Antonio Oliva • Ángel Oliva • Iván Novara
Editors

Marx and Contemporary Critical Theory

The Philosophy of Real Abstraction

palgrave
macmillan

CHAPTER 17

Real Abstraction in the History of the Natural Sciences

Peter McLaughlin and Oliver Schlaudt

TECHNOLOGY AND SCIENCE

What is the relation of science and technology? A common view is that technology applies science—the view is sometimes even radicalized as: Science is pursued for the sake of technology. Francis Bacon is often cited in this connection: 'Nature to be conquered must be obeyed'.[1] The natural interpretation of this slogan is that, if you want to dominate nature, you should pursue science, learn nature's laws, and then obey them in their application to technology. But we can also read the relation in the other direction and say that since we do in fact regularly conquer nature in technology, we must having been implicitly obeying her laws all the time; and thus our technology already embodies natural laws. If we study what is done in technology, we can learn about the laws of nature. Furthermore, this view allows us to avoid speculations about the noble—or ignoble—motives of individual scientists and to concentrate on the structural determinants of social action (cf. Merton 1939). The interpretation of nature

---

P. McLaughlin (✉) • O. Schlaudt (✉)
University of Heidelberg, Heidelberg, Germany
e-mail: peter.mclaughlin@uni-hd.de; oliver.schlaudt@urz.uni-heidelberg.de

A. Oliva et al. (eds.), *Marx and Contemporary Critical Theory*,
Marx, Engels, and Marxisms,
https://doi.org/10.1007/978-3-030-39954-2_17

in terms of technology or the view of the world as a machine is an integral part of the early modern scientific world view. The metaphor of the clockwork universe is compatible with both versions of Bacon's dictum: science can be pursued *for the sake of* technology, but science can also be pursued *on the basis of* technology.

The view of technology as the source rather than the goal of science is articulated by Galileo Galilei in the opening lines of his *Discorsi* of 1638:

> Frequent experience of your famous arsenal, my Venetian friends, seems to me to open a large field to speculative minds for philosophizing, and particularly in that area which is called mechanics, inasmuch as every sort of instrument and machine is continually put in operation there. (Galilei 1974: 11)

Galileo visited the Arsenal in Venice, not to build better ships but to 'philosophize', that is, to use his training in Aristotelian natural philosophy and Archimedean mathematics to study technology and thereby learn about nature.

This Galilean perspective on the relation of science and technology was at the core of Marxist historiography of science in the first half of the twentieth century as represented by Boris Hessen and Henryk Grossmann.[2] Early historiography of science had made it clear that in spite of all the proclamations in the seventeenth and eighteenth centuries on the utility of science for the improvement of production and the wealth of society, it was only in the nineteenth century that science actually became useful for production. Whereas traditional historians concluded that technology was, therefore, irrelevant to an explanation of the Scientific Revolution of the early modern age,[3] Hessen and Grossmann viewed technology not as the final cause of science but as the material basis of an experimental exploration of nature. They saw in the development of (especially mechanical) technology the basis and determining factor for the subsequent emergence of a science of mechanics. To give an example, the production norm of a transmission mechanism such as a clockwork expresses an abstract notion of friction-free motion. This abstract notion is in a sense already embodied in the technology as such.

What we are interested in here is the extent to which science can be viewed as the analysis of technique/technology and the extent to which the analysis of technology can be seen as the articulation or conceptualization of the 'real' abstractions performed by technology. When we ask what can be learned about nature or the study of nature from various human practices, the concept of *real abstraction* might be useful, even if used in a different way than it has been used in sociology. We shall propose a notion of real abstraction for the study of the nature and history of the natural sciences, especially with regard to their relation to technological practice.

Real Abstraction

The term 'real abstraction' was brought to currency by Alfred Sohn-Rethel in *Intellectual and Manual Labour* (1978) to describe the fact that in the exchange of goods people actually, but in general not consciously, abstract from the use value of the commodity which they trade away. This means that in the exchange itself, a commodity is used only as a means for obtaining a different commodity, not as a means to the end that defines its own use value or utility. The commodity is so to speak 'frozen' into pure quantity and immutable substance. Even if the people involved in the exchange of goods are not conscious of the abstraction from the commodity's use value, the abstraction still constitutes an objective feature of their actions. In this sense the abstraction is *real* as opposed to being effected merely in thought. This phenomenon is of philosophical importance according to Sohn-Rethel because he holds the real abstraction, once the exchange of goods becomes a widespread practice in a society, to impose a certain view of the world on the members of this society. Real abstraction is thus similar to the Kantian categories that structure experience or like a looking-glass which shows us an image of the world in terms of numbers and general laws.

The mechanism by which the real abstraction that takes place in exchange is translated into categories of thought, however, remains mysterious, as has been noted by many critics (e.g. Falk 1977: 393–394). We think, nonetheless, that the notion of real abstraction can be made useful for understanding the history of the natural sciences, and we will offer a reading that permits us to use this concept without having to rely on such obscurities. The basic idea is to view the exchange of commodities, from which Sohn-Rethel derived the real abstraction, as just one special case of a more general process of real abstraction. Thus any abstraction that is carried out so to speak by hand rather than merely in thought may be called a real abstraction.

Marx himself provides an instructive example. In the first chapter of *Capital* Marx explains how in exchange one commodity, which in itself is simply one particular use value among others, becomes the *expression* of the economic value of another commodity: 'use value becomes the form of manifestation, the phenomenal form of its opposite, value. The bodily form of the commodity becomes its value form'. Marx illustrates this point by comparing the exchange of goods of equal value to establishing an equilibrium on the balance between objects of the same weight. He then goes on saying (Marx and Engels 1975: 35, 66–67):

> A sugar-loaf being a body, is heavy, and therefore has weight: but we can neither see nor touch this weight. We then take various pieces of iron, whose weight has been determined beforehand. The iron, as iron, is no more the form of manifestation of weight, than is the sugar-loaf. Nevertheless, in order to express the sugar-loaf as so much weight, we put it into a weight-relation with the iron. In this relation, the iron officiates as a body representing nothing but weight. A certain quantity of iron therefore serves as the measure of the weight of the sugar, and represents, in relation to the sugar-loaf, weight embodied, the form of manifestation of weight. This part is played by the iron only within this relation, into which the sugar or any other body, whose weight has to be determined, enters with the iron. Were they not both heavy, they could not enter into this relation, and the one could therefore not serve as the expression of the weight of the other. When we throw both into the scales, we see in reality, that as weight they are both the same, and that, therefore, when taken in proper proportions, they have the same weight. Just as the substance iron, as a measure of weight, represents in relation to the sugar-loaf weight alone, so, in our expression of value, the material object, coat, in relation to the linen, represents value alone.

Here Marx establishes an analogy between economic value and physical weight. Let us isolate the crucial elements. We start with some given concrete objects, say pieces of iron and sugar-loafs. These objects can be put in different kinds of relations: We can trade iron for a sugar-loaf in an exchange. Within such an exchange relation, the pieces of iron are reduced to economic value, or more precisely, to the bodily manifestation of the economic value of the sugar-loaf they are to be exchanged for. Similarly, we can put both kinds of objects on a balance, first the sugar-loaf in the one pan and then add iron pieces in the other until equilibrium is reached. Now, the pieces of iron have been reduced to embodiments of weight or, more precisely, to the expression of the weight of the sugar-loaf in the opposite pan of the balance.

The key to our approach is that, in exchange, goods are not reduced to pure quantity, as Sohn-Rethel would have it, but to the (the expression of) economic value, that is, the quantity of the qualitative dimension, economic value. Once this is taken into account, it becomes clear that weight is analogous to value. Of course, Marx carefully determines the limits of this analogy: weight is a ‘natural’ property whereas economic value is purely ‘social’. This difference, however, does not affect the possibility we want to explore in this paper: namely that both properties, weight and value, are the outcome of analogous types of abstractions. The categorical difference between ‘natural’ and ‘social’ properties simply reflects corresponding categorical differences between the underlying material processes of abstraction: on the one hand, the balance, a physical device, and on the other, commodity exchange, a cultural practice. Indeed, what Marx actually describes in the passage cited above is that, when we put concrete objects on the balance, we reduce them to their character as weights and abstract from all other properties. For the engineer this perspective is quite normal. From an engineering point of view, an object is a multidimensional causal actor, interacting with its environment in various ways: by reflecting and absorbing light, through direct contact and through various kinds of forces acting at a distance through fields (electric, magnetic and gravitational). A balance in this perspective is a particular material arrangement which ‘filters’ modes of interaction. The balance reacts to weight but not to color, odor or electric charge. It thus *really* carries out an abstraction from various properties, that is, it effects a *real* abstraction.

Thus Marx’s analysis of the exchange relation, from which Sohn-Rethel derives the concept of real abstraction, can also be seen as the analysis of an equivalence relation *on the example of* the exchange of commodities. From this perspective we have an analysis that applies more generally and points to a more general form of abstraction that also occurs in other areas of human practice. We agree with Sohn-Rethel in his attempt to locate the source of key abstractions in human thought in the real abstractions made in human practice, but we reject his restriction of the forms of practice to those of commodity exchange. There are multifarious examples of real abstraction in technological practice. Furthermore, Sohn-Rethel’s distinction between the *form* of science (determined by the exchange abstraction) and the *content* of science (determined by problems derived from production) is not fruitful for the analysis of science (Sohn-Rethel 1976: 45/6). Sohn-Rethel allowed the content of science to be derived from the sphere of production but insisted that the theory form of science was due exclusively to the distribution sphere. Thus, he was unable to envision real abstraction in production—or anywhere but commodity exchange.

The aim of our contribution is to discuss the extent to which abstraction, understood in this way, can be regarded as a common phenomenon in the history of science, and thus as a useful key to concept formation in the sciences. The view which we want to put forward in this paper is that things happened in the opposite way as usually conceived. That is, from an historical perspective, the device, embodying a real abstraction, often comes first and only afterwards is the concept of the quality it instantiates derived.

An Example: The Law of the Lever

In what follows we shall examine a real abstraction on the example of the first mechanical law, the law of the lever, showing how some basic concepts of science were formed by studying technology, namely the balance with unequal arms.

If the concept of real abstraction is to help us give a satisfying account of the emergence of a new concept, there are two main questions that have to be addressed: (1) In what sense can a technical device 'be there' without first being invented in order to serve the specific purpose that gives it its name? (2) Under what circumstances are the real abstractions embodied in technical devices discovered and translated into corresponding concepts? We shall deal with both questions in our example.

The Law of the Lever, which posits the inverse proportionality of weights and lengths on a lever/balance in equilibrium, was first formulated near the end of the fourth century BC in the Peripatetic short treatise, *Mechanical Problems*, written by Aristotle (1936) or one of his better disciples.[4] This work is the first documented example of a sustained theoretical reflection on mechanical knowledge in Europe. Although the text that has come down to us is a hodge-podge of disparate topics thrown together, parts of the work also contain an ambitious program of theoretical investigation of technical devices, reducing each of them to the lever and the lever to a balance with unequal arms—and then the balance arms are reduced to radii of circles.

The aim of the *Mechanical Problems* is to explain why technical devices work—and also to show that their success is compatible with Aristotle's physics—although the latter goal appears to be secondary. What is shown again and again is that technical devices can be made intelligible on the model of the balance, the lever and the circle. Particular concrete objects and relations are taken as instantiations of abstracted concepts and relations: an oar or a mast is a lever; a nutcracker is two levers fixed together, long boards bend more than short ones because they are like levers farther from the fulcrum. All these devices can be analyzed in terms of lever, load, fulcrum and force. What the author does is to develop general abstract concepts in the study of technical devices which embody these abstractions. Theoretical analysis (science) arises here in a particular kind of study of technique.

A special role in the construction of the *Mechanical Problems* is played by the balance with unequal arms. This asymmetric balance, which became common in Greece after the mid-fifth century, had a fixed counter-weight and a moveable suspension point, which could be adjusted until the beam reached equilibrium—unlike later Roman devices with a moveable counterweight. This device is characterized as at once a balance and a lever. As a balance, it establishes equilibrium or equality in which counteracting forces mutually cancel out each other's effects. And as a lever, it allows a smaller weight (on the longer arm) to balance or overcome a greater weight. In the *Mechanical Problems*, the asymmetric balance provides the point of departure and the model for the cognitive development realized in the treatise.

There are many technical devices embodying some form compensation of weight by length or length by weight. The *shadoof*, a long pole with a bucket on one end and a counterweight on the other, had long been in use in Mesopotamia and Egypt in irrigation to lift water from a river or a basin. The Macedonian army under Aristotle's employer Phillip, by putting counterweights on its long spear (*sarissa*), was able to increase the effective length of the spear without reducing the maneuverability of the phalanx. All such devices embody a 'complementarity' of weight and distance and make the experience possible that weights are balanced not only by other weights (as in the symmetric balance) but also by lengths. The abstraction from the dimensional difference between length and weight is made by the device itself. The subsequent question will then be: When and how is this real abstraction intellectually recognized and appropriated in thought.

The answer to our first question as to how a technical device can 'be there' without first being intended to serve the specific purpose that gives it its name, hence simply, is that the device first served a different purpose, as is exemplified by the *shadoof* and the *sarissa*. This answer probably holds in general. Any material device can be used for various ends, including ends they were not originally intended. A similar phenomenon is known in evolutionary biology as *exaptation*. Biologists Gould and Vrba (1982) introduced this term to account for traits that evolved for one function and were later adapted for another. The French archaeologist, Sophie de

Beaune has applied this term to technological invention in prehistory in order to account for more complex inventions without having to refer to pure chance or ingeniousness (2008: 83). Finally the dialectics of means and ends also applies to commodity exchange: People discover that goods can also be used for acquiring different goods, that is, that they have an exchange value. Understanding 'real abstraction' in the way, we suggest, thus demands that we identify an original end, which was served by the tool, and which led to the practice with the device that created the real abstraction.

But let us get back to Aristotle and asymmetric balance in order to think about the second question, under what circumstances are the real abstractions embodied in technical devices discovered and translated into corresponding concepts?

Due to their military and architectural activities, the Greeks possessed practical mechanical knowledge of the simple machines and the planning knowledge needed for their application. And counterweights, which practically embody the complementarity of weight and distance (or provide a real abstraction from their difference), were common in ancient Greece. Any such device could in the right context have occasioned theoretical investigations. But there are good reasons why the asymmetric balance provided that occasion. As a lever and balance at the same time, the asymmetric balance embodies two conflicting notions. It is a lever, that is a machine that allows a smaller force to conquer a greater force and thus tricks nature by (seemingly) getting more out than it puts in. However it is also a balance and thus is a machine for establishing equality of weight (equilibrium). As long as these different practices are separate, the conflict need not become a problem. But in the context of Aristotle's project of cataloguing and analyzing practices in order to integrate them into an encompassing system of knowledge, the conflict has to be dealt with. A concept was needed that permitted the reconciliation of the lever and the balance by identifying the equal within the unequal, the equality of cause and effect when the smaller weight overcomes the larger one. The concept of weight is a real abstraction embodied in the symmetric balance, and the notion of 'inclination' (*rhopê*) or momentum, denoting the combined effects of weight and length, could be discovered on any counterweight devices. But the real abstraction in the asymmetric balance is much more complex than the simple complementarity of the *sarissa* and simply equality of the standard balance. The asymmetric balance embodies the equality of inclination, which can be formulated as the law of the lever, when we discover the real abstraction in this device.

This answer to this second question differs in nature from the answer to the first question. First, it is less likely to be generalized. Whereas the first answer hinted at a dialectics of means and ends which might turn out to be quite general in cultural and even in natural evolution, the second answer made it necessary to tell a highly specific story about the circumstances under which the law of the lever was discovered. A second difference consists in the fact that the story told in the second answer, referring to logical constraints of Aristotle's intellectual project, resembles much more traditional history of ideas. We insist however that we do not intend to engage in traditional history of ideas. On the contrary, we suggest a model of discovery in science driven by developments in technology. In order to fully understand discovery in science, that is, to provide a full historical account rather than to gesture at a general scheme, the relevant technological developments must be studied in the specific cultural context which triggered the discovery of real abstractions embodied in existing technological devices and practices.

Conclusion

The use of the concept of real abstraction in the history of science presupposes that technical devices can be studied to recognize such real abstractions and thus that the development of technology has a role in determining the direction of scientific development—not as the final cause but as the material basis or subject matter of science. Boris Hessen pointed to the striking fact that the development of physics in the nineteenth century from mechanics to thermodynamics to electrodynamics did not follow any a priori immanent logic of physics but rather followed the actual development of technology.[5]

It is worth mentioning that Sohn-Rethel is one of the few critics of Hessen or Grossmann to correctly describe their view of the relation of science and technology. In fact he criticized them specifically for believing that science arises *out of* technology not *for the sake of* technology: 'The argumentation therefore leads involuntarily to the strange view that machines generate natural sciences rather than the reverse'. And in another paper he sharpens the critique: 'After all, it is science that helps to build machines, rather than the machines hatching out science, even mechanistic science'.[6] Sohn Rethel was one of the few to understand the thrust of the analyses of Hessen and Grossmann, but he failed to see the fruitfulness of their position because he restricted real abstraction to the distribution sphere. If there is a real abstraction in technique, then of course the machines (with our help) can 'hatch out' science. This disregard for the production sphere reflects a more general disdain of instrumental reason, common in the Frankfurt School, which hinders any serious analysis of the intellectual opportunities offered by the second reading of Bacon's dictum, which hints at a general dialectics of means and ends. Instrumental reason need not be restricted to searching for appropriate means for given ends, as Horkheimer would have it (1947: 3–4), but can also discover new ends contained in given means as real abstractions.

Notes

1. 'Natura enim non nisi parendo vincitur' (Bacon [1620] 1858, Bk. I, §3).
2. Hessen (*Social and Economic Roots*) cites the opening lines of the *Discorsi* as his first appendix. On the historical work of Hessen and Grossmann see Freudenthal and McLaughlin (2009).
3. See especially Koyré (1943, 1948).
4. For a detailed account of this work and of the role Greek balances see Renn and McLaughlin (2018).
5. See Hessen in Freudenthal and McLaughlin (2009: 78–82).
6. Sohn-Rethel (1973a: 85, 1973b: 37). A long footnote on Hessen and Grossmann was not included in the English version of the book (1978).

References

Aristotle. (1936). Mechanical Problems. In W. S. Hett (Ed.), *Aristotle: Minor Works* (pp. 329–411). Cambridge, MA: Harvard University Press.

Bacon, F. ([1620] 1858). Novum Organum. In J. Spedding, R. Ellis, & D. D. Heath (Eds.), *The Works of Francis Bacon* (Vol. 1). London: Longmans.

De Beaune, S. A. (2008). *L'homme et l'outil. L'invention technique durant la préhistoire*. Paris: CNRS Editions.

Falk, P. (1977). Review of R. W. Müller, Geld und Geist. *Acta Sociologica, 20*(4), 393–396.

Freudenthal, G., & McLaughlin, P. (Eds.). (2009). *The Social and Economic Roots of the Scientific Revolution: Texts by Boris Hessen and Henryk Grossmann*. Boston Studies in the Philosophy of Science 278. New York: Springer.

Galilei, G. (1974). *Two New Sciences, Including Centers of Gravity and Force of Gravity and Force of Percussion*. Trans. with introduction and notes, by Stillman Drake. Madison, WI: University of Wisconsin Press.

Gould, S. J., & Vrba, E. S. (1982). Exaptation – A Missing Term in the Science of Form. *Paleobiology, 8*(1), 4–15.

Horkheimer, M. (1947). *The Eclipse of Reason*. New York: Oxford University Press.

Koyré, A. (1943). Galileo and Plato. *Journal of the History of Ideas, 4*, 400–428.

Koyré, A. (1948). Les philosophes et la machine. I: L'appréciation du machinisme. *Critique* (pp. 324–333), 3. [Reprint in (1961). *Etudes de la pensee philosophique* (pp. 279–309). Paris: Armand Colin].

Marx, K., & Engels, F. (1975). *Collected Works (MECW)* (Vol. 35). London: Lawrence & Wishart.

Merton, R. K. (1939). Science and the Economy of Seventeenth Century England. *Science & Society, 3*, 3–27.

Renn, J. and McLaughlin, P., (2018): The Balance, the Lever and the Aristotelian Origins of Mechanics, in: R. Feldhay/J. Renn/M. Schemmel/M. Valleriani, *Emergence and Expansion of Pre-Classical Mechanics*, New York: Springer, Boston Studies in the Philosophy of Science.

Sohn-Rethel, A. (1973a). *Geistige und körperliche Arbeit. Zur Theorie der gesellschaftlichen Synthesis*. Frankfurt a.M.: Suhrkamp.

Sohn-Rethel, A. (1973b). Intellectual and Manual Labour. An Attempt at a Materialistic Theory. *Radical Philosophy, 6*, 30–73.

Sohn-Rethel, A. (1976). Das Geld, die bare Münze des Apriori. In P. Mattick, A. Sohn-Rethel, & H. G. Haasis (Eds.), *Beiträge zur Kritik des Geldes* (pp. 35–117). Frankfurt am Main: Suhrkamp.

Sohn-Rethel, A. (1978). *Intellectual and Manual Labour. A Critique of Epistemology*. Atlantic Highlands: Humanities Press.