Differences in the methodology and justification of the field sciences and the classical experimental sciences

Carol E. Cleland

Department of Philosophy

Center for Astrobiology

University of Colorado (Boulder)

Experimental science has long been held up as the prototype of “good” science. Yet many scientific hypotheses cannot be tested in the classical manner of experimental science, namely, by means of experiments in controlled laboratory situations. Historical hypotheses about long past, natural events (e.g., the hypothesis that the continents were united in a supercontinent 250 mya and the hypothesis that the end-Cretaceous extinctions were precipitated by the impact of an enormous meteorite) provide especially salient (but not the only) illustrations. Such hypotheses are “tested” by searching for and identifying telling traces of the past in the messy, uncontrollable world of nature (in the cases at hand, respectively, patterns of frozen magnetism in igneous rocks and high concentrations of iridium and shocked quartz in K-T boundary sediments). As I discuss in several papers (Cleland 2001, 2002, 2011) such research is quite different from what goes on in classical experimental science. Yet as I also explain, it is a mistake to conclude from this that the former is somehow inferior to the latter.

The target hypotheses of most historical scientists is on large-scale, particular past events, e.g., a specific mass extinction event, such as the end-Cretaceous, as opposed to mass extinctions in general. Such events cannot be directly tested in a laboratory scenario because they are unrepeatable and moreover too large in scale to be artificially replicated in a laboratory setting. Given this difference in scientific focus it is hardly surprising that the practices of historical scientists differ in significant ways from those of classical experimental science. Prototypical historical research exhibits a distinctive pattern of evidential reasoning characterized by two interrelated stages: (1) the proliferation of multiple, competing, alternative hypotheses to explain a puzzling body of traces (present-day effects of past causes) encountered in fieldwork; (2) a search for a “smoking gun” to discriminate among them. A smoking gun discriminates among rival historical hypotheses by revealing that one (or more) provides a better explanation for the total body of evidence available than the others. While historical research involves a significant amount of laboratory work (to sharpen and interpret attenuated traces) it is different from what typically goes on in classical experimental science (Cleland 2002).

The differences between historical natural scientists and classical experimentalists in methodology are underwritten by a pervasive time asymmetry of causation well known to physicists (Cleland 2002). This *asymmetry of overdetermination* (as it has been dubbed by philosophers) consists in the fact that most local events (broadly construed to include material and structures) *over*determine their past causes (because the latter typically leave extensive and diverse effects) and *under*determine their future effects (because they rarely constitute the total cause of an effect); put simply, the present contains records of the past but no records of the future. Historical scientists exploit the overdetermination of past events by their localized present-day effects by searching for telling traces of (aka smoking guns for) hypothesized past events, and because most events leave many such traces in the environment they can never rule out finding them; it is this that justifies the search for a common cause when faced with a body of puzzling traces discovered through field work (Cleland, 2011). As an illustration consider an explosive volcanic eruption. Its effects include extensive deposits of ash, pyroclastic debris, masses of andesitic or rhyolitic magma, and a large crater. Only a small fraction of this material is required to infer the occurrence of the eruption. Indeed, any one of an enormous number of remarkably small subcollections of effects will do. This helps to explain why geologists can confidently infer the occurrence of long past events such as the massive, caldera forming, eruption that occurred 2.1 mya in what is now Yellowstone National Park.

In contrast, predicting even the near future eruption of a volcano, such as Mt. Vesuvius, is much more difficult. There are too many causally relevant conditions (known and unknown) in the absence of which an eruption won’t occur. This underscores the other side of the asymmetry of overdetermination, namely, the *under*determination of the future by localized events in the present. Classical experimentalists attempt to circumvent this problem by conducting their investigations within the artificial confines of a laboratory where (unlike events in the messy uncontrollable world of nature) they have some control over potentially interfering factors. For it is always possible for a prediction to fail (or succeed) for reasons independent of the falsity (or truth) of the hypothesis concerned. This makes predictive work, such as is involved in volcanology or studies of climate change, especially problematic because such systems cannot be artificially replicated within the artificial confines of a laboratory; while computer simulations are invaluable they are primarily theoretical and hence should be carefully distinguished from experiments.

In summary, because our universe is characterized by a physically pervasive, time asymmetry of causation, scientists engaged in historical and experimental research find themselves in very different evidential situations and their practices reflect these differences: Historical scientists exploit the *over*determination of the past by the localized present by searching for a smoking gun in the messy, uncontrollable world of nature to discriminate among competing hypotheses about long past occurrences; such a trace(s) is likely to exist (but not necessarily easy to recognize) because the present contains so many traces of past events. Experimentalists, on the other hand, are faced with the *under*determination of the future by the present and attempt to circumvent it by controlling for false positives and false negatives, which are always a threat when predicting future events. In closing let me also note that I have recently begun investigating the methodology and justification of the non-historical field sciences; see Cleland & Brindell (forthcoming) for some preliminary thoughts. I look forward to some lively discussions on this topic at the upcoming workshop!

**References**

Cleland, C. E. and Brindell, S. (forthcoming): “Science and the Messy, Uncontrollable World of Nature,” in Pigliucci, M and Boudry, M. (eds.), *Philosophy of Pseudoscience: Reconsidering the Demarcation Problem* (University of Chicago Press) (in press).

Cleland, C. E. (2011): “Prediction and Explanation in Historical Natural Science,” *British Journal of Philosophy of Science* 62, pp. 551-582.

Cleland, C. E. (2002): “Methodological and Epistemic Differences Between Historical Science and Experimental Science,” *Philosophy of Science* 69, pp. 474-496.

Cleland, C. E. (2001): “Historical science, experimental science, and the scientific method,” *Geology* 29, pp. 987-990.