

Mokyr thus takes the analogy between biological evolution and technological change considerably farther than Basalla, and presents an account on which technological change is strongly analogous to biological evolution, although disanalogies are also present. Mokyr does not adhere to the principle of blindness, since he holds that variation and selection are driven by conscious human agents. In Basalla's theory it was artifacts that were the object of variation, reproduction, and selection by humans. In Mokyr's theory, the object is techniques, which are a type of knowledge. In both cases, the trajectory of these objects may be described in evolutionary terms, but is nevertheless the immediate result of human deliberation and purposive action.

5 Robert Aunger's Theory

Anthropologist Robert Aunger has developed an account of technological change within the context of memetics (Aunger, 2002). Memetics is an evolutionary approach to culture that was initially proposed by evolutionary biologist Richard Dawkins (1976). Dawkins claimed that culture might have its own evolutionary mechanism, separate from that of biological evolution, and that it is dependent on basic units of propagation similar to genes, which he called "memes". A meme is the basic meaningful unit of culture and the basic unit of cultural inheritance. Memes are akin to ideas. The religious concept of heaven, the Newtonian concept of gravitation, the notion of a scarf, the notion of a semicolon, the idea of a handshake, all these are memes, or complexes of memes. Memes are capable of reproduction, and are subjected to Darwinian processes of blind variation and selection. They compete with each other in an environment of other ideas, and human biological needs, that determine whether they will be selected and survive in their hosts, or be copied by other hosts and hence spread throughout a population. Importantly, memeticists believe that the basic selection mechanism for memes is not conscious, and involves forces that are beyond the control of individual agents.

The analogy between biological evolution and cultural evolution thus goes all the way: all six principles of biological evolution outlined in section 2 are also thought to apply to cultural evolution, in some form. However, there is debate on whether a genotype-phenotype distinction applies to memetics. Dawkins claimed that this distinction does not hold in memetics, because selective pressures operate directly on memes. Memes are like genes that carry phenotypic traits on their sleeves. Memetic evolution on this conception is Lamarckian, because it upholds the heritability of acquired traits (new memes). Others have claimed that a genotype-phenotype distinction is tenable for memes. If memes are ideas in the mind, then their phenotypic expression may be a realization or manifestation of this idea. This phenotypic expression may be an artifact or behavior. For example, a recipe for a cake in someone's mind is a set of memes, and a cake baked according to this recipe the memetic phenotype. Likewise, the remembered idea of a song may be a set of memes, while the performance of a song is the phenotype. On this view, selective

pressures do not operate directly on memes, but indirectly, on their phenotypic expressions. In this debate, Auger largely follows Dawkins's idea that memes are both genotypic and phenotypic. He moreover holds that memes are brain structures, or ideas in the brain.

Auger holds that a theory of technological change should focus on memes and artifacts. He holds, like Basalla, that artifacts evolve. However, he claims they evolve through interaction with mental artifacts, or memes. Auger hypothesizes a process of coevolution between memes and artifacts. He claims that this process of coevolution involves "two lines of inheritance working together, feeding off each other in a positive fashion," and that it is responsible for the "incredible dynamicism of cultural modification in modern Western societies" (2002, 277). Auger emphasizes that artifacts do not have a single role in meme-artifact coevolution. Artifacts sometimes function as phenotypes, that are the focus of selective pressures. But they may also function as vehicles or interactors for memes, as signal templates, or even as replicators, as in computer viruses and nanites (self-replicating pieces of nanotechnology). Different relations with memes are established in these different roles of artifacts. In all cases, however, there is coevolution: memes give rise to artifacts, and artifacts may feed back to memes and alter them or generate new ones. Both memes and artifacts are subjected to their own selective pressures.

Auger sums up his theory of technological change as follows: "New artifact types are created through *invention*, or random mutations in form. This starts a new evolutionary lineage. *Innovations*, on the other hand, are modifications of these inventions through the recombination of parts. ... Such single-step recombinations between artifact lineages ("combinatorial chemistry") can rapidly produce complexity. Over time, an artifact lineage can therefore show evidence of cumulative selection (variation with descent) and manifest an adaptive design with greater and greater power to transform the environment. Simultaneously there is a process of mental evolution in know-how that can be described as Darwinian." (2002, 299). Auger holds that the production of artifacts is first simulated in the mind, in which different varieties of artifacts are "tried out" for their competitive advantage. This process of mental trial and error may recur at the level of research and development within a firm, and then again in the marketplace. So it is the interaction of two Darwinian processes, "of descent with modification in the body of knowledge available to a society relevant to the production of some artifact, as well as the embodied modifications in the artifact itself – that must be modeled for a complete understanding of technological evolution." (2002, 299–300). Auger notes that precise models of the interaction between memes and artifacts will still have to be developed.

Auger's theory incorporates an analogue of most principles of biological evolution, and he therefore conceives of technological change as strongly analogous to biological evolution. Auger adopts principles of variation, inheritance, and differential fitness for memes and artifacts that strongly mirror those in biology. He holds that the relation between memes and artifacts sometimes resembles the genotype-phenotype relation, but claims that memes and artifacts may also have a different relation to each other. When this relation occurs, the principle of genetic reproduction seems to apply. Auger moreover assumes that the invention of new memes and artifacts