1

Darwin, Culture and Expert Systems

Dr. Yoram Romem
The Cohn Institute for the History and Philosophy of Science and Ideas
Tel-Aviv University, Tel-Aviv,
Israel

1. Introduction

Darwin's theory of evolution by natural selection targeted the living parts of nature. This paradigm, which is one of the foundations of the living world, attracted scholars as a mechanism which might apply to other areas that change over time.

This paper creates an analogy between Darwinian evolution processes and Expert Systems (ES), where human expertise is utilized by computerized technology. Firstly, Darwinian theory is applied to social and cultural areas in general; then, as a special case of culture, it is applied to science and technology; lastly, as a special case of technology, Darwinian processes are applied to ES.

The revelation of the strong resemblance that ES bears to Darwinian processes may trigger new approaches for future generations of ES.

2. Initial step: Cultural evolution

A natural extension of Darwin's evolution theory is to the social and cultural behavior of humans. As physical characteristics are governed by genes, there is no reason to restrict the theory to this layer. Since behavior is a phenotypic (i.e. observable) phenomenon, and behavior includes social and cultural aspects, there is an obvious interest in studying how evolutionary ideas apply to these layers too.

One of the earliest and most influential scholars to apply Darwinian theory to human cultural evolution was Donald Campbell. In his view (Campbell, 1960; Campbell, 1965), cultural inheritance is a process of imitation, in which successful people are imitated. This, of course, differs from natural inheritance which is "blind": the descendant cannot choose to inherit from his ancestor only the desired genes…. Cultural evolution includes all that humans learn from each other. There is a kind of "injustice" in this process, for what some individuals learn by themselves through hard effort others often imitate, typically at much less cost to themselves[1]. However, this "cheaper" way is not perfect and involves variations, intended or unintended.

---

[1] Latour (1987) referred to another type of cultural inheritance (without using this term), by analyzing knowledge and expertise. While those who have the "real" knowledge (whom he called "insiders") know the actual facts and understand them, the others (whom he called "outsiders") have only the perception of the real knowledge, or "beliefs" in Latour's

Source: Expert Systems, Book edited by: Petrică Vizureanu,
ISBN 978-953-307-032-2, pp. 238, January 2010, INTECH, Croatia, downloaded from SCIYO.COM

As such, cultural evolution applies to technical knowledge, to the language, the habits, sentiments and ideas that guide participation in social and political life, systems based on belief, like religion, and artistic traditions.

Cultural inheritance involves variation as humans pick and choose their adopted elements. Moreover, the inherited culture is modified by experience. On the other hand, each individual has only marginal influence on the group culture, which is shaped by the cumulative choices of the whole group. These cultural changes are the evolutionary forces.

In some cases, natural selection operates directly on cultural variation. For example, the mortality rate for drunken drivers directly affects this type of cultural behavior.

On a personal level there is a clear distinction between genetic and cultural inheritance: a childless person can still transmit his or her culture. Even if a person's genetic fitness is in doubt, he or she may nevertheless be favored by cultural natural selection if he or she succeeds and is influential. However, both approaches intervene in the theories of group selection: when the unit of selection is a group, e.g. a species, the forces that act must include both the social and cultural aspects [2].

Socio-cultural forces affect Darwinian natural selection processes: natural selection will, for example, cause a species to develop appropriate measures better adapted to cool weather or other climatic conditions; similarly, societies and corporations find new niches in which to prosper in changing economic and competitive environments (surviving or disappearing, as the case may be, by natural selection processes)[3].

Just as evolution in living nature is based on many forces in the struggle for survival of any particular variation of species, cultural evolution is affected by various forces as well: in the economic market, for example, the success (or even survival) of a company or business depends on or is influenced by market conditions, workers' morale, government regulations, random catastrophes and so on. Also, in the case of cultural evolution, the variation is "guided" and the inherited transmission is biased, as people, societies and companies make changes in order to improve or even survive. Even the term "innovation" is used both in classic Darwinian evolution for variation, and obviously in social changes, especially in science and technology.

An even greater connection between evolution in living nature and cultural evolution is found when considering cooperation and altruism vs. selfishness in both domains. In the classical Darwinian theory these phenomena were deeply researched, with the resulting

---

definition. Thus, the imitators (in the present context), acquire only the "surface" of the knowledge, gaining only perceived knowledge but not the real thing. This observation will be very important later as we focus on Expert Systems.

[2] Richerson & Boyd (2000, 4): "Suppose, for example, a tendency to be more cooperative arose through natural selection on cultural variation. A cultural environment might thus arise in which excessively belligerent or selfish individuals suffered discrimination or ostracism, reducing their chances of acquiring mates. A population composed of more compliant personalities would follow, perhaps quite rapidly on the paleontological time scale." Other theories suggest that selfish individuals might prosper when residing among altruistic societies, e.g. Dawkins (1976).

[3] In order to adapt to the dynamic economic and technological environment, companies need to change their strategies (e.g. find new niches) and their structure (e.g. becoming more responsive).

conclusion that cooperative species are usually better fitted in many cases of struggles for survival: "A tribe including many members who…were always ready to give aid to each other and sacrifice themselves for the common good, would be victorious over most other tribes; and this would be natural selection" Darwin (1871, 166)[4].

Once the theory of evolution has been found to relate to the phenomena associated with cooperation as a driving force affecting natural selection, the next logical step is the determination of the unit of selection. While genetic inheritance affects individuals, thereby pointing to their fitness as the selection criterion, the cooperation aspect may change this. Less fitted individuals can survive when the group forces "protect" them. The cooperation tactics employed by the whole group may change natural selection effects.

The next step is a short one: if group tactics practically affect natural selection, then we must treat the "unit of selection" as group-centric and not only as gene-centric. According to this approach, in the struggle for survival, what matters (in addition to the fitness of the individual) is the group's fitness or ability to adapt to the environment and the threats[5].

This discussion reciprocally affects the altruism vs. selfishness dilemma: since altruism is, by definition, acting against one's immediate selfish benefit (e.g. sharing food with others, alerting the group while risking oneself, self-sacrifice), when considering the wider group aspects, one can benefit from the group's wellbeing. So may we refer to an altruistic behavior caused by selfish considerations….

The recognition of the importance of the group's characteristics, beyond the individual's, leads to focus on the forces that affect groups' behavior. Obviously, one of the main forces in human societies is culture, which like physical phenomena, is continuously changing, thus laying the basis for research of its variation, adaptation, survival and inheritance.

In a sense, cultural selection operates sometimes to prevent natural selection forces from having their way: when societies and corporations make changes (like reorganization, replacing management, mergers etc.), they fight against the forces of natural selection that would otherwise extinguish them. Sometimes the fight is against problems created by the same self society, such as the contamination of the ozone layer, where both the fighters and the perpetrators belong to the same species. So, evolution provided us with the intellectual capabilities to create problems and then to solve them.

Human societies created institutions (like universities) to enable better adaptation of the society to the dynamic environment by inventing new ways and technologies. This is their tactical way of guiding the way for the variations needed for adaptation and survival. Cooperation is another method of coping with threats in the struggle for survival, although natural selection sometimes favors uncooperative, selfish individuals[6]. Cooperation is,

---

[4] In animals, self-sacrifice and other altruistic behavior is very common (e.g. vampires sharing blood, bees caring for the queen, vervet monkeys alerting the group while risking themselves).

[5] One of the scholars promoting the group selection approach is Wynne-Edwards (1962), as well as Campbell (1965) and Richerson & Boyd (2005). On the other hand, critiques like Williams (1966) and Dawkins (1976) emphasized the dominance of gene-selection over the group's aspects.

[6] Various scholars (e.g. Dawkins [1976]) contended that selfishness is the regular "winning" strategy for individuals, especially within cooperative societies. This may be traced to Adam Smith's "invisible hand" principle as a major theory of directing a society comprising selfish

therefore, part of the broader argument about the unit of selection (group or individual). This argument is even broader when applied to nations and states: the socialist system which included government controlled economies (maybe the ultimate example of cooperation is the multinational one), collapsed while capitalist paradigms prevailed[7]. However, when applied to former communist states, not all absorbed it at the same success rate. It seems that the cooperative forces are less dominant compared to open-mindedness for changes as a winning strategy.

The ultimate outcome of cooperation, trust and collective decision making (which by definition apply only when groups are involved) is group selection on cultural variation: the survival of the fittest, in this context, relates to the culture of the group as a whole. Personal survival is not relevant, as even unfitted individuals (in the biological sense) may still transmit their culture. However, cultural group selections (e.g. political systems) affect only short-term phenomena (less than half a millennium), and not phenomena which take longer to develop. Capitalism vs. communism is an example of a short term phenomenon, while an example of a long term phenomenon is the transition from an agricultural society to an industrial one.

The reason why humans were able to develop complex societies compared to other species seems to be what Darwin called their "social instincts". Other close species, like chimpanzees, could not adapt and cooperate by inventing tools and machines that need large-scale planning and cooperation in their cultural evolution.

When we judge these social instincts using Darwinian methods, we should be cautious and not conclude as to which is better (or more fitted). Just as Darwinian evolution cannot predict future developments, we cannot state which of the various social approaches will prevail in the long run.

The attractiveness in applying Darwinian theory when analyzing cultural processes is in the use of its methods of dealing with change. The forces which pertain in the global evolutionary equilibrium include religious fundamentalism (of various religions), liberalism, global weather, free market economics and the like. The immediate evolutionary effect can be measured by birth rates, which may be regarded as a measure of natural selection[8], or standard of living. Another force which affects cultural evolution is human "happiness" (i.e. what makes individuals more comfortable or "happy"), as a driver of preference among societies when variation exists. However, this force is difficult to monitor as it varies from society to society. Open economies as a driving force, on the other hand, seem to be directly correlated to dynamic change, especially technological change, which affects social change.

The general tendency for people to cooperate and be trustworthy (at least within their own in-groups), to follow group norms, to be altruistic as expected when the group's well-being

---

individuals, however even he added another social aspect: "How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortune of others, and render their happiness necessary to him, though he derives nothing from it, except the pleasure of seeing it" (Smith [1790, II.1])

[7] After the recent global economic crisis of 2008-2009 we may see the signs of yet another needed adaptation cycle, mainly in capitalist societies.

[8] However, it is not clear what is meant by high birth rate: either a winning successful species or one doomed because of its inability to provide itself with food and therefore lagging behind.

is at stake – is basic to a social natural selection. In the struggle for survival, groups which developed high cooperative cultures were able to prevail when only a whole group effort could provide technological or economic solutions.

The above ideas about cultural evolution lacked a major element which resides in natural evolution: the mechanism for transmitting the genetic information. Since genes provide the physical data platform which is transmitted by inheritance, there must be an equivalent mechanism in cultural evolution to make it a real "colleague". This missing link was bridged by Dawkins (1976), who coined the term "memes" to describe units of human cultural evolution analogous to the genes. In his book "The Selfish Gene", Dawkins contended that the meme[9] is a unit of information residing in the brain and is the mutating replicator in human cultural evolution.

Memes contain the information about habits, skills, songs, stories, or any other kind of information that is copied from person to person. Memes, like genes, are replicators. That is, they are information that is copied with variation and selection. Because only some of the variants survive, memes (and hence human cultures) evolve. Memes are copied by imitation, teaching and other methods, and they compete for space in our memories and for the chance to be copied again[10]. Large groups of memes that are copied and passed on together are called co-adapted meme complexes, or memeplexes.

Blackmore (1999) took Dawkins' ideas to the extreme: as the memes are the replicators, they also have a selfish nature (like Dawkins' selfish genes). This selfishness drives human thoughts, talking, sex, and even communication instruments and Internet, for one major purpose: distribution of memes and their survival…The human large brain serves, of course, the same purpose; we are just Meme Machines (which is the name of her book). So, according to Dawkins and Blackmore, humans serve a dual purpose: the continuation of genes at the physical level, and the continuation of memes at the cultural level.

Several scholars criticized Dawkins' ideas (and those of other cultural evolutionists as well), especially his neglect of human special characteristics which differentiate us from other species. The main weak point, in the view of the critiques, was the randomness of variation in Darwinian evolution theory, which is not applicable in the human case. One of the most extreme objections was Midgley's (1999) attack on Dawkins' theories[11]. She claimed that since humans are actively making choices, affecting their environment and not only being affected, their progress cannot be determined by the same scientific methods that are

9 The word "meme" has recently been included in the Oxford English Dictionary where it is defined as follows: "meme (mi:m), n. Biol. (shortened from mimeme ... that which is imitated, after GENE n.) "An element of a culture that may be considered to be passed on by non-genetic means, esp. imitation".

10 It seems that Dawkins missed the dual meaning of inheritance in his memes analogy: on the one hand there are ideas and habits that are just memorized as existing; on the other hand, there are ideas and habits which influence the behavior of the "descendants". The difference between simply storing the information without causing any behavioral change (or continuity) vs. transmitting behavioral direction is significant, I believe, in cultural evolution. Interestingly, this distinction is equally important in genetic evolution: in fact, most genes of most organisms play no direct role in changing - either their behaviors or their morphologies.

11 Midgley also attacked Dawkins' attribution of selfish motivations to genes; this backfired on her when she was accused of misunderstanding Dawkins' metaphor.

applicable to other species. Another argument (Frank, 1988) was that in the case of humans emotions like love, sympathy, hate, preferences for fairness, anger or fear are strong incentives to people to react in certain ways; these emotions may even induce them to behave in ways not in accordance with conscious selfish rational calculus in a narrow sense. However even Frank concluded that emotions are a stable phenomenon in a selfish rational competitive environment[12].

Another criticism against Dawkins was of his elimination of God's role once evolutionary theories are adopted (McGrath, 2005). However, as religion is part of culture, it seems that it may nevertheless serve as an example of cultural inheritance, variation and evolution by natural selection.

Whether fully or only partially, it is clear that cultural evolution resembles almost all the ingredients of "classical" Darwinian evolution in nature[13]. Next, we will take a special case of culture – science and technology – and examine whether Darwinian methods can apply and be helpful in creating deeper understanding.

3. Second step: science and technology as an evolutionary process

Campbell (1974) took another step towards the application of Darwinian theory to science (although we can consider science as a subset of culture, hence every aspect is relevant by definition), by comparing new ideas to mutations in genes: as a prerequisite for a mutant gene to be able to survive, it must first meet the structural selective requirements of "being a

[12] I think that both Midgley and Frank attacked one of the weak points of the whole Darwinian evolution theory, and not only cultural evolution per se: the random variation component. While their criticism points to the intentional characteristics of human culture and motivation, it seems that there is a lack of any intentional direction or any kind of connection between challenges and the resulting "responsive" variations in the adaptation process, in current evolution theories. An initial step towards bridging the gap may be attributed to Jablonka & Lamb (2005), showing the existence of non-random semi-directed mutations and "induced and acquired changes" that play a role in evolution. They also strongly back the analogy between cultural and biological evolution.

[13] Darwin himself was rather surprised that his ideas were applied to social and cultural phenomena, but he nevertheless favored this approach: "You will readily believe how much interested I am in observing that you apply to moral and social questions analogous views to those which I have used in regard to the modification of species. It did not occur to me formerly that my views could be extended to such widely different and most important subjects." (Charles Darwin's letter to Hugo Thiel, 1869, in: Weikart (1995)). Darwin similarly corresponded with K. Marx as well. Later, Darwin adopted some of the cultural implications of his theory: "Selfish and contentious people will not cohere, and without coherence nothing can be affected. A tribe rich in the above qualities would spread and be victorious over other tribes: but in the course of time it would, judging from all past history, be in its turn overcome by some other tribe still more highly endowed. Thus the social and moral qualities would tend slowly to advance and be diffused throughout the world." Darwin (1871, Ch. 5). He also discussed the psychological forces driving human behavior in society while affecting evolutionary processes, e.g. the need to be praised by colleagues and to conform to the majority.

gene". Likewise, new scientific ideas must meet the implicit requirements of being accepted by the scientific community. Just as genes must adhere to the DNA "rules" which preserve the ever developing inheritance, the scientific community has its "tribal" continuity which must be maintained. There is a difference, however, between "illegally mutated" ideas and genes: ideas can still cause a paradigm shift which will make them "legal" in the new paradigm, whereas illegal genes (as defined above) will not survive.

So, in Campbell's view, the survival of scientific ideas depends not only on their actual compliance with some objective truth, but also on their conformity to the tribal basic instinct for survival[14]. Similar ideas were expressed by Collins (1985) who coined the term "core set" (which basically means the leaders who keep the scientific tribe together).

This criterion should be regarded as the environment which affects the natural selection of scientific ideas. Moreover, a strategy of maintaining tribal continuity is probably inherited in the scientific community and resides in the genes (or memes) of the members. In a way it resembles the "selfishness" of the genes, as discussed in Dawkins (1976), where the main driving force for survival in the natural selection is described as the need to preserve the genes' continuity.

After establishing the survival strategy, the next step must be to determine the variation mechanism: in natural Darwinism, it consists of random mutation and natural selection preferring the fittest; what is the equivalent in the scientific case? In fact, at first glance one might wonder if there is any resemblance, as science advances by logic, deduction, engineering and mathematical reasoning; how can these fundamental advantages of scientific thought be compared to a random, "blind" process?

Campbell's (1960) second major contribution was indeed the insight of the pseudo-random nature of scientific progress. In his paper he describes scientific progress as something which cannot be deduced from prior knowledge. Each step which expanded knowledge beyond anything that could be deduced, was "blind" and taken in a trial-and-error process. Thus we may have found the missing element in the analogy between scientific progress and Darwinian theory: "A blind-variation-and-selective-retention process is fundamental to all inductive achievements, to all genuine increases in knowledge, to all increases in fit of system to environment." Campbell (1960, 2.1.1).

Campbell was probably aware of the "hole" in his theory, which neglected the intentional nature of scientific progress, but he nevertheless contended that even planned steps (to which he referred as "shortcuts") are more blind than deductive.[15]

A more comprehensive theory of how scientific progress is achieved was presented by Pickering (1995). He referred to the two sides, scientists ("human agency") and science/technology ("material agency"), as participating in the same "actor-network", mutually affecting each other. The technological progress is an unstable process until it

---

[14] "An idea is not followed up because it would offend the laboratory head, or because it would give comfort to a rival research group, or because of lack of funding... an idea is rejected because of reasons why it will not work, or because of rumors that a trusted researcher is known to have tried it and failed." Campbell (1997, 8.12).

[15] "The many processes which shortcut a more full blind-variation-and-selective-retention process are in themselves inductive achievements, containing wisdom about the environment achieved originally by blind variation and selective retention." Campbell (1960, 2.1.3).

becomes "tuned". As human agencies strive to advance by modifying the material agencies, they encounter "resistance" (i.e. things are not working exactly as planned), which in turn needs to be accommodated by further modification.
This resistance-accommodation relationship was described as a kind of dance which has a direction. This direction is not straightforward and is continuously modified by redefining of the gaps and the new goals. This type of progress was called by Pickering "the mangle of practice", with an evolutionary type of unpredictable behavior.[16]
Thus, Pickering was able to show that although technological progress appears to have an intentional nature coupled with engineering logic, it is much closer to the trial-and-error process judged by the force of natural selection, as are other evolutionary blind-variation-and-selective-retention phenomena[17].
Lastly, as a special case of technological change, we will examine Expert Systems' fundamental paradigms, and endeavor to identify additional analogies with Darwinian evolution processes, beyond those that are common to every technology.

4. Third step: expert systems in evolutionary perspective

4.1 Knowledge renewal – expertise as an evolutionary process

Expert Systems (ES)[18] are based on a simple and attractive paradigm: since experts are able to perform better than others, if their unique knowledge is extracted, stored in a computerized system, and then made available to the "users" to be applied by them – we can achieve an expert-level performance by any user.
However, there is a fundamental concern when we look at the future: may we assume that something that worked in the past will work in a similar way in the future? The underlying paradigm of ES is that if we apply the unique expert knowledge, based on past experience, in future events, we will be able to succeed. This assumption seems obvious, when applying the same rules repeatedly with the same results. However, various scholars warned in the past that this inductive assumption is dangerous. David Hume (1748), as early as the eighteenth century, doubted that any prediction of future events based on past experience, is justified. Karl Popper (1972) added the insight that we believe in causal relationship only because we observe the repetition of past results coupled with our expectation that there is an underlying rule which is the reason for them. Actually, claimed Popper, this is a deductive process rather than an inductive one[19].

---

16 Others (Tenner (1997); Brown & Duguid (2000)) referred to the same phenomenon as "technologies bite back" and "fight back".
17 "Scientists do not simply fix their goals once and for all and stick to them, come what may. In the struggles with material agency that I call tuning, plans and goals too are at stake and liable to revision. And thus the intentional character of human agency has a further aspect of temporal emergence, being reconfigured itself in the real time of practice, as well as a further aspect of intertwining with material agency, being reciprocally redefined in the contours of material agency in tuning." Pickering (1995, 20).
18 The discussion on ES and the analogy suggested in this paper is limited to "Rule-Based Expert Systems", which are the most popular type of ES. Also, much debate exists on ES's successes and failures, limitations, social resistance and others; this paper deals only with the basic paradigms. A more comprehensive discussion on ES may be found in Romem (2007) and Romem (2008).
19 Popper (1972) even named his book as providing "an evolutionary approach"…

So, if we want to be cautious, we should not just take for granted that what has worked in the past will do so in the future. Still, the rules are written in ES for future use, so perhaps this paradigm is too dangerous?

A partial answer to this concern is that experts, at least the better ones, are aware of the fact that what has worked in the past might not work in the future. Those who are fixated by former experience, always performing as they did in the past, are probably not "good experts". Only those who are capable of adapting past experience to new circumstances may be considered good experts. The rules, which refer to past experience, are only adequate as one input for the right decision in a new scenario. This "adaptation" capability is most important for making a good expert[20].

The issue of adaptation is strongly related to the dynamic nature of the relevant environment. If everything is stable, including the goals, then we may expect that all the concerns about updates of the rules are less significant. Once there is a "steady state" where the rules function as a "close enough" recipe for decision making, there will be no need to change them. All that is required is to learn how to use them properly. However, we must assume that organizations experience continuous changes, where the business and cultural environments are dynamic. As ES are static in nature, the adaptation issue becomes crucial.

There are various researches dealing with "adaptive expertise", trying to trace what makes experts employ adaptive capabilities[21]. However, the fact that experts can adapt better than others to new circumstances, is beyond our current knowledge extraction capability. This tacit, non-algorithmic and possibly intuitive capability, remains out of the reach of current ES, as further analyzed in Romem (2008). Since the need for adaptation originates from changes, and we assume that experts have good adaptation skills, the key to understanding this phenomenon is by trying to understand how successful knowledge changes occur.

Various scholars described the process of knowledge renewal as "a trial-and-error process, which leads unconsciously to improvement without specifically knowing how we do it" Polanyi, (1957, 101). The dynamics of this process presents an obvious challenge to ES: "…beliefs held by individuals are modified through negotiation with other individuals…But the information encoded in a knowledge base is not modified in this way" Forsythe (1993, 466). What is especially challenging is the innovation aspect. How experts find new ways to cope with new circumstances remains mystifying. Collins (1990) described innovation not as a structured methodological strategy, but rather more like a "gang of cutthroats" fighting for the wheel to direct a truck, with almost random result. Similarly, as mentioned in the previous chapter, Pickering (1995) described it as a kind of "dance of agencies" where human and material agencies participate in a "resistance – accommodation" relationship, resulting in unpredictable progress.

---

20 Polanyi (1958) found a clear distinction between assimilation of experience into an existing fixed environment, and the adaptation of a current framework according to the lessons of a new experience. The degree of novelty and an even heuristic approach is much stronger in the second case. In our case, the users of ES are required to perform the more challenging task of adaptation of the rules provided to them, which correspond to what Polanyi defined as "current framework". Shanteau (1992, 267) referred to "The competence seen in experts [which] depends on having stable strategies developed in response to their environments."

21 E.g. Fisher & Peterson (2001).

Combining all the above observations on expertise renewal, a dynamic, trial-and-error process, with random steps, which eventually lead to improvements (or "adaptation") – it is tempting to compare it to a Darwinian evolutionary phenomenon. Darwinian Theory is based on similar processes and even uses similar terminology[22]. As revealed here, ES and Darwinian evolution have similar characteristics, apart from a crucial one: natural selection's retention criterion. How can we compare these two processes if there is no mechanism which determines the "winning direction"?

A careful consideration may lead to an answer to the missing component: experts gain their positions as the ones who are able to adapt; the natural selection criterion is the survival of experts in their position. Those who do not adapt successfully do not survive as experts. Fisher & Peterson (2001) and Wineburg (1998) distinguished between "sure-footed" experts whose expertise is based almost solely on "prior knowledge" and experts who continuously seek new insights with a broader perspective, thus employing an "adaptive expertise". In the present context, the latter are the "winning species".

Thus, we may have found the missing link: experts react to dynamic environments; they (sometimes unconsciously[23]) engage in trial-and-error processes while creating intuitive "mutations" of previous behavior; as long as they are successful, thereby maintaining their expert status, they have successfully adapted; those who fail to adapt, are passed over as future expertise reference.

Although the analogy contains all the required ingredients, it seems that one step is weaker than the others: the variation step. While biological variation originates from random mutations, the usual strategy of experts when striving to solve an unprecedented problem is not to try "all" possible mutations, at random, until one prevails; they rather apply more thoughtful considerations, favoring those directions which seem to offer better solutions[24].

---

22 In the classical Darwinian Theory literature, the terms of "random variation", "mutations", "adaptation" and "survival of the fittest" are fundamental. The last is discussed in this section; another basic Darwinian term – "inheritance" – is discussed in the next section.

23 Penrose's (1989) analysis reveals a somewhat surprising conclusion about the way humans make decisions: their consciousness enables them to make "non-algorithmic" decisions; only when they are unconscious do they make pre-defined procedural decisions. Therefore, we can conclude that rule-based Expert Systems are closer to simulated unconscious decisions. Unlike ES, when experts make conscious decisions, these decisions may be different from their corresponding rules…

24 Brandon (1994) contended that humans, unlike other species, act thoughtfully. Combining this idea with Penrose's (1989) (mentioned above) about humans' conscious non-algorithmic behavior, it may strengthen the concern that Expert Systems' rules can only cover unconscious decisions by experts. However, one explanation is that the reason that experts' conscious decisions seem to be intuitive/tacit/non-algorithmic is because the experts do not know their algorithm; yet when experts make conscious decisions (or thoughtful, as Brandom would say), the fact that they cannot tell us how they did it, may suggest that at *the moment of decision* they made it unconsciously. So, there might be some underlying rules which caused the decision (although experts are not aware of them). This means that even conscious decisions may be governed by rules; we simply asked the wrong person…

This difference between the human approach to solving unprecedented problems and nature's approach may indeed be regarded as, on the one hand, a gap in the analogy revealed in this paper and, on the other hand, a trigger for further research. For such research two potential directions are recommended: one, in the area of "genetic algorithms" – which currently imitate nature's approach by applying random variations when trying to find the best way to solve a problem; and the other in the post-Darwinian evolution theory itself – by seeking some hidden mechanism in the genes that reacts to problems which the species experience. I believe that such a mechanism which "shortcuts" the blind-variation-and-selective-retention process (by making it less blind) will make the evolution theory more comprehensive.
The two suggested areas of further research may strengthen the analogy suggested in this paper; nevertheless, there are much more important reasons for adopting them. In any case, the similarities between knowledge renewal (in life and in ES) and evolutionary process were shown; we are ready now to turn to another area of resemblance: the inheritance process.

4.2 Knowledge transference as an inheritance process

ES' common process of knowledge transference from experts to the users seems to be very straightforward: the expert tells a "Knowledge Engineer" (KE) all the details of his or her knowledge, than the KE codifies the knowledge as rules in the Knowledge-Base (KB) of the ES. These rules are in the form of: IF {A} THEN {B}: when situation {A} occurs, the users should do {B}. This process of knowledge extraction from the expert and the use of it by the user are described in figure 1.

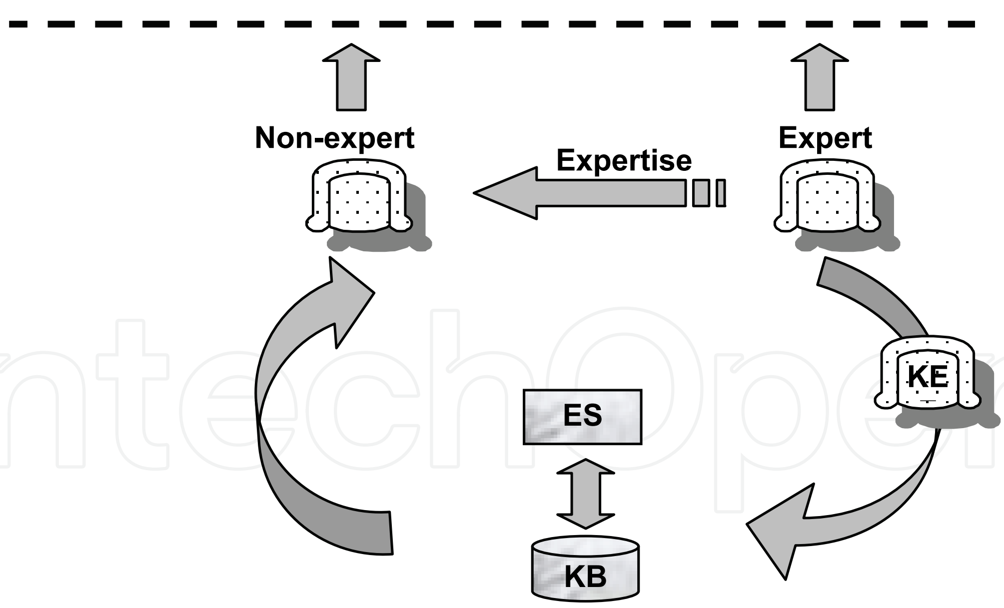


Fig. 1. Knowledge Transfer in Expert Systems

The goal of knowledge transfer is to enable the non-expert to act as an expert, or to be regarded by the outside world (above the dashed line in figure 1) as an expert. Adopting the Darwinian connotation, we may define the behavior of the expert as the phenotypic characteristics which should be transmitted to the non-expert, like an inheritance process (the upper arrow in figure 1). This can be regarded as "memetic" inheritance (using memes as the unit of selection). It differs from the original Darwinian inheritance only in that it is not between generations but rather between colleagues, but this is similar to any cultural evolution.

This difference should not detract from the analogy: Mameli (2005) contended that even the use of the term 'inheritance' for genetic transmission was always a metaphorical one. In his view, the reference by evolutionists (including Darwin himself) to the practice of parents giving property to their offspring to describe the "like-begets-like" phenomenon, should not mislead us in our research. In fact, knowledge transference and genetic inheritance seem to be closer than the original metaphor of gift of property: unlike the latter which involves the transition from one owner to another, in the knowledge case as well as the biological case, the donor remains in possession of the original "property".

Now, the next step is to examine how this inheritance mechanism is implemented in ES: the knowledge is articulated as rules in the Knowledge-Base (KB). Thus the rules in the KB are in essence the "code" representing an expert's behavior, just as genes are the code for the characteristics of any species. In other words: rules represent expertise, just as genotype represents phenotype. This relationship is shown in figure 2.

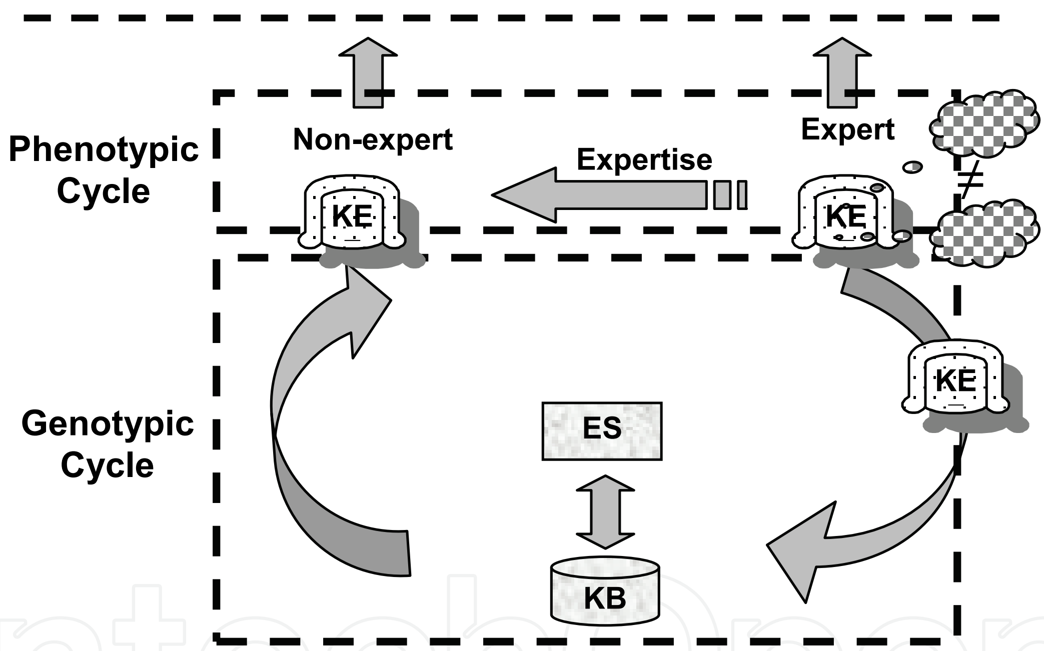


Fig. 2. Knowledge Transfer in Expert Systems

In the expertise inheritance process, the expert is asked to articulate his or her expertise. There is a hidden assumption in equating what we are doing with what we think or say we are doing namely, that when we do things we can always tell how we did them. This assumption is found to be wrong. This is marked in figure 2 in the gap between the expert's mind and the expert's words.

This gap was recognized by various philosophers such as Polanyi who argued that there is a distinction between practicing expertise and being able to explain it explicitly: “the aim of a skilful performance is achieved by the observance of a set of rules which are not known as such to the person following them” Polanyi (1958, 49). His conclusion: “even in the modern industries the indefinable knowledge is still an essential part of technology”. For this kind of indefinable knowledge Polanyi coined the term "tacit knowledge".

This is a rather surprising observation, as people naturally tend to assume that experts know the rules by which they practice their expertise. Examples include: the skill of swimming, a cyclist's balance, the 'touch' of the pianist, flying, skiing, cooking and many others. It is very difficult for experts to shift their attention from doing what they are doing to being aware of *how* they are doing it. In many cases, they cannot do both at the same time Polanyi (1957; 1958). The point is that describing explicitly what one does requires different skills from just doing it[25]. Proclaimed experts will have "earned" their title not on account of any skills of articulation they may have but because of their practicing skills. Yet, the whole process of knowledge transfer relies heavily on the ability of experts to describe what they do, something in which they are not experts at all.

But after our conclusion that knowledge transfer resembles inheritance in evolution, this difficulty is not so surprising: determining the underlying rules from the behavior of the expert is similar to determining the genetic structure from the phenotypic appearance… Just as the latter is not likely to succeed, we should not be surprised about the tremendous challenges that are encountered in expertise transference.

Another challenge was pointed out by Mameli (2005); in his view, simple DNA-copying is not sufficient for transmitting the full phenotypic behavior which is influenced by the environment and culture in a non-genetic way. ES knowledge transference resembles the same phenomenon: the rules must be interpreted in the context of the original environment when they were coded. As this environment is not part of the rules themselves, following them may produce wrong results.

There is a limit, however, to the suggested analogy: in the ES case, there is an ultimate measure of success: users performing in an expert-like way or being able to do "the right thing" as needed; in the genetic inheritance case the measure of success, if any, is more vague. Is the offspring "as good" as the ancestors? It seems that this direction is more philosophical than practical, although one may conclude, in the Dawkins' way of thinking, that the success of genetic inheritance is in the survival and continuity of the genes.

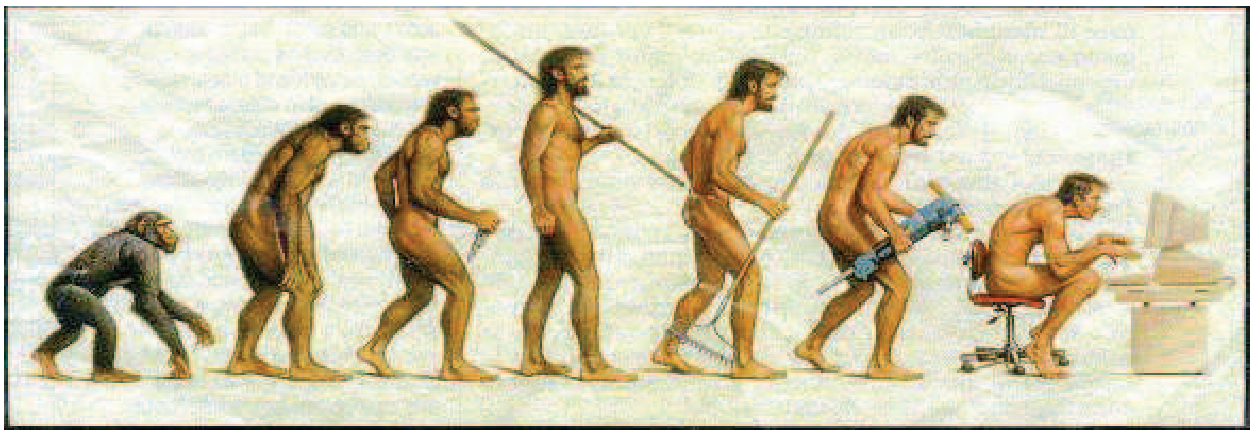
5. Conclusion

In summary, there is a close analogical relationship between Expert Systems fundamental processes and Darwinian evolution processes: Just as evolution reaches a stabilization phase only after a successful mutation survives the natural selection, so does the new knowledge of the expert become a habit and noticeable only after it has been successfully transmitted as rules in the Expert System[26].

[25] Polanyi (1958, 88) summarized this phenomenon: "I know that I know perfectly well how to do such things, though I know the particulars of what I know only in an instrumental manner and am focally quite ignorant of them; so that I may say that I know these matters even though I cannot tell clearly, or hardly at all, what it is that I know." Polanyi (1957) also quoted Gauss: 'I have had my solutions for a long time but I do not yet know how I am to arrive at them.'

[26] This is not enough to make the new knowledge inheritance successful: Romem (2008) showed that even if the rules are correct, the user might wrongly interpret them, the future scenario might be different, the goals or motivation for acting in a certain way may have changed and various other conditions may cause unexpected results.

The challenge of transforming phenotypic new knowledge to genotypic new explicit rules is the articulation challenge. In this analogy, rules in the Knowledge-Base act as does DNA in humans. The rules are implicit in their phenotypic phase and become explicit in their genotypic phase, thus enabling "inheritance" by the users. This inheritance is, in a sense, the goal of Expert Systems.



6. Acknowledgement

Dr. Oren Harman's important comments helped me sharpen the ideas; Professor Menachem Fisch and Professor Niv Ahituv's guidance in my original Dissertation; Dr. Noah Efron's continuous encouragement – they all turned my research and writing into an enjoyable and fulfilling experience.

7. References:

Avital, Eytan and Jablonka, Eva. 2000. *Animal Traditions: Behavioral Inheritance in Evolution.* Cambridge, MA: Cambridge University Press.

Blackmore,S.J. 1999. *The Meme Machine.* Oxford, UK: Oxford University Press.

Brandom, Robert B. 1994. Making it Explicit: Reasoning, Representing, and Discursive Commitment. Harvard University Press.

Brown, John S.and Duguid, Paul. 2000. *The Social Life of Information*. Cambridge, MA: Harvard Business School Press

Campbell, Donald. T. 1960. Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review*, 67: 380-400.

Campbell, Donald T. 1965.Variation and Selective Retention in Sociocultural Systems. In: *Social Change in Developing Areas* . Edited: Barringer et al.

Campbell, Donald T. 1997. From evolutionary epistemology via selection theory to a sociology of scientific validity. *Evolution and Cognition* 3: 5-38.

Collins, H.M. 1985 Changing Order: Replication and Induction in Scientific Practice Thousand Oaks, CA: Sage

Darwin, Charles. 1871. *The Descent of Man*. Penguin Classics (republished 2004).

Dawkins, Richard. 1976. *The Selfish Genes*. Oxford, UK: Oxford University Press

Fisher, Frank T.and Peterson, Penelope L. 2001. A tool to Measure Adaptive Expertise in Biomedical Engineering Students. Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition: 2793.

Forsythe, Diana E. 1993. Engineering Knowledge: The Construction of Knowledge in Artificial Intelligence. *Social Studies of Science* 23(3): 445-77

Frank, Robert. 1988. *The Strategic Role of Emotions.* New York & London: W.W. Norton & Company.

Greisemer, James. 2000., *Philosophy of Science* Vol. 67, Supplement. Proceedings of the 1998 Biennial Meetings of the Philosophy of Science Association. Part II: Symposia Papers: 348-68

Hume, David. 1748. *Enquiries Concerning Human Understanding and Concerning the Principles of Morals*. Oxford: Oxford University Press, 1975. Original: 1748; (ed. L.A. Selby-Bigge, rev. P.H. Nidditch).

Jablonka, Eva and Lamb, Marion. 2005. Evolution in Four Dimensions: Genetic, Epigenetic, Behavioral and Symbolic Variation in the History of Life. Cambridge, MA: MIT Press.

Latour, Bruno. 1987. *Science in Action*. Cambridge, MA: Harvard University Press

Mameli, Matteo. 2005. The inheritance of Features. *Biology and Philosophy* 30: 365-99

McGrath, Alister. 2005. Has Science Eliminated God? – Richard Dawkins and the Meaning of Life. *Science & Christian Belief* 17(2): 115-35

Midgley, Mary. 1999. *Science and Poetry.* New York: Routledge.

Penrose, Roger. 1989. *The Emperor's New Mind*. Oxford, UK: Oxford Univ. Press.

Pickering, Andrew. 1995. The Mangle of Practice: Time, Agency and Science. Chicago, IL:The University of Chicago Press.

Polanyi, Michael. 1957. Problem Solving. *British Journal for the Philosophy of Science*. 8 (30): 89-103

Polanyi, Michael. 1958. *Personal Knowledge: Towards a Post-Critical Philosophy.* Chicago, IL: The University of Chicago Press 1958,1962.

Popper, Karl R. 1972. *Objective Knowledge: An Evolutionary Approach.* Oxford, UK: Oxford University Press.

Richerson, Peter J.and Boyd, Robert. 2000. Evolution: the Darwinian Theory of Social Change, an Homage to Donald T. Campbell. In: *Paradigms of Social Change: Modernization, Development, Transformation, Evolution*. Edited: Schelkle, W. et als. Frankfurt: Campus Verlag.

Richerson, Peter J.and Boyd, Robert. 2005. *Not by Genes Alone: How Culture Transformed Human Evolution.* Chicago, IL: University of Chicago Press.

Ridley, Matt. 1998. The Origins of Virtue: Human Instincts and the Evolution of Cooperation. USA: Penguin.

Romem, Yoram. 2007. The Social Construction of Expert Systems. *Human Systems Management*. 26: 291-309.

Romem, Yoram. 2008. *Expert Systems: the Promise, the Disappointment, the Comeback.* Bar-Ilan Univ. Israel, (Ph.D. dissertation)

Shanteau J. 1992. Competence in Experts: The Role of Task Characteristics. *Organizational Behavior and Human Decision Processes* 53: 252-66.

Smith, Adam. 1790. *The theory of Moral Sentiments*. London, UK: A. Millar 6th edition (1st published 1759)

Tenner, Edward. 1997. Why Things Bite Back: Technology and the Revenge of Unintended Consequences. New York: Vintage Books.

Weikart, Richard. 1995. A recently discovered Darwin Letter on Social Darwinism. *ISIS* 86: 609-11

Williams, G.C. 1966. *Adaptation and Natural Selection*. Princeton, N.J: Princeton University Press

Wineburg, S. 1998. Reading Abraham Lincoln: An Expert/Expert Study in the Interpretation of Historical Texts. *Cognitive Science* 22(3): 319-46

Wynne-Edwards, V.C. 1962. *Animal Dispersion in Relation to Social Behaviour*. Edinburgh: Oliver & Boyd

Expert Systems
Edited by Petrica Vizureanu

ISBN 978-953-307-032-2
Hard cover, 238 pages
Publisher InTech
Published online 01, January, 2010
Published in print edition January, 2010

Expert systems represent a branch of artificial intelligence aiming to take the experience of human specialists and transfer it to a computer system. The knowledge is stored in the computer, which by an execution system (inference engine) is reasoning and derives specific conclusions for the problem. The purpose of expert systems is to help and support user's reasoning but not by replacing human judgement. In fact, expert systems offer to the inexperienced user a solution when human experts are not available. This book has 18 chapters and explains that the expert systems are products of artificial intelligence, branch of computer science that seeks to develop intelligent programs. What is remarkable for expert systems is the applicability area and solving of different issues in many fields of architecture, archeology, commerce, trade, education, medicine to engineering systems, production of goods and control/diagnosis problems in many industrial branches.