Abstract:
I address the relationship between phenomena, models and theories. A phenomenon starts off as something that raises interest and therefore becomes subject to investigation. As research into a phenomenon proceeds, what we take the phenomenon to be is increasingly influenced by the way in which we model it. Models are designed to ‘describe’ and interpret phenomena. While models are about concrete phenomena, theories are abstract in the sense that they do not account for some of the concrete properties of a phenomenon which, in turn, makes them more general than many models. Correspondingly, theories are applied to phenomena only via models; they provide constraints for the model construction.

1. Introduction
Let me start with the question of what models are models of. Models can be models of things or processes, or models of data, or models of a theory in the model-theoretical sense. I am not concerned with models as the term may be used in mathematics. I am, however, interested in all those models that are models of ‘things’ in nature. I call these things in nature ‘phenomena’ and will spell out in Section 2 what I mean by a phenomenon. Very broadly construed,
the subject of science is to deal with phenomena. ‘Dealing with’ such phenomena can, for instance, mean describing them or explaining them. If a model deals with a phenomenon, meaning that a models describes or explains a phenomenon, then a relationship is established between the model and ‘the world’ to which the phenomenon belongs. I shall outline what I take models of phenomena to be in Section 3. Given the history of the philosophy of science, there is no way that one can discuss models without also addressing theories. So, in Section 4 I consider what the difference between models and theories is. My concern in Section 5 is whether what we take a certain phenomenon to be changes in the course of the phenomenon being modelled. Section 6 contains my conclusions.

2. What is a phenomenon?
In my understanding of phenomenon, I largely follow Jim Bogen and Jim Woodward (1988, 1992). A phenomenon is a fact or event in nature, such as bees dancing, rain falling or stars radiating light. A phenomenon is not necessarily something as it is observed; Bogen’s and Woodward’s point is precisely to distinguish data about a phenomenon from the phenomenon. A phenomenon may be something that is originally picked up by observation and then raises certain questions. Observing a bees’ dance – and even calling it that – may bring about the conjecture that there is something systematic about the bees’ movements which warrants further investigation. To conjecture thus is not to take the movements of the bees as something happening entirely at random. It is treating what is observed as a phenomenon. So, in the very first instance, a phenomenon is something that is taken to be a subject to be researched. At this stage, it is not strictly known whether there really is a distinguishable fact or event to be found, even if one has an inkling that this is so. Similarly, if we observe rain falling, asking what causes the rain is the first step of turning this observation into something that constitutes a phenomenon. This seems to suggest that picking out a phenomenon has something to do with distinguishing the causal processes that make up that phenomenon.
Some may say that the phenomenon exists, even if it is not recognized. As Jim Bogen puts it (private communication), Jacksonian epileptic seizures occurred long before Jackson began to study them and were not changed by his investigation of them. Bogen and Woodward have been criticised for their ‘static’ understanding of ‘phenomenon’ (McAllister 1997; Glymour 2000). Glymour presents Bogen’s and Woodward’s position quite poignantly:

“To say that a scientist is wrong about the data she reports is necessarily to say that she did not in fact see what she claims to have seen, while to say that a scientist is wrong about the phenomena she reports need only be to say that she has drawn incorrect inferences from what she indisputably did see. The two differ ontologically in that phenomena are stable, repeatable features of the natural world, while data are not. Phenomena are ineliminable, bedrock elements of the furniture of the world.”

(Glymour 2000, p. 30)

Bogen and Woodward (1988) are adamant that data must not be identified with the phenomenon itself. How they are different can be illustrated with an example. Bogen and Woodward (1988) adopted this example from Ernest Nagel’s ([1960]1979, p. 79) Structure of Science. The topic is the melting point of lead. This can be measured and found to be 327 degrees centigrade. What does it mean, however, to find the melting point to be this precise temperature? To establish the melting point of lead, data are collected: a whole series of measurements are carried out. The temperature at which lead melts is typically not measured only once, but many times, in order to take account of measuring errors that are expected. In principle, it can happen that, during a whole series of measurements, the precise value of 327 centigrade is never once read off the thermometer. Instead, the average of the measured values is taken, the measurement error calculated and the result of this data analysis declared the melting point of lead. Because measuring errors occur in exploring nature, measurements have to be repeated many times. As a consequence, large amounts of data are produced that need to be interpreted and analysed in a way
that allows scientists to extract a definite empirical finding about a phenomenon, i.e. one value for the melting point of lead. Moreover, the same phenomenon, e.g. the melting point of lead, can be examined with many different experiments. The experiments can be varied, while the phenomena remain fixed. Bogen and Woodward consider them as natural kinds.

McAllister (1997) and Glymour (2000) have different reasons for questioning that phenomena can be quite so static and unchangeable. McAllister thinks that scientists need to add criteria, other than simply looking for patterns in the data, in order to make out phenomena. Glymour, in turn, thinks that the concept of a phenomenon is unnecessary because causal relations could be hypothesized directly from statistical correlations in a data sample suitably analysed. My own line of thought on the problem is the following: Yes, in some sense Jacksonian epileptic seizures may have existed before Jackson discovered them, but there is no way that the phenomenon existed for us before their discovery or recognition. In my view, before their recognition, Jacksonian epileptic seizures were not a phenomenon because they were not a subject of study that raised our curiosity. Only after our curiosity is raised about what is happening and how it is brought about do the seizures become noticed and eventually established as a phenomenon.

Interestingly, certain phenomena would not even be recognized without at least some basic research into them. An example for such a phenomenon is the order of acquisition of prepositions in children. It takes considerable observation and experimentation to establish that children acquire the meaning of IN before ON and finally UNDER. Once this is established as a phenomenon in some languages (e.g. English and German), it becomes possible to examine whether this finding is more universal and holds for other, structurally different languages (e.g. Polish) too (Rohlfing 2002). It will matter for the constitution of this phenomenon whether this prepositional order is only found in English and German, say, or whether research shows that this order of acquisition of prepositions holds for all (or most) languages (in a way appropriate to the structures of the languages). In the case of the latter, we would consider the
phenomenon not as one resulting from language and/or culture, but the phenomenon would appear to be cognitively universal. Whether or not the order of acquisition of IN, ON and UNDER is found in languages other than English and German will have an impact on what this phenomenon is. In fact, for a phenomenon like this, without prior examination it is not even obvious that anyone could recognize it as a phenomenon. Sensual perception is certainly not in all instances enough to identify and establish a phenomenon. Correspondingly, James Bogen and James Woodward acknowledge:

"It is overly optimistic, and biologically unrealistic, to think that our senses and instruments are so finely attuned to nature that they must be capable of registering in a relatively transparent and noiseless way all phenomena of scientific interest, without any further need for complex techniques of experimental design and data analysis“

(Bogen und Woodward 1988, p. 352).

Thus, that something is identified as a phenomenon is, in many instances, already the result of research, i.e. of systematic data acquisition on a subject.

Let me now illustrate the point about a phenomenon 'changing definition' in the course of being examined. To start with, the facts or events that come to be considered as a phenomenon may not be clearly defined (although sufficiently defined to be treated as a phenomenon). At this stage, a phenomenon is something about which one wants to know more. Then, in the process of learning and discovering more about a phenomenon, what the phenomenon is taken to be changes. Take gold. Gold is a material which was originally identified probably by its colour and some of its properties. In a larger theoretical context it is the element on the periodic table that has the proton number 79. Gold can be involved in various physical processes constituting phenomena, such as chemical reactions, and it is in the context of these reactions that the proton number of gold receives its significance. It turns out that this proton number is inseparably linked to how gold is involved in natural processes that constitute certain phenomena. This means, for instance, that gold behaves and reacts in a way that is comparable to other elements of the same main group of the periodic
table, such as copper and silver. One phenomenon is constituted by the fact that
metals of this group do not corrode as easily as other metals, such as iron. So,
the study of gold which places gold in a certain theoretical context changes how
one would delineate phenomena involving gold.

Of course, even if the data are to be distinguished from phenomena, as
Bogen and Woodward argue, one expects that a phenomenon manifests itself
empirically somehow – that phenomena can become noticed in the empirical
world, even if they also get to be captured at a different level. Let me now look
again at the phenomenon of lead melting at a certain temperature\(^1\) which, as it is
claimed, differs significantly from data about the melting point. This phenomenon
is also about the factors that make up that melting point. One can, for instance,
ask why the melting point is as high or as low as it is. At a theoretical level, this
question has to do with the forces that hold together the atoms and molecules
and so influence the melting point. There are different forces and correspondingly
different models of chemical binding. For different chemical elements, different
forces are pronounced, e.g. the London forces in crystals, hydrogen bridge
binding in water or ion binding in metals. The melting point of a specific element
depends on the binding forces that act in the case of that element. One has to
ask which binding force is most central in determining the melting point. For this,
the comparison with similar elements, those of the same main group of the
periodic table, is relevant. In the case of lead, this is the fourth main group of the
periodic table, carbon, silicon, germanium, tin and lead. In this group, covalent
binding decreases and metallic binding increases (Figure 1). Correspondingly,
lead is subject to stronger metallic binding than tin which is why it has a higher
melting point, whereas both have much lower melting points than carbon, silicon
and germanium because these latter elements have much stronger covalent
binding.

\(^1\) For help with this example, I am very grateful to Rüdiger Stumpf.
<table>
<thead>
<tr>
<th>Element</th>
<th>Melting Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>3550°C</td>
</tr>
<tr>
<td>Si</td>
<td>metallic covalent</td>
</tr>
<tr>
<td>Ge</td>
<td>binding binding</td>
</tr>
<tr>
<td>Sn</td>
<td>increases decreases</td>
</tr>
<tr>
<td>Pb</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1

Although these theoretical considerations may not suffice to calculate the melting point of lead, they nonetheless allow us to appreciate what constitutes the phenomenon of the melting point of lead. Part of this is to be able to explain and predict a certain behaviour of lead, something which is not possible purely on the basis of measuring the melting point. Such systematic explanation of facts about phenomena is precisely what can be achieved with models. The phenomenon of the melting point of lead is thus conceptually different from data about lead which are produced when one tries to establish the melting point of lead experimentally. Different ramifications apply to the data analysis and to the theoretical description of the phenomenon in a model.

3. **What is a scientific model?**

Let me now introduce my notion of a scientific model. I consider the following as the core idea of what a scientific model is: A model is an interpretative description of a phenomenon that facilitates access to that phenomenon. This access can be perceptual as well as intellectual. Interpretative descriptions may rely, for instance, on idealisations or simplifications or on analogies to interpretative descriptions of other phenomena. Facilitating access usually

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2 If access is not perceptual, it is often facilitated by visualisation, though this need not be the case.
involves focusing on specific aspects of a phenomenon, sometimes deliberately disregarding others (Bailer-Jones 2000). As a result, models tend to be partial descriptions only. Models can range from being objects, such as a toy aeroplane, to being theoretical, abstract entities, such as the Standard Model of the structure of matter and its fundamental particles. As regards the former, scale models facilitate looking at something by enlarging it (e.g. a plastic model of a snowflake) or shrinking it (e.g. a globe as a model of the earth). This can involve making explicit features which are not directly observable (e.g. the structure of DNA or chemical elements contained in a star). The majority of scientific models are, however, a far cry from consisting of anything material like the rods and balls of molecular models used for teaching; they are highly theoretical. They often rely on abstract ideas and concepts, frequently employing a mathematical formalism (as in the big bang model, for example), but always with the intention to provide access to aspects of a phenomenon that are considered to be essential. Bohr’s model of the atom informs us about the configurations of the electrons and the nucleus in an atom, and the forces acting between them; or modelling the heart as a pump gives us a clue about how the heart functions. The means by which scientific models are expressed range from the concrete to the abstract: sketches, diagrams, ordinary text, graphs, mathematical equations, to name just some. All these forms of expression serve the purpose of providing intellectual access to the relevant ideas that the model describes. Some of these forms of expression are non-propositional. Providing access means giving information and interpreting it and expressing it efficiently to those who share in a specific intellectual pursuit. In this sense, scientific models are about empirical phenomena, whether these are how metals bend and break or how man has evolved.

4. What is a theory, in contrast to a model?

Nancy Cartwright (1991) characterizes theories as abstract. She does so in the context of the analogies between models and fables (‘theories are like morals of
fables’). Fables have a moral which is abstract and they tell a concrete story that instantiates that moral, or ‘fits out’ that moral. A moral of a fable may be ‘the weaker is prey to the stronger’, and a way to ‘fit out’ (Cartwright’s formulation) this abstract claim is to tell the story of concrete events of the marten eating the grouse, the fox throttling the marten, and so on. Similarly, an abstract physical law, such as Newton’s force law, $F=ma$, can be fitted out by different more concrete situations: a block being pulled by a rope across a flat surface, the displacement of a spring from the equilibrium position, the gravitational attraction between two masses. Thus, Newton’s law may be fitted out by ‘different stories of concrete events’. Drawing from the analogy between models and fables, models are about concrete things; they are about concrete empirical phenomena. The contrast between models and theories is not that theories are abstract and models are concrete. Rather, models are about concrete phenomena, whereas theories are not about concrete phenomena. If at all, theories are about concrete phenomena only in a very derivative sense. ‘Force’, which is a theoretical concept and belongs to the realm of the abstract, does not manifest itself outside concrete empirical situations. Cartwright’s everyday example for this relationship is ‘work’: The abstract concept of ‘work’ may be filled out by washing the dishes and writing a grant proposal, and this does not mean that a person washed the dishes and wrote a grant proposal, and worked – working does not constitute a separate activity – since working consists in just those activities. Force is a factor in and contributing to empirical phenomena:

“Force – and various other abstract physics’ terms as well – is not a concrete term in the way that a color predicate is. It is, rather, abstract, on the model of working, or being weaker than; and to say that it is abstract is to point out that it always piggy-backs on more concrete descriptions. In the case of force, the more concrete descriptions are ones that use the traditional mechanical concepts, such as position, extension, motion, and mass. Force then, on my account, is abstract relative to mechanics; and being abstract, it can only exist in particular mechanical models”
I will concentrate on one aspect only of theories being abstract. This aspect is that theories, being abstract, are not directly about empirical phenomena. Abstractness is opposite to concreteness. The phenomena that are explored by modelling are *concrete* in the sense that they are (or have to do with) real things – things such as stars, genes, electrons, chemical substances, and so on.

Wanting to say that models are about concrete phenomena, while theories are not, brings with it still another problem, however. Often, the subject of models is a class of phenomena, rather than a specific individual phenomenon. Of most phenomena we can find many specimens in the world; these phenomena belong to the same class. Modelling a star, there are many different individual stars that could serve as a prototype. One tries to model, however, not any odd specimen of a phenomenon, but a typical one. Often this involves imagining the object of consideration as having ‘average’ or ‘typical’ properties, and this ‘prototypical’ object or phenomenon may not even exist in the real world. The point is that it could typically exist in just this way and that there exist many very much like it. So, the prototype is selected or ‘distilled’ from a class of objects. The prototype has all the properties of the real phenomenon; it is merely that the properties are selected such that they do not deviate from a ‘typical’ case of the phenomenon. It is then this prototype that is addressed in the modelling effort. The assumption behind this process of prototype formation is nonetheless that the model is not only a model of the prototype, but one of the real phenomenon, including specimens that display a certain amount of deviation from the norm. Correspondingly, modelling the human brain is not about modelling the brain of a

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3 Cartwright seems to imply here that position, extension, motion and mass are concrete concepts, or at least more concrete than force. This seems like a claim hard to defend, but I will leave this issue here.

4 Cartwright discusses idealisation and abstractness in Chapter 5 of *Nature’s Capacities and their Measurement* (Cartwright 1989). There the notions of abstractness and idealisation are expected to do work in the context of the concept of capacities and of causality, but this is a somewhat different context from theories being abstract.

5 There are exceptions to this. For some phenomena that are modelled there exists only one specimen that is taken into account, e.g. the earth.
specific person, but that, roughly, of all ‘typical’ people. For my purposes, the prototype of a phenomenon still counts as concrete, because it has all the properties of the real phenomenon and could exist in just this manner. The target of the examination remains an empirical phenomenon, even if members of the class of phenomena that belong to a certain type can come in different shapes and variants. This prototype-forming procedure is often needed in order to grasp and to define a phenomenon and to highlight what it is that one wants to model. The important point here is that despite prototype formation, the phenomenon is not in any way stripped off any of its properties.

Phenomena have properties. Abstraction I take to be a process where properties are taken away from a phenomenon, and are not replaced by another property. That which is abstract lacks certain properties that belong to any real, concrete phenomenon. To put it very crudely, something concrete becomes abstract when certain properties, that belong to the ‘real thing’ (and that make it concrete), are taken away from it. Not all concepts, principles or theories that are called ‘abstract’ are abstract in the same way, but I think the notion of taking away some of those properties that make something concrete can still serve as a guideline. It is important to recognize that no theory is conceivable without the concrete instantiations from which the theory has been abstracted. We need to go through different example problems in order to understand how \( F=ma \) is instantiated in different models. The theory is that which has been distilled from several more concrete instantiations. In this sense, the abstract theory is not directly about concrete phenomena in the world. The properties that are missing in such an abstract formulation as \( F=ma \) are how the force makes itself noticed in

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6 I am aware that the term ‘prototype’ has some connotations that are counterintuitive to my use of it, but for want of a better alternative I introduce it here as a technical term to be used in the way described in the following.
7 Idealisation, in contrast, means that properties are changed rather than omitted.
8 The Oxford English Dictionary gives for ‘abstract’: “Withdrawn or separated from matter, from material embodiment, from practice, or from particular examples. Opposed to concrete”, besides older uses. Cartwright (1989, p. 197 and 213f.) identifies this as the Aristotelian notion of abstraction. She recounts: “For Aristotle we begin with a concrete particular complete with all its properties. We then strip away – in our imagination – all that is irrelevant to the concerns of this moment to focus on some single property or set of properties, ‘as if they were separate’” (p. 197). See also Chakravarty (2001, p. 327f.).
different individual situations. Think again of a block being pulled across a flat surface, or the displacement of a spring from the equilibrium position, or the gravitational attraction between two masses. It depends on the situation what the force or the acceleration consists in (deceleration due to friction, the repulsion of a spring, or acceleration due to gravitation). Moreover, for each concrete situation one would have to establish what the body is like whose mass features in the physical system. Correspondingly, force, acceleration and mass can be associated with different properties in different physical systems. Force, abstractly speaking, can be something that applies to an object or system, but force alone, without an object or a system, is not something about which we can say anything, nor know the properties of. To establish a theory we need models that tell us how the theory is relevant with regard to the phenomenon or process modelled.\(^9\)

Consider the example of the pendulum. To think about the force in this particular case, it is necessary to take into account the specifics of this system, first of all the geometry of the system, involving the displacement angle, the length of the string and the gravitational attraction of the earth. The treatment of the ideal pendulum then usually continues assuming that the displacement angle of the pendulum is small, because this allows us to replace the sine of that angle with that angle itself. Obviously, physicists modelling pendula are fully aware of the idealisations they have introduced into their model. In reality,

- the string is not weightless;
- the string is not inextensible;
- the mass of the pendulum bob is not located in one point.

It is for a good reason that they specifically talk about the ‘ideal’ or ‘mathematical’ pendulum when they refer to this particular model involving the specified idealisations. This is why they also consider the physical pendulum. This is supposed to be a model that is nearer to some real pendula. This kind of pendulum is taken to be a rigid body of any arbitrary shape, pivoted about a fixed

\(^9\) For a case study supporting this kind of ‘division of labour’ between models and theories, see Suárez (1999).
horizontal axis. In this case, the centre of mass is treated as if it was the pendulum bob and the moment of inertia about the axis of rotation plays a role when calculating the restoring force. It is perfectly possible to make the model of a pendulum ‘more real’ and to correct for, e.g., the frictional forces of the air resistance, the buoyancy of the pendulum bob (that the apparent weight of the bob is reduced by the weight of the displaced air) and the gravitational field of the earth not being uniform, etc. (cf. Morrison 1999, p. 48-51). It is clear that, in order to make these corrections to the model, theories that go beyond Newton’s Law are employed and customized to the problem in hand.\footnote{Interestingly, Suárez (1999) employs just this example of the pendulum to argue that using idealisation, and subsequently de-idealisation, in order to apply theory to phenomena makes models appear superfluous in comparison to theories. I tried to illustrate here, in contrast, that...} Of course, in this case they all fall under the reign of classical mechanics, but this need not be so. Morrison comments:

“We know the ways in which the model departs from the real pendulum, hence we know the ways in which the model needs to be corrected; but the ability to make those corrections results from the richness of the background theoretical structure”

(Morrison 1999, p. 51).

Let me go back to the earlier example of the melting point of lead. There can be phenomenological laws that are merely generalisations of concrete instances, e.g. “the melting point of lead is 327 degrees Centigrade” which is presumably true of all lead. This is not abstract. An abstract law would be one that told us, for instance, how to infer the melting point of quite different metals. It would cover the general differences between London forces, hydrogen bridge binding and ion binding. These are not specific to any element, but can apply in all sorts of different elements, more in some than in others, depending on the element. For a law that simply states the melting point of lead, be it right or wrong, i.e. for phenomenological laws, we do not need a model in order to apply it to the world. Such a law does not apply to a range of different instances from...
which it is abstracted; such a law applies only to one kind of instance (rather than, perhaps, to all metals in a certain main group of the period table). This makes the law not theoretical.\footnote{Some laws have the status of theories, but not all do. Some sciences may be hard-pressed to formulate theories or principles that are abstract enough to apply quite generally, although an effort is often made. In other words, there can be sciences which only employ models and do not have theories.}

Theories can become general because they are abstract; they are free of the properties that are typical of certain individual instances where the theory might apply, or the properties that are typical of different prototypes. In order to model a phenomenon, abstract theory needs to be made more concrete, taking into account the specifications of the phenomenon that is modelled and inserting the ramifications and boundary conditions of that phenomenon (or the prototype thereof). To see how the theory holds in a model, we need to fill in the concrete detail that is not part of the theory because, being abstract, the theory has been stripped precisely of those details.

5. \textit{What happens to a phenomenon in the course of being modelled?}

The thesis I promote in this section is that what we take a phenomenon to be is shaped by how we model this phenomenon. I said earlier that, in order to be recognized as a phenomenon, something about this phenomenon needs to raise a question. Think of the bees’ dance. A model is some kind of answer to the question raised about a phenomenon, and the answer to this question will influence how we think about the phenomenon.

Interpreting data without having a phenomenon in mind is sometimes hardly possible. Prajit Basu (2003) presents a nice case study illustrating just this point that “observations, when transformed into evidence for a hypothesis, phenomena, or a theory, are theory infected” (Basu 2003, p. 356). Basu considers a case where two researchers perfectly agree on the data, but they take it to be evidence for different phenomena. The two researchers are Antoine-
Laurent Lavoisier (1743-1794) and Joseph Priestley (1733-1804). Lavoisier wanted to argue that water is a compound. One indication was that hydrogen and oxygen react together to form water. The other indication was that iron and steam (water) react to iron oxide and hydrogen (i.e. in this reaction, water is split up into oxygen and hydrogen).\textsuperscript{12} While Priestley had no doubts concerning the observational side of this reaction, we doubted that the black powder which Lavoisier took to be iron oxide was in fact iron oxide (see also McEvoy 1988, p. 208). The lesson Basu draws from this example is the following:

“A piece of evidence for (or against) a theory is a construction in the context of that theory from (raw) data. In this construction, a set of auxiliary assumptions is employed. These auxiliaries may themselves be theoretical in character. From the same (raw) data it is possible to construct different evidence for (or against) different theories since the auxiliaries employed in connection with different theories can be different. Finally, although the (raw) data are expressed in a language which is acceptable to partisans of competing theories, the evidence constructed from the same (raw) data is often expressed in the partisans’ differing theoretical languages”

(Basu 2003, p. 357).

That the chemical reaction described above resulted into a black powder (raw data) both Priestley and Lavoisier could agree upon, but not on what that black powder would be taken evidence for. Priestley claimed that in addition to the black powder a gas was formed during the reaction. Lavoisier accepted the principle of the conservation of mass, that the weights of what went into the reaction were the same as the weights of what came out. On the basis of this (theoretical) principle Lavoisier had reason to argue that there was no gas in addition to the black powder. (This is evidence rather than data.) Basu even identifies a number of levels of evidence. For instance, even to establish that the sample of iron is pure requires a test that is based on certain theoretical assumptions (the Stahlarian theses). At this lower level, Priestley agreed with

\textsuperscript{12} For an account of these experiments, see Carrier (2004, to appear).
Lavoisier, but obviously evidence could be questioned at any level. Agreement may be required even to establish to which level something counts as raw data. Basu then concludes:

“To the extent that these (raw) data are transformed into evidence, and for any evidential bearing these data might have on a particular theory and hence any bearing they might have on theory resolution, the evidence is theory-laden.”

(Basu 2003, p. 364).

So, in a way, depending on their theoretical assumptions, Priestley and Lavoisier could have taken the same data, on which they agreed (namely black powder), as evidence for different phenomena. There may not be any problem with raw data, but using raw data as evidence for a phenomenon is difficult without having the particular phenomenon in mind.

It is a long way from data to phenomenon, or sometimes from suspecting that there is a phenomenon to systematically collecting data about it in order to establish facts about the phenomenon (that can then be organized in a model). A phenomenon is experimentally or observationally examined. In the first instance, a phenomenon may be an object encountered in nature or the human environment. Yet, how to capture this phenomenon also increasingly depends on its empirical examination and theoretical description to this point, i.e. on one or more existing theoretical models of the phenomenon. The theoretical model is an attempt to capture the phenomenon by providing a description of it that is as complete as possible. This includes highlighting those factors that are relevant for constituting the phenomenon and may require omitting others that are considered more accidental. Data about a phenomenon can be produced by a whole range of different experimental procedures. They therefore present individual or isolated evidence about the phenomenon, while the phenomenon itself is expected to display a certain robustness in the face of the different

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13 The aim here is specifically not to express a preference for Lavoisier’s chemical interpretation over Priestley’s. At the time, such a preference would not have been empirically warranted. See, for instance, McEnvoy (1988) who emphasizes the overlap between Lavoisier’s and Priestley’s methodological and ontological practices. See also Carrier (1992).
experimental situations. Bogen and Woodward are right about this point, but this robustness does not automatically make phenomena into natural kinds or “bedrock elements of the furniture of the world”, as Glymour put it. Raw data cannot serve to confirm a theoretical model about a phenomenon, but have to undergo procedures of data analysis and be put into the form of a data model in order to be usable for an empirical test. Thus, empirical confirmation takes place between the analysed data and the theoretical model, not between data and phenomenon.

![Diagram]

**Figure 2**

Figure 2 shows that phenomenon and theoretical model remain closely connected, but the test of the model for a phenomenon takes a ‘detour’ via data generation and data analysis. When the phenomenon is examined experimentally or observationally, data about the phenomenon are produced. To compare the data with the theoretical models, data are required, but what the data are taken to be evidence for can depend on the phenomenon one has in mind and which one takes to be one’s subject of investigation.

6. **Conclusions**

To summarize,

- phenomena are facts or events of nature that are subject to investigation;
• models are interpretative descriptions of phenomena that facilitate access to phenomena;

• theory in science is not that which tells us what the world is like, but that to which we (sometimes) resort when we try to describe what the world is like by developing models.

• ‘Abstract’, said of theories, means having been stripped of specific properties of concrete phenomena in order to apply to more and different domains.

• Models, in turn, are about concrete phenomena (or prototypes thereof) that have all the properties that real things have.

• Theories are applied to real phenomena only via models – by filling in the properties of concrete phenomena.

Being abstract and therefore not directly about empirical phenomena does not, however, render theories worthless or unimportant. Theories and models have to prove themselves at different levels, models by matching empirical phenomena and theories by being applicable in models of a whole range of different phenomena (or prototypes thereof).

A scientific model and its phenomenon are closely connected from the start in that the model is designed as a model of the phenomenon. Modelling involves judgements regarding which properties of a phenomenon need to be covered in a model in order to capture the central features of the phenomenon, and which properties count as accidental and can be omitted. What is taken to be the phenomenon becomes somewhat reconstructed in the course of the modelling process. The modelled phenomenon may depart somewhat from the physical reality, due to idealisations, both of the phenomenon (causal idealisation) and of the model (construct idealisation) (McMullin 1985). However, despite this air of constructivism, it is the phenomenon the investigation of which results into data about the phenomenon. The link of the model to empirical evidence is required to be strong. While there is an empirical link, how we delineate and describe a phenomenon is invariable linked to the way we have
learned to model it. What we take a phenomenon to be and how we model it develop together over time.

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