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ABOUT THE BOOK

Stephen Jay Gould's writing remains the modern standard by which popular science writing is judged. Ever since the last 1970s, his monthly essay in *Natural History* and his full-length books have bridged the yawning gap between science and the wider culture. This fascinating new collection of essays contains some of Gould's best writing on a variety of subjects ranging from Leonardo da Vinci and Martin Luther to fossils and the history of science. As always, these essays brilliantly display his gift for colloquial and vivid explanation, and include fascinating oddities from the natural world and the printed word.

ABOUT THE AUTHOR

Stephen Jay Gould is the Alexander Agassiz Professor of Zoology and Professor of Geology at Harvard University, and the Vincent Astor Visiting Professor of Biology at New York University. His publications include *Ever Since Darwin*, *Wonderful Life*, *Eight Little Piggies*, *Life's Grandeur* and, most recently, *Questioning the Millennium*.

ALSO BY STEPHEN JAY GOULD

Ontogeny and Phylogeny

Ever Since Darwin

The Panda's Thumb

The Mismeasure of Man

Hen's Teeth and Horse's Toes

The Flamingo's Smile

An Urchin in the Storm

Time's Arrow, Time's Cycle

Illuminations

(with R. W. Purcell)

Wonderful Life

Bully for Brontosaurus

Finders, Keepers

(with R. W. Purcell)

Eight Little Piggies

Dinosaur in a Haystack

Life's Grandeur

Questioning the Millennium

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TO RAY SIEVER
AND TO THE MEMORY OF BERNIE KUMMEL,
two dear colleagues and friends
who nurtured (and protected)
a young pain in the ass
and helped him to become a scientist

LEONARDO'S MOUNTAIN OF CLAMS AND THE DIET OF WORMS

Essays on Natural History

Stephen Jay Gould

VINTAGE BOOKS
London

Introduction

PIECES OF EIGHT: CONFESSION OF A HUMANISTIC NATURALIST

I CAN EASILY UNDERSTAND WHY, FOR MOST NATURALISTS, THE HIGHEST form of beauty, inspiration, and moral value might be imputed to increasingly rare patches of true wilderness—that is, to parcels of nature devoid of any human presence, either in current person or by previous incursion. When we recognize that all but the last geological eyeblink of life’s history evolved in competence and fascination (but to whose notice?) before humans intruded upon the scene—and when we acknowledge that most of our substantial incursions cannot be viewed as fortunate either for local organisms or environments—why should we not glory in bits of space that have perpetuated a 4.5-billion-year tradition of noninterference by any self-conscious agency? (As I do not wish to engage the theological dimensions of the last sentence, I will restrict my meaning to overt “footprints” of undeniable physical presence.)

I do have a confession to make in this context. My odd attitude may arise only from the happenstance of my birth and happy childhood in New York City, when safe subways cost a nickel, museums were free, and the Yankees, led by Joe DiMaggio, ruled the world. Wordsworth’s wisdom cannot be gainsaid. Childhood’s sense of wonder cannot be sustained in the same manner through life, but the child is father to the man. So childhood’s “splendor in the grass” and “glory in the flower” must set a lifelong prototype for aesthetic wonder. And my early epiphanic moments

included the view of Lower Manhattan's buildings at sunset, seen from the magnificent walkway in the center of the Brooklyn Bridge; the growing tip of Manhattan as the Staten Island Ferry (also only a nickel) passes the Statue of Liberty and heads for the Battery; the lobbies of the Woolworth and Chrysler buildings (each, in turn and temporarily, the tallest skyscraper in the world); and the building line of the surrounding city, seen in winter from the middle of Central Park through bare tree branches.

I am not speaking here, by absurd dichotomy, of city versus wilderness, with a personal preference for the former based on accidents of upbringing. Rather, the dichotomy itself has no meaning, if only because "pure" examples of either extreme scarcely exist when plastic flotsam pervades the seas, and twisted jetsam washes up on the beaches of every isolated and uninhabited Pacific island; and when almost every spot perceived with rapture as "virgin" wilderness (at least here in northeastern America) really represents old farmland reclaimed by new forest. No satanic "purity" marks the other end either, except in science fiction scenarios. We do not build cities without parks, streets without trees, homes without gardens. At a bare minimum, bits of nature's diversity still burst through, if only as rats by the garbage piles, cockroaches in the kitchen, mushrooms through the pavement, weeds galore in the lot, and bacteria everywhere—to cite all major kingdoms of life in the big city.

For whatever reasons of childhood's happenstances and gifts of temperament, I am a humanist at heart, and I love, best of all, the sensitive and intelligent conjunction of art and nature—not the domination of one by the other. We want, in our wondrously diverse world, a full spectrum of interactions from near wilderness to near artificiality, but I will seek my own aesthetic optimum right in the middle, where human activity has tweaked or shaped a landscape, but with such respect and integration that a first glance may detect no fault line, no obvious partitioning: the wooded

hillslope adjoining Kiyomizudera in Kyoto, where the gorgeous scene looks so perfectly “rustic” and untouched until you realize that every tree has been selected, pruned, and trained; the genius of Olmsted’s big city parks, with their sculpted diversity of “natural” landscapes crisscrossed by a respectful system of constructed pathways, built of local stones artificially rusticated if necessary; the smooth transition between a Chinese “scholar’s rock” (selected for calming contemplation based on the fortune of naturally formed beauty, but usually sculpted a bit to enhance the appearance), and the wooden stand expressly carved to accommodate every random bump and crevice of the stone above; and the Hopi pueblo towns, built of local rocks as a layer on the tops of mesas made of horizontal strata, so that the town, from a distance, can hardly be distinguished from the natural layers below, a village marked as a human construction only by vertical ladders protruding from the tops of kivas.

I even believe—though I would not push the point, for the concept can too easily cede to human arrogance and a discounting of natural forms—that intelligent reconstruction can “improve” upon natural design (though only by the criterion of human aesthetic preference, the most parochial of all possible judgments). I do ally myself with the most famous quatrain of Omar Khayyám’s *Rubáiyát* (in FitzGerald’s Victorian version), a passage usually misinterpreted today because the subjunctive mood has virtually disappeared from modern English:

*A Book of Verses underneath the Bough,
A Jug of Wine, a Loaf of Bread—and Thou
Beside me singing in the Wilderness—
Oh, Wilderness were Paradise enow!*

That is, if you would join me in the wilderness, and we could share good reading, food, drink (and perhaps more), then

even the ugly, scary, untamed forest would become a paradise, literally a lovely *enclosed and cultivated garden*. (The old subjunctive of the last line must be read: “Even wilderness *would be* close enough to paradise” if you and all the accoutrements would join me there.) After all, in many cultures, wilderness (with an etymology of “wild beast”) denotes fear and foreignness, while human cultivation tames a landscape to beauty and peace of soul. (I also love the old legend—maybe it’s even true—that Eugene O’Neill changed Omar’s last line to “Ah, Wilderness!” so that the title for his marvelous coming-of-age play would appear first in *The New York Times*’s alphabetical list of Broadway shows.)

I make this humanistic confession (or profession, really) because I have tried, in the prefaces to each of my essay volumes (this is the eighth in a series that will reach ten before the millennium calls a halt), to figure out how the present effort differs from (and, I hope, builds upon) the varying themes of preceding books. I began with emphasis on evolutionary basics, proceeded to evolutionary implications, social and philosophical usages, the interaction of predictive rules with contingent history to form the unique and surprising patterns of life’s history, and the interaction of human history with natural environments.

This eighth volume, as usual, includes all these themes, but differs in emphasis primarily in my own increasing comfort with my unconventional approach to “natural history” writing, as outlined above. If any overarching theme pervades this body of writing (now standing at 270 successive monthly essays), I suppose that a groping effort toward the formulation of a humanistic natural history must unite the disparity. I think that I have been reluctant to recognize, address, or even admit this feature, either to myself or to my readers, because such an approach does contravene a deep (and usually unstated) convention in writing about nature. We are supposed to love nature for

itself, and we are, therefore, presumably charged with the task of characterizing and interpreting nature (as she is) so that interested people with less expertise can learn new information and draw appropriate messages, both factual and ethical. Well, I do love nature—as fiercely as anyone who has ever taken up a pen in her service. But I am even more fascinated by the complex level of analysis just above and beyond (and I do mean “abstracted from,” not “better than”)—that is, the history of how humans have learned to study and understand nature. I am primarily a “humanistic naturalist” in this crucial sense.

Of course I yearn for answers to all the puzzles, great and small, that build the order (and wondrous disorder) of nature “out there”—an order that our intellectual ancestors could only read (understandably) as a proof of God’s existence and benevolent intent. And I am convinced that such answers exist, if only to be seen “through a glass darkly,” given the necessary interposition of human history, sociology, and psychology between the “real” world, and any abstractions of disembodied logic that might manipulate and order our observations. (In this sense, no practicing scientist can be a pure “relativist,” although I trust the more sophisticated and self-analytical among us know that “pure” observation, “unsullied” by human foibles and preferences, can only rank as idealized legend.)

But I prefer to emphasize the interaction of this outside world with something unique in the history of life on Earth—the struggle of a conscious and questioning agent to understand the whys and wherefores, and to integrate this knowledge with the meaning of its own existence. That is, I am enthused by nature’s constitution, but even more fascinated by trying to grasp how an odd and excessively fragile instrument—the human mind—comes to know this world outside, and how the contingent history of the human body, personality, and society impacts the pathways to this knowledge.

A map of the roadblocks—imposed by the evolutionary limitations of an instrument clearly not designed for this style of inquiry, and then joined with the improbable and unrepeatable contingencies that built our modern technological society—holds just as much interest as an accurate map of nature's geography. Moreover, a humanistic focus on how we know about nature—rather than an “objective” account, unattainable in any case, of how nature “is”—gives an essayist a “whole ‘nother” level of juicy material, for we lose nothing of the primary topic, the world as we find it, and gain all the foibles and fascination of *how* we find it so.

As another benefit of this humanistic focus, we acquire a surprising source of rich and apparently limitless novelty from the primary documents of great thinkers throughout our history. But why should any nuggets, or even flakes, be left for intellectual miners in such terrain? Hasn't the *Origin of Species* been read untold millions of times? Hasn't every paragraph been subjected to overt scholarly scrutiny and exegesis?

Let me share a secret rooted in general human foibles, and in the faint tinge of anti-intellectualism that has always pervaded American culture. Very few people, including authors willing to commit to paper, ever really read primary sources—certainly not in necessary depth and completion, and often not at all. Nothing new here, but this shortcutting propensity of the ages has been abetted in our “journalistic” era by a lamentable tendency to call experts, rather than to read and ponder—yet another guarantee of authorial passivity before secondary sources, rather than active dialogue, or communion by study, with the great thinkers of our past.

I stress this point primarily for a practical, even an ethical, reason, and not merely to vent my spleen. When writers close themselves off to the documents of scholarship, and rely only on seeing or asking, they become

conduits and sieves rather than thinkers. When, on the other hand, you study the great works of predecessors engaged in the same struggle, you enter a dialogue with human history and the rich variety of our intellectual traditions. You insert yourself, and your own organizing powers, into this history—and you become an active agent, not merely a “reporter.” Then, and only then, can you become an original contributor, even a discoverer, and not only a mouthpiece.

What could be more democratic than the principle that nuggets of real discovery abound in primary sources, located in such accessible places as major university and city libraries, for those willing to do the work and develop the skills. (And there’s the rub. I do, of course, acknowledge the impediment for most Americans that many of these works, representing the ecumenical range of international scholarship, have never been translated into English—a fact that should be a spur to study, and not a barrier.) Good anatomists have told me that novel and important observations can still be made by dissecting a common frog, despite millions of prior efforts spanning several centuries. I can attest that all major documents of science remain chock-full of distinctive and illuminating novelty, if only people will study them—in full and in the original editions. Why would anyone *not* yearn to read these works; not hunger for the opportunity? What a thrill, whatever the outcome in personal enlightenment, to thus engage the greatest thinkers and doers of our past, to thumb the pages of their own printings, to speculate about past readers who pondered the same copies with the differing presuppositions of other centuries, as the candle of nighttime illuminated their silent labor.

Of the six parts in this humanist’s natural history of evolutionary essays, the first four—on art and science, mini-biographies, human prehistory with emphasis on paleolithic cave art, and human history from a naturalist’s standpoint—

emphasize our side, though several focus on particular organisms, as in chapter 9 on giant deer (“Irish elks”) painted on cave walls, chapter 11 on Bahamian land snails for a fable about Columbus, and chapter 12 on the dodo’s fate, made even sadder by human insult added to the ultimate injury of extirpation. The essays of the last two sections—on evolutionary theory, and on perspectives of other organisms—focus on the nonhuman side (again with such exceptions, as chapter 14 on papal statements about evolution, chapter 15 on the contrast of Robert Boyle and Charles Darwin on natural design, and chapter 18 on Percival Lowell versus Alfred Russel Wallace on Martian canals and the true domination of earthly life by bacteria.)

All these essays are grounded in a precious paradox that has defined the best of the genre ever since Montaigne: intimate and accurate detail—the foundation of most good essays—serves as a source of delight in itself, and also as a springboard to discourse about generalities of broadest scope. I would never dare to take on “the nature of truth” by frontal assault and abstract generalization—for fear of becoming an empty, tendentious buffoon, pontificating about the unanswerable and undefinable. But the subject must rivet us, and we can legitimately “sneak up on” (and even genuinely illuminate) this great issue by discussing how Darwin and his creationist American soulmate Dana constructed alternative taxonomies for toothed birds that should not have existed under previous concepts of reality, but had just been discovered as fossils (chapter 5). Similarly, if I tackled “the nature of tolerance” head-on, naked of intriguing and specific illustration, I would sound like a vain preacher crying in the wilderness (negative definition!). But if I confess some childhood humor in juxtaposing, for alliteration as well as content, the Diet of Worms with the Defenestration of Prague (chapter 13), then a seemingly superficial, even ridiculous, union wins

legitimacy for joint illustration, and provides fair access to factual and moral dimensions of the general topic.

These essays probe, arrange, join, and parry the details within a diverse forest of data, located both in nature and in the documents of human struggle—all to access an inherently confusing but infinitely compelling world. As I survey the contents of this eighth volume, I find that I have followed four primary strategies to promote these details into coherent frameworks with sufficient generality to incite an essay.

1. In some cases, an intense study of original sources yields genuine discovery, despite the paradox that materials for a solution have always been patent. The story of nonuse for the giraffe's neck by early evolutionists had not been documented before (chapter 16), and surprising absences often reveal as much as unrecognized presences. I located a new dimension, largely in favor of the "vanquished" Owen and not the "victor" Huxley, in the great hippocampus debate that animated evolutionary discussion in the 1860s (chapter 6). Dana's important theory of cephalization, and its link with his natural theology (in interesting contrast with Darwin's developing alternative), has never been elucidated, in part because Dana scattered his views through so many short and technical papers (chapter 5).

But I am, I confess, most proud of the opening title essay on Leonardo's paleontology. The excellence and prominence of his observations on fossils have been recognized—and dutifully honored in all accounts, popular, textbook, and technical—for more than a century, since the full publication of his private notebooks in the 1880s. But no one had identified the special reasons (based on his own, and largely medieval, views of the earth as analogous to a living body) for his intense focus on fossils, and for the placement of his statements in a codex largely devoted to the nature of water. So these wonderful observations had stood out,

disembodied from context, and misinterpreted as the weird anachronisms of a transcendent and largely unfathomable genius. But the full document of the Leicester Codex sets the proper context, when read in its entirety and understood by the physics of Leonardo's own time.

2. In most cases, I do not report observations never made before, but try to place unfamiliar (or even well-known) items into a novel context by juxtaposition with other subjects not previously viewed as related—invariably in the service of illuminating a general point about the practice of science, the structure of nature, or the construction of knowledge. In reviewing the essays for this volume (not planned as an ensemble when first written, but collected from my monthly series for *Natural History* magazine), I noticed that I had most often made such a juxtaposition by the minimal method of pairing, or contrast between two—perhaps a general mode of operation for the human mind, at least according to several prominent schools of research (discussed here in the context of paleolithic cave art in chapter 8). For example, all the essays in part 2 on mini-biographies, although focusing on one previously unappreciated or misunderstood character, interpret their subject by his contrast with a standard figure—Linnaeus and the eighteenth-century English Jewish naturalist Mendes da Costa (chapter 4), James D. Dana and his British soulmate Darwin (chapter 5), Richard Owen versus T. H. Huxley (chapter 6), and the tragic Russian genius Vladimir Kovalevsky (and his equally tragic and more brilliant wife, Sophia, one of the greatest mathematicians of the nineteenth century) with Darwin on the potential of error to illuminate scientific truth (chapter 7).

Many other essays also pursue this strategy of illumination by paired contrast, with novelty in the joining: Boyle and Darwin on natural theology and evolution (chapter 15); Percival Lowell versus Alfred Russel Wallace on

the canals of Mars and the uniqueness of life (chapter 18); sloths and vultures as prototypes for traits that we, in our parochial and irrelevant way, judge as negative but yearn to understand (chapter 20); the Diet of Worms and the Defenestration of Prague as events of European history, related by more than their shared initial *D* and funny names (chapter 13); the Abbé Breuil and André Leroi-Gourhan for two sequential and maximally contrasting (but strangely similar) theories about the genesis of cave art (chapter 8); the great artist Turner and the prime engineer Brunel on the similarity of art and science (chapter 2); a forgotten theory about the origin of vertebrates with stunning new data to validate an even older view, all as an entrée to the subject of major evolutionary transitions and the prejudices that impede our understanding of this topic (chapter 17); the dodo of Mauritius and the first New World victims of Western genocide (chapter 12); and the striking difference between two popes in their common willingness to support the factual truth of evolution (chapter 14).

3. If my second category works by joining disparate details, a third strategy operates by careful excavation—elucidation by digging rather than elucidation by joining. As the mineshaft widens and deepens, one may reach a richness of detail justifying promotion to an essay because the requisite generality has been attained by one of two routes: (1) By casting a truly novel, or at least sufficiently different, light on an old subject, so that readers become willing to devote renewed interest, and may even obtain some provocative insight (Darwin always wrote to his creationist friends that he dared not expect to change their minds, but did hope to “stagger” them a bit)—as when intricate details of the life cycle of the maximally “degenerate” parasite *Sacculina* suggest new attention to the fallacies of evolutionary progress (chapter 19), and when the subtle (and almost entirely unreported) distinctions in the affirmation of

evolution by two very different popes (Pius XII and John Paul II) illuminate the old and overly discussed issue of proper relationships between science and religion (chapter 14). (2) By gaining the “right” to address a large and general issue through the new perspective of previously unapplied detail (as in the examples of chapters 5 and 13, previously discussed, and chapter 10 on the relevance of new data about the multiplicity of human species until 30,000–40,000 years ago and the consequent oddity of our current status as a single species spread throughout the globe) for a discussion of predictability versus historical contingency in the evolution of self-conscious life on Earth.

4. “Promotion” to an essay may depend upon the coalescence of details into a general theme worthy of report, but sometimes those details, all by themselves, become arresting enough to merit treatment entirely for their own value (and then I will confess to using the emerging generality as an excuse for almost baroque attention to the details). I do value the theme eventually addressed, but don’t you adore, entirely for their own sake as stories, the four tales of conventional prey that devour their predators (chapter 21), or the excruciatingly intricate and beautiful details of the bizarrely complex life cycle of the barnacle parasite, the “root-head” *Sacculina* (chapter 19)? And, as my personal favorite (and here I do rest my case), how could anyone but a dolt not be moved by the fact that we know about the giant deer’s hump only because paleolithic cave painters left us a record—and that no other even potential source of evidence exists (chapter 9). I tell this story within a perfectly valid and sufficiently interesting context of discourse on biological adaptation as a general evolutionary principle, but don’t you thrill to the notion of this kind of gift provided by such distant forebears; and aren’t you riveted by the details of these rare images, and the story of their discovery and recognition?

The foregoing discussion accounts for all individual bits in this eighth piece of my series. But just as the “two bits” of legend represented a cut from a totality called a “piece of eight,”¹ my bits have no coherence or valid generality without an overarching rationale or coordinating theme to make them whole. I pay my homage to evolution in the preface to every volume of this series, and will now do so again. Of all general themes in science, no other could be so rich, so deep, so fascinating in extension, or so troubling (to our deepest hopes and prejudices) in implication. Therefore, for an essayist in need of a ligature for disparate thoughts and subjects, no binder could possibly be more appropriate—in fascination and legitimacy—than evolution, the concept that inspired the great biologist Theodosius Dobzhansky to remark, in one of the most widely quoted statements of twentieth-century science, that “nothing in biology makes sense except in the light of evolution.”

Moreover, and finally, with this series’ emphasis on a humanistic natural history—an account of evolution that focuses as much on how we come to know and understand this great principle as on how such a process shapes the history of life—we encounter an endless recursion that provides even greater scope and interest to the subject. The wondrously peculiar human brain arose as a product of evolution, replete with odd (and often misleading) modes of reasoning originally developed for other purposes, or for no explicit purpose at all. This brain then discovers the central truth of evolution, but also constructs human cultures and societies, replete with hopes and prejudices that predispose us toward rejecting many modes and implications of the very process that created us. And thus, in a kind of almost cosmically wicked recursion, evolution builds the brain, and the brain invents both the culture that must face evolution and the modes of reasoning that might elucidate the process of its own creation. Round and round we go—into a whorl that may be endless and eternal, yet seems to feature

some form of increasing understanding in all the gyrations that, at the very least, give us topics for essays and, at best, provide some insight into the nature of our being.

I

ART AND SCIENCE

THE UPWARDLY MOBILE FOSSILS OF LEONARDO'S LIVING EARTH

MORGAN DESCRIBES HIS DESPAIR AS THEIR CAPTORS STRING UP KING Arthur for a hanging: "They were blindfolding him! I was paralysed; I couldn't move, I was choking, my tongue was petrified . . . They led him under the rope." But, in the best cliff-hanging traditions, and at the last conceivable instant, Sir Lancelot comes to the rescue with five hundred knights—all riding bicycles. "Lord, how the plumes streamed, how the sun flamed and flashed from the endless procession of webby wheels! I waved my right arm as Lancelot swept in. I tore away noose and bandage, and shouted: 'On your knees, every rascal of you, and salute the king! Who fails shall sup in hell to-night!'"

I am not citing either Monty Python or *Saturday Night Live*, and I didn't mix up my genders in the first sentence. The speaker is not Morgan le Fay (who, no doubt, would have devised a magical, rather than a technological, solution to the same predicament), but Hank Morgan, the Connecticut Yankee in King Arthur's court, and the hero in Mark Twain's satirical novel of the same name. Morgan, transported from nineteenth-century Hartford, wreaks mayhem in sixth-century Camelot by introducing all manner of "modern" conveniences, including tobacco, telephones, baseball—and bicycles.

As a literary or artistic device, anachronism exerts a powerful hold upon us, and has been a staple of all genres from the highest philosophy to the lowest comedy—as Jesus

is crucified in a corporate board room by Dali, condemned at his Second Coming by Dostoyevsky's Grand Inquisitor, but only offered a half-price discount (as he changes to modern dress) by the Italian barber or the Jewish tailor of various ethnic jokes, now deemed tasteless and untellable.

Anachronism works this eerie and potent effect, I suppose, because we use the known temporal sequence of our history as a primary device for imposing order upon a confusing world. And when "the time is out of joint. O cursèd spite," we really do get discombobulated. We also know that correction of a perceived time warp cannot be achieved so easily in real life as in magical fiction (where Merlin can put Hank Morgan to sleep for 1,300 years, or Dracula can be dispatched with a wooden stake driven into the right spot). We regard Hamlet's blithe confidence as a mark of his madness when he completes his rhyming couplet with the Shakespearean equivalent of "no sweat" or "hakuna matata": ". . . That ever I was born to set it right!"

Science, for reasons partly mythical, but also partly accurate and honorable, presents itself as the most linear and chronologically well ordered of all disciplines. If science, working by fruitful and largely unchanging methods of reason, observation, and experimentation, develops progressively more accurate accounts of the natural world, then history provides a time line defined by ever-expanding success. In such a simple linear ordering, mediated by a single principle of advancing knowledge, any pronounced anachronism must strike us as especially peculiar—and subject to diametrically opposite judgment depending upon the direction of warp. An ancient view maintained in the present strikes us as risible and absurd—the creationist who wants to compress the history of life into the few thousand years of a literal biblical chronology, or the few serious members of the Flat Earth Society. But a "modern" truth, espoused out of time by a scholar in the distant past, fills us with awe, and may even seem close to miraculous.

A person consistently ahead of his time—a real-life Hank Morgan who could present a six-shooter to Julius Caesar, or explain the theory of natural selection to Saint Thomas Aquinas—can only evoke a metaphorical comparison with a spaceman from a more advanced universe, or a genuine angel from the realms of glory. In the entire history of science, no man seems so well qualified for such a designation as Leonardo da Vinci, who died in 1519, but filled his private notebooks with the principles of aeronautics, the mental invention of flying machines and submarines, and a correct explanation for the nature of fossils that professional science would not develop until the end of the eighteenth century. Did he have a private line across the centuries to Einstein, or even to God Himself?

I must confess that I share, with so many others, a lifelong fascination for this man. I was not a particularly intellectual child; I played stickball every afternoon and read little beyond comic books and school assignments. But Leonardo captured my imagination. I asked, at age ten or so, for a book about his life and work, probably the only intellectual gift that I ever overtly requested from my parents. As an undergraduate geology major, I bought the two-volume Dover paperback edition of Leonardo's notebooks (a reprint of the 1883 compilation by Jean Paul Richter) because I had read some of his observations on fossils in the Leicester Codex,¹ and had been stunned not only by their accuracy, but also by their clear statement of paleoecological principles not clearly codified before our century, and still serving as a basis for modern studies.

Leonardo remains, in many ways, a frustrating and shadowy figure. He painted only about a dozen authenticated works, but these include two of the most famous images in our culture, the Mona Lisa (in the Louvre) and the *Last Supper* (a crumbling fresco in Milan). He published nothing in his lifetime, despite numerous and exuberant plans, though several thousand fascinating pages

of manuscript have survived, probably representing only about a quarter of his total output. He did not hide his light under a bushel and was, in life, probably the most celebrated intellectual in Europe. Dukes and kings reveled in his conversation and his plans for war machines and irrigation projects. He served under the generous patronage of Europe's most powerful rulers, including Ludovico il Moro of Milan, the infamous Cesare Borgia, and King Francis I of France.

Leonardo's notebooks did not become generally known until the late eighteenth century, and were not published (and then only in fragmentary and occasional form) until the nineteenth century. Thus, he occupies the unique and peculiar role of a "private spaceman"—a thinker of preeminent originality, but whose unknown works exerted no influence at all upon the developing history of science (for nearly all his great insights had been rediscovered independently before his notebooks came to light).²

The overwhelmingly prevailing weight of public commentary about Leonardo continues to view him as Western culture's primary example of a "spaceman," that is, as a genius so transcendent that he could reach, in his own fifteenth century, conclusions that the rest of science, plodding forward in its linear march to truth, would not ascertain for several hundred years. Leonardo stood alone and above, we are told over and over again, because he combined his unparalleled genius with a thoroughly modern methodology based on close observation and clever experiment. He could therefore overcome the ignorance and lingering sterile scholasticism of his own times.

For example, the "Introductory Note" in the official catalog for a recent exhibition of the Leicester Codex in New York summarizes the basis of Leonardo's success in these words: "In it [the codex] we can begin to see how he combined almost superhuman powers of observation with an understanding of the importance of experimentation. The