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ABSTRACT

The area of research known as Cold Fusion (CF) has been the arena of a science-and-society feud since 1989, as described by Stephen Ritter in a recent issue of Chemical and Engineering News (1).The conflict is very unusual in terms of duration, the caliber of combatants, and the deviation from basic principles of scientific methodology of validation of claims. The purpose of this article is to comment on methodological mistakes made during the still- ongoing feud among scientists.

1. INTRODUCTION

Scientific methodology (2) refers to the set of norms developed to deal with mistakes and controversies in scientific research. Most mistakes are recognized when new results are discussed with colleagues, or via the peer review process. Occasional errors in published papers are subsequently discovered during replications conducted by other researchers. Scientific results, if valid, wrote J.R, Huizenga, must be reproducible on demand. “When errors are discovered, acknowledged and corrected, the scientific process moves quickly back on track, usually without either notice or comment in the public press." (3) The process, in other words, is expected to be self-corrective.

The so-called "scientific method" is not a list of divine commandments. It is a set of norms described by scientists, and by those who observe their ways of working. The author of this article is a retired nuclear physicist who has observed cold fusion researchers over the last three decades, and participated in several CF conferences and three cooperative replication projects (in which the claimed sensational results were not confirmed). The CF episode is an unusual controversy resulting from a sensational 1989 announcement made by Fleischmann and Pons (F&P). The event (4,5,6,7,8) divided physical scientists into two feuding camps (9,10,11,12,13,14). This is a rare example of a situation in which the expected self-correction of the scientific process was essentially stopped by two formal governmental interventions.

2. ROLE OF ACCEPTED SCIENTIFIC THEORIES

Why is the CF controversy unresolved? Because CF experimental claims are not reproducible on demand, and because they conflict with the generally accepted theory of nuclear reactions. A theory, in this context, is a logical/mathematical structure that agrees with a wide range of already verified experimental data. Scientists know the rule--theories guide but experiments decide. But they are very reluctant to abandon accepted theories. To be reluctant means to insist on additional verification of new experimental results.

Referring to such situations, Huizenga wrote (3): “There are occasionally surprises in science and one must be prepared for them.” Theories are not carved in stone; scientists do

not hesitate to modify or reject them when necessary. Rejecting a claim because it conflicts with a theory is not as convincing as rejecting it on the basis of reliable empirical data. In that sense methods of validation of claims in physical and other sciences are similar. Scientific theories are models of objective reality; they are often changed, or modified, when new facts are discovered.

3. LEVELS OF CONFIDENCE IN SCIENTIFIC CLAIMS

A discovered experimental fact is usually presented to the scientific community, to be independently confirmed or refuted. Experimental results are accepted--at a high level of confidence--when they become reproducible on demand. Absence of such reproducibility justifies suspicion of possible errors or fraud. Methods of validation of theories (explanations of facts) are slightly different. A new scientific theory is also presented to a community of experts, to be independently evaluated. Their level of confidence in a theory depends on the validity of underlying assumptions and on the rigor of quantitative analysis. But even a most reliable scientific theory, usually called a law, is said to be falsifiable, in principle, when conflict with reproducible-on-demand data becomes undeniable (15). Such unusual conflict could trigger a scientific revolution (16).

To explain something usually means to identify causes and to construct a logically satisfying model of reality. An attempt to explain a fact, or to resolve an apparent logical conflict, usually leads to discoveries of other facts. A classical example was the discovery of planet Neptune, in 1846. A more recent and less widely known example was the discovery of a subatomic particle named neutrino. Experimental data collected in the 1920's showed that beta rays (electrons emitted in radioactive decay) had lower mean energies than expected on the basis of the theoretical $E=mc^2$ formula. Austrian theoretical physicist W. Pauli solved this "logical inconsistency" by suggesting that tiny neutral particles, later named neutrinos, were responsible for the missing energy. His hypothesis was formulated in 1933. Experiments confirming the reality of neutrinos were performed, 23 years later.

4. UNFORTUNATE TERMINOLOGY

The essence of the discovery announced by F&P was "excess heat." Their small electrolytic cell generated more thermal energy than the amount of energy supplied to it. Trying to establish priority, under pressure from University of Utah administration, the scientists announced their results at a sensational press conference (March 23, 1989). They wanted to study the CF phenomenon for another year or so but were forced to prematurely announce the discovery.

The unfortunate term "cold fusion" was imposed on them (17). Why unfortunate? Because it created the unjustified impression that cold fusion is similar to the well known hot fusion, except that it takes place at much lower temperatures. This conflicted with what had already been known--the probability of nuclear fusion of two heavy hydrogen ions is negligible, except at stellar temperatures. It was a mistake to interpret experimental data before the results were recognized as independently reproducible. In fact, F&P had no evidence for the emission of energetic ^1H, ^3H and ^3He products, listed in their first published paper (4). Such evidence appeared only five years later (22). The only thing they knew was that the measured excess heat could not be attributed to a known chemical reaction. Claiming that the measured excess heat was due to a nuclear process was premature. The

adjective "non-chemical" does not automatically translate into "nuclear."

Suppose the discovery had not been named cold fusion; suppose it had been named "anomalous electrolysis." Such a report would not have led to a sensational press conference; it would have been made in the form of an ordinary peer review publication. Only electrochemists would have been aware of the claim; they would have tried to either confirm or refute it. The issue of "how to explain the heat" would have been addressed later, if the reported phenomenon were recognized as reproducible-on-demand. But that is not what happened. Instead of focusing on experimental data (in the area in which F&P were recognized authorities) most critics focused on the disagreements with the suggested theory. Interpretational mistakes were quickly recognized and this contributed to the skepticism toward the experimental data. Using unconfirmed data to justify the nuclear origin of excess heat, by F&P, was inconsistent with the prevailing norms of scientific methodology. A more recent case of violation of scientific norms, by a CF researcher, Andrea Rossi, is described in (14).

5. TWO US GOVERNMENT INVESTIGATIONS OF CF

The significance of CF, if real, was immediately recognized. Some believed that ongoing research on high-temperature fusion, costing billions of dollars, should be stopped to promote research on CF. Others concluded, also prematurely, that such a move would be opposed by "vested interests" of mainstream scientists. Responding to such considerations, the US government quickly ordered a formal investigation.

A panel of scientists, named Energy Research Advisory Board (ERAB), and headed by John Huizenga, was formed to investigate CF in 1989. The final report (18), submitted to the DOE several months later, negatively interfered with the normal development of the field. Modest financial support for additional CF research, by the DOE, NSF, and other agencies, was practically stopped after the report was published.

It is interesting that only one of the ERAB's six conclusions referred to CF experiments; the remaining five conclusions were about anticipated practical uses of CF, and about various aspects of the suggested interpretation of results. Instead of focusing on reality of excess heat, critics focused on the fact that the hypothesis was not consistent with what was known about hot nuclear fusion. The same observation can be made about the six ERAB recommendations. Only one of them referred to possible experimental mistakes. It is clear that the ERAB observations were based mostly on "theoretical grounds," not on independently performed experiments. The unfortunate governmental intervention had one serious and unprecedented consequence--editors of some scientific journals started rejecting manuscripts written by CF scientists, bypassing peer review (19).

The second DOE investigation (20) of CF was announced in March 2004, nearly 15 years after the first. A group of 18 experts was selected to review a very significant CF claim--the correlation between excess heat and generation of helium (21,22).

But the DOE experts were not asked to replicate correlation experiments; they were asked to read the report submitted by five CF scientists (20), and to vote on whether or not the evidence for the claims was conclusive. Such a way of dealing with a controversy was not

consistent with the scientific method.

Ideologically and politically motivated rejections of scientific claims are not new. Giordano Bruno and Galileo Galilei are well known examples. Lysenkovism--Stalin's discrimination of geneticists--is a more recent illustration. And cybernetics, in the Soviet book entitled “Short Philosophical Dictionary,” was defined as “bourgeois pseudo-science serving American imperialism.” Ludwik Kowalski accepted this kind of "truth" as a communist student in Poland (23). What can be done to make sure that similar discrimination will not be used in the US, to impose "the truth" about evolution, stem cell research, etc.?

6. CONCLUSION: MORE QUESTIONS THAN ANSWERS

Long-lasting controversies about scientific discoveries are not new. Alfred Wegener's theory of continental drift is a good illustration. Mainstream geologists rejected experimental data supporting his now-accepted theory for half a century. The CF controversy, however, seems to be different both in terms of governmental involvement and in the caliber of adversaries on both sides of the divide. Huizenga and Fleischmann were indisputable leaders in nuclear science and electrochemistry. Most leading CF researchers are PhD-level scientists. The same is true for many scientists who reject CF claims.

The long-lasting CF episode is a social situation in which the self-correcting process of scientific development was not allowed to evolve. To what extent was this due to extreme difficulties in making progress in the new area, rather than to negative effects of competition, greed, jealousy, and other "human nature" factors? Such unanswered questions (24) are worth addressing in the context of debates about science and society.

One thing is undeniable; the world is still waiting for the first reproducible-on-demand demonstration of a nuclear process resulting from a chemical process. No progress is possible when reported experimental data cannot be reliably replicated in other laboratories. Considering potential CF benefits, and relatively low costs of research in this area, the DOE should have helped to resolve the controversy, one way or another, in a well-equipped national laboratory, during the second investigation. But it failed to do so. How can such a policy be explained? Why is CF research allowed to stagnate without financial support? These questions also belong to debates about science and society. Will the past 25 years be recognized as the painful beginning of a new paradigm (16), or will this period be known as pseudoscientific (24) ? How can the persistence of the CF controversy be explained?

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OPTIONAL ADDENDUM: THREE INTERESTING BIOGRAPHIES

The discovery of CF was made nearly simultaneously by three highly competent scientists: Martin Fleischmann, Stanley Pons (both chemists) and Steven Jones (physicist). Excerpts from their biographies, taken from Mallove's book)25), are shown below.

Martin Fleischmann was born March 29, 1927, in Karlsbad, Czechoslovakia, to Jewish parents. The family came to England to avoid persecution by the Nazis. Martin went to high school in Sussex, England during the war, attended Imperial College in London after the war (1947-1950), and later distinguished himself by achieving at age forty the professorial Chair in Electrochemistry at the University of Southampton.

Since 1986, Fleischmann has been a Fellow of the Royal Society, an honor given only to the most distinguished of scientists. The author of over 200 scientific papers -- a number of them with Pons as collaborator -- and a number of portions of textbooks, Fleischmann won the Royal Society of Chemistry's medal for Electrochemistry and Thermodynamics in 1979. He was president of the International Society of Electrochemistry (1970-1972). In 1985 he was awarded the Palladium Medal by the U.S. Electrochemical Society.

Stanley Pons, who is almost young enough to be Fleischmann's son, was born in 1943 in the small town of Valdese in the North Carolina foothills Pons's Italian Protestant ancestors had fled religious persecution in the old world... He was drawn to the world of chemistry as a child, as many youngsters had also been, encouraged by parent-bestowed chemistry sets and the like.

Pons attended Wake Forest University in Winston-Salem, North Carolina, graduating in 1965, and began advanced studies at the University of Michigan at Ann Arbor. But with his doctorate almost in hand in 1967, he left school to work in his family's businesses. Eventually, his love for chemistry drew him back to active science. With the encouragement of faculty at University of Southampton in England, he entered its graduate program in chemistry and received his Ph.D. there in 1978. Martin Fleischmann was one of his professors. ... Pons came to the University of Utah in 1983 as an associate professor, becoming a full professor in 1986, and Chairman of the Department in 1988. He has authored or coauthored over 150 scientific publications.

Steven Jones was well known to physicists and the hot fusion community, which gave him a credibility that Fleischmann and Pons could not match. Born in 1949, he was raised a Mormon, with all that his religion's outlook and demanding codes of conduct implies. Jones was a missionary in Europe for the Church of Latter-Day Saints and pursues his science with religious fervor, almost literally. His University stationery bears witness, inscribed as it is with the Brigham Young University motto, "The Glory of God Is Intelligence."