Deconstructing the "Science Wars" by Reconstructing an Old Mold

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I. What If They Gave a War and Nobody Came?

For reasons that seem to transcend cultural peculiarities, and may lie deep within the architecture of the human mind, we construct our descriptive taxonomies and tell our explanatory stories as dichotomies, or contrasts between inherently distinct and logically opposite alternatives. Standard epitomes for the history and social impact of science have consistently followed this preferred scheme, although the chosen names and stated aims of the battling armies have changed with the capricious winds of fashion and the evolving norms of scholarship—as in scientific novelty versus permanent wisdom in the founding 17th-century debate of "moderns" (the empirical method for gaining new knowledge) versus "ancients" (Greek and Roman perfection) (*1*); science versus religion in a favorite trope of late 19th-century secularism (*2*); and the sciences versus the humanities in the icon for the second half of the 20th century, C. P. Snow's "two cultures" (*3*).

At the close of this millennium, the favored dichotomy features a supposed battle called "the science wars." The two sides in this hypothetical struggle have been dubbed "realists" (including nearly all working scientists), who uphold the objectivity and progressive nature of scientific knowledge, and "relativists" (nearly all housed in faculties of the humanities and social sciences within our universities), who recognize the culturally embedded status of all claims for universal factuality and who regard science as just one system of belief among many alternatives, all worthy of equal weight because the very concept of "scientific truth" can only represent a social construction invented by scientists (whether consciously or not) as a device to justify their hegemony over the study of nature.

But all these dichotomies must be exposed as deeply and doubly fallacious—wrong as an interpretation of the nature and history of science, and wrong as a primary example of our deeper error in parsing the complexities of human conflicts and natural continua into stark contrasts formulated as struggles between opposing sides. When we reject this constraining mental model, we will immediately understand why a science war can only exist in the minds of critics not engaged in the actual enterprise supposedly under analysis. The exposure of this particular naked emperor can only recall the wisdom embedded in a familiar motto of recent social activism: "What if they gave a war and nobody came?"—a statement that may seem a bit limp in its irenic humor at first, but that actually embodies a deep insight about the nature of categories falsely judged as natural and permanent, while truly originating as contingent and socially engendered. (The defining model of dichotomous pairing also lies within the set of mental categories falsely imputed to nature's intrinsic order.)

The best scholars have always been able to scrutinize their own foibles, and an antidote to dichotomous pairing has also existed since antiquity as the *aurea mediocritas*, or "golden mean," of Horace and Aristotle. The *Oxford English Dictionary* traces a first English use to Spenser's *The Faerie Queene* (1590), with an explicit contrast to dichotomous pairing:

> ... the face of golden Meane.
> Her sisters, two Extremities:
> strive her to banish cleane.

Most falsely dichotomized battles include important aspects of virtue at each pole, if only we can break through the emotion of mutual anathema and move toward literal mediation. The golden mean of the science wars could not be more commonsensical, or more enlightening, in upholding, at the same time and without contradiction, both the continuous social construction *and* the growing empirical adequacy of scientific knowledge. Why did we ever construe such consonant notions as antithetical? Science, as done by human beings, could only be envisaged and practiced within a constraining and potentiating set of social, cultural, and historical circumstances—a variegated and changing context that, by the way, makes the history of science so much more interesting, and so much more passionate, than the cardboard Whiggery of conventional marches to truth over social impediments (the model that scientists devised for self-serving motives and that still permeates the obligatory historical

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paragraphs of most scientific textbooks). On the other side, who would wish to deny the probable truth value of science, if only as roughly indicated by increasing technical efficacy through time—not a silly argument of naïve realism, by the way, but a profound comment, however obvious and conventional, about the only workable concept of factual reality.

II. Francis Bacon and the Instrument of Instauration

The objectivist myth of science as a fully general method, rooted in observation by minds consciously free of constraining social bias and using universal tools of reason to accumulate reliable knowledge leading toward an increasingly synthesized theoretical understanding of causes, affixes a definitive label upon our profession, as represented by the false dichotomy of the science wars. The conventional hero in English versions of this myth, Francis Bacon (1561–1626), upheld the new birthright of the scientific revolution by asserting a central paradox in his generation's "battle of the books" between classical and modern knowledge: *Antiquitas saeculi, juventus mundi*, or "the good old days were the world's youth." We should not, as the resolution of this paradox proclaims, regard ourselves as callow, and the ancient Greeks as hoary with wisdom that we might learn to emulate but could never surpass—the standard argument that motivated the Renaissance (literally, the rebirth), a movement that did not strive for novelty on a modern scientific model but sought to rediscover the supposedly eclipsed perfection of ancient knowledge. In contrast, the Greeks and Romans lived during the *world's* youth, whereas we represent the graybeards, enjoying time's benefit and seeing farther by standing on the shoulders of earlier giants (to cite Newton's famous phrase, borrowed from a common aphorism in his day) (*4*). Knowledge accumulates through time; we now know more than ever before and will continue to advance through the empirical methods of a new and developing discipline called science.

Objectivists' poster boy. The English philosopher Francis Bacon (1561–1626) is typically credited with formulating and championing a scientific strategy in which knowledge emerges from a corpus of disciplined observation unbiased by preconceptions of theory or by social constraint. A closer look at Bacon's own writings casts this accreditation into question.

Bacon's name therefore became an adjective in the objectivist myth, a symbol for accurate observation, uncluttered and unbiased by theoretical preferences rooted in social constraints. In a famous passage of his autobiography, for example, Darwin described his procedure in devising the theory of natural selection (*5*):

> My first note-book was opened in July 1837. I worked on true Baconian principles and without any theory collected facts on a wholesale scale.

As many historians have noted, Darwin did not (and could not, for no one can) proceed in such an empty-headed manner, and his later recollection that he did so in his youth can only represent an imposition of unachievable professional ideals upon a forgotten reality. Darwin may have had no inkling of natural selection when he began, but his notebooks represent an extended mental adventure in the constant test and rejection of sequential hypotheses (*6*). In private letters, Darwin often expressed his keen intuition that facts must be ordered and selected as tests of ideas, and that objectivity can only be meaningfully defined by fair recording and by a willingness (even an eagerness) to alter and reject favored hypotheses in the light of such records. In an equally famous letter of 1863, Darwin wrote (*7*): "How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!"

Bacon's dubious, and wholly undeserved, reputation as the apostle of a purely enumerative and accumulative view of factuality for the source of theoretical understanding in science rests upon the tables for inductive inference that he included in the *Novum Organum*, the first substantive section following the introduction to his projected *Great Instauration*. Bacon, who has never been accused of modesty, had vowed as a young man "to take all knowledge for my province." To break the primary impediment of unquestioned obeisance to ancient authority (the permanence and optimality of classical texts), Bacon vowed to write a *Great Instauration* (or New Beginning), based on principles of reasoning that could increase human knowledge by using the empirical procedures then under development and now called "science."

Aristotle's treatises on reasoning had been gathered together by his followers and named the *Organon* (tool or instrument). Bacon therefore named his treatise on methods of empirical reasoning the *Novum Organum*, or "new instrument" for the scientific revolution. The "Baconian method," as Darwin used and understood the term, followed the tabular procedures of the *Novum Organum* for stating and classifying observations, and for drawing inductive inferences therefrom, based on common properties of the tabulations.

Perhaps Bacon's tables do rely too much on listing and classifying by common properties, and too little on the explicit testing of hypotheses. Perhaps, therefore, this feature of his methodology does buttress the objectivist myth that has so falsely separated science from other forms of human creativity. But when we consider the context of Bacon's own time, particularly his need to emphasize the power of factual novelty in refuting a widespread belief in textual authority as the only path to genuine knowledge, we may understand an emphasis that we would now label as exaggerated or undue (largely as a consequence of science's preeminent success).

Nonetheless, a grand irony haunts the *Novum Organum*, for this work, through its tabular devices, established Bacon's reputation as godfather to the primary myth of science as an "automatic" method of pure observation and reason, divorced from all gutsy and sloppy forms of human mentality, and therefore prey to the dichotomous separations advocated in our modern science wars. In fact, the most brilliant sections of the *Novum Organum*—scarcely hidden under a bushel by Bacon, and well known to subsequent historians, philosophers, and sociologists—refute the Baconian myth by defining and analyzing the mental and social impediments that lie too deeply and ineradicably within us to warrant any ideal of pure objectivism in human psychology or scholarship. Bacon referred to these impediments as "idols," and I would argue that their intrusive inevitability fractures all di-

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chotomous models invoked to separate science from other creative human activities. Bacon should therefore become the primary spokesperson for a nondichotomized concept of science as a quintessential human activity, inevitably emerging from the guts of our mental habits and social practices, and inexorably intertwined with foibles of human nature and contingencies of human history, not apart, but embedded—yet still operating to advance our genuine understanding of an external world and therefore to foster our access to "natural truth" under any meaningful definition of such a concept.

The old methods of syllogistic logic, Bacon argues, can only manipulate words and cannot access "things" (that is, objects of the external world) directly (*8*): "Syllogism consists of propositions, propositions of words, and words are the tokens and marks of things." Such indirect access to things might suffice if the mind (and its verbal tools) could express external nature without bias; but we cannot operate with such mechanistic objectivity: "If these same notions of the mind (which are, as it were, the soul of words) ... be rudely and rashly divorced from things, and roving; not perfectly defined and limited, and also many other ways vicious; all falls to ruin." Thus, Bacon concludes, "we reject demonstration or syllogism, for that it proceeds confusedly; and lets Nature escape our hands."

Rather, Bacon continues, we must find a path to natural knowledge—as we develop the procedure now known as modern science—by joining observation of externalities with scrutiny of internal biases, both mental and social. For this new form of understanding "is extracted ... not only out of the secret closets of the mind, but out of the very entrails of Nature." As for the penchants and limitations of mind, two major deficiencies of sensory experience impede our understanding of nature: "The guilt of Senses is of two sorts, either it destitutes us, or else deceives us."

The first guilt of *destitution* identifies objective limits upon physical ranges of human perception. Many natural objects cannot be observed "either by reason of the subtility of the entire body, or the minuteness of the parts thereof, or the distance of place, or the slowness, and likewise swiftness of motion."

But the second guilt of *deception* designates a more active genre of mental limitation defined by internal biases that we impose upon external nature. "The testimony and information of sense," Bacon states, "is ever from the Analogy of Man, and not from the Analogy of the World; and it is an error of dangerous consequence to assert that sense is the measure of things." Bacon, in a striking metaphor once learned by all English schoolchildren but now largely forgotten, called these active biases "idols"—or, "the Idolae, wherewith the mind is preoccupate."

Bacon identified four idols and divided them into two major categories, "attracted" and "innate." The attracted idols denote social and ideological biases imposed from without, for they "have slid into men's minds either by the placits and sects of philosophers, or by depraved laws of demonstrations." Bacon designated these two attracted biases as "idols of the theater," for limitations imposed by old and unfruitful theories that persist as constraining myths ("placits of philosophers"); and, in his most strikingly original conception, "idols of the marketplace," for limitations arising from false modes of reasoning ("depraved laws of demonstrations"), and especially from failures of language to provide words for important ideas and phenomena, for we cannot properly conceptualize what we cannot express. (In a brilliant story entitled "Averroes's Search," the celebrated Argentinian writer Jorge Luis Borges, who strongly admired Bacon, described the frustration of this greatest medieval Islamic commentator on Aristotle, as he struggled without success to understand two words, central to Aristotle's *Poetics*, but having no conceivable expression in Averroes's own language and culture: comedy and tragedy.)

But if these attracted idols enter our minds from without, the innate idols "inhere in the nature of the intellect." Bacon identified two innate idols at opposite scales of human society—"idols of the cave," representing the peculiarities of each individual's temperament and limitations; and "idols of the tribe," denoting foibles inherent in the very (we would now say "evolved") structure of the human mind. Among these tribal idols of human nature itself, we must prominently include both our legendary difficulty in acknowledging, or even conceiving, the concept of probability, and also the motivating theme of this article: our lamentable tendency to taxonomize complex situations as dichotomies of conflicting opposites.

In a key insight, and explicitly invoking his idols to dismember the myth of objectivity, Bacon holds that science must inevitably work within our mental foibles and social constraints by marshaling our self-reflective abilities to understand—because we cannot dispel—the idols that always interact with external reality as we try to grasp the nature of things. We might identify, and largely obviate, the theatrical and marketplace idols imposed from without, but we cannot fully dispel the cave and tribal idols emerging from within. The influence of these innate idols can only be reduced by scrutiny and vigilance: "These two first kinds of Idolaes [attracted idols of the theater and marketplace] can very hardly; but those latter [innate idols of the cave and tribe], by no means be extirpate. It remains only that they be disclosed; and that same treacherous faculty of the mind be noted and convinced."

In a striking metaphor, Bacon closes his discussion of idols by describing our scientific quest as an interplay of mental foibles and outside facts, not an objective march to truth—a marriage of our mental propensities with nature's realities, a union to be consummated for human betterment: "We presume ... that we have prepared and adorned the bridechamber of the Mind and of the Universe. Now may the vote of the marriage-song be, that from this conjunction, human aids, and a race of inventions may be procreated, as may in some part vanquish and subdue man's miseries and necessities."

III. Olaus Worm and the Archiater of Darmstadt

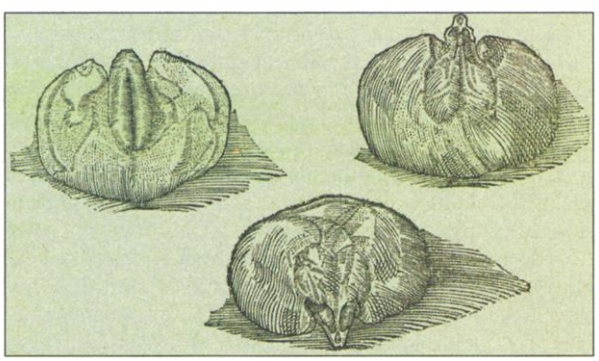
We need to invoke Bacon's general model of advancing science, inextricably intertwined with and potentiated by our mental foibles and social constraints, if we wish to fracture the false dichotomy of objective realism versus social constructionism that defines and fuels the illusory science wars. But small and concrete cases debunk this spurious conflict even more effectively by proving that both supposedly opposite poles invariably work together, as science builds genuine items of natural knowledge from constantly changing and persistently indivisible mixtures of observation and socially embedded interpretation. I therefore apply this truly Baconian model of advancing science *within* socially constructed explanatory matrices to a particular, well-bounded case—an exemplification of the most important voyage of discovery ever completed within my profession of paleontology: the 16th- to 18th-century debate on the nature of fossils (spanning the 17th-century "invention" of modern science from the early years of Bacon and Descartes to the consummation wrought by Newton's cohort).

I shall describe a complex transition that occurred over two centuries, from Agricola's first geological treatise of 1546

to Linnaeus's taxonomic compendium of 1753, and that indubitably features the genuine discovery and construction of an objective factual truth about the nature of a puzzling natural object. In a cryptic one-liner in his *Historia naturalis*, Pliny had spoken of stones that resembled female genitalia on one side and the corresponding male parts on the other. Georgius Agricola and Konrad Gesner, the mid–16th-century polymaths and founders of modern paleontology, described stones that corresponded to Pliny's words, and these specimens then assumed the standardized name of hysteroliths (womb stones, or vulva stones), because the female likenesses on one side seemed so much more impressive than the vague male analogies only sometimes found on the opposite side.

The nature of hysteroliths posed a major puzzle throughout the 16th and 17th centuries. No one regarded them as actual petrified parts of human females, so why did they resemble the human vulva so closely in form? Did the similarity merely represent an accidental *lusus naturae* (sport or joke of nature), or did this morphological correspondence between mineral and animal kingdoms express some causal property that might be utilized for human benefit? By the mid–18th century, all scientists had accepted the discovery that hysteroliths form as internal molds of fossil brachiopod shells, with the slitlike "vulva" corresponding to a ridge on the shell's interior, expressed on the mold as an incision. The resemblance that had inspired the original name must therefore be meaningless and accidental—and the old designation disappeared.

The first published illustration of a hysterolith adorns the famous 1655 museum catalog of the Danish naturalist Olaus Worm (*9*). He recognized the specimens as molds of some



Vulva stones. These are the first published illustrations of hysteroliths, alias vulva stones. They appeared in a 1655 museum catalog of the Danish naturalist Olaus Worm.

object but chose not to speculate about the organic versus inorganic status of the original model. He also felt comfortable with a claim for human utility, based on the formal resemblance and suggested by an eminent local physician who had discovered the specimens. Worm wrote (my translation from his Latin original):

> These specimens were sent to me by the most learned Dr. J. D. Horst, the archiater [chief physician] to the most illustrious Landgraf of Darmstadt. ... Dr. Horst states the following about the strength of these objects; these stones are, without doubt, useful in treating any loosening or constriction of the womb in females. And I think it not silly to believe, especially given the form of these objects that, if worn suspended around the neck, they will give strength to people experiencing problems with virility, either through fear or weakness, thus promoting the interests of Venus in both sexes (*Venerem in utroque sexu promovere*).

At first glance, and as nearly always interpreted, this story of scientific progress seems to fit the old model of empirical objectivity gradually dispelling the prejudicial darkness of antiquated social belief—the realist side of the science wars. How can we view Dr. Horst's opinion that an inert rock might cure human illness by virtue of an accidental resemblance to the afflicted human parts as anything but the silly superstition of a "prescientific" age?

The conventional and hagiographical history of paleontology affirms this view by presenting a heroic tale of scientific light dispelling ideological darkness in three sequential stages. Consider, as a standard source, the early 20th-century *Transformations of the Animal World* by the leading French paleontologist Charles Depéret (*10*). In the first stage, Depéret writes, nearly everyone viewed fossils as inorganic products of the mineral kingdom, formed by fatuous means that could not be regarded as scientific:

> The Middle Ages retained the ideas of Aristotle, and almost unanimously adopted the theories of the spontaneous generation of fossils or petrifactions under varying formulas, such as plastic force, petrifying force, action of the stars, freaks of nature, mineral concretions, carved stones, seminal vapours, and many other analogous theories. These ideas continued to reign almost without opposition till the end of the sixteenth century.

In stage two, advancing science fractured these myths and established the organic nature of fossils. But progress remained stymied by religious dogmas that designated all fossils as relics of Noah's flood:

> The seventeenth century saw little by little the antiquated theories of plastic force and of carved stones disappear, and the animal or vegetable origin of fossil remains was definitely established. Unfortunately the progress of palaeontology was to be retarded for a long space of time by the rise and the success of the diluvian theories, which attributed the dispersion of fossils to the universal deluge, and endeavoured to adapt all these facts to the Mosaic records.

Finally, in stage three, the advancing force of exact description dispels this final impediment and establishes the fossil record as a chronology for an immensely long history of life. The gradual and progressive triumph of objective observation over social and ideological constraint has now been completed.

> Yet there were, among these partisans of the Flood, a few men of worth, whose principal merit, outside their too frequent extra-scientific speculations, was that they deeply studied fossils and spread the better knowledge of them by exact representations. This task of the description and illustration of fossil animals was especially the work of the scholars of the eighteenth century which was the age of systematic zoology. From all quarters they set themselves to gather and collect fossils, to study and describe them by the aid of plates often of great beauty of execution, to which modern palaeontologists are still compelled to have recourse.

This simplistic tale may match some cardboard heroic fantasies about the invincibility of scientific reasoning and the inevitability of human progress. But Depéret's tripartite story fails miserably as an accurate history of a genuine scientific advance for at least three reasons:

1. The three putative stages (fossils as inorganic, fossils as relics of Noah's flood, and fossils as products of a long history of life) cannot represent a progressive chronology, because all three opinions vied as alternatives from the very beginning of recorded paleontology. In the first decade of the 16th century, well before the initiating publications of

Gesner and Agricola, both Leonardo da Vinci and Girolamo Fracastoro explicitly discussed these three interpretations as the full set of conceivable explanations for the greatest particular problem posed by fossils: How can objects looking so much like modern marine shells get into rocks on the tops of high Italian mountains? Moreover, both Leonardo and Fracastoro personally favored the third alternative, universally accepted today, and initially developed by nearly all classical Greek authors who wrote about fossils (and who generally accepted Aristotle's view of Earth's potential eternity, leading to a cyclical notion of changing positions for land and sea, with modern mountaintops representing ancient sea floors). Leonardo penned his ideas into private notebooks that had no influence upon the later history of science, but Fracastoro's opinions received prominent attention in several standard 17th-century sources (*11*).

2. The inorganic theory, supposedly first in time and most foolish in content, did not represent the emptiness of pure ignorance based on a failure to observe actual fossils carefully, but rather made eminently good sense in light of a different theory about the nature of reality—a defendable notion (even in the peculiar version of Darmstadt's archiater) under a disparate concept of causality that only became obsolete after the rise of modern science in the 17th century. Under the Neoplatonic doctrine of "signatures," all basic forms achieved explicit representation (through different means) in each of nature's three realms: animal, vegetable, and mineral. These correspondences not only recorded nature's inherent harmony and order but also embodied meaningful sympathies with potential curative power. Thus, the vulva form of the mineral kingdom might help to restore its diseased or depleted analog in the animal kingdom. Such signatures and sympathies make no sense, and seem risible, under a different (and clearly more adequate) concept of mechanistic causality that triumphed in the scientific revolution of the 17th century. But the anachronism of later dismissal cannot brand superseded ideas as foolish in their own time. Many of our most cherished beliefs, including concepts that we regard as factually established and free of social bias, will no doubt seem just as bizarre to our successors as the inorganic theory of hysteroliths strikes us today.

3. The reinterpretation of hysteroliths from inorganic replicas of human genitalia to internal molds of fossil brachiopods did not occur primarily by the weight of accumulating observation. Rather, this radical revision arose as a logically implied consequence of major changes in underlying world views—a crucial transition in human intellectual history provoked by complex factors rooted as deeply in altered social contexts as in improving empirical knowledge. First of all, the key factor that secured the organic nature of hysteroliths—the downfall of the Neoplatonic theory of signatures—owed little or nothing to advancing observation of fossils, but rather marked the imposition upon paleontology of a novel and revolutionary approach to understanding nature (called modern science) that specified an organic interpretation of fossils as the unavoidable consequence of a new view of causality.

Secondly, the "right answer" of brachiopod molds demanded far more than a simple accumulation of accurate observations, for this factual resolution presupposed a complex ideological shift in the basic taxonomy of "organized things in rocks," an achievement that required the dismemberment of several theatrical and marketplace idols. No distinct word for organic remains even existed (a classic Baconian idol of the marketplace) before the early 19th century, for "fossil," from the past participle of the Latin *fodere* (to dig up), initially referred to any organized object extracted from the ground, including crystals, concretions, geodes, stalactites, and other inorganic items of definite and "interesting" form. As their distinctive status became clear, organic objects first achieved separate recognition as "extraneous fossils" (that is, as objects introduced into rocks from the animal or vegetable kingdom), as opposed to "intrinsic fossils," or mineralogical phenomena. Finally, as both the coherence and the importance of organic objects rose to prominence, the general term "fossil" gradually shifted and contracted to designate organic remains alone.

Until scientists drew an unambiguous taxonomic distinction between organic objects on one side and all complex, regular, and intriguing inorganic phenomena on the other, the status of fossils (in the modern meaning of organic remains) could not be resolved, and hysteroliths would remain in cognitive limbo. As a striking example, consider two illustrations from the mid–18th century (*12*): first, from a French publication of 1755, the last gasp of a promiscuous taxonomy that included organic remains with inorganic objects of similar or analogous form. As long as scientists classified brachiopod molds that looked like female genitalia with stalactites that accidentally mimicked male genitalia, the proper causal distinctions would remain elusive, and hysteroliths could not be resolved as brachiopod molds. By contrast, Linnaeus's figure, printed at virtually the same time in 1753, forges the requisite taxonomic division and resolves two centuries of debate by placing hysteroliths into an exclusive category with other brachiopods that, as remains of external shells or as internal molds of species without interior ridges to impose vulvalike slits, show no accidental resemblance to female genitalia. Common causal genesis had finally replaced common overt appearance as the basic criterion for taxonomic union.

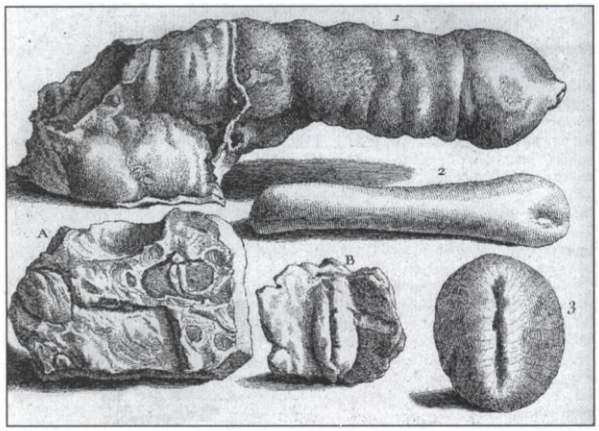
Once the necessary theoretical shifts had occurred, and hysteroliths became undoubted organic remains, the few persisting questions could be resolved by procedures close to the stereotype of canonically objective observation: Are hysteroliths the internal molds of vegetable nuts or animal shells? As molds of animal shells, do they represent impressions of clams or of brachiopods? As molds of brachiopods, what species within the phylum grow interior ridges that engrave vulvalike slits on their internal molds? But these observational resolutions only cleaned up a few remaining details. The major advances that converted hysteroliths from ambiguous objects of potentially mineral origin to the internal molds of brachiopods arose as consequences of deep theoretical and ideological transitions rooted as much in social, political, and philosophical changes in European life and values as in simple accumulation of accurate factual information about the natural world.

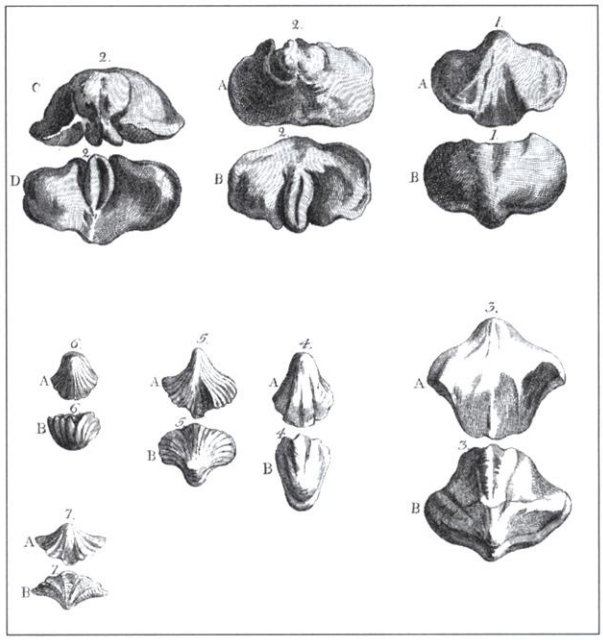
In short, and however modestly this small incident of two centuries may rank in the general scheme of things, the resolution of hysteroliths as brachiopod molds marks a genuine and indubitable gain in accurate factual knowledge about a fascinating item of external reality—and no genre of victory in all the annals of human achievement could possibly be deemed more noble or more sweet (although other achievements in the arts and humanities may surely claim equal merit!). Nonetheless, paleontology resolved this small problem as all increments in the genuine "progress of science" must be won—by a complex and socially embedded construction of new modes for asking questions and attaining explanations. Science advances within a changing and contingent nexus of human relations, not outside the social order and despite its impediments.

IV. Parsing Science Within All Human Creativity

If, to state four propositions arising from this paper and expressing its central argument:

1. Science truly does "progress" in the sense of gaining, albeit in a fitful and meandering way through time, more useful knowledge that, without mincing words, must record an improving understanding of an objective external world: and if science must also be the work of eminently fallible human beings, freighted with predispositions based on complex factors of social context, psychological hope, mental and temperamental construction, and historical circumstance—and if:





Changing taxonomies. These two sets of illustrations reflect competing mid–18th-century interpretations of hysteroliths. In the plate above (from a 1755 treatise), a variety of natural forms, including stalactites, are classified together because they superficially resemble genitalia. In the plate at right, a contemporary illustration in a work by Linnaeus (1753) forgoes the criterion of common appearances for a basis in common generation, thereby bringing hysteroliths into the narrower class of fossil brachiopods.

2. Francis Bacon, despite his stereotypical status as an apostle of objectivism based on the automaticity of observations and their mental manipulation to reach inductive conclusions, recognized and emphasized (in perhaps his most famous image) the "idols" of mind and social organization that inevitably make science a social enterprise constructed within changing ideological contexts—and if:

3. Close analysis of any apparently simple and linear sequence in factual gain, leading to the solution of a definite empirical problem—as in the transition from interpreting a prominent group of fossils as "vulva stones" that meaningfully mimic female genitalia to interpreting them as internal molds of certain brachiopods—invariably and ineluctably reveals the central role of social and ideological factors in crucial theoretical shifts that make key observations possible by setting contexts for asking requisite questions—and, finally, if:

4. Dichotomous models of us against them represent Baconian idols of the tribe, or foibles of human mentality imposed upon more complex situations from within—

Then, we must reject the widespread belief that a science war now defines the public and scholarly analysis of this institution, with this supposed struggle depicted as a harsh conflict pitting realists engaged in the practice of science (and seeking an absolute external truth progressively reachable by universal and unbiased methods of observation and reason) against relativists pursuing the social analysis of science (and believing that all claims about external truth can only represent social constructions subject to constant change and unrelated to any movement toward genuine factual knowledge). The very concept of a science war only expresses a basically silly myth, rooted in our propensity for devising dichotomous schemes and supported by the invention of nonexistent, caricatured end-members to serve as straw men in a self-serving rhetorical ploy that can only generate heat without light. (And I do pronounce a plague on this tendency within *both* houses. Social commentators may be more guilty in their frequent mischaracterization of working scientists; but some scientists have constructed equally misleading, and basically philistine, images of social critics out to trash any statement about an ascertainable fact in an objective external world.)

Most working scientists may be naïve about the history of their discipline and therefore overly susceptible to the lure of objectivist mythology. But I have never met a pure scientific realist who views social context as entirely irrelevant, or only as an enemy to be expunged by the twin lights of universal reason and incontrovertible observation. And surely, no working scientist can espouse pure relativism at the other pole of the dichotomy. (The public, I suspect, misunderstands the basic reason for such exceptionless denial. In numerous letters and queries, sympathetic and interested nonprofessionals have told me that scientists cannot be relativists because their commitment to such a grand and glorious goal as the explanation of our vast and mysterious universe must presuppose a genuine reality "out there" to discover. In fact, as all working scientists know in their bones, the incoherence of relativism arises from virtually opposite and much more quotidian motives. Most daily activity in science can only be described as tedious and boring, not to mention expensive and frustrating. Thomas Edison was just about right in his famous formula for invention as 1% inspiration mixed with 99% perspiration. How could scientists ever muster the energy and stamina to clean cages, run gels, calibrate instruments, and replicate experiments, if they did not believe that such exacting, mindless, and repetitious activities can reveal truthful information about a real world? If all science arises as pure social construction, one might as well reside in an armchair and think great thoughts.)

Similarly, and ignoring some self-promoting and cynical rhetoricians, I have never met a serious social critic or histo-

rian of science who espoused anything close to a doctrine of pure relativism. The true, insightful, and fundamental statement that science, as a quintessentially human activity, must reflect a surrounding social context does not imply either that no accessible external reality exists, or that science, as a socially embedded and constructed institution, cannot achieve progressively more adequate understanding of nature's facts and mechanisms.

The social and historical analysis of science poses no threat to the institution's core assumption about the existence of an accessible "real world" that we have actually managed to understand with increasing efficacy, thus validating the claim that science, in some meaningful sense, "progresses." Rather, scientists should cherish good historical analysis for two primary reasons: (1) Real, gutsy, flawed, socially embedded history of science is so immeasurably more interesting and accurate than the usual cardboard pap about marches to truth fueled by universal and disembodied weapons of reason and observation ("the scientific method") against antiquated dogmas and social constraints. (2) This more sophisticated social and historical analysis can aid both the institution of science and the work of scientists—the institution, by revealing science as an accessible form of human creativity, not as an arcane enterprise hostile to ordinary thought and feeling, and open only to a trained priesthood; the individual, by fracturing the objectivist myth that can only generate indifference to self-examination, and by encouraging study and scrutiny of the social contexts that channel our thinking and the attracted and innate biases (Bacon's idols) that frustrate our potential creativity.

Finally, how shall we respond to a harried and narrowly focused scientist who might exclaim: "Fine, I agree; the history of science may be interesting, relevant, and socially constructed. But I have no time to study such ancillary matters, and the results make no practical difference to my life because an objective reality exists 'out there,' and science would eventually arise to access this factuality in the same basic way, even if our actual history must follow contingent and meandering pathways of social construction."

I would respond that no inevitability attends our eventual understanding of a real world outside our social construction. All basically scientific roads through any conceivable human culture may lead toward an exterior "Rome." But the same Rome shines with different lights tuned to the form and direction of the particular path that people actually construct for their excursion to the eternal city of natural knowledge. We would still know a great deal (perhaps more than now) about the surrounding universe if Zheng He's 15th-century ships (five times the length of Columbus's biggest caravel) had continued their explorations beyond Africa, and imperial China had conquered the world. Or if Tamarlane, or Genghis Khan, or Suleiman the Magnificent had vanquished Europe (as each could probably have done, if such issues depended only upon pure technological prowess, and not upon the vicissitudes and contingencies of social practice and personal decision as well). We would still gaze upon Rome, but at what distance, and with what different eyes and concepts?

Not to mention the ultimately sobering thought that, just because Rome exists in a position accessible to roads of many forms and styles, no guarantees for human visitation can be located anywhere in the structure of mind or the nature of the universe. We might never have gazed upon this wondrous light in any hue or texture. The dispersal of such false dichotomies as the science wars, and the promotion of science from the heart of its social construction, build a maximally reliable vehicle for this most adventurous of all improbable journeys toward the grandest goal of human striving and natural order.

References and Notes

1. This public and self-conscious struggle culminated in the late 1600s, as older Renaissance convictions about the acme of achievement and textual authority of classical authors ceded to the acknowledgment that newer empirical methods (now called "science") could transcend ancient understanding. In 1704, Jonathan Swift wrote the most famous commentary on this debate, a wickedly satirical essay called "The Battle of the Books," featuring a war in a deserted library between "ancient" and "modern" volumes.

2. This favored late 19th-century dichotomy (still persisting today) viewed social and technological progress as the outcome of a "warfare" between science and theology, and received a "semiofficial" status in two contrasting and phenomenally successful volumes: J. W. Draper's *History of the Conflict Between Science and Religion* (1874) and A. D. White's *A History of the Warfare of Science with Theology in Christendom* (1896). Draper, a vehement anti-Catholic who hoped that liberal Protestant theology might live in peace with science, had presented the speech (on "the intellectual development of Europe considered with reference to the view of Mr. Darwin") that unleashed the famous "debate" between T. H. Huxley and Bishop Samuel Wilberforce in 1860. White, as the first president of Cornell University and a dedicated and ecumenical theist, hoped to persuade his fellow believers that the beneficial and unstoppable advances of science posed no threat to genuine religion but only to outmoded dogmas and superstitions.

3. C. P. Snow, a scientist by training and a novelist and university administrator by later practice, delivered his famous talk on "The Two Cultures and the Scientific Revolution" as the Rede Lecture at Cambridge University in May 1959. He spoke of the growing gap between literary intellectuals and professional scientists, noting for example how "one found Greenwich Village talking precisely the same language as Chelsea, and both having about as much communication with M.I.T. as though the scientists spoke nothing but Tibetan."

4. The great American sociologist of science Robert K. Merton wrote an entire book on pre-Newtonian uses of this image to make the serious point, with a wonderfully light touch, that supposed personal inventions (not claimed by Newton in this case but attributed to him by later commentators) often reflect long and complicated social settings and previous uses. See R. K. Merton, *On the Shoulders of Giants—A Shandean Postscript* (The Free Press, New York, 1965). See also my appreciation of Merton's book: S. J. Gould, "Polished pebbles, pretty shells: An Appreciation of *OTSOG*," in *Robert K. Merton: Consensus and Controversy*, J. Clark, C. Modgil, S. Modgil, Eds. (Falmer Press, New York, 1990), pp. 35–47.

5. F. Darwin, Ed., *The Life and Letters of Charles Darwin, Including an Autobiographical Chapter* (John Murray, London, 1888), vol. 1, p. 83.

6. Darwin's intellectual journey toward the theory of natural selection is brilliantly described, along with a transcription of two key notebooks, in H. E. Gruber and P. H. Barrett, *Darwin on Man* (Dutton, New York, 1974).

7. F. Darwin, Ed., *More Letters of Charles Darwin* (D. Appleton, New York, 1903), vol. 1, p. 195.

8. All the following quotations from Bacon come from his preface to the *Great Instauration*, translated (from the original Latin) by Gilbert Wats: Francis Bacon, *On the Advancement and Proficiencie of Learning: or the Partitions of Science* (Thomas Williams, London, 1674), pp. 17–21.

9. O. Worm, *Museum Wormianum seu Historia rerum rariorum* [Elsevier (already selling books at high prices!), Leiden, 1655], p. 84.

10. C. Depéret, *The Transformations of the Animal World* (Kegan Paul, London, 1909), pp. 4–5.

11. At least three 17th- and early 18th-century museum catalogs describe Fracastoro's views. The earliest reference I can find comes from Andrea Chiocco, *Musaeum Francisci Calceolari Veronensis* (Angelo Tamo, Verona, 1622), p. 407.

12. The 1755 figure of hysteroliths shown with a stalactite resembling male genitalia appears on plate 7 of Dezallier D'Argenville, *L'histoire naturelle éclaircie dans une de ses parties principales, l'Oryctologie* (De Bure, Paris). Linnaeus's accurate picture of 1753 comes from his famous catalog of the collection of Count Tessin: *Museum Tessinianum* (Laurentius Salvius, Stockholm), plate 5.

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