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Review

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Review by: Allan Franklin

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REVIEW ARTICLE

How Experiments End: Galison, Peter [1987]

ALLAN FRANKLIN. University of Chicago Press. *xii* + 330 pp. $39.95 (cloth), $14.95 (paper)

One of the most interesting and important trends in the history and philosophy of science has been the recent work on experiment. Most philosophy of science, and sometimes even history of science, either neglects experiments—how they are done and what role they play—or treats their results as unproblematical. Peter Galison's *How Experiments End* is a major contribution to the growing body of work that is correcting that view. Galison provides excellent histories of three experimental episodes: the measurement of the gyromagnetic ratio of the electron, the discovery of the mu meson, or muon, and the discovery of weak neutral currents. These studies of actual experiments will provide valuable material for both philosophers and historians of science and Galison's own thoughts on the nature of experiment are extremely important.

One of these is that, contrary to the prevalent view of theory dominated science, experimental practice and instruments often persist across major changes in theory, and thus provide continuity across these conceptual changes. Thus, the experiments on the gyromagnetic ratio of the electron spanned classical electromagnetism, Bohr's old quantum theory, and the new quantum mechanics of Heisenberg and Schrodinger. As Hacking pointed out, and Galison reinforces, experiment often has a life of its own. This is not to say that Galison neglects theory, but rather that he offers new insights into the way in which experiment and theory interact. This view of experimental continuity is tied to Galison's concept of experimental traditions, in which scientists develop skill in using certain types of instruments and apparatus and will therefore regard particular kinds of evidence as most convincing. In particle physics, Galison discusses the traditions of visual detectors such as the cloud chamber and the bubble chamber in contrast to the electronic tradition of Geiger counters, scintillation counters, and spark chambers. Scientists within the visual tradition tend to prefer 'golden events' that clearly demonstrate the existence of a phenomenon, such as Anderson's photograph of the positron. In the electronic tradition, statistics tend to be more important than single events. In the weak neutral current episode a large number of

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events were needed so that the real effect could be separated from neutron background.

Galison also emphasizes that the decision to end an experiment, to accept a result as valid, is very complex. In large groups, certain pieces of evidence will be more convincing for some group members than for others. In the Gargamelle experiment on weak neutral currents, several group members, particularly Perkins, found the single photograph of neutrino-electron scattering particularly important. For others, the difference in the spatial distribution between the observed neutral current candidates and the neutron background was decisive. In contemporary high energy physics, the extremely large experimental groups may contain members from both the visual and electronic traditions. It may already be the case that some of the most interesting discussions and arguments concerning the validity of experimental results occur within these large experimental groups and are not revealed in the published work. One of the interesting features of this book is that it makes such arguments available.

The theoretical presuppositions of the experimenters may also enter into the decision to end an experiment. Einstein and de Haas ended their search for systematic errors when their result for the gyromagnetic ratio, $g = 1$, agreed with their belief that magnetism was due to orbitting electrons. As Galison points out, the search for systematic effects is both subtle and difficult. If one looks at the history of measurements of η_{+-}, the CP violating parameter in K° decay, one finds that the world average of measurements before and after 1973 differ by eight standard deviations, an extremely unlikely result if the two sets of measurements are both valid measurements of the same quantity. It is clear that systematic effects have been overlooked by some of the experimenters. A reasonable point at which to stop looking for such systematic effects is when the result agrees with previous measurements or when it agrees with existing theory. Theory may also influence what is considered to be a real effect, demanding explanation, and what is considered background. Galison shows that part of the discovery of the muon involved the calculation by Oppenheimer and Carlson, which showed that showers were to be expected when electrons passed through matter, and that what needed explanation was the behavior of penetrating particles, later found to be the muon. Theory may also give both the size of the effect expected as well as the size of the expected backgrounds. This will indicate whether or not an experiment is feasible. Galison does not say that theory determines the results of an experiment, but he does argue, very persuasively, that both the theoretical and instrumental commitments of the experimenters help to determine the alternatives considered.

In this discussion, Galison also emphasizes that the elimination of background that might simulate or influence a result is not a peripheral activity, but one that is central to the experimental enterprise. In the Gargamelle

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experiment, events that apparently demonstrated the existence of neutral currents could also be produced by neutron background. A considerable part of demonstrating the existence of neutral currents consisted of showing that the observed events could not be due to such neutron background. In E1A, the other neutral current experiment, the group believed, for a time, that they had not observed the currents. This was because hadrons were punching through the muon shield, simulating muons, and eliminating valid neutral current events. It was only after a complex Monte Carlo calculation was performed, and checked, that this effect was eliminated. Because the group had found evidence earlier for neutral currents, this led to some wags to remark that 'alternating' weak neutral currents had been found.

Galison emphsasizes that it is not whether or not theory enters into the decision to end an experiment, but where and how it enters. He distinguishes between long, medium, and short term theoretical commitments. Thus, in the neutral current experiments the long term commitment was the unification of weak and electromagnetic forces, the medium term was gauge theories, and the short term was the particular Weinberg-Salam theory of electroweak forces. There are similar experimental, or instrumental, commitments. Galison gives instrumental type, specific device, and a particular experimental run as the long, medium, and short term experimental commitments, respectively. These, too, will influence the decision to accept a result and end an experiment.

Recently, there has been a continuing argument between those who regard science as a reasonable, dare one say rational, activity and those who view it as merely a social construction by scientists—between those who consider evidence important and justified and those who argue that it is just socially accepted practice, with no deeper justification. For example, social constructivists argue that the dominance of theory will always guarantee that experiment will fit theory, and thus give rise to global incommensurability between theories. Galison argues that there are three difficulties with this approach. The first is that although experiment may not logically compel a particular theoretical conclusion, it may provide very persuasive, if not convincing, evidence. The second point is that the social constructivists exaggerate the flexibility of theory. Although it may be possible in principle to adjust a theory to fit any particular piece of evidence, in practice the mathematical and physical constraints on a theory are not easily dismissed. What is logically possible may not be physically plausible or interesting. A third point is that there are constraints on experimentalists' conclusions imposed by the skills and techniques of their work. One might also add that there may be very good arguments to support the validity of a particular experimental result. This position fits in with Galison's view that experimental techniques, instruments, and results persist through major theoretical change. Galison recognizes, and documents in detail, that the decision to end an experiment is a social process, but he argues persuasively that it is based on

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evidence that 'will hold up in court'. In contrast to Pickering, who, in his study of the weak neutral current experiments, argued that the discovery was only a change in the interpretive practice of physicists, with the implication that the conclusion will change if the practice changes, Galison shows how complex, difficult, and ultimately reasonable it was to conclude that the currents existed. He cites David Cline, one of the E1A expermenters, who wrote in an internal memorandum, "At present I don't see how to make these effects go away." Galison notes that although theory can tell you what to look for, and what experimental cuts, selection criteria, to make, it cannot guarantee that the events will be seen. The world does have an effect on what is observed.

There is one minor quibble I have with Galison on this point. He correctly emphasizes that it is the judgement of the scientific community that is really at stake, and that the evidence that is used to persuade those outside the experimental group may differ from that which persuades a group member. He has concentrated on arguments internal to the group and has, I believe, slighted the published arguments. I wish these public arguments had been given a little more emphasis.

In this review I have concentrated on some of Galison's points that will, and should, be of real interest to philosphers of science. His previously published studies of these episodes, which are included in this book in modified form, have already given us much of value, but in placing them in a deeper and more general context he has enhanced their value. I have not done justice to the wealth of historical detail presented or to the excellent writing. Galison understands the physics and tells his stories in an exciting way. Even though I had read the papers, I found myself eager to find out what happened next, a trait I usually find more often in fiction than in the history of science.

If there is one criticism I have of this excellent book, it is that Galison tends to slight the more traditional philosophical questions concerning experiment, evidence, and theory. Perhaps this is understandable in a book that gives us a new and valuable way of looking at these issues, but I would have liked to see a little more epistemology, for example. Galison argues that in these episodes the experiments were progressively more direct and that the results achieved increasing stability. Directness is achieved by eliminating background and stability by varying experimental conditions and changing methods of analysis. I agree with Galison that these are good arguments, and that they are part of what we intuitively recognize as good science, but why they are, and should be, good reasons to believe a result is not dealt with extensively. This is, however, a minor criticism. Galison has given both philosophers and historians much to think about. I strongly urge you to read this book.

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