FOREWORD

Epistemology Historicized

Making Epistemic Things

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Hans-Jörg Rheinberger emerged as the leading historian and philosopher of the biological sciences in the decade following the publication of his path-breaking book *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (1997). Although conceived as a philosophy of experimental practice, this work has had a far-reaching impact beyond the history and philosophy of science, in fields ranging from anthropology, sociology, and economics, to literary studies. Rheinberger's book came out in a period characterized by the ascendancy of the biological sciences and a growing preference for practice-oriented as opposed to theory-dominated accounts of knowledge production. At the same time, critics of the monolithic discourses of identity and representation firmly embedded within many fields in the humanities and social sciences were gravitating toward epistemic models foregrounding repetition and difference; and all of this was occurring in the midst of a revolution in the cognitive neurosciences that was dissolving the traditional static epistemic framework of a solitary subject confronting a pre-given object in favor of distributed cognition, embodied reason, enaction and process.

Rheinberger's work resonated with these themes, and for good reason. He held degrees in both molecular biology and philosophy. For more than a decade prior to writing his now classic book, he was a researcher in one of the world's leading molecular biology laboratories—the Max-Planck Institute for Molecular Genetics in Berlin—developing models of the ribosome and its role in protein biosynthesis. While Rheinberger was steeped in every dimension of laboratory practice and experimental work, he also continued to engage deeply with traditions of continental philosophy, particularly the works of Edmund Husserl, Martin Heidegger, Jacques Derrida, Michel Foucault, Gilles Deleuze, Jacques Lacan, and others; indeed he was the translator of works of Derrida and Lacan into German. His background of experimental and theoretical work in molecular biology combined with his deep engagement in continental and postmodern (particularly French) philosophy has provided the foundations of a philosophical oeuvre with profound interdisciplinary significance.

Rheinberger's work is an exercise in historical epistemology, a distinctive Franco-German approach to the history and philosophy of science. In contrast to earlier traditions in the philosophy of science that treated truth as independent of the context of discovery and the history of scientific knowledge as a linear, progressive march in the elimination of error, asymptotically approaching nature, historical epistemology treats knowledge as historically contingent and focuses on uncovering the conditions of possibility and fundamental concepts that organize the knowledge of different historical periods. Rheinberger regards the aim of historical epistemology as to understand the conditions of possibility underlying the knowledge and practice of specific conjunctions of scientific and technical practice, the social, institutional, and cultural configurations in which they operate. Historical specificity is essential to this philosophical project.

Rheinberger traces the formative questions of an epistemology of the concrete to the work of Edmund Husserl, Ludwik Fleck, Gaston Bachelard, and Georges Canguilhem. Each of these epistemologists engaged in a concerted critique of the positivist movement in the natural sciences of the early twentieth century. Against the positivists, Fleck and Bachelard in particular show that the objects of scientific knowledge are not given ready made in nature. Indeed, according to Bachelard scientific objects do not even exist in nature; rather, they are technically produced in a continuous process of assemblage, rectification, and repetition—a process Rheinberger calls "recursion"; that is to say, the theory of knowledge considered classically as an existing structure of logic applied to fit lock-and-key to an externally existing, pre-given nature is replaced in Rheinberger's account by epistemology considered as a deeply historical process of constituting both the scientific object and our knowledge in a never-ending recursive process of reconfiguration and rectification.

Rheinberger's unique ability to engage molecular biology, continental philosophy, and the early architects of historical epistemology in a dialogue allows him to introduce a new conceptual repertoire to the analysis of knowledge production. Foremost within this new conceptual repertoire are the closely interrelated notions of "experimental systems," "epistemic things," and the "phenomenotechnique."

Bachelard's idea of the "phenomenotechnique" is crucial to Rheinberger's enterprise of historical epistemology. This is the notion that technology is not just an ancillary result of scientific investigation but also the very modus operandi of science. New phenomena, Bachelard tells us, are not simply discovered, but invented—constructed from scratch; and in another memorable formulation, Bachelard calls the phenomena that are the object of scientific investigation, such as the trajectories of isotopes in a mass spectrometer, "reified theorems." Accordingly the very concepts that science operates with are bound up inextricably with the instruments through which phenomena are produced and stabilized as objects of investigation. Rheinberger writes, "Phenomenon and instrument, object and experience, concept and method are all engaged in a running process of mutual instruction." The instrument represents the material existence of a body of knowledge—a reified theorem—while the emphasis on "instruction" underscores the point that the instrumentally mediated object becomes an agent too in the process of making knowledge.

Breaking with the notions of a pre-existent referent grounding scientific representations and theory-dominated accounts of knowledge construction, Rheinberger focuses on how research is enacted at the frontiers between the known and the unknown through the construction of experimental systems that give rise to epistemic things. Modern biological research, Rheinberger argues, is not theory-driven but rather dominated by the choice of experimental systems. The name of the game is constructing a robust experimental arrangement of instruments, chemical processes, physical structures, and biological materials capable of generating a network of experiments.

The experimental systems that Rheinberger investigates do not consist solely of scientific instruments but also include appropriately cultivated or even engineered bits of nature, such as a model organism. The many varieties of mutant Drosophila flies that fueled much of classical genetics, the nematode worm *C. elegans* central to modern molecular genetics and developmental biology, and the specially designed embryos of zebra fish used in contemporary environmental impact studies of nanotechnology are examples of model organisms. A model organism is a living thing from the plant, animal, or bacterial kingdom that has been tailored to experimental purposes; manipulating it can generate insights into the constitution, functioning, development, or evolution of an entire class of organisms. The operative criteria for selection of a model organism are the ease with which it can be maintained and handled, the quantity and quality of the knowledge already accumulated about it, and the relative accessibility of the phenomenon under investigation.

Just the right amount of vagueness rather than theoretical precision is the key to a powerful experimental system, because the scientific object, the research object, or "epistemic thing" is latent within and emerges out of the technical conditions embedded within the experimental system. As Rheinberger explains, "epistemic things" are what one does not yet know, things contained within the arrangements of technical conditions in the experimental system. Experimental systems are thus the material, functional units of knowledge production; they co-generate experimental phenomena and the corresponding concepts embodied in those phenomena. In this sense, experimental systems are techno-epistemic processes that bring conceptual and phenomenal entities—epistemic things—into being. Epistemic things themselves are situated at the interface, as it were, between the material and conceptual aspects of science.

Once revealed, epistemic things become materialized interpretations that form the components of models. According to Rheinberger, the referent of scientific work is the model, comparison never being made to nature but always to other models, a process that Rheinberger analogizes to the operation of Derrida's supplement. In Rheinberger's study of the molecular biology of protein synthesis, for example, different cellular components are defined by centrifugation, sedimentation properties, radioactive tracers, and chromatograms using a DNA sequencing gel. The scientific object is gradually configured from the juxtaposition, displacement, and layering of these traces. The experimental systems molecular biologists design are "future generating machines," configurations of experimental apparatus, techniques, layers of tacit knowledge, and inscription devices for creating semi-stable environments—little pockets of controlled chaos—just sufficient to engender unprecedented, surprising events. When an experimental system is working, it operates as a difference-generating system governed by an oscillatory movement of stabilization-destabilization-re-stabilization—what the molecular biologist François Jacob, echoing a similar statement of Derrida, called the "jeu des possibles." At the heart of the laboratory/labyrinth are experimental arrangements for transforming one form of matter into another and inscription devices for transforming matter into written traces. The products of this complex of experimental arrangements and inscription devices are trace-articulations, which Rheinberger calls "graphemes." They represent certain aspects of the scientific object in a form that is manipulable in the laboratory. Graphemes in turn are the elements for constructing models. They are the manipulable signs scientists use in "writing" their models.

Also contributing to the graphematic traces of a well-oiled lab and experimental system is what Rheinberger refers to as an "economy of the scribble": the notes and scribbling of the lab members, from excerpts of literature to notes on basic concepts and fragmentary ideas, striking correlations, sketches of experimental setups, data from single sets of experiments, tentative interpretations of experimental results, corrections, provisional calculations, calibrations of instruments, designs for new equipment, and so on. Through the economy of the scribble, the organization of an experiment in space and time is projected onto a two-dimensional surface, which facilitates exploration of new ways of ordering and arranging data. More than serving a merely reductive function, laboratory notes, protocols, and the economy of the scribble are themselves new resources and materials that give research its distinctive contours and prevent it from being prematurely closed off.

For Rheinberger and the architects of the epistemology of the concrete the production of knowledge is not only a deeply historical process. It is also a product of culture. Husserl emphasized that scientific knowledge is the product of scientists working together, and Ludwik Fleck famously argued in the *Genesis and Development of a Scientific Fact* (1935) that the historical is deep at work in the research process shaping scientific facts from local interactions among communities of scientists he called "thought collectives." For Bachelard as well, scientific knowledge always marks an ongoing technical and instrumental evolution emerging from processes situated within cultural configurations. But while the construction of knowledge is a deeply historical and cultural process, none of the historical epistemologists of interest to Rheinberger's account regard science as an arbitrary or purely social construct. The centrality of the "phenomenotechnique" provides the primary counterweight to a purely social constructivist account. For Rheinberger, nature appears simultaneously as agent and epistemological obstacle in the construction of both knowledge and society. Like Bruno Latour, another close student of Bachelard's work, Rheinberger describes the entities constructed in the labs as hybrids of nature and culture. The scientific phenomenon, technically produced, is also discursively constructed, so that phenomena are always material and discursive entities; and just as the objects contemplated by science are not immediately given but always constructed in a continuous material-discursive dialectic, so too, the scientific mind is not immediately given. Discussing Bachelard's elaboration of this important notion, Rheinberger writes that "The knowing mind has to externalize itself and become instrumental; for it is itself technically mediated, as are all its concepts, the categories of scientific knowledge not excepted. The consequence is that the scientific mind and scientific object enter into a symbiotic relationship of reciprocal externalization, and simultaneously, interiorization." The centrality of the phenomenotechnique to the production of knowledge has the consequence that the external world is deeply intertwined with the production of the scientific mind and particular scientific communities.

In learning about how epistemic things arise from the hybrid assemblages of machines, practices, concepts, and humans inhabiting laboratory spaces, the reader is struck by the similarity of Rheinberger's experimental systems to Andy Clark's or Edwin Hutchins's accounts of distributed systems of cognition in which cognition resides as much in distributed external objects as in the human cognitive agents themselves. Thus, Rheinberger talks about the extended tangle of networks of experimental systems and technical objects and how researchers are embedded within them as symbiotic elements of the machinic assemblage. Elaboration of the network, extracting the signals that carve out the epistemic things, requires the researcher's intimate familiarity with the system. This process takes time, which explains why, as Rheinberger argues, once experimenters have established their experimental network, they often stick to it in an almost symbiotic fashion. But once the system has become familiar to those who inhabit it, its own momentum may take over. The more the experimenter learns to manipulate the system, the better the system comes to realize its intrinsic capacities: in Rheinberger's terms the experimental system starts to manipulate the researcher and to lead him or her in unforeseen directions.

This radically historicized account has two important implications for the shape of historical epistemology. On the one hand the obstacles at the heart of research activity are never fully containable or predictable. Empirical thought is clear only in retrospect, Rheinberger tells us. While knowledge gained through this agonistic encounter with nature is confirmable through acts of recursion, there is no pre-specifiable golden path or universal method that can provide a blueprint for knowledge production. Research is inherently untidy and requires an appropriate cultural setting that sustains innovation by allowing the new and unpredictable to emerge. Environments that sustain controlled chaos are the heartland of innovation.

The deeply historical and constantly evolving character of epistemic events has as a further consequence that the epistemology of the sciences is best investigated through detailed historical case studies. This view contrasts sharply with earlier philosophers of science, such as Karl Popper and Imre Lakatos, who proclaimed that the history of science belonged in the footnotes of epistemologies treating the logic and methodology of the growth of knowledge. Science, according to Rheinberger, might be described as the most profoundly historical of cultural enterprises, since scientific activity is defined precisely by its need to render itself obsolete in order to remain scientific. As we have seen, scientific knowledge is constructed in highly localized and constantly evolving contexts. Knowledge emerging from such localized processes is disunified, fragmented, and always driving toward specialization. The history of epistemic events that Rheinberger maps is a rhizomatic structure. Accordingly, epistemic history should not be a history of grand unified theories but of conjunctions that give rise to new concepts and instrumental configurations. In this view the history of science is focused on dense material-discursive configurations, conjunctures, or nodal points in which something comes about that has its origins in minor decisions constrained by local, particular conditions.

Rheinberger argues that molecular biology, for instance, did not arise from the articulation of a preexisting theoretical paradigm. What was involved was an "assemblage" arising from work on bacteriophages and the tobacco mosaic virus. This work crystallized in the early 1950s with the biophysical characterization of the double helix structure of DNA and peaked with the deciphering of gene expression and the genetic code between 1960 and 1965. The research of this period was conducted with instruments and techniques such as the ultracentrifuge, liquid scintillation counters, electron microscopy, chromatography, and electrophoresis. These instruments had their origins in contexts having nothing to do with molecular biology or classical genetics. Molecular biology took over various biophysical and chemical analytical techniques without prior theoretical coordination. In the midst of this assemblage, new, biologically specific concepts emerged shaped by the language of information, giving molecular genetics its distinctive profile by the end of the 1960s.

The 1970s brought a second assemblage fashioned from the development of genetic engineering techniques, such as cloning, recombinant DNA, the polymerase chain reaction (PCR), as well as new molecular biology techniques involving nucleic acids and enzymes. Unlike the first phase of molecular biology, these new techniques were not imported from other research fields but were born from the first phase of molecular biology itself, and they became instruments for manipulation of materials at the intracellular level. These new developments enabled increasingly complex conceptions of the expression and transmission of genetic information, and, indeed, a new and richer set of conceptions of genes.

The lesson Rheinberger wants to impress upon us with this history of the two phases of molecular biology is that epistemic history should be focused on examining the configurations of instruments, techniques, and the conditions that have brought about productive experimental settings and the operational concepts materially tied to them, rather than on the history of theory. This position is forcefully represented in this book by an examination of the multiple transformations the concept of the gene has undergone over the period of more than fifty years since the discovery of DNA. The "gene" in Rheinberger's account is an example of an "epistemic thing." From the outset, the gene was a fuzzy concept, an imprecise boundary object with no exact, systematically fixed meaning. The fertility of imprecise concepts like it depends on their ability to generate productive tension—what Rheinberger calls "contained excess"—an operational potential for being integrated into different experimental contexts in accordance with changing needs. Over the course of its history the gene has not been a unified concept, and molecular biologists, in Rheinberger's view, have not needed a unified, unambiguous, rigorously determined notion of the gene to make major advances in their field. On the contrary, molecular biology, despite its claim to general validity, has been a mosaic of many contexts, consisting in contributions from different disciplines, experimental systems, and views of the genome. Molecular biology is a hybrid science combining experimental systems from biophysics, biochemistry, and genetics. It makes use of a great diversity of model organisms in its search for biological functions at the molecular level. It is no wonder, writes Rheinberger, that its concepts are hybrid. Indeed the expansive potential of its discourse resides precisely in the hybrid nature of its concepts.

Hans-Jörg Rheinberger has given us a profound treatment of the philosophy of experiment and a powerful set of instruments for understanding the construction of knowledge. Intertwined among the carefully drawn case studies in the book is one penetrating analysis after another in which Rheinberger's proposals for an epistemology of the concrete are shown to resolve the key debates that have shaped science studies and the philosophy of science over the past three decades—issues such as constructivism versus realism, theory domination versus practice and experiment, and more—all discussed beautifully in an organically interconnected exploration of experimental systems in classical and molecular genetics, the close mutual dependence of model organisms and key instruments in the formation of concepts that have shaped molecular biology, and the role of writing and graphemes in shaping the hybrid nature/culture entities that become epistemic things. *An Epistemology of the Concrete* offers a methodological framework and a set of research exemplars that will shape science studies for years to come.