The interpretations offered here are based on new data and critical geological evaluation of dates previously obtained by the radiocarbon method. How valid these interpretations are can be ascertained only through careful scrutiny of all man-mammoth associations found in the future, to assure precise relating of dates, fossils, and artifacts to the stratigraphic framework. We must pay closer attention to stratigraphic detail if we are to make the fullest use of radiocarbon dating.

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41a. My attention has been called to a pertinent paper by O. H. Prufer and R. S. Baby [*Paleo-Indians of Ohio* (Ohio Historical Society, Columbus, 1963)]. These authors interpret the distribution of some fluted points in relation to glacial moraines and ancient beach ridges as evidence for occupation of Ohio by makers of fluted points before the Two Creeks interstade. The geochronology of fluted points in the East has been plagued by the almost total lack of stratigraphic context that would permit definitive estimation of age. In the absence of such context, much reliance has necessarily been placed upon the surface distribution of fluted points in relation to datable geomorphic features, but as Prufer and Baby state (p. 53), "mere association with a certain beach system [or moraine] does not preclude the possibility that a specimen so discovered postdates the formation of this particular system; such association merely implies a maximum date." It should be added that the temporal position of the geomorphic features themselves is not adequately known. For the moment it appears that fluted points occupy the base of projectile-point sequences, but the definitive age of fluted points in the East must await the finding of more sites with stratigraphically controlled dates and artifacts.

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A Measure for Crackpots

How does one distinguish between valid scientific work and counterfeit "science"?

Fred J. Gruenberger

For every article one sees in a technical journal or, for that matter, even in the public press, a decision has to be made: Is this worth reading or is it something that can safely be skipped? It would seem that there is no acid test or even a small group of tests which will serve to distinguish infallibly between crackpot work and good science. For every criterion that is advanced one can quickly think of a counter example. Every idea that is offered to us falls somewhere between the two extremes. Since there is no single test, the best that can be done is to offer a checklist of some of the attributes of science and of the crackpot to help in making this decision.

Let me illustrate what I mean by the failure of any single test. A scientist generally strengthens his stand greatly by his ability to predict. Einstein's early work in the general theory of relativity gained credence by accounting in part for a known error in the perihelion of the planet Mercury. His theories gained real acceptance, however, many years later when British astronomers (during World War I, when Einstein was a citizen of an enemy country) verified by direct observation his statements about the previously unsuspected bending of light in a gravitational field. Here was the principle of predictability used to the fullest.

If predictability is to be used as a

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test of science, what then shall we do with the astronomer? Astronomy is universally conceded to be a science and in fact is one of the few sciences not only acclaimed but supported by the general public with no demand for a "practical" payoff. Some aspects of astronomy include predictions; orbital motions, for example, can be predicted with great precision, but there are large areas of astronomy for which prediction is virtually impossible. The astronomer announces no pending novas, or undetected Cepheid variables, or even star densities in as yet unexplored areas. Thus, if predictability were the criterion of the moment, then the astronomer would rate rather poorly as a scientist.

In a similar way it could be argued that a crackpot can be spotted by the (crackpot) way he tries to communicate. If he talks like a crackpot, fine; perhaps you can thereby damn him, but you take a real risk by doing so. Many weird ideas (weird, that is, after the acid test of time) have been advanced in the canonical form of true science. Yet there are many examples in history of people we now regard as outstanding scientists whose early writings look like those of a raving lunatic.

Each possible test, it would seem, can fail to discriminate by itself. It is the aggregate of many of them that one may use to make up a discriminator. It seems fruitful (and fruitfulness is one of the attributes of science) to try to list some of the attributes of scientific endeavor (and/or crackpotism) and try to use the list as a measuring device.

Checklist

What follows, then, is a checklist of some significant items that are thought to be among the main attributes of the scientist (or, in some cases, the crackpot). In order to weight the items, and thus provide a rough metric for the scale, point values (totaling 100) have been assigned the items.

1) *Public verifiability—12 points.* The scientist says "I did thus and so and observed its effect; you are free to repeat my steps." The crackpot often says, "This is revealed truth; sorry, but I and my followers are the only ones who can obtain these results."

This does not mean that all science is publicly verifiable. Even such a simple thing as the population of the United States at any given moment cannot be verified by anyone except the Census Bureau itself (although it is nevertheless still verifi*able*). The astronomer working with the 200-inch telescope or the nuclear physicist working with an atomic reactor will announce results which are beyond the ability of most other men to duplicate. Nevertheless, when something is publicly verifiable, it has increased scientific stature. On the other hand, when some simple technique cannot be verified publicly, its stature as a scientific technique is in doubt. Public verifiability is not a necessary or sufficient condition (nor is any other item on this checklist), but where it applies it constitutes an attribute of science.

2) *Predictability—12 points.* To what extent can the technique or "science" being advocated be applied to the future? When a man can predict, and the predictions turn out to be true (as in the case of Einstein) a great deal has been gained toward credibility. Notice that it is really a batting average that is involved, in order that the principle of predictability should not be misused. For example, any idiot can predict the result of next year's World Series simply by listing all possibilities, writing them down, and then noting after the fact that one of them was indeed correct. The honest scientist will usually admit those predictions that did not work out. If his batting average becomes high enough, his stature increases. Scientific predictability is something more than guessing, whether lucky or not.

3) *Controlled experiments—13 points.* This item has been assigned the greatest weight on the list. The scientist seeks to devise controlled experiments if he can (the astronomer, for example, rarely can). The crackpot, on the other hand, often seeks to avoid controlled experiments, or, if some are performed, he may invent marvelous excuses to explain why they did not bear out his theories.

4) *Occam's razor—5 points.* This is the principle which says that, of two possible explanations for the same phenomenon, scientists prefer the simpler—that is, the one requiring the fewest hypotheses. It is not a stringent test, but it is a point to consider.

A simple hypothesis which explains *everything* is that the devil deliberately makes what appear to be patterns to deceive us, but in reality there is no pattern. Consider, however, those cases in history where Occam's razor has applied. The classic case is that of Copernicus, who advanced a much simpler explanation for planetary motion than the one invoked by his contemporaries. Lacking all other evidence, the scientist is inclined to accept the simpler explanation.

5) *Fruitfulness—10 points.* The argument here is that the more scientific a subject is the more it tends to lead to "fruitful" results. *Fruitful* here means the ability to suggest new ideas —new approaches and new tests—rather than practical or material results. Of course, one man's fruit is another's rotten apples. Probably every scientist in history has met many times the question, "What good is it?"

While fruitfulness is probably an important attribute of science, it is a priori a poor discriminator between the scientist and the crackpot. Sometimes, by the time one is able to tell whether a given venture is fruitful or not, it would probably be possible to tell on the basis of other criteria whether the working theory was indeed scientific.

6) *Authority—10 points.* Weight of authority tells, among scientists; it is equivalent to building up credit. Each new subject that claims the mantle of science is supposed to be immediate-

Table 1. Box scores.

Test	Maximum points	Physicist	ESP-er	Dowser
1. Public verifiability	12	12	5	0
2. Predictability	12	11	2	2
3. Controlled experimentation	13	13	5	0
4. Occam's razor	5	4	0	4
5. Fruitfulness	10	10	7	5
6. Authority	10	10	3	0
7. Ability to communicate	8	8	4	4
8. Humility	5	5	1	0
9. Open-mindedness	5	4	0	0
10. Fulton non sequitur	5	5	5	5
11. Paranoia	5	5	4	4
12. Dollar complex	5	5	2	2
13. Statistics compulsion	5	5	0	2
Total	100	97	38	28

ly submitted to known and recognized scientists for both opinion and test. Indeed, usually the first goal of any newcomer is to seek the endorsement of known authorities. If those authorities say "what nonsense!" the weight of authority has been exerted (in this case against), and it does count. The authorities may be wrong; they have been many times in the past.

7) *Ability to communicate—8 points.* Most scientists soon discipline themselves in accepted methods of communication with their colleagues, their cohorts, and the public. The crackpot scorns accepted channels (he is even apt to deride those who "knuckle under" to accepted practices). Many scientists may even go to the extreme of advocating dullness in their written communications. Perhaps this tends to cut understanding of their communications, but it indicates a high degree of conformity.

8) *Humility—5 points.* This is a minor point, perhaps, but we expect a scientist to tend toward humbleness, and we tend to honor him accordingly. To be sure, there have been (and will be) arrogant scientists; we try to forgive them, but the very act of forgiving implies that the test exists.

This is an after-the-fact test. Few, if any, crackpots have ever demonstrated humility.

9) *Open-mindedness—5 points.* Here again the test as a discriminator is weak. Many persons judged by time to be true scientists were stubborn and pigheaded in their early days. In general, however, the scientist tends to use such phrases as "It appears that," "It would seem plausible," and the like. The crackpot is generally dogmatic and arbitrary and seems to imply, "Agree with me, now, or lie forever beyond the pale." Probably a given person would score either 0 or 5 points on this test: there seems to be little middle ground.

10) *Fulton non sequitur—5 points.* This is a negative test. The true crackpot can frequently be spotted on this test alone. He proceeds with an argument like this: "They laughed at Fulton. He was right. They're laughing at me. *Therefore*, I must be an equal genius." It is so obvious, but the Fulton non sequitur keeps recurring.

11) *Paranoia—5 points.* This is another negative test. It is the lack of paranoia characteristics that is on the 5-point end of the scale. Again, the crackpot can be spotted on this test alone. Every large corporation meets this characteristic frequently. A crackpot feels that the world deliberately hates him and actively opposes his project (and somehow, to the crackpot, the very existence of oppression supports his cause).

12) *Dollar complex—5 points.* This is another negative test: the crackpot almost always is overly impressed with the value of his discoveries—they're earth-shaking. The test is somewhat related to humility, but different enough to be worth its own 5 percent of the total vote. The true scientist will score high: there are few, if any, instances of a scientific announcement that says or implies, "This is truly revolutionary." The crackpot, of course, scores low. The question is not "What is the worth of this thing?" but, rather, "What does the sponsor *claim* its worth is?"

13) *Statistics compulsion—5 points.* It seems to be a characteristic of crackpot literature (perhaps because a little knowledge is a dangerous thing and the crackpot has as little as anyone) that statistics are not only used but continuously explained. The crackpot is fascinated to discover that a coin tossed 1000 times doesn't necessarily fall heads 500 times. He is compelled to tell the reader—sometimes on every page—the probability of having 523 heads. The scientist who knows his statistics generally assumes that his reader is informed; he may give the chi-squared value, but he seldom ends the sentence with an exclamation point.

Application

Any new measuring device is customarily applied to known cases for calibration (this practice is another characteristic of scientists). Suppose we apply our checklist to three types of people.

1) The universally recognized scientist (for example, the physicist).

2) The widely discredited crackpot —say, the advocate of dowsing rods as a method of locating underground treasure. Such an advocate will, of course, cry "foul" immediately. I'm sorry; all members of group 1 (and most of the general public) consider the dowser a crackpot.

3) The middle group, whose status is still open to debate, represented by the advocates of extrasensory perception (ESP).

Table 1 shows scores that I have assigned to each of these three groups for the 13 items. The scores are personal, arbitrary, and biased. The reader is urged to fill in his own values, rather than waste time quibbling over mine. I cannot defend any precise values (indeed, if I were to fill out the sheet again I would probably use different values). It is their relative size that is important, and their meaning *to me* as a tool for discrimination.

I should, however, explain my reasoning in arriving at some of the values shown.

Low scores for the person who is peddling black magic and shark's teeth (either through ignorance or avarice) should not be surprising. The charlatan and the boob are both intrinsically opposed to a search for truth; the last thing they want is public verifiability and controlled experimentation. In fact, when outsiders crassly insist on such tests, and the results fail to support the claims, the nonscientist calls on a marvelous array of excuses as to why the uninitiated have perverted his domain.

Such things are not all black-and-white. Thus, I do not assign zero scores to more than three items for the ESP advocate. Those books on ESP that I have waded through exhibit a complete lack of open-mindedness; one of them is singularly annoying in its compulsion to explain statistics to me on every other page. Using the principle of Occam's razor, I can find a marvelously simple explanation for all the wonders of ESP—namely, that they don't exist, or that simple natural explanations are at hand.

The devotees of ESP *have* sought public verification; they *do* observe all the niceties and conventions of the scientific community, and so on. Perhaps their case is still open. My personal score for them is 38; others' may be considerably higher.

Conclusion

The checklist, in the aggregate, is a necessary (but not sufficient) condition for the claim that "this pursuit is scientific." Each item by itself is open to attack.

This article offers a theory—namely, that a metric can be assigned to the merits of another theory. It would be an interesting exercise for the reader to apply the measure (using, of course, his own weights) to the article itself.