Design of the Modern Inquiring System-X. The Interplay of Theory and Experiment in Science From Thales (600 B.C.) to Higgs (21st Century)

In "Design of the Modern Inquiring System", the thinking of past and present philosophers and thinkers are surveyed and discussed to discover how their logic and methods of reasoning can be used to design the Modern Inquiring System – a system dedicated to the acquisition and production of knowledge and to the solution of contemporary problems. The concept of 'inquiring system is borrowed from C.W. Churchman's book (The Design of Inquiring Systems, Basic Books, 1971). Authors interested to contribute to this series should contact the undersigned with the name of a system thinker who they would like to feature.

Key words – Philosophy; epistemology; design of inquiring system; system movement; knowledge acquisition; modern thinkers, methods of reasoning of; paradigm of.

Abstract – Book review of Leon Lederman's[1] The God Particle. If the Universe is the Answer, What is the Question?
(Houghton Mifflin, Boston and New York, 1993, 434 pp). This is the tenth installment of a series of articles which traces the development of the modern inquiring system (IS), a system devoted to the acquisition, production and dissemination of knowledge. The idea behind this series is to feature the thinking of old as well as contemporary thinkers whose paradigms bear relevance to the system movement, in general, and to the understanding of how the modern inquiring system has evolved, in particular.
Previous installments of this series have appeared in System Research, *as follows: Parts I and II in Vol. 5(3), 1988; Part III and IV in Vol. 5(4, 1988; Part V in Vol. 6(2), 1989; Part VI in Vol. 6(3), 1989; Part VII in Vol. 9(1), 1991; Part VIII in Vol. 7(4), 1990; Part IX in Vol. 10(1), 1993.*
Readers are referred to these publications[2-10].

Democritus: The First Particle Physicist

Leon Lederman's book (with Dick Teresi), THE GOD PARTICLE. *If the Universe is the Answer, What is the Question?* (Houghton Mifflin, Boston, 1993, 434 pp.) chronicles the progress of science and, in particular, the progress of modern Physics, to unravel the secrets of the universe. See[1]. The title refers to the nuclear physicists' attempts to discover the particles and subparticles of which atoms are made. In actual fact, Lederman – the author – traces this search right from the times of the Greek philosopher Democritus who he calls the "first particle physicist". Already two thousands years ago, Democritus postulated the existence of the "a-tom" which is to be differentiated from what we call today the "atom".
Democritus' *a-tom* corresponds to the God Particle's which is the ultimate sub-sub particle which today's physicists are searching beyond the pedestrians neutrons, electrons, and protons which crowded the physics lessons of our youth. Here, we are referring to quarks, leptons and their components and sub-components. Basically, Lederman explains that in order to unravel Nature's secrets further we will need the energy of stronger accelerators such as the super-collider which is being built in Texas. According to the author who was director of the Fermilab in Chicago, the energy of present-day colliders does not allow breaking the particle code any further. Of necessity, stronger machines are needed.

Newtonian Physics and Nuclear Physics

The book is eminently well written. It is written in a conversational style. However, it will not be easy reading, unless an individual has some scientific background, in particular, elementary high school physics. The book is divided into two parts: the first part is devoted to Newtonian physics, a label which the present reviewer assigns to all of Physics before entering the twentieth century and, the second part, which I call nuclear physics, and which starts approximately when Einstein obtained his Ph.D. in 1903 and which takes us right to the present day. I am an Engineering Physics graduate of the 1950's and could understand the first part with some effort. I found that my knowledge of Newtonian Physics was lacking and that I did not have a firm grasp of Newton's laws. Lederman gives a strong Physics refresher in a lively style, interspersed with wit and funny anecdotes. The second part on nuclear Physics was much beyond my comprehension and, I suspect, that of the average reader. However, this fact should not discourage you from reading this book which I found extremely interesting and valuable. In what follows, I will endeavor to tell why.

Constant Interplay of Theorists and Experimenters

Throughout his book, Lederman's tries to explain how Physics developed from the constant interplay of Theorists and Experimenters. He is an experimeter and, thus facetiously he pokes fun at theorists who, according to him, are a lazy bunch who do not need to spend weekens in the laboratory and who can earn their living by merely pushing pencils at their desks!

Throughout its book, Lederman opposes the epistemology of theorists with that of experimenters, a contrast which is very useful to the investigation of the design for the modern inquiring system.

Lederman explains that Boyle (1627-1691) became a champion of experimentation, which "despite the feats of Galileo and others, was still viewed with suspicion in the seventeenth century". "Boyle carried on a long debate with Spinoza, the Dutch philosopher..., over the question of whether experiment could provide proof". "To Spinoza *only logical thought was proof*; experiment was simply a tool for confirming or refuting an idea. Such great scientists as Huygens and Leibniz also doubted the value of experiment. Experimenters have always had an uphill battle". Of course, Lederman often illustrates, experminters have seen their efforts amply vindicated in the modern era of Science.

The reader may recall that in a previous article in this series[10] we already discussed at length the role of theory in the design of the inquiring system for creativity, where we argued that modern nuclear physics owes its extraordinary development to the work of theorists. In the book reviewed here, the emphasis is placed neither on the role of theory nor on that of experiment: rather it is placed on the provocative interplay of one over the other.

Rutherford, Einstein and Bohr: Reading the Mind of God

As an example, Lederman recounts how Rutherford arrived at the research laboratory of Cambridge University "from the boonies of New Zealand as a special research student in 1895". In 1908, "he set up what became the historical prototype of a scattering experiment", as a result of which he declared that he understood what a chemical atom looked like. "Rutherford's model was a clear milestone". "It was very much a miniature solar system: a dense, positively charged central nucleus with a number of electrons in various orbits such that the total negative charge exactly canceled the positive nuclear charge". "It marked the demise of classical physics". Lederman goes on to illustrate how Rutherford's legacy propelled his successor, Bohr, to "see the real significance of the new model". "He realized that to satisfy Maxwell's equations, the electrons in circular orbits around a central nucleus would have to radiate energy...".

"...Bohr proposed that in these very special orbits the electron *doen't* radiate (emphasis in the original)." "...To get spectral lines, Bohr realized he must allow the electron to have the option of a number of different orbits corresponding to different energy contents. So he gave hydrogen's single electron a set of allowed radii representing a set of states of higher and higher energy". "To explain spectral lines, he POSTULATED (out of the blue) that radiation occurs when an electron 'jumps' from one energy level to a lower one; the energy of the radiating photon is the difference of the two energy levels. He then PROPOSED an absolutely outrageous RULE for these special radii that determine the energy levels". "Orbits are allowed, he said, in which the angular moment, a well known quantity that measures the rotational momentum of the electron, takes on only integer values when measured in a new quantum unit. Bohr's quantum unit was Planck's constant *h*". "What right does (Bohr) have to make up rules for the behavior of invisible electrons orbiting the nucleus (also invisible) of the hydrogen atom?". "*...His legitimacy is ultimately established by his success in explaining the data*". "*...He understands that his rules ultimately emerge from some deep principle, but first the rules*". "This is how theorists work". "In the words of Einstein, Bohr was trying to know the mind of God". (Capitalized words, to show the role of theory, are mine.Ed.) Thus, out of Rutherford's experimental evidence, theoretical statements in the form of model, postulates, propositions and rules emerge which attempt "to explain" the behavior of the event or the phenomenon witnessed in the laboratory. It is an excellent example of how experiment and theory meet and interplay.

> "Bohr's ad hoc, quasi-classical explanation of the atom was a virtuoso, if unorthodox, performance. He used Newton and Maxwell when they were convenient. He discounted them when they weren't. He used Plank and Einstein when they worked. It was outrageous. But Bohr was smart and got the right answer".

As all theories and models, even Bohr's was proven wrong and in 1924, de Broglie "was mulling over the significance of (Einstein's) light quanta". He asked: "How could light behave like a swarm of energy bundles – that is, like particles – and at the same time exhibit all the behaviors of waves, such as interference, diffraction, and other properties that require wavelength?". "De Broglie invoked a new symmetry: if waves can be particles, then particles (electrons) can be waves". Lederman tells us that de Broglie's faculty advisors, at the University of Paris, accepted his thesis in 1924. It eventually earned him a Nobel Prize, "making de Broglie the only physicist up to that time to win the Prize on the basis of a dissertation".

Pas-de-Deux of Theory-Experiment

Lederman's book is a vivid compilation and description of the "*pas de deux of theory-experiment*". From de Broglie we go to Schrodinger (equation of wave mechanics), Heisenberg (Uncertainty Principle), Born ("The wave function is a wave of probability"), Pauli (Exclusion Principle), Einstein (EPR thought experiment) and so on until the present.

Between parts one and two of the book, Lederman includes an "interlude" in which he comments in passing about the work of Gary Zukav (*The Dancing Wu Li Masters*) and of Fritjof Capra (*The Tao of Physics*).

Lederman considers these authors and others who try to popularize the complexity of modern technology and physics as rather amateurish. It is interesting that he derides Zukav for stating that:

> "Atoms were never 'real' things anyway. Atoms are hypothetical entities constructed to make experimental observations intelligible. No one, not one person, has ever seen an atom".

Lederman has an emphatic reply: "...Many people have seen atoms, thanks to the scanning tunneling microscope, which takes beautiful pictures of the little fellows". We, the readers, can only speculate and ask ourselves: What is closer to reality, a model of the atomic sub-particle world, or the trace of the so-called "little fellows" on the screen of a scanning tunneling microscope. What do you think? The reviewer will not be drawn to take sides on this debate. Suffice it to say that Lederman is a master at making the world of nuclear phyisics come alive. It is easy to be swayed by his conversational and not overly technical language into believing that this world of quarks, leptons, muons and other countless "critters" is real. Let me give a sample of this writing:

> "...[a] photon...can virutally dissolve into a pair of oppositely charged particles – just fleetingly – and then restore itself before anyone can see. The electron, isolated in its void, is pulled by the transient virtual positron, pushed by the virtual electron, twisted by the transient magnetic forces. These and other, even more subtle, processes in the seething broth of virtual happenings connect the electron ever so weakly, to all the charged particles that exist. The effect is a modification of the electron's properties. In the whimsical linguistics of theoretical phyisics, the 'naked' electron is an imaginary object cut off from the influences of the field, whereas as 'dressed' electron caries the imprint of the universe, but it is all buried in extremely tiny modifications of its bare properties".

That the Lederman's electron is *more real* than Zukav's atom, is very questionable to this reader! To me, it is all the same "seething broth".

Scientific Revolutions

Lederman explores how scientific revolutions take place by explaining how the different thinkers' ideas can be comprehended in the thinking of their successors. Thus the Quantum Physics of today encompasses the ideas of Einstein, which encompass those of Maxwell, whose ideas include those of Newton, who borrowed from Galileo, who, in turn, takes from Archimedes. Scientific revolutions occur when there is a set of phenomena that are not yet explained. "The experimental scientists hope their observations will kill the reigning theory. Then a better theory will take its place and reputations will have been made. More often, either the measurements are wrong or a clever application of the current theory turns out to explain the data. Since there are always three possibilities – (1) wrong data, (2) old theory resilient, and (3) need new theory – experiment makes science a lively metier".

It is natural that when talking about theory that reference be also made to a "model". In actual fact, Lederman's book is like a travelogue which describes how the so-called "standard model of particle physics" has evolved through the centuries. He provides an accelerated history of this model starting with Thales (600 B.C.) and finishing with the modern version (1992) due to Fermi, Gell-Mann, Lederman (of course), and others. This history spans Antiquity, Democritus, Newton, Dalton, Faraday, Mendeleev, Rutherford. He evaluates the simplicity and completeness of each of these versions of the standard model of the universe and concludes by noting that the present version is still incomplete and awaits the research to be done with the Super-Collider in the 21st century.

Today's Standard Model of the Universe

In the standard model of today, 20 parameters must be specified: "We need *twelve* numbers to specify the masses of quarks and leptons. We need *three* numbers to specify the strength of forces... We need *some numbers* to show how one force relates to another. Then we need a number for how the CP-symmetry violation enters, and *a mass* for the Higgs particle and a few other handy items". Lederman concludes: "The drive for simplicity leads us to be very sarcastic about having to specify twenty parameters". "IT'S NOT THE WAY ANY SELF-RESPECTING GOD WOULD ORGANIZE A MACHINE TO CREATE UNIVERSES". (My emphasis).

"Among theorists the marriage of general relativity and quantum theory if the central problem of contemporary physics"... "No one has yet succeeded in forcing gravity – the general theory of relativity – to conform to the quantum theory"... "Today's theorists have a bold objective: they're searching for a theory that describes a pristine simplicity in the intense heat of the very early universe, a theory with no parameters. Everything must emerge form the basic equation; all the parameters must come out of the theory. The trouble is, the only candidate theory has no connection with the world of observation – not yet anyway". Thus, we are back to the "pas-de-deux" *theory-experiment* which Lederman interlaces throughout, in his narration of how science progresses over time. Lederman quotes Coleridge who tried to define beauty. Apparently Coleridge always returned to one deep thought: "Beauty, he said, is 'unity in variety'". Whereupon, Lederman retorts: "Science is nothing else than the search to discover unity in the wild variety of nature – or more exactly, in the variety of our experience".

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