New Replicators, The

It has long been clear that, in principle, the process of natural selection is substrate-neutral. That is, evolution will occur whenever and wherever three conditions are met: replication, variation (mutation), and differential fitness (competition).

In Darwin's own terms, if there is “descent [i.e., replication] with modification [variation]” and “a severe struggle for life” [competition], better-equipped descendants will prosper at the expense of their competitors. We know that a single material substrate, DNA (with its surrounding systems of gene expression and development), secures the first two conditions for life on earth; the third condition is secured by the finitude of the planet as well as more directly by uncounted environmental challenges. We also know, however, that DNA established its monopoly position over early variations that have left their traces and ongoing exemplars, such as the RNA viruses and prions. Have any other completely different evolutionary substrates arisen on this planet? The best candidates are the brainchildren, planned or unplanned, of one species: Homo sapiens.

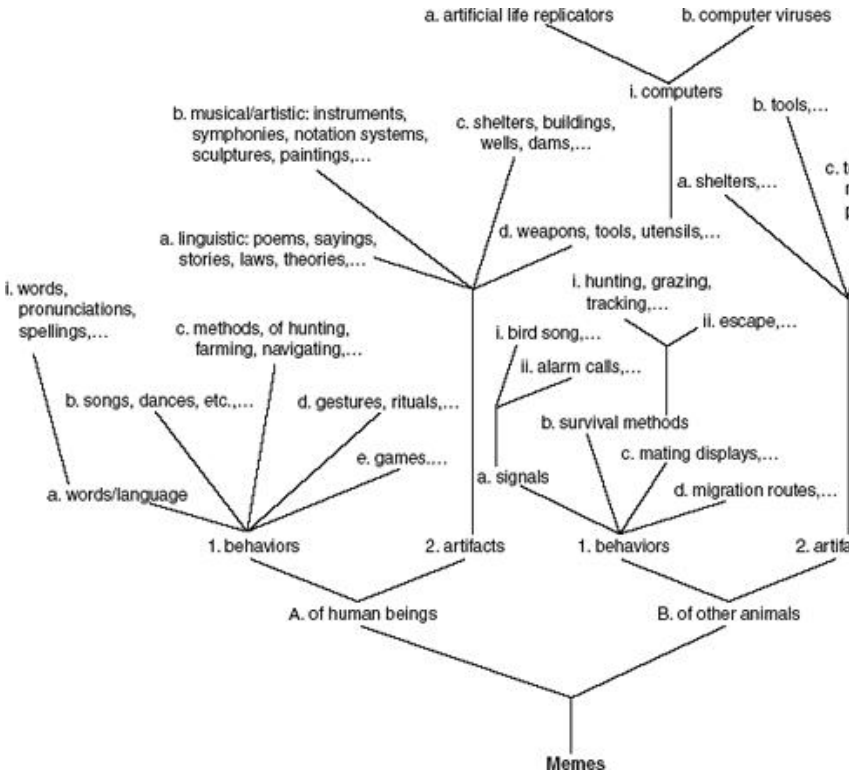

Figure 1. The New Replicators. A Simple Taxonomy of the New Replicators.

Courtesy of Daniel Dennett.

Darwin himself proposed words as an example: “The survival or preservation of certain favoured words in the struggle for existence is

natural selection" (*Descent of Man*, 1871, p. 61). Billions of words are uttered (or inscribed) every day, and almost all of them are replicas—in a sense to be discussed below—of earlier words perceived by their utterers. Replication is not perfect, and there are many opportunities for variation or mutation in pronunciation, inflection, or meaning (or spelling, in the case of written words). Moreover, words are roughly segregated into lineages of replication chains; for instance, we can trace a word's descendants from Latin to French to Cajun. Words compete for air time and print space in many media; words become obsolete and drop out of the word pool, while other words spring up and flourish. We discover *conTROVersy* going to fixation—surviving while all competing pronunciations go extinct—in some regions and *CONtroversy* going to fixation in others, while the original meaning of "begs the question" is supplanted in some quarters by a variant. The detectable historical changes in languages have been studied from one Darwinian perspective or another since Darwin's own day, and a great deal is known about patterns of replication, variation, and competition in the processes that have yielded the diverse languages of today. Some of the investigative methods of modern evolutionary biology—in bio-informatics, for instance—are themselves descended from pre-Darwinian researches conducted by paleographers and other early scholars of historical linguistics. As Darwin noted, "The formation of different languages and of distinct species, and the proofs that both have been developed through a gradual process, are curiously the same" (1871, p. 59).

Words, and the languages they populate, are not the only culturally transmitted variants that have been proposed. Other human acts and practices that spread by imitation have been identified as potential replicators, as have some of the habits of nonhuman animals. The physical substrates of these media are various indeed, including sounds and all manner of visible, tangible patterns in the behavior of the vector organisms. Moreover, behaviors often produce artifacts (paths, shelters, tools, weapons, and signs or symbols) that may serve as better exemplars of replication than the behaviors that produce them, being relatively stable over time and hence in some ways easier to copy, as well as being independently movable and storable. One human artifact, the computer, with its prolific copying ability, has recently provided a distinctly new substrate in which both deliberate and inadvertent experiments in artificial evolution are now burgeoning, taking advantage of the emergence of gigantic networks of linked computers that permit the swift dispersal of propagules made of nothing but bits of information. These *computer viruses* are simply sequences of binary digits that can have an effect on their own replication. Like macromolecular viruses, they travel light, being nothing more than information packets—including a phenotypic overcoat that tends to gain them access to replication machinery wherever they encounter it. Finally, researchers in the new field of artificial life aspire to generate both virtual (simulated, abstract) and real (robotic) self-replicating agents that can take advantage of evolutionary algorithms to explore the adaptive landscapes in which they are situated, generating improved designs by processes that meet the three defining conditions while differing from carbon-based life forms in striking ways. At first glance these phenomena may appear to be only models of evolving entities, thriving in modeled environments, but the boundary between an abstract demonstration and an application in the real world is more easily crossed by these evolutionary phenomena than by others, precisely because of the substrate-neutrality of the underlying evolutionary algorithms.

Artificial self-replicators can escape from their original environments on researchers' computers and take on a “life” of their own in the rich new medium of the Internet.

All these categories of new replicators are dependent, like viruses, on replicative machinery that is built and maintained directly or indirectly by the parent process of biological evolution. Were all DNA life forms to go extinct, all their habits and metahabits, their artifacts and meta-artifacts, would soon die with them, lacking the wherewithal (both the machinery and the energy to run the machinery) to reproduce on their own. For the time being, our computer networks and robot fabrication and repair facilities require massive supervision and maintenance by us, but it has been suggested by the roboticist Hans Moravec (1988) that silicon-based electronic (or photonic) artifacts could become entirely self-sustaining and self-replicating, weaning themselves from their dependence on their carbon-based creators. This improbable and distant eventuality is not a requirement for evolution, however, or for life itself. After all, our own self-replication and self-maintenance are entirely dependent on the billions of bacteria without which our metabolisms would fail; and if our artifactual descendants similarly have to enslave armies of our biological descendants to keep their systems up and running, this would not detract from their claim to be a new branch on the tree of life. We have reached a point where we can no longer survive on this planet without our artifacts, just as they can no longer survive without us. This codependency is in some important regards like the codependency of RNA and DNA, and the codependency of multicellular hosts and their symbionts—an emerging fact of life.

As with many taxonomies in evolutionary theory, there are controversies and puzzles about how to draw the branchings and how to name them. Some of these puzzles are substantive, and some are merely disagreements about which terms to use. The zoologist Richard Dawkins coined the term *meme* in his 1976 book, *The Selfish Gene*, and the term has caught on. He opened his discussion of these “new replicators” with a discussion of bird song, but others who have adopted the term have wanted to restrict memes to human culture. Should such evolving animal traditions as alarm calls, nest-building methods, and chimpanzee tools also be called memes? Researchers concentrating on cultural transmission in animals, such as John Tyler Bonner (1980) and Eytan Avital and Eva Jablonka (2000), have resisted the term, and others writing on human cultural evolution, such as Luca Cavalli-Sforza and Marcus Feldman (1981), and Robert Boyd and Peter Richerson (1985) have also chosen to use alternative terms. But since the word *meme* has secured a foothold in the English language, appearing in the most recent edition of the *Oxford English Dictionary* with the definition “an element of culture that may be considered to be passed on by non-genetic means,” we may conveniently settle on it as the general term for any culturally based replicator—if such there are. Those who are squeamish about using a term whose identity conditions are still so embattled should remind themselves that similar controversies continue to swirl around how to define its counterpart, gene, a term that few would recommend abandoning.

Memes include not just animal traditions, then, but also computer-based replicators, for two reasons: not only do computers and their maintenance and operation depend on human culture, but the boundaries between computer viruses and more traditional human

memes have already been blurred. Simple computer viruses in effect carry the instruction *copy me*, which is directed to the computer in machine language and is entirely invisible to the computer's user. Like the toxins unwittingly ingested by people who catch and eat freshwater fish, such a computer virus, though an element of the users' environment, is arguably not part of their *cultural* environment. However, at least as widespread and virulent as such “proper” computer viruses are bogus computer virus warnings, directed to the computer user in natural language. These warnings, which depend directly on a comprehending (but duped) human vector to get themselves replicated on the Internet, are definitely within the intended understanding of memes; intermediate cases are the computer viruses that depend on enticing human users to open attachments (thereby triggering the invisible copying instruction) by promising some amusing or titillating contents. These too depend on human comprehension; one written in German will not spread readily to the computers of monoglot English speakers. (This pattern may change if users avail themselves regularly of on-line translation services.) In the arms race between virus and anti-virus, ever more elaborate exploitations of human interests are to be expected, so it seems best to include all these replicators under the rubric of memes. Note, however, that some of them make only indirect use of human vectors and hence are only indirectly elements of human culture. We are beginning to see this porous boundary crossed in the other direction as well: it used to be true that the differential replication of such classic memes as songs, poems and recipes depended on their winning the competition for residence in human brains, but now that a multitude of search engines on the Web have interposed themselves between authors and their (human) audiences, competing with one another for a reputation as high-quality sources of cultural items, significant fitness differences between memes can accumulate independently of any human appreciation or cognizance. The day may soon come when a cleverly turned phrase in a book gets indexed by many search engines, and thereupon enters the language as a new cliche without anybody human having read the original book.

Problems of Classification and Individuation

Some problems of classification are substantive, depending in part on historical facts that are not well established, and others are tactical problems for the theorist: What divisions of the phenomena will prove most perspicuous? Are all computer viruses properly descended from the earliest forays into artificial life, or should at least some of them be shown as arising independently of that intellectual movement? Not all computer hackers are A-Life hackers, but there is also the unanswered tactical question of how to characterize what is copied. If one hacker gets the *general idea* of a computer virus from somebody else and then goes on to make an entirely new kind of computer virus, is that new virus properly a descendant, with modifications, of the virus that inspired its creation? What if the hacker adapts elements of the original virus's design in the new type? How much sheer mindless copying must there be, or alternatively, how much comprehending inspiration *may* there be, in an instance of replication? (More on this question below.) Is there cross-species meme-copying in the animal world? Polar bears build a den that includes a raised snow shelf that permits cold air to drain out the depressed opening of the den. Is this wise trend in arctic technology entirely innate (now), or do bear cubs have to copy their mother's example? The same snow shelf is found in an Inuit snow shelter. Did the Inuit copy this tradition from the polar

bear, or was it an independent invention? Does it ever happen that one species begins attending to the alarm calls of another and then develops an alarm call tradition of its own? Does the *alarm call* meme spread from species to species, or should we consider the intraspecific alarm calls and their variants as entirely independent lineages (Reader and Laland, 1999)?

Exacerbating these problems are other problems of meme individuation. Should the (English) word "windsurfing" be seen as distinct from the (language-neutral) windsurfing *meme*? Are these two memes or one? Do styles, such as *punk* and *grunge*, count as memes before they have names? Why not? Joining forces with a name-meme is no doubt an excellent fitness advantage for almost any meme. (An exception could be a meme that depends on spreading insidiously; the coining of a name-meme, such as *male chauvinism*, may actually hinder the spread of male chauvinism by sensitizing something like an immune reaction in potential vectors.) It is probably true that as soon as any human meme becomes salient enough in the environment to be discerned, it will thereupon be named by one of its discerners, tightly linking the two memes thereafter: the name and the named, which typically have a shared fate, but not always. (The musical characteristics identifiable as *the blues* include many robust instances that are not *called* "the blues" by those who play and listen to them.) Undiscerned memes can also flourish. For instance, changes in the pronunciation or meaning of a word can move to fixation in a large community before any sharp-eared linguist or other cultural observer takes note. There are more than a few people—comedians as well as anthropologists and other social scientists—who earn their living by detecting and commenting on evolving trends in cultural patterns that have heretofore been at best dimly appreciated.

Until these and other problems of initial theoretical orientation are resolved, skepticism about memes will continue to be widespread and heartfelt. Many commentators are deeply opposed to any proposals to recast questions in the social sciences and humanities in terms of cultural evolution, and this opposition is often expressed in terms of a challenge to prove that "memes exist":

Genes exist [these critics grant] but what are memes? What are they made of? Genes are made of DNA. Are memes made of neuron-patterns in the brains of enculturated people? What is the material substrate for memes?

There are some proponents of memes who have argued in favor of an attempt to *identify* memes with specific brain-structures—a project still entirely uncharted. On current understandings of how the brain might store cultural information, it is unlikely that any independently identifiable common brain structures, in different brains, could ever be isolated as the material substrate for a particular meme. Although some genes for making eyes do turn out to be identifiable whether they occur in the genome of a fly, a fish, or an elephant, there is no good reason to anticipate that the memes for wearing bifocals might be similarly isolatable in neuronal patterns in brains. It is vanishingly unlikely, that is, that the brain of Benjamin Franklin, who invented bifocals, and the brains of those of us who wear them should "spell" the *idea* of bifocals in a common brain-code. Besides, this imagined path to scientific respectability is based on a mistaken analogy. In his 1966 book *Adaptation and Natural Selection*, the evolutionary theorist George Williams offered an influential definition of a *gene* as "any hereditary information for which there is a favorable or unfavorable selection bias equal to several or many times its rate of endogenous

change." As he went on to stress in his 1992 book, *Natural Selection: Domains, Levels, and Challenges*, "A gene is not a DNA molecule; it is the transcribable information coded by the molecule."

Genes—genetic recipes—are all written in the physical medium of DNA, using a single canonical language, the nucleotide alphabet of adenine, cytosine, guanine, and thymine, triplets of which code for amino acids. Let every strand of smallpox DNA in the world be destroyed; if the smallpox genome is preserved (translated from nucleotides into the *letters* A, C, G, and T and stored on hard disks on computers, for instance), smallpox is not truly extinct; it could have descendants someday because its genes *still exist* on those hard disks, as what Williams calls "packages of information."

Memes—cultural recipes—similarly depend on one physical medium or another for their continued existence (they aren't magic), but they can leap around from medium to medium, being translated from language to language, from language to diagram, from diagram to rehearsed practice, and so forth. A recipe for chocolate cake, whether written in English in ink on paper, or spoken in Italian on videotape, or stored in a diagrammatic data structure on a computer's hard disk, can be preserved, transmitted, translated, and copied. Since the proof of the pudding is in the eating, the likelihood of a recipe getting *any* of its physical copies replicated depends (mainly) on how successful the cake is. How successful at doing what—at getting a host to make another cake? Usually, but even more important is getting the host to make another copy of the recipe and passing it on. That's all that matters, in the end. The cake may not enhance the fitness of those who eat it; it may even poison them, but if it first somehow provokes them to pass on the recipe, the meme will flourish.

This is perhaps the most important innovation in outlook permitted by recasting traditional investigations in terms of memes: they have their own fitness as replicators, independent of any contribution they may or may not make to the genetic fitness of their hosts, the human vectors. Dawkins put it this way: "What we have not previously considered is that the cultural trait may have evolved in the way that it has, simply because it is *advantageous to itself*" (1976, p. 200). The anthropologist F. T. Cloak, (1975), put it this way: "The survival value of a cultural instruction is the same as its function; it is its value for the survival/replication of itself or its replica."

Those who question whether memes exist because they cannot see what material thing a meme could be should ask themselves if they are equally dubious about whether words exist. What is the word *cat* made of? Words are recognizable, re-identifiable products of human activity; they come in many media, and they can leap from substrate to substrate in the process of being replicated. Their standing as real things is not at all impugned by their abstractness. In the proposed taxonomy, words are but one species of memes, and the other species of memes are the same kind of things that words are—you just can't pronounce or spell them. Some of them you can dance, and some of them you can sing, or play, and others you can follow by making something out of the various building materials the world provides. The word *cat* isn't made out of some of the ink on this page, and a recipe for chocolate cake isn't made of flour and chocolate.

There is no single proprietary code, parallel to the four-element code of DNA, that can be used to anchor meme-identity the way gene-

identity can be anchored, for most practical purposes. This is an important difference, but one of degree. If the current trend of language extinctions continues at its present pace, every person on the earth may someday speak the same language, and it will then be difficult to resist the temptation (which should still be resisted!) to *identify* memes with their (now practically unique) verbal labels. But so long as there are multiple languages, to say nothing of the multiple media in which nonlinguistic cultural items can be replicated, we are better off keeping strictly to the abstract, code-neutral understanding of a meme as a "package of information," bearing in mind that for high-fidelity replication to occur, there must always be some "code" or other. Codes play a crucial role in all systems of high-fidelity replication, since they provide finite, practical sets of norms against which relatively mindless editing or proofreading can be done. But even in the clearest cases of codes, there are often multiple levels of norms. Suppose Tommy writes the letters "SePERaTE" on the blackboard, and Billy "copies" it by writing "seperate." Is this really copying? The normalization to all lower-case letters shows that Billy is not slavishly copying Tommy's chalk-marks, but rather being triggered to execute a series of canonical, normalized acts: *make an "s," make an "e,"* and so on. It is thanks to these letter-norms that Billy can "copy" Tommy's word at all. But he does copy Tommy's spelling error, unlike Molly, who "copies" Tommy by writing "separate," responding to a higher norm at the level of word spelling. Sally then goes a step higher, "copying" the phrase "separate butt equal"—all words in good standing in the dictionary—as "separate but equal," responding to a recognized norm at the phrase level. Can we go higher? Yes. Anybody who, when "copying" the line in the recipe "Separate three eggs and beat the yolks until they form stiff white peaks," would replace "yolks" with "whites" knows enough about cooking to recognize the error and correct it. Above spelling and syntactic norms are a host of semantic norms as well.

Norms can both hinder and help replication. The anthropologist Dan Sperber (2000) has distinguished copying from what he calls "triggered reproduction" and has noted that, in cultural transmission, "the information provided by the stimulus is complemented with information already in the system." This complementing tends to absorb mutations instead of passing them on. Evolution depends on the existence of mutations that can survive the proofreading processes of replication intact, but it does not specify the level at which this survival must occur. A brilliant cooking innovation might indeed get corrected away by an all-too-knowing chef in the course of passing on the recipe, but other "errors" might get through and replicate indefinitely. Meanwhile, the correction of other varieties of noise at other levels, responding to spelling norms or others, must be ongoing in order to keep the copying process faithful enough so that multiple exemplars of each innovation can be tested against the environment. As Williams puts it, "A given package of information (codex) must proliferate faster than it changes, so as to produce a genealogy recognizable by some diagnostic effects" (1992, p. 13). Recognizable, that is, to the unfocused, independently varying environment, so it can yield probabilistic verdicts of natural selection that have some likelihood of identifying adaptations of projectible fitness. It is possible, for instance, that encodings of the same meme in different media will differentially compete and differentially mutate, so that they should be considered different memes for some purposes. When a Welsh folk song transmitted orally for hundreds of years is transcribed and transliterated by an ethnomusicologist and then adapted by a

composer in a choral work that becomes a popular concert item for amateur choruses whose members know no Welsh, the change in encoding makes a difference to the susceptibility to mutation in subsequent replication streams, which bifurcate into code-dependent trajectories.

Just how big or small can a meme be? A single musical tone is not a meme, but a memorable melody is. Is a symphony a single meme, or is it a system of memes? A parallel question can be asked about genes, of course. No single nucleotide or codon is a gene. How many notes or letters or codons does it take? The answer in both cases tolerates blurred boundaries: a meme, or a gene, must be large enough to carry information worth copying. There is no fixed measure of this, but the bountiful system of case law on copyright and patent infringements indicates that verdicts on particular cases form a relatively trustworthy equilibrium that is stable enough for most purposes.

Other objections to memes seem to exhibit an inverse relationship between popularity and soundness: the more enthusiastically they are championed, the more ill-informed they are. They have been patiently rebutted again and again by proponents, but those who are appalled by the prospect of an evolutionary account of anything in human culture don't seem to notice. A common mistake by critics is to imagine that memes must be more like genes than they need to be for the three conditions to be met. It has been observed, for instance, that when an individual first acquires some encountered cultural item, this is typically not a case of imitating a single instance of it. (If I take up the practice of wearing my baseball cap backwards, or add a new word to my working vocabulary, am I copying the first instance of it I ever noticed, or the most recent instance, or am I somehow averaging over all of them?) This embarrassment of riches in the search for the parent of the new offspring does complicate the model of cultural replication, but it does not in itself disqualify the process as one of replication. For instance, the ultra-high-fidelity copying of computer files depends in many instances on error-correcting code-reading systems that in effect let “majority rule” determine which of several candidate exemplars should count as canonical. In such cases, no single vehicle of the information can be identified as the source—but this is undeniably an instance of replication. Darwin's trio of requirements is both substrate-neutral and implementation-neutral to a degree that is not always appreciated.

Is Cultural Evolution Darwinian?

Marking these unresolved problems of nomenclature and individuation, we can turn to the more fundamental and important question: Do any of these candidates for Darwinian replicator actually fulfill the three requirements in ways that permit evolutionary theory to explain phenomena not already explicable by the methods and theories of the traditional social sciences? Or does this Darwinian perspective provide only a relatively trivial unification? It would still be important to conclude that cultural evolution obeys Darwinian principles in the modest sense that nothing that happens in it contradicts evolutionary theory, even if cultural phenomena are best accounted for in other terms. In *The Origin of Species*, Darwin himself identified three processes of selection: “methodical” selection by the foresighted, deliberate acts of farmers and others intent on artificial selection; “unconscious” selection, in which human beings have engaged in activities that have unwittingly contributed to the

differential survival and reproduction of species, mostly on their way to domestication; and "natural" selection, in which human intentions have played no role at all. To this list we can add a fourth phenomenon, genetic engineering, in which the intention and foresight of human designers plays a still more prominent role. All four of these phenomena are Darwinian in the modest sense. Genetic engineers do not produce counterexamples to the theory of evolution by natural selection, any more than plant breeders over the eons have done; they produce novel fruits of the fruits of the fruits of evolution by natural selection. The idea of memes promises similarly to unify under a single perspective such diverse cultural phenomena as deliberate, foresighted scientific and cultural inventions (memetic engineering), such authorless productions as folklore, and even such unwittingly redesigned phenomena as languages and social customs themselves. As we enter the age of deliberate, purportedly foresighted tinkering with our own genomes and the genomes of other species, we face the prospect of strong interactions between genetic and memetic evolution, including many that may take off without having been foreseen at all. It behooves us to investigate these possibilities with the same vigor and attention to detail that we devote to the investigation of the evolution of carbon-based pathogens and to the swift disappearance of natural barriers that have structured the biosphere until very recently.

We should also remind ourselves that, just as population genetics is no substitute for ecology—which investigates the complex interactions between phenotypes and environments that ultimate yield the fitness differences presupposed by genetics—no one should anticipate that a new science of memetics would overturn or replace all the existing models and explanations of cultural phenomena developed by the social sciences. It might, however, recast them in significant ways and provoke new inquiries in much the way genetics has inspired a flood of investigations in ecology. The books listed below explore these prospects in some detail, but still at a very programmatic and speculative level. At this time, there are still only a few works that might be listed as pioneering empirical investigations in specialized branches of memetics: Hull (1988), Lynch, (1996b), Pocklington and Best (1997), and Gray and Jordan (2000).

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Daniel C. Dennett