Distinguishing Science and Pseudoscience

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The word "pseudo" means fake. The surest way to spot a fake is to know as much as possible about the real thing—in this case, about science itself. Knowing science does not mean simply knowing scientific facts (such as the distance from earth to sun, the age of the earth, the distinction between mammal and reptile, etc.) It means understanding the nature of science—the criteria of evidence, the design of meaningful experiments, the weighing of possibilities, the testing of hypotheses, the establishment of theories, the many aspects of scientific methods that make it possible to draw reliable conclusions about the physical universe.

Because the media bombard us with nonsense, it is useful to consider the earmarks of pseudoscience. The presence of even one of these should arouse great suspicion. On the other hand, material displaying none of these flaws might still be pseudoscience, because its adherents invent new ways to fool themselves every day. Most of the examples in this article are related to my field of physics, but similar beliefs and behavior are associated with iridology, medical astrology, meridian therapy, reflexology, subluxation-based chiropractic, therapeutic touch, and other health-related pseudosciences.

Pseudoscience displays an indifference to facts.
Instead of bothering to consult reference works or investigating directly, its advocates simply spout bogus "facts" where needed. These fictions are often central to the pseudoscientist's argument and conclusions. Moreover, pseudoscientists rarely revise. The first edition of a pseudoscience book is almost always the last, even though the book remains in print for decades or even centuries. Even books with obvious mistakes, errors, and misprints on every page may be reprinted as is, over and over. Compare this to science textbooks that see a new edition every few years because of the rapid accumulation of new facts and insights.

Pseudoscience "research" is invariably sloppy.
Pseudoscientists clip newspaper reports, collect hearsay, cite other pseudoscience books, and pore over ancient religious or mythological works. They rarely or never make an independent investigation to check their sources.

Pseudoscience begins with a hypothesis—usually one which is appealing emotionally, and spectacularly implausible—and then looks only for items which appear to support it.
Conflicting evidence is ignored. Generally speaking, the aim of pseudoscience is to rationalize strongly held beliefs, rather than to investigate or to test alternative possibilities. Pseudoscience specializes in jumping to "congenial conclusions," grinding ideological axes, appealing to preconceived ideas and to widespread misunderstandings.

Pseudoscience is indifferent to criteria of valid evidence.

The emphasis is not on meaningful, controlled, repeatable scientific experiments. Instead it is on unverifiable eyewitness testimony, stories and tall tales, hearsay, rumor, and dubious anecdotes. Genuine scientific literature is either ignored or misinterpreted.

Pseudoscience relies heavily on subjective validation.
Joe Blow puts jello on his head and his headache goes away. To pseudoscience, this means jello cures headaches. To science this means nothing, since no experiment was done. Many things were going on when Joe Blow's headache went away—the moon was full, a bird flew overhead, the window was open, Joe had on his red shirt, etc.—and his headache would have gone away eventually in any case, no matter what. A controlled experiment would put many people suffering from headaches in identical circumstances, except for the presence or absence of the remedy it is desired to test, and compare the results which would then have some chance of being meaningful. Many people think there must be something to astrology because a newspaper horoscope describes them perfectly. But close examination would reveal that the description is general enough to cover virtually everyone. This phenomenon, called subjective validation, is one of the foundations of popular support for pseudoscience.

Pseudoscience depends on arbitrary conventions of human culture, rather than on unchanging regularities of nature.
For instance, the interpretations of astrology depend on the names of things, which are accidental and vary from culture to culture. If the ancients had given the name Mars to the planet we call Jupiter, and vice versa, astronomy could care less but astrology would be totally different, because it depends solely on the name and has nothing to do with the physical properties of the planet itself.

Pseudoscience always achieves a reduction to absurdity if pursued far enough.
Maybe dowsers can somehow sense the presence of water or minerals under a field, but almost all claim they can dowse equally well from a map! Maybe Uri Geller is "psychic," but are his powers really beamed to him on a radio link with a flying saucer from the planet Hoova, as he has claimed? Maybe plants are "psychic," but why does a bowl of mud respond in exactly the same way, in the same "experiment?"

Pseudoscience always avoids putting its claims to a meaningful test.
Pseudoscientists never carry out careful, methodical experiments themselves—and they also generally ignore results of those carried out by scientists. Pseudoscientists also never follow up. If one pseudoscientist claims to have done an experiment (such as the "lost" biorhythm studies of Hermann Swoboda that are alleged basis of the modern pseudoscience of biorhythms), no other pseudoscientist ever tries to duplicate it or to check him, even when the original results are missing or questionable! Further, where a pseudoscientist claims to have done an experiment with a remarkable result, he himself never repeats it to check his results and procedures. This is in extreme contrast with science, where crucial experiments are repeated by scientists all over the world with ever-increasing precision.

Pseudoscience often contradicts itself, even in its own terms.
Such logical contradictions are simply ignored or rationalized away. Thus, we should not be surprised when Chapter 1
of a book on dowsing says that dowsers use newly cut twigs, because only "live" wood can channel and focus the "earth-radiation" that makes dowsing possible, whereas Chapter 5 states that nearly all dowsers use metal or plastic rods.

Pseudoscience deliberately creates mystery where none exists, by omitting crucial information and important details.

Anything can be made "mysterious" by omitting what is known about it or presenting completely imaginary details. The "Bermuda Triangle" books are classic examples of this tactic.

Pseudoscience does not progress.
There are fads, and a pseudoscientist may switch from one fad to another (from ghosts to ESP research, from flying saucers to psychic studies, from ESP research to looking for Bigfoot). But within a given topic, no progress is made. Little or no new information or uncovered. New theories are seldom proposed, and old concepts are rarely modified or discarded in light of new "discoveries," since pseudoscience rarely makes new "discoveries." The older the idea, the more respect it receives. No natural phenomena or processes previously unknown to science have ever been discovered by pseudoscientists. Indeed, pseudoscientists almost invariably deal with phenomena well known to scientists, but little known to the general public—so that the public will swallow whatever the pseudoscientist wants to claim. Examples include firewalking and "Kirlian" photography.

Pseudoscience attempts to persuade with rhetoric, propaganda, and misrepresentation rather than valid evidence (which presumably does not exist).
Pseudoscience books offer examples of almost every kind of fallacy of logic and reason known to scholars and have invented some new ones of their own. A favorite device is the non sequitur. Pseudoscientists also love the "Galileo Argument." This consists of the pseudoscientist comparing himself to Galileo, and saying that just as the pseudoscientist is believed to be wrong, so Galileo was thought wrong by his contemporaries therefore the pseudoscientist must be right too, just as Galileo was. Clearly the conclusion does not follow! Moreover, Galileo's ideas were tested, verified, and accepted promptly by his scientific colleagues. The rejection came from the established religion which favored the pseudoscience that Galileo's findings contradicted.

Pseudoscience argues from ignorance, an elementary fallacy.
Many pseudoscientists base their claims on incompleteness of information about nature, rather than on what is known at present. But no claim can possibly be supported by lack of information. The fact that people don't recognize what they see in the sky means only that they don't recognize what they saw. This fact is not evidence that flying saucers are from outer space. The statement "Science cannot explain" is common in pseudoscience literature. In many cases, science has no interest in the supposed phenomena because there is no evidence it exists; in other cases, the scientific explanation is well known and well established, but the pseudoscientist doesn't know this or deliberately ignores it to create mystery.

Pseudoscience argues from alleged exceptions, errors, anomalies, strange events, and suspect claims—rather than from well-established regularities of nature.
The experience of scientists over the past 400 years is that claims and reports that describe well-understood objects behaving in strange and incomprehensible ways tend to reduce upon investigation to deliberate frauds, honest mistakes, garbled accounts, misinterpretations, outright fabrications, and stupid blunders. It is not wise to accept such reports at face value, without checking them. Pseudoscientists always take such reports as literally true, without independent verification.

Pseudoscience appeals to false authority, to emotion, sentiment, or distrust of established fact.
A high-school dropout is accepted as an expert on archaeology, though he has never made any study of it! A psychoanalyst is accepted as an expert on all of human history, not to mention physics, astronomy, and mythology, even though his claims are inconsistent with everything known in all four fields. A movie star swears it's true, so it must be. A physicist says a "psychic" couldn't possibly have fooled him with simple magic tricks, although the physicist knows nothing about magic and

sleight of hand. Emotional appeals are common. ("If it makes you feel good, it must be true." "In your heart you know it's right.") Pseudoscientists are fond of imaginary conspiracies. ("There's plenty of evidence for flying saucers, but the government keeps it secret.") And they argue from irrelevancies: When confronted by inconvenient facts, they simply reply, "Scientists don't know everything!"

Pseudoscience makes extraordinary claims and advances fantastic theories that contradict what is known about nature.
They not only provide no evidence that their claims are true. They also ignore all findings that contradict their conclusions. ("Flying saucers have to come from somewhere—so the earth is hollow, and they come from inside." "This electric spark I'm making with this electrical apparatus is actually not a spark at all, but rather a supernatural manifestation of psycho-spiritual energy." "Every human is surrounded by an impalpable aura of electromagnetic energy, the auric egg of the ancient Hindu seers, which mirrors the human's every mood and condition.")

Pseudoscientists invent their own vocabulary in which many terms lack precise or unambiguous definitions, and some have no definition at all.
Listeners are often forced to interpret the statements according to their own preconceptions. What, for for example, is "biocosmic energy?" Or a "psychotronic amplification system?" Pseudoscientists often attempt to imitate the jargon of scientific and technical fields by spouting gibberish that sounds scientific and technical. Quack "healers" would be lost without the term "energy," but their use of the term has nothing whatsoever to do with the concept of energy used by physicists.

Pseudoscience appeals to the truth-criteria of scientific methodology while simultaneously denying their validity.
Thus, a procedurally invalid experiment which seems to show that astrology works is advanced as "proof" that astrology is correct, while thousands of procedurally sound experiments that show it does not work are ignored. The fact that someone got away with simple magic tricks in one scientific lab is "proof" that he is a psychic superman, while the fact that he was caught cheating in several other labs is ignored.

Pseudoscience claims that the phenomena it studies are "jealous."
The phenomena appear only under certain vaguely specified but vital conditions (such as when no doubters or skeptics are present; when no experts are present; when nobody is watching; when the "vibes" are right; or only once in human history.) Science holds that genuine phenomena must be capable of study by anyone with the proper equipment and that all procedurally valid studies must give consistent results. No genuine phenomenon is "jealous" in this way. There is no way to construct a TV set or a radio that will function only when no skeptics are present! A man who claims to be a concert-class violinist, but does not appear to have ever owned a violin and who refuses to play when anyone is around who might hear him, is most likely lying about his ability to play the violin.

Pseudoscientific "explanations" tend to be by scenario.
That is, we are told a story, but nothing else; we have no description of any possible physical process. For instance, Immanuel Velikovsky (1895-1979) claimed that another planet passing near the earth caused the earth's spin axis to flip upside down. This is all he said. He gave no mechanisms. But the mechanism is all-important, because the laws of physics rule out the process as impossible. That is, the approach of another planet cannot cause a planet's spin axis to flip. If Velikovsky had discovered some way that a planet could flip another's spin axis, he would presumably have described the mechanism by which it can happen. The bald statement itself, without the underlying

mechanism, conveys no information at all. Velikovsky said that Venus was once a comet, and this comet was spewed out of a volcano on Jupiter. Since planets do not resemble comets (which are rock/ice snowball-like debris with connection whatsoever to volcanoes) and since Jupiter is not known to have volcanoes anyway (or even a solid surface!), no actual physical process could underlie Velikovsky's assertions. He gave us words, related to one another within a sentence, but the relationships were alien to the universe we actually live in, and he gave no explanation for how these could exist. He provided stories, not genuine theories.

Pseudoscientists often appeal to the ancient human habit of magical thinking.
Magic, sorcery, witchcraft—these are based on spurious similarity, false analogy, false cause-and-effect connections, etc. That is, inexplicable influences and connections between things are assumed from the beginning—not found by investigation. (If you step on a crack in the sidewalk without saying a magic word, your mother will crack a bone in her body; eating heart-shaped leaves is good for heart ailments; shining red light on the body increases blood production; rams are aggressive so someone born in the sign of the ram is aggressive; fish are "brain food" because the meat of the fish resembles brain tissue, etc.)

Pseudoscience relies heavily on anachronistic thinking.
The older the idea, the more attractive it is to pseudoscience—it's the wisdom of the ancients!—especially if the idea is transparently wrong and has long been discarded by science. Many journalists have trouble in comprehending this point. A typical reporter writing about astrology may think a thorough job can be done by interviewing six astrologers and one astronomer. The astronomer says it's all bunk; the six astrologers say it's great stuff and really works and for $50 they'll be glad to cast anyone's horoscope. (No doubt!) To many reporters, and apparently to many editors and their readers, this would confirm astrology six to one!

This table contrasts some of the characteristics of science and pseudoscience

Science	Pseudoscience
Their findings are expressed primarily through scientific journals that are peer-reviewed and maintain rigorous standards for honesty and accuracy.	The literature is aimed at the general public. There is no review, no standards, no pre-publication verification, no demand for accuracy and precision.
Reproducible results are demanded; experiments must be precisely described so that they can be duplicated exactly or improved upon.	Results cannot be reproduced or verified. Studies, if any, are always so vaguely described that one can't figure out what was done or how it was done.
Failures are searched for and studied closely, because incorrect theories can often make correct predictions by accident, but no correct theory will make incorrect predictions.	Failures are ignored, excused, hidden, lied about, discounted, explained away, rationalized, forgotten, avoided at all costs.
As time goes on, more and more is learned about the physical processes under study.	No physical phenomena or processes are ever found or studied. No progress is made; nothing concrete is learned.
Convinces by appeal to the evidence, by arguments based upon logical and/or mathematical reasoning, by	Convinces by appeal to faith and belief. Pseudoscience has a strong quasi-religious element: it tries to convert, not to convince.

making the best case the data permit. When new evidence contradicts old ideas, they are abandoned.	You are to believe in spite of the facts, not because of them. The original idea is never abandoned, whatever the evidence.
Does not advocate or market unproven practices or products.	Generally earns some or all of his living by selling questionable products (such as books, courses, and dietary supplements) and/or pseudoscientific services (such as horoscopes, character readings, spirit messages, and predictions).

This table could be greatly expanded, because science and pseudoscience are precisely opposed ways of viewing nature. Science relies on—and insists on—self-questioning, testing and analytical thinking that make it hard to fool yourself or to avoid facing facts. Pseudoscience, on the other hand, preserves the ancient, natural, irrational, unobjective modes of thought that are hundreds of thousands of years older than science—thought processes that have given rise to superstitions and other fanciful and mistaken ideas about man and nature—from voodoo to racism; from the flat earth to the house-shaped universe with God in the attic, Satan in the cellar and man on the ground floor; from doing rain dances to torturing and brutalizing the mentally ill to drive out the demons that possess them. Pseudoscience encourages people to believe anything they want. It supplies specious "arguments" for fooling yourself into thinking that any and all beliefs are equally valid. Science begins by saying, let's forget about what we believe to be so, and try by investigation to find out what actually is so. These roads don't cross; they lead in completely opposite directions.

Some confusion on this point is caused by what we might call "crossover." "Science" is not an honorary badge you wear, it's an activity you do. Whenever you cease that activity, you cease being a scientist. A distressing amount of pseudoscience is generated by scientists who are well trained in one field but plunge into another field of which they are ignorant. A physicist who claims to have found a new principle of biology—or a biologist who claims to have found a new principle of physics—is almost invariably doing pseudoscience. And so are those who forge data, or suppresses data that clash with their preconceptions, or refuse to let others see their data for independent evaluation. Science is like a high peak of intellectual integrity, fairness, and rationality. The peak is slippery and smooth. It requires a tremendous effort to remain near it. Slacking of effort carries one away and into pseudoscience. Some pseudoscience is generated by individuals with a small amount of specialized scientific or technical training who are not professional scientists and do not comprehend the nature of the scientific enterprise—yet think of themselves as "scientists."

One might wonder if there are not examples of "crossovers" in the other direction; that is people who have been thought by scientists to be doing pseudoscience, who eventually were accepted as doing valid science, and whose ideas were ultimately accepted by scientists. From what we have just outlined, one would expect this to happen extremely rarely, if ever. In fact, neither I nor any informed colleague I have ever asked about this, knows of any single case in which this has happened during the hundreds of years the full scientific method has been known to and used by scientists. There are many cases in which a scientist has been thought wrong by colleagues but later —when new information comes in—is shown to be correct. Like anyone else, scientists can get hunches that something is possible without having enough evidence to convince their associates that they are correct. Such people do not become pseudoscientists, unless they continue to maintain that their ideas are correct when contradictory evidence piles up. Being wrong or mistaken is unavoidable; we are all human, and we all commit errors and blunders. True scientists, however, are alert to the possibility of blunder and are quick to correct mistakes. Pseudoscientists do not. In fact, a

short definition of pseudoscience is "a method for excusing, defending, and preserving errors."

Pseudoscience often strikes educated, rational people as too nonsensical and preposterous to be dangerous and as a source of amusement rather than fear. Unfortunately, this is not a wise attitude. Pseudoscience can be extremely dangerous.

- Penetrating political systems, it justifies atrocities in the name of racial purity
- Penetrating the educational system, it can drive out science and sensibility;
- In the field of health, it dooms thousands to unnecessary death or suffering
- Penetrating religion, it generates fanaticism, intolerance, and holy war
- Penetrating the communications media, it can make it difficult for voters to obtain factual information on important public issues.

Recommended Reading

- Science and Unreason, D. & M. Radner, Wadsworth, California, 1982.
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- Paranormal Borderlands of Science, Ed. by Kendrick Frazier, Prometheus, Amherst, N.Y., 1981.
- Science as falsification, Karl R. Popper (1963)
- Science Confronts the Paranormal, Ed. by Kendrick Frazier, Prometheus, Amherst, N.Y., 1985.
- Science, Good, Bad and Bogus, Martin Gardner, Prometheus, New York, 1981; Avon, New York, 1982.
- Science and the Paranormal, Ed. by George O. Abell and Barry Singer, Scribners, New York, 1981.
- Extrasensory Deception, Henry Gordon, Prometheus, Amherst, N.Y.,1987.
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This article was revised on May 30, 2001.
