(DRAFT 29 July 02)

for Think: the journal of the Royal Institute of Philosophy

THE SEVEN WARNING SIGNS OF VOODOO SCIENCE

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A best-selling health guru insists that his brand of spiritual healing is firmly grounded in quantum theory; half the population believes Earth is being visited by space aliens who have mastered faster-than-light travel; and educated people are wearing magnets in their shoes to restore their natural energy. Why, in an age of science, does irrationalism appear to be raging out of control?

The persistent irony is that science begets pseudoscience. The more science succeeds, the more it attracts imitators who cloak foolish and often fraudulent claims in the language and symbols of science. With spectacular advances in science and medicine being announced almost daily, the public has come to expect scientific "miracles." And of course, there are "miracles" aplenty, or at least scientific wonders that would have seemed like miracles a few short decades ago. Too often, however, those with little exposure to the methods and ideas of modern science are unable to distinguish genuine scientific advances from the claims of misguided zealots or unscrupulous hucksters.

This is a particular problem in the courts, which are increasingly confronted with controversies that turn on questions of science. In judging the credibility of testimony, the scientific credentials of "expert" witnesses are of only limited help. A Ph.D. in science is not an inoculation against foolishness or mendacity, and even some Nobel laureates seem to be a bit strange. The sad truth is that there is no claim so preposterous that a Ph.D. scientist cannot be found to vouch for it.

In its 1993 landmark decision, Daubert v. Dow Pharmaceuticals, the United States Supreme Court addressed the problem of junk science in the courts, instructing federal judges to serve as "gatekeepers," screening juries from testimony based on scientific nonsense. Recognizing that judges are not scientists, the Court invited the m to experiment with ways to fulfill their gatekeeper responsibility. The solution is usually to appoint an impartial panel of scientific experts to preview questionable scientific testimony and advise the judge on whether a jury should be allowed to hear it. Advice on the com position of the panel is generally provided by leading scientific societies.

Although this approach has worked well, it still leaves the judge with the problem of having to decide when such a panel is called for. Indeed, in modern society it seems that everyone might benefit from a short course in recognizing the warning signs of sham and error among conflicting claims about how the world works.

The most likely place to look for such warning signs would seem to be among recent claims, made in the name of science, that are universally judged by the scientific community to lie well outside the bounds of rational scientific discourse. In some cases, several of the warning signs apply to a single claim. They are, nevertheless, only warning signs; and do not guarantee that the science is flawed. Seven distinct warning signs of foolish or fraudulent science were identified:

1) A discovery is pitched directly to the media. The integrity of science rests on the willingness of scientists to expose new ideas and findings to the scrutiny o f other scientists. While there is no rigid set of rules, it is generally expected that the initial exposure of new work will be at a scientific conference or in a scholarly journal. Thus, by the time the general public learns of a discovery, a limited body of expert opinion concerning its validity and importance should already exist. An attempt to bypass the scientific community by taking a new finding directly to the media, suggests that the work is unlikely to stand up to close examination by other scientists.

The most notorious example in recent years was the discovery of "cold fusion" by two University of Utah chemists, Stanley Pons and Martin Fleischmann. They claimed to have developed a simple electrolytic process to induce fusion between deuterium nuclei in a solution of heavy water, creating helium and liberating substantial amounts of heat. The scientific community did not learn of the claim until it was announced by the University of Utah at a press conference in Salt Lake City. Moreover, the announcement de alt largely with the economic potential of the discovery, and was devoid of the sort of details that might enable other scientists to judge the strength of the claim or repeat the experiment. Even after the press conference, details that might have enabled other scientists to repeat the experiment were not freely available.

Ordinarily, scientists who believe they have made a significant discovery consult first with colleagues in their own institution, and go public with their findings only after the work has been fully vetted by whatever segment of the scientific community is best qualified to judge its value. Attempts to bypass rigorous scientific evaluation by going directly to the media, suggest a desire to turn a quick profit on the work before its flaws can be exposed. Nevertheless, within a few weeks, other scientists felt they had assembled enough details from media accounts to repeat the Pons and Fleischmann experiment. They found no evidence that fusion was taking place.

In some cases, even the scrutiny of the news media is avoided by making scientific claims in paid commercial advertisements. Dennis Lee, a notorious huckster who peddles "dealerships" for perpetual motion machines, regularly takes out full page ads in major newspapers and news magazines touting demonstrations of his machines. The demonstrations are obviously rigged, since simple physics suffices to show such devices are an impossibility. Needless to say, those who purchase his dealerships n ever actually get delivery of the devices.

A health-food company marketed a dietary supplement called "Vitamin O" in full-page newspaper ads that falsely claimed the supplement had been developed for NAS A to

protect astronauts against oxygen deficiency. "Vitamin O" turned out to be ordinary salt water.

2) A powerful "establishment" is said to be suppressing the discovery. Revolutionary discoveries that might shift the balance of wealth and influence in society are said to be threatening to powerful establishment interests. The establishment will presumably stop at nothing to suppress such discoveries. The "scientific establishment" is often pictured as a part of a larger conspiracy that includes industry and government

In the early '70s, an inventor named Sam Leach built an automobile that he claimed used only water as a fuel. Leach explained that electrolysis was used to separate the water into hydrogen and oxygen. The hydrogen was then burned as a fuel. In the burning of hydrogen, water is the only combustion product. Leach's water-powered car was a classic violation of the First Law of Thermodynamics: you start with water and you end up with water plus heat. Scientists pointed out that it would take more energy to decompose the water than it is possible to recover by burning the hydrogen. Ordinarily that would be true, Leach acknowledged, but he claimed to have discovered a new catalyst that makes the electrolysis process much more efficient. The wonderful thing about the laws of thermodynamics, however, is that you can set limits on the outcome without knowing the details of the process. It's is clear from the First Law that no matter how efficient the electrolysis, there will still be a net energy loss.

Nevertheless, after Leach drove his water-powered car across the United States, investors who didn't understand, or didn't believe, the First Law of Thermodynamics, clamored for a share of the invention. No one else was allowed to test the car, lest they steal the secret catalyst. The President of Budget-Rent-A-Car sank $2 million in the idea, envisioning a fleet of cars that could be fueled with a garden hose. And what of Sam Leach? He retired a wealthy man, without ever having revealed his secret catalyst. The rumor spread that the oil companies had bought him off. There is a simpler explanation: there never was a secret catalyst, and the water-powered car was a fake.

The cold-fusion chemists, Pons and Fleischmann, insisted that negative reports about cold fusion were the work of physicists, who realized that their costly research into high-temperature plasma fusion would be curtailed when cold fusion proved to be successful. In presentations to potential investors, perpetual-motion machine swindler Dennis Lee, actually boasts of the term he served in a California prison for fraud. It is proof, Lee contends, that the authorities, in league with the power companies, are out to silence him.

3) An effect is always at the very limit of detection. All scientific measurements must contend with some level of background noise or statistical fluctuation. Normally, the noise problem can be reduced by shortening distances and increasing the flux. If the signal-to-noise ratio cannot be improved, even in principle, the effect is probably not real and the work is not science.

The most egregious examples are all in parapsychology. Indeed, in studies spanning more than a century, not one of the many thousands of published papers alleging t o have observed telepathy, psychokinesis, or precognition, has achieved any level of acceptance among scientists outside the parapsychology community. This is truly remarkable. I can find no other example of a research area in which such a huge body of work h as failed so completely to persuade scientists outside the band of true

believers conducting the studies. Indeed, in the case of parapsychology it is difficult to see how even the true believers remain convinced.

In the first place, there is nothing resembling progress in parapsychology. Ordinarily, the maturing of an area of research involves three phases: the initial studies a re devoted to showing the effect is real, and to identifying the parameters that control t he strength of the effect. As the effect is made stronger, research moves on to identifying plausible mechanisms. The final phase involves controlled laboratory tests of these mechanisms. Research into parapsychology is still stuck in the first phase, with each new study merely trying, without much success, to establish that there is something to study.

It seems there is little that can be don e to strengthen paranormal effects. There is no indication, for example, that distance is a factor. There are claims that sensory deprivation increases the sensitivity of subjects to paranormal stimulation. In ganzfe ld experiments, for example, the eyes of the subject are covered with diffusers. Any effect, however, is still too slight to convince most scientists.

4) Evidence for a discovery is anecdotal. The most important discovery in modern medicine was not vaccines or antibiotics, it is the randomized double-blind- test, by means of which we know what works and what doesn't. If medical science has learned anything in the past one-hundred years, it is to distrust anecdotal evidence. Anecdotes have a very strong emotional impact. Indeed, in an age of science, it is anecdotes that keep superstitious beliefs alive.

My own impression is that the most fertile venue for the exchange of anecdotes is the golf course, although the evidence is admittedly somewhat anecdotal. Thirty year s ago, most golfers wore copper bracelets to suppress arthritic pain and stiffness. Some still do, but the practice, which had no scientific basis, is no longer common. Instead, golfers now tend to wear some form of therapy magnets, usually in the form of thin flexible magnets, not unlike the magnets used to attach slips of paper to refrigerators or file cabinets. Indeed, when magnet therapy experienced a revival a decade or so ago, after 200 years of desuetude, golf pro shops were about the only place you could buy them. Today, they are available in pharmacies and department stores everywhere. It is a $15 billion business, although there are no independent studies indicating they have any therapeutic value, no plausible mechanism by which they might interact with our decidedly non-magnetic bodies, and little assurance that they are even what they purport to be.

My attention was first drawn to magnet therapy claims by an advertisement showing a magnet rated at 800 gauss being worn on the wrist. That's a very strong fie ld for a small permanent magnet, but within the range available using rare-earth alloy magnets. Indeed, magnet therapy owes its revival to modern material science, which has made thin, flexible, magnets with very strong fields possible. What captured my attention in the advertisement is that when I walk, my wrist passes within a few centimeters of the hip pocket in which I keep my wallet, which contains my credit cards. 800 gauss is more than enough to erase those credit cards, and I was pretty sure that was not what the advertiser wanted.

The fact is that virtually all therapy magnets are constructed with some pattern of alternating North and South magnetic poles. This results in a very high fie ld at the surface of the magnet, which is where magnets are rated, but a very short distance a

way from the surface, fields from the North and South poles cancel each other out. The result is that the field of most therapy magnets is very short range. It barely extends through the epidermal layer and never reaches the joints and muscles where most pain occurs.

A magnetic field would not help anyway. The claim is that a magnetic field attracts blood to the injury because blood contains iron. But the iron in blood is in the chemical form of hemoglobin, which is not ferromagnetic and is not attracted by a magnet.

This sort of outrageous misinformation i s difficult to counter because it spreads outside formal channels of communication by means of shared anecdotes. The fact that many people are convinced they have been helped by magnets is not at all persuasive. After all, two hundred years ago, most educated people believed bleeding to be a cure for a wide assortment of ailments. The practice of bleeding continued until it was scientifically compared to doing nothing.

5) A belief is said to be credible because it has endured for centuries. Science is conditional. When better information becomes available, either as a result of more sophisticated experiments or improved theoretical analysis, science textbook s are rewritten with hardly a backward glance. To remain productive, scientists must struggle throughout their career to stay current in their field. There is a persistent myth among non-scientists, however, that our ancestors made miraculous discoveries hundreds or even thousands of years ago that have eluded modern science. The claim is that these ancient ideas survive because they work, but it is difficult to find any credible evidence.

Much of what is termed "alternative medicine" is part of this "ancient wisdom myth." We are somehow expected to believe, for example, that long before it was known that blood circulates or that germs cause disease, people had determined the precise locations of hundreds of acupuncture points, and catalogued the diseases that can be treated by stimulating them. In fact, long before vivisection was first practiced, Chinese medicine included elaborate charts showing meridians on the human body, imaginary lines along which the acupuncture points are distributed. The problem is simply that nothing can be found in actual human physiology that corresponds in any way to these meridians.

It can be frustrating that so many other wise intelligent and educated people choose to dabble in astrology or feng shui, but we must remind ourselves that this thin thread of "magical thinking" was once the entire fabric of human belief about the universe.

6) An important discovery is made in isolation. Most scientific advances draw heavily on research by a number of scientists or groups working in related areas. Successful innovators tend to be actively involved in the open exchange of scientific ideas and results, presenting their work at scientific conferences and publishing in mainstream scholarly journals. The image of a lone genius working in secrecy in an attic laboratory who makes a revolutionary breakthrough, is a staple of Hollywood horror films, but its hard to find examples in real life. There are frequent claims by lone inventors to have made such breakthroughs, but the claims rarely if ever stand up.

Many of the examples of isolation that come to mind involve claims that a source of unlimited free energy has been discovered. Indeed, claims of unlimited free energy could have been treated as a separate warning sign. In the case of Pons and Fleischmann, the chemists who claimed to have discovered cold fusion, isolation was

self-imposed. They had previously been prolific producers of mainstream scientific publications , but so beguiled were they by the dream that they had made the "discovery of the Century" that they did not share their findings even with close colleagues in the Chemistry Department. Their belief that a competitor was about to publish similar findings added to their secretiveness, and led them to release their claim to the media prematurely.

Among the hordes attempting to replicate the Pons and Fleischmann result was a young Harvard M.D. named Randell Mills, but Mills concluded it was not fusion, but an even more unlikely process. Mills, who had no record of scientific publication, called a press conference of his own to announce that the excess energy was produced by the transition of hydrogen into a "state-below-the-ground-state." He called hydrogen atoms in this new state "hydrinos." To a scientist, a "state-below-the-ground-state" is physically meaningless. It would be like talking about a place "south of the south pole." There can be no such place. Mills, however, proceeded to concoct an entirely new theory, which he called "the grand-unified theory of classical quantum mechanics," and to create a new company, now called BlackLight Power, which has raised tens of millions of dollars from investors who understand even less physics than Mills.

7) New laws of nature are proposed to explain an incredible observation. Extraordinary claims demand extraordinary evidence. They also demand some explanation of how they can be reconciled with the same natural laws that govern everything else. If existing laws of nature must be changed, or new laws must be proposed, the observation is almost certainly wrong.

Paranormal phenomena, for example, would contradict virtually everything that has been learned about how the universe works. A far more likely explanation is that reports of paranormal happenings are simply in error.

In homeopathy, medications are diluted far beyond their dilution limit. That is, there is a vanishingly small probability that even a single molecule of the medication remains in a homeopathic solution. Homeopathists insist it doesn't matter; "the water remembers." No plausible explanation for this memory has been offered. It's just as well. Residents of many communities, including Washington, DC, devoutly hope their water can't remember.

Alas, there is never a clear photograph of a flying saucer, or the Loch Ness monster.