beyond which the star is no longer stable, leading to the runaway redistribution of its contents into nearby space. An information explosion, too, is triggered when critical thresholds are crossed, but here there are multiple bursts, organised in a sequence of increasing complexity.

Dawkins identifies ten separate thresholds, each of which acts as a trigger for a new period of explosive growth. The first threshold is the appearance of replicators: a population of self-copying molecules with the property of heredity but suffering occasional random copying mistakes. The second he calls the phenotype threshold: when replicators begin to propagate from one generation to the next not by virtue of their own interactions with the outside world but via an organism in which they have become embedded, a biological phenotype; and the third, closely related, is the appearance of the biological cell in which replicators work together in groups.

Dawkins ends his list with a radio technology threshold, which makes the planetary information explosion perceptible to outside observers at interstellar distances, and finally a space travel threshold. Because this last has not yet really been crossed in the only example we have so far been able to observe, Dawkins is only able to speculate on what happens next:

> "We do not know how this kind of explosion ends. Presumably it eventually fades away like a supernova, but we do not know how far it typically builds up first. Perhaps to a violent and self-destructive catastrophe. Perhaps to a more gentle and repeated emission of objects, moving, in a guided rather than a simple ballistic trajectory, away from the star into distant reaches of space, where it may infect other star systems with the same tendency to explode." (*River Out of Eden*, p.158.)

The latter scenario suggests that the human heritage could be extremely long-lasting, and might in due course lead to the discovery of new thresholds. Dawkins does not allow these prospects to affect his notoriously mechanistic views on the meaning of life: "The universe we observe has precisely the properties we should expect if there is, at bottom, no design, no purpose, no evil and no good, nothing but blind, pitiless indifference" (*River Out of Eden*, p.155). But it is not necessary to delve into metaphysical speculation as to what exists "at bottom" in order to arrive at the following useful conclusions:

* The evidence of cosmology, astronomy and biology demonstrates that we inhabit a universe whose initial conditions have allowed an initially homogeneous mass of hydrogen and helium to undergo successive stages of elaboration into progressively more complex structures.
* An arrow of progress from structures of type A to others of type B may be defined if instances of type A can exist without type B ever having existed, whereas instances of type B cannot appear except as an elaboration of pre-existing structures of type A (for example, a universe in which bacteria are the only life form is possible, and must be presumed to have existed some billions of years in the past, but a universe containing mammals can only exist if it contained bacteria at an earlier date, and indeed continues to contain them).
* The most evolutionarily advanced phenomenon known to date may be variously identified as the human brain, or as human civilisation (containing such brains), or as

the present-day terrestrial biosphere (containing that civilisation), in all cases necessarily being constructed upon the simpler antecedents found in the fossil record.

* The stelliferous universe is young (13.7 billion years into a lifetime of tens of trillions of years), and the limits of evolutionary growth during its lifetime are unknown.

The Nested Shell Model of Progress

Both Gould and Dawkins in their own ways are concerned to combat the traditional view, derived from pre-modern religious thought, that our human existence is somehow preordained by a benevolent creator god. To Gould, human intelligence is “a relatively minor phenomenon”. To Dawkins, even though intelligence has implications for the spread of the information explosion which escaped Gould, the long-term view is still the same: that we should derive no sense of meaning, purpose or comfort from the sequence of blind cosmic accidents that led to the synthesis of the chemical elements heavier than helium, the consequent formation of planet Earth, the consequent appearance of surface-dwelling, aqueous, carbon-based life, the consequent evolution of the vertebrates, or the consequent development of the human brain and culture.

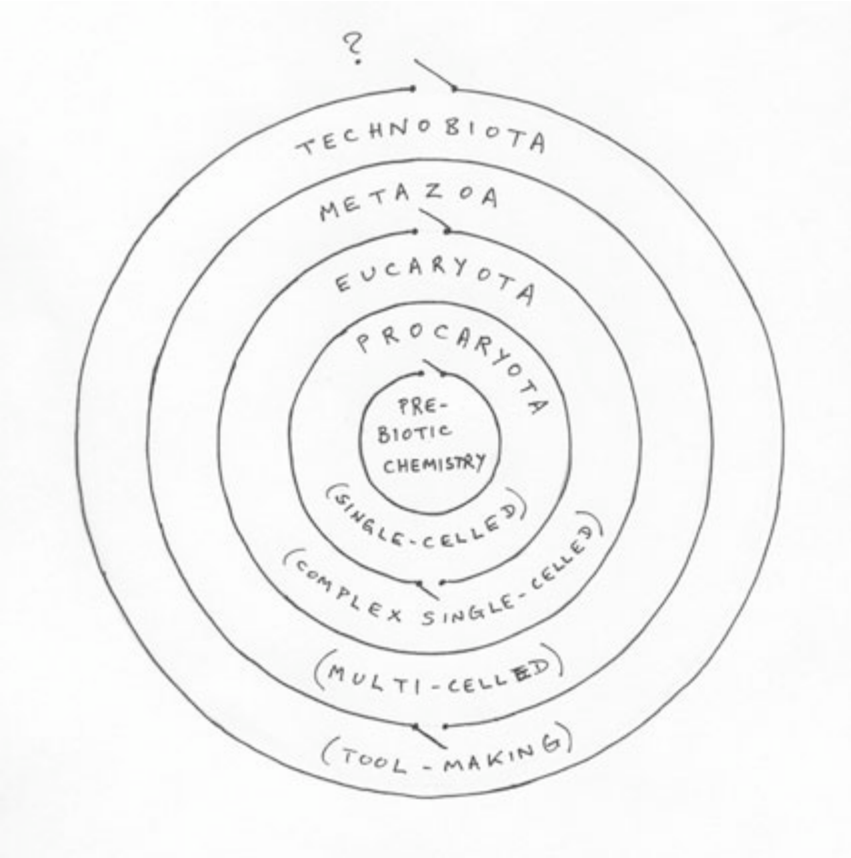
As argued above, an arrow of evolutionary progress may be defined. But if it is real, how can it be reconciled with the scientific view that evolution, in both its cosmological and its biological aspects, is driven only by local events, not by implementation of a master plan conceived by some external guiding intelligence?

Firstly it has to be said that the innate creativity of the universe does present us with a genuine mystery. It would be possible to conceive of an evolutionarily static universe in which no such developments ever take place: following an initial Big Bang, the subsequent history of such a universe might for example consist exclusively of the motions of amorphous clouds of hydrogen and helium under the influence of gravitational and electromagnetic forces, with no coherent structures on either a large scale (galaxies) or a small scale (living cells) ever taking shape. Our universe is not like that: it exhibits a hierarchical accumulation of organised complexity (the galaxies must appear before the living cells do). Why our universe is so creative and not like that imaginary static, non-evolving universe remains a mystery. Of course if our own universe were static then we would not exist to wonder at it, but the fact that we do exist does not explain how it was possible for us to be brought into existence.

But given the fact that our universe is indeed creative, and given a sequence of thresholds for successive levels of self-sustaining creativity along the lines of those described by Dawkins, the picture emerges of an abstract “design space” of possibilities, inherent in the initial conditions of our universe, which may be represented graphically by a set of concentric shells as shown in the diagram on the following page.

This discussion derives from, but is an extension of, the concept of an abstract design space presented by Daniel Dennett in chapters 4 to 6 of his book *Darwin’s Dangerous Idea*

(Allen Lane, The Penguin Press, 1995). Dennett, however, used the concept for the space of all possible permutations of DNA; here it is applied differently.



The innermost space in the diagram represents the pre-biotic organic chemistry from which the procaryota, the simplest bacterial cells, emerge, in the next shell. One may imagine a number of balls bouncing around in each shell, modelling species (chemical, then biological) changing over time. To begin with, only the innermost circle is populated, representing conditions on Earth some 4 billion years ago, but over time a ball occasionally bounces through the first gateway and begins to populate the next shell.

Each ball moves randomly from one point to another, bouncing off the walls, from time to time vanishing (as a species becomes extinct) and from time to time splitting into two (as a species generates multiple successor species). Under clement environmental conditions, more new species will appear than go extinct, until a domain is filled with some maximum population of different species.

The shells are nested for two reasons. As life becomes more complex, so the range of possibilities available to it becomes greater – there is a greater variety of permutations of multicellular life than of single-celled life, so the multicellular domain takes up more space in the diagram. And secondly, a world containing life at one level also contains life at all the earlier levels – in our present-day situation the multicellular life of which we humans are a part coexists with single-celled life, and in fact could not exist without it. Thus the different levels of life are like storeys in a building: one may have a one-storey building, a two-storey or a three-storey building, but however high the topmost floor is, all the lower floors must be in place to support it, and the lower floors must have been built before the higher ones.

The narrow gateways that exist between one domain and the next make the diagram resemble a labyrinth puzzle. As balls (species) bounce around in one domain, a small chance exists that one will randomly find the gateway into the next domain up, and the more balls there are and the longer they have been in existence, the greater the likelihood that one of them will happen to pass through that gateway. Under favourable conditions the first ball that passes into a vacant domain will produce offspring before it goes extinct, eventually fully populating that new domain. Occasional bouncebacks into a lower domain will have no effect on the overall distribution of species.

While all the gateways are shown open, on other planets a particular gateway may be closed. On a world like Europa, for example, whose hypothetical life would be confined to a subsurface ocean, there may be no way for multicellular life to form, given that photosynthesis of oxygen is impossible. On planets which have not yet been explored it may be the case that other domains of life are possible that are not found in terrestrial experience, or there may be found a different geometry of relationships between domains.

Progress within a single domain is only meaningful to the extent that a species wanders closer to an upper gateway. A species grows legs, a later species returns to the sea and loses those legs again (ichthyosaurs, dolphins); a species develops eyes, a descendant species makes a living underground and loses those eyes (the star-nosed mole, the Texas blind salamander). Progress on the nested shell model is generated entirely by the ratchet effect when species cross the threshold from one domain into another, which happens only by chance, not by design or intent. Within any one domain change is subject to local forces alone. Within that shell the Gouldian paradigm is secure: there is change, but no purposive direction towards any long-range goal beyond the immediate survival and procreation of each organism.

But the overall, multi-shell, pre-existing landscape of discrete levels of potential activity, which Gould did not envisage, sets up a meaningful direction of longer-term change, and offers a mechanism through which random movements are converted to long-term progress in the direction of creating higher domains of life. It will not do so on all terrestrial planets, but it will do so on some, while the gateways to higher domains remain open.

The nested shell model thus represents the propositions that life as we know it is arrayed on a hierarchical structure of qualitatively different domains, that once a domain becomes populated it tends to remain so, and that this underlying structure defines a direction of progress. While industrial civilisation – the form I have labelled "technobiota" – occupies the topmost known shell at present, there is no reason to believe that it may not in due course act as a foundation for a further qualitatively different domain of life.

The origin of the particular geometry of possibilities represented by the nested shell diagram remains mysterious, but then so does the origin of the possibility that humans can emerge at all in an initially inanimate, unconscious universe. We are left with the puzzle as to why the universe should support this hierarchy of creative activity, but this is no worse than the puzzle of why it should not have been any other way.

The multi-shell model removes any need for a supposed mystical force or guiding hand towards the evolution of successive levels of more complex forms of life by confining that invisible steering element to the abstract concept of the design space of all possible life-forms. It is the hierarchical structure of this theoretical concept, with narrow gateways from one shell to the next, which makes evolutionary progress meaningful in the real world.

Steering Human Progress

Given, then, the reality of evolutionary progress, the question arises as to what the role of human beings is, and where this natural process may be leading us. The following points need to be taken into account:

* The past history of life on Earth is one of the progressive occupation of all accessible ecological niches through biological evolution.
* Our own and other solar systems contain large quantities of materials and energy, in addition to those available on Earth, which could be employed by living creatures for the further elaboration of life – in Dawkins's terminology, for further episodes of information explosion.
* The evolution of our kind of surface-dwelling, aqueous, carbon-based life has depended upon a particular configuration of sunlight, air, water, rocks and carbon compounds which is relatively rare, existing only on Earth in our own Solar System.
* So far as is known at present, therefore, Earth is the only confirmed location of life in the universe.
* The resources of the other planets and asteroids, and the full power of the Sun and stars, which could be used by life but at present are not, can only be drawn into the information explosion by an advanced industrialised species capable of using technology to both access and digest those resources.
* No fundamental technical barriers to the existence of a technological species have yet been convincingly identified: extraterrestrial resources use the same physics and chemistry as on Earth, they can in principle be accessed through space technology, and could therefore be utilised for the support of living organisms.
* If a technological species were to evolve, it would have to go through an intermediate semi-technological phase closely resembling present-day human society.
* The logical conclusion is therefore that *Homo sapiens* represents an intermediate stage between a terrestrial and an astronomical order of life.

This evolutionary process is analogous to the emergence of our vertebrate ancestors onto the land during the late Devonian period. We today are amphibians in the sense that the solutions we are finding to immediate problems of life on Earth are fortuitously at the same time equipping us for occupation of new ecological niches away from Earth.

Examples of these solutions include industrialised agriculture, the trend towards self-contained, fully air-conditioned buildings, and manufacturing by 3-d printing. Several lines of technological progress, particularly nanotechnology, information technology, robotics, genetics and medicine, are together converging on a new definition of what it is to be human, or perhaps on a range of new definitions, and this increased flexibility will be valuable as humans adapt to living in novel engineered environments away from the planet on which they originally evolved. The large-scale colonisation of space is therefore a potential outcome of the present-day rapid growth of human society, providing that the technical and economic problems of adapting to space can be overcome.

Being an evolutionary process, it is not controlled by any goal-oriented entity such as a government, a committee of scientists, a deity or a mystical force, and therefore its success cannot be guaranteed in advance. When evolution encounters new opportunities for growth it is capable of producing radical innovation without needing to be steered by a conscious intelligence. But at the same time an evolving system may happen not to take advantage of an opportunity for growth, just as earlier human species (such as *H. erectus*) did not develop a technological culture, despite there having been time for them to have done so had evolutionary pressures moved them in that direction, or just as social, bipedal dinosaur species did not develop intelligence. In our present case a number of specific dangers could abort the continued material progress of civilisation and by extension prevent any leap into space, notably including nuclear war, climate change, exhaustion of local resources, asteroid impact, and supervolcano eruption.

Yet the extension of life into astronomical space represents a logical continuation of its past history, one with much greater opportunities for growth than before. The evolution of the first technological species can be seen in the same light as the evolution of the first eucaryotic cell: a natural departure from an existing situation caused by local forces, yet which happens to have immense implications for future diversification.

These theoretical considerations are now of practical interest, since the growth of modern industrial civilisation is beginning to run up against ecological limits imposed by Earth's biosphere. The question as to where growth is leading us is one of the most critical social, economic and political issues of the current century. Exponential growth is hardwired into the system, and it is therefore crucial for the continued health and long-term survival of our civilisation that the focus of material growth should now begin to move out into space.

The ongoing technological revolution has its greatest leverage on the human future through its applications to spaceflight, because space opens up new material and power resources on a much greater scale than heretofore, because it opens up the chance of the widest possible diversification among humanity's successor species through their dispersal on a galactic scale, and because for the same reason it guarantees the long-term security of the human heritage through those successor species.

Critics of this view have asserted that extraterrestrial resources are too widely diffused over too large a volume of space for economic retrieval. Some hold that the difficulties of sustaining an affluent civilisation on Earth itself are too great, and that retreat, with major declines in power consumption, material wealth and population sizes, is inevitable. If they are correct, ultimate extinction of the human heritage will be the result.

But engineering is not an armchair pursuit, and the reality of vast untapped extraterrestrial resources cannot be rationally denied. So long as engineers and entrepreneurs continue to make progress towards lowering the costs of spaceflight and improving its reliability, humanity preserves the chance of an open-ended future of continued growth and diversification.

The development of civilisation on the verge of a space revolution is the first major biological innovation in which conscious reasoning has played a major part, but it is still mainly driven by the large-scale unconscious forces of politics and the economy. Innovations such as the personal computer and now space tourism (an essential component of an affordable space economy) emerge in an unplanned way from the creative chaos of a liberal economy.

Humanity is, therefore, not in a position to literally steer its own future, and were it to appoint an autocratic elite to attempt to do so the results would not be impressive, judging from historic attempts at a planned economy, and from the near-stagnation in the capabilities commanded by government space agencies worldwide. But there does exist an opportunity for the enlightened discussion of past and future scenarios to contribute towards public acceptance of a creative future which transcends Earth alone. The resulting view of the place of our species in the cosmos should engender confidence that the dangers which face the continuation of our civilisation can and should be overcome, and that our core values of democracy, science and humanity can be preserved and developed further over the long term.

As shown here, that discussion demonstrates a meaningful role for the human species in the evolution of the universe. While continuing to acknowledge the scientific insights that evolutionary change is driven by haphazard local circumstances, that our species is of recent origin and of a form which was not predestined to appear in advance, we may also assert that human progress, including rational humanitarian values, the growth of technological capabilities and their extension from the infinitesimal speck of matter we call Earth out into the broader galactic environment, is a meaningful part of broader evolutionary trends.

This is how humanity should "steer the future": through spreading enlightened understanding of our place in the universe and our potential for future growth using the material and energy resources of our own and other solar systems, using that long-range perspective to cut present-day problems down to a manageable size, and allowing a free, diverse, creative economy to do its work inspired by that understanding.