

[For "The Writing Life":]

ADVOCATING SCIENCE AND HOPE

by Carl Sagan

I was lucky enough to be a child in a time of hope. I wanted to be a scientist from my elementary school days. The crystallizing moment came when I first caught on that the stars are mighty suns, and that they must be staggeringly far away to appear to us as mere points of light. I'm not sure I even knew the word science then, but I was gripped by the prospect of understanding how things really work, of helping to uncover deep mysteries, of exploring new worlds -- maybe even literally. It has been my good fortune to have had that dream in part fulfilled. Doing science is still among my chief pleasures.

For me, popularizing science -- making its methods and findings accessible to non-scientists -- then follows naturally and immediately. Not explaining science seems to me perverse. When you're in love, you want to tell the world.

But there's another reason. I have a foreboding of an America in my children's or grandchildren's time -- when we're a service and information economy; when nearly all the key manufacturing industries have slipped away to other countries; when awesome technological powers are in the hands of a very few, and no one representing the public interest can even grasp the issues; when the people have lost the ability to set their own

agendas or knowledgeably question those in authority; when, clutching our crystals and religiously consulting the newspaper horoscopes, our critical faculties in decline, unable to distinguish between what feels good and what's true, we slide, almost without noticing, back into superstition.

We've arranged a civilization in which most crucial elements -- transportation, communications, and all other industries; agriculture, medicine, education, entertainment, and protecting the environment; and even the key democratic institution of voting -- profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. We might get away with it for a while, but eventually this combustible mixture of ignorance and power is going to blow up in our faces.

I know of no area of human endeavor in which science has not had at least something important to say. Of course, there is much about which even experts are ignorant; this will probably always be the case. Science is far from a perfect instrument of knowledge. It's just the best one we have. In this respect, as in many others, it's like democracy. (Science by itself cannot advocate courses of human action, but it can certainly illuminate the possible consequences of alternative courses of action.)

The predictive powers of science are astonishing -- in foretelling eclipses, say, or the sex of an unborn child. There isn't a religion on the planet that doesn't long for a comparable ability -- precise, and repeatedly demonstrated before committed

skeptics -- to prophecize future events. No other human institution comes close.

One of the reasons for its success is that science has built-in, self-correcting machinery at its very heart. It takes account of human fallibility. One of its commandments is, "Mistrust arguments from authority." Too many such arguments have turned out to be painfully wrong. Authorities must prove their contentions like anybody else. This independence of science, its unwillingness to pay automatic obeisance to conventional wisdom, makes it dangerous to doctrines less self-critical.

Because science carries us toward an understanding of how the world is, rather than how we would wish it to be, its findings may not in all cases be immediately comprehensible or satisfying. It may take a little work to restructure our mindsets. Some of science is very simple. When it gets complicated, that's usually because the world is complicated -- or because we're complicated. When we shy away from it because it seems too difficult (or because we've been taught so poorly), we surrender the ability to take charge of our future. We're disenfranchized. Our self-confidence erodes.

But when we penetrate the barrier, when the findings and methods of science get through to us, when we understand and put this knowledge to use, many feel, if not wild exhilaration, at least deep satisfaction. This is true for everyone, but especially for children -- born with a zest for knowledge, aware

that they must live in a future molded by science, but so often convinced by their culture that science is not for them. I know personally, both from having science explained to me and from my attempts to explain it to others, how gratifying it is when we get it, when obscure terms suddenly take on meaning, when we grasp what all the fuss has been about, when wonders are revealed. We feel reassured: We're not so stupid after all. We can influence the decisions touching on science that will determine our future. And we're moved -- because in its encounter with Nature, science invariably conveys reverence and awe.

Being human, scientists are not perfect. New evidence, here too, is sometimes resisted when it challenges favored doctrines. Scientists have, both inadvertently and intentionally, developed formidable, downright mythical, powers of destruction. The technological perils that science serves up, its implicit challenge to received wisdom, and its perceived difficulty are all reasons for some people to mistrust and avoid it. You can see the disquiet easily enough in the image of the mad scientist on Saturday morning television, or in the plethora of Faustian bargains in popular culture, from ^{Dr.} Frankenstein to Dr. Strangelove to Jurassic Park.

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Here are some of the reasons that a concerted national effort is needed [-- in radio, television, newspapers, and classrooms, but especially in widely-available books --] to bring science to every citizen:

- It makes the national economy and the global civilization run. Other nations well understand this. This is why so many graduate students in science and engineering at American universities -- still the best in the world -- are citizens of other countries. Science is the golden road out of poverty and backwardness for emerging nations. The corollary, one that the United States sometimes fails to grasp, is that abandoning science is the road back into poverty and backwardness.

- It alerts us to subtle dangers introduced by our world-altering technologies, especially to the environment.

- It teaches us about the deepest issues of origins, natures, and fates -- of our species, of life, of our planet, of the Universe. For the first time in human history we are able to secure an understanding of some of these matters. Every culture on the planet addresses such questions and values their importance. In the long run, the greatest gift of science may be in teaching us, in ways no other human endeavor has been able, something about our cosmic context, and about who we are.

- The values of science and the values of democracy are concordant, in many cases indistinguishable. Science confers power on anyone who takes the trouble to learn it. Science thrives on the free exchange of ideas; its values are

antithetical to secrecy. Science holds to no special vantage points or privileged positions. Both science and democracy encourage unconventional opinions and vigorous debate. Both demand adequate reason, coherent argument, rigorous standards of evidence and honesty. Science is a baloney detector, a way to call the bluff of those who only pretend to knowledge. The more widespread its language, rules, and methods, the better chance we have of preserving what Jefferson and his colleagues had in mind. But democracy can also be subverted more thoroughly with the tools of science than any pre-industrial demagogue ever dreamed.

In all these uses of science, it is insufficient and dangerous to produce only a small, highly competent, well-rewarded priesthood of professionals; some fundamental understanding of the findings and methods of science must be available on the broadest scale.

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As nearly as I can see, the only secret in popularizing science (or anything else) is remembering what thinking went on in your head when you first really understood whatever it is you're now explaining: especially (1) what misunderstandings needed to be cleared away, (2) what metaphors and analogies proved helpful, and (3) what reassurance had to be offered. The effort involved is slight, the benefits great. Among the potential pitfalls are oversimplification, the need to be sparing

with qualifications (and quantifications), inadequate credit given to the many scientists involved, and insufficient distinctions drawn between helpful analogy and reality. Doubtless, compromises must be made.

Like some editors and television producers, some scientists believe the public is too ignorant to understand science, that the enterprise of popularization is fundamentally a lost cause. Among the many criticisms that could be made of this judgment is that it is self-confirming.

Most scientists, I think, are comfortable with the idea of popularizing science. (Since nearly all support for science comes from the public coffers, it would be self-defeating, an odd flirtation with suicide, for scientists to oppose competent popularization.) What the public understands and appreciates, it is more likely to support.

Newspaper articles or television programs can strike sparks as they give us a glimpse of science, but -- apart from apprenticeship or well-structured seminars -- the best way to popularize science is books. With books, you can mull things over, go at your own pace, revisit the hard parts, compare texts, dig deep. As a youngster, I was inspired by the popular books of George Gamow, James Jeans, Arthur Eddington, J.B.S. Haldane, Rachel Carson, and Arthur C. Clarke. The popularity of well-written, well-explained books on science that touch our hearts as well as our minds seems greater in the last twenty years than ever before, and the number and disciplinary diversity of

scientists writing these books is likewise unprecedented. Among the best contemporary scientist-popularizers, I think of Stephen Jay Gould, E.O. Wilson and Richard Dawkins in biology; Steven Weinberg, Alan Lightman and Kip Thorne in physics; Roald Hoffman in chemistry; and the early works of Fred Hoyle in astronomy. Isaac Asimov wrote capably on everything. (While requiring some calculus, the most consistently exciting, provocative and inspiring science popularization of the last few decades seems to me to be Volume I of Richard Feynman's Introductory Lectures on Physics.) Nevertheless, current efforts at science popularization are clearly nowhere near commensurate with the public good and the national need.

An extraterrestrial being, newly arrived on Earth -- scrutinizing what we mainly present to our children in television, radio, newspapers, magazines, the comics and many books -- might easily conclude that we are intent on teaching them murder, rape, cruelty, superstition, and consumerism. We keep at it, and through constant repetition many of them finally get it. What kind of society could we create if, instead, we drummed into them science and a sense of hope?