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THEORIES AS REPRESENTATIONS*

ABSTRACT

In this paper we argue for the thesis that theories are to be considered as representations. The term "representation" is used in a sense inspired by its mathematical meaning. Our main thesis asserts that theories of empirical science can be conceived of as geometrical representations. This idea may be traced back to the very beginnings of Western science, to wit, Galileo. The geometric format of empirical theories cannot be simply considered as a clever device for displaying a theory. Rather, the geometric representation deeply influences the theory's ontology. Embedding the representational approach in the framework of a Peircean semiotics enables to take into account explicitly the role of the cognizing subject for the representational constitution and development of empirical theories. Finally, we address the recently much debated problem of whether the concept of representation is a philosophically respectable notion or not. We argue that it would be disastrous for philosophy if it followed Rorty's "neo-pragmatic" proposal to discard the concept of representation from philosophical discourse.

I. Introduction

A central question of the philosophy of science, arguably the most central one[1], is "What is the structure of scientific theories?" (cf. Duhem 1906). In the history of the philosophy of science this question has been answered in many different ways.[2] Probably, *the theory question* will never get a unique and unanimously accepted answer. Nevertheless, we firmly believe that it has good and not-so-good answers.

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[1]In the light of some contemporary currents of philosophical thought the centrality of the "theory question" has been challenged. Some philosophers have argued that the most important problem of the philosophy of science is to get an adequate understanding of the practice of scientific inquiry, in particular experimental practice, cf. Hacking (1983), Kitcher (1993), Rouse (1996). Be this as it may, we think there is sufficient importance still remains to justify the further pursuit of the theory question.

[2]Cf. Duhem (1906), Kuhn (1962), Suppe (1974), Hung (1981), Balzer, Moulines and Sneed (1987), Giere (1988), da Costa and French (1990).

In this paper we argue for the thesis that theories are to be considered as *representations*. This idea is not new, and it has been put forward by many authors in many different ways.[3] A representational account of empirical theories crucially depends on the underlying concept of representation. Within philosophy, the concept of representation may be considered as controversial and obscure. Its long and involved philosophical history can be traced back at least to Descartes and Locke.[4] On the other hand, it has a long, uncon-troversial and clear use within mathematics. In this paper, we use the term in a sense inspired by its mathematical meaning (Mundy 1986, Swoyer 1991). Thereby we hope to avoid unnecessary philosophical quarrels. In particular we would like to point out at the very beginning of our endeavour that the representational account is not necessarily committed to a thorough-going realism, according to which, the aim of science is to give the one and only *true representation of the world.* Nor, as will become clear in what follows, must the representational account lead to an austere empiricism or positivism according to which the aim of science is solely *to save the phenomena* (Duhem 1908).

The outline of the paper is as follows: in section 2, our point of departure is a classical account of the representational approach, namely, Margenau's *Methodology of Modern Physics* developed some 60 years ago. It may be considered as one of the earliest attempts to conceptualize empirical theories as representations. It will provide us with a general idea of how theorizing in empirical science is based on representationally constituted theoretical concepts. In section 3 we specify our main thesis about the representational character of empirical theories by pointing out that the theories of empirical science can be conceived of as geometrical representations in a generalized sense. Geometric representations may be traced back to the very beginnings of modern Western science, i.e., to the *Two New Sciences* of Galileo (Drake 1974) and even to some currents of medieval natural philosophy such as Oresme's configurational doctrine of the 14th century. As can be shown from a detailed study of the "law of uniform acceleration" the geometric format of empirical theories cannot be considered simply as a clever device for presenting a theory. Rather, the geometric representation deeply influences the theory's ontology as is shown by contrasting the ontology of Galilean mechanics (and Oresme's configurational doctrine) with the ontological framework of Aristotelian natural philosophy. In section 4 the role of geometric representations for the ontology and the epistemology of modern

[3] See Churchland (1992), Mundy (1986), Swoyer (1991).

[4] A very interesting new version of the history of representational ideas in Western philosophy since antiquity has been recently given by Watson (1995).

empirical theories is pursued further by dealing with some crucial concepts such as state spaces, processes, and laws. In section 5 the representational approach is embedded in the framework of a Peircean semiotics. This allows us to explicitly take into account the role of the cognizing subject for the representational constitution and development of empirical theories. Finally, in section 6 we address the recently much debated problem of whether the concept of representation is indeed a philosophically respectable notion or not. We argue that it would be disastrous for philosophy if it followed Rorty's "neo-pragmatic" proposal to discard the concept of representation from philosophical discourse.[5] Rather, philosophers should engage in the task of explicating and developing this complex and difficult but indispensable notion.

II. Data and Symbolic Constructs

For explicating the thesis of the representational structure of empirical theories let us start from an approach proposed by the philosopher and scientist Margenau some sixty years ago (Margenau 1935). Margenau's account has the virtue of being a vivid, scientifically well-informed description of how physical theories are conceptualized by scientists which tries to make its points without unnecessary "philosophical" fuss. He distinguishes two levels of physical conceptualization as explained in his paradigmatic example:

> ... we observe a falling body, or many different falling bodies; we then take the typical body into mental custody and endow it with the abstract properties expressed in the law of gravitation. It is no longer the body we originally perceived, for we have added properties which are neither immediately evident nor empirically necessary. If it be doubted that these properties are in a sense arbitrary we need merely recall the fact that there is an alternate, equally or even more successful physical theory - that of general relativity - which ascribes to the typical bodies the power of influencing the metric of space, i.e. entirely different properties from those expressed in Newton's law of gravitation (Margenau 1935, p. 57).

Thus, according to Margenau, for any physical theory we have the level of *data*, e.g. the falling body or the deflections of an ammeter, and the level of what Margenau calls *symbolic constructs*, e.g. forces, space curvature or electric currents. This two-level structure pervades all realms of physics. Even if the realm of symbolic constructs in physics is not determined in the same

[5] One may wonder how Rorty comes to conceive of his antirepresentationalism as being compatible with pragmatism. After all, the founding father of pragmatism Peirce thought of representation, i.e. the category of thirdness, as the backbone of pragmatism (Peirce 1905). The explanation is that Rorty's neo-pragmatism may be considered as an updated version of James's or Dewey's pragmatism that has not much to do with the original account of Peirce.

rigid way as the realm of data, it is not completely arbitrary. There are general requirements concerning symbolic constructs. According to Margenau, the main task of the symbolic constructs is to provide the means for physical explanation, this term to be understood in a broad sense. Thus, for a long time all permissible constructs had to be of the kind often described as mechanical models or their properties, but this view is now recognized as inadequate. What is required is "that there be a permanent and extensive correspondence between constructs and data" (Margenau 1935, p. 64). Putting together data, symbolic constructs, and their correspondence we propose the following general format of an empirical theory:

(2.1) DEFINITION. Let *D* be a realm of data, and *C* be the realm of symbolic constructs. An empirical theory is a representation $f: D \longrightarrow C$. The mapping f is said to provide a representation of the realm *D* by the realm *C* of symbolic constructs.

Margenau's requirement that there be a permanent and extensive correspondence between constructs and data is expressed by the requirement that the representing map f from *D* to *C* cannot be just any map but has to respect the structure of *D* and *C*. Thus some constraints of structure preservation have to be put upon it. The details depend on how the data and symbolic constructs are conceptualized precisely. We shall have more to say about it in section 4.[6]

(2.1) gives us a rather crude picture of the structure of an empirical theory. The specific nature and the relation of these two components of a theoretical representation $f: D \longrightarrow C$ have been the topic of much discussion. A rather popular account took *D* as the observable and *C* as the non-observable. But this has not been the only approach. Others have considered *D* as the empirical, and *C* as the theoretical. No unanimity has been achieved as to how these levels of conceptualization are to be understood precisely. Probably, as is often the case, the one and only right explication does not exist. For the purposes of this paper we need not offer any argument for any specific position in this issue. We are content to point out the following facts:

(i) The distinction between data and symbolic constructs is no absolute distinction, i.e., in one context entities can function as data and in another

[6]Margenau is not the only one and not the first who makes such a distinction: some more or less implicit remarks on the representational character of empirical theories can be found in Duhem's account of *The Aim and Structure of Physical Theory*, see especially (Duhem 1906, Ch. 8).

context as symbolic constructs. In particular, data need not be considered as the "immediately given" as some Logical positivists are said to have done.[7]

(ii) It is an important task for the philosophical reconstruction of empirical theories to explicate in a precise manner the structure and the function of the correspondence between data and symbolic constructs. As has been indicated already by Margenau, symbolic constructs generate a "conceptual surplus" which can be used for determining, explaining and predicting previously unacessible aspects of data. For example, partially known kinetic data are embedded into the framework of symbolic constructs like forces, hamiltonians, or lagrangians in order to obtain new information not available without them.

The representation of data by symbolic constructs has *explanatory* and *exploratory* functions. It serves to embed the data into a coherent explanatory theoretical framework.[8] That is, the correspondence between data and symbolic constructs is the basis of physical explanation. To use once again the just mentioned example: a kinetic system may be explained causally by referring to theoretical constructs like forces. Hence, physical explanation can be described as a movement of the following kind: it starts in the range of data, swings over into the field of symbolic construction, and returns to data again. More generally, one can characterize the activity of scientists, be it explanation, or prediction, or conceptual exploration, as an oscillating movement between the area of data and the area of symbolic constructions. Following Margenau it may be called "swing".[9] Hence we may characterize an empirical theory more fully as follows:

(2.2) DEFINITION. Let *D* be a realm of data, and *C* be a realm of symbolic constructs. An empirical theory is given by a domain *D* of data and *C* of symbolic constructs endowed with a map $f: D \longrightarrow C$ and a symbolic interpretation $s: C \Longrightarrow D$. The map *f* is called a *representation* of the realm

[7]As Margenau remarks, the misleading expression "data" should be replaced by *habita*, implying that there may exist no external agency to which we are indebted for its gifts (Margenau 1935, p. 60). In what follows we will stick to the established term data with the caveat that we understand data as habita. Moreover, we take the distinction between data and constructs as a relative one, i.e., in some contexts, data (habita) may be considered as symbolic constructs for some other data, while symbolic constructs may be considered as data with respect to still other symbolic constructs. This relativization shows the indispensable role of a cognizing subject that interprets data *as* data, and constructs *as* constructs.

[8] Leytoneven claims "representation *is* explanation" (Layton 1992, ch. 4).

[9]As Margenau himself puts it: "The full course of physical explanation ... begins in the range of perceptible awareness, swings over into what we shall now term the field of symbolic construction, and returns to perceptible awareness, or, as we have said, nature. ... The essential feature of a physical explanation is evidently the transition from nature to the realm of constructs, and the reverse." (Margenau 1935, p. 59).

D by the realm C of symbolic constructs. The symbolic interpretation s may be thought of as an operator that (in a quite literal sense) pulls back meaningful structures of the conceptual realm C to the domain of data D thereby providing empirical interpretations for the theoretical concepts of the theory.

According to (2.2), a representational theory should be denoted by

$$D \xrightarrow{f} C \overset{s}{\Longrightarrow} D$$

or something similar. For the sake of typographical convenience, however, we continue to denote it simply by $f: D \longrightarrow C$. Before we go on, the following remarks on (2.2) may be helpful: As will be spelt out in the following the representation $f: D \longrightarrow C$ is to be conceived of as a structure-preserving map in the mathematical sense (see Mundy 1986, Suppes 1989, Swoyer 1991). Roughly, D and C are thought of as relational systems in the standard sense of model theory, i.e., they are sets together with an ordered set of relations R^i_D, and R^j_C respectively. The representation f is assumed to be a homomorphism with respect to at least some of the pairs (R^i_D, R^j_C) (cf. Mundy 1986, p. 394).[10] The symbolic interpretation $s: C \Longrightarrow D$ may be regarded as a more elusive notion. Structurally, it may be characterized as a device for pulling back meaningful structures from C to D via f. Consider the following example:

(2.3) EXAMPLE. Let C be endowed with an order structure $\leq$. If $f: D \longrightarrow C$ is any map $\leq$ may be pulled back to D by the definition

$$d \leq d' := f(d) \leq f(d')$$

In this way, f gives rise to a D-interpretation of a structure, originally living on C. In other words, the domain D inherits certain structures, originally defined only for C. Although this notion of pulling back meaningful structures seems to be not so well known we hope to make it reasonably clear how it works by discussing some examples.[11]

The distinction between data and symbolic constructs not only poses interesting epistemological or methodological problems. As has already been

[10]We don't want to specify the requirements for D, C and f too strictly. In any case, there is a developed theory of what may be understood by a structure preserving map between relational systems (Mundy 1986, Swoyer 1991, Suppes 1989).

[11]Actually, there is a mathematical theory dealing with pairs of relations such as f and s, to wit, category theory (Goldblatt 1979). In terms of category theory, the representation $f: D \longrightarrow C$ may be conceptualized as a functor. Then, the interpretation s is related to a functor $C \longrightarrow D$ called the adjoint of f. We hope to deal with this topic on another occasion.

pointed out by Margenau himself, it has some very interesting ontological ramifications. In modern terms it may be stated as the problem of realism concerning symbolic constructs: "Do masses, electrons, atoms, magnetic field strengths, etc. *exist*?" (Margenau 1935, p. 164). We don't want to delve into matters of realism in any depth in this paper, rather we'd like to outline Margenau's own quite original account of the problem of what is to be the ontological status of symbolic constructs.

According to him, almost every term that has come under scientific scrutiny has lost its initial significance and acquired a range of meaning of which even the boundaries are often variable. A notable exception seems to be the term "to be" and its ilk. This is a regrettable state of affairs. The question of whether symbolic constructs exist cannot be answered by a simple Yes or No:

> The main point we are making is this: physical constructs cannot be said either to exist or not to exist; their ontological status has to be fixed in accordance with a more elaborate analysis of the meaning of existence. In particular, the value of a construct bears absolutely no relation to its mode of existence. (Margenau 1935, p. 165)

One should resist the temptation to adopt a primitive instrumentalist stance according to which the data are the only "really" existing entities and the symbolic constructs are "really" non-existing symbols invented only for the sake of prediction. On the other hand, a symbolic construct such as an electron does not have the same ontological status as, say, the philosopher's notorious apple tree. Rather, we should define the physical universe as the totality of all data (nature) and of all symbolic constructs. This leads to an open ontology, in contrast, say, to a closed austere positivistic ontology that countenances only data. As Margenau points out, this austere stance may be attractive for philosophical or aesthetic reasons, but confronted with the reality of physics, it turns out to be untenable.[12] Representational theories are committed to a complex ontology that cannot be reduced to philosophically appealing but unrealistic simplicity. In the next section we want to show that this complex open ontology is not a peculiarity of 20th century physics but may already be found at the very beginnings of Western scientific thought.

III. Geometry and Ontology: Some Historical Considerations

Up to now, the characterization of empirical theories as representations $D \xrightarrow{f} C \overset{s}{\Longrightarrow} D$ has remained rather abstract. Not much has been said

[12]The positivist is challenged to cope with the following task of analyzing a simple proposition of the form "Light is an electromagnetic disturbance" without assuming two classes of things (Margenau 1935, p. 187).

about the represented domain D and the representing domain C except that they have to be connected by some sort of structure preserving map f. Looking at the actually existing science, we would like to launch a more specific thesis:

(3.1) THESIS. Theoretical representations $D \xrightarrow{f} C$ are geometrical representations in the sense that the representing domain C may be conceived of as a (generalized) *geometrical space*.

The usage of (generalized) geometry as a representational medium cannot be solely considered as a clever device for presenting empirical knowledge. Rather, as we want to show in the following, the conceptual usage of geometry has had a strong impact on the epistemology and ontology of empirical science.

In this section we want to study this impact through some elementary examples that nevertheless may be considered as important turning points for the historical development of Western science. More precisely, we want to compare the usage of geometrical representations in Nicole de Oresme's *Geometry of Qualities and Motions* (Clagett 1978) in the 14th century and in Galileo's *Two New Sciences* from the 16th century. This comparison will show how geometry has a deep influence on matters epistemological and ontological. More precisely, we show how Oresme's geometric account of qualities and motions provides an interesting link between traditional Aristotelian science and its substance-form ontology and the representationally informed ontology of modern science of which Galileo's *Two New Sciences* may be considered as an early landmark.

For Aristotle and modern empirical science in its early period one and the same problem occupied centre stage, to wit, the problem "What is motion?". As is well known, the Aristotelian notion of motion not only comprises the notion of motion in physical space, but also changes such as creation, growth and general changes of qualities and quantities. It is this all-embracing nature of the Aristotelian concept of motion that may considered as a hindrance to a thoroughgoing mathematical treatment of this concept.

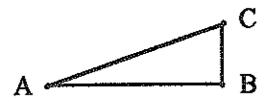
Oresme occupies a mediating position in the history of the mathematization of the concept of motion. His "configuration doctrine" may be considered as an attempt to apply geometrical representations as a universal tool for modelling motion (in its broad Aristotelian sense) without questioning the fundamental presuppositions of Aristotelian ontology. The programme of the configuration doctrine Oresme stated at the beginning of his treatise *De configurationibus qualitatum et motuum* can be described as follows (Clagett 1978, pp. 165-6). Usually, measurable quantities may be regarded as continuously changeable quantities. According to Oresme, for measuring such quantities it is therefore necessary that one imagines points, lines and areas, since in these objects one finds measure and proportion in a

paradigmatic way whilst in other realms these concepts are to be found by translation only. Even if points, lines, and areas do not exist in reality it is nevertheless necessary to presuppose them for the measuring of quantities and the understanding of their proportions. For this reason, the quantity of a continuously changeable quality should be represented by a straight line which is vertical on the point of the entity's space that has this quality. This is because for any relation of two quantities of the same kind there is a corresponding relation between two lines and vice versa. Oresme's account can be explained as follows: the object that has a continuously changeable property, e.g. warmth, coldness, colour etc. is represented geometrically by a so called base line AB. The intensity of the quality at one point of the object is represented by a straight line perpendicular to the base line AB:

(3.2)

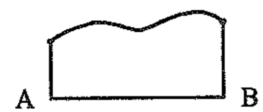
The global distribution of the quality is represented by the geometric figure ("configuration") $ABCD$. Hence, the rectangle $ABCD$ represents an object that possesses a quality that is always of the same intensity. A slightly less trivial example is the following configuration representing a uniformly changing quality distribution. For example an iron bar whose temperature is increasing from the left end to the right end:

(3.3)



In Oresme's terminology, this configuration is characterized as uniformly difform. These configurations may be combined in various ways leading to all kinds of continuously varying quantity distributions:

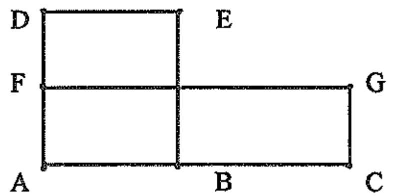
(3.4)



Nowadays, Oresme's configurational doctrine may appear as a rather simple-minded account. Historically, however, it is to be considered as a major conceptual achievement.[13] It already contains all the essential ingredients of a representational theory as laid out in the discussion of Margenau's account in section 2.

Oresme's account is a fully fledged two-level representational account in the sense of section 2. The realm *D* of data is given by the base-lines of the configurations. The realm *C* of symbolic constructs is defined as the configurations based on the members of *D*: If b is a member of *D*, i.e., a base line *b* is a configuration in a quite literal sense. Hence we may cast Oresme's configuration approach into the representational format $f: D \longrightarrow C$ as explained in section 2. The domain *D* is structured mereologically, i.e., if *b'* is the base line of an object that is part of another object with base line *b*, then *b'* is part of *b*. This mereological structure allows a limited comparison of different configurations. For example, the "hotness" of parts of a body may be symbolically calculated and compared with each other:

(3.5)



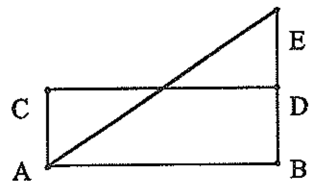
According to Oresme we may say that the total hotness of the small body represented by the base line *AB* equals the total hotness of the large body represented by the base line *AC*. More generally, the symbolic interpretation $s: C \Longrightarrow D$ is based on the comparison of areas "over" different base lines.

Despite its simplistic appearance, the configurational approach makes available quite powerful resources for applying the conceptual surplus of the representing medium of geometry to the realm of data. The configurational account enables us to quantify intensional qualities, e.g. temperature or whiteness, which could not be quantified according to the traditional Aristotelian account. The geometric structure of the representing realm leads to the definition of new complex qualities not available in the traditional Aristotelian ontology. For instance, Oresme's interpretation of the area of a configuration as a "total quality" defined as the symbolic product of other qualities expands the realm of available qualities beyond that of natural

[13]Duhem even claimed Oresme's doctrine to be the legitimate precursor of analytic geometry of Fermat and Descartes (Duhem 1913-1959, Vol. 7). Nowadays, experts consider this claim to be rather exaggerated.

qualities such as "length", "mass", etc. to complex qualities such as "global velocity", or "global impulse". With hindsight, this geometrically motivated constitution of new qualities can be considered as the most fruitful feature of Oresme's configurational account. It paves the way, or, at least, can be regarded as a forerunner of Galileo's geometrized science of motion which we will deal with in a moment. The most spectacular application of this early representational account may be considered to be the so-called Merton rule which can be stated as follows:

(3.6) MERTON RULE. The global quality of a uniformly difform configuration is equal to the global quality of uniform configuration whose intensity is half as large as that of the first:



This assertion is trivially proved by invoking the elementary fact of Euclidean geometry that the areas of *ABCD* and *ABE* are equal, as is indicated in the above diagram. If we interpret the base line functionally as a moving object in time, i.e., a point t of the base line *b* represents an object *x* at time *t*, and take the intensional quality at *t* as *x*'s momentaneous velocity, we may interpret the area of this configuration as the length of the path which *x* has travelled during the time interval considered. Comparing the area of a *triangle configuration* and a *rectangle configuration* over the same base line we get the "law of uniformly accelerated motion". We don't claim that this proof is valid in the framework of Galilean or Newtonian physics.[14] However, this early proof of the Merton rule is evidence for the quite powerful conceptual resources of this medieval doctrine of configurations.

Already in Oresme's own usage of the configurational doctrine, the geometric character of the configurations is to be taken in a quite general sense: it may well be the case that the dimensions of the configuration space are not to be interpreted as dimensions of the physical space *E*. This implies that the states of a physical system that are represented by its "positions" in the state space are not be interpreted as positions in physical space. It is one of the great conceptual achievements of modern empirical science over the

[14]Actually, in the *Two New Sciences* Galileo used a different argument to prove the law of uniformly accelerated motion (Drake 1974, p. 165).

Aristotelian science of the Greek and the Medieval ages to have reached this more liberal interpretation of geometry.

As a particularly interesting example of this generalized usage of geometry let us now consider Galileo's law of uniformly accelerated motion stated in *Two New Sciences* as the First Proposition of the Third Day (Drake 1974, p. 165). In non-Galilean, algebraic terms it may simply be stated as $s = 1/2\, v \circ t$. Galileo himself formulated this assertion as follows:

(3.7) LAW OF UNIFORMLY ACCELERATED MOTION. "The time in which a certain space is traversed by a moveable in uniformly accelerated movement from rest is equal to the time in which the same space would be traversed by the same moveable carried in uniform motion whose degree of speed is one-half the maximum and final degree of speed of the previous, uniformly accelerated, motion."

Galileo's proof of this proposition involves a geometrical representation as is exhibited in the following diagram:

(3.8)

The line *AB* represents the *time* in which the space *CD* is traversed by a body in uniformly accelerated movement from rest at *C*. The base of *EB* of the triangle *AEB* represents terminal speed. The area of the rectangle *ABFG* represents the distance travelled by the unaccelerated body travelling with constant speed *v*/2. The proof of the proposition reduces to the elementary demonstration that the triangle and the rectangle have the same area. What is striking about this geometrical representation is that lines represent not trajectories or distances in physical space but times and speeds. Areas, not lines, represent distances. The real path of the body in physical space is not represented at all.

The essence of Galileo's geometrical representation of physical phenomena may be seen in the fact that the structure of the representing geometrical realm controls the structure of the represented realm of physical phenomena.

The *New Sciences* of Galileo (of which Oresme's geometrical theory of quality and motion may be considered as a forerunner) open the gateway for the wealth of generalized geometric representations of modern science. Euclidean geometry as such, however, wasn't powerful enough to serve as the universal representational tool for the purposes of modern science. The decisive step was taken by the arithmetization of geometry, i.e. the invention of analytic geometry by Descartes (and Fermat). This amounts to a representation of the geometric domain, be it the Euclidean plane or space E^2 or E^3 by an algebraic domain of two or three-dimensional vectors. This leads to an ever more intimate penetration of algebra and geometry resulting finally in the modern mathematical theories of analysis, algebra and differential geometry which may be considered as the true organon of modern empirical science.

These generalized geometric representations should not be considered as clever conceptual devices only. Rather, they lead to deep reconceptualization in the ontology of empirical theories by introducing all sorts of novel ontological categories. These theoretical ontological categories crucially depend on the theory's geometric representations, i.e., without them they cannot even be thought of. For instance, naively one may think that something like mass or length "really" exists quite independent from any theoretical conceptualization. However, entities such as magnetic field strength or energy momentum tensors are entities not even thinkable without the concepts of modern generalized geometry. For modern empirical theories based on geometric representations, ontology and geometry become inextricably intertwined.

IV. States, Processes, Structures

In this section we want to consider some of the geometrico-representational concepts of modern empirical theories in more detail. This will enable us to understand how deeply geometric considerations are entrenched in the epistemology and ontology of modern empirical theories.

Let us start with the concept of a state space of a system. Although the idea of a state space is very simple it has far reaching ontological ramifications. For instance, as will be explained in this section, it brings into play important modal aspects into the theory's framework.[15]

[15] There is no unanimity on how to interprete this modal aspect exactly, see van Fraassen (1989), Ibarra and Mormann (1994).

We take the concept of a system as primitive. Examples of systems are provided by mechanical or thermodynamic systems such as particles, projectiles, pendulums, planets, gases, liquids, lasers. Even entities as large as galaxies may be considered as systems, or the universe itself taken as the largest possible system. Generally, a system is an appropriate chunk of the world taken to be the object of theoretical investigation. Systems are denoted by S, S', etc. Systems are assumed to possibly be in different states. For instance, an atom considered as a system in the sense of quantum theory may be in an excited state or not. In order to be accessible to theoretical considerations at all, for a system S a class of possible states must be selected. This class of possible states depends on a theory T and, is denoted by $\Sigma(S,T)$ or simply Σ if S and T are understood. It is called the state space of S (with respect to the theory in question).

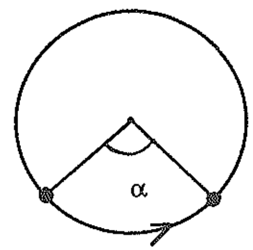
Here, "possible" is to be understood in a rather weak sense of logical possibility. That is to say, some of the elements of Σ may well turn out to be really, i.e. physically, impossible states for S. For instance, the state space $\Sigma(o)$ of a material object o may be taken, as a first approximation, to be the whole universe, even if most places in the universe are physically inaccessible for o, e.g. the centre of the sun. The state space $\Sigma(S,T)$ of a system S serves only as general stage on which S's story is rehearsed. It is not assumed that S has to occupy all possible locations during the play. Quite the contrary. It's a crucial task of the theory to select certain areas of the state space as containing the "really possible" states for S and to classify the complement of these areas as a sort of no-go area for S. This can be done in various ways. Before we consider some of them in some detail let us emphasize that this distinction between really possible states and the rest, which is drawn by the theory, introduces a modal component into the theory's framework. Some elements (or better areas) of Σ the system S is not allowed to be in, are impossible according to the theory. The rest is admissible or possible according to T. As we want to spell out later in some detail, this modal distinction may be considered as a geometrical realization of the theory's laws. Before we come to this topic we'd like to study in some more detail how this distinction between the area of possible and that of impossible states is made. As will turn out, for a rough and preliminary distinction purely set theoretical methods will suffice; for a more refined determination, in particular for the distinction between possible and impossible processes, more refined structures of the state space come into play.

Let us consider first some elementary cases. Consider the state space of a mechanical system in the sense of particle mechanics. Assume that the system S consists of two particles x_1, and x_2 that move independently from each other in an empty universe. In other words, there are no forces and in particular

there is no gravitational force between the x_i. At first sight one may think that the state space of the system of S is the space $E^3 \times E^3 = E^6$. A closer scrutiny reveals, however, that E^6 cannot be the space of "really" possible locations of S. Even if we take the x_1 and x_2 as point masses they cannot occupy the same place. In other words, even if the x_i move completely independently from each other the state space of the system (x_1, x_2) is not E^6 but the subspace $E^{*6} := E^6 - \{(x_1,x_2) | x_1 = x_2\}$. In other words, the state space of the system (x_1,x_n) is obtained from the full Euclidean space E^6 by imposing some further *constraints* on the "really possible" states of the system S. This is actually the generic case. Usually, the "really" possible states of a system are constrained by certain restricting conditions.

Let us look at some further examples. Consider the planar pendulum. What is interesting about this system from a mechanical point of view is the position of the pendulum's bob. Without taking into account any further considerations, this is located in E^2. But taking into account the system's mechanical restrictions and after having carried out the necessary idealizations, e.g. taking the pendulum's bob as a point mass, the state space of a planar pendulum can be conceptualized as a circle S^1:

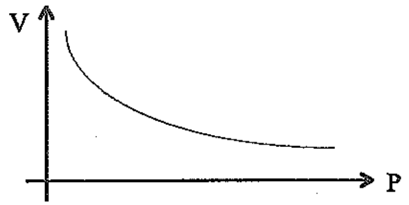
(4.1)



Similarly, the configuration space of a double planar pendulum, is to be conceptualized as the Cartesian product of two circles, i.e., the two-dimensional torus $T^2 = S^1 \times S^1$. To give a final, somewhat more complex example, let us determine the state space of a rigid rod r. The rod's position is determined by the positions of its endpoints $r(1)$ and $r(2)$. Hence, as a very rough first approximation of the r's state space we may take $\Sigma(r) = E^3 \times E^3 = E^6$. This, however, does not take into account the rigidity of r. Assuming that $r(1)$ may be posited anywhere in E^3 the position of $r(2)$ is restricted to the surface S^2 of the sphere with centre $r(1)$ and radius the distance between $r(1)$ and $r(2)$. Hence the state space of r is the Cartesian product $E^3 \times S^2 \subseteq E^3 \times E^3$.

Of course, not only mechanical systems have state spaces. As an elementary, non-mechanical system consider a rather idealized thermo-dynamical system S assumed to be characterized by two quantities only, volume and pressure. Then, as the first approximation of the state space $\Sigma(S)$ of the system S one may take a 2-dimensional Euclidean plane E^2 having an orthogonal base consisting of the two vectors V (volume) and P (pressure). Since negative volume and pressure do not exist, only the first quadrant of E^2 possibly represents the "really possible" states of s. Actually, further constraints will play a role. If we assume the ideal gas law to hold, the product $S(V) \cdot S(P)$ must be the same for all "really" possible states of S. Hence, the manifold of possible states of s is the hyperbola defined by the above equation:

(4.2)



Depending on what idealizations are performed, different state spaces for S may be obtained. In any case, the first step for theoretically understanding the behaviour of any empirical system S consists in providing an appropriate state space $\Sigma(S,T)$. In other words, a system S enters the theoretical realm only if it is represented by an appropriate state space. Now, as is already suggested by the term "space", usually, $\Sigma(S,T)$ is not simply a set but rather a space, i.e., a set endowed with some geometric structure. This structure is used to differentiate between really possible and really impossible states of the system.

The states a system is in (or is not), however, are not what is really interesting about a system. Rather, it is the processes, i.e. the temporal developments a system may undergo that really count. Let us consider perhaps the most outworn example in the history of science. We are interested in the orbit of the planets, not in a particular position. As is well known, state spaces provide a standard representation of processes by representing them as paths in the state space. Mathematically a path is a map of the unit interval I, to be interpreted as a time interval, into the state space $\Sigma(S,T)$

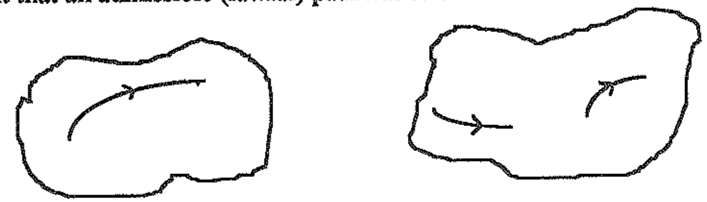
(4.3) $\phi: Y \longrightarrow \Sigma(S,T)$

In the same vein as for states (which may be considered as a special case of processes, to wit, constant processes) there is (an even more important) distinction between possible and impossible processes a system may undergo according the theory. A few paths represent processes allowed according to the laws of the theory, most paths represent forbidden ones. It may be considered as the essential task of the theory to distinguish the possible (admissible) and the impossible (not admissible) ones.

In order to do this job, taking into account merely set theoretical structures of the state space does not suffice. Rather, the full geometric structure of the representing state space has to be brought into play. Usually admissible paths are thought to be continuous, even differentiable. The ontological problem is where this necessity (a real path must have this form and not another) is located. In other words, the restrictions or constraints on admissible paths are defined by using certain geometric concepts such as vector fields, differential and tensor forms.

Instead of considering directly these rather technical devices let us take a closer look at a principle that is often taken for granted, namely, the venerable principle *Natura non facit saltus*. It is geometrically expressed as the constraint that an admissible (lawful) path has to be *continuous*:

(4.4)



(Admissible) (Not admissible)

Mathematically, this claim involves the topological structure of the state space $\Sigma(S,T)$ as follows: a path ϕ: Y $\longrightarrow \Sigma(S,T)$ is continuous iff for any open set O of $\Sigma(S,T)$ $\phi^{-1}(O)$ is an open subset of the interval I. If we consider the topological structure of $\Sigma(S,T)$ as a variable, one can bring it about by defining an appropriate topological structure with few open sets so that just *any* path is rendered continuous. Hence, the topological structure of $\Sigma(S,T)$ may be considered as a (rather coarse) constraint on the admissible, i.e. lawful paths of the theory that takes $\Sigma(S,T)$ as its state space. In terms of Margenau, the topological structure of the state space is a symbolic construct that is used for the symbolic interpretation of the data. It is coarse, since far from all continuous paths are admissible ones. To restrict the class of lawful paths further, more sophisticated geometrical tools are necessary. Familiar devices for many theories are certain geometrical structures, such as vector fields, differential forms or general tensors fields, and other differential operators such as Riemannian connections "living on" $\Sigma(S,T)$. Roughly, the task of distinguishing an admissible path from a non-admissible path is carried out as follows. If ϕ is a path, it defines a "vector field (or tensor field) V_ϕ along ϕ", i.e., for every time t there is defined a vector $V_\phi(t)$ at $\phi(t)$. For every element s of the state space $\Sigma(S,T)$, i.e., for every state s of S the geometrical structures defined on $\Sigma(S,T)$ define a sort of operator Γ that may be applied to vectors. Then the path ϕ is admissible, i.e. describes a temporal development allowed by the theory iff $\Gamma(V_\phi(t)) = 0$ for all t. Actually, in local coordinates, this amounts to the fact of ϕ satisying a certain differential equation. We have chosen this more abstract description since it renders evident the fact that the admissibility of ϕ does not depend on any specific frame of reference. In other words, admissibility is an invariant or symmetric notion (van Fraassen 1989). Being admissible is a feature of a path that does not depend on any specific frame of reference. Hence, it is an objective property. To give a specific example, take S to be a single particle not under the influence of any external force. In this situation, the admissible paths selected by the geometric structure Γ defined on $\Sigma(S,T)$ are just the geodesics of $\Sigma(S,T)$.

Admissible paths of a system represent those temporal developments of a system it *has* to follow if the theory is true. Hence, admissibility may be considered as a kind of lawhood defined by the geometric structure of the state space. Admissibility is defined as invariant notion. Hence, the question arises as to whether all invariant statements of the theory are to be considered as laws of the theory. Van Fraassen vigorously denies this: there are too many invariant statements that cannot reasonably be considered as laws of a theory. For instance, according to all mechanical theories, be they classical or relativistic, any statement concerning the number of planets of the solar system is an invariant statement. Nevertheless we would not consider the number of the planets to be a law of any mechanical or astronomical theory. Hence, the class of invariant statements cannot be the class of the lawful statements. Van Fraassen concludes that the concepts of symmetries, transformations and invariances cannot serve as a geometrical *ersatz* of the linguistic concept of law. According to him, the geometric concepts of symmetry and transformations belong exclusively to the realm of the representing, i.e., they have to be understood purely instrumentally and cannot be pulled back to the realm of the represented:

> The conceptual triad symmetry, transformation, and invariance does not explicate or vindicate the old notion of law - it plays the counterpoint melody on the side of representation. (van Fraassen 1989, p. 289).

In (Ibarra and Mormann 1994) we have argued against this radical proposal by pointing out that van Fraassen's approach is based on a mistaken notion of representation since he strictly separates the representing realm from the represented realm. In terms of our favourite author Margenau, this criticism may be rehearsed as follows. The realm C of symbolic constructs of a theory is given by the structured totality of the possible states it attaches to a system S. The realm of data is given by the actually observed states and processes. These may be interpreted as van Fraassen's "empirical substructures" (van Fraassen 1980, p. 64). Symmetries, transformations, and invariances exclusively belong to the realm of symbolic constructs, i.e. the representing models, and cannot, allegedly, be pulled back to the realm of data. In terms of

Margenau's account of empirical theories, van Fraassen ignores the role of "swing", i.e., the symbolic interpretation $s: C \Longrightarrow D$.

We think a good candidate for the law statements of the theory is the class of statements which state the admissibility of a class of paths with regard to certain structurally defined constraints. This class of process-statements may not be the whole class of lawlike statements of the theory. At least, it embraces a significant part of them.[16] We readily admit that the task of identifying structural laws, i.e. laws defined by the structures of state spaces, is not an algorithmic matter. Rather, it is a matter of interpretation to be carried out by some interpreting subject. This topic will be dealt with in more depth in the next section.

V. Peircean Complementations

Traditionally, the philosophy of science within the analytical tradition has been liable to neglect the role of the theorizing subject. Examples are to be found in the various positivist and postpositivist accounts according to which the basic task of the philosophy of science is to elucidate the notion of a scientific theory without ever saying a word about the theorizing subject who invents, and uses the theories in question.[17] The representational account sketched in this paper so far, may be judged guilty of the very same neglect as well. Till now we have talked about representations ignoring for whom these representations are made and who has invented them. In this section we want to show that the representational approach sketched in the previous sections can be completed in such a way that it fits nicely with the semiotic theory Peirce proposed a long time ago. We want to argue that Peirce's semiotics offers a general format for a deeper comprehension of the representational character of theories.

According to Peirce's semiotics, the concept representation cannot be fully understood in terms of sign and (signified) object only. Representation essentially requires the participation of an interpreting subject, called the interpretant. In Peirce's own terms, representation is the operation of a sign or its relation to the object for the interpreter of the representamen. In more familiar words, this may be expressed as follows: a sign or representation (I) cannot be understood without presupposing the existence of something real

[16]Moreover, in the case of mechanics, it does not contain any statement concerning the number of planets.

[17]Maybe the most extreme example is Popper's account of "Objective knowledge" deliberately designed to be an "epistemology without a knowing subject" (Popper 1972).

(III) that is represented by it, and the existence of something or somebody (II) that interprets the sign:

(5.1) FUNDAMENTAL ASSUMPTION OF PEIRCEAN SEMIOTICS.[18] A representation is always the representation of something (III) by something (I) for somebody(II).

Conceiving a theory as a representation, the Fundamental Assumption may be specialized to the following thesis:

(5.2) FUNDAMENTAL ASSUMPTION OF THE REPRESENTATIONAL APPROACH. A theory is always a representation of something by something for somebody.

As has been sufficiently made clear in the previous sections the representational account countenances at least the two Peircean components D (I) and C (III). These are related to each other by the representational map $f: D \longrightarrow C$. The reader may have had the impression we have neglected the mediating component of the interpreting subject (II). This is, however, not the case. The interpreting subject is taken care of by what we have called the symbolic interpretation $s: C \Longrightarrow D$. The aim of this section is to explicate this more fully.

Representations are not simply there; rather they are constructed by somebody for certain purposes. In the following we would like to consider two complementary purposes of representations:

(i) *Reduction of complexity*

(ii) *Induction of complexity*

Let us start with the reduction that may be considered as the more familiar notion. The reductionist account of representation claims that the task of representation is reduction of superfluous complexity. Examples abound: Looking for a book in a library, one will not go directly to the shelves, seeking at random for it. Rather, one will consult a catalogue in which the books are represented by index-cards or other, more modern devices. In an obvious sense, the catalogue may be considered as a representation of the library. There is a reliable relation between the real books, i.e. the content of the library and the corresponding index-cards of the catalogue. Obviously, this representation is motivated by the intention of reducing unnecessary

[18]Following Peirce one is committing an "abstractive fallacy" if one tries to reduce the triadic relation of representation. Apel sketches a nice classification of various epistemological "abstractive fallacies" (Apel 1974) which fallaciously neglect one or more constituent of the triadic representational relation, e.g.: (1) III without I and II leads to materialism-realism; (2) II without I and III amounts to a radical subjective idealism; according to which nothing exists except ideas in a (transcendental) mind; (3) I and III without II induces a version of ontosemantic realism according to which the world interprets itself, so to speak, i.e. there is one and only one representation which represents the world "as it is". The participation of an interpreting subject is not necessary.

complexity. For the purposes of finding the book, we need not know its content but only its author, the title and other relevant information for finding the book. The index-cards are signs that represent the books. They need not have any similarity with the book. The catalogue is a representation which only represents the books according to the aspects that are relevant for finding them on the shelves. This catalogue view of theories (Hung 1981) may be traced back to Duhem who as early as 1906 proposed such an account claiming that a physical theory is to be considered as a convenient classification of experimental facts (Duhem 1906, part I, ch. 2,3). To put it in a nutshell: the aim of a physical theory is the economical and parsimonious *classification* of empirical data:

> These classifications make knowledge convenient to use and safe to apply. Consider those utility cabinets where tools for the same purpose lie side by side, and where partitions logically separate instruments not designed for the same task: the worker's hand quickly grasps, without fumbling or mistake, the tool needed. Thanks to theory, the physicist finds with certitude, and without omitting anything useful or using anything superflous, the laws which may help him solve a given problem. (Duhem 1906, p. 24).

More generally, according to the reductionist conceptualization of representation, the representing entities are used as substitutes or surrogates for the represented entities. For some reason or other, the original entities cannot be dealt with directly and instead of them appropriate substitutes are manipulated. Hence, representational thinking in this way may be described as surrogative reasoning (Swoyer 1991, Cummins 1996). Particularly important examples of this kind of surrogative reasoning are numerical (or more generally) mathematical representations and simulations. There are some obvious advantages in not carrying out a test crash but rather to calculate or simulate its effects with the aid of some representational device. Although the reductionist account of representation captures some important aspects of representation, it tells us only half of the story. Distillation and abridgment may be important to representation, but representations typically add as well as subtract, having surplus features that do not correspond to anything in the phenomena they depict (Swoyer 1991, p. 463). This brings us to the other feature of representation that may be characterized as induction of complexity.

Already the elementary case of numerical measurement reveals that representation cannot be identified with reduction. Consider the following elementary example. Let O be a class of things to be measured. As usual, such a measurement is based on a mapping $r: O \longrightarrow \mathbb{R}$ from O into the real numbers $\mathbb{R}$. Obviously, the representing realm $\mathbb{R}$ has a very rich mathematical structure that has no counterpart in O. For instance, many arithmetical operations, such as division, subtraction, exponentiation, are defined real numbers,. but not for the members of the empirical domain O.

More generally this can be described as follows: the language of the representing domain ℝ contains many concepts and propositions that cannot be directly translated into concepts and propositions of the language describing *O*.[19] Nevertheless the "new" complexity of the representing domain is not superfluous. On the contrary, it is essential for every representation since it is used for generating new knowledge of the represented domain. For instance, in the case of numerical measurement the rich mathematical structure of the real numbers may be used for working out a comprehensive theory of approximation. More generally, the true purpose of representation may be said to be the application of the theory of the representing system to the represented system (Mundy 1986, p. 392). Hence, the invention of an appropriate representation may be considered as nothing less than the essential ingredient for the solution of an intricate problem. Furthermore, it may be that the process of inventing such representations is the highest human intellectual ability.

Maybe for some readers numerical representation of extensional quantities is an example too trivial for rendering plausible the thesis that representation is inextricably related to the induction of new complexity. A hopefully more convincing example for the creative and explorative power of representation is provided by the representational theory that marks the very beginning of modern science, to wit, Descartes's arithmetical representation of Euclidean geometry. By this representation, geometric entities such as points, lines, curves are represented by algebraic entities such as n-tuples of numbers, realvalued functions etc. This representation amounts to much more than a mere translation from one language to another. The point is that for many purposes the expressive power and the problem-solving ability of the algebraic approach is greater than that of geometry.[20] Summing up we may say that a good representation, and this doesn't simply mean an accurate translation, is one with "abductive" power in the sense that it facilitates reasoning in the representing domain that can be pulled back to the represented domain. It should be noted that both reduction and induction are features of representation which crucially depend on a subject interpreting a representation. There are no "good" or "bad" representational reductions or inductions *tout court*. Rather, the assessment of the reductive and inductive qualities of a representation depends on the theoretical and/or practical interests of the interpreting subject.

[19] In the case of numerical measurement, the distinction between rational and irrational numbers cannot be interpreted in terms of relations between measured empirical objects. It is a central task of a "theory of meaningful representation" to establish criteria that enable us to distinguish between meaningful and non-meaningful correspondences (artifacts) (Mundy 1986, Swoyer 1991).

[20] This is not to be understood as a historical remark only. In 20th century mathematics, the theories of algebraic topology may be conceived of as very successful representational devices for translating geometric problems into algebraic ones (Ibarra and Mormann 1992).

VI. Is the Concept of Representation Obsolete?

Even if the reader does not buy into every detail of the representational approach we have presented in the previous sections of this paper, it should have become evident that the concept of representation occupies a central place in the sciences, in particular in the natural sciences.[21] Nevertheless, the introductory question of this section is not only a rhetorical one. For some time, the concept of representation has come under heavy attack in philosophy from various quarters. According to Rorty and other neopragmatists, the concept of representation leads into a maze of deadlocks and unsolvable pseudo-problems (Rorty 1991, pp. 154f). Hence, the traditional paradigma of philosophy based on representation should be abandoned. We think that the dismissal of the concept of representation from the philosophical discourse, as proposed by the neopragmatists of Rortyian kind, would have disastrous effects on the relation between philosophy and sciences. It would amount to a new alienation and estrangement of philosophy and science confining again the connecting lines of philosophy to science to the realm of "hermeneutic" *Geisteswissenschaften*. As we want to show in the following, Rorty's argument against the philosophical respectability of the concept of representation is based on an impoverished, unscientific idea of representation.

According to Rorty, there are two different camps in philosophy: one is the reactionary group of representationalist philosophers who belong to the past. The other camp consists of the progressive antirepresentationlist philosophers who will be, as Rorty claims, the philosophers of the 21st century:

> Representationalists [are] those philosophers who find it fruitful to think of mind or language as containing representations of reality. [Antirepresentationalists] attempt to eschew discussions of realism by denying that the notion of "representation" .... has any useful role in philosophy. Representationalists typically think that controversies between idealists and realists were fruitful and interesting. Antirepresentationalists typically think both sets of controversies pointless (Rorty 1991, p. 2).

In this century, typical adherents of representationalism are Frege, Russell, Husserl, Tarski and Carnap (Rorty 1991, p. 151). Pioneers of the new

[21] The same holds for the cognitive sciences (Cummins 1996).

antirepresentationalist dogma are Quine, Sellars, and Strawson. The protagonists of the antirepresentational orientation are, however, Dewey, Wittgenstein, Heidegger, and Davidson (Rorty 1979). Now it is quite obvious that there is something wrong with Rorty's classification. For instance, during his philosophical career the allegedly arch-representationalist Carnap maintained the antirepresentationalist position that the traditional debate between idealism and realism was absolutely pointless. For Carnap, this debate was a paradigmatic example of a metaphysical, i.e. non-sensical philosophers' quarrel. According to his principle of tolerance, the choice of a linguistic or logical framework is not a matter of truth or falsehood, but a matter of expedience which is determined by practical considerations. Carnap considers the representationalist doctrine, according to which knowledge is an accurate representation of reality, to be a piece of obsolete metaphysics. There are no distinguished representations that represent reality as it "really" is. In the following we do not aim simply to draw the line between representationalists and antirepresentationalists in a somewhat different way than Rorty, thereby helping philosophers such as Carnap, Husserl, or Cassirer to reach the antirepresentationalist heaven as well. Rather, we want to show that Rorty's distinction between representationalism and antirepresentationalism is based on a flawed and distorted concept of representation. The original sin of Rorty's account is an inadequate account of representation. More precisely, his argument against representationalism runs as follows: first he offers an oversimplified and vague concept of representation, then he shows that this deprived notion of representation does not do any useful work in philosophy. Leaving the concept of representation he is using rather vague is justified by him by the thesis that representation has done its work in traditional philosophy not so much as an explicit and well-defined concept but rather as an implicit guiding metaphor:

> It is pictures rather than propositions, metaphors rather than statements, which determine most of our philosophical convictions. The picture which holds traditional philosophy captive is that of the mind as a great mirror, containing various representations... (Rorty 1979, p. 12).

Of course, the difficulty of a metaphorical description such as Rorty's is that the deconstruction of an account only vaguely described by a metaphor runs the risk of missing its target. It would do no harm to Rorty's generalized thesis of the principal opposition between representationalism and antirepresentationalism if the underlying notion of representation could be explicated more precisely.

The account of representation as mirroring is -- as a physical metaphor -- characterized by the idea that the represented and the representing are resemble each other to a large extent, namely, that one is the mirror-image of the other. This sort of representation does not play an important role, neither

in philosophy nor in science. Even perception, described by the best theories of cognitive science as visual representation, is not mirroring. There is no innocent eye that sees the world as it is. Even visual representations are representations *for* a representing subject, i.e. they are soaked with interpretations of the seeing subject.

One may object that we take Rorty's mirror conception of representation too seriously. Rorty must have known that one cannot squeeze the concept of representation as it has been used in philosophy and science, into the metaphor of mirroring. Somehow, Rorty knows it, or so it seems. Later, he generalizes his notion of representation and grants it a small and rather trivial role in cognition:

> .... we should restrict the term "representation" to things like maps and codes - things for which we can spell out rules of projection which pair objects with other objects, and thus embody criteria of accurate representation. If we extend the notion of representation beyond such things, we shall burden ourselves with a lot of philosophical worries we need not have.
> In particular, if we worry about what rules of projection connect sentences like "F = MA" ... with bits of reality, we get nowhere (Rorty 1993, p. 126).

Here, obviously, representation cannot be understood as mirroring: a map does not yield a mirror image of the landscape. A map that mirrored the landscape it represents would be worse than no map at all (Ziman 1978). On the other hand, Rorty's new concept of representation neatly fits the concept of structure preserving map. A geographical map is a structure preserving mapping that relates geographical structures of the landscape to certain topological or geometrical structures of the map. Some, even most features of the geography are ignored, i.e., have no counterparts on the map. On the other hand, many features of the map are artifacts with no counterparts in reality.

As the quotation given above reveals, Rorty takes pains to draw a strict line between the realms of codes, geographical map and other harmless representations on the one hand, and the realm of theories on the other. For the former, it is reasonable to speak of representations, while for the latter it is philosophically dangerous to attribute them representational features. This attempt at confining the concept of representation is not sound. It is not at all plausible that there is an essential difference between geographical maps and other harmless representational devices on the one hand, and representational theories on the other. Quite the contrary. The theories of representations developed in mathematics, science, and philosophy demonstrate that such a boundary does not exist.[22]

As is shown by the representational approach, the similarities between maps and theories, however, need not be pursued on the metaphorical level only. Rather, it may be considered as the aim of a general theory of representation (Mundy 1989, Swoyer 1992) to reveal the significant body of knowledge common to all those kinds of representations such as mappings, measurements, and theories.

Here, "general theory of representation" is not to be understood in the sense of Rorty, but designates a formal theory whose historical beginnings are to be located in the representational theories of measurement, geometry, and kinematics (Mundy 1986, p. 393). The basis for this theory is provided by the concept of representation as a structure preserving map. The new antirepresentationalism could claim victory if it were able to show that this concept of representation is obsolete. Representation as mirroring is a strawman that has nothing much to do with the practice of representation in science and philosophy. Thus, to counter the antirepresentational attack it is sufficient to point at the fact that the concept of representation does not possess an a priori harmless domain of application. Representation is a complex concept with an open domain of application that cannot be confined by a philosopher's decree. Representation starts a dialectical process of reduction and induction of complexity that completely eludes the simple conception of representation as mirroring. This process crucially depends on the activity of an interpreting subject of the representation. If the yardstick for a "good" representation were simply accuracy (Rorty), a mediating, i.e. interpreting subject, would not be needed. The represented object and its *doppelgänger* would not need the mediation of an interpreting subject. They could settle the matter between each other, so to speak. Rorty's mirroring conception of representation falls prey to a Peircean abstractive fallacy: instead of maintaining the triadicity of the representational relation it attempts to reduce it to a binary relation that only acknowledges the two components of a representational relation. In terms of the previous section, Rorty rightly criticises a naive ontosemantic realism. His criticism does not

[22] As has been pointed out some time ago by Ziman (Ziman 1978) the "map metaphor" that draws on the intimate relation between maps and scientific theories is a particularly fruitful one (ibidem, pp. 82 ff), and may be used to uncover many important characteristics of scientific knowledge. For instance, in the same way as more information can be read from a map than was needed to construct it, a scientific theory "is an endless source of reliable predictions going far beyond the existing accumulation of observational data."

hit a fully fledged triadic representationalism in general. Taking reduction and induction as essential aspects of representation (as one should), things are different. Evidently, there are a variety of possible representational reductions and inductions; it doesn't make sense to distinguish one of them as the "correct" one. Representation always possesses pragmatic components. This insight deprives Rorty's attempt to play representation against discourse of its persuasion. The assessment of the pragmatic qualities of a representation, i.e. the evaluation of the appropriateness of its reductive and inductive achievements with regard to the subject's interests takes place in a discursive context. It seems plausibe to conjecture that discourses directed towards knowledge, consist, at least to a large extent, of discussions on the fruitfulness and expedience of rival representations.

Although in this paper only some aspects of the concept of representation have been discussed it should be evident that the concept of representation cannot be dismissed as easily as Rorty seems to assume. There are good reasons to insist, against the antirepresentationalist current in philosophy, that the concept of representation as it appears "really" in philosophy and the sciences is not obsolete at all.

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