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Darwin's experimentalism

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The scientific revolution

It has become commonplace to describe any major scientific change as a *revolution*. The origin of this use of the term is perhaps to be found in the early 16th century Italy as *revoluzioni* for the 'overturning' of an established political order. By the end of the 17th century *revolution* was commonly used in England to refer to political upheavals.[1] A century later in France, major changes in mathematics and natural philosophy came to be seen as analogous to political revolutions. The invention of calculus, for instance, was described by Bernard le Bovier de Fontenelle as a revolution in mathematics, and Lavoisier declared his own research program as revolutionary.[2]

These revolutions in math and natural philosophy sometimes involved an overturning of political power in the institutions of science. The Cartesians, for instance, fought for institutional power against the Jesuits and Aristotelians. And it wasn't long before the Newtonians in turn fought the Cartesians for political control.[3] But there is a more intellectual sense of revolution here as well, where a new way of thinking replaces or overturns an older, entrenched way of thinking. Perhaps Descartes' philosophy was revolutionary in this sense as well, in that it represented a philosophical break with the Aristotelians. Eventually the term *revolution* came to be applied to almost any major change or development in natural philosophy, from the work associated with Copernicus, Kepler, Galileo, and Newton, to that of Lavoisier, Lyell, and Darwin. Thomas Kuhn, in *The Structure of Scientific Revolutions*, seems to have taken this to an extreme, arguing that revolutions are a recurring and expected feature of science in general.[4]

Alongside the identification of all these individual scientific revolutions, there was also a developing tendency to postulate a single overarching scientific revolution that served as the foundation for all modern science. Herman Butterfield, in his widely read *The Origins of Modern Science: 1300–1800*, expresses this idea:

> It is the so-called 'scientific revolution,' popularly associated with the sixteenth and seventeenth centuries, but reaching back in an unmistakably continuous line to a period much earlier still. Since that revolution overturned the authority in science not only of the middle ages but of the ancient world – since it ended not only in the eclipse of scholastic philosophy but in the destruction of Aristotelian physics – it outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements, within the system of medieval Christendom. Since it changed the character of men's habitual mental operations even in the conduct of non-material sciences, while transforming the whole diagram of the physical universe and the very texture of human life itself, it looms so large as the real origin both of the modern world and of the modern mentality that our customary periodization of European history has become an anachronism and an encumbrance.[5]

Butterfield was not alone. A. Rupert Hall, at about the same time, argued for a similar view in his *The Scientific Revolution: 1500–1800*.[6] More recently, this theme has continued in books by John Henry, in his *The Scientific Revolution and the Origins of Modern Science*[7], and Wilbur Applebaum, in his *The Scientific Revolution and the Foundations of Modern Science*.[8]

There have been worries, however, about this way of treating change in science as revolution. One worry about the idea of The Scientific Revolution is that in its reconstruction as the foundation of modern science, it seems too forward-looking, too 'whiggish' in its very conception. To treat the work of Galileo or Kepler as a*nticipations* of later science, to treat them as important simply because of what came later, is to be whiggish. We would be judging the past in terms of the present, thereby distorting the past. The science of the revolution is 'revolutionary' because it was like our own.[9] But whether or not there is a whiff of whiggishness, the idea of *The Scientific Revolution* may still be of value. It might lead us to look for, and perhaps find, factors that did in fact play important roles in the changes that led to modern science. So whether or not there was a single The Scientific Revolution, perhaps this way of

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[1] Christopher Hill, *A Nation of Change and Novelty: Radical Politics, Religion and Literature in Seventeenth-Century England*, Routledge, London, UK, (1990), 82–101; I. Bernard Cohen, *Revolution in Science*, Harvard Univ. Press, Cambridge, MA, (1985), x–xii.

[2] Cohen, *Revolution in Science*, 4.

[3] Cohen, *Revolution in Science*, 12–13.

[4] Thomas S. Kuhn, *The Structure of Scientific Revolutions, 3rd Edition*, The University of Chicago Press, Chicago, IL, (1996).

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[5] Herbert Butterfield, *The Origins of Modern Science 1300–1800*, Macmillan Publ. Co. New York, NY, (1957), 8.

[6] A. R Rupert Hall, *The Scientific Revolution 1500–1800*, 2nd Edition, Beacon Press, Boston, MA, (1966).

[7] John Henry, *The Scientific Revolution and the Origins of Modern Science*, Macmillan Press LTD, London, UK, (1997).

[8] Wilbur Applebaum, *The Scientific Revolution and the Foundations of Modern Science*, Greenwood Press, Westport, CT, (2005).

[9] Henry, *The Scientific Revolution*, 2–3.

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thinking about science and revolutions can help us better understand *how* the natural philosophy of the 16th and 17th centuries became modern science, and what factors were important in this transition.

Historical accounts of The Scientific Revolution tend to focus on a variety of factors – social, substantive and methodological. Social factors typically include the rejection of scholastic and religious authority in favor of free individual inquiry. Substantive factors typically include the rejection of a magical or supernatural worldview, the adoption of a mechanical worldview, and emphasis on scientific law. Methodological factors typically include first, a turn to observation in general and the requirement that causes be observable; and second, the importance of experiment – the manipulation of nature to uncover these laws and causes.[10]

Discussions of experiments and the experimental method are central to many accounts of method in The Scientific Revolution. Typically historians point to stories of Harvey's experiments in the circulation of blood, Galileo's experiments with inclined planes, Pascal's trials with mercury filled tubes, Boyle's air pumps and Newton's prisms.[11] These experiments were usually taken to have a special status, a status above that of mere observation. This is partly based on the idea that through the experimental manipulation of nature, her secrets, unavailable to mere observation, can be truly revealed. But it is also based on the fact that experiments could be repeated under similar or varied conditions, and by anyone who followed the correct procedures. There was something public, repeatable and therefore objective about experiments. Consequently, experiments also tended to have great persuasive power. Harvey's experiments in the circulation of blood, for instance, seemed to have persuaded his fellow physiologists almost immediately.[12]

If there are any scientific revolutions at all, surely there is a Darwinian revolution, as suggested by the title of Michael Ruse's *The Darwinian Revolution: Nature Red in Tooth and Claw*.[13] But it is not clear that the Darwinian revolution could be part of *The* Scientific Revolution, as that revolution is usually associated with the period from 1500 to 1700. After all, Darwin was not even born until 1809, a full century later. But is there some way Darwin's work could plausibly be seen as part of The Scientific Revolution nonetheless? The penultimate chapter in Butterfield's book *The Origins of Science*, is titled 'The Postponed Scientific Revolution in Chemistry,' and is devoted to the work of Lavoisier and Priestly near the end of the 18th century. The implication here is that the changes associated with the Scientific Revolution made their way more gradually into chemistry. Perhaps the same is true of biology. Perhaps we can see in Darwin's biological thinking, some of the same substantive and methodological ideas that were so distinctive of the period known as *The* Scientific Revolution. I shall here explore this idea, showing how Darwin's work exemplifies one of these themes – experimentalism, and in ways that may not be obvious.

Darwin's experiments

An account of Darwin's experimentalism would surely be expected to begin with his own experiments. In 1855, Darwin began a series of experiments to establish the 'vitality of seeds' – their capacity to sprout, when immersed in seawater. He tested this with a series of experiments on salt-water immersed seeds. In a letter dated November 21, 1855, to the Gardener's Chronicle, he reported the results of this experiment. Among other things, he reported that 30 of the 56 seeds of capsicum (peppers) were viable after 137 day, but only 6 out of hundreds of celery seeds grew. Broccoli seeds were fine after 11 days, but not after 22. He tested as well seeds from oats, spinach, lettuce, carrot, cress and radish, noting that different varieties of the same species will often vary in their resistance to the effects of salt water.[14] These results would have obvious implications for understanding the biogeography of plant species. If plant seeds could survive long periods of immersion, plant species could in principle spread across stretches of ocean. And since the seeds of some varieties retained vitality longer, these varieties could presumably be transported further.

Several years later Darwin engaged in a series of 'weed garden' experiments. He planted some weeds in a 2 by 3 foot plot and recorded how many of the plants survived over time. He reported the results in his *Origin of Species*. Seedlings seemed to suffer the most, 'destroyed in vast numbers by various enemies... out of the 357 no less than 295 were destroyed, chiefly by slugs and insects.'[15] The point of this experiment was to establish the magnitude of the struggle for survival, and by extension the power of natural selection. If a high proportion of weeds were destroyed (as in this case) then the power of natural selection must also be great.

In August and September of 1860, Darwin formulated and executed a series of experiments designed to reveal the functioning of insectivorous plants. In the Venus Flytrap (*Dionaea muscipula*) for instance, he tried to determine the degree to which meat, gelatin, egg white and cheese were 'digested,' chemically altered and absorbed by the plant. He described these experiments and offered his conclusion fifteen years later, in his *Insectivorous Plants*. The experiments demonstrated that 'the secretion from the glands of *Dionaea* dissolves albumen, gelatin, and meat' but that 'globules of fat and fibro-elastic tissue' are not digested. Other substances, such as casein and cheese, stimulated acid secretion, but were not absorbed.[16] (Figure 1).

Two other series of experiments are notable, in part because the results of each were published in book form.

[10] See, for instance Butterfield, *The Origins of Modern Science*; Hall, *The Scientific Revolution 1500–1800*; Henry *The Scientific Revolution*; and Applebaum, *The Scientific Revolution and the Foundations of Modern Science*.

[11] Applebaum, *The Scientific Revolution and the Foundations of Modern Science*, 94–95.

[12] Henry, *The Scientific Revolution*, 28.

[13] Michael Ruse, *The Darwinian Revolution: Nature Red in Tooth and Claw*, University of Chicago Press, Chicago, IL, (1979).

[14] Darwin Correspondence Database, http://www.darwinproject.ac.uk/entry-1783 accessed on Monday Feb. 24, 2014.

[15] Charles Darwin, *On the Origin of Species by Means of Natural Selection, Or the Preservation of Favoured Races in the Struggle for Life*, John Murray, London, (1859), 67–68.

[16] Charles Darwin, *Insectivorous Plants*, John Murray, London, (1875), 304.