MULTIPOLAR SELECTION IN BIOLOGY, HISTORY AND EPISTEMOLOGY

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Evolutionary Epistemology has evolved since the early studies of the late seventies. Donald T. Campbell's most recent model met Denis Buican's synergic theory of multipolar levels of cultural selection. This general paradigm brings solutions to the problems raised against the former Darwinian analogies between natural evolution and science history. It also suggests a new approach of old questions dealing with tempo and modes in the development of scientific ideas. Such a paradigm could finally have a more general validity and become a selectionist theory of all kinds of evolutions.

INTRODUCTION

In his last works, Donald T. Campbell (1990, 1995, 1997) realized the importance of the various levels of cultural selection in a more complete selectionist model of evolutionary epistemology. This conception thus came very close to the one I developed independently from Denis Buican's synergic theory of evolution. Indeed, both admit a strong analogy between:

– DNA and language as supports of encoded information;
– genetic mutations and new scientific hypotheses;
– natural and cultural selection;
– the biological organizational levels (genotypic, cellular, individual, group, etc.) at which selection acts (Campbell's "nodes of selection") and the cultural ones (the scientist's mind, research community, nation, etc.).

Since the works of pioneers as Dawkins (1976), Popper (1979) and Hull (1988), this is probably the most important step in a valid answer to the problems raised by the selectionist model such as presented by John Ziman (2000: 5–6), and especially:

– a certain "Lamarckian" feature of cultural evolution, opposed to the "Darwinian" selectionist model because of the conscious design of human thought (a);
– the fact that genes and memes (Dawkin's basic entity of cultural evolution) are not equivalent (b);
– the frequent recombination of memes from distant cultural lineages (c).

This paper aims at presenting some characteristics of this new conception of evolutionary epistemology and its advantages in a valid comprehension of cultural history.

1. THE SYNERGIC THEORY IN ITS BIOLOGICAL FIELD

1.1. GENOTYPIC SELECTION

In the first Romanian book of genetics (1969), Denis Buican created the concept of “genotypic selection” (A), which was a major step to a revolution in evolutionary biology: the synergic theory of evolution. Because of Lyssenkism, his works were censored and the new conception could not be popularised before D. Buican arrived some years later in France, where he faced an important neolamarckist opposition, in biology as well as in philosophy. Nevertheless, Denis Buican began to develop new selectionist ideas inspired by the neodarwinist synthesis of the years 1937–1945 (1989, 1997).

For more than forty years biologists discuss the question of whether or not natural selection acts only on organisms (i.e. phenotypes) or directly on genes. Most Darwin’s followers thought that natural selection plays only a role on phenotypes, because competition happens among organisms and in the relationship between each one and its environment. Ernst Mayr for example thought that it is impossible for natural selection to select one or some genes within an organism. However, as Denis Buican wrote thirty years ago, convincing proofs are actually showing that natural selection acts both on phenotypes and genotypes, and even beyond, on other levels of organization in living beings (Reeve and Keller, 1999: 5). For example, geneticists can cut up a single gene, as any part of a chromosome, or insert it in another genome. And there are lots of natural analogous to this artificial selection allowed by the methods of genetic engineering, for example in the cases of distant hybridisation. Thus, when a cultivated species of barley (*Hordeum vulgare*) is crossed as female genitor by a wild species (*Hordeum bulbosum*) as male, the embryo eliminates spontaneously its father’s chromosomes and its abnormal development generally leads to an abortion (Buican, 1997: 40). This proves the validity of genotypic selection, also called “intragenomic selection” or “meiotic drive”, which is completely independent of the relationship between a phenotype and its environment, because it acts before the existence of a phenotype. Here selection plays on a level of organization that Darwin did not consider with his struggle for life.

Still more convincing are the cases of selective conflicts. The *t* mutation in the mouse is lethal when inherited in two copies (one carried by each chromosome of the pair) and relatively neutral when possessed in one copy (only one of the two chromosomes). But in this latter case, the *t* mutation produces a poison that kills the male gametes (each one having only one chromosome) which have no *t*. Also all the surviving spermatozoids of a generation have a *t*. As a result, the whole population of mice soon bear the *t* mutation but half the embryos die (because they have two *ts*). Thus selection favours *t* (genotypic selection) and fights against it (phenotypic selection) at the same time. Another interesting case opposes cells to their genes. Indeed, botanists have known the phenomenon called "polyploïdy" for ages: concerned plants possess not only two copies of each type of chromosomes, but three, four, or even more, as in cultivated wheat. But this increase in the number of chromosomes presents a limit when the cell cannot hold all the chromosomes together anymore and die. On another level of organization, geneticists note cases of a great number of copies of a single gene in one chromosome. If so, there must be another limit when this multiplication reduces the efficiency of the infected cells.

Richard Dawkins deduced from these examples that genes are the only targets of selection whereas the organisms are their "vehicles", that is, the units directly confronting selection. According to him, Hull distinguished two key elements in all types of evolution: the "*replicator* – an entity that passes on its structure largely intact in successive replications" and the "*interactor* – an entity that interacts as a cohesive whole with its environment in such a way that this interaction *causes* replication to be differential" (1988: 408). But in the cases of intragenomic selection, genes appear both as replicators and as interactors. As D.T. Campbell wrote, "*Dawkins* (1976) made famous the conception of "the selfish gene" (not referring to selfish DNA). In my judgment, he confused the unit of retention (the gene) with the unit of selection" (1997). Thus genotypic selection is clearly different from the result of Darwin's struggle for life. But genotypic selection remains only one among many kinds of Buican's "multipolar" selection. Of course, the old cases of selection among phenotypes (B) remain valid and must be distinguished from genotypic selection. Indeed, numerous genes have pleiotropic effects which influence a lot of characteristics of the phenotype. So, the fitness of the organism is not equivalent to the addition of the fitness of its genes. The Darwinian natural selection is also a particular case of multipolar selection, and even the most frequent.

1.2. GROUP SELECTION

Furthermore, comparative ethology and Wilson's sociobiology proved that, at least in some ants' and bees' societies, phenotypic selection does not prevail, because all workers have the same genotype (2000). Only groups – ant-hills and hives – compete with one another. In this case, the queen's success lies in the victory of its colony. Even Ernst Mayr (1997) admitted this group selection (C) providing that there is a real cooperation among the members of the group. For example, sentries of some species of mammals give alarm to the rest of the group when predators are drawing near. Thus the fitness of the group is higher than the amount of each individual's fitness (and the whole is more than the sum of its parts, according to Bertallanfy's theory of systems). However, group selection does not simply take the place of genotypic and phenotypic ones, because, as Reeve and Keller wrote: "even if the creation of higher-level vehicles requires that attractive forces exceed repulsive and centrifugal forces, this does not imply that the latter forces will disappear once the higher-level vehicles are formed" (1999: 9). Campbell even indicated conflicts between these hierarchical levels of organization: "Vis-a-vis individual interests, we need to bear in mind a 'selfish group' concept and recognize that effective selection at that level is selection for organizational and institutional self-perpetuation, at the expense of the individual if need be (and within limits)" (1997). All selective pressures can be seen as vectors, sometimes complementary, often antagonistic, on the same or on different levels and acting on vehicles in Sewall Wright's adaptive landscapes (1980). Such a probabilistic conception of various selective forces is essential.

Indeed, it matches Buican's new concept of multipolar selection, that is, the fact that biological selection acts differently on each level of complexity. This remains controversial among specialists. However, it explains a lot of phenomena far better than the mysterious word of "constraints" used by Stephen Jay Gould and Richard Lewontin (1979). Above all, Buican's synergetic model agrees with Pierre Jaisson's theory of "cooperons" (about the role of cooperation in evolution) explaining that selection among lower-level biological vehicles creates higher-level vehicles (1993). According to the endosymbiosis theory, cellular organelles (mitochondria, chloroplasts) were integrated into the first cell before cells united themselves into individual organisms (Szathmary, 1999: 32–52). And sociobiology argues that an analogous phenomenon probably produced societies from the free individuals. Such a view matches Turchin's model of metasystem transition (see Heylighen and Campbell, 1995).

Thus, the levels of complexity are not artificial concepts, but results of biological evolution. Moreover, this conception agrees with recent discoveries about cellular competition inside the complex species as vertebrates and especially mammals. Jean Dausset explained an important part of the HLA system (for immunity) by a selective multiplication of the competent cells acting against an infection. And more recently, Pierre Sonigo proposed a selective model of cellular specialization during embryogenesis by a trial-and-error process (1997). All these new hypotheses and facts are increasing the plausibility of the synergetic theory and its multipolar selection acting on the various levels of complexity in living beings. Moreover, Gerald M. Edelman and Jean-Pierre Changeux showed that the development of the brain requires a selective retention of the activated neurons and the elimination of the others. This can bridge the gap between biological and cultural evolution.

2. THE SYNERGIC THEORY OF HUMAN SCIENCES

2.1. VIRTUAL SELECTION IN POPPER'S "THIRD WORLD"

Studying the works of the French evolutionary biologists and palaeontologists from the eighteenth century to the present day, I argued in many books and papers that the selectionist model offers an elegant interpretation of cultural history (Grimoult, 1998, 2000, 2001a). Indeed, it can solve old problems, such as the controversies between internalism *vs.* externalism and gradualist evolution *vs.* scientific revolutions. It also presents new ways of research for the future. However, the major problem raised against the selectionist model remains that scientific hypotheses are never as blind as genetic mutations (a), because they are "the products of conscious *design*" (Ziman, 2000: 5). Ernst Mayr and Gould, among others, also concluded that cultural evolution does not follow a Darwinist process. Nevertheless, this point has now been cleared. As David Hull pointed: "Novel variants in conceptual evolution are "pre-selected" in the sense that they have to fit into what a particular investigator already believes. For all the beliefs that are tested in a literal sense, there are hundreds that have been tested only via "thought experiments" (1988: 456). Further, Campbell understood that if new ideas do not appear by a trial-and-error process, then we must agree with inductionist philosophy – which seems completely refuted today.

Unfortunately, even specialists know very little about the process of ideation, i.e. how a new idea appears in the mind. Following Kant, idealists found some support in the innate ethograms of animals like ants or birds feeding their offspring (Lorenz). But the neurologist approach of Edelman and Changeux, who compare the brain with a simulator which recreates the facts and the data we face daily seems to be more interesting. The solutions of our problems often come from our past experience, with a system of time saving by reinforcement. But these first ideas may not be adapted to new puzzles. As the psychologist Osborn wrote: "In front of a new problem, we tend to think only of the limited solutions already used to solve analogous problems". But even when the scientist has understood that a problem is entirely new, he tries to compare it with old ones. Thus, the creation of a new hypothesis is a selective process, like any comparison. Creativity and imagination may use old elements, as life does with the rearrangement of old genes into new genetic sequences (it is what François Jacob called 'tinkering about' – 'bricolage'). Imagination also combines old and new ideas or parts of thoughts in all the possible ways, as in a kaleidoscope.

This is why the structuralist approach of many French philosophers (like Michel Foucault) remains false. Indeed, the structuralists insisted on the logical links between the ideas of a given historical time. Thus they believed more in the logic of collective science than in individual originality. For example, neither Foucault nor Canguilhem understood how the probabilism of Mendel's laws could appear in the context of scientism and determinist philosophy in the middle of the nineteenth century (Grimoult, 2003). Also they admitted more the necessity of a "development" of scientific ideas (analogous to a programmed embryogenesis) than historical chance and contingency. Actually, everything refutes such a determinist conception, especially when fine studies in science history prove that many competing solutions are often defended at a given time, as Kuhn already suggested (1969: 76).Then the structuralists underestimate the genealogical links among ideas in a perpetual recombination, which do not imply only scientific revolutions but a gradual conceptual evolution too.

Scientific revolutions happen above all when a new theory rises against its cultural context, like Darwinism during the Victorian era, and Kuhn (also like Bachelard) thought that there was no major theoretical change without a revolution. For him, "normal science" can record some new elements, but nothing of great importance. If this remains true, it can divert our attention from more discreet, peaceful and gradual changes. Indeed theoretical change is also a current phenomenon, especially in the modern scientific international community (as Latour's "technosciences"), because competition opposes not only cosmogonies but also local interpretations and even particular ideas. The least ambitious ones are the most numerous.

2.2. MULTIPOLAR CULTURAL SELECTION

This confirms our synergetic theory of cultural evolution based on three major selective levels. First, a new scientific hypothesis (completely new or made of a fresh arrangement of old elements) appears in a scientist's mind where it faces other analogous ideas. Here, the thinker considers the pros and cons, i.e. compares and evaluates their plausibility. His criteria are above all logical and concern the agreement of the idea with the known facts, which explains the importance of experimentation. Of course, scientists are often blinded by their prejudices and especially their religious beliefs. But they must present their new ideas in accordance with the criteria of validity of their time to have a chance of heard. This first level, made of a virtual competition, corresponds to Popper's "third world" and is analogous to genotypic selection (A). Science historians now consider it seriously, thanks to the notebooks of famous people as Darwin. François Jacob focused our attention on the differences between open science and its dark side of trials and errors consciously cut out of publications to make it appear as if the new hypotheses were obvious and undeniable.

But in fact, if a hypothesis succeeds in a scientist's mind and is published, then it faces other ideas supported by competing researchers. Nevertheless, the idea is generally not published alone, but integrated with others into a theory. This theory (or "paradigm" to use Kuhn's concept – we will examine the difference below) is presented as the solution of a puzzle. Scientific choice also passes to a social level, where logic and facts are still not the only criteria of success. For example, scientists generally pay more attention to the theories of famous peers or of the people belonging to their own network of research. Experiments play a role but method is a major point at this level, as it was discussed in the great debates which caused scientific revolutions (as Kuhn showed) or aborted ones (like the 1830 debate between Cuvier and Geoffroy Saint-Hilaire for the evolutionist theory in the eyes of the members of the French Academy of Sciences, see Grimoult, 1998). This level is analogous to the Darwinian natural selection (on phenotypes), because theories face one another in a general scientific context (B). Moreover, as natural selection cannot generally select a particular gene, the general cultural selection does not segregate the hypotheses allied in a theory. Above all, whereas more freedom is possible in the scientist's mind, there are more restraints on the social level. For example, when Weismann rejected the false hypothesis of the heredity of acquired characters, he was accused of disparaging the evolution theory, whereas he just specified its central mechanicisms. Each new scientific idea must serve the interests of fellow scientists who may first appear reluctant to give credit to someone else than them (because they are competing, too).

There is a third major selective pressure in cultural evolution. This one recalls group selection, because theories are not only evaluated alone, for themselves, but allied with others, to form systems and cosmogonies integrating values (C). On this more general level a competition takes place between sociocultural systems and civilisations. Thus, according to Merton, modern science appeared in Europe and North America, allied with other cultural themes as democracy and capitalism (all based on a selectionist mechanism). Stephen Shapin and Simon Schaffer showed how Boyle's air pump and the experimental method succeeded around 1660 because of particular political and social conditions. But, this does not imply a relativist epistemological point of view, as Raymond Boudon wrote: "what is true in the short term may become wrong in the long term. In the same way, convictions may seem to be based on subjective reasons at each moment and to be based on objective ones in the long term" (1995: 518). But, in all cases, science helps the societies where it takes place in their economic and geopolitical struggle and their success in turn benefits science. For example, Lyssenko fought against genetics in the USSR of the years 1935–1970. Stalin even wanted to eliminate nuclear physics – before Piotr Kapitza convinced him that he would never have atomic bombs without it – because his “historical materialism” remained purely determinist and left no place to chance in nature. Despite local successes (as in the space field), science was limited and censored in the USSR, which partially caused its failure during the 1970s and 1980s.

On all these levels, nothing else than the scientists’ intimate conviction and interests can explain the success of a given idea. But this does not imply that all adopted ideas are right or that right theories are necessarily adopted. Their success depends on the context and on the beliefs of individuals, as Latour showed in his famous *Science in action*. But no relativism is implied by such a fundamental remark whereas no “conviction can be forced”, as Kuhn wrote (1969, ch. XII). Because a speculative idea, founded on few references ordinary does not receive agreement of the colleagues, and above all, of the competitors. This explains why the social relativist look of cultural success finally matches the realist epistemology which is based on the practical efficiency of modern science through its technological applications, experiments, and finally: nature.

Moreover, social levels are no more artificial than biological ones. Thus, according to Latour (ch. 3), scientists must recruit others and show their interest in their support to ascertain a fact. Richard E. Michod almost used the same words about biology: “To understand the evolution of individuality and new levels of organization, we need to identify and explain evolutionarily those mechanisms and structures that serve to align the interests of the lower-level units with the interests of the group” (1999: 58). Of course, theories as living beings are also parts of their context and then constitute elements of the competition with the others. Thus, a new fact may make it necessary to change the adopted paradigm in its scientific field. This explains the importance of coevolution in culture as in nature. Indeed, as Reeve and Keller wrote, a problem is to know “given that multiple levels of vehicles exist, how natural selection at one level affects selection at lower or higher levels” (1999: 7). Of course, the selection on the first levels is stronger than the others. And it explains why it could remain unnoticed for a long time. Indeed, most of the mutations acting here are quickly eliminated because a stochastic change has little chance to be preadapted to so many conditions. A refoundation of physics or biology is improbable – but not impossible – and would cause a scientific revolution. On the contrary, minor refinements can easily appear and temporarily proliferate. In turn, a change in the social structure of science and culture can affect admitted knowledge, as Christian dogma ended antic philosophers’ speculations in the Middle Ages or as Marxism-Leninism touched science and education in the Stalinist USSR. Indeed, neither pure inductionism nor externalism alone can explain how a new idea (fact or theory) takes root in the cultural context. We must consider a synergic approach, which can be summed up by Fig. 1.

natural outer environnement		THE SCIENTIST'S MIND (inner environment)		**cultural outer environment**
phenomenon	→	PROBLEM	→	**search for models**
				↓
experience	←	HYPOTHESIS	←	←
↓				
→	→	CONFIRMATION (or REFUTATION)	→	**confrontation with the dominant theory**
				↓
				SUCCESS (or FAILURE) i.e. integration (or not) into the **dominant theory**

Fig. 1. – Scientist between nature and culture, a selective evolution.
The arrows indicate a confrontation of a probabilistic nature, and no strict determinism. The words define the major steps of the evolutive process in the human's acquisition of scientific knowledge. Of course, the confrontation with the dominant theory may happen first and generate its own experiments or lead to abandon new ideas which could appear valid after all. But this figure shows the synergy between nature and society which is necessary to ascertain new facts. The search for models corresponds to the first level of selection, the confrontation with the dominant theory to the second one. The results of experiments partake of the selection of ideas on both levels.

The general analogy between natural and cultural levels of selection is not superficial, because historians can observe selective conflicts in the development of science that match the biological ones. Thus, as Hull already suggested, "Science is both a highly competitive *and* a highly cooperative affair" (1988: 286). And Campbell noted: "For those beliefs and organizational forms that are beneficial for the group as a whole, but costly for individual inclusive fitness (producing self-sacrificial altruistic behavior), there is individual-level selection pressure operating against the adaptive group selection" (1997). Sometimes science history can show the opposition between the fitness of a scientific novelty on various levels. For example, the idea of long geological times gained a large support among scientists during the eighteenth and nineteenth centuries, whereas it was completely opposed to the Christian dogma which was imposed by the Church and the Monarchy in France as in England. Not only the biological and geological sciences contributed to weaken the political power of religions, but this process, also caused by the progress of democracy (for example the IIIrd Republic in France after 1875) reinforced the social role of scientists and thus the spreading of their theories and scientism. In fact, scientists are always thinking up new combinations of ideas, hypotheses and theories. They are negotiating with the different constraints of their field, too. But these pressures are always probabilistic and never deterministic, because all arrangements are possible *a priori*. This is well demonstrated by a careful study of the published theories at a given time.

3. ADVANTAGES OF THIS CONCEPTION TOWARDS OTHER EPISTEMOLOGICAL MODELS

3.1. CULTURAL NEODARWINISM

Regarding alternative evolutionary epistemology, as John Ziman's or Eva Jablonka's, three points must be raised. First, concerning the claimed "Lamarkian" feature of cultural change (a), we must ask ourselves by which process the scientists' solutions could be influenced by the problems they have to solve. In the biological examples given by these authors, adaptation is neither the result of a "Lamarckian" process but of a more complex selective one (Ziman and Jablonka, 2000: 16-17). As they wrote: "[…] natural selection sometimes has resulted in systems that lead to […] increased recombination under some situations of environmental stress". I think that our human species succeeded in the struggle for life thanks to such a selective system of cultural evolution. A neoDarwinist model does not make epistemology more complex, but Lamarckism leads to a dead-end, in philosophy as well as in biology. Moreover, we must keep in mind that there is a "natural" cultural selection, too. Indeed, the biological fitness of each beaver depends on the strength of its dams (Dawkin's "extended phenotype"). These animals compete through the adaptation of their artefacts with local environments. Man proceeds differently only in systematizing the virtual trial and errors process, thanks to the experimental method, which saves time and strength (Popper, 1979).

Of course, the scientists can anticipate their colleagues' objections or the difficulties entailed by their experiments. But experiments often fail and bridges may fall down (Ziman, 2000). And, above all, there is no automatic cultural heredity. Each generation selects what seems convenient, but rejects or forgets the rest. Precisely, Campbell and Heylighen present the origins of a possible conflict between the interests of the group and each of its members caused by such a flexibility: "In their mathematical model Boyd & Richerson find that under certain (plausible) conditions it would be optimal for the learners to adopt the majority or plurality beliefs, when several competing beliefs are transmitted by different individuals. Thus, individuals would tend to "conform" to the majority position of their elders and peers. In relatively small groups, this quickly leads to internal homogeneity on all cultural traits" (1995). The major problem of the Lamarckist approach lies in the origin of innovation: Could our senses really be "impressed" by nature? Is it still possible to believe in induction?

3.2. GENES AND MEMES

Second, about the fact that genes and memes are not equivalent (b), we must consider that there are many types of genes. The structural genes encode for the proteins which form the bricks of living beings. But the regulatory genes encode for proteins which play a role of signals in complex metabolic chains from the production of a single protein to the one of an entire new organism. Because of its relationship to language, I think that our scientific culture is based on concepts (as numbers, things, structures…, and other structural memes) and relations (as mathematic operations, comparative terms, and other regulatory memes). Moreover, as Dawkins suggested, we must distinguish between simple and complex ideas. A single concept – as the one of "gene", or Prietley's "phlogiston" – may put in question by scientific progress. But more often scientists work on hypotheses as, for example: "the gene is the unit of selection" or "the phlogiston is what makes a candle burn". Would this imply two selective levels, instead of the only one I proposed above? This may be so, but I think that does not affect science very much. It is more a problem of language evolution, because the smallest scientific entity is the hypothesis (such as "does phlogiston exist?"), which implies a relationship to nature. Be that as it may, scientists publish theories (i.e. combinations of hypotheses to solve scientific problems), which are far more complex than a single hypothesis. The Darwinian theory of the origin of species was made up of many hypotheses among which: the general variability of living beings, its gradual feature, and its persistence through crossings, natural selection, and the long term of geological times. Kuhn's paradigms also include methodological rules which are only implicit for theories. For example, Darwin's opponents refused to consider as scientific the question of the origin because of the impossibility of any direct experiment on the past. On the contrary, Darwin believed that his theory was good because it could explain all the known facts and precisely better than the Christian dogma because of its rational nature. Paradigms include experimental results and artefacts, which cannot be simply reduced to the lower level. Moreover, paradigms do not invade a scientific community without (often minor) individual variations. Such emergent properties are even more evident on the upper level. The sociocultural systems, as civilisations, constitute more general cultural entities which are analogous to populations, but (of course) inside the same (human) species. As biological populations, civilizations cannot multiply (without becoming another complex organism), but they grow larger. And they are helped by economic resources and military forces that are included neither in hypotheses nor in paradigms.

3.3. CULTURAL HYBRIDISATION

Third, about the frequent recombination of memes from distant lineages (c), we must bear in mind that there would be cultural "species" only with completely separate cultures. Indeed, there are living species, by definition, only because they cannot exchange their genes (except in rare cases of horizontal transfers due to viruses, for example). On the contrary, transfers of ideas, i.e. cultural hybridisation, occur frequently. The analogy remains valid for cultural evolution if we consider the previous comparison between hypotheses and genes, paradigms and individuals, civilizations and societies (or groups), always inside the same biological species. There is, with many local differences, a unique human form of thought as there is only one human species. Genotype, phenotype and group selection act on the same genes, as does selection on the mind's level and social ones act on the same memes. There would be different species if various cultures could not communicate with one another, which has become rare since the eighteenth century and worldwide travels.

There is here a parallel between the two major modes of biological speciation and cultural evolution. Evolutionists oppose "anagenesis" (i.e. the slow transformation of a large group of individuals) and "cladogenesis" (i.e. the split of many populations whose biological characters tend to diverge). With the present globalisation of economics and culture, cultural evolution looks like an anagenesis. But we know cases of "cladogenesis" in the past. Living species split thanks to two major mechanism of isolation: one prevents from mixing (the groups can not meet anymore because of a geographic or ethologic change), the other results of too great a difference (the embryo dies because of biological incompatibility). In the human species, geographic isolation favoured cultural divergence. But social choices play an important role, too: "a group or social system can be defined as the maximal assembly of individuals that share a particular belief. Indeed, we have argued that a shared belief provides a constraint or control (of the internalized restraint type) on the actions of all individuals having that belief" (Campbell and Heylighen, 1995).

Thus, human cultures (as biological races) are often partly separated, which is patent when we consider the problems of translation between languages. Moreover, recombination of ideas of various origins is often ambiguous, especially when not only a few concepts are imported in another culture, but also complete theories. Such hybrids may be as little convincing as biological mules are fertile. But the frontier is not closed among human cultures, even if they make coherent systems. Nevertheless, there are also biological associations of different species without any gene crossing, as in symbiosis. Why would there not be cultural associations of originally separated ideas, such as religious syncretisms? The flexibility and the high speed of cultural evolution is partly due to the fact that theories are not so closed to one another as biological species. It is why the structuralist approach fails. And this raises another interesting problem, about the evolutionary modes of cultural history.

4. THE MODES OF CULTURAL EVOLUTION

4.1. THE TEMPO OF CULTURAL HISTORY

Even if science evolves quickly, it takes place in a dynamics that remains fundamentally conservative. Kuhn explained it by psycho-institutional motives:

"Lifelong resistance […] is not a violation of scientific standards but an index to the nature of scientific research itself. The source of the resistance is the assurance that the older paradigm will ultimately solve all its problems". (1969: 151). All change implies a risk. Moreover, Popper insisted on the competition among scientists (1979), which is thus summed up by Wilfred Trotter: "The mind likes a strange idea as little as the body likes a strange protein and resists it with similar energy. It might not be too fanciful to say that a new idea is the most quickly acting antigen known to science" (quoted by Hallam, 1976: 41). But there is another reason for such conservatism. Campbell and Heylighen recalled that beliefs are not only targets of cultural selection, but also signals for group recognition in their competition. They added: "A group in this sense can be seen as the physical counterpart or "sociotype" of a cognitive belief pattern or "memotype", in analogy with the "phenotype" embodying an informational "genotype". This analogy between social and biological systems is most clear for beliefs that constrain social behavior, and thus control the interaction between the group members" (1995).

If science evolves quickly, it is also due to its rational principles. On the contrary, dogmas are less constrained by facts. They maintain themselves in domains where science is (still?) incapable of giving any solution, giving answers to the following questions: "why is there something instead of nothing?", "Does God exist?", "Does free will exist?", and so on. These are not scientific puzzles because they remain out of all experimentation. Thus, we can believe in systems, religions or philosophies which do not compete on facts, but on their social and political implications. Mircea Eliade already suggested such a struggle for dogmas: "Compared with the greatness and with the vigorous optimism of the communist myth, the mythology used by national-socialism seems strangely awkward. This is not only because of the limitations of the racist myth (how could we imagine that the rest of Europe would have voluntary, accepted to submit to the *Herrenvolk*), but above all thanks to the fundamental pessimism of Germanic mythology" [my translation] (quoted by Buican, 2003: 23–26). And Buican added: "The messianisms of Judaeo-Christian or Islamic religious type overcame – probably thanks to the eternal felicity they promised to the "elected" of their paradises – the worlds of shadows proliferating in the depths of the earth, watched over by the Cerberus of the Greco-Latin mythologies; these new gods, unique and jealous into the bargain, threaten with their stick – *argumentum baculinum* – people who disagree with their supposed paradises" (2003: 158).

4.2. THE RHYTHM OF CULTURAL CHANGE

To go back to scientific theoretical change, there are not only transformations of ideas. There may also be divisions. Thus, Weismann created neoDarwinism by rejecting acquired heredity, which became the central dogma of neoLamarckism.

On another level, a new science often emerges from a particular branch of an old one. For example, natural history and philosophy split during the early eighteenth century with a division of labour: the first was based on facts, the second on speculations. This caused the methodological rejection out of science of early evolutionism (up to Darwin) under the pretext that this theory was philosophical, in other words (Cuvier's or Owen's), not based enough on factual proofs.

Even more interesting for science historians are the consequences of the synergic theory of cultural change for the tempo of the evolution of ideas. Biologists and palaeontologists are divided over this point between: gradualists and saltationists who are the two extreme positions in the present scientific community. But if we look at the problem more closely, we can see that both conceptions can complete one another, because they may explain the evolutionary modes on different levels. Gradualists focus on the genetic change in populations, i.e. at generational times, estimated between years and thousands of years, depending on the reproductive speed of the species. On the contrary, saltationists generally consider millions of years, because morphological changes are often the only ones that a specialist of fossils can study. In the same way, historians can distinguish two scales in the process of scientific revolutions. According to Darwin and Max Planck, Kuhn estimated it must take a generation, in other words about thirty years. During this time, a gradual change may occur.

During the eighteenth and nineteenth centuries, the most important French biologists and palaeontologists occupied official functions in the Académie des Sciences de Paris, the Muséum National d'Histoire Naturelle and the chairs of the great university of Sorbonne in Paris. They may have many of these jobs at the same time. But in all cases, it is easy to count them: about twenty. This is enough to build a statistical series on the following criterium: what is the proportion of scientists who believed in biological evolution? This study considers as truly evolutionists only the people who published this opinion (because they are challengers) and who accepted a global evolution (as Lamarck and Darwin), but not a limited one (as Buffon or Isidore Geoffroy Saint-Hilaire, too close to the idea of Linneus, and even Cuvier or Owen). Figure 2 shows the proportion of evolutionists every thirty years from 1730 to 1990 (but built upon data taken every ten years from 1800 to 1880 to take into account some significant dates as 1800: the first Lamarckian evolutionary paper; 1830: the debate between Cuvier and Geoffroy Saint-Hilaire; 1860: the year following the publication of Darwin's *Origin of Species*. This shows a classical scientific revolution. Despite a small "Lamarckian" effect about 1810, the bend shows that the French community is only convinced by Darwin's arguments in the last decades of the nineteenth century, after a certain delay compared with their British or German colleagues. This figure represents a classic case of a sudden scientific revolution.

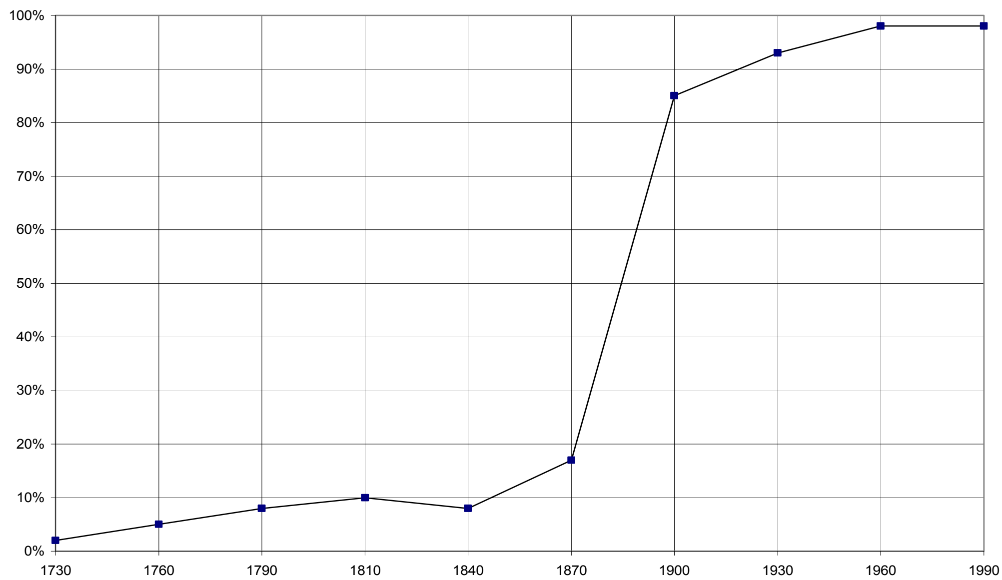

Fig. 2. The proportion of evolutionists among the leading French naturalists (1730–1990).

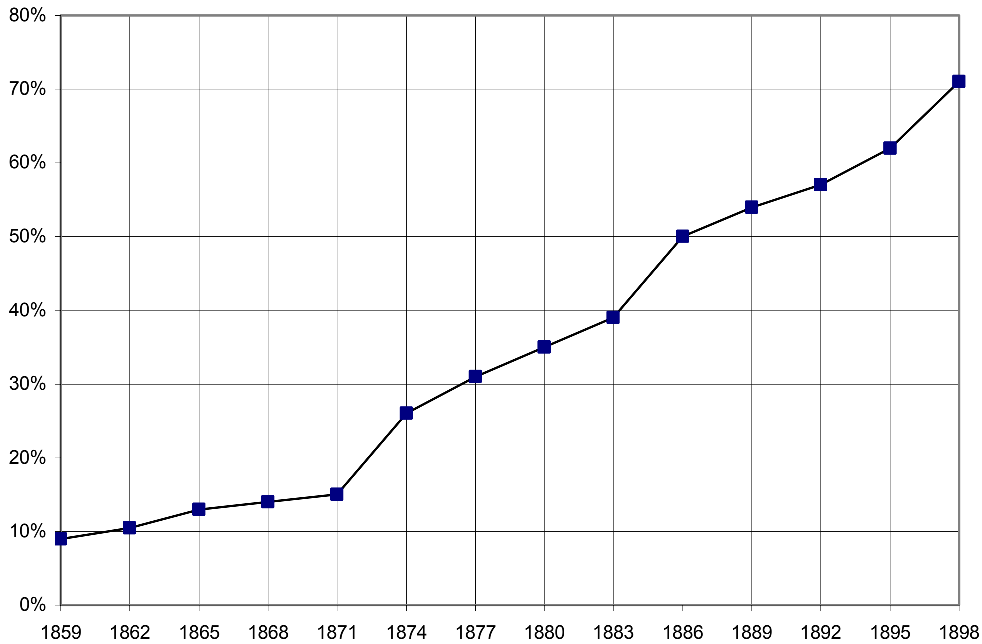

Fig. 3.– The proportion of evolutionists among the French palaeontologists (1859–1898).

However, focusing on the most interesting period of 1859–1898, I studied in detail the works of all the French paleontologists (about forty) who published papers and books during this time (Grimoult, 2000b and 2000c). After having obtained the date of acceptance of the new paradigm for each French palaeontologist, a new trend was built which shows a more gradual acceptance of biological evolution among a more specialized group (but studied as a whole, including the most important writers in scientific reviews and the chairs of provincial universities – thus a total between 33 and 43 people). Figure 3 shows a gradual acceptance of evolution. A majority appears only in 1886, four years after Darwin's death. But this trend in accordance with qualitative indicators, as the contemporaries' testimonies or the attribution of the chair entitled "d'évolution des êtres organisés" in Sorbonne in 1888 to Alfred Giard, the only biologist who taught evolution as early (!) as 1877 (and maybe 1873, see Grimoult, 2001a: 171–173).

The study of the evolution of the French scientific community about the question of evolution demonstrates this fact: cultural change is both gradual and revolutionary.

CONCLUSION

Of course, the synergetic theory of human sciences explains not only scientific history, but the evolution of all of the cultural models, as religions and philosophies, too. Moreover it might also be used as a general evolutionary model for organizational change, including the analogy between economic dynamics and both biological and cultural ones. Indeed, economics also includes three major selective levels:

– the technological and strategic one (made of innovations), which includes the means of a better profit (A);
– the level of the market, where firms compete (B);
– the level of economic systems, as capitalism *vs.* socialism or as the different nations whose exchanges are strongly regulated and/or limited (C).

So, we propose this recapitulation of the main levels of general evolution:

Level of selection	**Biology**	**Science**	**Economy**	**Society**
A	genotypic	scientist's mind	entrepreneur	individual
B	natural	research community	firm	group
C	group	society	society	civilization

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