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ESSAY

Science: Past, Present, and Future[1]

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Abstract—When someone says "science", we think "physics". The reasons for that are rooted in the history of science and in the historical development of philosophy of science. Science-as-physics has countless implications for the public image of science, the conventional wisdom about scientific method, the notion of "hard" versus "soft" sciences, and the belief that science means repeatability, predictability, falsifiability. But the age of physics is at an end, and the age of biology has begun. As biology becomes the most prominent among the sciences, the conception of what it means to be "scientific" will also change. Parapsychology will morph into a mainstream science.

Keywords: science in the future—future of science—biology as epitome of science

Synopsis

Scientific knowledge and methods are very different now than a century or two or three ago; nevertheless, the science of our day remains shaped by the sciences of the past. Our understanding of the nature of science and its role in society has not kept up with the rapid changes within science itself. The conventional wisdom about science is still based on the first centuries of so-called "modern" science—approximately, the 17th century to the middle of the 20th century.

The science of the future will differ from that of the past and present in at least two major respects: Science will be more a corporate enterprise than the sum of independent individual efforts; and the epitome of science will be biology instead of physics. These changes will affect in important ways how science is carried on. But the effect will be even more significant, on how society thinks about science and makes use of science.

These are not predictions, or even extrapolations, but certainties, for the changes have already begun, even if not much note has yet been taken of them. I shall discuss chiefly the second, the move from physics-inspired science to biology-inspired science. The change from an individualist science to a corporate one has been treated authoritatively and comprehensively by Ziman (1994) and I have suggested some rather gloomy corollaries (Bauer, 2004).

Intellectual Development of Science

At the outset I should note that some implications of the term "science" are peculiar to the English language and its cultural environment (Bauer, 2001: chap. 2). "Naturwissenschaft" in German and "sciences" in French do not carry the same baggage of connotations as "science" does in English. However, it is universally agreed that at least physics, chemistry, geology, and biology are sciences; so by "science" I shall explicitly mean those, the generalized body of subjects like these four main ones, in other words what are often called the natural sciences[2].

For well over a century, (this) science has been widely regarded as humankind's best—or even only—source of reliable, even certain, knowledge about the material world (Knight, 1986). Often this has been further extrapolated to reliable or even certain knowledge about everything, on the presumption that the material world encompasses all existence (Bauer, 2001: chap. 1, 3, 6). In popular usage—again, in English!—the adjective "scientific" is a virtual synonym for "proven true" (Bauer, 2001: chap. 2, 6).

This high status of science—initially in the Western world, and still chiefly in Western culture--came about through a process that historians have traced back many centuries, millennia even. The earliest generally recognized development was in ancient Mesopotamia, to which we owe our division of hours into 60 minutes and circles into 360 degrees. Later contributions came from Greek philosophy and geometry and astronomy, from Indian mathematics, and from Islamic scholarship over a wide range of fields[3]. Modem science was shaped by the Renaissance and the Reformation, by interactions of intellectuals and artisans, and by social and political circumstances that made room for a necessary freedom of thought and action (Marks, 1983).

The Conception of Science

Generalizing from individual sciences to "science" as a whole has been anything but egalitarian. The scholarly image of science has not been shaped at all equally by insights into what is done by physicists, by chemists, by geologists, by biologists, and by other scientists. Physics was the first of the sciences to become modem, and—no doubt for that reason—history and philosophy and sociology of science (increasingly grouped together as "science studies") have, until very recently, made their studies of, and conclusions about, "science" synonymous with their studies of and conclusions about physics. This has yielded a biased, misleading view of what science as a whole really is and has left us with mistaken ideas about how science should be done. Most unfortunately of all, science-as-physics is responsible for a vastly and mistakenly inflated opinion about how certain are the conclusions that science can reach.

The popular, public image of science, continually reinforced by the media, reflects this scholarly distortion. Physics is seen as the most scientific science. Non-quantitative sciences—sciences that are not like physics—are called "soft", weak, imperfect. Almost all the presidential science advisers in the USA have been physicists. Physics is the epitome and the very model of science (Bauer, 1992: 37–38).

What are the most impressive things about physics? Simple, quantitative laws that afford accurate predictions. But highly accurate predictions can only be made about highly repeatable phenomena. And highly repeatable events are found only with simple systems—only with simple *non-living* systems. So the precision and reliability of laws and predictions are pre-eminent in physics not because physicists have developed a so-called scientific method most fully, nor because physics is the basis of all other sciences, but just because physics deals with simple, inanimate systems, for which it is relatively straightforward to construct mathematical models and to test hypotheses. Doubtless it is also because of its relative simplicity that physics was the first science to become modern: The Mesopotamians and the Greeks and the Chinese and the Maya, among others, knew much more about physics and astronomy than they did about geology or biology or even chemistry.

The methods of physics, however, are not applicable in most of the rest of science. Every field of scholarship and every field of science develops approaches and methods best suited to studying the particular phenomena that are its concern (Bauer, 1992: chap. 2). Furthermore, any substantial discipline investigates phenomena that are not reducible to those of other fields. As systems become more complex, *emergent properties* are encountered, phenomena not predictable by the laws that govern the separate, individual parts of the system. The study of such unprecedented properties inevitably requires new approaches. Michael Polanyi (1967) has been famously cited (and also famously misappropriated) for pointing out that even the actions of simple machines cannot be predicted from the Newtonian laws of mechanics, since questions of function and design arise that have no basis in physics: "Machines are not formed by physical-chemical equilibration .... The functional terms needed for characterizing a machine cannot be defined in terms of physics and chemistry". Many others, too, have pointed out that such reductionism is untenable[4].

Reductionism is an illegitimate child of science-as-physics, but it is far from its only bastard child. Another is the myth of *the* scientific method (Bauer, 1992) that, supposedly most highly refined in physics, is applicable to all investigations. Thus some social scientists have sought to make their own fields "scientific" by attempting to model their methods on those of "science", by which they mean physical science; introductory college textbooks of psychology and sociology, at least in the USA, typically insist that science must be done by the hypothetico-deductive approach.

Yet another unfortunate consequence of science-as-physics is the notion that scientific theories can be proved and that they somehow represent scientific knowledge. The simple phenomena of physics can so often seem to be so fully described by its theories as to tempt us to call those theories "true", even though philosophy of science has long been crystal clear that no theory can ever be proved finally valid for all time. Theories are always underdetermined by whatever evidence is available—no theory is absolutely required by any given set of facts. And one can never exclude the possibility that some not-yet-conceived theory could be better[5] than any current one.

No matter how repeatable and predictable a phenomenon may be, its explanation can only be a matter of opinion—highly informed opinion, perhaps, and constrained by facts and context, but nevertheless opinion. No more support for this statement should be needed than the historical fact that scientific theories have a limited life-time before they are abandoned, modified, or subsumed into other theories. Scientific theories are useful tools, short-hand for organizing knowledge, and heuristic guides to further investigation; but scientific theories can never be proved, and they should never be accorded the status of "truth". But that will become more widely appreciated only when science is no longer equated with physics.

Social Context of Science

After its birth in the 16th or 17th century, modern science was nurtured in particular social circumstances in Europe. Following Galileo's unhappy experiences, advances came in the Protestant North-West rather than in the Catholic culture of southern Europe. In England, the Royal Society and the Lunar Society exemplified the freedom of thought and association in which artisans and craftsmen and thinkers could interact fruitfully to spur intellectual and material progress. Such freedom allowed people from every social class to become entrepreneurs and capitalists and midwives to the Industrial Revolution.

That period of history bequeathed us the view that science is done by self-motivated individuals freely associating with one another, convinced that it is right to expand human understanding and reaping material benefits for themselves as a by-product (only!). Such voluntary and disinterested interactions were fore-runners to the system of peer review that has been primarily responsible for the continuing and increasing soundness of scientific knowledge. The scientific method is not some abstract protocol for posing and answering questions, it is the concrete interactions among interested people who keep each other honest through mutual criticism based on substantive criteria. Those interactions create a "knowledge filter" that winnows the valid from the unreliable among the mass of competing claims (Bauer, 1992: chap. 3). This knowledge filter has worked so well because of the prevailing scientific ethos: Scientific knowledge is the same in all cultures, it is universal; it is publicly available, communally shared; scientists practice skepticism and disinterestedness[6].

Those are not descriptions of actual practice, of course; they are ideals that scientists have sought to live by. In the early days of modern science, when science was done by dedicated amateurs, there were fewer hindrances to ideal behavior than after science became a profession: It is hardly possible to be entirely disinterested as to the validity and significance of the results of one's investigations if one's career and livelihood are affected by them. Still, for many decades and into the latter part of the 20th century, peer review and other practices of science were carried on with a very high degree of integrity and concern for substance by contrast to personal preferment[7]. Perhaps the most notable barrier to progress during that time was just intellectual conservatism (Barber, 1961), which accompanies naturally a remarkably reliable body of knowledge consensually accepted by almost all competent practitioners.

Because the fruits of science were so prized by the wider society, and because the practitioners of science had conducted themselves so admirably, science was well supported by society while also being allowed a huge measure of self-governance. Society provided funds for research while permitting science itself largely to choose how to spend those funds.

The second part of the 20th century saw a progressive change in these circumstances. A decisive event was the success of the Manhattan Project that created the atomic bomb: Science and scientists had brought a World War to an earlier conclusion than would have been possible without their efforts[8], and it was widely presumed that they could bring equivalent peace-time marvels. Society began to support even basic scientific research with unprecedented largesse. Spectacular scientific-technologic achievements became part of the competition between nations: Who can first place an artificial satellite around the Earth? Who can first set a human foot on the Moon? Even the social sciences and the humanities were given unprecedented, tangible public support in the belief that they could deliver social fruits as beneficial as the material fruits that science and technology were delivering.

All this patronage, given in good faith but with enormously high expectations, carried a price that is beginning to be recognized only in retrospect. The expectations were not realistic in several ways: in believing that the speed of scientific progress could be increased just by having more people do more science—whereas more quantity inevitably meant lower average quality. As a career in science became increasingly attractive for its material benefits, so the reasons for becoming a scientist became less that of having a vocation for knowledge-seeking and more that of just doing well for oneself. Universities began to measure and reward their faculty not according to their intellectual quality and dedication to disinterested scholarship but according to how many research dollars they could inveigle out of the patrons of science. Research grants were increasingly awarded not for the most original ideas but for the most faddish, those so obvious that everyone could agree—no matter how mistakenly—on their value (Muller, 1980). Graduate students were increasingly treated as necessary pairs of hands rather than as budding intellects to be disinterestedly and conscientiously helped to develop independence.

In a word, science has become increasingly corrupted by conflicts of interest, a possibly inevitable consequence of formal organization and external influence. Decisions have come to be made increasingly for political reasons as well as—or even instead of—intellectual ones.

It is clearer in retrospect that the useful social spin-offs of science had resulted as by-products of a largely self-governing community of people driven largely by curiosity about the workings of the world. That is very little appreciated even nowadays. The most wonderful advances have come under circumstances where the right degree of intellectual freedom was allowed, as the best long-term guarantee that golden eggs would be laid. The contemporary belief that economic markets are the best social decision-makers has brought a focus on the short rather than the long term, with such inestimable losses for science and society as the dissolution of the Bell Laboratories, which had brought humankind transistors and lasers, among other things. That is all spilled milk, to be regretted but not recovered. But it is important to recognize the extent to which science has changed from an activity of self-governing, curiosity-driven, disinterested and skeptical amateurs to a highly organized, bureaucratically directed enterprise held accountable for its short-term performance by those who pay for it. That change and its implications have been underscored by Ziman (1994) in Prometheus Bound; anyone wishing to understand both classic and contemporary science could do no better than to read that book, as well as Ziman's most recent overview of science (Ziman, 2000).

The important thing for the present purpose is to note that science is not what it was, and that assessing scientific activities calls for the sort of approach practiced by students of politics, as well as the attention of philosophers and historians of science.

Dissatisfaction with Contemporary Science

Criticisms similar to those just made have come from a variety of directions over the last several decades. New-Age idealists have pointed out that science has not fulfilled and cannot fulfill its 19th-century promise of answering all the questions that matter to human beings[9]. It should not be idolized as the be-all of human understanding but rather seen as a Glorious Entertainment for human beings (Barzun, 1964). Some critics have gone quite overboard, pushing such ideologies as post-modernism, relativism, constructivism, and the like, an intellectual Luddism that has itself been exposed and deconstructed, succinctly and tellingly by Alan Sokal's (1996a,b) wonderful spoof as well as in discursive scholarly argumentation by, for example, Gross and Levitt (1994) in their book Higher Superstition or by Susan Haack (1998, 2003: especially chap. 7, 8, 11). But dissenters from New-Age notions also include naive defenders of science-as-it-is, holding forth on a variety of topics with the dogmatic, scientistic certainty that belongs to the 19th-century Age of Science (Knight, 1986) and early-20th-century positivism; some of these naïfs are prominent members of the scientific mainstream[10], others belong to such more populist groups as the Committee for the Scientific Investigation of Claims of the Paranormal.

New-Age critiques have been concerned chiefly with the social role and influence of science. Others have been concerned about perceived *intellectual* deficiencies of contemporary science. The Society for Scientific Exploration (SSE) was formed to attend to certain phenomena ignored by contemporary science—UFOs, parapsychology, cryptozoology[11], and the like[12]. As it turns out, the SSE has also served as a forum for consideration of unorthodox views well within mainstream science, for instance alternatives to plate tectonics in geological hypothesizing, unorthodox views about the origin of hydrocarbons on Earth, cold fusion, and others as well. Observers of science have begun to recognize, implicitly at least, that science-as-physics has reached a dead end: Historians and philosophers of science, together with sociologists and scientists and others, have established such distinct specialties as history of geology[13], philosophy of chemistry[14], and history, philosophy, and social studies of biology[15].

The contemporary scene, in other words, is one of unrest and change. The inadequacy of traditional science-as-physics is becoming evident, for a variety of reasons, to more people and more various people, including members of the scientific community. What then will the science of the future be like?

The Future of Science and of Scientific Exploration

Physics has had its day, even though few may have suspected it before the Superconducting Super-Collider was abandoned. Biology has become the most publicly visible science and the one from which the most is expected. Gene therapy, cloning, genetically modified foods, stem cell research, are familiar terms; British newspapers use the acronym "GM foods" without further explanation. Increasingly as time goes by, biology will attain the pre-eminence among sciences that presently still belongs to physics[16].

Though this is becoming well recognized, its implications are not; yet they can hardly be overstated. Philosophers of science will be hard pressed not to adopt a realist view[17]. Philosophy of science, to be followed by other punditry and eventually by public opinion, will take a quite different view of the roles of repeatability, predictability, falsifiability, and so on, within "the scientific method". The illusion will dissipate, that "science" can deliver definite answers on demand—or, for that matter, definite answers *at all* on such matters of central human interest as health and longevity. "In this sprawling swamp of a science called biology, the short list of physical variables, such as force, mass, and energy, gives way to an endless catalogue of Latin taxonomy; prediction gives way to retrospective analysis; universal laws give way to idiosyncratic natural histories"; such generalizations or "laws" as natural selection "do not encapsulate the transformations of life in quite the same way that Newton's laws capture the motions of objects. They render evolution intelligible, but not predictable or reducible" (Hirsh, 2003). Explanations become probabilistic instead of precise.

Though biology and biologists will become pre-eminent, they will not enjoy the freedom of thought and research that accompanied the birth of modem science, and that physicists and other scientists enjoyed well into the latter part of the 20th century. Society will not return to that brief period when huge sums were provided for scientists to do with as they wished. Not only will pressure continue for quick results; biologists will experience even in democratic societies strong ideological, political, social constraints on their activities. That can already be glimpsed in furors over GM foods, stem cell research, and cloning, not to speak of the continuing attempts to sabotage exposition of evolutionary concepts in classrooms in the USA. For biology to progress optimally, its administrators will have to be the most adept, astute politicians that science administration has ever brought forth.

Returning to intellectual considerations: I am not suggesting that the science of the future will take *contemporary* biology as its model. Just as present-day science as a whole takes physics as its model, so present-day biology too remains rather imitative of physics. Elucidating the structure of DNA was greeted as though the very secret of life had been uncovered. Molecular biology, the part of biology that is most akin to physics and chemistry, is widely viewed as the most advanced, the most scientific biology; according to James D. Watson, "There is only one science, physics" (Brown, 1999: 47). The study of animal behavior remains almost as excluded from mainstream attention as the search for the Loch Ness Monster. The biology of the future, by contrast, will encompass the behavior of organisms as well as their biochemical and physiological characteristics; Marjorie Grene (Depew & Grene, 2004) suggests ethology or ecological psychology as perhaps the best guide for philosophy of science.

Even at the molecular level, though, future biology will be less physics-like than it now is. Molecular biologists and medicine men are coming to recognize that the Double Helix was not the Philosopher's Stone or the Elixir of Life, just the beginning of a very long and exceedingly intricate exploration. The newly established field of bioinformatics reflects the realization that novel methods are needed to extract humanly usable information from amounts of data so vast that current procedures cannot uncover regularities among the simultaneous interactions of the many variables. Though the goal of bioinformatics can be conceived, its realization will take centuries rather than decades. Let me illustrate it by contrasting contemporary medicine with that of the future. Nowadays, my level of blood sugar and of cholesterol, and my pulse rate and my blood pressure, my PSA[18], and much else, are compared with average values for the population, and my doctors seek to bring all my levels into that average range by administering one or more drugs for the blood sugar, one or more for the cholesterol, and so on. Far in the future, by contrast, the physician will estimate each individual's healthy level of blood sugar, cholesterol, etc., given that person's specific genome and specific body development and using an understanding of the systems that interconnect blood sugar and cholesterol and PSA and every other physiological property. Treatment will be holistic, not some collection of individual "magic bullets".

Bioinformatics is not just another tool. It portends a change in scientific style. Instead of cleanly crucial experiments that can dispose of inadequate theories in short order, enormous amounts of information will be examined by computerized and statistical means to yield answers that are suggestive and probabilistic rather than definite and precise. Inevitably the accumulation of reliable knowledge will proceed slowly, no matter how highly automated the information-gathering and information-analysis techniques may become.

And still this is not the biggest transformation that future biology will undergo; the most portentous will be direct, no longer avoidable, engagement with the mind-body problem. Developmental biology is already coming up against it: The human brain develops not only under instructions from the genome and the influence of the environment but also according to the intellectual tasks the brain is set and that it performs. Apparently, the continually changing software of the mind is able to modify the instructions continuously delivered by the hard-wired genome as it further hard-wires the brain. Already, too, more attention is being paid to the placebo phenomenon, with its indisputable evidence that, at least sometimes, quite powerful physiological agents can be overpowered by will or hope or suggestion—at any rate, by the consciousness that activates the placebo response. So the study of consciousness has to become part of biology, part of mainstream science.

There are three chief ways of envisaging consciousness (or mind, or perhaps soul):

1. It is different and separate from matter-energy. This is the philosophical stance known as dualism.
2. It is a fundamental property of matter-energy. This is the most natural view for a physics-like science: Consciousness of an observer collapses wave functions; wave functions may incorporate consciousness in some manner even at the level of atoms.
3. It is an emergent property of a sufficiently complicated system with appropriate feedback capabilities. This seems the most natural view for a biology-like science to take, and may well become the mainstream scientific view of the nearer future.

Dualism has enjoyed a long vogue. Perhaps it is time to discard it once and for all, if only for the reason offered by Jacques Barzun in praising Robert Burton's Anatomy of Melancholy: "Burton at least did not separate mind and body .... Today, the phrase psychosomatic medicine continues to imply a separation, as if any physician had ever seen a soma enter his office without a psyche, or the psychiatrist a psyche without a soma" (Barzun, 2000: 224).

Concluding Comments

The science of the future will take as its role model biology, not physics. The wider society will come to acknowledge that science cannot deliver definite answers in short order; like all other human activities, it can only do its imperfect and fallible best at any given time. The role of consciousness will be acknowledged and investigated. The knotty issue of subjectivity will be directly addressed (Jahn & Dunne, 1997), and thereby the present gap between natural science and behavioral science will be narrowed[19]—though some important differences will remain, for example that the physical sciences (chemistry and physics) are governed by a single, consensual, over-arching paradigm whereas the social sciences are multi-paradigmatic.

The concept of "scientific method" will change out of sight. Instead of the hypothetico-deductive method—hypothesize, test, accept or reject the hypothesis—science will rely on every scrap of useful evidence, including case studies and anecdotes. That is already the case in medical science, of course, where ethical considerations bar experiments on humans designed as they would be for inanimate objects[2']. In discussion at the Paris meeting where I presented these ideas, Jacques Benveniste pointed out that the complexities of laboratory work in much of biology entail so many levels of inference that it makes no sense to talk glibly of testing a hypothesis. Even the experimental material itself may not be easily defined or controlled. I was reminded of one of my friends, who had made a genuinely major contribution relating to mitochondria in certain strains of yeast. He was aghast when other workers questioned his results and his students could not repeat their observations using "the same material" as before. After months of nerve-wracking mental and laboratory efforts, it was realized that the yeast had mutated as it was moved from one university to another.

So the criterion of "reproducibility" will be drastically re-defined, or applied with more subtle sophistication. In Paris, Peter Wadhams suggested that there can be reproducibility even in observational biology, for example 500 reports of sea serpents would constitute reproducibility. I should have responded that this actually illustrates my point. "Concordant" descriptions of a type of animal do not refer to *precisely* the same sort of object in the way that concordant descriptions of the spectrum of a molecule do. Instead, they describe what philosophers call a "family resemblance": The various observed objects are not identical, they are "the same" *only in essential respects*. That qualification, "essential", allows room for argument. Thus there is a long-standing controversy in biology (or perhaps in the philosophy of biology) over the definition of a species, in large part because the individual members of a species are not identical but bear only a family resemblance to one another.

Again in Paris, Roderick Boes suggested that falsifiability could still be a useful criterion in biology. True enough, in concrete everyday practice, in that there are undoubtedly suggestions made about biological phenomena that can be decisively disproved. But the Popperian suggestion that theories be regarded as scientific only if they are falsifiable would find no basis in the experience of biologists (and, in any case, few if any philosophers of science still regard it as a good criterion; though some popularizers of science, and even some scientists-as-physicists, have not yet discarded the idea). Even in everyday practice, the difficulties of testing and disproving significant claims in biology should not be underestimated, for the reason given earlier: Biological materials and biological individuals are not "the same" in the manner that atoms of deuterium are, which makes generalizing from specific instances appreciably more hazardous.

When all is said and done, "scientific" may come to be understood simply as "rigorous and self-critical, whether quantitative or not", as Max Payne put it in Paris.

A corollary of the present train of thought, a situation that may seem unimaginable at the moment, is that some of the *raison d'être* for the SSE will fade away. When mainstream science addresses consciousness and subjectivity, it will find itself grappling with phenomena that are presently left to such outsiders as parapsychologists. The placebo phenomenon, after all, offers an entirely tangible protocol for investigating mind-body interactions, and its magnitude is quite comparable to claims of macro-psi (poltergeist phenomena, physical mediumship), whose spontaneous, irreproducible nature has tended to make macro-psi *persona non grata* among many serious investigators.

Physics-like science sought to explain the cosmos in objective, impersonal terms, formulas, and equations. Its goal was and remains an abstract, God's-eye view of universe and man. Its unwarranted hubris has alienated a wide swath of the public. But what we have called "modern science", and have regarded as almost a final culmination of millennia of development, is really just *adolescent* science: brash, contemptuous of older traditions, all too sure of itself, with glib, dogmatic opinions and definite answers. The biology-like science of the future, by contrast, with the mind-body question as a central focus, will have to take a humbler, more realistic, human-scale view of the cosmos—the only view, after all, that humans should aspire to. At the same time, values and meaning will be seen to inhere in the world[21], a marked and welcome contrast to the science-as-physics view of, for example, Steven Weinberg (1993), that "The more the universe seems comprehensible, the more it also seems pointless". It was said long ago that the proper study of Man is Man; if so, then the proper tool of study must be a biology-like science.

Not, of course, that science-as-biology offers only improvements and no dangers. Social Darwinism was, after all, an extrapolation from biology, as dangerously wrong as the extrapolation of reductionist materialism from physics[22]. I don't claim that we can foresee all the implications. But what is quite plain and certain is that biology will supersede physics as the exemplar of what science is, and that science thereby has an opportunity to become more human-friendly.

Notes

[1] Based on the invited paper prepared for the 6th European Meeting of the Society for Scientific Exploration, Paris, 29–31 August, 2003.

[2] Thereby including such obvious additional subjects as astronomy or biochemistry, but explicitly excluding the social and behavioral sciences.

[3] This has long been well known to historians of science, yet it is still not common knowledge, for example one could read quite recently that "As Dick Teresi discovered [sic], the roots of much Western science reach back to India, Egypt, Mesopotamia and China" whereas the standard history of science "locates its birth around 600 B.C. in ancient Greece" (Hall, 2002).

[4] No matter how obvious it may seem that reductionism is unsustainable, prominent people continue to promulgate it, albeit more often implicitly rather than explicitly. Thus some physicists speak of seeking "Theories of Everything", thereby implying that such theories could entail all the laws of chemistry and all other sciences, tantamount to *The Mind of God* (Davies, 1992) and explicating perhaps *The Physics of Immortality* (Tipler, 1994).

The distinction is not always clearly made or adhered to, between materialism and reductionism. Reductionism treats human free will as an illusion; whereas materialism can contemplate the possibility of genuine free will as an emergent property made possible through the interactive organization of the systems that make us human beings. (Of course this is a gross simplification, for the sake of emphasizing the distinction; philosophers recognize various shades and degrees of both materialism and reductionism.) But a physics-based materialism tends to be reductionist: "when materialists are up, physics is the 'model' and vitalists and idealists are down; when these last two are up, biology is strong and materialists muted" (Barzun, 2000: 365). Barzun's description, that these two attitudes alternate "in seesaw fashion", is congruent with Stephen Brush's account of the historical alternation between Romanticism and Rationalism (Brush, 1978).

[5] "Better" not necessarily in the sense of fitting better the given corpus of data: It may fit those data about equally well while encompassing a greater range of phenomena. Thus Einstein's relativity theories are better than Newton's laws of gravity and of mechanics. Or considerations of aesthetics or range may lead to calling a theoretical treatment "better" even when its equations fit the data less well, as in the case of the theoretical chemist Dave (Bauer, 1992: 20).

[6] First described by sociologist Robert K. Merton, these ideals are often referred to as the Mertonian norms of science.

[7] At least within many Western cultures. In some societies, even fairly industrialized ones, social norms of deference to authority, to tradition, or to

one's personal mentors have sometimes trumped the incisive, public critiquing that peer review calls for. In such totalitarian societies as Nazi Germany or the Soviet Union, ideology made scientific peer review essentially irrelevant.

[8] Not only through the atomic bomb, but also through development of radar, sonar, and many other technical advances, including the building of forerunners of today's computers which made possible the breaking of previously invulnerable codes.

[9] A fine exposition is by Appleyard (1992). It has been much criticized by defenders of the status quo in science.

[10] Consider for example that indiscriminate critic of anomalies, physicist Robert Park (Kauffman, 2001), or that hasty critic of cold fusion, physicist Frank Close (Bauer, 1991).

[11] The International Society of Cryptozoology was founded at about the same time as the SSE.

[12] Also initiated at the beginning of the 1980s was Correlation, the Astrological Association Journal of Research in Astrology. Interest in unorthodox science may be stimulated by the advance of established science (Bauer, 1986–87).

[13] The History of Earth Sciences Society was founded in 1982.

[14] See HYLE (International Journal for Philosophy of Chemistry), which grew out of the former bulletin of the group "Philosophie und Chemie", founded in Germany in 1993.

[15] The International Society for History, Philosophy, and Social Studies of Biology (ISHPSSB) was founded in 1989.

[16] Biology "enters the twenty-first century as the most dynamic and far-reaching of all the scientific disciplines" (Miller, 1999: 168); "Einstein's century was the century of physics .... Our century is likely to become the age of biology" (Andreasen, 2002).

[17] Marjorie Grene (Depew & Grene, 2004) suggests that "if we take the biological sciences as our model for philosophy of science, we have a better chance of accepting a realist point of view ... the hands-on realism of our everyday experience". One can easily question the reality of the "objects" with which physics deals—the likes of quarks or wave-functions—but "it is difficult for a biologist to deny the reality of living things".

[18] Amount of Prostate Specific Antigen. High levels indicate enlargement of the gland (benign prostatic hyperplasia, BPH) that is merely a nuisance; rapid increases may be, but need not be, indicative of prostate cancer.

[19] In other words, a biology-like "science" will be a better model for social scientists than is the physics-like "science" of today. A similar notion underlies the recent suggestion that historians should take as their model the historical sciences of biology and geology (Brinkley, 2002). One might equally argue that science should take as its model the best work done by historians.

[20] Bar increasingly, but not yet always, not even in the contemporary USA.

[21] "The world itself exhibits values, or meanings: relations between perceivers and features of their environments that offer them goals to seek or avoid. An animal's world is, from the beginning, a world full of meanings, and evolution has endowed that animal with the potentialities to respond to such a world" (Miller, 1999: 168).

[22] In discussion at the Paris meeting, Peter Moddel pointed out that a biology-based science could nevertheless be reductionist, whose implications would be even more dangerous than those of a reductionist physics-based science. The contemporary infatuation with genomics and molecular biology is indeed reductionist, and certain trials and experiments carried out on this basis do seem to me to be exceedingly hazardous. But recent recognition that genomes are dynamic systems and not linear arrays of fixed genes, and that humans have fewer "genes" than does corn and only 25% more than flatworms (Ast, 2005), should put some crimp into biological reductionism.

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The mind-body question is central in all this, and my thoughts on that and on much else have been greatly influenced by what I have learned, through interactions over more than two decades, from my valued friend and colleague Robert Jahn. I had planned to include this essay in a Festschrift mooted by another journal to acknowledge the achievements of the PEAR program as it comes to its close; but as so often, too many potential contributors promised but did not deliver, so those of us who did deliver are now publishing separately.

References

Andreasen, N. (2002). Recorded remarks. *Bulletin of the American Academy of Arts and Science, LVI #1,* 18–21.

Appleyard, B. (1992). *Understanding the Present: Science and the Soul of Modern Man.* London: Pan Books (also New York: Doubleday, 1993).

Ast, G. (2005). The alternative genome. *Scientific American, April,* 58-65.

Barber, B. (1961). Resistance by scientists to scientific discovery. *Science,* 134, 596–602.

Barzun, J. (1964). *Science: The Glorious Entertainment.* Harper & Row.

Barzun, J. (2000). *From Dawn to Decadence: 500 Years of Western Cultural Life–1500 to the Present.* HarperCollins.

Bauer, H. H. (198687). The literature of fringe science. *Skeptical Inquirer,* 11 *(#2, Winter),* 205–210.

Bauer, H. H. (1991). Review of Frank Close, *Too Hot to Handle: The Race for Cold Fusion. Journal of Scientific Exploration, 5,* 267–270.

Bauer, H. H. (1992). *Scientific Literacy and the Myth of the Scientific Method.* Urbana: University of Illinois Press.

Bauer, H. H. (2001). *Fatal Attractions: The Troubles with Science.* New York: Paraview Press.

Bauer, H. H. (2004). Science in the 21" century: knowledge monopolies and research cartels. *Journal of Scientific Exploration,* 18, 643–660.

Brinkley, A. (2002). Review of John Lewis Gaddis, *The Landscape of History: How Historians Map the Past. New York Times Book Review,* 17 November, p. 50.

Brown, A. (1999). *The Darwin Wars: The Scientific Battle for the Soul of Man.* London: Simon & Schuster.
Brush, S. (1978). *The Temperature of History.* New York: Burt Franklin.
Davies, P. (1992). *The Mind of God: The Scientific Basis for a Rational World.* New York: Simon & Schuster.
Depew, D., & Grene, M. (2004). *A History of the Philosophy of Biology.* Cambridge University Press, concluding chapter.
Gross, P. R., & Levitt, N. (1994). *Higher Superstition: The Academic Left and Its Quarrels with Science.* Johns Hopkins University Press.
Haack, S. (1998). *Manifesto of a Passionate Moderate.* University of Chicago Press.
Haack, S. (2003). *Defending Science-Within Reason: Between Scientism and Cynicism.* Amherst, NY: Prometheus.
Hall, S. S. (2002). Mapping the heavens, curing dandruff (review of *Lost Discoveries: The Ancient Roots of Modern Science—from the Babylonians to the Maya,* by Dick Teresi). *New York Times Book Review,* 1 December, pp. 13–14.
Hirsh, A. E. (2003). The scientific method—Signs of life. *American Scholar, 72 (summer),* 125–130.
Jahn, R. G., & Dunne, B. (1997). Science of the subjective. *Journal of Scientific Exploration, 11,* 201–224.
Kauffman, J. (2001). Review of Robert Park, *Voodoo Science: The Road from Foolishness to Fraud. Journal of Scientific Exploration, 15,* 281–287.
Knight, D. (1986). *The Age of Science.* Oxford & New York: Basil Blackwell.
Marks, J. (1983). *Science and the Making of the Modern World.* Oxford: Heinemann.
Miller, K. R. (1999). *Finding Darwin's God.* New York: Cliff Street Books.
Muller, R. A. (1980). Innovation and scientific funding. *Science, 209,* 880–883.
Polanyi, M. (1967). Life transcending physics and chemistry. *Chemical & Engineering News, 21 August,* 54-66.
Sokal, A. (1996a). Transgressing the boundaries: Toward a transformative hermeneutics of quantum gravity. *Social Text 46/47, 14 (#1 & 2, Spring/Summer),* 217–250.
Sokal, A. (1996b). A physicist experiments with cultural studies. *Lingua Franca, May/June,* 62-64.
Tipler, F. (1994). *The Physics of Immortality: Modern Cosmology, God and the Resurrection.* Doubleday.
Weinberg, S. (1993). Cited by John S. Rigden, "A reductionist in search of beauty (review of Steven Weinberg, *Dreams of a Final Theory)". American Scientist, 82 (January–February 1994), 69.*
Ziman, J. (1994). *Prometheus Bound: Science in a Dynamic Steady State.* Cambridge University Press.
Ziman, J. (2000). *Real Science—What it is, and What it Means.* Cambridge University Press.