The Philosophical Breakfast Club

& THE INVENTION OF THE SCIENTIST

by Laura J. Snyder

Dibner Library Lecture | December 6, 2011

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ABOUT THE AUTHOR

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Laura J. Snyder is professor of philosophy at St. John's University in New York City. She is a life member of Clare Hall College, Cambridge, and served as president of the International Society for the History of Philosophy of Science in 2009 and 2010. She was a Fulbright Scholar to the United Kingdom in 1999.

Her book, *The Philosophical Breakfast Club: Four Remarkable Friends who Transformed Science and Changed the World* (Crown/Broadway Books, 2011) was a Scientific American Notable Book, an Official Selection of the TED Book Club, and winner of the 2011 Royal Institution of Australia Poll for Favorite Science Book.

Snyder is also the author of *Reforming Philosophy: A Victorian Debate on Science and Society* (University of Chicago Press, 2006). Her work has appeared in *The Wall Street Journal, The Scientist,* and *Design Mind* as well as numerous professional journals. She is currently working on a book about the relation between science—especially optics—and art.

FOREWORD

It is an honor for the Dibner Library of the History of Science and Technology to present the 18th annual Dibner Library Lecture, which was given on December 6, 2011. Each year we seek a well-known and well-regarded historian whose work relates in some way to the Dibner Library's collection. Because of the richness and depth of the collection's 35,000 rare scientific and technological works, dating from the fifteenth to the nineteenth centuries in mathematics, engineering, transportation, chemistry, physics, electricity and astronomy, and 2,000 manuscript groups, including a late 13th century encyclopedia of natural history, finding a suitable topic over the years has not been difficult.

Fortunately, we have again found an award-winning historian, whose work is not only acclaimed but accessible to the general public. Laura J. Snyder comes with exemplary credentials. A philosophy professor at St. John's University in New York City, Dr. Snyder received her education at Brandeis and Johns Hopkins Universities and is a life member of Clare Hall College, Cambridge. Her book, *The Philosophical Breakfast Club*, from which this lecture is drawn, reveals the lives and ideas of four amiable Victorian men—Charles Babbage, John Herschel, Richard Jones, and William Whewell—who met at Cambridge and proceeded to transform what was known as natural philosophy into the discipline of science. Along the way, one of their number began to invent the nomenclature of science, using terms like "scientist," "cathode," and "Miocene" that are still in use today. Descriptions of what they ate, how their lives interconnected, and the world around them add depth to the tale, described by the *Washington Times* as "A fascinating story, one told with considerable charm."

The Dibner Library glitters among the twenty libraries that form the network of the Smithsonian Libraries. Spread among the museums and research centers of the Smithsonian, from Washington, D.C. to the Republic of Panama, to New York City, and to Edgewater and Suitland, Md., these libraries advance knowledge on a global scale by serving the Smithsonian's research and education enterprise and by making their collections and expertise accessible to the American people and the world through the Smithsonian Libraries Digital Library (library.si.edu/digital-library) and the Smithsonian Research Online website (research.si.edu), as well as traditional services.

Bern Dibner, whose magnificent gift of 10,000 rare books, manuscripts, and objects forms the nucleus of the Dibner Library of the History of Science and Technology, would be proud of the Library's active education and outreach program, which includes lectures, exhibits, resident fellowships, and tours and programs for students and scholars of every age. The Dibner family, Bern's son David, his wife Frances, and their three sons, Brent, Daniel, and Mark, have continued to support this legacy by creating an endowment that will ensure that the Dibner Library's programs remain vibrant, helping visitors to understand the antecedents of today's scientific and technological environment. The family's contributions have guaranteed that this precious heritage will be carefully stewarded and available to future generations. We are supremely grateful to these three generations and the gift they have mutually given to the world.

Nancy E. Gwinn
Director, Smithsonian Libraries
September 12, 2013

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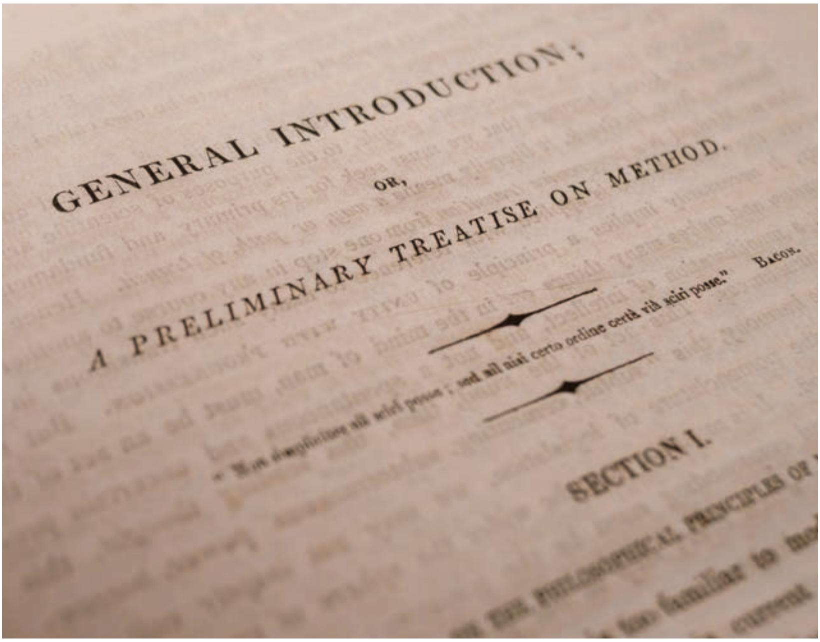


Figure 1. S. T. Coleridge's "General Introduction" to the *Encyclopedia Metropolitana*

When the members of the British Association for the Advancement of Science convened their third annual meeting in Cambridge in 1833, they had no idea that they would be witness to a confrontation that would have far-reaching effects for all those who studied the natural world. This conflict occurred in the grand Senate House of the University, during the general meeting for members and their guests on the first evening of the conference. At a lull in the proceedings, an elderly white-haired man stood up. The members realized, with some surprise, that it was Samuel Taylor Coleridge, the renowned Romantic poet. Decades earlier, Coleridge had written a treatise on scientific method, which had served as the introductory volume to the *Encyclopedia Metropolitana (Figure 1)*; he had long been interested in science and discussed the newest discoveries with his good friend, the chemist Humphry Davy. However, Coleridge had not interrupted the solitude of his last few years to join in the celebrations of the activities of the British Association. On the contrary, he had come to criticize them.

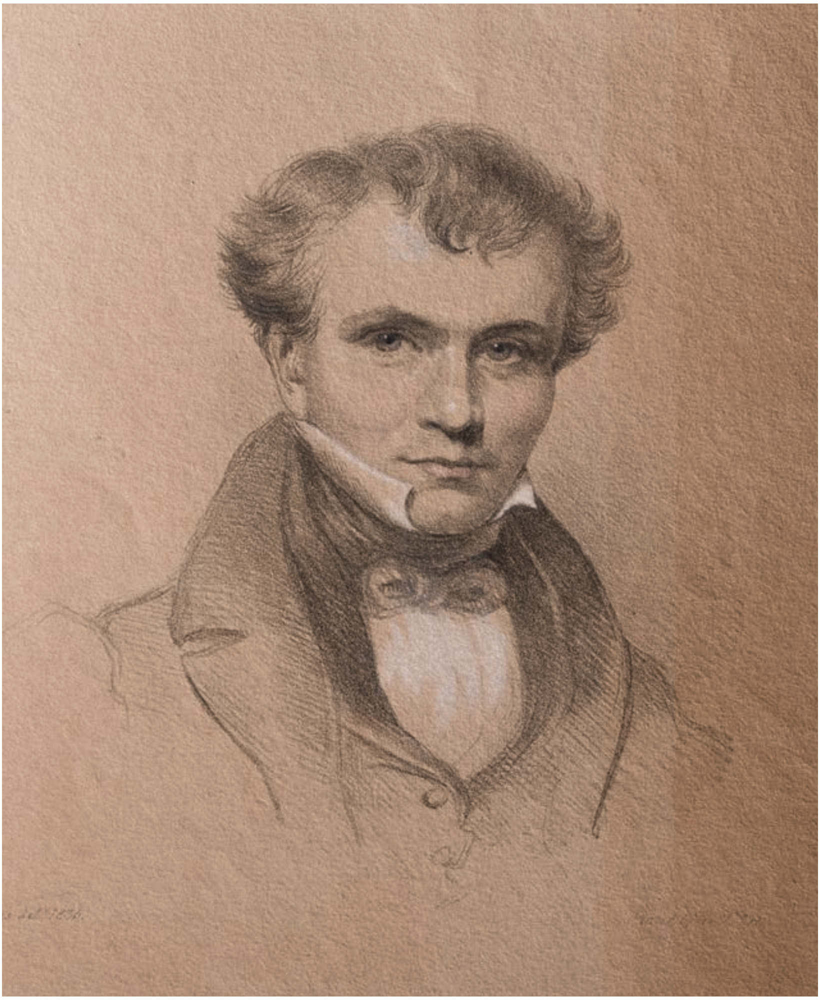


Figure 2. Portrait of William Whewell, 1835

At the time, those who studied the natural world were known as "men of science" (they were rarely women in those days), or "natural philosophers," indicating the intimate relation between science and philosophy that had existed since ancient times. The members of the Association, Coleridge insisted, should cease calling themselves "natural philosophers." Indeed, as a "real metaphysician," he forbade them the use of this honorific.

We can imagine the audience erupting in an angry din. Why were the members of the British Association not entitled to use that name of long-standing? Although we cannot know with certainty Coleridge's motivation for this assault, it is fair to speculate that he was dismayed by the members' proclivity to muck about in the fossil pits, or experiment with messy electrical batteries. They were no longer, as he might have said, "armchair philosophers," pondering the cosmos from their firesides.

In the midst of this uproar, one man rose to quiet the crowd. William Whewell, a Cambridge don and secretary of the meeting, was a tall, well-built, and imposing man in his thirties, who was known to the crowd for his most recent work on the relation between science and religion, as well as his earlier writings on mineralogy, crystallography, mechanics, and other topics *(Figure 2)*. With great courtesy, Whewell announced that he agreed with the "distinguished gentleman" that a satisfactory name was

Figure 3. Portrait of Michael Faraday, 1830s

wanting. If "philosophers" was taken to be "too wide and lofty" a term, then "by analogy with *artist*, we may form *scientist*." This was, as far as anyone knows, the first time the word "scientist" was uttered in public.[1]

That the word was first spoken—and most likely invented—by Whewell was fitting. In several of his written works, Whewell had already expressed the view that new discoveries in science require new terminology to denote the entities and properties referred to by the new theory. As he later put it in a letter to the chemist and physicist Michael Faraday *(Figure 3)*, "Such a coinage [of new terms] has always taken place at the great epochs of discovery, like the medals that are struck at the beginning of a new reign."[2]

Whewell would soon be renowned for his terminological prowess; several months after the confrontation with Coleridge, Faraday wrote to him, "I am in a trouble which, when it occurs at Cambridge is, I understand, referred by everyone . . . to you for removal."[3] In response, Whewell coined the words anode, cathode, and ion.[4] Later, answering a request by the geologist Charles Lyell, Whewell proposed Eocene, Miocene, uniformitarianism, and catastrophism, more terms still in use today.[5]

Whewell's invention of the term "scientist," then, was a sign that he believed a new epoch had arrived for the natural philosopher. And he was right, though the complete transformation would take decades more.

This transformation saw the man of science evolve from the talented amateur—the clergyman collecting beetles or fossils in his spare time, the country squire constructing a voltaic battery in his cellar laboratory, the "literary companion" hired by a nobleman to instruct and entertain him with novel experiments—to the professional scientist, who was trained in science at the university, followed a certain scientific method, belonged to scientific communities open only to those actively pursuing natural knowledge, and participated in other hallmarks of modern scientific practice. What is most remarkable about this sea change in science is that it was brought about in great part by the efforts of four men who met as students at Cambridge University: Charles Babbage *(Figure 17)*, John Herschel *(Figure 4)*, Richard Jones *(Figure 5)*, and William Whewell.

Each of the four would go on to accomplish great things: Charles Babbage (1791-1871), a brilliant mathematician, would invent the first prototype

Figure 4. Portrait of John Frederick William Herschel, 1830s

of a modern computer; John Herschel (1792-1871) would map the stars of the Southern Hemisphere, make other important astronomical discoveries, and co-invent photography; Richard Jones (1790-1855), a talented economist, would be the first major critic of David Ricardo's theories and an influence later on Karl Marx; and William Whewell (1794-1866), who was not only an expert etymologist and author of groundbreaking works in the philosophy and history of science, but also inaugurated international "big science" with his world-wide study of tidal patterns.[6]

As soon as they became acquainted in 1812, the men realized that they would be "friends of a lifetime," as Whewell would later say.[7] Shortly after meeting, for example, Babbage and Herschel were sending each other

Figure 5. Portrait of Richard Jones in *The Literary Remains: Consisting of Lectures and Tracts on Political Economy of the Late Richard Jones* (London: John Murray, 1859)

letters during the summer vacation signed "Yours 'till death shall stop my breath."[8] Over the next 60 years the four men wrote hundreds and hundreds of letters to each other, visited as often as possible, traveled to the Continent together, jointly conducted experiments, and read and critiqued each other's works in manuscript.

Their family lives were intertwined as well: Jones and Whewell, both childless, were godfathers to Herschel's children; Babbage, and then Whewell, arranged Herschel's marriage settlements (including one for an early engagement that was broken off); Jones was the clergyman officiating at Whewell's first wedding; and Whewell performed the wedding of Herschel's daughter Louisa to his own nephew by marriage. When Whewell's first wife was ill, Herschel's daughters helped nurse her, and when his second wife died, they came again to stay with the grieving Whewell; so that he was never alone again until his own death nine months later.

Soon after the four men first became friends, they began to meet for breakfast on Sunday mornings after the compulsory chapel services at their respective colleges. Nearly two decades later, when he was Master of Trinity College at Cambridge, Whewell received a letter from another student who had been invited to some of these meetings. "We have all made some advances in physical science, but in *metaphysics* . . . I am not conscious of having advanced one single step, since the period when you and I and Herschel and Babbage used to meet at our Sunday morning's philosophical breakfasts."[9]

They would gather in Herschel's rooms in the New Court of St. John's College, and Herschel's college servant, or "gyp," would bring in the breakfast that had been ordered in advance from the college kitchens. Thanks to other visitors to Cambridge, who recorded details of the breakfasts they had in college rooms, we know what the four men most likely ate. The Irish novelist Maria Edgeworth (who would later befriend all four men) noted that when she visited a don at Cambridge in 1813, she was offered "Tea, coffee, tongue, cold beef, exquisite breads, and many inches of butter. . . . All the butter in Cambridge must be stretched into rolls . . . an inch in diameter, and these are sold by inches, measured out by compasses, in a truly mathematical manner." The students, it appears, ate even better. A visiting American student was awed by the breakfasts hosted by fellow students in their rooms: "Toast, muffins, crumpets, eggs, and two inches each of butter; ham, cold chicken, beef-steaks, audit ale [so called because it was traditionally reserved for the feast or "audit" days], tea, and coffee; honey, marmalade, and anchovies, with all the et ceteras."[10]

The four men fondly recalled their philosophical breakfasts even into old age. After reading Jones's long-awaited treatise on economics, Babbage told him that he "recognized the fruit of the undergraduate confabulations of the good old set on every page."[11] In a letter written later in life, Jones asked Herschel "Do you remember sitting in your rooms at St. John's with feet on your [fireplace] fender?" As Whewell recalled in a preface he contributed to a posthumous edition of Jones's unpublished lectures and essays, their favorite topic of conversation at these meetings was the work of the seventeenth-century philosopher and politician Francis Bacon (1561-1626) *(Figure 6)*.[12]

In his book the *Novum Organum (Figure 7),* Bacon had called for a sweeping revolution in science unlike any ever seen before. Bacon's

Figure 6. Portrait of Sir Francis Bacon in his *Opera Omnia*

Figure 7. *Novum Organum* by Francis Bacon

writings had been an influence on those who had brought about the so-called "scientific revolution" in the seventeenth century. However, since that time, the members of the philosophical breakfast club believed, science had stagnated. It was time for a new scientific revolution. And they pledged themselves to bringing it about. What is remarkable about these men is that, by the end of their lives, they had succeeded—even beyond their wildest dreams—in bringing about the revolution they had imagined in their undergraduate days.

There are, in particular, four Bacon-inspired hallmarks of modern scientific research that were inaugurated by these men: an inductive, evidence-based scientific method; the notion that science should be for the public good; the founding of new scientific societies solely for those actively pursuing scientific research; and the initiation of external funding for science.

One of Bacon's most important precepts was that scientific knowledge ought to be gained by an *inductive,* rather than a *deductive,* reasoning process. The medieval followers of Aristotle had stressed their master's use of deductive reason while ignoring his emphasis on inductive reason; Bacon himself recognized that this was a distortion of Aristotle's own views.[13] In deductive reasoning, the conclusion of an argument necessarily follows from its premises. One example of deductive reasoning is the type of argument known as the syllogism. So, for instance, take this syllogism:

Premise 1:	All men are mortal
Premise 2:	Socrates is a man
Conclusion:	Therefore, Socrates is mortal.

If the two premises are true, then the conclusion *must* be true (that is what it means for the conclusion to follow necessarily from the premises). Nothing external to the argument itself is needed to know that the conclusion is true; no evidence from nature—for example, our experience of other men, or any experience about Socrates—is required. Moreover, the conclusion is certain, not merely probable. That is, it is not only *likely* that Socrates is mortal, it is *certain* (again, assuming that the premises are true).

The medieval Aristotelians believed that deductive reasoning was the way to gain true knowledge. A younger contemporary of Bacon's, René

Descartes *(Figure 8)*, argued more specifically that deductive reason was the proper method of science. The natural philosopher, according to Descartes, must start from self-evident truths or universal axioms, and then *deduce* natural laws from them. Descartes himself used this method in his scientific writings. So, for instance, his Law of Conservation of Motion was deduced from properties of God that Descartes considered self-evident: constancy and immutability. The amount of motion in the world is held constant because to allow otherwise would be a form of inconstancy in God. As Descartes put it, "God himself, who created motion and rest in the beginning . . . now, through his ordinary concourse alone preserves as much motion and rest in the whole as he placed there then."[14]

Bacon argued that, on the contrary, science required inductive reasoning. The true scientific method, he wrote, "derives axioms from the senses and particulars, rising by a gradual and unbroken ascent, so that it arrives at the most general axioms last of all." [15] Inductive reasoning, that is, starts from the evidence of the senses, or from particular facts, and then generalizes to a conclusion that cannot be absolutely certain, but only probable. So, for instance, we get this kind of argument:

> *x* number of crows have been observed to be black
>
> No crows have been observed to be not-black
>
> Therefore, probably, all crows are black

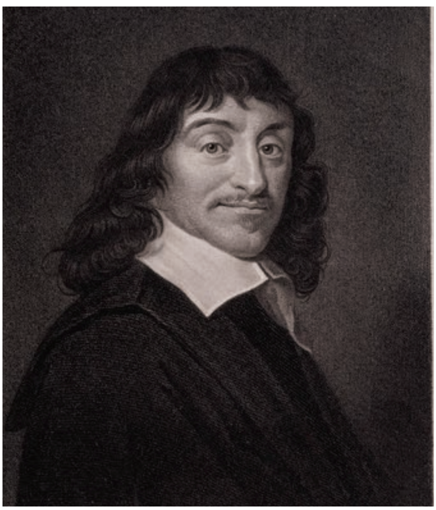


Figure 8. Portrait of René Descartes by Franz Hals

The conclusion can be very highly probable—that is, extremely likely to be true—but can never have the certainty one gets with deductive reasoning, because it is impossible to observe every crow that ever has been or ever will be in every part of the world. It is always possible that at some time, somewhere, there will be one non-black crow.

However, Bacon's inductive scientific method was not a matter of simply collecting instances and generalizing from them. Rather, it was a complex process starting from experiential data and then using them to build concepts that could then be utilized to organize and interpret those and other data. More than just experience was necessary; the natural philosopher must also use reason to create scientific laws from observed data. Bacon expressed this idea in his famous aphorism comparing the natural philosopher to the bee:

"Those who have handled sciences have been either men of experiment or men of dogmas. The men of experiment are like the ant, they only collect and use; the reasoners resemble spiders, who make cobwebs out of their own substance. But the bee takes a middle course: it gathers its material from the flowers of the garden and of the field, but transforms and digests it by a power of its own. Not unlike this is the true business of philosophy . . . ." [16]

The "men of experiment," or the ant, are those who would use simple inductive generalization to build scientific theories, while the "men of dogmas," the spiders, are those like Descartes, using deductive reasoning. Bacon sought a "middle way" between the two. He used his method in his own "Investigation into Heat," in order to define the concept of heat: "*Heat is motion, expansive, restrained, and acting* in its strife upon the smaller particles of bodies."[17]

Although Bacon's call for an inductive scientific method had been reinforced by Isaac Newton's advocacy of induction later in the seventeenth century, the early nineteenth century saw a resurgence of interest in deductive method. Much of the impetus for that resurgence came from the science then known as "political economy." David Ricardo (1772-1823), a stockbroker who had become interested in economics after reading Adam Smith's *Wealth of Nations* while on vacation, came to believe that, as he put it, economics should be "a strict science like mathematics." He championed a deductive method, which began from certain self-evident axioms such as "man is a profit-maximizer" and deduced conclusions about human behavior in economic situations from these.[18] No observations of how people actually *did* behave were required.

The members of the philosophical breakfast club believed that this approach to economics held much danger for their project of bringing about a Bacon-inspired scientific revolution. Political economy was one of the most popular topics in these days of social and economic unrest, so economic writings found huge audiences. And these readers were being convinced that deductive method could lead to new knowledge. Indeed, the English essayist Thomas De Quincey expressed a common view in his best-selling work, *Confessions of an English Opium-Eater* (1821):

"[Before Ricardo,] all other writers had been crushed and overlaid by the enormous weight of facts. . . . Mr. Ricardo alone had deduced, a priori, from the understanding itself, laws which first gave a ray of light into the unwieldy chaos of materials, and had constructed what had been but a collection of tentative discussions into a science of regular proportions now first standing on an eternal basis." [19]

De Quincey's implication is that the other sciences, even the natural sciences, could benefit from applying the same deductive method. Over in Oxford, the logician Richard Whately (soon to be appointed Archbishop of Dublin) and his followers were arguing explicitly that deduction was the proper reasoning method to use not only in political economy but also the natural sciences.

The members of the philosophical breakfast club were concerned that the acceptance of deductive method in economics would lead to the conviction that the natural sciences should use that method as well. They agreed with those who argued that economics and physical science should proceed by the same method, but ardently argued that this shared method was an inductive, not deductive, one.

To counter what they saw as the pernicious effect of the deductive method in economics, the members of the philosophical breakfast club began publishing articles and books aimed at a wide audience. In these works they attacked Ricardo's economic theory and promoted an inductive method in both economics and natural science. In their works on economics, Babbage, Whewell, and Jones criticized Ricardo and others who believed that economists could be "closet philosophers" who determined economic laws without ever leaving their armchairs. On the

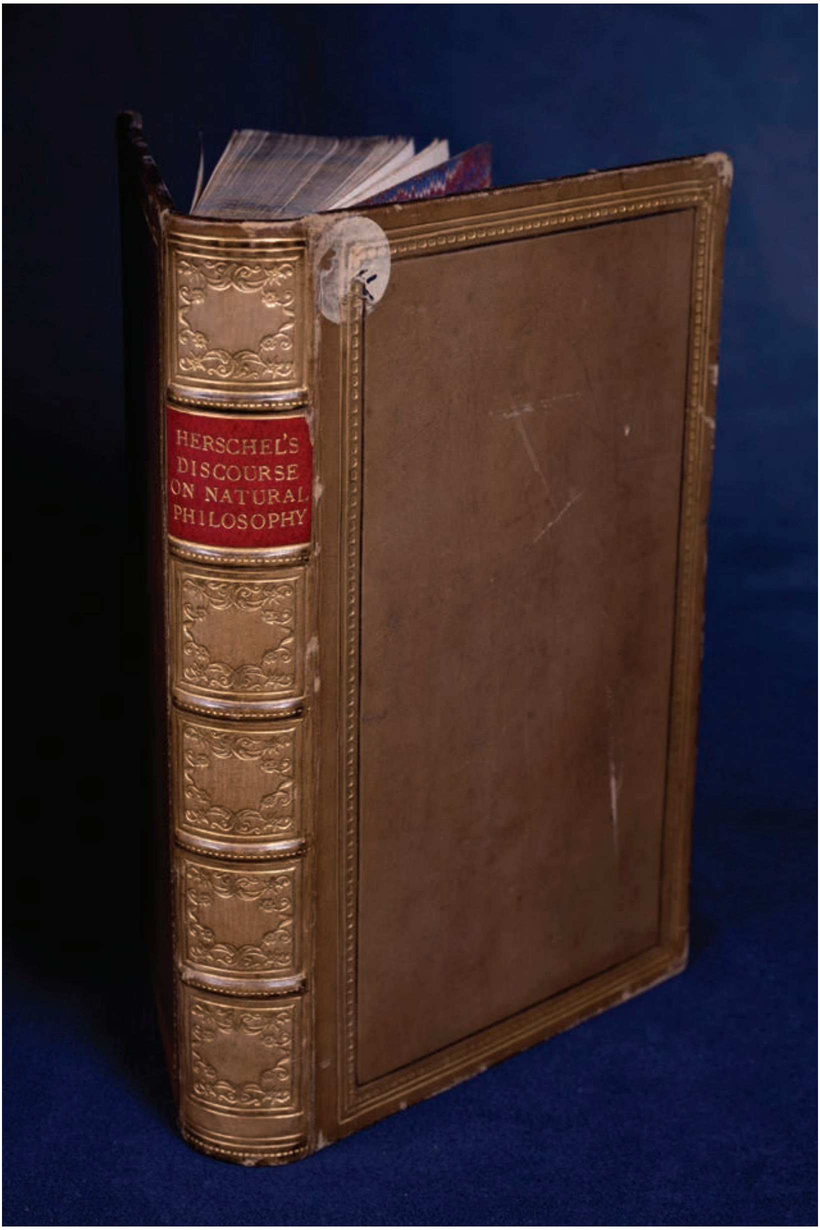
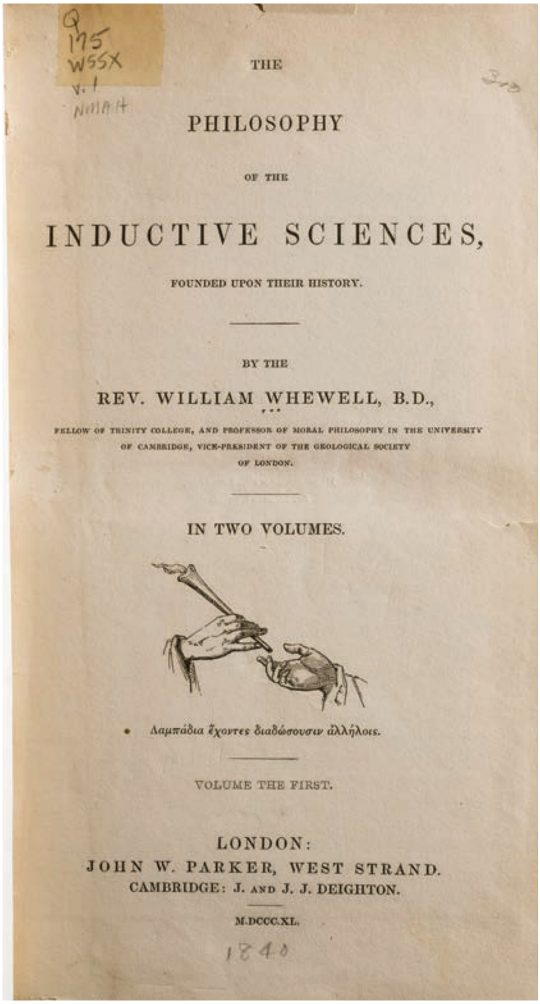


Figure 9. *A Preliminary Discourse on the Study of Natural Philosophy* by John Herschel

contrary, just as it was necessary for a geologist to go out and examine for himself the geological strata, so too the economist must "look and see" how people actually have behaved in various economic situations over time. For instance, in his treatise on economics, Jones wrote that Mr. Ricardo . . . produced a system very ingeniously combined, of purely hypothetical truths; which, however, a single comprehensive glance at the world as it actually exists, is sufficient to shew to be utterly inconsistent with the past and present condition of mankind.[20]

While his friends were writing on economics in the late 1820s and early 1830s, Herschel was working on and publishing his book *A Preliminary Discourse on the Study of Natural Philosophy (Figure 9)*. Like Coleridge's book 14 years earlier, Herschel's work was the first part of a multi-volume encyclopedia; in this case, the *Cabinet Cyclopedia* published by the science popularizer Dionysius Lardner. Herschel prominently displayed an engraving of the bust of Bacon on the frontispiece of the work, and throughout the book he endorsed an inductive method. As soon as it was published, the *Preliminary Discourse* had an enormous influence on how science was viewed by the public, as well as by aspiring natural philosophers. One historian of science has rightly said that in the nineteenth century, to be "scientific" was to emulate Sir John Herschel.[21] A young Charles Darwin, for instance, read the book when it first appeared in 1831, just as he was studying for his exams at Cambridge, and later said that "Scarcely anything in my life made so deep an impression on me. . . . It made me wish to try to add my mite to the accumulated store of natural knowledge."[22] Whewell's later works, *The History of the Inductive Sciences* and *Philosophy of the Inductive Sciences (Figure 10)*, would further enshrine inductive method as the correct way to do science; both books were required reading for the next several generations of natural philosophers trained at Cambridge.

Bacon had also championed the idea that science should serve the public good. Science, he believed, should be for the "relief of man's estate." As he put it, "Knowledge may not be as a courtesan, for pleasure and vanity only . . . but as a spouse, for generation, fruit, and comfort."[23] This was quite different from earlier views of scientific knowledge, which held that it was to be used for the good of the king, or for a group of initiated adepts.



THE

PHILOSOPHY

OF THE

INDUCTIVE SCIENCES,

FOUNDED UPON THEIR HISTORY.

BY THE

REV. WILLIAM WHEWELL, B.D.,

FELLOW OF TRINITY COLLEGE, AND PROFESSOR OF MORAL PHILOSOPHY IN THE UNIVERSITY
OF CAMBRIDGE, VICE-PRESIDENT OF THE GEOLOGICAL SOCIETY
OF LONDON.

IN TWO VOLUMES.

Λαμπάδια ἔχοντες διαδώσουσιν ἀλλήλοις.

VOLUME THE FIRST.

LONDON:
JOHN W. PARKER, WEST STRAND.
CAMBRIDGE: J. AND J. J. DEIGHTON.

M.DCCC.XL.

1840

Figure 10. Title page of *Philosophy of the Inductive Sciences* by William Whewell

The members of the philosophical breakfast club agreed with Bacon that science should be aimed towards the good of the public. This is another reason why they addressed political economy in their early writings on scientific method. They believed that Ricardo's theories were leading to pernicious social consequences, such as the reestablishment of the requirement (originally imposed during Queen Elizabeth's reign) that the laboring poor enter workhouses in order to receive any public relief. Whewell and Jones were especially incensed by this policy change, seeing it as counter both to Christian charity and sound economic principles. They believed that economic principles attained using the proper, inductive, method would lead to very different solutions for what was widely considered to be "the pauper problem." Herschel did not write specifically about political economy, but in his *Preliminary Discourse* he referred to the value of the inductive scientific method for improving society through putting the science of political economy on "sound principles" once it is seen to be an "experimental science."[24]

Another way that the philosophical breakfast club sought to bring about the public good through science was by championing Babbage's calculating engines, which he had begun designing in 1821. In these days before pocket calculators, the numbers that were needed for calculations by bankers, insurance companies, engineers, surveyors, ship captains, and nearly every other professional, were to be found in "look-up books" filled with tables of figures *(Figure 11)*. Such tables existed for actuarial statistics, astronomical data, taxation rates, interest rates, logarithms, conversions of units, multiples of fractions, and other figures. These tables were calculated by men and women known as "computers." Generally the computers were clergymen, schoolteachers, and surveyors who were employed part-time to compute the numbers in the tables by applying a fixed procedure over and over. Although these calculations were done by a fixed procedure, that does not mean they were simple. For instance, the *Nautical Almanac (Figure 11),* used by ship navigators to determine longitude by the method of lunar differences, published the lunar differences for every month of the year; each month required 1,365 calculations using logarithms applied to numbers in base-60![25]

It should not be surprising, then, that these tables were often riddled with errors. Not only could mistakes enter in during the calculations, but also during the transfer of the numbers to the columns of the handwritten

Figure 11. *Nautical Almanac*, 1806

table, then during the typesetting process. In a sample of only 40 tables, the science publisher Dionysius Lardner found 3,700 *acknowledged* errata—even "errata of errata."

Babbage's Difference Engine, the first mechanical general purpose calculator, was devised to compute the figures for any of these tables, using the mathematical "method of finite differences." This was the first mechanical invention that could do more than merely add, subtract, multiply, and divide. Later, Babbage's Analytical Engine was the first mechanical computer in the modern sense: it had parallel processing, memory, and was "programmable" using punched cards. The members of the philosophical breakfast club—especially Babbage himself—believed that these engines, by doing away with the sources of error in the printed tables, could improve the lives of people everywhere. As Herschel put it, "an undetected error in a logarithmic table is like a sunken rock at sea yet undiscovered, upon which it is impossible to say what wrecks may have taken place."[26] This was literally true, as well as metaphorically so; if ship navigators could not reliably compute longitude, they were very often doomed to be lost at sea.

However, not everyone was convinced that Babbage's engines had value for the public. Even other men of science were skeptical. G.B. Airy *(Figure 12)*, who as Astronomer Royal was in charge of the *Nautical*

Figure 12. George Biddell Airy

Almanac, said of Babbage, "I think it likely he lives in a sort of dream as to [the engine's] utility."[27] To that kind of attitude, Babbage had a retort:

"Propose to an Englishman any instrument, however admirable, and you will observe that the whole effort of the English mind is directed to find a difficulty, defect, or an impossibility in it. If you speak to him of a machine for peeling a potato, he will pronounce it impossible; if you peel a potato with it before his eyes, he will declare it useless, because it will not slice a pineapple." [28]

Unfortunately, however, Babbage's engines never were built in his day, in part because most people did not believe that non-human computers would have value for the public.

In his book *New Atlantis*, Bacon depicted an ideal scientific society: Solomon's House. This work was a clever inversion of the travelogues common in the day, in which European sailors stumbled upon "savages" living in the New World. Bacon's book finds European sailors lost at sea, expecting to perish, when they are saved by a group of men who take them to an uncharted island. Compared to the islanders, it is the sailors who are the savages; the island civilization is far superior to that of the West. One mark of this superiority is the emphasis the islanders place on scientific knowledge. The king of the island has endowed Solomon's

House as a special organization devoted entirely to scientific research. The fellows who live at this institution dedicate their lives to science, and in return they are wholly supported by the king. Bacon believed that scientific institutions such as this could be powerful engines for scientific discovery.[29]

The members of the philosophical breakfast club believed that such organizations were necessary, and that few, if any, existed. Britain's preeminent scientific institution, the Royal Society of London, had been founded in the seventeenth century explicitly as a prototype of Solomon's House; its earliest members believed that they were being true to Bacon's precepts. However, since that time the Royal Society had devolved into a kind of "gentlemen's club," most of whose members were not actively conducting scientific research. Many were antiquarians, literary people, or noblemen, who enjoyed mingling with the men of science and watching some of their experiments. Babbage, with his habitual interest in numbers and statistics, calculated that only about ten percent of the members of the Royal Society had even published two articles in the society's journal, *Philosophical Transactions of the Royal Society.* [30]

The members of the philosophical breakfast club attempted to recreate Bacon's Solomon's Houses as much as possible by helping to form a number of scientific institutions: the Astronomical Society (1820), the British Association for the Advancement of Science (1831), the Statistical Section of the British Association for the Advancement of Science (1833), and the Statistical Society of London (1834). These new scientific societies had several important long-term effects on science. For one thing, their requirement that their members be actively working in scientific research soon became the norm. Additionally, these societies reinstated a tradition that had long vanished from the meetings of the Royal Society of London: the discussion of scientific papers after they were presented. It had been thought by the leaders of the Royal Society that such discussion was "ungentlemanly," as it would encourage petty disputes and personality clashes. However, once these discussions began to be seen as useful, the Royal Society did reinstate them, and as a result the meetings of these societies were more fruitful and interesting. To be sure, there were some heated moments—such as the angry political debates following some of the economics papers presented to the Statistical Section of the British Association—but the divisiveness of these was more than balanced by the sense that scientific theories were strengthened by being exposed to questions and dissenting evidence.[31] As Bacon had put it, "truth will sooner come out from error than from confusion."[32]

Another interesting result of these new scientific societies, one perhaps unintended by the members of the philosophical breakfast club—though they were not at all dismayed at this result—was that women got their first "foot in the door" of institutionalized science. Women had been explicitly precluded from membership in the Royal Society of London. But, little by little, they began to become more involved in the meetings of the British Association for the Advancement of Science, until in 1853 it became the first of the national scientific societies to admit women as full members. (They had already been welcomed into the membership of the Botanical Society.) The Royal Society lagged far behind; it admitted its first women fellows in 1945 (the French Royal Academy only did so in 1979).[33] At first, the (male) attendees of the British Association were encouraged to bring along their wives, daughters, and sisters as a way of making the pilgrimage to the provincial location of the meetings more of a family vacation. (This not only made it easier for the members to attend, but it made it more lucrative for towns to host the meetings, as increased attendance benefitted the owners of local inns, pubs, and other businesses that served visitors to the town.) The women were invited to the evening "conversaziones," sessions of gossiping, promenading, and eating ices, where the finely dressed ladies were able to mingle with the men of science.

The British Association also sold "ladies tickets" to the public evening lectures; these were a major source of revenue to the society. But soon the more popular speakers, such as the geologist Adam Sedgwick *(Figure 13)* (who was quite a ladies' man, apparently), began to attract women to the section meetings as well. Although this was officially not allowed, it became so common that the organizers of the meetings were forced to take the expected attendance of women into account when finding rooms to hold the audiences for the section meetings. Before the 1836 meeting in Bristol, for example, the organizers worried that one of the section meeting rooms held only 350 people, so that "it may be necessary to enforce almost absolutely the law as to the exclusion of ladies from the sections." After the following year's meeting, one of the organizers

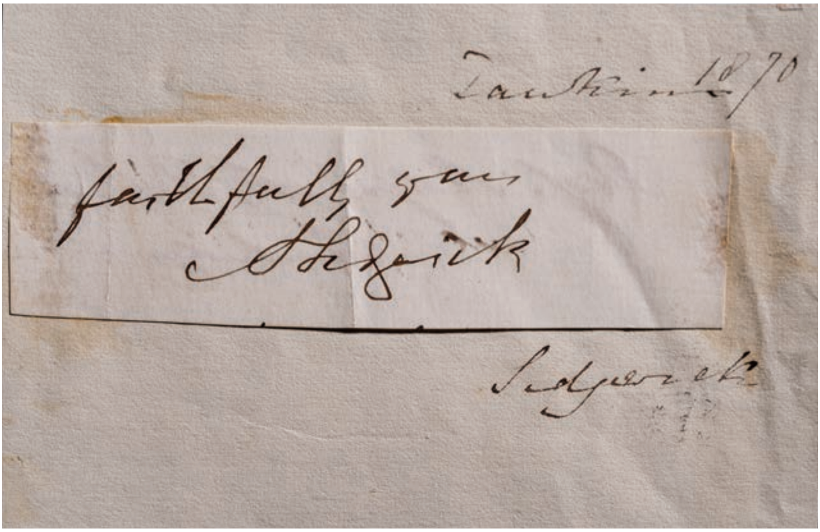


Figure 13. Adam Sedgwick autograph signature

announced triumphantly to the president of the association that "the sections here have been excellent, and Sedgwick as president of the geological surpassed himself. He smitted the hearts of all the ladies of whom we had 300 daily in our gallery."[34]

One of the most radical innovations of Bacon's Solomon's House was that scientific activity was fully funded by the king of the island. This was far from the case in the seventeenth century, and no more so in the nineteenth century; men of science were expected to pay for their own equipment, experiments, and building their inventions. The one slight exception to this was the Royal Academy of Science in France, which paid a stipend to its members. However, the membership of the Academy was small, and the price of that stipend was great—members were expected to work on the kind of science that was endorsed by the Academy, so completely new ways of thinking were discouraged.

For instance, the Scottish inventor James Watt *(Figure 14)*, who devised and built a new kind of steam engine, spent his own fortune to do so—about £50,000, an enormous amount of money in those days.[35] Professors of chemistry at Cambridge even had to buy their own chemicals. Occasionally, prizes were offered to solve certain problems, such as the "Longitude Problem," that is, finding a way for sailors to determine their longitude at sea, without the lengthy calculations required by the method of lunar differences. (John Harrison's chronometer was invented as an entry in this contest, and it did revolutionize navigation.)[36] However, these prizes were infrequent, and they only paid the "winner" after a long process, if at all. A natural philosopher still needed to fund his own work with no expectation of recouping his expenses.

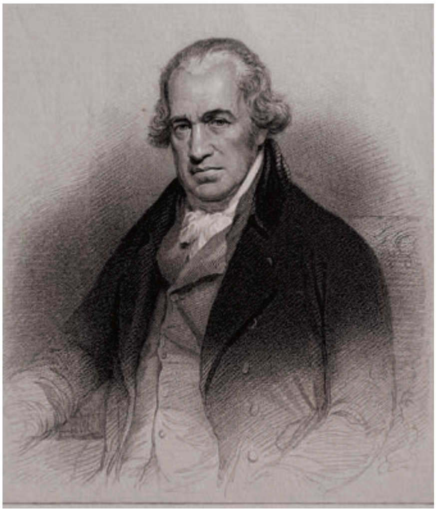


Figure 14. Portrait of James Watt by William Beechey

When the Royal Society of London was founded in the 1660s in response to Bacon's call for a Solomon's House, the organizers approached Charles II with the request for his royal approval, as well as his funding. The king granted the first, but not the second. Two centuries later, the members of the philosophical breakfast club debated the issue.

Of the four men, Herschel was the most conservative on this topic; he felt that men of science, if they could afford it, should fund their own work. He, at least, would pay for his own experiments and even his expedition to the Cape of Good Hope to map the stars of the Southern Hemisphere. When the British Admiralty offered Herschel and his family free passage on a navy ship, Herschel refused.[37] At the same time, however, he knew there were many who could not continue their labors without financial support, who were "starving for science," as he put it in a letter to Dionysius Lardner.[38] By the time Herschel returned from the Cape, his opinion had altered somewhat. Indeed, soon afterwards, he met with the queen and the prime minister to discuss the Crown funding an expedition to Antarctica to find the magnetic South Pole. As he wrote in his diary, "Dined today with the Queen at Windsor Castle where had much conversation with Lord Melbourne about the projected South Polar Expedition." [39]

Babbage was on the other end of the spectrum from Herschel. Although he was himself quite wealthy, having inherited £100,000 when his father, a banker, died in 1827, he refused to spend his own money to build his engines. His friends Herschel and Whewell, as members of the Royal Society, were on numerous committees recommending that the government grant Babbage funds for this immense undertaking. Babbage was insistent on this point; indeed, when his machinist Joseph Clement stopped working on the Difference Engine due to a dispute with Babbage, and returned all the pieces to him, Babbage never completed the engine even though, as his son later estimated, it could have been built with merely another £500.[40] By the end of Babbage's life, the British government had granted over £17,000 (£1.6 million/$2.5 million in today's money) for building the Difference Engine—more than double the cost of building an Admiralty warship![41] And yet, the machine was never completed. (It is not surprising that parliamentary discussions about building Babbage's engines often sound like today's congressional debates about "pork" in the budget!)

When Babbage and Whewell helped found the British Association for the Advancement of Science in 1831, they raised the issue of grants right away. At the very first meeting, a special committee gathered to award money to researchers. As Whewell pragmatically pointed out to Herschel, the funds of the group "ought to get spent, and not saved, and with good management we may get money's worth of it."[42] Whewell was himself a recipient of numerous grants for his tidal research project; others were given funds for studying fossil fish, analyzing astronomical data, and conducting chemical analyses of the atmosphere.[43] The money came from the surplus collected at the meetings, especially the "ladies' tickets," which became a large source of income for the Association. A decade later the French Academy of Science followed the lead of the British Association and began giving grants to its fellows; the Royal Society of

London lagged behind until the 1850s.[44] Now, fortunately, external funding is a major part of the scientific landscape.

The members of the philosophical breakfast club devoted their lives to bringing about their college dream—a Bacon-influenced scientific revolution. By the time of their deaths, they had seen much of that revolution take hold. Charles Babbage, John Herschel, Richard Jones, and William Whewell had in this sense helped invent the modern scientist.

That is the heroic part of their story. However, there is a flipside as well—an ironic aspect to their revolution. In creating the modern scientist, these men left no room for themselves. They were not like the professional scientists who emerged by the end of the nineteenth century; rather, they were the amateurs and generalists, the "natural philosophers" of the previous time. The members of the philosophical breakfast club would have bemoaned parts of the revolution they themselves had wrought.

Figure 15. Portrait of James Clerk Maxwell

In particular, they would have decried the over-specialization of today's professional. Only 10 years after Whewell's death, his former student James Clerk Maxwell *(Figure 15)* could write:

"We frequently hear the complaint that as the boundaries of science are widened its cultivators become less of philosophers and more of specialists, each confining himself with increasing exclusiveness to the area with which he is familiar." [45]

These men worked in so many fields that it is hard even to fathom today! A natural philosopher could conduct chemistry experiments, make astronomical observations, attend economic lectures, and geologize while on holiday. Such wide-ranging expertise often led to the serendipitous discovery in one field because of knowledge of a different field. By the time Maxwell expressed this common complaint, science had become more specialized; it was no longer really possible to have expertise in so many areas. This was, in part, a result of a burgeoning of knowledge that made it difficult to know everything, as well as the greater mathematization of certain areas of physics (which made the discoveries out of reach of all but the mathematically trained). But it was also a result of the specialized societies, and specialized journals, and specialized education that the philosophical breakfast club had helped foster.

Another change these men would have condemned was the increasing disjunction between science and the rest of culture, especially that between scientists and artists. This disjunction was the topic of C.P. Snow's famous "Two Cultures" lecture, which he delivered in the very same Senate House meeting hall in which Whewell had invented the term "scientist." In 1959, Snow argued that the intellectual life of the whole of western society is increasingly being split into two polar groups. ". . . Between the two a gulf of mutual incomprehension—sometimes . . . hostility and dislike." [46]

There was no such disjunction in the nineteenth century. Indeed, the members of the philosophical breakfast club—especially Herschel and Whewell—viewed themselves as artists as much as scientists. Their scientific work helped them to further develop their artistic sense of the wonders of nature—a sense of wonder so beautifully expressed by Whewell in a letter he wrote to Jones before departing for a trip to the Lake District:

"You have no idea of the variety of different uses to which I shall turn a mountain. After perhaps sketching it from the bottom I shall climb to the top and measure its height by the barometer, knock off a piece of rock with a geological hammer to see what it is made of, and then evolve some quotation from Wordsworth into the still air above it." [47]

Moreover, these men were able to transmit their excitement about nature to the general public, which eagerly followed developments in science in the many popular journals being published in the day, as well as in books and pamphlets written by the natural philosophers themselves. The members of the philosophical breakfast club, as well as their colleagues, wrote works describing their own cutting-edge research for general audiences. This was not seen as a diversion from their "real" work, but part of it. Charles Darwin would later tell his friend T.H. Huxley, "I sometimes think that general and popular treatises are almost as important for the progress of science as original work." Indeed, his own *Origin of Species (Figure 16)* was aimed at a "general and popular" audience; that is why, for instance, Darwin begins with a chapter on breeding, a topic with which most of his contemporaries were quite familiar.

The members of the philosophical breakfast club were very engaged with sharing their discoveries with the broader public. The works on political economy by Babbage, Jones, and Whewell were aimed precisely at the

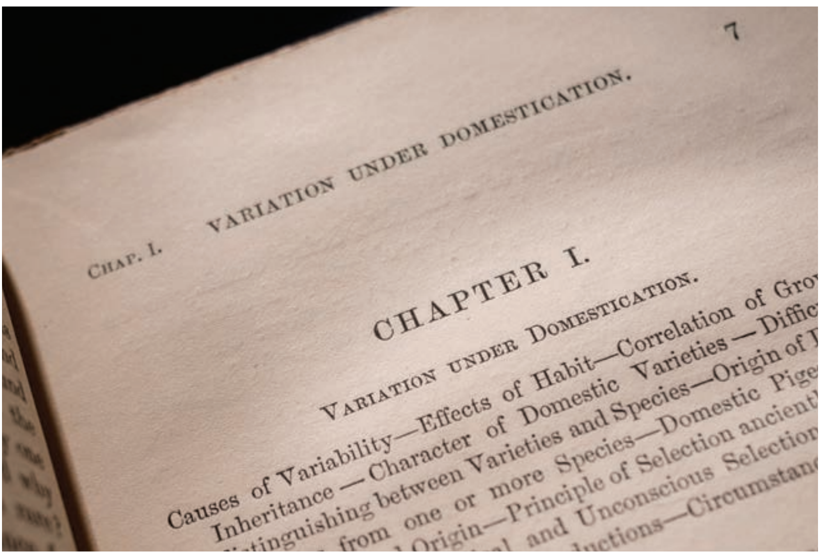


Figure 16. Image of first page, Chapter 1, of Darwin's *Origin of Species* ("Variation under Domestication")

politicians and general population who were grappling with the consequences of the “pauper problem.” And in the natural sciences, as we have seen, Babbage, Herschel, and Whewell each wrote articles and books aimed at broad readerships. Moreover, they encouraged the public to take part in scientific efforts. In the early 1830s, all three men published “forms” that the general public could use to make their own observations of various kinds of data for the purpose of helping to form general economic or scientific laws. Babbage published forms to be used when touring factories (a common leisure activity in that time) to gain knowledge of how factories work; Herschel described “skeleton forms” for recording various kinds of scientific observations; and Whewell wrote and distributed a pamphlet with forms giving anyone living near a coast detailed instructions on making and recording accurate tidal observations.[48] He hoped that people would send the completed forms back to him for his use in discovering laws of the motions of the tides. So the members of the philosophical breakfast club not only wanted to bring scientific advances to the public, but they wanted to bring the public to science, by allowing them to help record data for scientists.

The members of the philosophical breakfast club would be terribly grieved to know the extent to which most members of the general public are detached from science. Only 28 percent of Americans, for example, have even a very basic level of science literacy, tested by asking whether humans and dinosaurs inhabited the earth at the same time, what proportion of the earth is covered in water, and other rather simple questions. Most other countries’ citizens fare even worse.[49] What is most disturbing about this is that the general public is being asked to weigh in on science-related policy questions, such as those surrounding climate change, stem cell research, and cloning. To be a good citizen in these times, a person must know more about science than he or she typically does.

There are many reasons for widespread scientific illiteracy, of course. But in part it has to do with the disjunction that Snow diagnosed so long ago. Much more than in the nineteenth century, the perception of the general public is that science is only for scientists. What can scientists do to help? I suggest that they could do worse than try to be more like the members of the philosophical breakfast club—ironically, more like those men who created the modern scientist.*(Figures 17 and 18)*

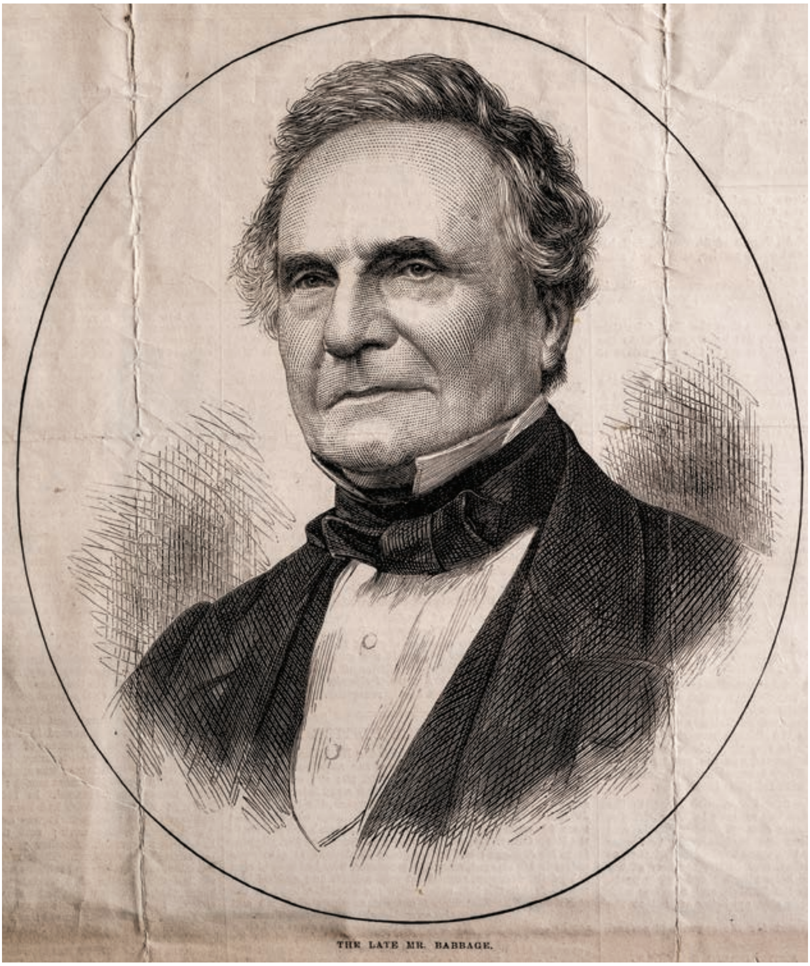


Figure 17. Charles Babbage, 1860s

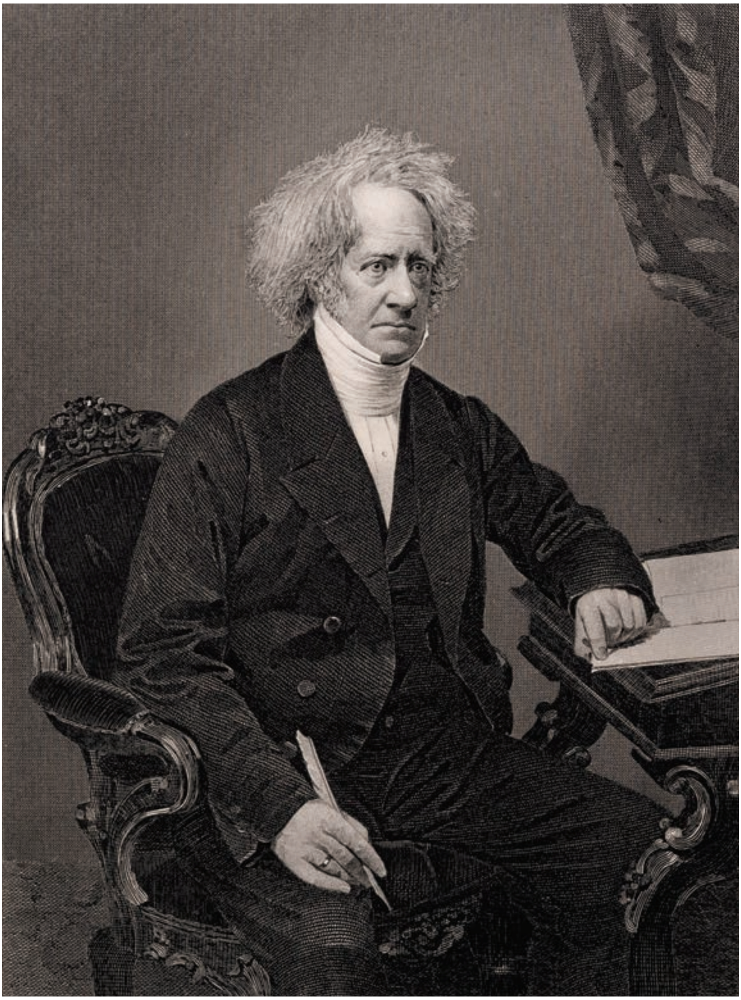


Figure 18. John Frederick William Herschel, 1860s

NOTES

1 On the confrontation between Coleridge and Whewell, see Whewell, "Mrs. Somerville," 59-60; and Ross, "Scientist."

2 Whewell to Faraday, October 14, 1837, in James, *Correspondence of Michael Faraday,* vol. 2, 464.

3 Faraday to Whewell, April 24, 1834, in Ross, *Nineteenth Century Attitudes,* 150. See also Ross, "Faraday Consults the Scholars."

4 Whewell to Faraday, April 25, 1834, and May 5, 1834, in Todhunter, *William Whewell,* vol. 2, 178-181 and 181-183.

5 See letters Whewell to Lyell, January 31, 1831, February 19, 1831, and February 22, 1831, in Todhunter, *William Whewell,* vol. 2, 109-114.

6 For more on these men and their transformation of science, see Snyder, *Philosophical Breakfast Club*.

7 Stair Douglas, *Correspondence of William Whewell*, 50.

8 See correspondence between Herschel and Babbage in the summer of 1812, John Herschel Papers (RS HS): 2.1, 2.2, 2.3, 2.358, 20.4, 2.4.

9 Forster to Whewell, December 24, 1841, in Todhunter, *William Whewell,* vol. 1, 6.

10 M. Edgeworth to C. Sneyd Edgeworth, May 1, 1813, in Edgeworth, *Life and Letters,* vol. 1, 91; and Wright, *Alma Mater,* vol. 1, 83.

11 Reported in Jones to Whewell, March 9, 1831, Whewell Papers (WP) Add.ms.c.52 f. 27.

12 Whewell, "Prefatory Notice," *Literary Remains.* See also Whewell to Jones, June 19, 1818, WP Add.ms.c.51 f. 2.

13 For more on Bacon and his inductive method, see Snyder, "Renovating the *Novum Organum.*"

14 Descartes, *Principles of Philosophy,* vol. 2, 36, quoted in Garber, *Descartes's Metaphysical Physics,* 200. For an excellent discussion of this topic, see Garber, chapter 9.

15 Bacon, *Novum Organum*, aphorism 19.

16 Bacon, *Novum Organum*, aphorism 95.

17 Ibid, aphorism 20.

18 For more on debates about political economy in Britain in the nineteenth century, see Snyder, *Philosophical Breakfast Club,* chapter five; and Snyder, *Reforming Philosophy,* chapter five.

19 De Quincey, "Confessions," 371.

20 Jones, *Distribution of Wealth*, vii.

21 Cannon, "John Herschel."

22 Darwin, *Autobiography*, 67.

23 On this point, see Farrington, *Francis Bacon*, 38, 44-45.

24 Herschel, *Preliminary Discourse*, 73.

25 See Croarken, "Tabulating the Heavens."

26 Quoted in Swade, *The Difference Engine,* 13.

27 See Swade, 37-38; the quote is on 38..

28 Babbage, "Preface to the 3rd Edition" of "Thoughts on the Principles of Taxation," *Works of Charles Babbage,* vol. 5, 32-56; quoted, 41.

29 See Bacon, "New Atlantis," in *Works of Francis Bacon*.

30 Babbage, *Decline of Science in England*, 155.

31 Morrell and Thackray, eds., *Gentlemen of Science*, 296.

32 Bacon, *Novum Organum,* aphorism 20.

33 See Sheffield, *Women and Science*, 140.

34 Phillips to Harcourt, August 5, 1836, in Morrell and Thackray, eds., *Gentlemen of Science,* 233.

35 Lardner, "Babbage's Calculating Engine," 52.

36 See Sobel, *Longitude*.

37 See Francis Baily to Herschel, April 22, 1832, RS: HS 3.109; Herschel to Baily, April 24, 1832, RS: HS 3.110; and Herschel to John Lubbock, May 16, 1833, RS: HS 21.136.

38 Herschel to Gilbert, July 1, 1830, RS: HS 25.1.5.

39 Herschel, diary entry, October 15, 1838; quoted in Cawood, "The Magnetic Crusade," 509.

40 Bromley, "Difference and Analytical Engines," 67.

41 See Swade, *The Difference Engine*, 67-69.

42 Whewell to Herschel, July 25, 1841, RS: HS 18.196.

43 See Morrell and Thackray, *Gentlemen of Science: Early Years,* 313-24.

44 See Crosland, *Science Under Control,* 30; and Hall, *All Scientists Now,* 39-40.

45 Maxwell, "Whewell's Writings and Correspondence," 206.

46 Snow, "The Two Cultures," 3.

47 Whewell to Jones, August 4, 1821, in Todhunter, *William Whewell,* vol. 2, 43.

48 See Herschel, *Preliminary Discourse,* 134; Babbage, *Economy of Machinery and Manufactures,* in *Works of Charles Babbage,* vol. 8, pp. 115-17; Whewell, *Suggestions for Persons*. Whewell also gave instructions for tidal observation to the audiences of his public lectures at the meetings of the BAAS; on this see Morrell and Thackray, *Gentlemen of Science: Early Years,* 513-14.

49 University of Michigan. "US public's knowledge." See also Miller, "Public Understanding of Science."

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FIGURES

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