EMBO reports

viewpoint

Science, an essential part of culture

Ignoring the fact that science is an integral part of human culture is a serious error if we want to overcome humanity's problems

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When peace was restored after the end of the Second World War, 44 countries convened in London to debate how to reconstruct educational systems and to enable countries to work together. Spurred on by France and Britain, the delegates decided to create an organization that would embody a culture of peace with the ultimate aim of preventing another world war. This was originally intended to be an educational and cultural organization, but two British biologists, Julian Huxley and Joseph Needham, proposed adding science to its agenda. The United Nations Educational, Scientific and Cultural Organization (UNESCO; Paris, France) was thus established by 37 countries in 1945, with Huxley acting as its first Director-General from 1946.

Huxley was convinced that knowledge is the key to mutual understanding and peace, and envisaged UNESCO as the future 'brain' of the UN. In his view, UNESCO should be an assembly of independent personalities from countries all over the world who would design and draft proposals to be implemented by the UN and its member states. The mission of the organization, founded on the idea of 'evolutionary humanism', would be to overcome prejudices and superstition and to enrich all cultures with scientific knowledge. In this way, the accumulation of scientific knowledge and its distribution—helped by UNESCO—would gradually shape a common, universal culture for humankind (Huxley, 1947). French Nobel laureate Jacques Monod (1971) later reinstated Huxley's vision when he wrote about the "duty which more forcibly than ever thrusts itself upon scientists to apprehend their discipline within the larger framework of modern culture, with a view to enriching the latter not only with technically important findings, but also with what they may feel to be humanly significant ideas arising from their area of special concern."

Huxley did not succeed in his vision. The Cold War began and UNESCO became one of its battlegrounds. The political elite of the newly independent countries in Africa, Asia and South America strived to obtain legitimacy by popular support; the ideology of preserving the ethnic and cultural identity of their people and 'protecting' them against 'cultural imperialism' served their purpose. Huxley's ideal of universalism was replaced with a romantic conception of ethnicity—in the spirit of the German philosopher Johann Gottfried Herder—in which ethnic groups are seen as immutable ontological entities. Science, hardly a suitable tool for political manoeuvring, was pushed to the margins.

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Even after the Cold War, UNESCO did not return to Huxley's ideals but firmly held on to a definition of culture, originally set out in the 1982 Mexico Declaration on Cultural Policies: "…in its widest sense, culture may now be said to be the whole complex of distinctive spiritual, material, intellectual and emotional features that characterize a society or social group. It includes not only the arts and letters, but also modes of life, the fundamental rights of the human being, value systems, traditions and beliefs" (UNESCO, 2001). In this context, 'culture' becomes a metonym for 'social' or 'ethnic group'. Naturally, hundreds of other definitions of culture exist alongside UNESCO's. Culture is not a physical object, but a concept that constantly develops and morphs. It is, in essence, an expedient human construction.

The problem with UNESCO's and many other definitions of culture is that it completely ignores science and instead bases its recommendations and its actions on an axiomatic and narrow definition of culture (see sidebar). That definition has further implications, as UNESCO's conceptions

UNESCO´S CONCEPT OF CULTURE

UNESCO's concept of culture could be interpreted as a closed axiomatic system:

(i) Equal dignity should be attributed to all cultures and all religions without distinction.
(ii) The principle of cultural diversity should be promoted and firmly supported.
(iii) Cultural diversity is as necessary for humankind as biodiversity is for nature. Biological diversity and cultural diversity are mutually reinforcing and profoundly interdependent.
(iv) While each culture draws from its own roots, it will probably fail to blossom without contact with other cultures.

Altogether, this is a consistent set of Platonic statements, which largely lack empirical evidence, or downright contradict experience.

UNESCO (2001) *UNESCO Universal Declaration on Cultural Diversity*. Paris, France: UNESCO

and definitions are directly used by the UN as instructions to implement their policies. But to disregard science as an essential component of human culture, as UNESCO has done for so long, is a grave error; science and culture are connected and mutually influence each other in manifold ways. It is obvious that neither the idea of diverse cultures living in peaceful harmony, nor scientific progress, has succeeded in creating a more peaceful world. The icon that marks the beginning of the twenty-first century is not the completion of the Human Genome Project but the collapsing towers of the World Trade Center, a result of fundamentalism, intolerance and hatred. Only by appreciating the essential role of science in culture may we be able to find solutions for many problems that still plague humanity today.

A basic definition of culture could come from a coarse cognitive screen of the universe as known to humankind. Through this, we can distinguish two basic entities: those that came into existence without human involvement, and those created by humans. All products of human action—as opposed to all naturally occurring entities—therefore count as products of human culture. But this would be too broad a notion, with too little discrimination. For example, human life can be attributed both to biological and cultural evolution. Similarly, such a definition of culture would not reveal its double character, which has escaped many theorists who have not observed that human culture is shaped both by human action and human biology.

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This definition of culture would also not take into account the role of evolution. Through its tested mechanisms of mutation and selection, humans have become social—or even hypersocial—animals. We are undoubtedly herd animals: the survival of the individual has always been dependent on belonging to a particular group of humans, distinct from other social groups. According to the social brain hypothesis, our large neocortex evolved to deal with the complexities of living together in social groups and of having to manage an increasing number of interindividual relationships (Humphrey, 1976; Byrne & Whiten, 1988).

Our capacity for self-awareness, which may have emerged with this increase in brain size, created new needs: the need for better orientation in a physical and social environment, the need to make sense of cognitive chaos and, probably most important, the need to explain the manifestations of the physical world and our social environment. Humans did this by first using myths—spirits and gods that populate the universe and control the world—and later using knowledge based on rational enquiries. If we call this exclusively human desire for an all-encompassing explanation of the universe a myth, it again reflects our typical human demand for myths. It may be no less pervasive than the need for food, sex and social affiliation, and it makes humans a unique kind of animal: mythophils. Throughout history, humans have devised a plethora of myths to explain the universe and their place in it. Conversely, myths or beliefs that are specific to a certain social group determine the behaviour of that group. Owing to these idiosyncrasies, human groups may differ almost as much as biological species; Konrad Lorenz (1966) called this phenomenon "human pseudo-speciation".

Similar to any other animal, humans perceive their environment by use of receptor molecules and sensory organs. Because these provide only raw data—smells, noise, or patterns of light—it is up to the brain to make sense of these inputs, attribute significance and record them for potential future use. This process of signification, which is inseparable from our recording of the environment, is a result of our evolution—our brain decides and memorizes what seems to be relevant to survival. The additional need for explanations, as pointed out above, has enormously increased the amount of information that today's humans now consider relevant, as compared with other animals or our ancestors. Consequently, the number and design of our receptor molecules to provide the raw data is no longer sufficient for survival in today's highly complex environment. It is culture that provides additional information and helps our brains to make sense of the environment. But even this process is determined and constrained by human biology: predetermined gene interactions form specific configurations of the central nervous system, which are filled by experiences from our environment, our education and our culture. Such configurations might be conceived as 'receptors of the higher order', or, as Sperber (1996) has called them, "cognitive modules". In an analogy to gene loci, these modules may be dubbed 'cultural loci'; just as a gene may have several alleles, of which only one is active at a given time, a cultural locus can be occupied by one of several alternative 'cultural alleles'. The term 'meme'—a matter of unceasing debate (Richerson & Boyd, 2005)—would therefore describe such a cultural allele (Fig 1).

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The number of cultural loci is limited to perhaps fewer than the number of genes in the human genome. But the number of cultural alleles is many orders of magnitude greater than the number of gene alleles. For instance, a cultural locus for 'transcendental order' can be occupied with a meme of scientific causality, of transcendental meditation, or of the belief in a personal deity, such as Jehovah, Christ, or Allah, depending on the existing meme pool. A cultural locus for 'aggression' might carry a meme of militancy, of political violence, of scientific obstinacy, of religious fanaticism, of artistic creativity or of a passion for sport. It also follows that memes change over time in response to the evolution of human culture: Jehovah, Christ and Allah have largely replaced older memes such as Baal, Odin and Zeus.

Another standard explanation for human brain evolution links it with the evolution of the hand. Continual refinement of the hand, along with that of the central nervous system, enabled artefaction: the construction of tools, which, over time, have become instruments and machines. Therefore, the beginning of artefaction marks the beginning of cultural evolution. This also explains why cultural evolution is a cumulative process: new artefacts are either improvements of existing tools, or more complex innovations that rely on existing tools and instruments. It also means that regression—a de-evolution

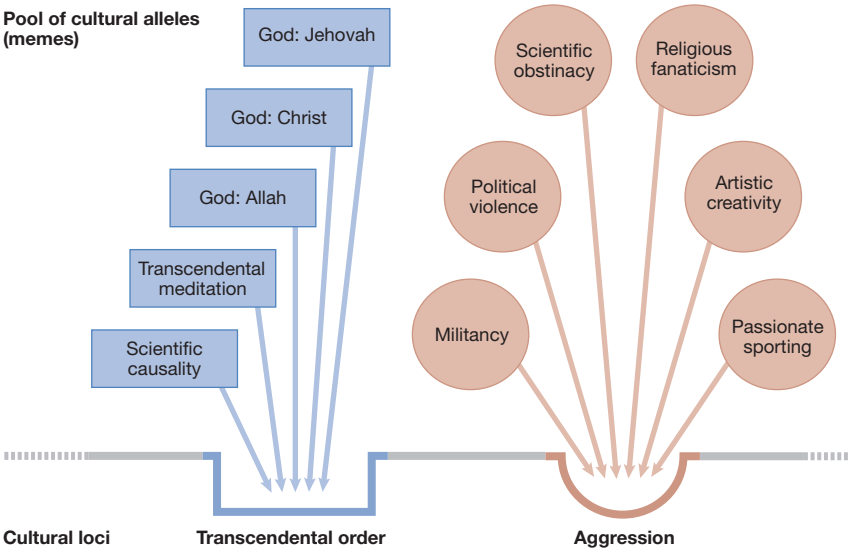

Fig 1 | Cultural loci and alternative memes that could occupy them. A cultural locus may be visualized as a predetermined potential mental state, an 'empty slot', which becomes concrete by being filled in with a fitting allele from a given meme pool.

of material artefacts—is virtually impossible. Cultural evolution therefore works like a ratchet (Tomasello, 1999): new and improved artefacts gradually replace existing ones. For example, the computer and the word processor have largely replaced the typewriter and the writing pen. A similar ratchet effect applies to social institutions: occasional regressions to more primitive levels may take place, but they seem to be temporary.

Cultural significances—human convictions about the world—are another kind of artefact: symbolic artefacts. Here, the ratchet effect is hardly discernible because the set of genes and cultural loci that define a human being has not changed appreciably during the brief period of cultural evolution. Humans are still hypersocial animals and mythophils. The combination of these two constants is the cause of an almost insurmountable human penchant for animism: the explanation of the world in terms of purpose and intention (Monod, 1971). There is no substantial difference between the earliest interpretations of the world—full of spectres, gods and ghosts—and today's monotheistic religions.

It is this difference between signifaction and artefaction that gives culture its dual character. On the one hand, culture is a consistent and exhaustive set of specific significances that a human group attaches to the items of the world in addition to the significances that are common to all humans and imposed on them by their biology. Specific significances determine the behaviour of the individual and of the whole group; they function as a glue to tie individuals together and as a badge to signal membership. Such group-specific cultural significances can be symbolic artefacts—for example, works of art, products of the entertainment industry or particular religious beliefs.

On the other hand, culture is a process of constant evolution of material artefacts, which was one of the determinants of the rise of modern science. New and sophisticated measurement instruments provided new data that forced society to abandon long-held convictions. The telescope allowed better measurements of planetary orbits, which eventually removed the heliocentric view of the solar system. The particle accelerator has helped to discover new elementary particles beyond the level of nuclei and electrons, which constantly change our view of the physical world. Imaging technologies in neurobiology are challenging long-held ideas about human consciousness and free will. From Galileo's inclined plane to computers, particle colliders and DNA microchips, scientific instruments have defined the horizon of scientific inquiry. In this way, the evolution of artefacts has helped to replace vague and deceptive beliefs with justified convictions, which we commonly designate to be pieces of knowledge. The ratio between these justified convictions and other beliefs is the epistemic quotient of culture. Cultures differ in their epistemic quotients, but the higher the quotient, the greater the evolutionary advancement of the culture. The highest epistemic quotient attained at a particular stage of human history is the measure of the human civilization of that era. The achievements of technology aside, our knowledge of the universe is still meagre. Therefore, the epistemic quotient of all cultures, including those that cherish science, is rather low.

From this point of view, cultures cannot be considered to be equivalent. Differences between cultures in which diseases are cured by exorcizing malicious spirits, little girls are mutilated by circumcision, or members of foreign groups are treated as if they are not human, and cultures in which daily lessons of science shake the certitude of one's exclusive truth and induce tolerance, cannot be dismissed as irrelevant.

However, through an increase in their epistemic quotients, cultures are becoming more similar to each other. At the same time, the size of social groups increases—after tribal groups and nation states, we now see the rise of globalized movements—and the boundaries between groups cease to be distinct and insurmountable. From this, we can see a trend towards a single universal culture. This universal culture would not be uniform: science progresses thanks to a diversity of hypotheses, views and interpretations, and artists crave for distinctiveness and originality. However, the diversity of the universal culture would not be a diversity of unjustified beliefs and prejudices; the preservation and promotion of which continues be a major concern of UNESCO.

Within this concept of the epistemic quotient, contemporary biology might seem to be in line with the ambitions of the Enlightenment of the eighteenth century. Its protagonists believed in the unlimited potential and capacity of human reason. According to them, once humankind had

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eliminated superstition by scientific progress and the spread of knowledge, all human beings would finally see things as they truly are, which would open the way to human perfectibility. Some contemporary biologists, such as Richard Dawkins (1998), Edward O. Wilson (1998) and Jean-Pierre Changeux (2002), therefore see a need to return to the ideals of the Enlightenment—according to Dawkins' famous dictum, we humans, "alone on earth, can rebel against the tyranny of the selfish replicators" (Dawkins, 1976). Many other prominent scientists continue to proclaim that an appropriate education will eventually enable all humans to share a scientific view of the world and the moral of tolerance and mutual respect, and will, in this way, eradicate fanaticism, religious fundamentalism and all other prejudices.

> …groups of mythophilic animals no longer battle with bows and axes but with the terrible weaponry provided by modern technology

This straightforward optimism of the neo-enlighteners has a fatal flaw: it does not take into account the fact that an attempt to accomplish the ideals of the Enlightenment ended in disaster. In the twentieth century, communism subjected humanity to an unintended and gigantic experiment to put these ideas into practice. Inspired by the Enlightenment vision, Karl Marx presented his ideas for a society of total equality. Instead of a rational, scientifically managed society, political and social systems with unprecedented irrationality were established and the experiment of universal equality and well-being extolled a price of tens of millions of human deaths. Communism may have suppressed or even removed religious 'prejudices', however the empty slots were not filled by a 'scientific world view', but by new myths, epitomized by opportunism and cynicism.

The crash of the communist utopia should be the most important lesson for humankind if we want to draw realistic implications from the dual character of culture (Fig 2). The growth in the number and complexity of artefacts roughly corresponds to the growth of science, which has been exponential for the last two centuries at least. This growth is becoming even faster and is now hyperexponential. Eigen & Winkler (1975) analysed the consequences of such hyperbolic growth: If a variable is growing hyperexponentially, it will reach infinity in a finite time. In mathematics, this point is called a 'singularity'. During exponential growth, different variants can coexist and compete with each other, but when growth becomes hyperbolic, only one single variant thrives and displaces all the others. Any new variant, however strong its selective advantage may be, has no chance of survival.

Notwithstanding a handful of specialists engaged in the analysis of consequences of hyperexponential growth, it is amazing how scientists and the rest of humanity continue to ignore this phenomenon. The twenty-first century will see almost a thousand times more technological change than its predecessor (Kurzweil, 2001). Extrapolations of recent hyperexponential growth indicate that humanity should reach the technological singularity somewhere within the next 50 years. The conclusion is inexorable: Even though the actual infinity may not be reached, a fundamental transition must take place in this century. This was prophecized, probably for the first time, in the 1950s by John von Neumann and Stanislav Ulam. "One conversation centered on the ever accelerating progress of technology and changes in the mode of human life, which gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue." (Ulam, 1958).

As shown in Fig 2, the explosive growth of artefaction, by which the unaware human creators transcend our own biology, contrasts with the unchanged human nature, as reflected in the constant number of cultural loci. The twenty-first century is not only a time of scientific and technological progress, but also a century of serious cultural conflicts caused by the same unfortunate reasons we have known for millennia: intolerance, greed and hatred. However, groups of mythophilic animals no longer battle with bows and axes but with the terrible weaponry provided by modern technology. The imminence of the technological—and possibly also scientific and economic—singularity on the one hand, and the daunting political, social and cultural problems that still divide humankind on the other hand, are two manifestations of the same phenomenon: the discrepancy between how much we can do and how little we understand about who we are and what we are doing.

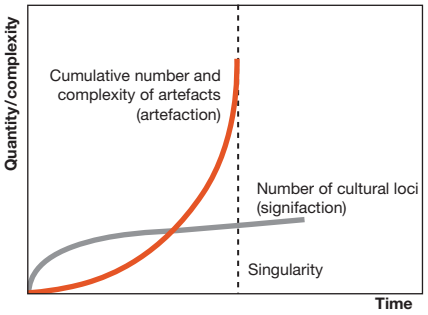

Fig 2 | Dual character and disparate dynamics of culture. In the course of cultural evolution, the cumulative number and complexity of material artefacts have been expanding, seemingly without limits, whereas the modalities of signifaction are kept virtually constant by the biologically restricted number of cultural loci.

This discrepancy is the main challenge for science today. Science is part and product of human artefaction; it happened and it cannot be 'disinvented' because it is the essential component of the evolutionary ratchet. It is not a panacea as the Enlightenment thinkers have professed. Yet of all the constituents of culture, science is the one most competent to apprehend the present state of humankind and to analyse it in depth. We have to bear in mind that the Enlightenment misjudged the easy accessibility of the universal truth, and thus the feasibility of a universal culture. But we must also admit that the gospel of diversity of cultures, presumably capable of mutually beneficial dialogues, may also have failed. Today, the best brains are busy tinkering with genes and contriving sophisticated nanotechnological devices. What if the same number of brilliant thinkers invested their ingenuity into the analysis of the precarious stage of the human species? Nobel laureate Rita Levi Montalcini expressed a principle which could become, along with

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the appeal from Monod, a second motto for science's role in the twenty-first century: "At the dawn of the third millennium, scientists claim their right to intervene in a field, which was once considered to be under the exclusive competence and jurisdiction of philosophers and churchmen: the field of values."

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