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A DARWINIAN MODEL OF SCIENTIFIC CULTURE: PATH DEPENDENT REPRESENTATIONS EMBODIED IN PRACTICES.

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Darwin developed an evolutionary account of society while developing his views about the role of natural selection in organic evolution. Although he never developed a systematic theory of social evolution Darwin´s exploitation of the analogy between social evolution and biotic diversification was a rather crucial turning point not only in the systematization of his theory of organic evolution, but also of his view on social evolution (Ghiselin 2009). However, as diferent as they are in different respects, most models of cultural (social) evolution until recently have relied upon attempts to extend the application of the mechanism of natural selection to the social sphere, and most importantly for us, have tend to assume that units of evolution, (in analogy with genes), are units of information stored in individual human beings.[1] Memetics, for example, usually refers to approaches based on the assumption that imitation is the main mechanism of transmission of information. Theories of cultural evolution like those developed by Boyd and Richerson, that exploit the explanatory resources of Darwinian "population thinking" (Boyd and Richerson 1985) as different as they are from memetics in different respects , also assume that an evolutionary model of culture requires the identification of units of cultural evolution consisting (mainly) of information stored in human brains.

But once we take seriously the idea that cognition is grounded on social structures and on the role of material culture, as we want to do in this paper, we have to find the way of accommodating the "social life of things" as part of culture, and thus one has to acknowledge that instruments as well as other artifacts can be both, and

[1] In this paper we start from the assumption that science is culture and thus, that to the extent that evolutionary models of social processes are successful they should be able to model scientific change (as an special type of cultural process). Talking of culture does not mean to imply a well defined type of social phenomena or processes that are cultural as opposed to merely social. It is rather a matter of emphasis on processes for which the accumulation of modifications is important to understand the sort of process they are. Models of "cultural evolution" and models of "social evolution" tend to address different problems. Models of cultural evolution aim to model stability and persistency in the first place, whereas models of social evolution tend to model first of all social change (dynamics). I take that these distinctions have to be understood as merely an indication of different connotations associated with culture in contrast to social evolution. They do not point to a significant epistemological or ontological distinction.

simultaneously, part of a process of replication and a process of interaction (Lake 1998, Griesemer 2000). In this case we cannot assume that there are such “units” of information to which culture is reduced (as it is assumed in most accounts of cultural evolution). One important sort of processes that do not accommodate to the view that culture is information is what are called “path dependent phenomena”.

In this paper I want to show that traditional accounts of culture based on the idea that culture is information have difficulty accounting for the sort of stability and change that matters in cultural evolution. I suggest this is related to the fact that path dependence is crucial for modeling such stability and change. I will not address the question of explaining change and rather will focus on showing how the stability that matters in cultural evolution can be explained assuming path dependence of the relevant cultural phenomena. Such explanation requires introducing the concept of scaffolding. I will take scientific culture as my paradigmatic example of culture in order to illustrate the importance of the concept of scaffolding and the related concept of artifactual representation. It might be argued that science is a very special sort of culture, and that it might be misleading to conclude something about the evolution of culture using scientific culture as an example. On the contrary, from my perspective, scientific culture is constituted by the sort of cultural phenomena in which the importance of the sort of cognitive scaffolding that support its path dependent structure is easier to appreciate. In any case, I do not think that it is reasonable to expect that a single model can account for the evolution of culture as a whole.

2. The concept of path dependence was initially developed in economics, and later entered other social sciences. It is a central concept in approaches whose aim is the characterization of dynamical processes as "historical". The basic idea is to show the explanatory power of social processes that depend on previous outcomes, not merely on current conditions. In Economics such conditions have been discussed a lot. One uninteresting form of path dependence is the durability of capital equipment. An obsolete machine might remain in use because its variable costs are lower than the cost of replacement. It is usually considered uninteresting because it is easily explained away by more standard theories that do not require using the concept of path dependence, and also because such path dependence is short lived. Path dependence ends when the machine is discarded. One interesting famous example is the array of the standard keyboard, the so called QWERTY keyboard. This keyboard that is now used as a standard owes its entrenchment to its layout, because it minimized the clashes between the mechanical keys, and not to its capacity to write fast. This restriction disappears once the technology of the writing spheres is developed, and nowadays such restriction plays no role in the keyboard of computers, nonetheless, it continues to be the standard keyboard. David (1985) considers that such entrenchment, that is not optimal from the point of view of the criteria of efficiency supporting more standard explanations in economics, can be explained as the result of three conditions (that would characterize the interesting forms of path dependence).[2]

The first one is **technical interrelatedness** of system components; in the case of the keyboard this condition refers to the fact that different components of the machine have to fit together, and thus changing the keyboard involves several other changes. The second condition is **economy of scale**, or rather increasing return to scale in the use of a common technique. The more extended the use of a technique is, the more it costs to changeit. Both conditions point to the costs involved in the amount of complex coordination required of economic actors to change a technique in several applications at roughly the same time. The third condition is "**quasi-irreversibility of investment**". Once an investment is made in a given technology there is a cost in changing the technology.

A series of critiques to the concept of path dependence (particularly by Liebowitz and Margolis 1995) have made clear that the importance of path dependent processes in economics, and in particular the difficulty of accounting for such processes in standard models, depends on the assumption that decisions are taken on the basis imperfect foresight (Arthur 1994, and Puffert 2003). The point can be reformulated as a more general claim: *the explanatory value of path dependence, and thus the explanatory value of current conditions (not reducible to explanations based on principles regulated by general laws) requires the recognition of cognitive limitations of the economic agents which leads to model rational decisions as the result of heuristic rules rather than as the result of the application of a formal model of rationality as the one assumed by standard models of rational choice* (Martinez 2003, 2005). Once it is recognized that local current conditions have explanatory value then the overall economy has to be seen as the consequence of several relatively independent enterprises, each of them caught in a mesh of consequences of earlier interrelated decisions. Each technique has a fuzzy radius of interrelatedness in which the quasi irreversibility of investment and the increasing return to scale shape the environment in which decisions are taken. You might wonder, what has path dependence to do with Darwinism? We answer this question in section 4, but first we provide some observations which are required in order to understand the answer.

3. Evolutionary models of social processes are usually considered to be either one of two types, Lamarckian or Darwinian. This distinction is usually seen as exhaustive and exclusive. If a model does not clearly fit in one of these disjunctive options it is considered confused. This is particularly clear in the philosophical literature. Henry Plotkin, for example, grounds his universal model of evolution on this distinction.

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[2] David has since his 1985 paper changed somewhat his views (see David 2007), but the differences are not relevant for our purposes.

Plotkin argues that evolutionary processes can be either the result of selection or else the result of instruction and direction (Plotkin 1994) There are no other alternatives. The two alternatives can be characterized by the sort of inheritance mechanism compatible to them. Darwinian evolution forbids inheritance of acquired characteristics whereas Lamarckian evolution requires it. This is related to the role of the environment in evolution. Evolution in Lamarckian models requires dependence of variation on changes in the environment, whereas Darwinian models requires independence of such changes.

Such a simplistic view is clearly inadequate to understand social evolution. Hodgson, for example, has shown in several writings how evolutionary economics cannot fit such simplistic distinction, and that evolutionary models of economy are a complex array of Lamarckian and Darwinian features at least in the sense that models that turn out to have explanatory power have to include as factors of evolutionary change not only uncertainty and complexity but also learning and novelty (see for example Hodgson 1993, 2001, 2006). Lamarckian and Darwinian Models, Hodgson claims, are both required for a satisfactory model.[3] Hodgson's evolutionary model of economic processes is an example of an important sort of evolutionary models of social processes focused on the explanation of change. Another major category of models focuses on the explanation of the distinctive persistency and stability of socio-cultural items (usually identified as "representations"). In the following section we give a brief summary of one of such models as well as its shortcomings.

Memetics is a generic name (initially proposed by Dawkins) for models of cultural evolution that assume that in analogy to natural selection there are units of cultural selection that are the "memes". Memes are cultural replicators and units of cultural inheritance. As with genes, the constituents of success will be long life and accuracy of replication, and for token-memes fecundity is the crucial factor. Memes have often been criticized because they seem to have too little fidelity to support an evolutionary explanation.[4] Dawkins has suggested that the objection can be overcome once we distinguish "to copy something" from "to copy instructions". Dawkins (1999) gives the following example. We show a child a Chinese boat and ask her to draw it. The drawing is shown to a second child who in turn is asked to draw her own version, and so on until we have 20 drawings. Dawkins guesses that the result of the thought experiment is clear: the last drawing will be so different from the first that no relation could be established between the two.

Dawkins asks us to carry out a second experiment. Instead of asking each child to draw a boat we show one of them how to make a boat following the Origami technique. When the first child has mastered the technique he is asked to show it to a second child, and so on. Dawkins thinks that the result is predictable. Even if it is possible that a child forgets one of the steps of the technique another child might realize what is missing and end up with a boat not better or worse than the first. The

[3] The recognition that both Lamarckian and Darwinian elements are required for modeling culture is also to be found in the writings of Griesemer and Wimsatt as well as those of Richerson and Boyd.
[4] Dawkins 1976, Dawkins 2000, Blackmore 1999. Aunger 2000, Sperber 1996

paper phenotype is not transmitted and thus the phenotypic defects are not transmitted, only a set of instructions is transmitted, and those **instructions are "self normalizing"**. The idea is that memetics deals with different ways in which the copying of instructions has an impact on human culture. But how is this self normalization carried out? In other words, how is this self normalization to be understood? Dawkins does not says much about it, and to that extent he only points to an underlying problem, not to a solution. How can the stability in the transmission of instructions be explained?

Boyd and Richerson (1988), (in Aunger 2000) argue that the ability to acquire novel behaviors by observation is essential for cumulative cultural change. This requires a distinction between observational learning and other mechanisms of social transmission, and in particular requires distinguishing observational learning from mechanisms such as *local enhancement*. Local enhancement occurs when the activity of other animals in the group increases the chance that younger animals will learn a behavior. A monkey learns through the mother where the best locations to search for food are. But wherever observational learning allows for cumulative cultural change, other mechanisms, including local enhancement, do not. Local enhancement is a mechanism that does not allow for learning to take place on top of what another individual has already learned. Observational learning is thus a set of adaptations that enable humans to learn by imitation, and the sort of stability associated with "self-normalizing" pieces of information can be understood directly as a consequence of the role of observational learning in the process of cumulative cultural change. There is no doubt that observational learning can account for important cases of stability, but it hardly can account for the sort of stability associated with phenomena that cannot be explained in terms of the normalizing role of instructions. Here the stability in question is presupposed rather than explained.

There are often cases in which the stability in question cannot be explained in terms of the normalizing role of instructions (See for example the discussion in Sperber 1996). This is often the case when we pay attention to cultural processes whose stability is supported by the normalizing role of artifacts-representations used as symbols (Renfrew 1994). Roughly, *an artifact represents through its symbolized role, through its use*.[5] Thus, representation in this sense is not something we can summarize as information. Learning what a confocal microscope is, involves learning how this type of microscope is part of a lineage of artifactual representations. It involves learning how it forms part of scientific practices that have certain general and specific objectives.[6] *Once it is recognized that what needs explanation is not shared beliefs but shared practices, artifacts-representations have*

[5] Below we explain further this notion of representation.
[6] Of course, this is not a simple matter. As Halle puts it: There is no substitute for the difficult work of uncovering the symbolism of particular types of artifacts in particular types of social setting." (p. 52, Halle 1998).

to be in the center of attention of any explanation of the stability that matters in a model of cultural evolution, and an evolutionary model of science in particular. [7]

4. An elaboration of this proposal requires the introduction of the concept of *scaffolding*. Scaffolding allows us to incorporate a type of development (analogous to biological development) in an evolutionary model of culture. This has been done above all in models of cultural evolution developed by Wimsatt and Griesemer. For them, scaffolding abstracts general features of development in such a way that makes understandable how "extraorganismal cultural resources form repeated assemblies that serve as critical scaffolding for the development and inheritance of culture". (p.244, Wimsatt and Griesemer 2007). The order in which the configurations of resources turn into stable nodes serving as scaffoldings for further configurations creates "downstream dependencies which entrenches the dependencies in development". (p. 244, Wimsatt and Griesemer 2007).

In a similar vein, I have suggested that cognitive resources are articulated in what I call "heuristic structures" which serve as scaffoldings for the development of inferential contexts, explanations, models, and other cognitive resources.[8] Such cognitive scaffolding takes place in the social environment nurtured by relevant institutions and practices. Both notions of scaffolding are quite close. Wimsatt and Griesemer emphasize the repeated assembly of entity-environment relations, and I emphasize the repeated assembly of "heuristic structures" which are stable relations between kinds of cognitive environments and kinds of things or processes . Both notions of scaffolding are closely related with ways in which cultural entities become reproductive and form chains of inheritance which are dependent on (organismal and cultural) developmental history. One difference seem to be the

[7] It might seem that artifactual representations might be in any case suitable for the characterization of experimental traditions, but it might seem that it is not very useful beyond such traditions. However, in the sense that I am using the term, a diagram is an artifactual representation. Feyman´s diagrams are artifactual representations and Euclidean diagrams are artifactual representations. In this connection it might be worth recalling the way in which Netz shows that deduction gets stabilized as a type of inference (Netz 1999). According to Netz, diagrams for Euclidean geometers were understood as practices that united the community of Euclidean geometers precisely because such diagrams articulated implicit norms about what was a good inference. For the Greeks, diagrams were not considered appendages of propositions; rather, they were considered to be the core of a proposition. Propositions were individuated by diagrams, and thus such diagrams and the implicit norms they represented (in the sense of artifact-representing I had introduced above) had to be seen as standards for a type of knowledge which was (relatively) autonomous from the propositions it allow to individuate. That said, I hasten to add that I do not pretend that what I am calling artifact-representations are the only sort of representation there is or matters in cultural evolution. My claim is only that such representations are indispensable to understand the source of stability that matters in some important cases of cultural evolution.

[8] I have characterized a heuristic structure as a group of heuristic procedures integrated in a normative (hierarchical) structure with functional coherence that gives shape to a practice. A heuristic rule or procedure requires the implicit recognition of a situation or context (which often consists of norms or involves norms or standards) as part of the characterization of the procedure. That the heuristic is not a mere universal rule constrained to a given context can be seen from the fact that a heuristic leads to the right decision or answer (or more generally, answer to norms) in a biased way. Error is not random (a point often emphasized by Wimsatt). A technique is a kind knowing how supported by heuristic structures and artefact-representations that leads to the production of standards, phenomena, technology or further techniques. See Martínez 1995 and Martínez 2003.

following. Wimsatt and Griesemer follow Birkhard in suggesting that scaffolding creates "bracketed trajectories of potential development through artificially created nearby points of stability" (p. 35, Bikhard 1992, quoted in p. 229, Wimsatt and Griesemer). Here the functional role of scaffoldings is closely related to the idea that in given "windows" of time scaffolding lowers "fitness barriers" to developmental performances or achievements. Whereas in the sense that I use the term scaffolding is related primarily to the way different resources get distributed in practices (in a way that involves distribution of labor and paths of dependence) as an implicit structure required for the display of cognitive abilities in *socially meaningful space.* They are not provisional in time, but rather *implicit or in the background*. I use the notion of scaffolding very much in the sense that cosmologists say that dark matter scaffolds visible matter. Scaffolding thus is related to the idea that implicit cognitive structures in specific (socially meaningful) environments lower fitness barriers for the development and fruitful diversification of (stable) practices (and artifactual representations associated with such practices).

Cognitive scaffoldings are often implicit resources. Netz points out that Diagrams for Euclidean geometers were understood as practices configuring an epistemic community (paradigmatically stable), precisely because the diagrams articulated implicit norms about what is a good inference in the context of what end up being identified as Euclidean Geometry. It seems reasonable to think that the stabilization of such norms involve the creation of bracketed trajectories of potential development leading to the corpus we know as Euclidean Geometry through the creation of points of stability represented by the diagrams.[9]

Another example of the sort of cognitive scaffolding I have in mind is the way in which medieval masters used earlier buildings as "approximate models" to estimate the stability of a new design (see Mark 1990). Models in this sense are not "blueprints", but are rather reference points or beacons to be taken in consideration for the development of new stable constructions.[10] In this way new designs increased their fitness through the use of earlier structures. Such paradigmatic buildings play a decisive role in the generation of new buildings (and the selection of new variants of designs). One can think of such model-buildings as branching points for *path dependent representations*. Mark claims for example that different sorts of evidence support his thesis that the cathedrals of Bourges and Chartres, were constructed with a design that took in consideration lessons drawn from observation of the performance of the buttressing system used in Notre-Dame.[11] It is clear that lineages of approximate models satisfy the three conditions we have use

[9] The elaboration of such ideas would require showing how specific features of spatial reasoning capacities brackets trajectories of potential development through the generation of normative structures for inferences. I cannot go into this issue here.
[10] I elaborate this idea of aproxímate models in Martínez 2009
[11] Notice that this role of early buildings is analogous to the sense in which heuristic structures function as approximate models for other heuristic structures, or more generally, is analogous to the sense in which a set of norms often function as aproxímate models of another set of norms (in model building, for example). Approximate models would be examples of "false models" playing an important role in science (see Wimsatt 2002)

to characterize path dependence: (1) There is technical interrelatedness of system components. The different parts of the building have to fit each other. (2) They have an increasing return to scale, the longer and diversified the lineage of approximate models the costlier is not to use it. And (3) once effort has been put into learning a particular lineage of models one is inclined to use it, since it is costly to change the skills and techniques involved in the construction. In science, the way in which the design of experiments gets modified through the history of science has a similar path dependent structure (Martínez 1995).

Habits of mind, says Margolis are entrenched responses to ordinary problems that take place without consciouss attention. Such "habits of mind" usually have a functional structure and thus one can see them as examples (or components) of heuristic structures. It is not difficult to see that such "habits of mind" are path dependent and constitute a good example of scaffolding in Wimsatt and Griesemer sense but also in my sense.[12] Habits of mind support each other and the longer and diversified the habit in different practices is, the harder it is to change it. As the old saying goes (and Planck and Dewey famously said it in relation to science) old habits die hard. Margolis uses this idea of "habits of mind" as part of his explanation of what happens in revolutionary periods in science according to Kuhn. Kuhn had to talk of revolutionary periods as non-rational because he had no way of explaining the way in which a scientific field changed rationally in such cases. He had no way of explaning new habits of mind unless they had come formed and ready from "outside", as a new paradigm. But if we think of heuristics (or habits of mind) as part and parcel of representations having a path dependent structure (what I am calling artifactual representations), then it is possible to explain novelty. Creation or modification of new trajectories of path dependence is hard but not impossible. To take again seriously Darwin´s analogy between biology and culture, speciation is a path dependent process, and Darwin explains how new species come to be and diversity of life ensues. And how can we explain the modification and diversification of path dependent representations? This can happen in several ways. For example, in science it is clear that we modify path dependence through the the efforts we put into the development of one technology or one research program as opposed to another, for example. As another example, the path dependent lineage of buildings-as-models were guided by different values and interests, the search for more imposing and bigger buildings, or a search for better illumination and acustics inside the churches.

In the case of science and technology, it is not hard to see how research projects can be modified (consistently with its path dependence) and how new ones can arise from hibridization. In the philosophy of technology there is an ample debate on such matters (see for example Garud y Karnoe 2001). Rao y Singh 2001 show how social factors can play a role in the mobilization of resources leading to the creation of new paths or modification of old ones. Analogously, cognitive factors can play a role in the mobilization of resources leading to the creation or

[12] See Margolis 1993.

modification with descent of new paths..[13] Once we think of science as a complex array of practices supporting artifactual representations it becomes clear that the the source of the stability of representations which is such a distinctive feature of scientific-technological traditions is often closely related to its path dependent structure.

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[13] The creation of new scientific-technological paths is discussed in Martinez and Suarez 2008.

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