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INTERPRETATION IN SCIENCE

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There is a traditional account of objectivity that has grounded a characterization of what is, and what is not, an interpretation. The account relies on an old metaphysical distinction, the distinction between primary and secondary properties. The idea of a core distinction between these two sorts of properties as the basis for an account of objectivity is an achievement that marks the beginning of modern science. The lists of "primary" (or "essential", "original" or "simple") qualities drawn up by Galileo, Descartes, Boyle, Newton and Locke differ in some respects, but they also have an important common core.[2] For Galileo an important distinction has to be made between the properties that one cannot think separately from bodies and the properties for which "one does not feel compelled to bring in as necessary accompaniments" (those properties that according to Galileo "reside only in the consciousness"). Galileo uses the distinction to argue that comets are not real and heat is not a substance. Newton thinks that primary properties are those properties that we can perceive in all sensible bodies and which, as I will say using contemporary terminology, are *additive*, in the sense that the property of the whole is the result of the addition of the (same sort of) properties of the parts.[3] Newton believes that these primary properties (what he calls "essential qualities") can be characterized *physically*, as the properties that enter in the description of fundamental laws of nature. Newton seems to think that the assumption of the existence of primary properties is the basic metaphysical assumption required to do physics.

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[2] Here is Galileo in the "Assayer": "Now I say that whenever I conceive any material or corporeal substance, I immediately feel the need to think of it as bounded, as having this or that shape; as being large or small in relation to other things, and in some specific place at any given time, as being in motion or at rest; as touching or not touching some other body; and as one in number, or few, or many". (in Galileo 1957[1623] p.274)

[3] Here is Newton in the Principia: "the least particles of all bodies [are] ... extended, and hard, and impenetrable, and moveable, and endowed with their proper *vires inertiae*. And this is the foundation of all philosophy". See Newton Rule III of Reasoning in book III of 1962[1686].

According to this traditional view, real objects are distinguished from illusions (from "nothing more than names when separated from living beings", as Galileo says in the "Assayer") by the fact that they have primary properties. Underlying this view is an important assumption. Primary properties are properties that an object has not only independently of the mind, but also independently of whether anything else exists. This idea is implicit in Locke's characterization of the material substratum of objects (characterized by the primary properties). It is made explicit by Newton in the context of his discussion of the physical qualities of bodies. Newton's characterization of primary properties as exemplifiable by systems in empty space excludes the possibility that a primary property is an irreducibly relational property of a certain configuration of particles. More generally, it excludes the possibility of a property of a body in a physical context being irreducible to (or not supervenient on) physical properties of the primitive constituents (characterized by primary properties).

Instead of going further into the subtleties of an historical account I will sum up the traditional account of primary and secondary properties as follows: (1) Primary properties are intrinsic or objective in the sense that they can be represented from any point of view. They are considered to be properties that hold independently of context. (2) Primary properties are additive (in the sense indicated above). (3) If a property is primary it cannot be explained in terms of other properties. The characterization of secondary properties has always been more problematic and controversial. It is enough for the purposes of this paper to say that secondary properties have been regarded as (1) contextual, (2) non-additive, (3) reducible (to primary properties) and (4) mind-dependent in the sense of being projected by us onto the world. This classical account of objectivity is the basis of the traditional distinction between explanation and interpretation. Explanations ultimately refer to the primary properties of objects, or refer to objects that are considered in some sense reducible to primary properties. Interpretations refer to secondary properties of objects, and thus they include a non-eliminable element of subjectivity, or what is the same, they describe the world in a way that cannot be reduced to its objective features. It is natural, then, that the philosophy of science throughout the twentieth century has centered on questions of explanation and predictability and has had little to say about interpretation. Within the traditional account of what is objective interpretation has no place. To the extent that this distinction can be accepted as the metaphysical ground of the scientific view of the world science can ignore issues of interpretation.

There is one important problem which throughout the twentieth century has generated problems of interpretation in the traditional sense sketched above. This is the problem of the interpretation of quantum mechanics. There is a problem of interpretation of quantum because it seems that the descriptions or models that the theory offers, do not seem to fit the characterization of objectivity based on the distinction between primary and secondary properties. I will give a brief account of this problem of interpretation in order to illustrate the way in which a certain account of objectivity shapes our understanding of what is, or is not, interpretation.

Intuitively it is not hard to see that the traditional account of objectivity implies *the principle of separability:* Any physical process occurring in spacetime can be explained as the result of an assignment of physical properties at spacetime points. There are different ways in which it can be shown that the principle of separability is a fundamental principle of classical physics; those of you that do not find the principle intuitively clear will have to believe me that it is a basic tenet of the classical account of objectivity. It might help to remember that this account relies on the assumption that there are properties of bodies which are the result of the addition of the same sorts of properties of the components that can be located at spacetime points. That is, each and every process can be explained as the result of changes in physical properties which can be located in spacetime points. One way of understanding the source of the problem of interpretation of quantum mechanics is that the theory seems to be saying that the separability principle is not true in our world, or else that the theory does not generate objective representations of reality. There is a problem of interpretation here because as far as we know there is no more fundamental theory that could explain what the theory predicts, and, more importantly, there is a series of experiments which seems to confirm the predictions of quantum mechanics concerning the non separability of quantum interactions. There is a problem of interpretation because what our best theory about the microworld says does not fit the basic picture that we have been cultivating since the seventeenth century.[4] It seems that there are physical interactions that do not fit the basic representation of interactions as explainable in terms of what happens point by point.

Implicitly -and this is the lesson I want to draw for you today- the claim is that an acceptable interpretation of a theory has to generate objective representations. The way in which the term 'interpretation' is used in

[4] For a discussion of the problem of interpretation of quantum mechanics from a non-technical perspective, see for example Forrest 1988.

discussing the problem of interpretation of quantum mechanics is a good guide to understanding the discussions about interpretation in other scientific contexts. For example, many interpretations of quantum mechanics are considered unacceptable because they seem to advert to some sort of intentionality in nature. To the extent that an attribution of intentionality involves projections, and not primary properties, those interpretations are considered to be defective. For example, some interpretations claim that when a experiment takes place and the person "looks" into the interaction, then the interactions behave classically. But as many physicists and philosophers have protested, that suggests that a human observation, in a sense that cannot be explained in physical terms, modifies the physical situation. Some popular accounts of quantum mechanics which follow this line of interpretation suggest that we should not even say that the other side of the Moon is "there" since we do not observe it, and what we do not observe is not "really there".

More generally, issues of interpretation often arise because the objectivity of scientific knowledge is considered to require a sharp distinction between the realm of objectivity and the realm of actions and intentions. Were we able to talk of something like "contextual" properties of objects as objective then the problem of interpretation of quantum mechanics could be dissolved. I think one can do this in various ways but I will not attempt to elaborate such a view of objectivity, I will simply assume that some account of objectivity, which is not grounded on the distinction between primary and secondary properties is possible.

Summarizing what we have so far. In the positivistic tradition problems of interpretation are considered to be outside the realm of science, since it is assumed that science deals with facts, not with interpretations of facts.[5] A version of this idea is that the very distinction between explanation and interpretation allows us to draw a line between the natural and the social sciences.

The crumbling of the positivist tradition has shown the importance that the theme of interpretation has well beyond the social sciences. The acknowledgment of the importance of the history and sociology of science (as well as other empirical studies of science) in any project directed towards understanding the nature of the scientific enterprise has underscored the importance of issues of interpretation in the natural sciences. Among other things, those studies have led to the recognition of the importance of the social structure of scientific practices, as well as the

[5] A committed positivist would simply deny that there is a problem of interpreting quantum mechanics.

importance of the wide variety of material contexts in which science develops. Instruments are not considered mere useful extensions of theories, merely useful for expressing materially an idea implicit in a theory. A whole series of "laboratory studies", and more generally constructivist approaches, as well as other projects inspired by deconstructionist views like Derrida's have called our attention to the similarities that exist between literary inscriptions and the facts.

In particular they have called our attention to the conviction that a discussion about the facts cannot be separated from the manner in which knowledge gets "inscribed". This has been heralded as allowing approaches to the material aspects of the scientific notion of representation. In some of these studies there is a tendency to emphasize the narrative structure that embodies a representation, and to think of whatever requires interpretation as a "text". A representation is considered historically situated and to have a multivalent nature that gets expressed through patterns of analogy and metaphors. Those different ways of representation are important in establishing a fruitful relation between the text and its environment.[6]

One can also emphasize the constructivist nature of scientific experimental procedures. Rheinberger has produced a paradigmatic example of this sort.[7] In the case he studies, the molecular biology of protein synthesis, he shows that the different components of the cells are defined through different procedures of centrifugation, sedimentation, radioactivation, and the like. Scientific object gets configured from juxtaposition, displacement and positioning of different "traces. Representation in this sort of studies is equivalent to "bringing epistemic things into existence" (Rheinberger, 1997, p. 107). Representations are not mere depictions but ways or modes of working.

There are constructionists that think that a key to understand the manner in which contemporary scientific interpretations are produced is the study of scientific laboratories. Others, however, think that it is necessary to go well beyond those sort of studies to have a good grasp of the ways in which interpretations get constructed and authority conferred. What the appropriate context is in which to study the constructions of interpretations

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[6] A classic example of the first sort of studies is *Laboratory Life: The Construction of Scientific Facts*, by LATOUR, B. and WOOLGAR, S., 2ed. Princeton, NJ, Princeton U. Press, 1990.

[7] RHEINBERGER, H.-J.: *Toward A History of Epistemic Things, Synthesizing Proteins in the Test Tube*, Stanford, California, Stanford U. Press, 1997.

and the granting and acknowledgment of authority is a major issue in contemporary discussions, but this is not an issue that concerns us today. All what I want is to make minimally clear how a different view of representation is being elaborated under the slogan that the idea of representation as referentiality has to be abandoned.

Remember that the traditional claim was that explanations describe the world as it is. They are objective and do not depend on interests or perspectives or contexts. Interpretations depend on interests, perspectives and contexts. The idea that the concept of interpretation is characteristic of the social sciences is an important claim within a tradition that goes back to Wilhem Dilthey. G. H. Wright made famous a distinction inspired in that same tradition. Wright claimed that there were two fundamental world views, the Galilean and the Aristotelian world views[8]. The first one embodies the ideal of objectivity characteristic of the natural sciences, the sort of objectivity that grounds the understanding that gets expressed in explanations, the other embodies the sort of understanding that gets expressed in interpretations.

The social sciences require interpretation because the understanding of human actions require uncovering the meaning expressed by those actions. There have been different proposals as to where to situate the meaningfulness of actions, in actor's intentions, background practices, constitutive rules of behavior, and so on. All of them coincide in reaffirming the divide between natural and social sciences and thus the divide between explanation and interpretation. The naturalistic turn in philosophy of science in the mid twentieth century led to a revision of this account. Several writers, Thomas Kuhn, Stephen Toulmin, and Mary Hesse, among others, pointed to the striking similarities present in the view of the natural sciences resulting from the critique of positivism and the interpretive nature of the social sciences. Toulmin looked at "ideals of natural order" which endow terms with meaning, and Kuhn thought of taxonomies similarly. As Joseph Rouse has recently expressed this tendency, "the very arguments that are supposed to establish the uniqueness of the human sciences have contributed to our accounts of natural science, thereby further undercutting the distinction".[9] Nonetheless, one can argue that there are important differences between the sense in which one

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[8] *Explanation and Understanding*, by G. H.. Wright, Cornell U. Press, 1972

[9] ROUSE, J. "Interpretation in Natural and Human Science" in *The Interpretative Turn*, edited by David R. Hiley, James F. Bohman, and Richard Shusterman, Cornell U. Press, 1991.

interprets nature and the sense in which one interprets human beings. That is, one can acknowledge similarities among notions of interpretation used in the natural and the social sciences but still insist in there being significant differences among them.

An important discussion that took place in the late seventies (with inroads to the present) was precisely about this issue. Charles Taylor argued that in spite of the similarities between notions of interpretation that were useful in the natural sciences and the social sciences, there were fundamental differences among those notions.[10] Though Taylor recognizes that interpretations have to complement the explanations offered by the natural sciences, he thinks that natural science seeks to gain access to an objective reality, a reality that could be described independently of purposes and interests, and independently of interpretations. That is, Taylor seems to think that the classical account of objectivity is still appropriate to the natural sciences, if not to the social sciences.

Against Taylor one can argue that there is no fundamental difference in the scope of the notions of interpretation used in the natural and the social sciences, and thus, implicitly or explicitly one is led to question the classical account of objectivity. Richard Rorty has claimed that such a distinction between the natural and the social sciences is a relic of a bygone era. For Rorty, as for Gadamer, there is no understanding free of interpretation. In that case one has to find a way of overcoming the apparently obvious differences between the objects of inquiry in the two types of disciplines. For example, one can say that in the natural sciences the objects of inquiry are subjects of interpretations but not generators of interpretations, whereas human beings, the objects of inquiry of the social sciences, are both subjects and generators of interpretations. How significant this difference is depends on the notion of interpretation that we put forward (implicitly or explicitly).

If the notion of interpretation relies heavily on a notion of intentionality, then it is natural to conclude that the notion of interpretation characteristic of the social sciences is different from the notion of interpretation characteristic of the natural sciences. The notion of interpretation can also be characterized independently of the notion of intentionality, and I think this is true of the most interesting proposals for understanding the nature of science which are discussed nowadays. I will say something about these sort of proposals later, but roughly speaking, the idea is

[10] See by TAYLOR, C., "Rationality", in *Philosophical Papers*, vol.2, Cambridge University Press, 1985.

that to the extent that interpretations are grounded in representations, and representations are not essentially characterized in terms of intentions, the issue of intentionality and its role in the characterization of what an interpretation is diminishes.

This way of addressing the similarities between different notions of interpretation reflects a clear tendency in the contemporary philosophy and sociology of science. But I do not think that this tendency has much to say positively, that is, beyond questioning the old idea of a fundamental distinction between the natural and the social sciences. In order to go beyond this dispute, I think we need to search for a more basic account of interpretation.

Had we more time it would be rhetorically advisable to present and criticize alternative accounts of interpretation and show how they are related to different accounts of objectivity. In the present circumstances I think it the best to proceed directly to suggest the sort of characterization of interpretation that I find more promising: interpretation, as the process of generating interpretations, consists of the construction of representations. At first sight it might seem we have not gained much, if anything. The notion of representation, it can be argued, is as vague and polysemic as the notion of interpretation. The notion of construction is also vague and polysemic. This may be right, but nonetheless, the explicit acknowledgement of the relation between interpretation and representation via "construction" helps to orient us to a characterization of interpretation distinct from its characterization in terms of intentionality. Focusing on the concept of representation suggests a different account of the nature of the relevant differences between interpretations in the various sciences. Roughly, the idea is that there is a wide variety of ways in which we can "represent" a process or an object, and that those different ways of representing are part and parcel of our account of processes and objects. Representation is an aspect of the transformation of objects that emphasizes its prospects and etiology in specific cultural settings. In traditional scientific culture representations are often associated with virtual transformations of objects in mathematical models, but mathematical models are only one way in which objects get represented. Objects also get represented in charts, diagrams, partitures, experimental settings and technological devices. There are no definite ways in which we can characterize what a representation is or is not. Representing is an open-ended process. Ways of representing are as varied and unpredictable as trends in architecture or developments in technology. This is not surprising, since representing is a crucial task for technology as it is for art.

There are different senses in which we can put together representations to "construct" other representations. I think that in scientific cultures an interpretation is nothing much beyond a representation that is seen as a prospect for further research or applications, or as a prospect for connecting or developing other representations. We represent electricity as a fluid to facilitate its prospects to be transmitted like water, and represent electricity as a field in order to explore or understand its relation with magnetism. We represent an evolutionary process through molecular models in order to profit from the relations between micro and macro processes that molecular biology offers. We search for different representations in order to profit from the wide variety of representational techniques and connections among those representations that constitute what we call molecular biology, and beyond.

Representations are not private, they are part of a public language, but they are more than language. They are the result of distinctive practices. One can represent electrons in terms of diagrams, bubble-chamber photographies electron microscopy, or in terms of contrivances made of paper and polyurethane. It is important to notice that the different ways in which one can represent electrons are not in any way fixed prior to the individuation of practices that support the representations. We associate with representations a certain degree of durability that is really attributable to the stability of the supporting social practices, which in turn relies on the entrenchment of features of material culture embodied in technological devices. This is an idea that Latour has exploited in the development of the concept of "immutable mobiles" (in Latour 1990, p. 26). Different technologies might be used, and combined, to generate new representations and thus new prospects of interpretation. Notice that each representation can be seen as constituted, or configured, by different sorts of representations, - photometers, Geiger counters, light-sensitive paper, magnetometers, statistical techniques, and so on.

One can derive from the variety of representations of a molecule an argument for realism, but without going that far one has to recognize that molecules are entrenched in a wide variety of representations, and that those representations are connected in many different ways with technological devices and theoretical principles. There is no simple way of describing those relations. The variety of representations has a geography and a history but most probably there is no overall theory of representations. There is no reason to think that all this variety of representations and relations among them can be captured in anything worth calling a theory in the traditional sense, that is, in the sense that all representations ultimately can be represented in a unifying framework. The suggestion is that there is no theory of scientific representations, just as there are no interesting theory of earth-geography.

I think that representations in science are aspects of culture embodied in techniques and more generally in practices that allow for the generation, the stabilization and entrenchment of objects, and a social grasp of their prospects. A representation in my sense has a socially recognizable history which can be traced to the practices supporting the generation and maintenance of representations as distinguishable modules in the construction of reality. A representation always carries a claim of objectivity, but the relevant notion of objectivity is not the classical notion of objectivity ultimately grounded on the distinction between primary and secondary properties. Something is objective within a certain context, maybe not in others. Such notion of objectivity might sound incoherent; one might think either this is not objectivity or else it is not contextual. As I have already mentioned, I will not attempt to characterize and defend a notion of contextual objectivity, but assuming that such characterization is possible, one could answer the crucial questions that underlie the discussion of the relation between interpretation and objectivity in scientific culture. For example, representations have a content, but this content does not need to be cashed out in terms of a non-cognitive reality that supports its status as representation. The content of representations can be, and I would say usually are, other representations.

Kinds of representations are distinguished culturally. Different sorts of models - models in the sense that maps are models, in the sense in which miniature airplanes are used in the wind-tunnel, models in the sense of logic, models in the sense of grammatical paradigms for verb conjugations - all of those senses of models, and many others, are to be seen as (generating) different sorts of representations, distinguishable because we distinguish the practices that support their claim to contribute to our understanding. Visual documents, graphs, charts, laboratory journals, textual figures, instructions for the use of a device, computer programs, experimental techniques, techniques for studying or communicating with an alien culture, etc. should be considered to be different sorts of representational techniques, and thus generators of different representations. They are different because they are the result of different sorts of material conditions stabilized in social practices. They are recognized as different sorts of representations, and thus as candidates to serve as modules in other representations, because they rely on different sorts of resources to connect with other representations.

I have explained elsewhere the sense in which evolutionary models might be helpful in understanding this characterization of representations as supported by scientific practices as well as the sense in which we can talk of a "geography" of practices.[11] Roughly, a feature or aspect of a practice gets individuated in the context of other practices to the extent that those features or aspects enter into the constitution of other practices, suffering often slight modifications, and thus point to the variability and at the same time relative durability of those features or aspects. Like geographical facts indicated in a map, a practice gets individuated only in relation to neighboring practices and their related prospects. Here I just want to conclude emphazising the open-ended nature of the processes that can be characterized as (resulting in) representations, and in particular the modular nature of representations.

Representations are modular in the sense that they are composed of other representations that can get loose, disperse, and enter into other representations. The modularity of representations is closely related to the modularity of the procedures, embodied in practices, that generate representations. Experimental techniques are examples of this sort of modular procedure. Roughly, experimental techniques are modular in the sense that they are composed of other techniques, some of which, in certain circumstances can become detached and enter in other associations to generate other representations. This fundamental feature of techniques and representations in general, their modularity, is crucial to understanding the wide variety of sorts of interpretation that can exist. The possible stable combination of a given number of modules is not something fixed in advance. That one combination of modules can generate a new representation depends on the world and on the resources of a scientific culture that can be directed to the stabilization of representations. But the resources that enter into these modular constructions can differ widely. Linguistic resources, abilities to manipulate specific instruments, knowledge of distinctive properties of materials, metaphors and analogies, and many others can be combined in a successful representation. What is considered a representation, and thus what is considered an interpretation, depends on the supporting context. If we change the supporting context we should not expect that the representational capacities of a complex of representations survive in the new setting. Representations have roots in other representations, and thus in the variety of practices that generate them. *Practices generate "inmutable mobiles", but they are not "inmutable mobiles".*

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[11] "Historia y Geografía de la razón", en *Filosofía, Historia y Educación de la Ciencia*, edited by Godfrey Guillaumin y Sergio Martínez, Mexico, UNAM, in press.

Summarizing, whereas in classical philosophy of science representations were assumed to be objective because of the way they fixed reference for us, by transcending subjectivity, I suggest that, as many empirical studies on science suggest, representations can be understood philosophically as the building blocks of interpretations. In any case, nowadays it is clear that the discussion about the notion of interpretation in science is deeply related to the way in which we think of the nature of scientific representations and their claim to objectivity.

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