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The Hedgehog, the Fox and the Magister's Pox

Stephen Jay Gould

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About the Author

Stephen Jay Gould was the Alexander Agassiz Professor of Zoology and Professor of geology at Harvard and the curator for invertebrate palaeontology in the university's Museum of Comparative Zoology. He died in May 2002.

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For the American Association for the Advancement of Science (AAAS), a truly exemplary organization, serving so well as the “official” voice of professional science here and elsewhere. With thanks for allowing me to serve as their president and then chairman of the board during the millennial transition of 1999–2001. This book began as my presidential address in 2000. The address is then traditionally published in *Science* magazine, the association’s official organ, and America’s best general journal for scientific professionals. And with apologies to the editor, Don Kennedy, one of the finest people I have ever known in the world of intellectuals. I promised to follow the tradition, but failed because I soon realized that I needed to write at greater length than I could ever ask you to publish. Thus, I now present the printed version of my presidential address (obviously greatly expanded, for I did not filibuster on your podium), and I dedicate this book to AAAS. It was truly a pleasure and privilege to serve—a line often intoned as the boilerplate of a meaningless cliché, but stated, this time in a heartfelt manner, by a quintessential non-joiner who enjoyed the work and truly gained more than he could ever give.

Stephen Jay Gould

THE HEDGEHOG, the FOX, and the MAGISTER'S POX

Mending and minding the misconceived gap between science and the humanities

A Note to the Reader

The Hedgehog, The Fox, and the Magister's Pox is the last of the seven books that Stephen Jay Gould contracted to write for Harmony Books. It was my privilege to be his editor, and it is an honor to have been asked to write a brief note for this signal volume.

Several years ago, I received a catalog for an auction of decommissioned museum pieces. Being especially interested in amber and fossils, I flipped through the catalog pages, marveling at the amazing variety of pieces that included triplets of trilobites and other vanished creatures frozen in tumbling poses like puppies in strange prehistoric attitudes of play. In the middle of the catalog, I came upon a letter penned by Charles Darwin to an unknown correspondent. I have an enormous admiration of the great man, instilled in me by dedicated science teachers and by years of reading Gould's essays and books, but I had never imagined that such a relic could be owned and contemplated by a layperson. I had to have it.

Months later, having happily triumphed in the auction, I received the letter, framed with glass on both sides to enable a full view. I was excited, yet, as I tried to read it, was immediately dismayed to find that I could barely make out two words in succession. Darwin's penmanship was atrocious. After poring over the letter and drawing up a map of those words that I felt sure I'd interpreted correctly, juxtaposed with many guesses and question marks and not a few blanks, I still had very little sense of the meaning of my prized possession.

At that time, I was working with Steve on his book *Rocks of Ages*. I mentioned my acquisition as well as my

frustration to him; he was interested to see the letter and generously agreed to try to help me figure it out. He told me that Darwin was renowned for his illegible script and that he was one of the few people who had ever had the talent for deciphering it. This he did for me, writing the missing words on my map in his own (somewhat) clearer hand, along with a couple of notations, reproduced here in brackets.

Down Bromley Kent
Ap 30/81

My Dear Sir

I must send you a line to thank you for your "Ice & Water" which I also saw with interest very much [This sentence doesn't make much sense, so I may well be wrong here. I think everything else is pretty surely right. The "also saw" words are particularly badly scrawled]; though I believe we split a little about solid glacier ice and icebergs.—Thanks, also for extract out of newspaper about Rooks and Crows—[Leslie: This must be right. Darwin was interested in the taxonomy and names of these birds] I wish I dared trust it. I see in cutting pages half-an-hour ago, that you fulminate against the skepticism of scientific men.—You would not fulminate quite so much, if you had had my many wild-goose chases after facts stated by men not trained to scientific accuracy. I often vow to myself that I will utterly disregard every statement made by any man who has not shown the world he can observe accurately. I wish I had space to tell you a curious History, which I was fool enough to investigate on almost universal testimony of Beans growing this year upside down. —I firmly believe that accuracy is the most difficult quality to acquire.—I did not, however, intend to say all this.—I very

thoroughly enjoyed my half-hour's talk at your pleasant House. —I have been corresponding with Mr. Davidson on the genealogy of Brachiopods; and he will someday, I believe, discuss subject as we wish. He has seen Galton's talk of species grouped like a tree. Mr. D is not at all a full believer in great changes of species which will make his work all the more valuable.—I have also written to Mr. Jamison, urging him to take up Glen Roy. My dear Sir Your very sincerely C Darwin

As Steve told me, it's a "nice letter, a good letter, an interesting letter," although not an important letter. "But, it was written only a couple days *before* an important letter." He was happy to have had the opportunity to read it. Along with his translation, he sent me a photocopy of a catalog page and wrote, "This is the author Darwin refers to in your letter—Davidson/Brachiopods. Pretty pricey and a classic work." Indeed, T. Davidson's *British Fossil Brachiopods*, with 234 plates, six volumes in seven, cloth, 1851–86, was priced at 490 pounds sterling about four years ago, confirming another Darwinian prediction.

Steve's death still seems impossible. He was at the fulcrum of so much activity. For almost a decade, I'd been speaking with him and his literary agent, Kay McCauley, about a book he planned to write, centered on the intense, early twentieth-century correspondence, which he owned, of two paleontologists. He also planned to write about realized geniuses unrecognized in their time. But these are the unrealized books of a recognized genius. It is a tragedy for readers that we have lost Stephen Jay Gould, the great writer, the irreplaceable teacher, the pioneering researcher and creative thinker, the champion and defender of scientific education. Even given the wealth of brilliant work he has left us, his death is made worse by our loss of his unwritten thoughts, his unrecorded insights, the

connections that only he could make, but had yet to make. To borrow a verse, “Gould thou shouldst be living at this hour, The world hath need of thee . . .”

Yet Stephen Jay Gould has indisputably left behind many great treasures, one of the last of which you hold in your hands. *The Hedgehog, the Fox, and the Magister’s Pox* is of particular interest because it is an original book, not a collection of his previously published essays from *Natural History* magazine, and his last book on natural history. *Triumph and Tragedy in Mudville*, his baseball memoir, also remains to be published. Steve also left his biological family, his many friends, an extended family of students, colleagues, and readers whom he inspired, his intellectual line, which, like the description of evolution in *Full House*, will prove to be “a copiously branching bush with innumerable present outcomes, not a highway or ladder with one summit.”

Steve’s brilliant and challenging works, his amazing energy and insights, and his urge to examine that which had yet to be explained will continue to inspire readers, students, and other scientists for generations to come. In his dedication for his book *Rocks of Ages*, Steve wrote to his two sons that they “will have to hold on beyond their father’s watch.” We, his readers, have to hold on, too, as Steve writes in his preface to this book, to our ethical principles, our commitment to the great experiment of democracy, and our commitment to many paths of intellectual inquiry in the sciences and the humanities “that make our lives so varied, so irreducibly, and so fascinatingly, complex.”

In Stephen Jay Gould’s books, his voice and purpose are beautifully preserved, clearly visible, literary amber. With my Darwin letter, I also acquired several pretty little pieces of amber in which float flower fragments, a flower bud, and a tiny complete flower and leaves. Whenever I look at these bits, I flash to exchanges I had with Steve that revealed his

extraordinary mind, his generosity as a teacher, his joy in discovery and knowledge, and his Darwin-like scrupulousness in observation, writing, and research. I long to hear a disquisition by Steve on these botanicals, just as he translated my Darwin letter and put it into historical context. But it will be up to me to investigate the amber without his guidance and to ferret out the important letter related to my letter, and the evolutionary and humanistic forces they reveal. And it is up to you, the reader, to investigate these final writings of Steve's without his last ministrations and corrections. For Steve died before he could proof the manuscript for this book, before he could double-check his facts and figures, before he could correct the page proofs. So if there are any errors floating in the text, think of them as bits in amber left for you to decipher and puzzle over, and perhaps correct, left by one of the greatest forces in scientific thought and writing with whom we have been privileged to live and from whom we have been privileged to learn for a while, and, through his books, forever.

Leslie Meredith
Senior Editor
November 2002

PREFACE

Introducing the Protagonists

I PREFER THE MORE EUPHONIOUS RUSSIAN BEGINNING FOR FAIRY TALES to our equivalent "once upon a time"—*zhili byli* (or, literally, "lived, was"). Thus I begin this convoluted tale of initial discord and potential concord: "*Zhili byli* the fox and the hedgehog." In his *Historia animalium* of 1551, Konrad Gesner, the great Swiss scholar of nearly everything, drew the initial and "official" pictures of these creatures in the first great compendium of the animal kingdom published in Gutenberg's era. Gesner's fox embodies the deceit and cunning traditionally associated with this important symbol of our culture—poised on his haunches, ready for anything, front legs straight and extended, hindquarters set to spring, ears cocked, and hair erect down the full line of his back. Above all, his face grins enigmatically and throughout, from the erect eyelashes to the long smirk, ending at the tapered nose with widespread whiskers—all seeming to say, "Watch me now, and then tell me if you've ever seen anything even half so clever."

The hedgehog, by contrast, is long and low, all exposed and nothing hidden. Spines cover the entire upper surface of his body; and his small feet neatly fit under this protective mat above. The face, to me, seems simply placid: neither dumb nor disengaged but rather serenely confident in a quiet, yet fully engaged manner.

I suspect that Gesner drew these two animals to emphasize these feelings and associations in a direct and purposeful way. For the *Historia animalium* of 1551 is not a

scientific encyclopedia in the modern sense of presenting factual information about natural objects, but rather a Renaissance compendium for everything ever said or reported by human observers or moralists about animals and their meanings, with emphasis on the classical authors of Greece and Rome (seen by the Renaissance as the embodiment of obtainable wisdom in its highest form), and with factual truth and falsity as, at best, a minor criterion for emphasis. Each entry includes empirical information, fables, human uses, and stories and lists of proverbs featuring the creature in question.

The fox and the hedgehog not only embodied their separate and well-known symbols of cunning versus persistence. They had also, ever since the seventh century B.C., been explicitly linked in one of the most widely known proverbs about animals, an enigmatic saying that achieved renewed life in the twentieth century. Gesner clearly drew his fox and hedgehog in their roles as protagonists in this great and somewhat mysterious motto.

In Gesner's time, and ever since for that matter, any scholar in search of a proverb would turn immediately to the standard source, the Bartlett's beyond compare for this form of quotation: the *Adagia* (adages, or proverbs) compiled, and first published in 1500, by the greatest intellectual of the Renaissance, Erasmus of Rotterdam (1466–1536). Gesner, of course, directly used and credited Erasmus's exhaustive discussion of the linking proverb in both his articles, *De Vulpe* (on the fox) and *De Echino* (on the hedgehog) of his 1551 founding treatise.

This somewhat mysterious proverb derives from a shadowy source, Archilochus, the seventh-century B.C. Greek soldier-poet sometimes considered the greatest lyricist after Homer, but known only from fragments and secondary quotations, and not from any extensive writings or biographical data. Erasmus cites, in his universalized Latin, the Archilochian contrast of fox and hedgehog: *Multa*

novit vulpes, verum echinus unum magnum (or, roughly, “The fox devises many strategies; the hedgehog knows one great and effective strategy”).

I use this well-trodden, if enigmatic, image in two important ways (and in the book’s title as well) to exemplify my concept of the proper relationship between the sciences and humanities. I could not agree more with the vital sentiment expressed by my colleague E. O. Wilson (although Part III of this book will also explain my reasons for rejecting his favored path toward our common goal): “The greatest enterprise of the mind has always been and always will be the attempted linkage of the sciences and the humanities” (from his book *Consilience*, Knopf, 1998, page 8). I use Archilochus’s old image, and Erasmus’s extensive exegesis, to underscore my own recommendations for a fruitful union of these two great ways of knowing. But my comparison will not be based on the most straightforward or simpleminded comparison. That is, I emphatically *do not claim* that one of the two great ways (either science or the humanities) works like the fox, and the other like the hedgehog.

Of my two actual usages, the first is, I confess, entirely idiosyncratic, fully concrete, and almost as enigmatic as the proverb itself. That is, I shall refer, in a crucial argument, to the specific citation of Erasmus’s explication of Archilochus’s motto as preserved in one particular copy of Gesner’s 1551 book. Moreover, although I regale you with foxes and hedgehogs in this introduction, this first usage will now disappear completely from the text until the very last pages, when I cite (and picture) this passage to make a closing general point with specific empirical oomph. As to the equally mysterious Magister who shares titular space with the fox and hedgehog, he will make a short intermediary appearance (in chapter 4) and then also withdraw until his meeting with the two animals on the closing pages.

But my second usage pervades the book, although I try to keep explicit reminders to a bearable minimum (an effort demanding great forbearance, and courting probable failure in any case, from such a didactic character as yours truly). This second employment also sticks closely to the metaphorical meanings that have been grafted upon Archilochus's image throughout history, especially since Erasmus's scholarly exegesis. This usage became central to twentieth-century literary commentary when Isaiah Berlin —my personal intellectual hero, and a wonderful man who befriended me when I was a shy, beginning, absolute nobody—invoked the pairing of fox and hedgehog to contrast the styles and attitudes of several famous Russian writers. Ever since then, scholars have played a common game in designating their favorite (or anathematized) literati either as hedgehogs for their tenacity in sticking to one style or advocating one key idea, or as foxes for their ability to move again and again, like Picasso, from one excellence to an entirely different mode and meaning of expression. The game maintains sharp edges because these attributions have been made both descriptively and proscriptively, and people of goodwill (and bad will too, for that matter) can argue forever about either and both. (I must also confess that I named one of my books of essays *An Urchin in the Storm*, to designate my own stubborn invocation of Darwinian evolution as a subject to fit nearly any context or controversy. Hedgehogs, to Englishmen, are urchins.)

Erasmus (and I am quoting from my 1599 edition of his *Adagia*) begins with the usual and obvious reasons for Archilochus's famous contrast. When pursued by hunters, the fox figures out a new and sneaky way to escape each time: *Nam vulpes multijugis dolis se tuetur adversus venatores* (for the fox defends itself against the hunters by using many different guiles). The hedgehog, on the other hand, tries to keep out of harm's way, but will use its one

great trick if overtaken by the hunters' dogs: the animal rolls up into a ball, with its small head and feet, and its soft underbelly, tucked up neatly and completely within the enclosing surface of spines. The dogs can do what they wish: poke the animal, roll it about, or even try to bite, but all to no avail (or to painful injury); for the dogs cannot capture such a passive and prickly ball, and must ultimately leave the animal alone, eventually (when the danger has passed) to unroll and calmly walk away. Erasmus writes: *Echinus unica dun-taxat arte tutus est adversus canum morsus, siquidem spinis suis semet involuit in pilae speciem, ut nulla ex parte morsu, prendi queat*. (The hedgehog only has one technique to keep itself safe against the dogs' bite, since it rolls itself up, spines outward, into a kind of ball, so that it cannot be captured by biting.)

Later on in this exegesis, Erasmus even adds an old tale of intensification, delicately mentioning only the outline of the story, and referring his readers to the original sources if they wish to know more. If this one great trick seems to be failing, the hedgehog often ups the same basic ante by letting fly a stream of urine, covering the spines, and weakening them to the point of excision. But how can this dramatic form of self-imposed haircut help the creature? Erasmus goes no further, but when we turn to Pliny and Aelianus (the two classical sources cited by Erasmus), we learn what a tough and determined little bastard this apparently timid creature can be. The ultimate urine trick, we are told, can work in three possible ways. First, with the spines excised, the animal can often slither away unnoticed. Second, the urine smells so bad that the dogs or human hunters may simply lose interest and beat a quick retreat. Third, if all else fails, and the hunters take him anyway, at least the hedgehog can enjoy his last laugh in death, for his haircut has rendered him useless to his captors (who, in a fourth potential utility, might also abandon him in frustration by recognizing this outcome in

advance)—for the main attraction of the hedgehog to humans lies in the value of his hide, but only with spines intact, as a natural brush.

The power and attraction of Archilochus's image lies, rather obviously, in its two levels of metaphorical meaning for human contrasts. The first speaks of psychological styles, often applied for quite practical goals. Scramble or persist. Foxes owe their survival to easy flexibility and skill in reinvention, to an uncanny knack for recognizing (early on, while the getting remains good) that a chosen path will not bear fruit, and that either a different route must be quickly found, or a new game entered altogether. Hedgehogs, on the other hand, survive by knowing exactly what they want, and by staying the chosen course with unswerving persistence, through all calumny and trouble, until the less committed opponents eventually drop away, leaving the only righteous path unencumbered for a walk to victory.

The second, of course, speaks to favored styles of intellectual practice. Diversify and color, or intensify and cover. Foxes (the great ones, not the shallow or showy grazers) owe their reputation to a light (but truly enlightening) spread of real genius across many fields of study, applying their varied skills to introduce a key and novel fruit for other scholars to gather and improve in a particular orchard, and then moving on to sow some new seeds in a thoroughly different kind of field. Hedgehogs (the great ones, not the pedants) locate one vitally important mine, where their particular and truly special gifts cannot be matched. They then stay at the site all their lives, digging deeper (because no one else can) into richer and richer stores from a mother lode whose full generosity has never before been so well recognized or exploited.

I use the fox and hedgehog as my model for how the sciences and humanities should interact because I believe that neither pure strategy can work, but that a fruitful

union of these seemingly polar opposites can, with goodwill and significant self-restraint on both sides, be conjoined into a diverse but common enterprise of unity and power. The way of the hedgehog cannot suffice because the sciences and humanities, by the basic logics of their disparate enterprises, do different things, each equally essential to human wholeness. We need this wholeness above all, but cannot achieve the goal by shearing off the legitimate differences (I shall critique Wilson's notion of consilience on this basis) that make our lives so varied, so irreducibly, and so fascinatingly, complex. But if we lose sight of the one overarching goal—the hedgehog's insight—underneath the legitimately different concerns and approaches of these two great ways, then we are truly defeated, and the dogs of war will disembowel our underbellies and win.

But the way of the fox cannot prevail either, because too great a flexibility may lead to survival of no enduring value—mere persistence with no moral or intellectual core intact. What triumph can an ultimate chameleon claim if he gains not even the world, but only his basic continuity, at the price of his soul? Fortunately, and in the most parochial American sense, we know a model of long persistence and proven utility for the virtues in fruitful union of apparent opposites. This model has sustained us through the worst fires of challenge (both voluntary self-immolation from 1861 to 1865, and attempted external prevention at several times, beginning with the first battles of 1775).

We have even embodied this ideal in our national motto, *e pluribus unum*, "one from many." If the different skills and wondrous flexibilities of the fox can be combined with the clear vision and stubbornly singleminded goal of the hedgehog, then a star-spangled banner can protect a great expanse of maximal diversity because all the fox's skills now finally congeal to realize the hedgehog's great vision. Never before in human history has the experiment of

democracy been tried across such a vast range of geographies, climates, ecologies, economies, languages, ethnicities, and capabilities. Lord knows we have suffered our troubles, and imposed horrendous and enduring persecutions upon sectors of the enterprise, thus sullying the great goal in the most shameful way imaginable. Yet, on balance, and by comparison to all other efforts of similar scale in human history, the experiment has worked, and has been showing substantial improvement in the course and memories of my lifetime at least.

I offer the same basic prescription for peace, and mutual growth in strength, of the sciences and humanities. These two great endeavors of our soul and intellect work in different ways and cannot be morphed into one simple coherence, so the fox must have his day. But the two enterprises can lead us onward together, ineluctably yoked if we wish to maintain any hope for arrival at all, toward the common goal of human wisdom, achieved through the union of natural knowledge and creative art, two different but nonconflicting truths that, on this planet at least, only human beings can forge and nurture.

But I learned one other important lesson from reading Erasmus's commentary, and by considering the deeper meaning of Gesner's pictures. Erasmus does, following the literal lead of Archilochus's minimality, depict the styles of the fox and hedgehog as simply different, with each strategy effective in its own way, and expressing one end of a full continuum. But Erasmus clearly favors the hedgehog in one crucial sense: foxes generally do very well indeed, but when the chips go down in extremis, look inside yourself, and follow the singular way that emerges from the heart and soul of your ineluctable being and construction, whatever the natural limits—for nothing beats an unswerving moral compass in moments of greatest peril.

Erasmus, after praising the many wiles of the fox (as quoted above), then adds *et tamen haud raro capitur*—"yet,

nonetheless, it is captured not rarely." The hedgehog, on the other hand, almost always emerges unscathed, a bit stressed and put-upon, perhaps, but ultimately safe nonetheless. And thus intellectuals of all stripes and tendencies must maintain this central integrity of no compromise to fashion or (far worse) to the blandishments of evil in temporary power. We have always been, and will always be, a minority. But if we roll with the punches, maintain the guts of our inner integrity, and keep our prickles high, we can't lose—for the pen, abetted by some modern modes of dispersal, really is mightier.

Finally, I don't mean to despise or dishonor the fox, and neither does Erasmus, despite his clear zinger, quoted just above, against this ultimate symbol of wiliness. For Erasmus ends his long and scholarly commentary with two stories about dialogues between the fox and another brother carnivore. The first tale of the fox and cat simply extends Erasmus's earlier point about the hedgehog's edge in episodes of greatest pith and moment. The two animals meet and begin to argue about better ways to elude packs of hunting dogs. The fox brags about his enormous bag of tricks, while the cat describes his single effective way. Then, right in the midst of this abstract discussion, the two creatures must face an unexpected and ultimately practical test: "Suddenly, amidst the dispute, they hear the voices of the dog pack. The cat immediately leaps up into the highest tree, but the fox, meanwhile, is surrounded and captured by the crowd of dogs." *Praestabilius esse nonnunquam unicum habere consilium* (perhaps it is better to have one way of wisdom), Erasmus adds, *id sit verum et efficax* (provided that it be true and effective).

But the second tale of the fox and panther saves our maligned character and shows the inner beauty of his flexibility, as illustrated by his avoidance of mere gaudy show for true dexterity of mind. Erasmus writes:

Cum aliquando pardus vulpem pre se contemneret, quod ipse pellem haberet omnigenus colorum maculis variegatem, respondit vulpes, sibi decoris in animo esse, quod ille esset in cute.

"When the panther disparages the fox by comparison to himself, because his [the panther's] skin is so beautifully variegated with so many colored spots of all kinds, the fox responds that it is better to be so decorated in the mind than upon the skin."

And so I say to the sciences (where I reside with such lifelong pride and satisfaction) and to the humanities (whose enduring technique of exegesis from printed classical sources I try, in my own conceit, to utilize as the primary mode of analysis in this book): what a power we could forge together if we could all pledge to honor both of our truly different and equally necessary ways, and then join them in full respect, in the service of a common goal as expressed in old Plato's definition of art as intelligent human modification and wondrous ornamentation, based on true veneration of nature's reality. For then, as the Persian poet said:

Oh wilderness were Paradise enow.

Then wilderness (nature's unvarnished tangle of wonders) would become a paradise (literally, a cultivated garden of human delight).

The goal could not be greater or more noble, but the tensions are old and deep, however falsely construed from the start, and stirred up by small minds ever since. Thus the union of the fox and hedgehog can certainly be accomplished, and would surely yield, as progeny, a many-splendored thing called love and learning, creativity and knowledge. But we had best proceed, in this hybridization, by the resolution of a bad old joke about an animal not

closely related to the hedgehog, but functionally equivalent in the primary manner of this discussion. How, using more decorous language than the joke enjoins, can two porcupines copulate? The answer, of course, is “carefully.”

I

THE RITE AND RIGHTS OF A SEPARATING SPRING

1

Newton’s Light

THE EPITAPH CZAR of Westminster Abbey must have demurred, for the great man’s grave does not bear these intended words. But Alexander Pope did write a memorable (and technically even heroic) couplet for the tombstone of his most illustrious contemporary. Biblical parodies, perhaps, could not pass muster in Britain’s holiest of holies, both sacred and secular,[1] for Pope’s epitome of a life well lived recalled the first overt order of the ultimate boss:

> Nature and Nature’s laws lay hid in night:
> God said, let Newton be! and all was light.

Pope surely wins first prize for succinctness and rhyme, but we may cite any number of statements from the wisest of his contemporaries to the best of later scholars, all affirming that something truly special roiled the world of seventeenth-century thinkers, changing the very definitions of knowledge and causality, and achieving a beginning of control over nature (or at least predictability of her ways) that previous centuries had not attained or, for the most part, even sought. Although hard to define, and even denied by some, this transforming period has been awarded the two ultimate verbal accolades by a generally timid profession of academic historians: the definite article for uniqueness, and uppercase designation for importance. Historians generally refer to this watershed of the seventeenth century as the Scientific Revolution.

To cite a key contemporary, a poet rather than a scientist, at least by current disciplinary allocations that would not then have been granted or conceptualized in the same way, John Dryden wrote in 1668:

> Is it not evident, in these last hundred years (when the Study of Philosophy has been the business of all the Virtuosi in Christendome) that almost a new Nature has been revealed to us? That more errors of the School [that is, of the medieval scholastic thinkers and followers of Thomas Aquinas, generally called Schoolmen] have been detected, more useful Experiments in Philosophy have been made, more Noble Secrets in Opticks, Medicine, Anatomy, Astronomy, discovered than in all those credulous and doting Ages from Aristotle to us? So true it is that nothing spreads more fast than Science, when rightly and generally cultivated.

To cite one of the twentieth century's most celebrated philosophers, A. N. Whitehead claimed, in *Science and the Modern World*, that "a brief, and sufficiently accurate description of the intellectual life of the European races during the succeeding two centuries and a quarter up to our own times is that they have been living upon the accumulated capital of ideas provided for them by the genius of the seventeenth century."

A broader range of views could be cited among historians of science, but few would deny that truly extraordinary changes in concepts of natural order—changes that we continue to recognize today as the familiar bases of modern sensibilities—occurred in seventeenth-century Europe, leading to the enterprise that we call "science," with all attendant benefits, travails, and transformation in our collective lives and societies.

In 1939, Alexander Koyré, the dean of twentieth-century students of the Scientific Revolution, described this seventeenth-century transformation as a "veritable 'mutation' of the human intellect . . . one of the most important, if not the most important, since the invention of the Cosmos by Greek thought." The Scientific Revolution, according to the eminent historian Herbert Butterfield (1957), "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." And, in 1986, historian of science Richard S. Westfall stated: "The Scientific Revolution was the most important 'event' in Western history. . . . For good and for ill, science stands at the center of every dimension of modern life. It has shaped most of the categories in terms of which we think, and in the process has frequently subverted humanistic concepts that furnished the sinews of our civilization."

In the cartoonish caricature of a "one-line" primer, the Scientific Revolution boasts two philosophical founders of the early seventeenth century—the Englishman Francis Bacon (1561–1626), who touted observational and experimental methods, and the Frenchman René Descartes (1596–1650), who promulgated the mechanical worldview. Galileo (1564–1642) then becomes the first astoundingly successful practitioner, the man who discovered the moons of Jupiter, rearranged the cosmos with a raft of additional telescopic defenses of Copernicus, and famously proclaimed that the "grand book" of nature—that is, the universe—"is written in the language of mathematics, and its characters are triangles, circles, and other geometrical figures." (Galileo's status as martyr to the Roman Inquisition—for he spent the last nine years of his life under the equivalent of "house arrest," following his forced recantation in 1633—also, and justly, enhances his role as a primary hero of rationality.) But the culmination, both in

triumphant practice and in fully formulated methodology, resides in a remarkable conjunction of late-seventeenth-century talent, a generation epitomized and honored with the name of its preeminent leader, Isaac Newton (1642–1727), who enjoyed the good fortune of coexistence with so many other brilliant thinkers and doers, most notably Robert Boyle (1627–1691), Edmund Halley (1656–1742), and Robert Hooke (1635–1703).

As with all caricatures based on simplistic historical models of accreting "betterness" (whether by smoothly accumulating improvement or by discontinuous leaps of progress), and on false dichotomies of a bad "before" replaced by a good "after," this description of the Scientific Revolution cannot survive a careful scrutiny of any major aspect of the standard story. To cite just two objections with pedigrees virtually as long as the conventional formulation itself: First, the break between the supposedly benighted Aristotelianism of medieval and Renaissance scholarship, and the experimental and mechanical reforms of the Scientific Revolution, can be recast as far more continuous, with many key insights and discoveries achieved long before the seventeenth century, and abundantly transmitted across the supposed divide. In an early rebuttal that became almost as well known as the basic case for a discontinuous revolution, the French scholar Pierre Duhem, in the opening years of the twentieth century, published three volumes on Leonardo and his precursors. Here Duhem argued that several cornerstones of the Scientific Revolution had been formulated by Aristotelian scholars in fourteenth-century Paris, and had also become sufficiently familiar and accessible that even the formally ill-educated Leonardo, albeit the most brilliant raw intellect of his (or any other) age, sought out and utilized this work, often struggling with Latin texts that he could only read in a halting fashion, as the foundation for his own views of nature. (Duhem

developed his thesis under a complex *parti pris* of personal belief, including strong nationalistic and Catholic elements, but his predisposing biases, although markedly different from the *a priori* commitments of historians who built the conventional view, cannot be labeled as stronger or more distorting.)

Second, and in an objection close to the heart of my own persona and chosen profession, the conventional view does seem more than a tad parochial in its nearly exclusive focus on the physical sciences, and upon the kinds of relatively simple problems solvable by controlled experiment and subject to reliable mathematical formulation. What can we say about the sciences of natural history, which underwent equally extensive and strikingly similar changes in the seventeenth century, but largely without the explicit benefit of such experimental and mathematical reconstitution? Did students of living (and geological) nature merely act as camp followers, passively catching the reflected beams of victorious physics and astronomy? Or did the Scientific Revolution encompass bigger, and perhaps more elusive, themes only partially and imperfectly rendered by the admitted triumphs of new discovery and discombobulations of old beliefs so evident in seventeenth-century physics and astronomy? (Because these questions intrigue me, and because my own expertise lies in this area, I shall choose my examples almost entirely from this neglected study of the impact of the Scientific Revolution upon natural history.)

I derived much of the framework, and many of the quotations, for this opening section from the long and excellent treatise of H. Floris Cohen (*The Scientific Revolution: A Historiographical Inquiry*, University of Chicago Press, 1994), a work not so much about the content of the Scientific Revolution as about the construction of the concept by historians. Cohen locates much of the difficulty in defining this episode, or any other

major “event” in the history of ideas for that matter, in the complex and elusive nature of change itself. We encounter enough trouble in trying to define and characterize the transformation of clear material entities—the evolution of the human lineage, for example. How shall we treat major changes in our approach to the very nature of knowledge and causality? Cohen writes: “To strike the proper balance between a perception of historical events as relatively continuous or relatively discontinuous has been the historian’s task ever since the craft attained maturity in the course of the nineteenth century.” The Scientific Revolution becomes so elusive in the enormity of its undeniable impact that Steven Shapin, something of an *enfant terrible* among conventional academicians, opened his iconoclastic, but much respected, study (*The Scientific Revolution*, University of Chicago Press, 1996), with a zinger rich in wisdom within an apparent self-contradiction: “There was no such thing as the Scientific Revolution, and this is a book about it.”

We may epitomize the fundamental nature of an episode so fecund in scope and effect, albeit so difficult to characterize, by citing any preferred motto or metaphor in the tradition of “crossing the Rubicon” or “opening Pandora’s box.” Something tumultuous, permanent, and revolutionary, both for the history of society and the history of ideas, occurred during the course of the seventeenth century. And we may epitomize this extended “event” as the birth pangs and adequate initial development of what we call “modern science,” with all its practical consequences for technology, and its intellectual implications for our definition and understanding of “reality” itself. Something happened. Something very big indeed, yet something that we have still not integrated fully and comfortably into the broader fabric of our lives, including the dimensions—humanistic, aesthetic, ethical, and theological—that science cannot resolve, but that