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Symbolic versus Modelistic Elements in Scientific Modeling*

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ABSTRACT: In this paper, we argue that symbols are conventional vehicles whose chief function is denotation, while models are epistemic vehicles, and their chief function is to show what their targets are like in the relevant aspects. And we explain why this is incompatible with the deflationary view on scientific modeling. Although the same object may serve both functions, the two vehicles are *conceptually distinct* and *most* models employ both elements. With the clarification of this point we offer an alternative account to the deflationary view – the Hybrid Account; and we defend our account in contrast with deflationism.

Keywords: symbol, model, scientific representation, reference, denotation, conventional, epistemic, pragmatic.

RESUMEN: En este artículo argumentaremos que los símbolos son vehículos convencionales cuya función principal es la denotación, mientras que los modelos son vehículos epistémicos cuya función primordial es mostrar que lo modelado es similar en los aspectos relevantes. Explicamos también por qué esto es incompatible con la concepción deflaccionista de la modelización científica. Aunque el mismo objetivo puede servir para ambas funciones (ser denotado y ser modelado), los dos vehículos son conceptualmente distintos y la mayoría de modelos emplean ambos elementos. Tras la clarificación de este punto ofrecemos un enfoque alternativo al deflaccionismo, el enfoque "híbrido", y lo defendemos en contraposición a aquél.

Palabras clave: símbolo, modelo, representación científica, referencia, denotación, convencional, epistémico, pragmático.

1. *Introduction*

In daily life as well as in more specialized scientific works we humans use representational vehicles to recognize and communicate what we find in our surroundings, and the vehicles we use are usually divided into two large categories. There are symbols that include labels, names, signs, and statues, and there are models that include physical objects as well as mathematical/abstract entities. Most symbols are conventional objects, namely, they represent not by any physical resemblances with the represented objects but rather by stipulations that connect them to those objects, while most models are commonly thought to bear some special relationship, such as resemblance (or similarity or isomorphism or…), with their target systems in order to show what the systems are like. For example, when we see a model of the solar system in a museum, we usually see a sign bearing the inscription, "the solar system," in front a structure that is perhaps made of medal and has a particular figure. The sign signifies the solar system without bearing any resemblance to it, while the struc-

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ture bears a strong overall resemblance to the structure of the solar system (assuming it is a good model).

Philosophical reflections soon find issues with this naïve conception of representation. For instance, some may find it problematic to tolerate both physical objects and abstract entities as candidates for modeling. If because of ontological commitments one finds it objectionable to posit abstract entities, one may argue that only physical objects qualify as means of representation. But if one has good reasons to put one's faith in abstract entities, it may make more sense to think that only they can serve to represent (and the physical objects the above naïve view calls "models" are merely different expressions of such, as in the analogous case of language, where sentences as physical markings may be regarded merely as expressions of propositions, and only propositions represent). Our view is in fact neutral to this dispute; however, because there are too many examples of abstract models in science, we are inclined to the view that models are abstract entities, but many of them are actually used in practice in one or more of their physical realizations.

At least two authors have in recent years challenged the strict division between symbols and models and the naïve view on how they play their separate roles in representation, especially in the case of scientific representation. Suárez (2003, 2004, 2010) has focused on dismantling any requirement of resemblance (or similarity or isomorphism) as a necessary condition for representation[1], and on producing an "inferential account" of scientific models that he himself regarded as deflationary. According to Suárez, for any entity to qualify as a model in science, it has to (1) possess a force of pointing towards its potential target system and (2) be able to serve as an "inferential surrogate" in a theory concerning that system; and whether an entity (abstract or concrete) has such a force as a disposition for representation depends on whether or not it can be used as a vehicle to denote (or point to) a target system (cf. Suárez 2004). Any entity that satisfies these two conditions —possessing such a disposition and serving as an inferential surrogate— can always be used as an actual model. Callender and Cohen (2006), though never called their own view deflationary, have actually produced to our mind the most deflationary view[2]. By generalizing a Grician argument beyond the scope of language, which they call "General Gricianism," Callender and Cohen are able to reach the conclusion that models could be anything that are brought to represent targets by conventional stipulations or habits. In the context of the distinction between symbols and models, models are *constitutively* no different from symbols; any conditions or requirements that in usual contexts distinguish models from symbols belong to the realm of pragmatics. Because different symbols are used for different purposes, extra re-

[1] To avoid confusion, I shall use the term "resemblance" as a technical term to mean the same as "similarity or isomorphism" in Suárez's theory or as resemblance of the chosen aspects. It is meant to be a catch-all term in our discussion.

[2] To set the record straight, Teller (2001) has announced his deflationary attitude towards models before Suárez and C&C. But his is more of an attitude than a view fully argued for. It is announced early as a pragmatic stand on "what are models?" (cf. Teller 2001, 397) in a paper that deals with other issues. Van Fraassen (2008) also takes the same pragmatic stance in his "Hauptsatz" for representation that says, *"[t]here is no representation except in the sense that some things are used, made, or taken, to represent some things as thus or so."* (23). So, both think that anything can represent (or be a model of) anything as long as it is so used, made, or taken; but neither has formulated specific arguments for such a stand, very much unlike C&C and Suárez.

quirements such as similarity or resemblance relations may be necessary for a certain purpose. But they are no more than symbols in essence, and therefore any imputation of special status for models or philosophical search for distinct identifying characters is entirely unnecessary (hence, deflationism).

A comprehensive criticism of the Callender-Cohen brand of deflationism is given in another larger paper (suppressed for the review of this paper). This paper aims at further elucidating the difference of symbols and model elements and how they combine to form most of scientific models. But first, in contrast with the Callender-Cohen brand of deflationism, Suárez's might not be regarded as deflationary, for in coming up with his inferential view, Suárez actually enlists commonsense reasons for why scientific models cannot be merely symbolic, and why an epistemic dimension must be added. But then, Suárez may well agree with Callender and Cohen that his two requirements —to possess a pointing force and to be able to serve as an inferential surrogate— are essentially conditions of pragmatics: an entity possesses a disposition of representation just in case it can be used to represent in a given context; and the second requirement of serving as inferential surrogates, though called "epistemic," is no more than a pragmatic requirement. Therefore, even though Suárez does not hold that models are fundamentally no different from symbols, he nevertheless regards all models as pragmatic vehicles. This may qualify his as a different version of deflationism.

It is worth pointing out that similar intuition about mere symbols not being able to serve as models is felt and mentioned in at least two other critical works (cf. Frigg 2010, Contessa 2010). However, because of the vexed problem of using any binary relation such as resemblance or similarity (or even isomorphism) as a constitutive relation for representation (namely, requiring some such relations between models and their targets), people seem to fear that the extra requirement that makes symbols into models should not be construed as anything more than a pragmatic requirement of use and convenience. There is clearly a tension between not willing to see scientific models as merely symbolic and not willing to require any additional condition for modelhood that comes near requiring something like resemblance relation. Callender and Cohen resolve the tension by trying to dissolve the problem of seeing models as constitutively symbolic objects, while Suárez resolves it by adding a pragmatic requirement (clearly not a binary relation of any sort). Our approach also aims at resolving this tension, and the difference, as we shall explain in the following, is that we fully embrace the hybrid nature of modeling and give a full account of how the symbolic and the modelistic elements work together in a model to render a scientific representation.

2. *Representations and Reference*

In the literature on scientific representation it is frequently acknowledged that models, unlike theories, are not truth-apt. It means that they are not the sorts of things that make sense to be regarded as true or false. And this non-truth-aptness has even occasioned speculations on the ontology of models (cf. Godfrey-Smith 2006, Frigg 2010, 2011, Contessa 2010, Levy 2012). However, symbols are not truth-apt either, and as mentioned above, the deflationists on models deny any fundamental distinctions between models and symbols despite their pragmatic differences. In the following, we first argue against this view, showing how implausible it is to identify models as a species of symbols if we pay attention to how representation works even in simple cases.

Let us use some simple examples to explore the issue. Take the notions of Rutherford's model of hydrogen atom and Boyle's model of ideal gas and think about how we use them to communicate our thoughts on hydrogen atoms and diluted gases. The following statements or the like might easily be found in physics textbooks:

1. In Boyle's (ideal) gas model for diluted gas, molecules have negligible sizes.
2. The average kinetic energy in Boyle's gas with temperature T is …
3. Rutherford's hydrogen atom structurally resembles a one-planet solar system.

Reflecting on what is really said in these statements, we should have no difficulty realizing that they do not make good *literal* sense. There are no molecules in Boyle's model of diluted gas nor is Rutherford's model of hydrogen atom an atom. Only the gas and atom that the models represent have molecules or structure; what their models have are "stand-ins". The stand-ins —the model components— may also be rendered by physical objects which have physical magnitudes, but these are not what are stated in the examples, or at least not according to a commonsense reading of them. A scaled rendering of gas molecules may exhibit small plastic balls that are many orders of magnitudes larger than real molecules.

However, even though this is correct as is, it is not impossible (some would even say very plausible) to interpret the statements as talking about model components and their structures and dynamics, rather than about the targets, as we shall see in a moment. Therefore, the statements such as 1, 2, 3, above are *ambiguous.* One can imagine different contexts in which one or the other reading of the statements is justified. But first, it must be remarked that at least such possible alternative interpretations are not possible in the use of symbolic vehicles for representation. In other words, the ambiguities that exist in the reading of statements 1-3 are impossible for the following examples:

4. "Socrates" is Plato's teacher.
5. Socrates's name is full of wisdom.
6. The Statue of Liberty is one of Americans' core values.

These statements are unmistakably recognized as not making good sense; no careful reflections are necessary to realize what's wrong with them. The predicates in these sentences are about the entities that the subjects represent; they are not about the subjects themselves. But why is there this difference between models and symbols? If they are fundamentally of the same sort, namely conventional vehicles of representations as the deflationists would insist, surely there should not be such a marked discrepancy. Constitutively similar while pragmatically different symbols should not show up in our language as one being intrinsically ambiguous and the other being not.

The reasons for why symbols are never confused with what they symbolize whereas models can be (mis)taken for what they model are not difficult to find. A symbol does not have to be related to its target by any other relations except a community-recognized convention —by agreement or long-term use— while a model usually possesses, or perhaps must possess, some additional relations. The most commonly recognized relation for a model (i.e. the commonsense view mentioned earlier) is the resemblance relation it holds to its target. The often cited reasons for this point are: (i) without resemblance of some sort between A (the model) and B (the target), how can we recognize that A is intended to represent B? (ii) Without resemblance, how could one hope to gain any information about B by studying A? It is actually interesting to note that the first reason is only apparently reasonable; it is false upon reflections. In fact, if we can recognize a symbol as a symbol of its target without any resemblance relation, why couldn't we do the same with models? But obviously the reason goes as follows. Since a model must resemble (as a technical term here) its target in order to meet condition (ii) above, the same relation also fulfills the first condition so much so that models do not need convention or agreement to be recognized as representing their targets. Hence, the same resemblance relation may serve both as a reference device and as a showing-what-it-is-like device. The point we shall be making in the next section is very briefly this: the above two points do not necessary go together. The need for some sort of resemblance (e.g. resemblance in chosen aspects) is an epistemic need that differs essentially from the need for denotation/reference. The latter is fulfilled by the use of symbolic elements in models. Therefore, models are hybrid entities that comprise both symbols and non-symbolic model elements.

Models do have pragmatic dimensions as well. Modelers usually determine pragmatically what information they want to get out of their models; and since pragmatic purposes can be of diverse kinds, the resemblance relations tailored to such purposes may also be radically different one from another. And this accounts for the diversity of the apparent resemblance relations between models and their targets. But whatever pragmatic concerns one introduces to fix the type of resemblance desired, the relation must be present to make a model work, and that is the epistemic dimension that symbolic representations emphatically do not have. Once A is recognized as representing B and it is pragmatically determined which aspects of B A is used to represent, A must fulfill the role of showing what B is like in those aspects in order to be qualified as a good model. And this role is an epistemic role, not a pragmatic one.[3]

Let us now return to a point touched on above when discussing the ambiguity problem. One may object that, or at least question whether, it makes sense to interpret those statements about models as talking about the real things rather than about the "stand-ins" in the models. One may wonder whether those stand-ins in models rather than the real things are the referents in a straightforward manner in statements 1, 2, 3 given above. One may with good reason think of Boyle's model of diluted gas as referring to an abstract or a possible system of gas, and the molecules referring to the basic components in that system. It is therefore correct to say that in that system, not in actual gases, molecules are of negligible sizes. To see how this works, let us briefly retrace a venerable tradition that goes back at least to Giere (1988) and Suppe (1989), which takes models to be either abstract entities (Giere) or physically possible systems (Suppe). According to this view, within a theoretical framework concerning certain types of physical systems, most statements are about the models, not directly about the actual systems that the models represent. In this sense, Newtonian mechanics is about configurations and dynamics of Newtonian models, which includes frictionless planes and ideal pendulums and point-mass planetary systems.

[3] The full argument for why epistemic roles or functions are not also pragmatic ones is given in another paper against deflationism on modeling. It has multiple parts and therefore cannot be easily summarized here.

There are complications and problems for such a conception of models, but whatever ontology one embraces for models, the following fact does not seem controversial. The construction of models helps to insulate the modelers from the actual world they aim at studying. And yet claims regarding this world have to be made with the help of the models and tested against experimental findings. Whether we take the claims as mostly about the behavior of model components (i.e. the stand-ins), which would make these claims purely mathematical or highly estipulative, or as about the real things that the models as stand-ins represent, which would make them fully empirical/synthetic, there has to be a clear notion of representation that specify the main representational relationship between models and reality. *In the former case*, the question is how the abstract systems as models relate to actual systems, and hence how claims about models and their components get to be translated into claims about components of actual systems. In Giere's account (1988), this is accomplished by a meta-claim, a theoretical hypothesis that has the form "X is a Y," where X names a real system and Y names a model. For instance the hypothesis may be "the solar system is a Newtonian system, where the latter is a theoretical model. In Frigg's account (2010, 2011), this is done through his "t-representation" that relates the model systems and the target systems.[4] Now *in the latter case*, the question is how the claims about real systems in accordance with idealized models may be legitimately regarded as true or false. In either case, the investigation into the nature of idealization and approximation plays an important role. In the former case, claims are literally true or false, but only true or false within the frame of the model systems; and yet such claims tell us in an approximate way what the real systems the models represent are like. In the latter case, claims are almost never literally true (or always literally false), and yet they can be seen as approximately true. A theory of approximate truth as part of philosophy of language should occupy the center stage in this approach.[5]

Be that as it may, what is not in doubt is the fundamental difference between symbolic vehicles and model vehicles and why there is such a difference.

3. *Combining the Symbolic and the Modelistic – A Hybrid Account of Modeling*

The argument in the previous section is intended to *conceptually* distinguish the fundamental difference between symbols and models. It by no means implies that an object commonly used for modeling cannot be actually used as a symbol or vice versa, or an object cannot be used as a symbol and a model at the same time. A statue of a human figure commonly used to model a particular person or a type of people may be used as a symbol of courage or liberty (e.g. the Statue of Liberty). It can be used to play such a symbolic role either by a pure conventional means or by a circuitous connection to what is symbolized. For instance, a statue may look like a particular person and the person is by common consent a courageous person[6]. And some words in the form of hieroglyphics or pictograms may well

[4] We shall discuss Frigg's solution and our alternative later.

[5] In this discussion we assume that idealization makes sense with regard to model-building for unobservable systems, such as Rutherford's models. If this assumption is challenged, and there certainly are good reasons to challenge it, a different conclusion results. This alternative is discussed in another paper.

[6] If one questions, why is it regarded as a symbol rather than a model of courage, the answer may come as follows. It may be difficult to assert this in complete generality, but at least in the context of scien-

be regarded both as a symbol and a model. Moreover, a plaque containing a miniature diagram of a castle fixed above the castle's entrance may be properly regarded as a symbol and a model of the castle. Nor does the view imply that an object cannot be a mixture of symbols and models. In fact, most models contain symbols, such as having names attached to their parts. The names are an integral part of the models and yet they are purely symbolic vehicles. All these examples exhibit nothing against the conceptual distinction that has to do with how symbols and models function differently in the practice of representation. One is for reference or denotation, and the other is for showing or displaying. And the last situation is the one that fits our view of modeling as will be shown later.

One may also raise a seemingly more difficult objection to the above conceptual distinction.[7] Sometimes modelers in science call a set of equations a model for some phenomena, e.g. Maxwell's equations are said to be the model of electromagnetic phenomena. If equations are concatenations of mathematical symbols, are they not symbolic themselves? And yet they are models par excellence. To respond, we first observe that equations such as Maxwell's are no models if taken only syntactically. The letters such as the **E** and **B** are merely symbols, and the four differential equations as mere concatenations of such symbols and symbols in calculus are not models either. The models are abstract entities that the equations signify/describe. These are idealized entities (charged particle trajectories or field configurations) that satisfy the equations under a variety of boundary conditions. The abstract mathematical entities may also be physically realized as visual models for electromagnetism. Neither of these two types of things can be said to belong to symbols proper. If one accepts propositions and the differences between them and sentences, we may say that the equations of Maxwell's are the sentences while the propositions the sentences express are the model. This by the way is not very different from using pictorial figures to symbolize geometric figures (if one believes in such entities), and then the geometric figures, not the pictorial ones, are used to represent physical objects or events in reality. In the same sense that equations cannot show by their orthographic features what the phenomena are like, sentences can't either.

The above point also agrees with Frigg's tripartite account of scientific representation (Frigg 2010, 2011), where the middle part is occupied by the model systems —abstract entities or physical objects (depending on your ontological commitment about models)— while on the one side are the linguistic descriptions of the models, and on the other, real target systems.[8] The relationship between the linguistic and the models is called "p-repre-

tific representation, models are for particular or types of systems, not for properties. We have models for gravitational or electromagnetic fields, but we don't have models for being disposed to be affected by such fields. We have models for individuals or economic systems that are rational, but we don't have models for rationality as a property.

[7] I thank a referee of this article for raising the objection.

[8] Frigg (2010, 2011) takes models systems to be abstract entities, as do many others in the same tradition, such as Giere (1988) and Suppe (1989) cited above. However, it is not too difficult to work out a version of the tripartite theory of modeling where models are all physical objects, which also include life specimens of organisms, pictures, and markings on surfaces (cf. Rowbottom 2009). The key difference between the symbolic and the modelistic is not whether something is abstract, but whether something is constructed to show rather than to refer. A physical model unlike a sentence has to play the function of showing —a success or a failure— by its recognizable structure.

sentation," while that between the models and the targets "t-representation." Therefore, taking sentences and equations for "scientific models" is a mistake of oversimplification. Linguistic items as series of sound or marks are symbols and they do not directly "model" any real systems. In recent literature on scientific representations, Frigg's theory, at least this core of tripartitism, has been accepted as common ground.

With these worries cleared, let us state and argue for our account of how models actually accomplish their job of representation. Our account —the Hybrid Account of modeling— at the end of the following argument comes out in full as follows.

> [**HA**] In the context of scientific representation, most models serve the functions of reference (or denotation) and of showing (or demonstration) and comprise a symbolic element and a modelistic element (i.e. the abstract entities that have certain static or dynamic structures). The symbolic elements (mostly written names and labels but also memorized sound sequences) do not name or refer to the modelistic elements they are attached to; they refer to the components in target systems, thereby securing the correspondence between those components and the modelistic elements (to which the symbols are attached but do not symbolize). The modelistic elements present the structures that the corresponding components in target systems are supposed to possess according to the model. Whether A is a model of B depends solely on whether the symbolic elements in A refer to the intended components in B, while whether A is a good model (or representation) of B depends on how the modelistic elements are constructed (how they are structured) in A.

Note that the symbolic elements that serve for denotation do not have to be explicitly displayed with the modelistic elements to which they are supposed to be attached. Memorized verbal symbols often suffice, e.g., a portrait of Barack Obama does not need to be always accompanied by a printed name "Barack Obama" in order to serve as a model of the man. The name is verbally attached to it in viewers' memory. When we look at the portrait and say, "Obama is a lean man," we use the name "Obama" to refer to the real man and stating that he is like the figure in the portrait, namely, appearing to be a lean man. Therefore, names and labels are usually attached to their supposed elements even if they are not visibly attached[9].

We now begin our argument by looking at a typical example of representation. Maps have long been considered a typical sort of models for spatial regions, but unless we are thinking about some special ones that aim at showing geographical details, maps are usually abstract geometrical representations of spatial configurations of, e.g., streets and buildings in cities or towns. For some maps, such as a subway map, any notion that it is similar to the actual subway system it represents is far fetched. Unlike many pictures and scientific models, a municipal or subway map fulfills its representational function despite its dissimilarity or non-resemblance of the observable features of its target. How is the job of representation done in this case then? Frigg (2011), in proposing an account of his "t-representation" (i.e., how a model as an independent abstract entity is related to a target system so as to fulfill its role of representation), argues that a model represents its target just as a map does; and

[9] A tribal chief may have found an ancient tree suitable for representing the power structure of the tribe, and designated the tree and its major branches to the tribe and some of its prominent members. The tree over the ages may have served as a model of the tribe and yet no names have ever been attached. This is clearly a case of memorized symbols attaching to the tree and its major branches.

a map first shows geometrical facts about the relations among the dots and lines, and then from a *key*, we can figure out what the map says about its target. Following Frigg's lead, a moment's reflection on how a map of New York City, for instance, represents it reveals a simple fact: if we remove all the names of places in the city from the map and give it to someone who frequents NYC but has never used a map of it before, it is unlikely that the person will recognize it as a map of the city. This shows (1) which city a map represents is not determined by the geometrical structure that the line segments and the dots represent in the map. These markings in the map represent geometrical structures and, what's more, they are almost never used as reference or denotation devices that uniquely pick out their target.[10] And (2) the reference or denotation function is normally played by names or labels of the streets and buildings in the city that are correctly attached to the line segments and the dots. Once the denotation is fixed, once we know which city the map is a map of, we are *shown* the relations among the streets and buildings in the city. The map may not look anything like the observable layout of the city, it may even be so different that it turns out to be a bad map, but once the reference is given, we must recognize it as a map of the city, good or bad. Furthermore, it is only when the reference is fixed by its symbolic elements that we can evaluate whether the map is any good, and that does depend in the resemblance of the selected aspects (e.g. the geometry of the streets).

To generalize, what identifies the target system that a model represents —*what fixes the referent*, if you will— is not the structure the model contains, but rather the symbol for the model and symbols it contains for its components. The symbolic vehicles such as names are the determiner of WHAT is represented. The geometrical patterns in a map are HOW the target is represented. And the "how" in principle does not and cannot serve the purpose of identification or denotation, and that is why it is a mistake to think that somehow it must be the similarity relation between a model and a system that makes the former a legitimate representation of the latter.

And it is precisely because the referential relations between model components and components in the target system are fixed by symbols via a convention, the representation *qua* modeling may take a two-dimensional liberty. Modelers have the liberty of picking the aspects of the target for representation, and with the selected aspects, they also have the liberty of distorting them to fit their purposes. And they do not have to fear that such distortions would defeat the denotation function of their models, for that is taken care of by the symbolic elements in the models. These two directions of liberty are on full display in the above discussed example of a subway map: first, only geometric aspects of the subway system are selected, and then the geometrical properties of the subway lines are greatly distorted (i.e. idealized) to fit the schematic design so long as the direction and distribution of the lines are approximately adhere to. Nobody is going to complain about how "ridiculously dis-analogous" the map is to the system as long as there are names in the map to identify which station is where and on what line. And most importantly, the names and symbols in a map refer to the target objects; they are al-

[10] Here we assume that the line segments and dots on a map represent geometric figures, which are abstract entities. This is consistent with the tripartite view of modeling. But as mentioned in footnote 8, one does not have to assume this; one may take the line segments and the dots themselves to be directly representing the geometrical relations among streets and buildings in the city.

most never used to refer to the "model components," namely, geometrical figures in the maps. This two-dimensional freedom in model representation is an essential feature of our account, HA, of modeling.

This point about the unnecessary requirement of resemblance is thoroughly explored by Suárez and Frigg and all the other recent authors on modeling, and yet very different approaches are taken in trying to resolve the problem of how, without overall resemblance, denotation or reference can be secured. HA differs from Frigg's essentially on the point of how symbols are used in the descriptive part of the tripartite conception of modeling, and it differs from Suárez's essentially on the point that some symbolic devices must be in place to serve as picking out the target systems, rather than evoking the "force" or "disposition" some objects has in pointing towards its target, and that full epistemic virtues rather than means for inference serve as the second requirement for modelhood.

In Frigg's tripartite account: Model Description =(p-represent)=> Model Systems =(t-represent)=>Target Systems, the elements in the first part, sentences and equations, appear to be pointing only to the model systems in the second part, which *can be interpreted* as meaning that the terms use in the first only refer to modelistic elements in the second. When it comes to how model systems represent their targets, Frigg evokes the metaphor of maps to illustrate how it might be done, as explained above. We point out in HA that there is no difference between symbols used in the Description part and in the Model part. Maps are not essentially different from descriptive sentences. "London Bridge" in a map of London plays the same role in referring to the London Bridge as it does in a narrative about London. Therefore, the tripartite picture, which we agree with, should not be understood in Frigg's sense as comprising three independent parts that are connected only by the p- and t-representation relations. Model systems contain symbols that do the same job as they do in sentences and equations.

And because of this hybrid nature of models, HA also differs from Suárez's because we look at the reference question in modeling differently. The question Suárez asks seems to be, "what entities can be used as models?" And the answer is, "that which has, or can be given, a force pointing to its target." This appears to be a dispositional account of the usability of objects as models. And the answer in the deflationary spirit that Suárez shares with Callender and Cohen with also with Teller is that "anything can." Our question, however, is "by what means is an entity serving as a model hooked up with its target?" And our answer is "by symbolic or conventional means," and what counts as symbols should be understood in the broadest sense of that notion. We believe HA is superior to Suárez's because of the following reason. According to Suárez's view, a piece of paper with line segments and dots connected and crossed in a certain geometrical pattern can be used to serve as a model of a metropolitan area, such as Paris, for it has the disposition or force to point to that city. Our view says no; although in very special circumstances that piece of paper may be used as model of Paris, but in most cases only by adding names and labels to those line segments and dots can one turn it into a map of Paris. In addition, if the geometrical patterns on the paper resemble little of the layout of Paris streets, it's "force" of serving as a map of Paris would have to be said to be very weak. And yet according to HA, when the names are added, it is definitely a map of Paris; a very bad map perhaps, but no less a map of Paris than any other excellent maps. In other words, HA makes the reference relations explicit and explains better why a terribly bad representation of A is still clearly recognized as a representation of A.

One may object to the hybrid account of modeling, however, by insisting that it is not always or necessarily true that labels or names have to be given before an entity can be legitimately used for representational purposes. Pictures of the Brooklyn Bridge in NYC without any referring labels may well serve as representations of that bridge; and similar examples abound, which *prima facie* seems to refute the account given above.

Given that we accept the existence of such cases where referring and showing are done by one and the same object, we think our view stems from the following perspective. The origin of symbolic representations (or all representations) with humans may well be the recognition of overall similarities between the symbols and their targets (e.g. earlier written symbolic systems as hieroglyphics or pictograms). As the complexity of representation increased and a demand of resemblance became obviously impossible for, e.g. representing events or more abstract matters, systems of symbolic representation shed their reliance on similar objects; but for pictorial representation, of which modeling is a species or an extension, because of its essential role in showing what the represented is like in required aspects, the symbolic and the pictorial are combined in most cases. However, in special cases, as in the case of the picture of the Brooklyn Bridge, the most primitive scheme of representation can still operate, where the structure in the model serve as a symbol as well as showing off the target object (for a related point, see the point connected to footnote 9).

As to why we do not go along with Suárez in regarding models as necessarily playing an inferential role in the practice of science, nor do we at least follow Callender and Cohen in regarding the role of models as purely pragmatic, we here briefly give our reasons. Unless one presupposes that models are mere instruments in the enterprise of science or they are not in the business of showing us what reality is like, taking either view needs a lot more convincing than what we have in the works of Suárez and Callender-Cohen, even though the authors never explicitly endorse instrumentalism about modeling in science. One reason for assuming the instrumental, explicitly or implicitly, may simply be that all models are idealized, and therefore, they cannot be taken as showing us the likeness of their targets in the chosen aspects, rather they can only be used as practical tools. But this prejudges the issue too quickly. Defending realism in modeling by using the notion of being real at the idealized limits is by no means an impossible task. Particularly with regard to models for the unobservable systems[11] that serve as underlying causes for observable phenomena, it is far from conclusive that they are no more than tools that get scientists to make inferences about the phenomena. They also play an explanatory role, which suggests that they show us what the unobservable reality is like in the respects in which we construct our models. They may be idealized in the sense that we modularize components of microsystems; but idealization in this sense may be true of the real systems asymptotically at the limits of "separation" of the modules in nature.

Therefore, it is more reasonable to stay neutral in one's account of scientific modeling over the debate between realism and anti-realism. And the hybrid account of modeling

[11] One should not get hung up on the notion of unobservable systems used here. We shall not get into the realists vs. anti-realists debate on this notion. It suffices that we go with the scientists to regard some systems as obviously observable and some as typically unobservable, while acknowledging that borderline cases abound. If one really wants clear-cut cases, one can think of the absolute space and time or ether or angels (if there are any) as the unobservables, which could all have models to represent them.

which requires a robust epistemic dimension for the modelistic elements in models is just such an account. According to HA, if one has good reasons to believe that successful models in science asymptotically approach the true states of real systems, one can adhere to realism. But if one is convinced that there are no good reasons to go the realist route, one does not have to revise one's account for models. In that case, one has the option to take models to be fictional entities just as one can avoid Platonism (or realism) in philosophy of mathematics by taking the fictionalist route as well. In such a version of HA, symbols that are attached to the modelistic elements do not refer to anything real, but rather they are names for fictional entities, such as numbers and lines are regarded by the mathematical fictionalists fictional entities to which numerals and marks on paper refer.

In his "Models and Representation" R. I. G. Hughes (1997) gives an attractive account of the subject, which he calls the DDI account (Denotation, Demonstration, and Interpretation) and which has been widely acknowledged. A vivid example is used to illustrate the working of this account, which recounts how Galileo uses a geometric model to solve the problem of the distance of a free falling body in a given time interval. Galileo first transforms the phenomenon of a body's free fall into a geometric figure, and then geometric demonstration is carried out without referring back to the phenomenon, and lastly the result of the demonstration is "interpreted back" to the phenomenon to see if it matches with the observation record; and thus solving the problem. We have little problem with the second and the third part of this account, but our account disagree with the first, the part about denotation. It is difficult to miss at the outset that a more natural way of talking about this step, as clearly shown in this example, is of "translation" or "transformation" rather than "denotation." We say that the problem of a free falling body is translated or transformed (by Galileo) into a problem of geometry rather than a label or name is found (by Galileo) in geometry to denote the problem of a free falling body. The geometric line segment shows what a body's free falling is like in a model, it does not denote the motion. What denotes the free falling motion is an implicitly understood or explicitly written phrase that has the effect of the phrase, "free falling motion." This is a more plausible interpretation because the first step or process of model building in this case is more like transforming the free falling motion into an element in geometry than looking for an element in geometry to "label" the path. More generally, the first step of modeling is better rendered as translation or transformation rather than looking for symbols or labels. Hughes's own way of introducing the notion of denotation for this first step is less than convincing. True, in Galileo's case, it might not have been necessary to explicitly employ a referring term for the model because his geometric model was made solely for the problem of a free falling body at hand. If this model had been made for a type of problems of locomotion that includes many different scenarios, a name would have been necessary for it and the geometric element is securely hooked onto those problems by the referring function of the name or label. For example, a vertical line has the label of "free-fall," a parabola the name of "projectile," and a slanting line the name of "incline." Galileo's geometric model does not "denote" the type of motion it represents; it *reveals* its relevant structure by striping away (or idealizing away) those physical aspects of the phenomenon that are irrelevant to the problem. So, the first step is in essence a step of transformation in terms of idealization, not a step of getting the problem hooked up with an element of geometry by conventional denotation. Searching for names or labels that results in the fixing of denotation would have become necessary had Galileo been thinking of making his model one in a catalogue of geometric models for locomotion.

4. Conclusion

Deflationists as well as many other philosophers seem to regard models as autonomous entities that have to secure their relationship with their target systems through a certain elaborate pragmatic/conventional means. And this is necessary because the naïve idea that overall resemblance or some such relations may serve as this relationship is found on the wrong track. The solution deflationism offers is to identify such a relationship as essentially the same as the relationship between any symbol and its referent. It is an in-principle arbitrary and conventional relationship that is determined exclusively by pragmatic concerns. In this paper we first argued how differently symbols and model elements (without referring symbols attached to them) function in scientific modeling; and then we stated and defended a hybrid account of modeling that fully recognizes the separate functions of symbols and modelistic elements and how they work together in a model to fulfill the task of representation. One of the main merits of HA is that it resolves the problem of why resemblance relation between the modelistic elements and the target components is strongly felt to be both unnecessary for representation and essential to it. It is not necessary for fixing the reference buy it is essential for showing what the target systems are like in the chosen aspects. The division of labor of the two elements in a model resolves this puzzling tension.

Another merit of HA is the recognition that symbolic elements used in models are not tags for the modelistic elements they are attached to; they are rather tags for what the latter elements represent – the target systems and their components. This is so as long as the circumstances are such that a model is constructed for the purpose of representing a target system or type of target systems, such as the model of the hydrogen atoms and the model of DNA molecules. That not all models are of this sort in science is true but it is an issue that can only be discussed in full on another occasion.

A further merit of HA is that we do not have to believe that scientists have to constantly disambiguating terms used in scientific literature whether they refer to the things in nature or elements in a model. There are many occasions of course when terms are invented to name the elements, but those terms are not ambiguous either because they are known not to refer to any real systems in nature. But for those terms, such as “atoms,” “electrons,” and “genes,” we do not have any good reason to believe that scientific modelers use them to refer to different things —electrons in nature or schlectrons in a model— in different contexts.

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