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Science as evolution of technologies of cognition

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1. Attempts to develop evolutionary models of social processes have been the testing ground for many proposals as to how understand the relation between the social sciences and biology. One important discussion that goes back to Darwin and his contemporaries concerns the extent to which we can give an evolutionary model of culture.[1] Nowadays we are familiar with a wide variety of such models. There are models that start with a paradigmatic example of how biological models, relying on specific mechanisms of biological inheritance, can explain what is considered a paradigmatically socially structured behavior, and then the solution is extrapolated to other modes of social organization. The sociobiology of E. O. Wilson is a well-known example of this sort of approach. Other approaches identify what is considered the main mechanism for the social transmission of beliefs. Memetics, for example, refers usually to approaches based on the assumption that imitation is the main mechanism of transmission. And Boyd and Richerson have developed a theory based on the explanatory resources of Darwinian "population thinking" (Boyd and Richerson 1985). As in the case of Memetics, Boyd and Richerson assume that an evolutionary model of culture require the identification of units of cultural replication that are units of information stored in human brains. It follows that an explanation of the way this storage takes place (and changes) is sufficient to explain culture.
Alternatives to such storage accounts of culture usually deny that a significant distinction can be drawn between biological and cultural evolution. Griffiths and Gray point out that since it is not possible to draw a sharp boundary line between channels of biological inheritance and channels of cultural inheritance, we should not try to draw a line between cultural and biological evolution (Griffiths and Gray 1994). Nonetheless, accepting that drawing a sharp boundary between biological and cultural inheritance is not possible does not imply that cultural inheritance is not a distinctive problem with important implications for the social sciences and the philosophy of science. In order to see its distinctive features we have to pay attention not only to the question whether a distinction can be drawn or not drawn between the gene and other causal factors in development, but also, and in particular, we have to address the question of how to model what we can call the "phenomenology of culture", the

[1] 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.

stable but changing structure of cultural phenomena. In other words, the issue is how cultural items get the sort of stability that matters for explaining the cumulative sort of change that distinguishes cultural processes. Such question requires studying cases of cultural (stable) traditions that can shed light on the sort of explanation we want. As we shall see, it also requires taking seriously discussions in the cognitive sciences concerning the way in which cognition is grounded in social structures and processes and in particular requires taking seriously views of language that abandon the idea that language is constituted by encodings of mental content.

From the perspective we take in this paper the issue is not about the nature of information, or the way structures of information mentally encoded are transmitted from one agent to another, but it is first of all an issue about lineages of artifacts-norms-representations usually structured in scientific practices that explain the sort of cumulative change we associate with culture. In this paper we will take science as a paradigmatic sort of culture. It is considered paradigmatic because of its centrality in contemporary life but also because of the fact that the way in which its representational structure is supported by artifacts is relatively easy to grasp (to the extent that we understand the role, in the generation of scientific culture, of things like laboratory practices, observational techniques, mathematical models or diagrams, among other resources), allowing us to draw conclusions about the sort of evolutionary process that support stability and change.

Models of cultural evolution often have presuppositions that conflict with such view. Selectionist models that assume that evolution takes place mainly through ´blind´ retention are committed to the view that the psychological processes that support culture promote the uncritical acceptance of information acquired from others. And thus, tend to assume (most often implicitly) that such norms are not the result of individual or group learning, or more generally, assume that norms can only play the role of passive constraints in evolution. As Heyes puts it, "to the extent that culture depends on fidelity of social transmission in the face of local environmental fluctuations, the formation of cultural attributes is likely to depend crucially, not on processes of information acquisition (e.g. social learning, imitation and instruction), but on processes that contribute to faithful or ´blind´ (Campbell 1974, 1983) information retention" (Heyes 1993). But once we take seriously the role of material culture as scientific culture we have to find the way of accommodating the view that material things can be both, and at the same time, part of a process of replication and a process of interaction (Lake 1998, Griesemer 2000).

What I am suggesting is that scientific practice can be used as revealing interesting aspects of the way cultures evolve. This might sound counterintuitive to many ears, and in particular to philosophers of science used to think of science as a rather special kind of culture. I agree that scientific cultures can be special in many ways, but it is hardly the case that there is something that makes scientific culture as a whole special. One way in which science has been understood to be a special sort of culture is related to the idea that science deals with a very special sort of representations. But if as I will argue below, representations cannot be understood as mere passive copies of structure, then such objection does not hold water. Scientific representations, as other culturally significant representations have to be understood as part and parcel of processes in which artifacts represent through its function or use (and the history of such use).[2]

[2] One can add against this chauvinistic view of scientific representations the sort of arguments elaborated by Callender and Cohen 2005.

In sections 2-4 we review different answers that have been given to account for the stability of cultural processes. We shall see that all of them have serious shortcomings. Either because they want to identify one single mechanism that is responsible for the sort of stability that matters, or else because they involve the attributions of intentions in a way that makes culture, by decree, a phenomenon confined to human beings. It might be that there are good reasons for saying that culture is an only human phenomenon, but such assertion has to be understood as an empirical assertion[3]. In section 5 we will suggest that Goody´s thesis that writing is the technology of the intellect point to a way in which scientific cultures exemplify a kind of stability that matters for explaining cultural processes in general. In section 6, I introduce the concept of representation as scaffolding of further action that will provide the framework in which my proposal (to be developed mainly in section 7 and 8) for understanding science as the technology of cognition can be seen as a extension of Goody´s thesis once the notion of representation as encoding is abandoned in favor of the notion of representation as scaffolding for action or intervention.

Shifting the search for an explanation of the sort of stability that matters, in the case of cultural processes, away from questions about the transmission of mental representations or symbols, lead unavoidably to take seriously the role of cultural development and models of adaptive design in the explanation.

The concept of generative entrenchment of Wimsatt and its role in evolutionary models of culture will be taken here as a point of departure for my proposal (see in particular Wimsatt 1986 and Wimsatt and Griesemer 2007). Wimsatt and Griesemer have shown the crucial importance of a concept of "scaffolding", closely related to that of generative entrenchment. Our emphasis in material culture will lead to a development of two related but different concepts of "scaffolding". Scaffolding will be seen to be crucial to understand the way in which lineages of normative environments (articulated in practices) evolve.

2. Memetics (the science of memes as it is called) has been often critized because memes 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 gives the following example (in the preface to The Meme Machine, Blackmore 1999). We show a child a Chinese boat and ask her to draw it. The drawing is shown to a second child and asks to draw its version, and so on until we have 20 drawings. Dawkins guesses that the result of the thought experiment is clear, that the last drawing will be so different from the first that no relation could be established between the two. However, ordered in the way they were drawn would certainly allow us to see a path leading from the first to the last. The observation leads to a test for memetic replication. In the case of memetic replication the order in which the copies were made is as informative (or uninformative) as random order.

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

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[3] Wimsattt and Griesemer 2007

[4] Dawkins 1976, Aunger 2000, Blackmore 1999.

a boat not better or worse than the first. The 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 the 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 anything about it, and to that extent he is only pointing to an underlying problem, not to a solution. How can the stability in the transmission of instructions be explained?

3. Boyd and Richerson (in Aunger 2000) have developed a different type of evolutionary model of culture, an epidemiological model that is based not so much on the explanatory role of selection of cultural units (as in the case of memetics) but rather on the explanatory role of "population thinking". They give an answer to the question posed above on the basis of what they consider "three well-established facts":

1. *There is persistent cultural variation among human groups.* Any explanation of human behavior must account for how this variation arises and how it is maintained.
2. *Culture is information stored in human brains.* Every human culture contains vast amounts of information. Important components of this information are stored in human brains.
3. *Culture is derived.* The psychological mechanisms that allow culture to be transmitted arose in the course of hominid evolution. Culture is not simply a by-product of intelligence and social life.

On this basis, their explanation of the stability of the replication of instructions is roughly the following. First, it is argued 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 that increases the chances of learning the behavior. A monkey learns through the mother where are the best locations to search for food in this way. 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 taking place on top of what other individual has already learned. Observational learning is thus a set of adaptations that enable humans to learn by observation, 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. No matter how we end up specifying the underlying mechanisms for observational learning, a precondition for cumulative change is the sort of stability that requires explanation. Again, it seems that the stability in question is presupposed rather than explained. A key question for any explanation of culture is thus, whether the sort of mechanism postulated by Boyd and Richerson, what they call "observational learning", is indeed as central as they claim it is. They suggest that observational learning can be grounded on empirical findings. But such grounding is only hinted at, and it seems that they rely rather in some questionable epistemic assumptions about the way we learn from experience.[5]

I have no quarrel with the first and third principles proposed by Boyd and Richerson, but I do think that the second one cannot be accepted, and the reason why it cannot be accepted suggests a way of explaining the stability in question Culture is not merely information stored in human brains, and the extent to which it is something more matters in the explanation of the sort of cumulative cultural change (for which the stability in question is a precondition).

4. Sperber suggests a way of accounting for the stability of cultural items.[6] Sperber ask us to consider the following variant of the example of Dawkins. A child is asked to look carefully to the drawing in Fig. 1, and then it is asked to redraw it.

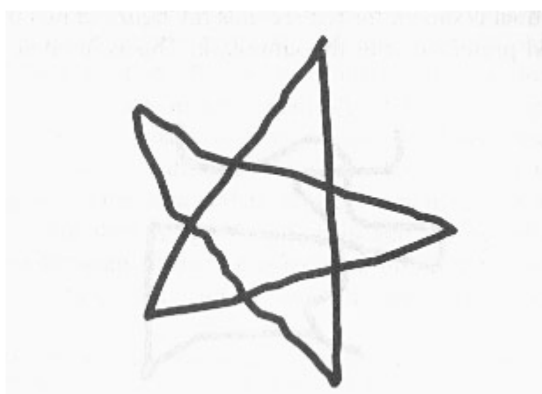

Fig. 1

Later one asks a second child to reproduce the drawing of the first child, and so on. Sperber thinks that to the extent that the children will identify what they are drawing, a five peaks star drawn without removing the hand from the paper, the drawings will be stable. According to Sperber this version of the experiment shows clearly something that Dawkins example did not allow us to see, to wit, that it is not the mere fact that there are instructions what makes the replication faithful, but the fact that one recognizes a pattern that one has the capacity to reproduce. In this case it is clear that we are not merely imitating, or observing and then

[5] Boyd and Richerson assume that all learning is explicit learning, that there cannot be any significant learning that is not explicit. But this is questionable. Polanyi speculated several decades ago that implicit learning is an important sort of learning. Nowadays there are many studies that support this view. See for example Reber 1993. As Reber makes clear, the idea of implicit learning fits nicely a model of learning grounded on Wimsatt´s notion of generative entrenchment. Elsewhere I show how this implicit learning involves the learning of the sort of normative structure that gets reproduced in scientific practices (Martínez 2003). See Netz 1999 for an example of how such implicit learning takes place through the learning of the epistemic use of diagrams in Euclidean Geometry.

[6] Sperber 2000.

reproducing. It is crucial the recognition of a pattern that is taken as the standard with respect to which the drawing will be judged. Sperber thinks that the most important difference between Dawkins example and his is that in his example it is clear that **one requires not only the ability to describe a given result, but the ability to attribute ends and intentions**. Sperber concludes that *it is this attribution of intentions the cause of the normalizing role played by the instructions*. Instructions are not simply copied from one person to another.

I think Sperber is pointing to an important issue, but it is important to realize that the attribution of intentions requires sharing standards and identifying situations. Unless sufficient standards are shared the attribution of intentions would not play the role it is suppose to play. It is the sharing of situations what provides an explanation of the normalizing role of instructions. We might think that the recognition of structural patterns or natural kinds can play this supporting role. But this cannot be all there is to the answer. Think of Dawkins example. We can recognize an origami ship, even the sort of ship it is constructed, but if we are not familiar with the sort of activity involved in the origami technique we might not be able to understand what is intended. Someone who is familiar with the origami technique, or at least with the folding properties of paper that play a role in the instructions, will be able to learn fast and accurately, and would be the sort of reproducer that could correct a mistake. Similarly, think of the second example of Sperber, the drawing of a five peaks star. If you have never drawn this sort of thing, if you have not played with pencil and paper and have been challenged to do this sort of thing you will have a hard time recognizing what is what you are suppose to draw. A prerequisite for acquiring the ability to reproduce something (most often) is the recognition that this something **is not merely a type of thing but a type of activity that requires learning.**

Furthermore, as we see later, there are often cases in which stability cannot be explained in terms of the normalizing role of instructions. As we shall see these are not isolated cases, 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.[7] Roughly, an artifact represents through its symbolized role, through its use. Thus, representation in this sense is not something we can know easily. Learning what a confocal microscope is, involves learning how the microscope is part of a lineage of artifact-representations. It involves learning how it forms part of scientific practices having certain general and specific objectives.[8] Once it is recognized that what needs explanation is not shared beliefs but shared practices, artifacts-representations have to be in the center of attention of any explanation of the stability that matters in a model of cultural evolution, and a evolutionary model of science in particular. [9]

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[7] See Renfrew 1994.

[8] 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 artefacts in particular types of social setting." (p. 52, Halle 1998).

[9] It might seem that the way I am approaching the question of representation (as part of my effort to characterize the sort of stability that matters in cultural evolution) might be in any case suitable for the characterization of experimental traditions, in which for example we have artefacts like microscops. However, in the sense that I am using the term, a diagram is an artefact-representation. Feyman´s diagrams are artefact-representations and Euclidean diagrams are artefact-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.

5. Jack Goody is famous for the thesis that writing is "the technology of the intellect". The idea is simple and powerful. Writing allows for ideas and norms to be "fixed" (to a text), to have generalizing power, that is, the capacity to be applied to new and diverse situations. Thus norms and standards become abstract representations of different more concrete norms. Literary traditions allow the development of more complex organizations than what is possible without writing, organizations that acquire a certain independence of their own associated often with the custodianship of the books and the preservation of the structure of norms associated with such writings. Goody shows how written formulations of codes or norms encourage its generalization, specialization and tailoring for very specific contexts (trade law, for example) and above all, its transportability to new contexts. Such modifications promote the diversification and selection of the generated alternatives. Written norms can thus accumulate and diversify as part of systems of abstract norms that do not apply to specific activities. Implicit in this account of writing as technology of the intellect there is a thesis about what is culture. Culture is not a mere mental phenomenon or situation, or a capacity to mentality in a genetic sense. Rather, culture is something learned and inherited.

Writing allows learning to diversify into a wide variety of different types of knowledge and allows such knowledge to be passed on through generations, and in that sense writing is associated with a diversification of norms supporting different institutions and practices. It is not important for us now to argue for the specific evolutionary nature of such processes. This could be done in different ways. The point is that such diversification of processes leads to a diversification of norms and practices with continuity in time that is not possible without the written word. The idea of culture implicit in Goody´s thesis is clearly not compatible with the idea of culture as information in the head, but I think it is compatible with the idea of culture as learned practices. This requires generalizing what we take "the written word" to be. Diagrams, and other artifact-representations (at least as they form part of certain sort of practices, laboratory practices, for example) can be seen as part of a generalized sort of writing. Such practices allow the fixing of norms, and its generalization and specialization, as the written word does in the case of laws and other norms.

The idea that culture can be identified with information is no doubt related with a common tendency to make a distinction between culture as abstract or as pertaining to "beliefs" and technique to the material and concrete. The idea of culture implicit in Goody´s characterization of writing as the technology of the intellect, as well as the idea of culture that stands behind our characterization of science as practices grounded on artifact-representations rejects such duality. But this rejection, I claim, requires also abandoning a traditional view of language as a system of representations encoding mental content. Language is more than

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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 the stability that matters in cultural evolution.

encodings. The development of an alternative view requires advancing an account of those artifact-representations that I claim support the stability in question.
A first step is to show how in the cognitive sciences, and in AI in particular, there are well motivated proposals that provide an account of representation that goes in the direction of our proposal.

6. Brooks tells us in 1999 how he came to see the need for a concept of representation that would not require what he called a central processing of symbols. Brooks presents his ideas contrasting two diagrams. The first diagram (fig. 2) describes the traditional account.

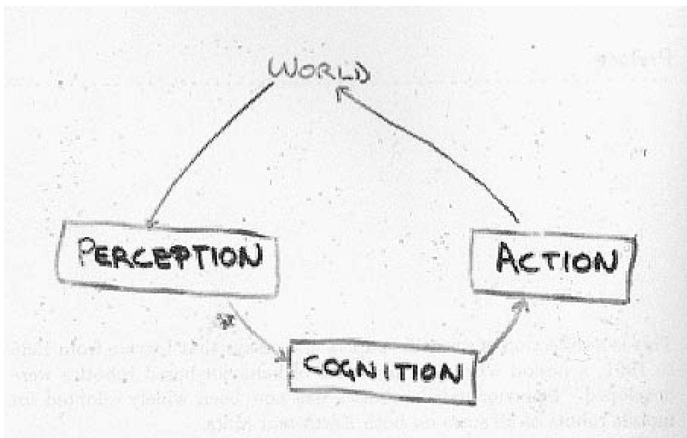

Fig.2

Cognition is understood as mediating between perceptions and plans of action. Notice that in this view there is a centralized instance devoted to cognitive tasks. In this case an evolutionary model of culture could be developed in terms of the representations of perceptual processes, to the extent that cognition models perception, or in terms of the modeling of action, under the assumption of some ontology of the world.[10] However, such ontology would enter as a unexplained (and ultimately unjustified) assumption, or in any case, as disassociated from the world (as perceived world). In this case an evolutionary model of culture would not be able to model the combination of normative and descriptive elements which constitute culture. In Fig. 3 Brooks depicts his view.

[10] For example, as Sperber has pointed out in relation to Dawkins account, it is not the mere fact that there are instructions what makes the replication faithful, but *the fact that one recognizes a pattern that one has the capacity to reproduce*. In this case it is clear that we are not merely imitating, or observing (that is, going from the world to perception and then to cognition) and then reproducing (acting). As Sperber points out, it is crucial the recognition of a pattern that is taken as the standard with respect to which the drawing will be judged. But this would require a coordination between perception and action that is not explainable in Dawkins account, nor in Sperber´s account, to the extent that such "pattern" involves sharing artefact-representations and the implicit normative structure associated with the relevant representational lineages.

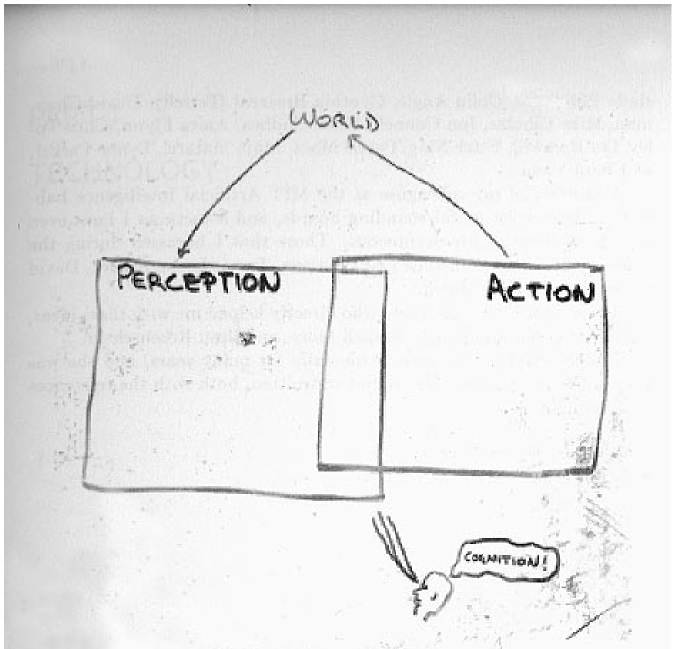

Fig. 3

According to this view there is no centralized cognition, rather, cognition takes place in the overlap of sensory and action systems. Ultimately, says Brooks, cognition is only a phenomenon defined for an observer attributing cognitive capacities to a system that interacts adequately with its environment.

Brooks tells us in the preface to his book 1999 book that when he proposed this alternative view he had no idea of how to combine perception and action, or in other words, how to understand the overlap in Fig. 3. Only later he came to the idea that this could be done through the development of a different cognitive architecture. The key idea is that such cognitive architecture is "bottom-up", cognition has to be the result of models of constraints that are the product of an evolution of technology which is analogous to the way biological evolution imposes constraints to human cognition. Below we will follow such idea to its consequences for models of cultural evolution that take seriously the concept of artifact-representations.

Birkhard and Terveen develop what can be seen as an alternative to Brooks account (and as far as I can see compatible) answer to understand the overlap in Fig. 3 (Birkhard and Terveen 1995). They suggest that, since the grounding of symbols is not as important as a characterization of the nature of interactions that ground the representations, the traditional view of representations cannot be made part of an evolutionary account of cognition, since "encodings" can only transform, "encode or recode representations that already exist" (p.21). But in the interaccionist view (the view suggested by Brooks and Birkhardt and Terveen among others), representations are constructed through development and learning, and thus representations have a history (a developmental history of the artifacts through which representations are used) that matters for understanding their role in cognition. Evolution of representation takes place through the accumulation of representational variants which are selected because of their contribution to potential strategies for future interaction (see Bickhard and Terveen 1995, Hendriks-Jansen 1996, Brooks 1999).

7. The point of this excurse into models of cognition is that in order for solving the problem that interest us, in order to account for the stability of normalization procedures which constitute cumulative cultural change, it is crucial to model such normalization procedures as an evolutionary process grounded on artifact-representations. The computational architecture behind traditional models of cognition cannot give the sort of principle explanation that would be required to account for the normative dimension distinctive of representational processes in cultural evolution. In order to be able to give a principled explanation of the origin of norms as this is required to account for culture we have to abandon the traditional account of representation as symbol processing and develop an account of representation grounded on the "overlap" mentioned by Brooks. Artifact-representations would be a way of elaborating such idea in the context of cultural phenomena. For such representations environmental feedback gets represented in use, and thus explains the origin of norms implicit in the characterization of the different situations that matter (i.e. that are significative). [11]

Roughly, for the purposes of this paper, we will take language to be a systematic characterization of the situations that matter for making sense of the environment for groups of interacting agents as interacting agents in given situations. Language then is a way of abstracting situations from interactions, which can serve as scaffoldings for further abstraction. Such abstraction implicitly or explicitly identifies situations and generates cycles of "repeated assemblies" (see Caporael 2003). A suggestion of how such a view of language can be developed can be found in (Birckhard 2009).[12] Now we have the elements required for the formulation of our modified version of Goody´s thesis.

To start with, instead of talking of "intellect" we shall talk of cognition. And the way in which we shall understand technology of cognition is not mere "internal technology".[13] Rather it is technology grounded in social relations and activities, distributed in stable environments articulated in practices, the maintenance and diversification of which allows for the diversification of variants of a technology, and its repeated assembly, which leads to its evolution. The claim is that not only writing is "technology of the intellect", but all activities that are learned as part of practices that promote the stability of norms which in turn promote the spreading of technology (and science in particular). As we are generalizing Goody´s thesis, scientific practices are technologies of the intellect (understood in a broader

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[11] Of course, this requires abandoning the idea of language as mere symbol processing of mental representations, and thus requires abandoning the idea that representations can be characterized as mere information. In most of the social sciences such view of language is simply not taken seriously, but as we have seen, it has been important in models of cultural evolution impressed by the idea that culture can be disassociated from technology (and the planning for action).

[12] As Birkhard puts it: "Language is not the only way in which social realities can be interacted with, but language constitutes a(n institutionalized) convention for the productive construction of utterances that have conventional interactions with situation conventions—language is constituted as a conventionalized system for interacting with conventions" (p.580, Birkhard 2009).

[13] Cultural change for Goody, at least the sort of change that writing generates, involves a change in "the internal technology (of the intellect) which endows [a person] with the written word" (Goody 1998).

externalist sense, as a characterization of the "overlap" mentioned by Brooks). In order to make sense of such proposal we have to say how science is to be understood as constituted by practices. And in particular, how practices are constituted that allow us to say that science can be understood as the technology of the intellect, or better, as the technology of cognition. Such account of science is at once an account of science as an evolutionary social process: science as the evolution of learned behavior.

8. Before we turn to an elaboration of such proposal we will have to say something about the crucial concept of scaffolding as a way of incorporating development in an evolutionary model of culture. This has been made above all in models of cultural evolution developed by Wimsatt and Griesemer. Scaffolding abstract 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).

In a similar vein, I have suggested that cognitive resources get articulated in what I call "heuristic structures" which serve as scaffoldings for the development of inferential contexts and other cognitive resources.[14] Such scaffolding takes place in the social environment nurture by relevant institutions and practices. Both notions of scaffolding are quite close. Wimsatt and Griesemer enphasize the repeated assembly of entity-environment relations, and I emphasize the repeated assembly of "heuristic structures", but ultimately, both notions of scaffolding are closely related with natural ways in which cultural entities become reproductive and form chains of inheritance which are dependent on (organismal and cultural) developmental history. One relevant difference is the 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 I tend to use the term scaffolding is related primarily to the way different resources get distributed in practices as 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. Scaffoldings are often implicit resources. But also, scaffolding in my sense includes for example the way in which medieval masters used earlier buildings as "approximate models" to estimate the stability of a new design (see Mark 1990). Such new designs increased its fitness through the use of earlier structures, which in my sense

[14] 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 of heuristic structure that leads to the production of standards, phenomena, technology or further techniques. See Martínez 1995 and Martínez 2003.

functioned as scaffoldings. This is very much the sense in which I think heuristic structures function as "paradigms" or "approximate models" guiding the evaluation of alternative scientific-technological designs (see Martínez 2003). Such paradigmatic buildings can hardly be thought as "generatively entrenched" in the sense of Wimsatt, but certainly we should think of them as playing a role in the generation of new buildings (and the selection of new variants of designs). One can think of such model-buildings as points of reference in *path dependent developments*.[15] Mark claims for example that different sort of evidence support his thesis that the cathedrals of Bourges and Chartres, were constructed with a design that took in consideration lessons that lead to a modification of the buttressing system used in Notre-Dame. Such role of early buildings is analogous to the sense in which early heuristic structures play the roles of referents or "approximate models" for later heuristic structures. In science, the way in which the design of experiments gets modified through the history of science has a similar path dependent structure (see Martínez 1995). The way in which for example J. Margolis talks of "habits of mind" as entrenched responses to ordinary problems that take place without consciouss attention is a very good example of scaffoldings in the sense I think is important to emphasize: as reference points for path dependencies.[16]

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9. Now back to our question. If culture is information store in human brains then the problem of stability is a problem about the reliability of the channels of cultural transmission. In this case "observational learning" or a similar mechanism has to play a central role in the explanation of the stability. To the extent that culture is technology of cognition articulated in artifact-representations, the stability can be explained through path dependence and (generative) entrenchment.[17] Since science is a paradigmatic example of processes constituted by lineages of artifact-representations articulated in practices, science can be seen as evolving technology of cognition. As Brooks suggests for the case of robotics, to the extent that cognitive architecture with explanatory power is "bottom-up", cognition has to be understood as the result of models of constraints that are the product of evolution of whatever social and cognitive organization we are willing to call culture. In this case, the stability of culture is explained as a by-product of the evolving structure of those scaffoldings that constitute the path dependent processes we identify as culture. Writing is an important example of a cognitive technology that promotes the complexity of cultural organizations thorough its capacity to provide abstract versions of norms that can represent a variety of more concrete norms, and render explicit and stable its content. Scientific practices through the management of artifact-representations constitute technology of cognition that can represent in a stable manner a variety of norms implicit in practices. Such stability promote the diversification and specialization of the sort of concepts, models and explanations that are

[15] Margolis (Margolis 1993) argues that the emergence of probability was delayed until the development of a new habit of mind (or as I would prefer to say, heuristic structure) develop that had a use for the new notion. Before the development of such new way of thinking the concept of probability had no use, its use was contained by "barriers" associated with old habits of thinking. Clearly these "barriers" can function as "fitness barriers" in the sense used by Bickhard (and Wimsatt and Griesemer). But such "habits of mind" or "heuristic structures" also function as scaffolding in the sense that they support artifact-representations that tend to be differentially reproduced.

[16] See Margolis 1993.

[17] The difference between the concepts of generative entrenchment and path dependence are related to the differences I have pointed out between different notions of scaffolding. I elaborate this distinction elsewhere.

distinctive of specific scientific practices and that can be seen as paradigmatic examples of cultural evolution.

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