Experimental Systems

Entry Encyclopedia for the History of the Life Sciences

In the autobiographical report on his laboratory work at the Pasteur Institute in Paris, the French molecular biologist François Jacob remarked a decade and a half ago: “In biology, any study … begins with the choice of a ‘system.’ Everything depends on this choice: the range within which the experimenter can move, the character of the questions he is able to ask, and often also the answers he can give” (Jacob 1987, p. 261). In the biological research literature, the notion of “experimental system” for the characterization of experimental arrangements has been in regular use since the first decades of the twentieth century, in particular in connection with the establishment of a vigorous in vitro biology (see, e.g., Gale and Folkes 1954, p. 1224) and with the coming into use of a variety of model organisms, especially bacteria and viruses, two features of experimental systems to which I will come back later. When Jacob speaks about “system,” the term is used in exactly this sense. A comparison may help set the stage. Two centuries ago, toward the end of the eighteenth century, when natural historians and biologists talked about “systems,” they meant systems of thought such as the “system of the eggs” or the “system of the sperms” with respect to the then concurring theories of generation, into which, sporadically, experimental arguments were inserted. Two hundred years later, it is experimental systems that determine the research context into which theorems can eventually become inserted.

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Despite its widespread practical use in the everyday language of life scientists in particular, the concept has for a long time not been analyzed with respect to its historiographical and epistemological usefulness for the description of the modern research process. We can find first hints at such a use in the writings of Ludwik Fleck (1979 [1935]), although he did not make a systematic terminological use of it. Fleck has stressed the fact that the research process is based on a stream of experiments, not on isolated experimental acts. It is only at the beginning of the 1990s and in the context of an ongoing replacement of theory-dominated perspectives of scientific change by practice-driven views on research that the concept of experimental systems has found entrance into the historical and philosophical literature on science (Rheinberger 1992, Rheinberger and Hagner 1993, Rheinberger 1997). In the same general context and for slightly varying purposes, notions such as "manipulable systems" (Turnbull and Stokes 1990), "production systems" (Kohler 1991), and "experimental model systems" (Amann 1994) have also been used.

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It needs to be justified if one picks up an actor’s category, withdraws it from its laboratory use, and dignifies it as a central epistemological category for the characterization of the dynamics of the empirical research process in general and the life sciences in particular. Such a justification cannot be derived from analytically oriented philosophies of science. It suggests itself rather, in the first instance, as a concept for ordering historical and contemporary empirical materials pertinent to the material culture of the sciences. Neither does the term carry systems theoretical connotations along with it. In a first approximation, “system” means here simply a kind of loose coherence both synchronically with respect to the technical and organic elements that enter into an experimental system and diachronically with respect to its persistence over time. The advantage of the concept lies rather in its capacity to tie together essential aspects of scientific research processes such as instruments and measuring devices, contrivances of various sorts, and the necessary skills to enact them in useful ways. It refuses to describe science as a system of concepts. Rather, it describes research as a process of the coming into being of scientific knowledge or, to speak with Bruno Latour, of science in action (Latour 1987).

How can experimental systems be characterized with respect to their more general features? Experimental systems exhibit epistemic and technical as well as social and institutional aspects. The social and institutional aspect is tied to the fact that experimental systems can be described as locally situated research connections that grant coherence to the activities of a single researcher or of a whole group of researchers. At the same time, they make for a sufficient distinction with respect to other such units, that is, they convey identity and individuality to the work of that individual researcher or group of researchers.

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The epistemic and technical aspect of experimental systems shall now be described in its general outline. It is anchored in four basic features. First, such systems are the smallest integral working units of research. Within them, scientific objects – “epistemic things” – and technical objects – the technical conditions of their production – are inextricably linked with each other in a given experimental unit. The first entity, the scientific object, is that badly defined something to be addressed as the target of the whole experimental endeavor. Paradoxically speaking, it embodies in an experimentally manipulable manner what one does not yet exactly know. The scientific object is therefore mandatorily underdetermined; it is blurred by definition. The technical objects, in contrast, are characteristically determined. They are the instruments, apparatus, and devices which bound and confine the assessment of the epistemic things. They are necessary in order to keep the vagueness of the scientific objects in a hypocritical condition. Within a particular research process, epistemic things can eventually be turned into technical things and become incorporated into the technical conditions of the system. And parts of the technical system can acquire epistemic status and thus turn into research objects. The dialectics between epistemicity and technicity is at the inner core of an experimental system; it is its driving force. Thus, experimental systems are a kind of dynamic research bodies that convey material shape to the scientific objects formed within them, and at the same time, determine the boundaries of their conceptual apprehension.

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A note will be advisable in this context on scientific instruments. Instruments have received much attention from historians of science participating in the practical turn of science studies. Instruments, however, should not be hypostasized as such. They receive their meaning less from the technical identity conditions built into them, than from the experimental contexts in which they become inserted as technical objects. They receive their meaning for research from the epistemic objects with which they are brought into connection and into friction within an experimental system. This appears to be a general feature of research enabling technologies. It is therefore the boundary between an instrument and an epistemic thing that is of particular relevance for the historian of experimental systems.

Second, experimental systems must be able to undergo series of differential reproductions, if they are to remain arrangements for the production of new bits of knowledge that lie beyond what one is actually able to conceive of and to anticipate. They are, therefore, “research generators” (Hoagland 1990, p. xvii). Difference and reproduction are the two inseparable faces of that coin. Their game determines the delays and breakthroughs in the course of a research process. In order to remain productive, experimental systems must be organized in such a way that the generation of differences becomes the reproductive driving force of the whole machinery. Differential reproduction conveys a peculiar kind of historicity to experimental systems. They can acquire, to speak with Ian Hacking “a life of their own” (Hacking 1983). They are units extending in time: emerging, growing, and eventually also disappearing again.

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Third, experimental systems are those units within which the material signifying units of knowledge are produced. They are usually termed data, but they should be rather addressed as facta in the sense of primary products of the research process. They acquire the horizon of their possible meaning within spaces of representation in which material traces and inscriptions – graphemes in a very general sense – become recorded, articulated, dislocated, reinforced, marginalized, and substituted. Researchers “think” within the confines of such spaces of representation, within the opportunistic and hybrid context of the representational machinery at hand making up the technical conditions of an experimental system.

Fourth, and finally, conjunctures and ramifications of experimental systems can lead to ensembles of such systems, or experimental cultures. Conjunctures and ramifications themselves are, as a rule, the result of unprecedented events within experimental systems, events that are often connected to the introduction of new technologies of representation. In the last instance, it is such experimental cultures that determine the contours of scientific disciplines, their emergence as well as their historical obsolescence. The concept of experimental culture as an articulated ensemble of experimental systems should allow to write histories of research fields without the burden of a disciplinary history. But this is not only a historiographical issue. The more basic argument is that experimental science does derive its dynamics less from the shaping of disciplinary boundaries and their social solidification than from the digressions and transgressions of smaller units below the level of disciplines in which knowledge is not yet labeled and classified, and in which new knowledge forms can take shape.

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A particular feature of experimental systems in the life sciences is that in one way or the other they are tied to the use of model organisms. It appears to be a peculiar characteristic of living beings that the differences they show among themselves are shaped by deep historical, evolutionary contingency. Yet the modern biologist also assumes that there are underlying commonalities between different organisms which, once developed, have been conserved throughout evolution. They represent more or less wide-ranging metabolic or developmental mechanisms up for description in terms of cellular and molecular structure and function. This situation leaves the biologist with two problems. The first is that it will basically be a matter of inductive generalization to decide how ubiquitous a particular character of living beings turns out to be. There are no a priori reasons for biological generalities. The second problem that the biologist will have to make choices: A particular character may be more accessible, more easily discerned and determined in its general features in one specific class of organism than in another. It is in this context that model organisms have started to play an increasing role in the second half of the nineteenth century in physiology, and at the beginning of the twentieth century, in research on heredity, cytology, and embryology. Here, model organisms are thus ‘ideal’ objects, first, in that they represent a particular phenomenon in an easily accessible fashion, and second, in that they can be handled in a productive operational way in the process of setting up an experimental system. This last point appears to be particularly important: In order to function as model organisms, they need to be embedded in experimental systems, where they can play out their dynamics and function as exemplars. Their entrenchment in experimental systems may even make them, at least to a certain degree, resistant against being replaced by potential competitors in a particular historical window of time. Model organisms entrenched in experimental systems can, to speak with Gaston Bachelard, turn into “epistemological obstacles” (Bachelard 1969). Idealization may go so far as to have material consequences, that is, to materially change the model organism under investigation, e.g., the creation of pure lines or of particular gene combinations in genetic model organisms. Drosophila serves as a good example here (Kohler 1994). Model organisms are thus, as a rule, also organisms modified for particular research purposes.

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A second particularity of experimental systems in the life sciences is the differentiation between in vitro and in vivo systems. This differentiation became established around the beginning of the twentieth century, after it had been demonstrated that enzymes are able to exert their action outside the cells or tissues or organs or the intact organism, in the test tube, if supplemented with appropriate ingredients and under specified buffer conditions. To be sure, working on dead bodies and preparing specimens had been a much older practice in the life sciences. But the in vitro systems of the first half of the twentieth century claimed to be able to generate artificial environments in which actions that normally went on in the living body took place outside the body and the cell. As such, they marked the transition from an organismic and cellular to a subcellular, and finally to a molecular biological knowledge regime. In vitro systems are usually reduced systems. They enhance certain features of a complex network by eliminating and purifying away others. Their proneness to the production of artifacts, which is inherent in the approach, has to be constantly qualified by relating in vitro systems back to the in vivo situation. Much of the history of twentieth century biology has inscribed itself into this very specific game of rectification.

What is the basic service that the concept of experimental system does to the history and epistemology of science? The comparative investigation of the complex structures that are captured by this concept will help us to understand how new, unprecedented knowledge arises in the process of research. Viewed structurally, novelty appears always to be the result of spatio-temporal singularities. There are good reasons to assume that the emergence of novelty in modern, late nineteenth and twentieth century empirical research is tied to structures such as experimental systems. Experimental systems are precisely those setups that allow for the generation of singularities in the realm of our knowledge spaces. They allow, to put it paradoxically, to create new knowledge effects in a regulated manner and yet one that transcends our capacities of anticipation. In this sense one can say with Bachelard that the “scientific real” (Bachelard 1968, p. 8) is not the ultimate reference point of the scientific spirit; the particular reality of the scientific real is rather its capacity to drive beyond itself, to give space to unprecedented events. It is exactly in this sense that experimental arrangements are, in a way, ‚more real’ than our good everyday reality. The reality of an epistemic thing explored within an experimental system resides in its resistance, its resilience, its capacity, as a joker and obstacle of practice, to turn around our previsions as well as our imprevisions, in a word, to give birth to unprecedented events. As Michael Polanyi once remarked: „This capacity of a thing to reveal itself in unexpected ways in the future, I attribute to the fact that the thing observed is an aspect of reality, possessing a significance that is not exhausted by our conception of any single aspect of it. To trust that a thing we know is real is, in this sense, to feel that it has the independence and power for manifesting itself in yet unthought of ways in the future“ (Polanyi in Grene 1984, p. 219).

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