Research Paper Social sciences

The Mechanisms of Cumulative Social Evolution

Halvor Naess | Department of Neurology, Haukeland University Hospital, Jonas Liesgt 65 5021 Bergen, Norway

ABSTRACT

Because Lamarckian evolution is incompatible with the Second law of thermodynamics it will be argued that cumulative social evolution is based on discrete units undergoing selection by Darwinian mechanisms. The only known units representing meaningful social knowledge capable of accurate copying are strings of words. Cumulative social evolution based on Darwinian mechanisms was inevitable once knowledge was stored by discrete units on cheap, durable, external media such as paper and easy to copy accurately. Thus cumulative social evolution accelerated after the advent of the phonetic alphabet and especially after the invention of the printing press.

KEYWORDS social evolution, Darwinian mechanisms, strings of words, printing press

Introduction

The general principles of biological evolution (natural selection) were delineated by Darwin. However, it was not until the 1950's that the genetic mechanisms underlying biological evolution were disclosed. Social evolution (cultural and economic evolution) of human beings has a short history compared to biological evolution, and the principal mechanisms are different from genetic evolution. In this paper, firstly, it will be argued that the general principles of social evolution are similar to the general principles of biological evolution. Secondly, the concrete mechanisms of cumulative social evolution will be discussed. Cumulative social evolution takes place when modifications based on discrete units are built up over successive generations.

Evolution is based on discrete units

Natural selection is based on three conditions. Firstly, there has to be variations. The individuals of a species are not identical. Secondly, the differences influence on both survival and reproduction. Thirdly, offspring have to be similar to the parents (inheritance) (Ridley, 2000). The mechanisms constitute genes that are copied to offspring with high fidelity (reproduction). Variations of genes produce different phenotypic effects and result in differential reproduction. Sometimes errors occur during reproduction. Infrequently, an error represents an improved phenotype which evolution feeds on, but most errors lead to decay. An important condition is that if the error rate exceeds the rate at which it is removed by selection, then evolution is impossible (Ridley, 2000). This entails that evolution is based on extremely exact copying procedures. It also strongly suggests that genes must be discrete. Otherwise, the copying procedures would not be exact, and decay would inevitably set in.

The problem of blending has been much discussed in biological inheritance. If the traits of the parents blended, then the traits of the offspring would lie between and not outside that of the parents. Variation, on which biological evolution feeds, would then diminish from generation to generation and completely halt evolution. The mixing of ink and water represents a blending model. The mixing of ink and water may produce an infinite one-dimensional variation between pure ink and pure water, but no novel characteristics outside this dimension. However, in biology favorable variations are not lost, as was first shown by Mendel. The solution of the problem of blending lies in inheritance based on discrete units (genes) (Fisher, 1999).

William Abler recognized that other natural systems also produce hierarchical structures based on discrete mechanisms (Abler, 1989). These systems constitute discrete units (particles) that can combine, yielding larger units at a higher organizational level with novel properties that may be very different from those of the constituent particles. In turn, this higher organizational level may constitute particles that can combine and produce yet more novel qualities and so on. Structures at higher organizational levels have an entirely different range of qualities (functions) compared with those below. Abler argued that all systems that produce properties beyond those of their constituents are based on particles, and he called these systems self-diversifying systems. Chemical elements represent self-diversifying systems with underlying particulate units (atoms) that may combine and produce a new organizational level (molecules) with novel qualities. For example, the combination of hydrogen and oxygen atoms produces water (a higher organizational level), which displays novel qualities outside the qualities of the constituting atoms. Thus, both the need for exact copying and the problem of blending show that Darwinian evolution depends on discrete units.

Cumulative social evolution has to be Darwinian

Before Darwin the most important theory of biological evolution was Lamarckism. Lamarckian evolution comprises two steps. Firstly, the environment induces a novel adaptive trait in an organism, and secondly, this trait is inherited by offspring (inheritance of acquired traits). Lamarckian mechanisms are no longer accepted in biology, but until recently, most theories on social evolution have been Lamarckian. Individual human beings are only the formless material directly transformed by culture according to the so-called standard social science model (Tooby & Cosmides, 1992). Knowledge thus acquired is then transmitted to offspring and other people.

Human beings are able to imitate the behaviours of others. It is possible that social learning (copying others) was the first strategy that lead to the development of culture (Pagel, 2012). Mathematical models have been designed to demonstrate the spread of culture by imitation (copying) (Mesoudi, 2011). Computer models have shown that copying strategies are more efficient than innovation strategies (Rendell et al., 2010). However, little has been done to work out a specific theory disclosing Lamarckian mechanisms in social evolution and it will be argued that the most interesting part of culture, cumulative social evolution based on innovations, depends on non-Lamarckian mechanisms by physical necessity.

Modern physics shows that Lamarckian evolution is highly unlikely in any domain. Information is an important concept both regarding biological and social evolution. All information is inevitably tied to physical representations (Landauer, 1987). There is no such thing as disembodied information. This means that all information (including knowledge and noise) is

subject to physical laws. Among physical laws the Second law of thermodynamics holds a supreme position. "It is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts," according Albert Einstein. The Second law has applicability outside classical thermodynamics. The involvement of energy and temperature in the classical formulations of the Second law is a historical accident (Ben-Naim, 2008). The Second law states that novel order (such as knowledge) requires the production of even more disorder elsewhere. Darwinian evolution is compatible with the Second law because large numbers of erroneous variations are discarded for every selected variation (Ridley, 2000). On the other hand, it has been shown that Lamarckian evolution is incompatible with the Second law (Elitzur, 1994; Naess, 2003). If this is right, then cumulative, social evolution is very likely based on Darwinian mechanisms.

In biology, phenotypic traits and characteristics of organisms are sometimes referred to as interactors in contrast to genes which are referred to as replicators. An interactor is defined as "an entity that directly interacts as a cohesive whole with its environment in such a way that this interaction causes replication to be differential" (Hull, 1999). For every interactor there is a corresponding replicator or set of replicators. Interaction with the environment causes selection of interactors and selection for replicators (Hodgson & Knudsen, 2010).

The Second law shows that only Darwinian principles remain to explain social evolution. Recently, an increasing number of social scientists agree that social evolution (both cultural and economic evolution) is Darwinian. However, there have been few advances as to the discovery of the underlying physical Darwinian mechanisms of cumulative, social evolution, because it is believed by many that social evolution also includes Lamarckian elements. Thus, it is argued that social evolution is based on non-random variations or guided variations (Mesoudi, 2011). However, as argued above cumulative, social evolution must include random variations due to the Second law. Social evolution (change) based on copying (imitation) of analogue (non-discrete, continuous) units (often interactors) most often leads to decay and has very little potential of cumulative, social evolution. Figure 1a shows that even rare favorable copies come to dominate when evolution is based on discrete units. In contrast, Figure 1b shows that evolution based on continuous (analogue) units rapidly deteriorates because most copies are unfavorable and rare favorable copies are unable to compensate for this decay. Only if analogue copying is associated with high probability of favorable copies may limited, trivial social evolution take place.

Schroedinger famously introduced the idea of aperiodic crystals that contained genetic information in its configuration (Schrödinger, 1967). This idea led to the discovery of the genetic role of DNA. As argued above the Second law of thermodynamics seems to restrict complex evolution in any domain to Darwinian mechanisms based on the copying of discrete units or aperiodic crystals in Schroedinger's jargon. The question then arises: what are the discrete units underlying cumulative social evolution? This is an important question which is rarely addressed in literature dealing with social evolution. However, there are a few theories suggesting mechanisms of social evolution based on so-called memes.

One popular theory is Dawkins' theory of memetic evolution. According to Dawkins, a meme is a unit of information residing in the brain (Dawkins, 1982). Dawkins' meme is a concrete physical structure that may represent phenotypic effects such as opinions, knowledge, music, skills and habits. The phenotypic effect may be perceived (imitated) by other people and represented by a copy of the original meme in the perceiving brain. Dawkins asserts that this copy does not need to be identical to the original meme. However, Dawkins' description of memes raises serious problems. If copies of memes are not identical to the original meme most of the time, how can culture be preserved in the long term? How imitation can give rise to cumulative evolution of culture is even more puzzling? Examples from biological evolution and children's play may help to elucidate the importance of these questions. As argued above exact copying requires that the replicating units are discrete. Otherwise the number of errors exceeds the number that selection removes and adaptations are lost (mutational meltdown). This is paralleled in the children's play Chinese whispers (also called broken telephone), in which each individual repeats the message to the next receiver. This inevitably results in corruption of the message. However, culture may remain stable over extended periods of time, and considering cultural change over the last 50,000 years, cumulative cultural evolution seems indisputable. Dawkins' theory sheds little light on the physical nature of the memes underlying social evolution. Memetics usually does not differentiate between levels corresponding to genotype and phenotype, and there is little discussion of the particulate principle.

There is another version of memetics which is more realistic. According to neuromemetics a meme is a neuronal network that is able to induce replication of its state in the brain (Aunger, 2002). William Calvin proposed a concrete model of replicating networks in the brain ("Darwin machines") (Calvin, 1996), but to my knowledge this model has not been verified by experimental research. According to neuromemetics novel cultural ideas are the result of Darwinian evolution of memes in individual brains. The novel idea is then transmitted to other people. Understanding of the idea results from competing conjectures (different memes) undergoing Darwinian evolution in the receiving individual brain until a meme that more or less successfully represent the novel idea, come to dominate (Naess, 2005). There are several problems with this theory. Firstly, nobody knows the physical nature of these memes. Secondly, only human beings experience cumulative social evolution and only for the last few tens of thousands of years. If neuromemetics were right, then the propensity for Darwinian evolution of replicating neuronal networks seems to have arisen long after our forefathers achieved brains as big as ours. This is highly unlikely.

However, cumulative social evolution based on Darwinian mechanisms including discrete units does not need Darwinian machines in individual brains as will be discussed in the next section.

The mechanisms underlying cumulative social evolution

The discrete units underlying social evolution are strings of words (parts of sentences, sentences, several sentences or paragraphs). Strings of words constitute the replicators underlying social evolution. Like genes strings of words are physical, discrete units based on discrete subunits (bases in genes and letters in strings of words). If the copying of strings of words is exact or nearly exact, then Darwinian mechanisms may unleash complex evolution of culture. Syntax probably provides a self-correcting mechanism in copying by restricting variations and therefore facilitates exact replication. In nature there are only two known physical, discrete units representing meaningful information. Those are genes and strings of words.

Language is a self-diversifying system. The particulate units of language are meaningless morphemes and phonemes. The meaning (corresponding to phenotype) of sentences (a higher organizational level) cannot be deduced from the underlying words (corresponding to genotype). If sentences were composed of blending words, then the communicative potential of speech would be exhausted rapidly (Studdert-Kennedy, 2000). In contrast, the particulate (discrete) nature of language provides infinite possible meanings based on finite morphemes and phonemes, or "infinite use of finite means", as von Humboldt argued in 1836 (Humboldt, 1999). Thus, speech is digital.

Novelty is based on combinations of pre-existing strings of words into new syntheses. Combinations are guided by syntax and context, but must also include random elements due to

the Second law as discussed above. Most new combinations are either trivial or meaningless, but sometimes a combination represents new knowledge that may last for some time. Preservation of novel ideas (interactors) depends on the reaction of receivers. Is the idea interesting, useful, worth remembering and spreading to others? To compare, evolution of life is also based on novel combinations of genes. Sharing of genes is common among bacteria and probably represented a precursor for sexual reproduction. It has been shown that technological evolution is based on combinations of prior technologies (Arthur, 2011). It is impossible in advance to know which novel combinations will be selected. The Darwinian process of copying and selection will decide the outcome.

In prehistory, the only storage space of strings of words was in individual brains as memory. Because memory is unstable, copying errors of strings of words are frequent. This applies especially to complex knowledge. Thus there is an upper limit as to the complexity of culture based on memory. This limit is reached when copying error exceeds the number of errors that social selection removes (Naess, 2005). Memory techniques and the number of interacting individuals may elevate this limit to some extent.

In accordance with this theory, history and anthropology show that all oral cultures are relatively simple. In addition, oral cultures that undergo a decline in the number of interacting individuals have been shown to experience cultural degradation. Due to rising sea levels Tasmania was isolated from Australia 10,000 years ago. Archaeologists have documented the disappearance of technologies such as needles, bone tools and even the art of fishing since then. A population of 4,000 was able to survive, but not preserve the cultural complexity which was brought from Australia before isolation (Diamond, 2008). In oral cultures, the strings of words representing culture are probably partly stored in the brains of certain persons who use memory techniques such rhymes, rhythms and formulas (Ong, 2001).

Literacy changed the rate and limits of cumulative social evolution. The discrete nature of phonetic alphabets such as the Latin alphabet makes copying very accurate. In addition, the Latin alphabet allows very minute nuances of meaning to be stored on durable material such as papyrus or paper. By contrast, texts based on pictographs, ideograms, or hieroglyphs are totally different from texts based on phonetic alphabets and more liable to copying error. Further, the more analogue (less discrete) nature of pictographs, ideograms and hieroglyphs makes breaking out of established knowledge and producing novel knowledge more difficult. It is no accident that the revolution in philosophy coincided with the advent of the Greek alphabet (Havelock, 1963; Popper, 1992). This accords with the theory of McLuhan who contended that the opening of closed societies was the work of the phonetic alphabet (McLuhan, 1962).

The printing press dramatically increased the rate of cumulative social evolution by accelerating the copying process and reducing copying errors. The introduction of cheap paper contributed to rapid social evolution. The printing press allowed ideas (interactors) to spread more widely and this increased the likelihood of novel, useful combinations of strings of words. As with speech, most novel combinations of written strings of words are trivial (or meaningless), but sometimes interesting and useful combinations worth preserving arise. These combinations tend to be copied to a larger extent than trivial combinations.

All new combinations of strings of words first appear in single minds, but do not require Darwin machines in individual brains. It is impossible to know in advance whether a new combination is interesting or not. "In going beyond what is already known one cannot but go blindly" as D. Campbell forcefully argued (Campbell, 1988). This means that at some basic level novel combinations of strings of words are always accidental. Correspondence to facts or shared culture tends to select winning combinations. Phenomena such as conformity, content-bias, frequency-bias, and other biases may select among different combinations.

Combinations of strings of words probe for new ideas (interactors) in the "adjacent possible". Social evolution can for probabilistic and thermodynamic reasons only proceed by small steps at a time. It is highly unlikely or impossible that successful, radical ideas will ever appear in one or a few steps of combinations. Compatible with this, history shows that novel ideas often occur more or less simultaneously to different persons because these persons are at the same knowledge level (Simonton, 2004). It is doubtful that social evolution is ever punctuated by radical new discoveries. Even Newton stood on the shoulder of giants. Recently, historians argue that there were no scientific or industrial revolutions. Both science and capitalism were based on slow evolution that started many centuries ago (Stark, 2011). Thus capitalist evolution was based on decentralized trial and error among companies based on written instructions. Success or failure (selection mechanisms) depended on profit or not guided by the prevailing monetary system, property laws, and business virtues such as trust and honesty. The rapid change of science and capitalism in recent centuries is due to the exponential nature basic to all Darwinian mechanisms. Exponential growth is barely perceptible for a long time until a certain point is reached and visible growth takes off (Kurzweil, 2005). Cumulative social evolution is a bottom up process. The works of even the most successful inventors and scientists are incremental. This also applies to entrepreneurs including political entrepreneurs.

Cumulative social evolution in literate societies is based on the subset of strings of words stored in the cultural canons of society (including laws and primary scientific literature). These cultural canons constitute just a minor part of all strings of words that are produced daily in books, newspapers, magazines, webpages and so on. If there were no written canon of cultural knowledge, then there would be no advanced culture. Further social evolution depends on efficient mechanisms for the incorporation of new strings of words representing useful knowledge (interactors) in the canon and the discarding of those parts of the canon which are no longer helpful.

Biological evolution is modular and this also pertains to social evolution in so far as the strings of words that represent the cultural canon are easily separated from the vast ocean of trivial strings of words in mass media, and books.

Science and technology are dependent on exact written descriptions. To avoid corruption of knowledge it is important to consult primary sources (the canon) which are basic to social evolution. Secondary literature may help novices to understand important theories, but without copying and spreading of primary sources it is doubtful that cumulative knowledge such as science and technology will prevail. This is because secondary sources most often represent degradation of the knowledge represented by the primary sources partly due to simplification.

Unlimited social evolution depended on the shift from internal storage of strings of words in individual brains to external (exosomatic) storage of discrete strings of words in books, magazines, and hard discs. Durable cheap, external media, discrete units, rapid copying and wide distribution are all important factors underlying cumulative social evolution.

Language has many functions and the strings of words that social evolutions feed on represent just a tiny amount of all strings of words that daily pervade communities of people. The most basic and phylogenetically oldest function is communication. Either the sender tries to obtain a response (for example evasion) from the receiver or the sender reveals its inner state (for example aggression) to the receiver. Communication is common to most life. A second function was developed by human language which made it possible for the sender to reveal information to the receiver about something

external to both the sender and receiver. A third function is to facilitate problems such as "visual theft" and need for reputation that arouse when our fathers acquired social learning (Pagel, 2012). This may have been the reason why human language evolved in the first place. A fourth function deals with information processing such as logic, reasoning, speculation, abstraction and conceptualization. Language makes possible an infinite amount of guessing. To avoid information overload unleashed by the advent of language different information processing methods were developed, perhaps including religion for control of speculations in domains shielded from empiric verification. A fifth function of language is the storage of knowledge. It is a small subset of stored knowledge that underlies cumulative social evolution and this subset became particularly important after knowledge was stored externally on durable media by discrete units. Most strings of words do not contribute to cumulative social evolution. This is probably a reason why social science has not considered strings of words to be the main replicator underlying cumulative social evolution. Analogous to this, it is probable that at the dawn of life the first replicators comprised just a tiny part of a soup consisting of the building material of the replicators (for example RNA bases). Even now, genes coding for proteins comprise far less than 10% of the genome.

Different mechanisms have evolved to separate strings of words acting as replicators from the vast soup of strings of words with other functions thereby facilitating social evolution. Modularity probably helps bring together strings of words that undergo copying and combining thereby facilitating social evolution. Novel scientific knowledge (interactor) is presented in scientific journals and different devices including search engines, indexes, and databases help make this knowledge available to scientists. This promotes increased interaction with other interactors. Selection of interactors (scientific knowledge) causes selection for the corresponding replicators (strings of words).

The present theory shows that there is a close connection between language and culture. It also shows that cumulative social evolution depends on the stability of strings of words. The speed of cumulative social evolution depends on cheap media for storage of strings of words and the number of interacting individuals. This seems to correlate well with what is known about evolution of culture in human history. Finally, this theory does not depend on Darwinian mechanisms in the individual brain.

Tacit knowledge

Most information underlying human actions is tacit, practical, inarticulate knowledge. This knowledge is subjective and not easily available to other people. Without tacit knowledge human action and interaction would be impossible (de Soto, 2010; Hayek, 1948). Articulate knowledge represents only a small part of the total knowledge stored in human beings. Because tacit knowledge by definition is not stored digitally on durable media it cannot underlie unlimited cumulative social evolution. However, it is likely that tacit knowledge contributes to social evolution when it is transferred by individual human beings to articulate knowledge stored by written language on durable media. Thus all knowledge underlying cumulative, social evolution may have originated as tacit knowledge in individual human beings.

Written or spoken information induces meaning in the receiving brain. This meaning is subjective and differs between individuals. However, the subjective nature of meaning does not inhibit cumulative social evolution which depends on accurate copying of discrete, exosomatic units. This is paralleled in biological evolution where accurate copying is based on genes whereas the phenotypic effect of genes may differ from one individual to another.

Conclusion

The Second law of thermodynamics implies that cumulative social evolution is based on Darwinian mechanisms. Further, the Second law and the particulate principle strongly suggest that Darwinian mechanisms are based on discrete units. The only widely available discrete candidates capable of causing cumulative social evolution are strings of words. Cumulative social evolution is based on the phonetic alphabet, printing press and cheap, durable storage. Combinations of strings of words by incremental processes through trial and error lead to cumulative social evolution. The strings of words underlying social evolution comprise only a small fraction of all strings of words expressed in print.

Because of the problem of blending, origin of language depended on discrete units. Cumulative social evolution was inevitable once knowledge was stored digitally on cheap, durable, external medium and easy to copy. Thus, there is probably no limit to cumulative, social evolution.

Figure 1a Copying and selection of discrete units in successive generations. X+ represents a favorable unit and X- an unfavorable unit

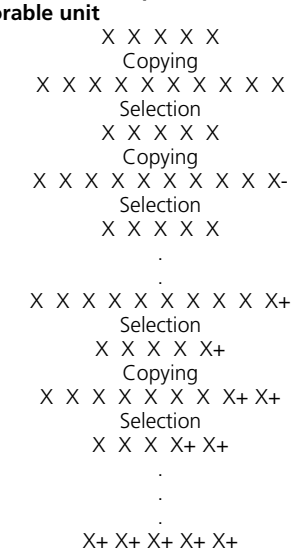
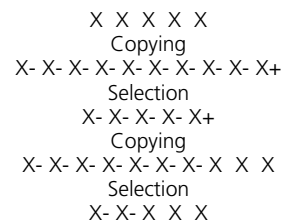


Figure 1b Copying and selection of continuous (analogue) units in successive generations. X+ represents a favorable unit and X- an unfavorable unit



REFERENCES

Abler, W. L. (1989). On the particulate principle of self-diversifying systems. J Social Biol Struct, 12, 1-13. | Arthur, W. B. (2011). The Nature of Technology: What It Is and How It Evolves. London: Free Press. | | Aunger, R. (2002). The electric meme. New York: The Free Press. | | Ben-Naim, A. (2008). Entropy Demystified: The Second Law Reduced to Plain Common Sense. Singapore: World Scientific Publishing Company. | | Calvin, W. (1996). The cerebral code. Cambridge, Massachusetts: The MIT Press. | | Campbell, D. T. (1988). Evolutionary epistemology. In W. W. Bartley, III (Ed.), Evolutionary Epistemology, Rationality, and the Sociology of Knowledge. Chicago: Open Court Publishing Company. | | Dawkins, R. (1982). The extended phenotype. Oxford: Oxford University Press. | | de Soto, J. H. (2010). Socialism, Economic Calculation and Entrepreneurship. Northampton, MA, USA: Edward Elgar. | | Diamond, J. (2008). Guns, Germs, and Steel: The Fates of Human Societies. New York: W.W. Norton & Company. | | Elitzur, A. C. (1994). Let there be life. Journal of Theoretical Biology, 168, 429-459. | Fisher, R. A. (1999). The genetical theory of natural selection. Oxford: Oxford University Press. | | Havelock, E. A. (1963). Preface to Plato. Cambridge, Massachusetts: The Belknap Press of Harvard University Press. | | Hayek, F. A. (1948). Individualism and Economic Order. Chicago: The University of Chicago Press. | | Hodgson, G. M., & Knudsen, T. (2010). Darwin's conjecture: The Search for General Principles of Social and Economic Evolution. Chicago: University Of Chicago Press. | | Hull, D. L. (1999). Science and Selection: Essays on Biological Evolution and the Philosophy of Science. Cambridge: Cambridge University Press. | | Humboldt, W. v. (1999). On language. Cambridge: Cambridge University Press. | | Kurzweil, R. (2005). The Singularity Is Near: When Humans Transcends Biology. New York: The Viking Press. | | Landauer, R. (1987). Computation: A fundamental physical view. Physica Scripta, 35, 88-95. | McLuhan, M. (1962). The Gutenberg galaxy. Toronto: University of Toronto Press. | | Mesoudi, A. (2011). Cultural Evolution: How Darwinian Theory Can Explain Human Culture and Synthesize the Social Sciences. Chicago: University Of Chicago Press. | | Naess, H. (2003). Instructionism is impossible due to the second law of thermodynamics. Journal of Mind and Behavior, 24, 57-66. | Naess, H. (2005). Evolution of Culture in the Light of the Second Law of Thermodynamics. Frontier Perspectives, 14, 32-37. | Ong, W. J. (2001). Orality and Literacy. London: Routledge. | | Pagel, M. (2012). Wired for Culture: Origins of the Human Social Mind. New York: W. W. Norton & Company. | | Popper, K. R. (1992). In search of a better world. London: Routledge. | | Rendell, L., Boyd, R., Cownden, D., Enquist, M., Eriksson, K., Feldman, M. W., . . . Laland, K. N. (2010). Why copy others? Insights from the social learning strategies tournament. [Research Support, Non-U.S. Gov't]. Science, 328(5975), 208-213. doi: 10.1126/science.1184719 | | Ridley, M. (2000). Mendel's demon. London: Weidenfeld & Nicolson. | | Schrödinger, E. (1967). What is life? Cambridge: Cambridge University Press. | | Simonton, D. K. (2004). Creativity in Science: Chance, Logic, Genius, and Zeitgeist. Cambridge: Cambridge University Press. | | Stark, R. (2011). The Triumph of Christianity: How the Jesus Movement Became the World's Largest Religion. New York: Harper Collins Publishers. | | Studdert-Kennedy, M. (2000). Evolutionary implications of the particulate principle: imitation and the dissociation of phonetic form from semantic function. In C. Knight, M. Studdert-Kennedy & J. R. Hurford (Eds.), The evolutionary emergence of language. Cambridge: Cambridge University Press. | | Tooby, J., & Cosmides, L. (1992). The psychological foundations of culture. In J. H. Barkow, L. Cosmides & J. Tooby (Eds.), The adapted mind. New York: Oxford University Press. |