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Philosophical Reflections on Facilitating Paradigm Shifts

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ABSTRACT

A paradigm shift by definition is a major change in scientific understanding that upends and replaces a prior paradigm. Over the past 47 years, I have made a number of paradigm shifts in the geosciences, planetary sciences, and astrophysical sciences. These include the composition of the inner core and deep interior of Earth, recognizing that Earth's early formation as a Jupiter-like gas giant makes it possible to derive virtually all the geological and geodynamic behavior of our planet, including the origin of mountains characterized by folding, the primary initiation of fjords and submarine canyons, the origin and typography of ocean floors and continents (described in Whole-Earth Decompression Dynamics), which upends and replaces plate tectonics theory, Earth's previously unanticipated, powerful, and variable energy sources, namely, a terra-centric nuclear fission georeactor and the stored energy of protoplanetary compression, the nuclear georeactor origin of Earth's magnetic field and the reasons for its variability. I also revealed a new concept that explains the thermonuclear ignition of stars and, concomitantly, the dark matter surrounding galaxies, the origin of heavy elements, and the reason why the vast multitude of galaxies in the universe display just a few prominent patterns of luminous stars. Recently, I discovered that particulate pollution, not carbon dioxide, is the primary cause of anthropogenic global warming. These are paradigm shifts which, unless successfully refuted, provide new, more-correct logical pathways for future discoveries. Here I reflect on some aspects of my personal science philosophy that has facilitated these fundamental paradigm shifts.

Observations, ideas, and understandings are the substance of science. We are, in a very real sense, creatures of the mind, building science upon nothing more tenuous than the fabric of human thought, a fabric that must be passed down from generation to generation without unraveling.

In 1974, only a few months after receiving the Ph.D. in nuclear chemistry, I presented a seminar at the University of California, San Diego. There were two men in the audience whom I only knew by reputations: Noble Laureate Harold C. Urey (1893–1981), who discovered deuterium and conceived the idea of oxygen isotope paleothermometry, and Prof. Dr. Hans E. Suess (1909–1993), co-discoverer of the shell structure of the atomic nucleus which earned J. Hans D. Jensen a share of the Nobel Prize (Figure 1).

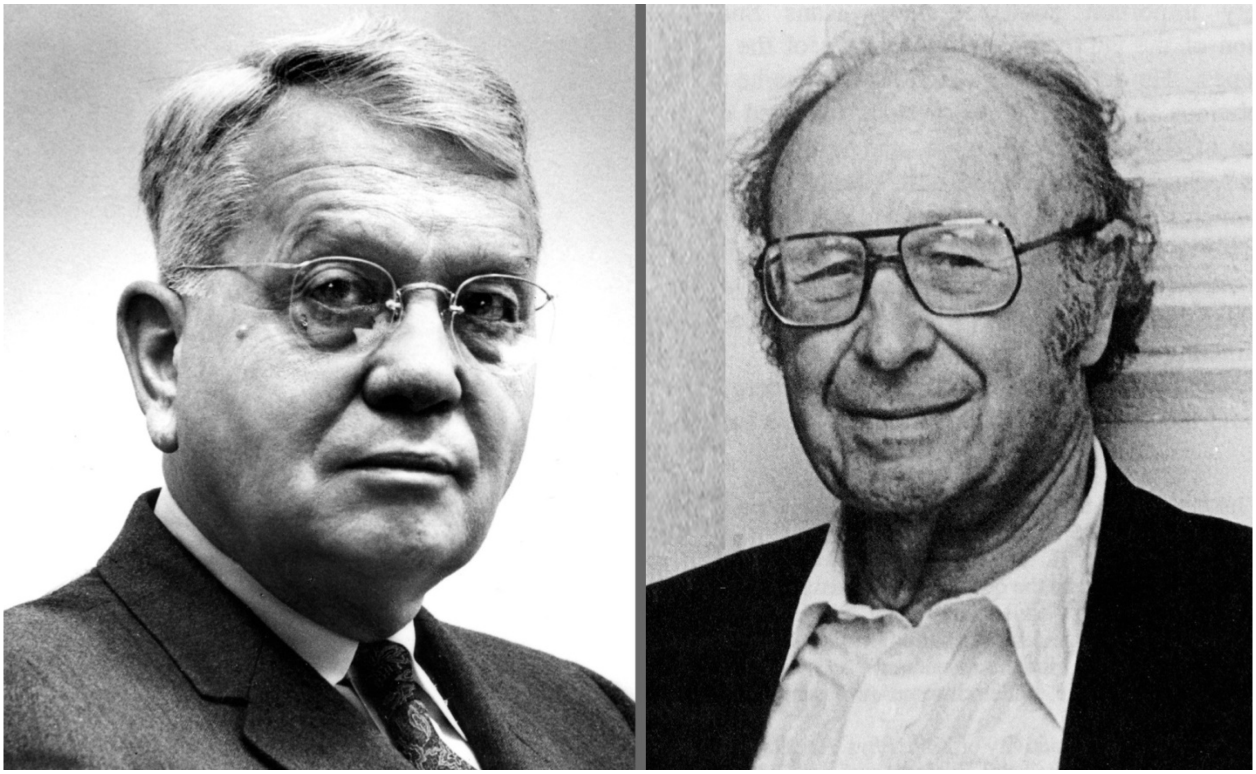

Figure 1. Harold Clayton Urey (left) and Hans Eduard Suess (right).

Both Urey and Suess were recipients of knowledge passed down from masters. Urey had served a post-doctoral apprenticeship with Niels Bohr in Copenhagen. Suess had learned geology from his father Franz Eduard Suess, a famous geologist, who had learned from his father, Eduard Suess, an even more famous geologist and author of *Das Antlitz der Erde* [1]. Something that I said during that seminar led to my being invited to serve a post-doctoral apprenticeship to these two senior giants.

Suess and Urey were well schooled in the principles, methods, and ethics of pre-WWII science, a time of little government funding. In 1951, the US National Science Foundation was established and wrote the rules for government administration of scientific research funding that today permeate the scientific community. Sadly, however, these rules were conceived without considering human nature, including secret funding-proposal reviews by one's competitors which encourage deceit, as well as proposal requirements that trivialize science. How can one specify beforehand what will be discovered that has never before been discovered and what one will do to make that discovery?

By 1974, the fabric of science was already being frayed. Now, 47 years later, I wish to share some of the insights I learned from Urey and Suess and also picked up along the paths of making scientific discoveries, for example [2-24].

The purpose of science is to determine the true nature of Earth and Universe and all contained therein. The word "true" is paramount. Science is all about truth and integrity. But in many other activities, politics for example, truth does not have the same necessity as it does in science, although as acknowledged by Mahatma Gandhi, "Truth never damages a cause that is just."

Science is the ever-evolving activity of replacing less-precise understanding with more-precise understanding. In this way, science advances. But how does one know, for example, whether a new idea represents an advance or not? How does one determine the truth in such an instance? In mathematics one can prove that which is true, but generally not so in science. When a new idea comes along there should be discussion and debate. If possible, efforts should be made to refute the new idea, to show that it is not true. If the scientific community is unable to refute the idea, ideally in the same journal where it was first published, then the idea should be acknowledged and cited in relevant scientific literature. Beware of the science-charlatans that ignore contradictory new ideas.

The criterion for truth in science is different than for truth in other fields. Jurisprudence, for example, filters evidence as to whether admissible or inadmissible and allows a jury to determine truth, i.e., guilt or innocence, which may or may not be the actual fact. In matters of political governance, for example, consensus is the criterion for truth, but in science, consensus is nonsense; science is a logical process, not a democratic process.

Fundamental new ideas sometimes meet with resistance. There is, I have observed, a human analogue to Lenz's Law in physics and Le Chatelier's Principle in chemistry, the tendency of a system to oppose change. On one occasion after a pleasant dinner, I began to explain my recent discoveries to a friend, a visiting scientist whom I had not seen for several years. As I described how Earth's interior differed from what he had been taught, his demeanor changed, his face became ashen; he hardly spoke the remainder of his visit. I have encountered similar experiences with others.

In 1623, Galileo Galilei (1564–1642), one of the greatest scientists of the millennium, precisely characterized human response to new ideas in a letter written to Don Virginio Cesarini, stating in part, "I have never understood, Your Excellency, why it is that every one of the studies I have published in order to please or to serve other people has aroused in some men a certain perverse urge to detract, steal, or deprecate that modicum of merit which I thought I had earned, if not for my work, at least for its intention" [25].

When I am exposed to a fundamentally new concept, I ask myself, "Suppose the new concept is correct? What does it mean? What advances might follow from it?" Therein might be opportunities for new discoveries.

Good science, properly executed and securely anchored to the abundances of the elements and to the properties of matter and radiation, transcends human opinion. Ideally, one seeks to derive fundamental quantitative relationships in nature. The making of models that are based upon assumptions, on the other hand, in my view is generally not science. Models are computer programs that generally begin with an assumed end result which is then attained by result-selecting variables and assumptions. A few models are useful [26], but they do not generally lead to scientific discoveries.

I had just begun a three-year postdoctoral apprenticeship with Hans E. Suess and Harold C. Urey when, in the morning of the third day, Suess stopped by my office , handed me a reprint of one of his scientific papers to read, and asked if I would like to stop by his office later and discuss it with him. Wanting to make a good impression, I read the paper quite carefully. It seemed simple enough, almost trivial. For good measure, I re-read it and then went to his office.

Not five minutes of discussion had taken place before it became painfully evident to me that I had completely failed to understand the paper, which contained neither complex mathematics nor necessitated specialized background information. Suess just shook his head and told me to come back when I understood it.

I was devastated. I had really wanted to make a good impression. Dejectedly, I left Suess' office to meet Harold Urey for lunch. Urey sensed that something was wrong and asked for an explanation. I explained the impossibility of understanding Suess' paper. Urey then smiled kindly and suggested that I might try reading scientific articles the way he does. Urey explained that he reads only one sentence and does not progress to the next until he understands fully the meaning of that one sentence. I put into practice Urey's suggestion, and it was as if a whole new world had opened up to me – I could understand Hans Suess' scientific papers just as he had intended them to be understood.

So, in the first week of my postdoctoral apprenticeship, I had learned how to read, but had not yet realized that I also needed to learn how to write in logical, causally related steps. That would come two months later.

One afternoon six months into my post-doctoral apprenticeship, Suess asked me directly if I knew why he had chosen me. Then he reminded me of my seminar and the questions that followed and one specific question in particular, which I had long since forgotten. He reminded me that I had answered by saying that I could not answer that question, that the information was simply not known. Looking at me with a gaze that seemed to stare into my soul, Hans Suess told me that not one young scientist in a thousand would have answered that way; most would have tried to answer the question. Then, he explained that it is much more important to know what is *not* known, than to know what *is* known.

There is a technique, a methodology, one can apply to begin to know what is not known and that is quite simply to go back in time [27]. Travel through time, not with a H. G. Wellsian time machine, but through a historical understanding of the events and ideas that led to the present state of understanding. All of that is documented in the scientific literature. Logically ordering historical observations and ideas into a sequential progression of understanding, while being keenly aware of later changes and discoveries, helps one to see gaps in the sequence, to begin to know what is not known, and perhaps to find mistakes that were made and not corrected in light of subsequent data.

Division and progressive subdivision with specialization comprise an integral process in nature and in human activity. Indeed, each of us began as a single cell which divided and progressively subdivided while achieving specialized functions. Ever-burgeoning observation, experimentation, derivation, calculation, and understanding, out of necessity, have led to division, progressive subdivision, and specialization of knowledge. By the 17th Century, chemistry was developing its distinction as a clearly separate science from physics. Then, in the 20th Century, as academicians expanded study of the Earth, those same divisions were carried forward as geochemistry and geophysics.

But there is a problem: As geochemistry and geophysics are only partial descriptions of the Earth, their separation and specialization poses a serious impediment to understanding, and, consequently, to making important new discoveries, particularly in instances when geochemists have little training in physics and when geophysicists have little training in chemistry. Another, sometimes even more serious impediment to making important new discoveries, and one often least appreciated, arises as a consequence of excluding, from the realm of scientific investigation, understanding of relevant science history.

Science is very much a logical progression through time. Advances are frequently underpinned by ideas and understandings developed in the past, sometimes under circumstances which may no longer hold the same degree of validity. It is of great benefit for a scientist, working within a conceptual framework, to understand the historical basis of that framework, to understand how the present state of knowledge arose and under what circumstances.

All too often, scientists, being distinctly human creatures of habit, plod optimistically along through time, eagerly looking toward the future, but rarely looking with question at circumstances from the past which have set them upon their present courses. Progressing along a logical path of discovery is rather like following a path through the wilderness. Occasionally, one comes to a juncture, the path splits, presenting a choice of scientific interpretations. Choose the correct logical interpretation and the way is clear for further progress; the wrong choice leads to confusion. That is often the way of science. To make matters even more complicated, the correct path is sometimes invisible, obscured because some requisite discovery has not yet been made. Moreover, the logical progression of scientific discovery is often opposed by the darker elements of human nature and institutional self-interest.

Much has been written about the Roman Catholic Church's opposition to the heliocentric hypothesis of Nicolaus Copernicus (1473–1543) [28] and its consequences on individuals and on the progression of human knowledge [29]. Less known, though, is that about 1800 years before Copernicus, Aristarchus of Samos (310–230 BC) had arrived at the same idea. Although the original explanatory document is lost, clear reference is given to his ideas by Archimedes (287–213 BC) in his book *The Sand Reckoner* which states in part, "His hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit, and that the sphere of fixed stars, situated about the same center as the sun …" [30].

What, one might logically ask, is the relevancy of the above historical references, especially now in the time of near-instantaneous global communications and Internet access? The relevancy relates to the persistence of human nature, which does not change on a time-scale of a few hundred or even a few thousand years, and which underlies impediments posed by institutional self-interest.

Phenomena, processes, or events, when described in terms of a problematic paradigm, yield explanations that are generally more complex, if not logically unrelated or physically impossible, than corresponding explanations posed later within a different, better understood, and more-correct paradigm. For example, in the Ptolemaic Earth-centered universe paradigm, the observed apparent motion of planets, specifically their retrograde motions, were described by complex epicycles (Figure 2). Within the state of knowledge at the time, that explanation seemed to explain the observed retrograde planetary motions, but we now know that epicycles are artificial constructs and that Earth is not located at the center of the Universe.

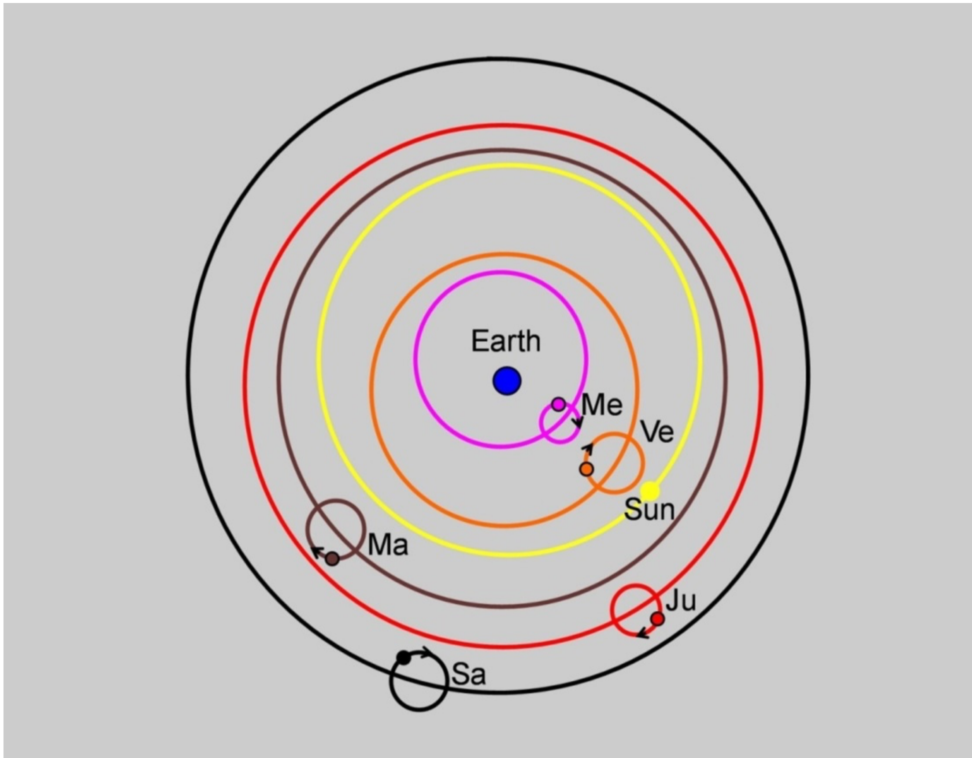

Figure 2. Epicycles were able to explain apparent retrograde motion of planets in the problematic Earth-centered Ptolemaic universe paradigm.

For another example, in plate tectonics theory mountains are thought to form by plate collisions [31], as plates move about the globe riding atop assumed mantle convection cells. Within that belief, mountains older than Pangaea required an earlier continent formation and breakup, and then an earlier one, etc. In other words supercontinent cycles, also called Wilson cycles [32] (Figure 3).

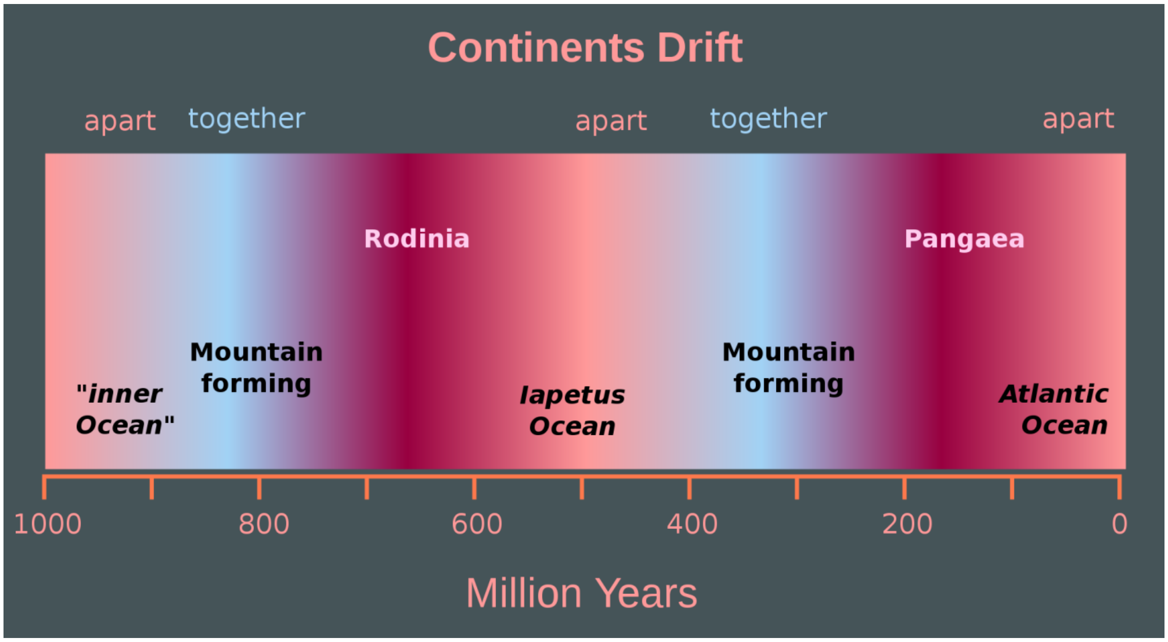

Figure 3. Illustration showing the fictional plate tectonics idea of supercontinent cycles. Courtesy of Hannes Grobe.

The lesson to be learned is this: If complex *ad hoc* explanations are necessary to make some observations seem to fit within current knowledge, then consider that as an invitation to question current knowledge.

Similarly, in the classical, pre-quantum physics paradigm, an ideal black body in a state of thermal equilibrium was calculated to emit radiation with essentially infinite power in the shorter wavelengths. This is the so-called ultraviolet catastrophe, a circumstance that is physically impossible. Later, in the now-known, more-correct quantum physics paradigm, black body radiation, and other phenomena, can be explained logically, causally, and with greater simplicity, without invoking complex, *ad hoc* assumptions. Such a fundamental change in understanding is referred to as a *paradigm shift* [33].

Science is like a long road paved with observations, ideas, and understandings. From a distance it might seem like a smooth strip of ribbon meandering through time. But up close, it can be seen as a rocky road indeed – a mix of insight and oversight, design and serendipity, precision and error, and implication and revision, all too often influenced by the vagaries of human behavior. By considering deeply the relevant science history, one might begin to recognize past faltering in the logical progression of observations and ideas and, perhaps then, to discover new, more precise understandings [27].

Science is a logical progression of causally related events, analogous to a really good movie where all the actions are logically and causally related; the pieces all fit together. Now, if something about nature seems like a really bad movie and does not make sense, ask the question, "What is wrong with this picture?" That can be the first step toward making an important discovery.

There is a more fundamental way to make discoveries than the variants of the scientific method taught in schools which I describe here: An individual ponders and through tedious efforts arranges seemingly unrelated observations into a logical sequence in the mind so that causal relationships become evident and new understanding emerges, showing the path for new observations, for new experiments, for new theoretical considerations, and for new discoveries [27].

Science should not simply be an academic discipline, but should aim to improve the well-being of life on Earth. By virtue of their abilities and training, scientists in my view have a special responsibility to humanity, not only to improve human and environmental health, but to protect life on this planet. Life on Earth is possible due to both the nature of Earth's composition and physical processes, which afford protection from the ravages and variations of solar radiation, and the myriad complex interactions by and between biota and their various environments. Scientists should avoid and indeed prevent any activity that upsets the delicate balance in nature.

Above all, scientists must be truthful.

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