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Exemplification, Idealization, and Understanding

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Abstract: Thesis: Idealized scientific representations are fictions that afford an understanding of the phenomena they concern by exemplifying features they share with those phenomena. I begin by explaining what exemplification is and what epistemological role it plays. I then explain how a fiction can exemplify something that obtains (but may be hard to recognize) in fact. Finally, I argue that construing scientific idealizations as fictions that exemplify features they share with the facts makes sense of the way they figure in understanding.

Science, we are told, is (or at least aspires to be) a mirror of nature. It provides (or hopes to provide) complete, accurate, distortion-free representations of the way the world is. This familiar stereotype is false and misleading. It gives rise to a variety of unnecessary problems in the philosophy of science. It makes a mystery of the way scientific models function and intimates that there is something intellectually suspect about them. Models simplify and often distort. The same phenomena are sometimes represented by multiple, seemingly incongruous models. The models that scientists work with often fail to match the facts they are adduced to account for. These would be embarrassing admissions if models were supposed to accurately reflect the facts. But they are not. Science is not, and ought not be, a mirror of nature. Rather, science embodies an understanding of nature. Since understanding is not mirroring, failures of mirroring are not necessarily failures of understanding. Once we appreciate the way science affords understanding, we see that the features that look like flaws under the mirroring account are actually virtues. A first step is to devise an account of scientific representations that shows how they figure in or contribute to understanding.

Representation:

The term 'representation' is irritatingly imprecise. Pictures represent their subjects; graphs represent the data; politicians represent their constituents; representative samples represent whatever they are samples of. We can begin to regiment by restricting attention to cases where representation is a matter of denotation. Pictures, equations, graphs, and maps represent their subjects by denoting them. They are representations *of* the things that they denote.[1] It is in this sense that scientific models represent their target systems: they denote them. But, as Bertrand Russell noted, not all denoting symbols have denotata.[2] A picture that depicts a unicorn, a map that maps Atlantis, and a graph that charts the increase in phlogiston over time are all representations, although they do not represent anything. To be a representation, a symbol need not itself denote, but it needs to be the sort of symbol that denotes. Unicorn pictures are representations then because they are animal pictures, and some animal pictures denote animals. Atlantis maps are representations because they are maps and some maps denote real locations. Phlogiston-increase graphs are representations because they are graphs and some graphs denote properties of real substances. So whether a symbol is a representation is a question of what kind of symbol it is. Following Goodman, let us distinguish between representations *of p* and *p*-representations. If *s* is a representation *of p*, then *p* exists and *s* represents *p*. But *s* may be a *p*-representation even if there is no such thing as *p*.[3] Thus, there are unicorn-pictures even though there are no unicorns to depict. There is an ideal-gas-description even though there is no ideal gas to describe.

Occasionally philosophers object that in the absence of unicorns, there is no basis for classifying some pictures as unicorn pictures and refusing to so classify others. Such an objection supposes that the only basis for classifying representations is by appeal to an antecedent classification of their referents. This is just false. We readily classify pictures as landscapes without any acquaintance with the real estate – if any – that they represent. I suggest that each class of *p*-representations constitutes a small genre, a genre composed of all and only representations with a common ostensible subject matter. There is then a genre of unicorn-representations and a genre of ideal-gas-representations. And we learn to classify representations as belonging to such genres as we study those representations and the fields of inquiry that devise and deploy them. This is no more mysterious than learning to recognize landscapes without comparing them to the terrain they purportedly depict.

Nor is it the case, as Suárez contends, that on Goodman's account, fictional and factual representations get entirely distinct treatments.[4] Both are *p*-representations, because they belong to denoting genres. Factual representations simply have an additional function that fictional ones lack. Besides being *p*-representations, factual representations are (or purport to be) representations *of* something.

Some representations denote their objects. Others do not. Among those that do not, some – such as phlogiston-representations – simply fail to denote. They purport to denote something, but there is no such thing. They are therefore defective. Others, such as ideal-gas-representations are fictive. They do not purport to denote any real object. So their failure to denote is no defect. We know perfectly well that there is no such animal as a unicorn, no such person as Hamlet, no such gas as the ideal gas. Nonetheless, we can provide detailed representations *as if* of each of them, argue about their characteristics, be right or wrong about what we say respecting them and, I contend, advance understanding by means of them.

So x is, or is not, a representation *of y* depending on what x denotes. And x is, or is not, a z-representation depending on its genre. This enables us to form a more complex mode of representation in which x represents *y as z*. In such a representation, symbol x is a z-representation that as such denotes y. Caricatures are familiar examples of representation-as. Churchill is represented as a bulldog; George W. Bush is represented as a deer in the headlights. According to R. I. G. Hughes, representation-as is central to the way that models function in science.[5] This is an excellent idea. But it needs elaboration.

The problem is this: Representation-of can be achieved by fiat. We simply stipulate: let x represent y and x thereby becomes a representation of y. This is what we do in baptizing an individual or a kind. It is also what we do in ad hoc illustrations as when, for example, I say (with appropriate accompanying gestures), 'If that chair is Widener Library, and that desk is University Hall, then that window is Emerson Hall' in helping someone to visualize the layout of Harvard Yard. So we could take any p-representation and stipulate that it represents any object. We might, for example take a tree-picture and stipulate that it denotes the philosophy department. But it is doubtful that the tree-picture, as a result of our arbitrary stipulation, represents the philosophy department as a tree.

Should we say then that representation-as requires similarity? In that case, what blocks seemingly groundless and arbitrary cases of representation-as is the resemblance between the representation and the referent. I regard this as hopeless. As Goodman, Suárez, and others have argued, similarity does not establish a referential relationship.[6] Representation is an asymmetrical relation; similarity is symmetrical. Representation is irreflexive, similarity is reflexive. One might reply that this only shows that similarity is not sufficient for representation-as. Something else effects the directionality. Then it is the similarity between symbol and referent that brings it about that the referent is represented as whatever it is represented as. The problem is this: Via stipulation, we have seen, pretty much anything can represent pretty much anything else. So nothing beyond stipulation is required to bring it about that one thing represents another. But similarity is ubiquitous. For any *x* and any *y, x* is somehow similar to *y.* Thus if all that is required for representation-as is denotation plus similarity, then for any *x* that represents *y, x* represents *y* as *x.* Every case of representation turns out to be a case of representation-as. In one way or another, the philosophy department is similar to a tree-picture, but it is still hard to see how that fact, combined with the stipulation that a tree picture represents the department, could make it the case that the department is represented as a tree-picture, much less as a tree. Suppose we add that the similarity must obtain between the content of the p-representation and the denotation. Then for any *x-representation* and any *y*, if the *x-representation* denotes *y*, it represents *y* as *x.* But contentful representations, as well as chairs and desks, can be used in ad hoc representations such as the one I gave earlier. If the portrait of the dean on the wall represents Widener Library, and the graph on the blackboard represents University Hall, then the chair represents Emerson Hall. This does not make the dean's portrait represent Widener Library as the dean. Evidently, it takes more than being represented by a tree-picture to be represented as a tree. In fact, I think that some philosophy departments can be represented as trees. But to do so is not to arbitrarily stipulate that a tree-picture shall denote the department, even if we add a vague intimation that somehow or other the department is similar to a tree. The question is, what is effected by such a representation?

> To explicate representation-as, Hughes discusses Sir Joshua Reynolds' painting, 'Mrs. Siddons as The Tragic Muse.' The painting denotes its subject and represents her as the tragic muse. How does it do so? It establishes Mrs. Siddons as its denotation. It might represent Mrs. Siddons, a person familiar to its original audience, in a style that that audience knows how to read. But the painted figure need not bear any particular resemblance to Mrs. Siddons. *We* readily take her as the subject even though we have no basis for comparison. (Indeed, we even take Picasso's word about the identities of the referents of his cubist portraits, even though the figures in them bear no discernable resemblance to anyone on earth.) Captioning the picture as a portrait of Mrs. Siddons suffices to fix the reference. So a painting can be connected to its denotation by stipulation. The painting is a tragic-muse-picture. It is not a picture of the tragic muse, there being no such thing. But it belongs to the same restricted genre as other tragic-muse-representations. To recognize it as a tragic-muse-picture is to recognize it as an instance of that genre. Similarly in scientific cases. A spring is represented as a harmonic oscillator just in case a harmonic-oscillator-representation as such denotes the spring. The harmonic-oscillator-representation involves idealization. So it is not strictly a representation of a harmonic oscillator, any more than the Reynolds is a picture of the tragic muse.

In both cases a representation that fails to denote its ostensible subject is used to denote another subject. Since denotation can be effected by stipulation, there is no difficulty in seeing how this can be done. The difficulty comes in seeing why it is worth doing. What is gained by representing Mrs. Siddons as the tragic muse, or a spring as a harmonic oscillator, or in general by representing an existing object as something that does not in fact exist? The quick answer is that the representation affords epistemic access to features of the object that are otherwise difficult or impossible to discern. To make this out requires resort to another Goodmanian device – exemplification.

Exemplification:

Let us begin with a pedestrian case. Commercial paint companies supply sample cards that instantiate the colors of the paints they sell. Of course, the cards also instantiate innumerable other properties. They are a certain size, shape, age, and weight. They are at a certain distance from the Prado. They are excellent bookmarks but poor insulators. And so on. Obviously, there is a difference between the colors and these other properties. Some of the properties the cards instantiate, such as their distance from the Prado, are matters of complete indifference. Others, such as their size and shape, facilitate but do not figure in the cards' standard function. Under their standard interpretations, the cards serve exclusively as paint samples. They are mere instances of the other properties, but telling instances of the colors. A symbol that is a telling instance of a property exemplifies that property. It points up, highlights, displays or conveys the property. Since it both refers to and instantiates the property, it affords epistemic access to the property.[7]

Because exemplification requires instantiation as well as reference, it cannot be achieved by stipulation. Only something that is dusky rose can exemplify that color. Moreover, exemplification is selective. An exemplar can exemplify only some of its properties. It brings those properties to the fore by marginalizing, downplaying, or ignoring other properties it instantiates. It may exemplify a cluster of properties, as for example a fabric swatch exemplifies its colors, texture, pattern and weave. But it cannot exemplify all of its properties. Moreover, an exemplar is selective in the degree of precision with which it exemplifies. A single splotch color that instantiates dusky rose, rose, and pink may exemplify any of these properties without exemplifying the others. Although the color properties it instantiates are nested, it does not exemplify every property in the nest. Exemplars are symbols that require interpretation.

Paint samples and fabric swatches belong to standardized, regimented exemplificatory systems. But exemplification is not restricted to such systems. Any item can serve as an exemplar simply by being used as an example. So items that ordinarily are not symbols can come to function symbolically simply by serving as examples. Moreover, in principle, any exemplar can exemplify any property it instantiates, and any property that is instantiated can be exemplified.

But what is the case in principle is not always the case in practice. The exemplification of a particular property is not always easy to achieve, for not every instance of a property affords an effective example of it. The tail feathers of a falcon are a distinctive shade of brownish gray. Nevertheless, a paint company would be ill advised to recommend that potential customers look at a falcon's tail in order to see that color. Falcons are so rare and fly so fast and display so many more interesting properties than the color of their tail feathers, that any glimpse we get of the tail is unlikely to make the color manifest. We could not see it long enough or well enough and would be unlikely to attend to it carefully enough to decide whether it was the color we want to paint the porch. It is far better to create a lasting, readily available, easily interpretable sample of the color – one whose function is precisely to make the color manifest. Such a sample should be stable, accessible, and have no properties that distract attention from the color. Effective samples and examples are carefully contrived to bring out particular features. Factors that might otherwise predominate are omitted, bracketed, or muted. This is so, not only in commercial samples, but in examples of all kinds. Sometimes elaborate stage setting is required to bring about the exemplification of a subtle, scarce, or tightly intertwined property.

Scientific experiments are vehicles of exemplification. They do not purport to replicate what happens in the wild. Instead, they select, highlight, control and manipulate things so that features of interest are brought to the fore and their relevant characteristics and interactions made manifest. To ascertain whether water conducts electricity, one would not attempt to create an electrical current in a local lake, stream or bathtub. Since the liquid to be found in such places contains impurities, a current detected in such a venue might be due to the electrical properties of the impurities, not those of water. By experimenting on distilled water, scientists bring it about that the conductivity of water is exemplified.

As Nancy Cartwright has emphasized, experiments are highly artificial.[8] They are not slices of nature, but contrivances often involving unnaturally pure samples tested under unnaturally extreme conditions. The rationale for resorting to such artifices is plain. A natural case is not always an exemplary case. A pure sample that is not to be found in nature, tested under extreme conditions that do not obtain in nature, may exemplify features that obtain but are not evident in nature. So by sidelining, marginalizing or de-emphasizing confounding factors, experiments afford epistemic access to properties of interest.

But not all confounding factors are easily set aside. Sometimes properties so tightly intertwine that they cannot be prized apart. So we cannot devise an experiment that tests one in the absence of the other. This is where idealizations enter. Factors that are inseparable in fact can be separated in fiction. Even if, for example, every swinging bob is actually subject to friction, we can represent an idealized pendulum that is not. We can then use that idealization in our thinking about pendulums, and (we hope) understand the movement of swinging bobs in terms of it. The question though is how something that does not occur in nature can afford any insight into what does. Here again, it pays to look to art.

Like an experiment, a work of fiction selects and isolates, manipulating circumstances so that particular properties, patterns, and connections, as well as disparities and irregularities are brought to the fore. It may localize and isolate factors that underlie or are interwoven into everyday life or natural events, but that are apt to pass unnoticed because, other more prominent events typically overshadow them. This is why Jane Austen maintained that 'three or four families in a country village is the very thing to work on.'[9] The relations among the three or four families are sufficiently complicated and the demands of village life sufficiently mundane that the story can exemplify something worth noting about ordinary life and the development of moral personality. By restricting her attention to three or four families, Austen in effect devises a tightly controlled thought experiment. Drastically limiting the factors that affect her protagonists enables her to elaborate in detail the consequences of the relatively few that remain.

If our interests are cognitive though, it might seem that this detour through fiction is both unnecessary and unwise. Instead of resorting to fiction, wouldn't it be cognitively preferable to study three or four real families in a real country village? Probably not, if we want to glean the insights that Austen's novels afford. Even three or four families in a relatively isolated country village are affected by far too many factors for the social and moral trajectories that Austen's novels exemplify to be salient in their interactions. Too many forces impinge on them and too many descriptions are available for characterizing their interactions. Any such sociological study would be vulnerable to the charge that other, unexamined factors played a non-negligible role in the interactions studied, that other forces were significant. Austen evades that worry. She omits such factors from her account and in effect asks: Suppose we leave such factors out, then what would we see? Similarly, the model pendulum omits friction and air resistance, allowing the scientist in effect to ask: Suppose we leave these out, then what would we see?

Models like other fictions can simplify, omitting confounding factors that would make direct epistemic access to the properties of interest difficult. They can abstract, eliminating unnecessary and potentially confusing details. They can distort or exaggerate, highlighting significant aspects of the factors they focus on. They can augment, introducing additional factors that focus attention on properties of interest.

Still the question is how this is supposed to inform our understanding of reality. That Elizabeth Bennet and Mr. Darcy, who do not exist, are said to behave thus and so does not demonstrate anything about how real people really behave. That an idealized pendulum, which also does not exist, is said to behave thus and so does not demonstrate anything about how actual pendulums behave.

Let us return to the paint company's sample cards. Most people speak of them, and perhaps think of them as samples of paint – the sort of stuff you use to paint the porch. They are not. The cards are infused with inks or dyes of the same color as the paints whose colors they exemplify. It is a fiction that they are paint samples. But since the sole function of the cards is to convey the colors of the paints, the fiction is no lie. All that is needed is something that is the same colors as the paints. A fiction thus conveys the property we are interested in because in the respect that matters, it is no different from an actual instance. The exemplars need not themselves be paint. Similarly in literary or scientific cases. If the sole objective is to exemplify particular properties, in a suitable context, any symbol that exemplifies those properties will do. If a fiction exemplifies the properties more clearly, simply, or effectively than a strictly factual representation, then it is to be preferred to the factual representation.

Both literary fictions and scientific models exemplify properties and afford epistemic access to them. We discern the properties and can investigate their consequences. Because confounding features have been omitted (the Napoleonic wars in the case of *Pride and Prejudice*, intermolecular attraction in the ideal gas, friction in the model pendulum) we can be confident that the properties we discern in the fictions are due to the factors the fictions make manifest.

Now of course this does not justify a straightforward extrapolation to reality. We cannot reasonably infer from the fact that Elizabeth Bennet was wrong to distrust Mr. Darcy that young women in general are wrong to distrust their suitors. But the fiction exemplifies the grounds for distrust and the reasons those grounds may be misleading. Once we have seen them clearly there, we may be able to recognize them better in everyday situations. Nor can we reasonably infer from the fact that ideal gas molecules exhibit no mutual attraction, that neither do helium molecules. But the behavior ideal gas molecules exemplify in the model may enable us to recognize such behavior amidst the confounding factors that ordinarily obscure what is going on in actual gases.

Representation-as:

Let us return again to Reynolds' representation of Mrs. Siddons as the tragic muse. The tragic muse is a figure from Greek mythology who is supposed to inspire works of tragedy – works that present a sequence of events leading inexorably from a position of eminence to irrecoverable, unmitigated loss, thereby inspiring pity and terror.[10] A tragic muse representation portrays a figure capable of inspiring such works, one who exemplifies such features as nobility, seriousness, stalwartness, and perhaps a somber dramaticality, as well as a capacity to instill pity and terror. To represent a person as the tragic muse is to represent her in such a way as to reveal or disclose such characteristics in her or to impute such characteristics to her.

An ideal gas representation is a fiction of a putative gas that would exactly satisfy the ideal gas law. Such a gas is composed of perfectly elastic spherical particles of negligible volume and exhibiting no intermolecular attractive forces. It exemplifies these properties and their consequences, and thereby shows how such a gas would behave. Hughes suggests that the relation between a model and its target is a matter of representation as. The model is a representation – a denoting symbol that has an ostensible subject and portrays its ostensible subject in such a way that certain features are exemplified. It represents its target as exhibiting those features. So to represent helium as an ideal gas is to represent it as composed of molecules having the features exemplified in the ideal gas model – elasticity, mutual indifference, the proportionality of pressure, temperature and volume captured in the ideal gas law.

Representing a philosophy department as a tree might exemplify the ways the commitments of the various members branch out of a common, solid, rooted tradition, and the way that the work of the graduate students further branches out from the work of their professors. It might intimate that some branches are flourishing while others are stunted growths. It might even suggest the presence of a certain amount of dead wood. Representing the department as a tree then affords resources for thinking about it, its members and students, and their relation to the discipline in ways that we otherwise would not.

I said earlier that when *x* represents *y* as *z*, *x* is a *z*-representation that *as such* denotes *y*. We are now in a position to cash out the 'as such'. It is because *x* is a *z*-representation that *x* denotes *y* as it does. *x* does not merely denote *y* and happen to be a *z*-representation. Rather in being a *z*-representation, *x* exemplifies certain properties and imputes those properties or related ones to *y*. 'Or related ones' is crucial. A caricature that exaggerates the size of its subject's nose, does not impute an enormous nose to its subject. Rather, by exemplifying the size of the nose, it focuses attention, thereby orienting its audience to the way the nose dominates the face. The properties exemplified in the z-representation thus serve as a bridge that connects x to y. This enables x to provide an orientation to its target that affords epistemic access to the properties in question.

Of course there is no guarantee that the target has the features the model exemplifies, any more than there is any guarantee that a subject represented as the tragic muse has the features that a painting representing her as the tragic muse exemplifies. This is a question of fit.

A model may fit its target well or badly or not at all. Like any other case of representation as, the target may have the features the model exemplifies. Then the function of the model is to make those features manifest and display their significance. We may see the target system in a new and fruitful way by focusing on the features that the model draws attention to.

In other cases, the fit is looser. The model does not exactly fit the target. If the features are not the precise features the model exemplifies, they may be relevantly analogous. If gas molecules are roughly spherical and fairly elastic, then we may gain insight into their behavior by representing them as perfectly elastic spheres. Perhaps we will subsequently have to introduce correction factors to accommodate the divergence from the model. Perhaps not. It depends on what degree of precision we want or need. Sometimes, although the target does not quite instantiate the features exemplified in the model, it is not off by much. Where their divergence is negligible, the models, although not strictly true of the phenomena they denote, are true enough of them.[11] This may be because the models are approximately true, or because they diverge from truth in irrelevant respects, or because the range of cases for which they are not true is a range of cases we do not care about, as for example when the model is inaccurate at the limit. Where a model is true enough, we do not go wrong if we think of the phenomena as displaying the features exemplified in the model. Obviously whether such a representation is true enough is a contextual question. A representation that is true enough for some purposes, or in some respects is not true enough for or in others. This is no surprise. No one doubts that the accuracy of models is limited.

In other cases, of course, the model simply does not fit. In that case, the model affords little or no understanding of its target. Not everyone can be informatively represented as the tragic muse. Nor can every object be informatively represented as a perfectly elastic sphere.

Problems eluded:

This account evades a number of controversies that have arisen in recent discussions of scientific models. Whether models are concrete or abstract makes no difference. A tinker toy model of a protein exemplifies a structure and represents its target as having that structure. An equation exemplifies a relation between temperature and pressure and represents its target as consisting of molecules whose temperatures and pressures are so related. Nor does it matter whether models are verbal or non-verbal. One could represent Mrs. Siddons as the tragic muse in a picture, as Reynolds did, or in a poem as Russell did.[12]

In all cases, models are contrived to exemplify particular features. Theoretical models are designed to realize the laws of a theory.[13] But we should not be too quick to think that they are vacuously true. For by exemplifying features that follow from the realization of the laws, the models may enhance understanding of what the realization of the laws commits the theory to. They may, for example, show that any system that realizes the laws has certain other unsuspected properties as well. The model then can provide reasons to accept or reject the theory. Such a model is a mediator between the laws and the target system.[14] It in effect puts meat on the bare bones of the theory, makes manifest what its realization requires, and exemplifies properties that are capable of being instantiated in and may be found in the target system. In talking about theoretical models, we should be sensitive to the ambiguity of the word 'of'. Such a model is a model *of* a theory because it exemplifies the theory. It is a model *of* the target because it denotes the target. It thus stands in different referential relations to the two systems it mediates between.

Not all models are models of laws or theories. There are phenomenological models as well. These too exemplify features they ascribe to their target systems. They are streamlined, simplified representations that highlight those properties and exhibit their effects. The difference is that the features phenomenological models exemplify are not captured in laws.

Data models regiment and streamline the data. They impose order on it, by smoothing curves, omitting outliers, grouping together readings that are to count as the same, and discriminating between readings that are to count as different. They thereby bring about the exemplification of patterns and discrepancies that are apt to be obscured in the raw data.

There is evidently no limit on what can be a target. It is commonplace that scientists rarely if ever test theoretical models or phenomenological models against raw data. At best, they test such models against data models. Only data models are apt to be tested against raw data. A theoretical model might take as its target a phenomenological model or a less abstract theoretical model.[15] Then its accuracy would be tested by whether the features it exemplifies are to be found in the representations that other model provides, and its adequacy would be tested by whether the features found are scientifically significant. We can and should insist that eventually models in empirical sciences answer to empirical facts. But there may be a multiplicity of intervening levels of representation between the model and the facts it answers to.

Because models depend on exemplification, they are selective. A model makes some features of its target manifest by overshadowing or ignoring others. So different models of the same target may make different features manifest. Where models are thought of as undistorting mirrors, this seems to be a problem. It is extremely difficult to see how the nucleus could be mirrored without distortion as a liquid drop and as a shell structure.[16] Since a single material object cannot be both liquid and rigid, there seems to be something wrong with our understanding of the domain if both models are admissible. But if what one model contends is that in some significant respects the nucleus behaves like a liquid drop, and another model contends that in some other significant respects it behaves as though it has a shell structure, there is in principle no problem. There is no reason why the same thing should not share some significant properties with liquid drops and other significant properties with rigid shells. It may be surprising that the same thing could have both sets of features, but there is no logical or conceptual difficulty. The models afford different perspectives on the same reality. And it is no surprise that different perspectives reveal different aspects of that reality. There is no perfect model[17] for the same reason that there is no perfect perspective. Every perspective, in revealing some things, inevitably obscures others.

As far as I can see, nothing in this account favors either nominalism or realism. One can run the whole story in terms of properties, as I have done, or in terms of labels. To do it in terms of labels seems perhaps a bit more cumbersome, but even that appears to be a function of familiarity with the devices deployed. Nor does anything in this account favor either scientific realism or anti-realism. One can be a realist about theoretical commitments, and take the success of the models to be evidence that there really are such things as charmed quarks. Or one can be an anti-realist and take the success of the models to be evidence only of the empirical adequacy of representations that involve charmed-quark-talk. Where models do not exactly fit the data, we can take an instrumental stance to their function. Or we can take a realist stance and say that the phenomena are a product of signal and noise, and that the models just eliminate the noise. I am not claiming that there are no real problems here, only that the cognitive functions of models that I have focused on do not favor either side of the debates.

Objectivity:

A worry remains. The intimate connection that I have sketched between scientific and artistic representations may heighten anxieties about the objectivity of science. I do not think this is a real problem, but I need to say a bit about objectivity to explain why.

We need to distinguish between objectivity and accuracy. A representation is accurate if things are the way it represents them to be. A hunch may be accurate. My completely uninformed guess as to who will win the football game may turn out to be correct. But there is no reason to believe it, since it is entirely subjective. An objective representation may be accurate or inaccurate. Its claim to objectivity turns not on its accuracy, but on its relation to reasons. If a representation is objective, it is assessable by reference to intersubjectively available and assessable reasons, where a reason is a consideration favoring a contention that other members of the community cannot reasonably reject.[18] Since we are concerned with science here, the relevant community is a scientific community. So scientific objectivity involves answerability to the standards of a scientific community. According to these standards, among the factors that make a scientific result objective are: belonging to a practice which regards each of its commitments as subject to revision or refinement on the basis of future findings; being grounded in evidence; being verifiable by further testing; being corroborated by other scientists; being consistent with other findings; and being delivered by methods that have been validated. And generating objective results is what makes a model or method objective.

It is not an accident that my characterization of objectivity is schematic. What counts as evidence, and what counts as being duly answerable to evidence, and who counts as a member of the relevant community are not fixed in the firmament. Answers to such questions are worked out with the growth of a science and the refinement of its methodology. This is not the place to go into the details of such an account of objectivity.[19] What is important for our purposes is this: To be duly answerable to evidence is not necessarily to be directly answerable to evidence. A representation may be abstract so it needs multiple levels of mediating symbols to bring it into contact with the facts. A representation may be indirect. It may involve idealizations, omissions, and/or distortions that have to be acknowledged and accommodated, if we are to understand how it bears on the facts. But if it is objective, then empirical evidence must bear on its acceptability and the appropriate scientific community must be in at least rough accord about what the evidence is (or would be) and how it bears or would bear on the representation's acceptability.

I said that the outset that science embodies an understanding of nature. An understanding is a grasp of a comprehensive general body of information that is and manifests that it is responsive to reasons. It is a grasp that is grounded in fact, is duly answerable to evidence, and enables inference, argument, and perhaps action regarding the subject the understanding pertains to. This entails nothing about the way the body of information is encoded or conveyed. Whether symbols are qualitative or quantitative, factual or fictional, direct or oblique, they have the capacity to embody an understanding. To glean an understanding requires knowing how to interpret the symbols that embody it. But we should not think that simply because symbols require interpretation that they are somehow less than objective. So long as there are justifiable, intersubjectively agreed upon standards of interpretation, objectivity is not undermined. So although scientific models do not accurately mirror anything in nature, they are capable of affording understanding of what occurs in nature.[20]

[1] This use of 'denote' is slightly tendentious, first because denotation is usually restricted to language, second because even within language it is usually distinguished from predication. As I use the term, predicates and generic non-verbal representations denote the members of their extensions. See Catherine Z. Elgin, *With Reference to Reference*, Indianapolis: Hackett, 1983, pp. 19-35.
[2] Bertrand Russell, 'On Denoting' *Logic and Knowledge,* New York: Capricorn, 1968, p. 41.
[3] Nelson Goodman, *Languages of Art*, Indianapolis: Hackett, 1968, pp. 21-26.
[4] Mauricio Suárez, 'An Inferential Conception of Scientific Representation,' *Philosophy of Science (supp),* PSA 2002, forthcoming. manuscript p. 7.
[5] R. I. G. Hughes, 'Models and Representation,' *PSA 1996*, vol. 2, (Philosophy of Science Association), pp. S325-336.
[6] Goodman, *op. cit.*, p. 4; Mauricio Suarez, 'Scientific Representation: Against Similarity and Isomorphism,' *International Studies in the Philosophy of Science*, 17, 2003, pp. 225-243.
[7] Goodman, *ibid.,*pp 45-68 ; Catherine Z. Elgin, *Considered Judgment*, Princeton: Princeton University Press, 1996, pp 171-183.
[8] Nancy Cartwright, 'Aristotelian Natures and Modern Experimental Method' *The Dappled World*, Cambridge: Cambridge University Press, pp. 77-104.
[9] Jane Austen, Letter to her niece, Anna Austen Lefroy, September 9, 1814, in *Letters of Jane Austen* Bradbourn Edition, www.pemberley.com/janeinfo/brablets.html Consulted May 4, 2005.
[10] Aristotle, *Poetics* Book 6, lines 20-30. *Introduction to Aristotle* ed. Richard McKeon Chicago: University of Chicago Press, 1973, p. 677.
[11] See Catherine Z. Elgin, 'True Enough,' *Philosophical Issues*, 14 (2004), 113-131.
[12] W. Russell, 'The Tragic Muse: A Poem Addressed to Mrs. Siddons,' 1783. www.dulwichpicturegallery.org.uk/collection/search/display.aspx?im=252, Consulted January 12, 2006.
[13] Ronald Giere, *Science without Laws*, Chicago: University of Chicago Press, 1999 p. 92.
[14] Margaret Morrison and Mary S. Morgan. 'Models as Mediating Instruments,' *Models as Mediators,* ed, Mary S. Morgan and Margaret Morrison*,* Cambridge: Cambridge University Press, 1999, 10-38.
[15] Suárez, 'Scientific Representation' *op. cit.,* p. 237.
[16] This example comes from Roman Frigg and Stephan Hartmann, *Models in Science*, p. 3.
[17] Paul Teller, 'Twilight of the Perfect Model Model,' *Erkenntnis* 55 (2001), 393-415.
[18] See T. M. Scanlon, *What We Owe to Each Other,* Cambridge, MA: Harvard University Press, 1998, pp. 72-75. I say 'assessible by reference to reasons' rather than 'supportable by reasons' because an objective judgment may not stand up. If I put forth my judgment as an objective judgment, submit it to a jury of my peers, it is objective, even if my peers repudiate it.
[19] For the start of such an account see Israel Scheffler, 'Epistemology of Objectivity,' *Science and Subjectivity*, Indianapolis: Hackett, 1982, pp. 114-124.
[20] I would like to thank the participants in the 2006 Workshop on Scientific Representation at the Universidad Complutense de Madrid for helpful comments on an earlier draft of this paper.