Abstract and Complete


**Abstract**

There are two notions of abstraction that are often confused. The material view implies that the products of abstraction are not concrete. It is vulnerable to the criticism that abstracting introduces misrepresentations to the system, hence abstraction is indistinguishable from idealization. The omission view fares better against this criticism because it does not entail that abstract objects are non-physical and because it asserts that the way scientists abstract is different to the way they idealize. Moreover, the omission view better captures the way that abstraction is used in many parts of science. Disentangling the two notions is an important prerequisite for determining how to evaluate the use abstraction in science.


## I. Introduction

The west pediment of the Parthenon is a physical object that exists in space and time, but it is also triangular. We say that the west pediment is concrete, but that triangles are abstract. What accounts for this difference? The received view in philosophy of science is that an object is abstract when it is not concrete (e.g. Cartwright 1994). Call this the *material view* of abstraction. The problem with the material view is that it implies that abstract objects are not physical. However, scientists often work with systems that are abstract but also physically instantiated. For example, experiments conducted in greenhouses abstract away from properties such as the color of the plants in question and whether or not they are subject to herbivory. Nonetheless, the plants in these experiments are concrete particulars like the west pediment of the Parthenon and unlike triangles. Moreover, the material view blurs the distinction between abstraction and idealization, as idealized objects are not concrete. For example, assuming that a population is infinite is common practice in models of population genetics, yet no actual population in the world is infinite. In this sense, infinite populations are like triangles and unlike the west pediment of the Parthenon. The problem is that the main goal of proponents of the material view is to defend abstraction from critics who argue that both abstraction and idealization involve distortion, hence they are not distinct processes (e.g. Humphreys 1995). Unfortunately, the material view of abstraction undermines the force of their arguments against the critics.

Thomson-Jones defends a different view of abstraction where abstraction means the omission of irrelevant parts and properties from an object or system (Jones 2005).[1] I will call this the *omission view.* Here, abstraction and idealization are distinct because idealization requires the assertion of a falsehood, while abstraction involves the omission of a truth (ibid). Thus, while both idealization and abstraction can result in the distortion of a system, the distortion is very different in each case. When we abstract, we do not describe the system in its entirety, so we are not telling the whole truth. However, when we idealize, we add properties to the system that it does not normally possess. Therefore, our description of an idealized system contains falsehoods.

Both the material and omission views about abstraction are relevant to parts of scientific inquiry, but it is important to keep them distinct. If we fail to do so and lump abstraction together with idealization, we are in danger of trivializing an important aspect of science. I will argue that the notion of abstraction that is relevant to models, modeling, experiments, and target system construction (Godfrey-Smith 2006) is a version of the omission view. Specifically, this is the view that abstraction is the opposite of completeness. We start off with a complete object or system, one that has all its parts

1 Cartwright also defends this view in places, yet she uses the two notions interchangeably (Cartwright 1994). This implies that she views the material and omission views as two different aspects of the same notion instead of two distinct notions of abstraction.

and properties. When we abstract, we omit the parts and properties that are irrelevant for our purposes. An important implication of this view is that the outcomes of the process of abstraction can be concrete and physical.

**II. The use of Abstraction in Science**

The material view of abstraction is intuitive and deeply entrenched. Prime examples of abstract objects are mathematical objects such as numbers and triangles, which are not physically instantiated. Examples of abstract objects in other disciplines are concepts and ideas which are not tangible (e.g., fairness, evil, superego). Interestingly, in many of these cases, we can arrive at these objects through the process of omission. For example, we can start off with two roses, omit properties such as color, smell, photosynthetic capacity, chemical composition and so on, until we arrive at the number two. Historically, philosophers writing on abstraction (e.g. Aristotle and Locke) have held versions of the material view but explained how we arrive at abstract objects with the omission view (Rosen 2009, Cartwright 1994). It is not surprising, therefore, that the two views of abstraction are often lumped together as aspects of the same notion.

However, the use of abstraction in science is often quite different. Scientists often omit a number of parts and properties from a system, yet do not treat the resulting systems as immaterial or intangible. In the remainder of this section I will give some examples systems used by scientists that are both abstract and concrete. The first is an experiment from plant ecology, aimed at determining the cause of competition between two plants. In this experiment, Jarchow and Cook (2009) conducted a series of experiments with the invasive aquatic cattail species *Typha angustifolia* and the native wetland species *Bolboschoenus fluviatilis*, which inhabit North American lakes. They took specimens from both species back to the greenhouse and grew them in a single controlled environment. The results showed that *T. angustifolia* had a competitive advantage over *B. fluviatilis* because of allelopathy (the exudation of toxins from its roots). These toxins inhibit the growth of the native species (with a resulting 50% reduction in biomass) which allows the invader to soak up the limited nutrients in the soil. Above ground, the invader rapidly increases in size and shades the native species, which further reduces its growth rate.

It seems strange to think of this experiment as an abstract system, if we retain the idea that abstract objects are immaterial. The system of the plants in the greenhouse is as tangible and physically instantiated as the plants in the lake ecosystem. However, by bringing the plants into the greenhouse, the scientists are excluding all the other parts and properties of the lake ecosystem. The experiment, conducted in a simplified environment, allowed the scientists to identify the existence of competition between the two plants and to isolate the cause of the competitive advantage of *T. angustifolia.* They achieved this by being able to isolate the important factors from the system and omitting or parametrizing the other, irrelevant factors. In other words, the scientists started off considering a complete system with all its parts and properties (the lake ecosystem) and ended up with a system with fewer parts (fewer individuals from fewer species) and properties (the particular plants are not thought of as prey, or as contributing to the uptake of atmospheric $CO_2$).

Moreover, this example is not a one-off case. The very nature of experimentation in ecology is based on the idea that ecosystems are very complex and identifying the most important causal factors that lead to ecological phenomena involves controlling and parametrizing other factors. The same is true of experiments in evolutionary biology. Geneticists test mutation rates in populations of *E. coli* and *Drosophila* in controlled laboratory settings. The point of those experiments is to isolate the genetic factors that affect mutation rates, without the compounding or mitigating effects of developmental and environmental variation. Even further afield, experiments in psychology are conducted in controlled environments, with the aim of minimizing irrelevant effects.

Abstraction is also an important step in modeling. As with experimentation, when scientists model a particular phenomenon in a system, they do not model the entire system but a subset of parts and properties of that system. The identification of which parts of the system are important and the omission of those parts that are not, is another example of the process of abstraction.

I will illustrate with an example from population ecology. The marmots of Vancouver Island (*Marmota vancouverensis*) are classified as critically endangered. It is estimated that their population has dropped 80%-90% since the 1980's and currently consists of roughly 200 individuals (Brashares et al. 2010). Ecologists studying these social rodents wish to understand how to bring back the population from the brink of extinction. In order to that, they must understand the causes of the decline in the marmot population. A good place to start is to look at a standard model of population growth and check if the actual marmot population deviates from the model (this was the exact strategy undertaken by Brashares and colleagues) (ibid). There are a number of models in ecology which measure population growth; the logistic growth model (originally developed in 1838 by Pierre Verhulst) is often used in the early stages of a study, because it is not entirely unrealistic (as it takes into account the effect of density on population growth) but at the same time it is quite simple (Fig 1).

**Fig 1. Logistic Growth Model**

$$\frac{dN}{dt} = rN\,(1 - \frac{N}{K}) \qquad (1)$$

*(N) is the number of organisms in population. (r) is the intrinsic growth rate of the population. (K) is the carrying capacity of the environment: the total number of organisms a particular environment can support.*

This model measures how the growth rate of a population (*N*) is limited by the density of the population itself. (*r*) is the intrinsic growth rate, the maximum possible growth rate of the population. It is roughly equivalent to the number of deaths in the population subtracted from the number of births in that population.[2] The second important component of the model is (*K*), the *carrying capacity* of the environment. (*K*) imposes the upper limit on population growth because it is the maximum number of

2 Different species have different intrinsic growth rates; for example, large mammals such as elephants reproduce slowly and therefore have a low (*r*) whereas most insects and plants have high reproductive rates and therefore have a high value of (*r*).

individual organisms that a particular environment can support. Factors that affect (*K*) are the environment's resources, yet they vary across environments and species.[3]

There are two sets of abstractions from the Vancouver Island (VI) ecosystem that need to occur so that the population growth of actual marmots can be compared with the prediction of the logistic growth model. The first is the elimination of *parts* that are not relevant. This includes the elimination of all units that are not relevant for measuring the population growth of marmots. The other animals, most of the plants on VI, and inanimate parts such as the marmot burrows will be omitted. The only other parts of the system that will be included are the plants that the marmots feed on (for example, cow parsnips, Kinnikinnick-fruit and huckleberries). The second set of abstractions concerns the *properties* that are relevant for the experiment or model. Properties such as eye color, fur length and fur color will not be relevant, because they do not affect short-term population growth. On the other hand, properties such as sex, time spent foraging and metabolic rate are relevant because they determine (*r*) the intrinsic growth rate of the marmot population.

With these abstractions in place, scientists were able to figure out that the growth rate of the marmot population on VI was falling, despite being far from close to the carrying capacity of the island. The reason for this is a phenomenon known as the Alee effect (named after Warder Clyde Allee who first described it). This effect occurs in

3 For example, in the case of plants, access to sunlight is very important, as are elements such as phosphorus and nitrogen. The amount and availability of each of these factors in the system will affect the (*K*) of plant populations. For many social mammals, space is very important as it affects the location of territory or the number of nesting sites. For example, the size of beaver populations in an area is partly determined by where each family can build its dam (and each dam's proximity to other dams).

small populations when a fall in population density decreases the growth rate instead of increasing it. Brashares et al. found that this instance of the Allee effect was caused by a 'social meltdown' (ibid). Unlike other marmots, VI marmots are very social and the decline in population leads to difficulty in finding mates, which reduces the growth rate even more.

This example is aimed at showing that abstraction is an integral part of modeling in science. In the paper, the logistic growth model is compared with the actual population of marmots, considered in isolation from the other parts of the ecosystem (ibid). There is no reason to think that the collection of marmots and the properties of their population is not concrete. Nonetheless, the population of VI marmots has fewer parts than the entire ecosystem on VI. In this second sense, it is more abstract that the entire VI ecosystem.

To recap the argument so far, there are two views of abstraction: the material view and the omission view. On the material view abstract objects are immaterial. On the omission view abstract objects are simply incomplete, and can be either material or immaterial. The two views are easily confounded because immaterial abstract objects result from the process of omission. However, there are a number of examples in science where the process of omission leads to physical objects or systems. Thus, the material view cannot account for all the objects or systems that arise from the process of omission. In contrast, the omission view accounts for all systems that result from omission, irrespective of whether or not they are concrete. Thus, if we want a single, unified notion of scientific abstraction, then we should opt for the omission view.

**III. Abstraction and Idealization**

In the introduction, I mentioned another criticism of the material view of abstraction, namely that abstraction and idealization are not distinct concepts and they can be used interchangeably to signify any distortion in the scientific representation of a phenomenon. This view, endorsed explicitly by some (Humphreys 1995) and implicitly by many more (McMullin 1985), implies that there is no real or interesting distinction between abstraction and idealization. The two processes are thought to be inextricably linked, if not identical, and attempting to separate them results in confusion. The main proponent of the material view of abstraction is Paul Humphreys, who argues that in order to talk about abstract systems we usually have to represent them in some manner, and this representation will not be concrete (Humphreys 1995). However, idealized systems are also representations that are not concrete. According to Humphreys, the two types of representations are, therefore, not easily distinguishable.

This diagnosis is quite apt. Cartwright (the main proponent of the material view) states that when we idealize, we start off with a concrete object and "mentally rearrange some of its inconvenient features -some of its specific properties- before we try to write down a law for it" (Cartwright 1994 187). In contrast, when we abstract, we strip away properties from a system "in our minds" (Cartwright 1994). Thus, for example, when we omit all the irrelevant properties from the west pediment of the Parthenon, we are left with the shape of a triangle. This shape cannot be a true triangle though, as it is not a perfect geometrical shape. This is because the west pediment contains imperfections which are retained in the process of abstraction. According to Cartwright, this does not really matter, as we can pretend that the abstract shape is a true triangle. The imperfections are already present in the real system and are not the result of our abstraction. In addition, these imperfections are themselves insignificant, and for all intents and purposes the abstract triangle is close enough to a true triangle. Thus, despite the imperfections retained in the process of abstraction, we are close enough to the real systems that we are entitled to pretend that our abstract shape is a true triangle.

The problem, as Humphreys points out, is that once we start pretending what a system is like, we blur the lines between abstraction and idealization. We cannot legitimately focus on the triangle's geometrical properties because an imperfect concrete triangle will remain imperfect after we abstract. If we want our abstract triangle to have geometric properties, then we have to *add* them to abstract triangle. In the case of *true* abstraction all the properties of the abstract object already exist in the real world. Hence, as soon as we start pretending, we are adding properties to our system that the material triangle does not have. In other words we are misrepresenting, or distorting the system. If this is the case, then abstraction and idealization seem very similar. To put the point differently, adding geometrical properties to a triangle is very much like assuming that a population in biology is infinite. No triangle in the actual world is perfect, just as no population of organisms in the world is infinite. In both cases, misrepresenting the system by adding properties is extremely useful, as it helps us model the system with the use of mathematics. Nonetheless, misrepresentation of a system, *according to proponents of the material view*, counts as idealization.

I agree with Humphreys that this is an important problem for the material view of abstraction. As soon as we disassociate abstract objects from concrete objects, then we are abstracting 'in our minds' and representing them imperfectly. However, this criticism loses its force when pitted against the omission view of abstraction. On this view, abstraction is 'mere omission', i.e., we only abstract properties that are irrelevant for our system (Jones 2005). In the case of the west pediment, these properties are the pediments color, the fact that it contains statues, that is made of marble. What we are left with is a concrete shape that is also triangular. Importantly, this triangular shape is *not* a true triangle, it is simply approximates a true triangle. Mere omission cannot give rise to an immaterial true triangle from the imperfect and concrete pediment.

On the omission view, abstracting from the west pediment is like abstracting parts and properties from the VI ecosystem in order to explain the population size of the VI marmots. In the case of VI, the ideal population is represented by the model which is compared to the size of the actual population of marmots. Similarly, a true triangle can be compared to the actual approximately triangular shape of the west pediment. The difference between the material and omission views is that in the latter, there is no pretending. On the omission view, we can identify differences are between the abstract and ideal systems. Hence abstraction and idealization can be kept distinct.

A distinct criticism which does bear against the omission view attempts to assimilate abstraction to idealization because both fundamentally involve distortion.[4] The idea is that omitting aspects of a system results in the misrepresentation of the

4 This criticism stems from the view that idealization is not a unified, singular concept. Proponents of this view (Weisberg 2007, Frigg & Hartmann 2009) believe instead that there are different kinds of idealization in science and that abstraction is subsumed under one of these kinds of idealization.

system. Consequently, abstraction is a special case of idealization. In other words, no parts or properties of a system are strictly speaking 'irrelevant', hence they cannot be omitted from without the system being distorted. Omission necessarily results in distortion, because systems in nature are irreducibly complex. For example, ecosystem ecology is subfield of ecology that advocates holistic approach that views ecosystems as wholes or even individuals (Odenbaugh 2007). This is in direct contrast to the subfield of population ecology, where population dynamics are thought to capture and explain ecological phenomena. The big difference between the two approaches is that population ecologists work with more abstract models, as they omit a number of factors (especially abiotic factors) as irrelevant. On the other hand, ecosystem ecologists think that omitting abiotic factors from complex ecosystems results in overly simplistic models. The problem with that is that various processes which involve abiotic factors are themselves omitted or misrepresented, which in turn gives a distorted view of the way an ecosystem functions. In other words, it is the omission of factors from the system that leads to its misinterpretation.

Thomson-Jones attempts to avoid this problem by restricting abstraction to precisely those omissions that do not result in misrepresentation (Jones 2005). As stated above, a 'mere omission' does not misrepresent a particular feature of a system because it retains 'complete silence' with respect to whether the system contains the feature (ibid). So if an omission results in a misrepresentation, then it is not the type of omission that is part of abstraction. The problem is that the criticism presented here is much stronger. The criticism denies the possibility of 'mere omission' altogether.

I agree with the critics that omission can be thought of as distortion. Still, I do not think that it should undermine the importance of abstraction in science. For the remainder of this section I will put forward some preliminary proposals which show how the omission view can help distinguishing between abstraction and idealization. The first point is that denying the possibility of 'mere omission' altogether is too strong. Phenomena in the world have a very large number of parts and properties and scientists always omit some of them in their experiments and models. Some of these properties do not have an effect on the study. For example, one of the properties of the VI marmots is eye color. The paper does not make any reference to this property, because the scientists did not think that it was relevant for population growth. I think it is safe to say that the property of eye color which was present in the system, was 'merely omitted' from the model.

The upshot is that abstraction and idealization are distinct processes that give rise to different types of phenomena. Therefore the norms that govern these processes should also be different. There is a substantial literature that deals with the methodology and evaluation of idealizations (see for example Giere 1988, Weisberg 2007a). An idealization misrepresents a factor that is considered important for the phenomenon of interest, by adding properties to it or changing some of its properties. For example, scientists may assume that a population is infinite, in order to construct an evolutionary model that is computationally tractable. In order to be successful, the idealized system must be informative about the real system, despite the misrepresentations. This can be achieved if the idealized system is to some extent isomorphic to its real-world counterpart, or if it is sufficiently similar to it (van Fraassen 1980, Weisberg 2007b).

The case of abstraction is different. Phenomena in nature have many more parts and properties than one can include in an experiment or model. Hence, when scientists abstract they want to preserve only those parts and properties that are relevant for the phenomenon they are studying. These omissions help them make sense of the phenomenon so they can study it. In many cases it might be impossible to study a phenomenon without omitting a large number irrelevant factors. As stated above, when abstracting, scientists aim for 'mere omission'. Therefore, the evaluation of an abstraction should focus on whether the it is a case of 'mere omission' or not. To my knowledge, there is no account that fully specifies a method for the evaluation of abstractions.[5] It is usually left to the discretion of the scientist.

It unlikely that the methods used to evaluate idealizations (such as isomorphism or similarity) can be applied to the evaluation of abstraction. Abstract systems are already very similar to their real-world counterparts, because they are concrete and real. The differences between concrete systems at different levels of abstraction are much more fine-grained than differences between idealized and real systems. Also, an abstract system can be to a large extent isomorphic to a complete system, yet lack a relevant property. For example, an experiment that looked at competition between *T.angustifolia* and *B.fluviatilis*, which focused only on above-ground competition and did not take into account below-ground competition would be isomorphic to the real-world ecosystem,

[5] There are some accounts that outline important aspects of the process of abstraction (for example Jones 2005, Weisberg 2007). Still, these accounts are focused on describing the process of abstraction and do not give a generalized account of how abstractions should be evaluated.

yet it would also be missing relevant aspects of complete system.[6] Thus, it seems that a different method is needed for a full and generalized evaluation of abstraction in science. This account will have to wait for another paper. The purpose of this paper was to show that before any such account is possible, the omission view must be distanced from the material view of abstraction and hence from idealization.

**IV. Conclusion: Abstract and Complete**

The two notions of abstraction captured by the material view and the omission view respectively, are easily confused. The examples that are usually used to illustrate discussions of abstraction exacerbate the situation, as they are often taken from mathematics and mathematical objects are seen as paradigm examples of abstract objects. While the distinction might not be necessary in mathematics, it is very important for science, especially biology. Failing to distinguish between the two notions undermines the role that abstraction plays in scientific experimentation and modeling, as it is often subsumed under the concept of idealization. Keeping these two concepts separate will give us a more accurate picture of scientific methodology and will help in the formulation of a generalized account for the evaluation of the process of abstraction.

[6] This is because allelopathy affects the uptake of nutrients, which occurs in the roots of plants. However, the effects of competition can be seen by looking at the differences in shoot biomass of the competing plants. Still, without the inclusion of below-ground competition and its effect on root biomass, the cause of competition could be missed. That is, if the scientists had not included the below-ground competition in their experiment, they could have overlooked the importance of allelopathy as the *main* cause of *T.angustifolia's* competitive advantage.

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