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Scientists, Scholars, Knaves and Fools

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Science, its imperfections notwithstanding, is the sword in the stone that humanity finally pulled. The question it poses, of ultimately lawful materialism, is the most important that can be asked in philosophy and religion. Its procedures are not easy to master, even to conceptualize; that is why it took so long to get started, and then mostly in one place, which happened to be western Europe.

Science, to put its warrant as concisely as possible, is the organized systematic enterprise that gathers knowledge about the world and condenses the knowledge into testable laws and principles. The diagnostic features of science that distinguish it from pseudoscience are first, repeatability: The same phenomenon is sought again, preferably by independent investigation, and the interpretation given to it is confirmed or discarded by means of novel analysis and experimentation. Second, economy: Scientists attempt to abstract the information into the form that is both simplest and aesthetically most pleasing—the combination called elegance—while yielding the largest amount of information with the least amount of effort. Third, mensuration: If something can be properly measured, using universally accepted scales, generalizations about it are rendered unambiguous. Fourth, heuristics: The best science stimulates further discovery, often in unpredictable new directions; and the new knowledge provides an additional test of the original principles that led to its discovery. Fifth and finally, consilience: The explanations of different phenomena most likely to survive are those that can be connected and proved consistent with one another.

Astronomy, biomedicine and physiological psychology possess all these criteria. Astrology, ufology, creation science and Christian Science, sadly, possess none. And it should not go unnoticed that the true natural sciences lock together in theory and evidence to form the ineradicable technical base of modern civilization. The pseudosciences satisfy personal psychological needs, but lack the ideas or the means to contribute to the technical base.

The work of real science is hard and often for long intervals frustrating. You have to be a bit compulsive to be a productive scientist. Keep in mind that new ideas are commonplace, and almost always wrong. Most flashes of insight lead nowhere; statistically, they have a half-life of hours or maybe days. Most experiments to follow up the surviving insights are tedious and consume large amounts of time, only to yield negative or (worse!) ambiguous results.

Over the years I have been presumptuous enough to counsel new Ph.D.'s in biology as follows: If you choose an academic career you will need 40 hours a week to perform teaching and administrative duties, another 20 hours on top of that to conduct respectable research and still another 20 hours to accomplish really important research. This formula is not boot-camp rhetoric. More than half of the Ph.D.'s in science are stillborn, dropping out of original research

after at most one or two publications. Percy Bridgman, the founder of high-pressure physics—no pun intended—put the guideline another way: "The scientific method is doing your damnedest, no holds barred."

Original discovery is everything. Scientists as a rule do not discover in order to know but rather, as the philosopher Alfred North Whitehead observed, they know in order to discover. They learn what they need to know, often remaining poorly informed about the rest of the world, including most of science for that matter, in order to move speedily to some part of the frontier of science where discoveries are made. There they spread out like foragers on a picket line, each alone or in small groups probing a carefully chosen, narrow sector. When two scientists meet for the first time the usual conversation entry is, "What do you work on?" They already know what generally bonds them. They are fellow prospectors pressing deeper into an abstracted world, content most of the time to pick up an occasional nugget but dreaming of the mother lode. They come to work each day thinking subconsciously, *It's there, I'm close, this could be the day.*

They know the first rule of the professional game book: Make an important discovery, and you are a successful scientist in the true, elitist sense in a profession where elitism is practiced without shame. You go into the textbooks. Nothing can take that away; you may rest on your laurels the rest of your life. But of course you won't. Almost no one driven enough to make an important discovery ever rests. And any discovery at all is thrilling. There is no feeling more pleasant, no drug more addictive, than setting foot on virgin soil.

Fail to discover, and you are little or nothing in the culture of science, no matter how much you learn and write about science. Scholars in the humanities also make discoveries, of course, but their most original and valuable scholarship is the interpretation and explanation of already existing factual knowledge. When a scientist begins to sort out knowledge in order to sift for meaning, and especially when he carries that knowledge outside the circle of discoverers, he is classified as a scholar in the humanities. Without scientific discoveries of his own, he may be a veritable archangel among intellectuals, his broad wings spread above science, and still not be in the circle. The true and final test of a scientific career is how well the following declarative sentence can be completed: *He (or she) discovered that….* A fundamental distinction thus exists in the natural sciences between process and product. The difference explains why so many accomplished scientists are narrow, foolish people, and why so many wise scholars in the field are considered weak scientists.

Yet, oddly, there is very little science culture, at least in the strict tribal sense. Few rites are performed to speak of. There is at most only a scattering of icons. One does, however, hear a great deal of bickering over territory and status. The social organization of science most resembles a loose confederation of petty fiefdoms. In religious belief individual scientists vary from born-again Christians, admittedly rare, to hard-core atheists, very common. Few are philosophers. Most are intellectual journeymen, exploring locally, hoping for a strike, living for the present. They are content to work at discovery, often teaching science at the college level, pleased to be relatively well-paid members of one of the least conspiratorial of professions.

In character they are as variable as the population at large. Take any random sample of a thousand and you will find the near full human range on every axis of measurement—generous

to predatory, well adjusted to psychopathic, casual to driven, gregarious to reclusive. Some are as stolid as tax accounts in April, while a few are clinically certifiable as manic-depressives (or bipolars, to use the ambiguous new term).

In motivation they run from venal to noble. Einstein classified scientists very well during the celebration of Max Planck's 60th birthday in 1918. In the temple of science, he said, are three kinds of people. Many take to science out of a joyful sense of their superior intellectual power. For them research is a kind of sport that satisfies personal ambition. A second class of researchers engage in science to achieve purely utilitarian ends. But of the third: If "the angel of the Lord were to come and drive all the people belonging to these two categories out of the temple, a few people would be left, including Planck, and that is why we love him."

Scientific research is an art form in this sense: It does not matter how you make a discovery, only if your claim is true and convincingly validated. The ideal scientist thinks like a poet and works like a bookkeeper, and I suppose that if gifted with a full quiver, he also writes like a journalist. As a painter stands before canvas or a novelist recycles old emotion with eyes closed, he searches his imagination for subjects as much as for conclusions, for questions as much as for answers. Even if his highest achievement is only to perceive the need for a new instrument or theory, that may be enough to open the door to a new industry of research.

This level of creativity in science, as in art, depends as much on self-image as on talent. To be highly successful the scientist must be confident enough to steer for blue water, abandoning sight of land for a while. He values risk for its own sake. He keeps in mind that the footnotes of forgotten treatises are strewn with the names of the gifted but timid. If on the other hand he chooses like the vast majority of his colleagues to hug the coast, he must be fortunate enough to possess what I like to define as optimum intelligence for normal science: bright enough to see what needs to be done but not so bright as to suffer boredom doing it.

Advice to the novice scientist: There is no fixed way to make and establish a scientific discovery. Throw everything you can at the subject, so long as the procedures can be duplicated by others. Consider repeated observations of a physical event under varying circumstances, experiments in different modes and styles, correlation of supposed causes and effects, statistical analyses to reject null hypotheses (those deliberately raised to threaten the conclusion), logical argument, and attention to detail and consistency with the results published by others. All these actions, singly and in combination, are part of the tested and true armamentarium of science. As the work comes together, also think about the audience to whom it will be reported. Plan to publish in a reputable, peer-reviewed journal. One of the strictures of the scientific ethos is that a discovery does not exist until it is safely reviewed and in print.