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Science Vs. Pure Mathematics, Einstein, Tesla, Musk, & the Myth of Exponential Growth

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4. Three-Dimensional Venn Diagram as an Explanation of Two Kinds of Generality in Science, Invention, & Engineering

This paper presents a three-dimensional Venn Diagram that seeks to show that there are two kinds of generality in physics, science, and engineering instead of one: Einstein’s theory that predicts the bending of light implies that his theory of gravity is more general than Galileo’s or Newton’s; however, by a standard of technological productivity, the work of Galileo and Newton and other trail-blazing scientists discussed in the paper have greater and more general consequences for technological growth and productivity than Einstein’s: these include the work of Alan Turing, Nicholas Metropolis, Claude Shannon, and Nikola Tesla.

Chapter - 01

Science Versus Pure Mathematics: Infinite Mathematical Lines Vs. the Number of Concepts in Science and Logical Space, or, Is the Underdetermination of Theory Wrong? Christopher Portosa Stevens Science Versus Pure Mathematics: Infinite Mathematical Lines Vs. the Number of Concepts in Science and Logical Space, or, Is the Underdetermination of Theory Wrong?

Abstract

In this paper I seek to demonstrate that in the evolution and growth of science, the 'Underdetermination Thesis' of some prominent philosophers and scientists (like Quine, Harding, or Feyerabend), that there are always a large number or possibly an infinite number of theories to fit the data or explain empirical patterns, is false. For centuries, philosophers and philosophers of physics have debated the 'Underdetermination Thesis,' and in the 20th century, philosophers from the US, Europe, Japan, and other countries, have continued to debate the 'Underdetermination Thesis.' I seek to identify and count the number of concepts and theories at different stages in the evolution and development of science and scientific knowledge, and show that at any stage in the development and evolution of science, there are only a few concepts and theories that compete with each other instead of a larger number of concepts and theories, or possibly an 'infinite' number of concepts and theories. In science, at any point in the evolution and development of science and its various branches, there are only a few or relatively small number of concepts and theories in any scientific field that compete with each other to explain the phenomena under the jurisdiction of any scientific branch or field. I also provide a review of kinds and styles of scientific explanation, including kinds and styles of scientific explanation used by scientists that go beyond traditional or classic categories of scientific explanation (developed by figures such as Karl Popper, Karl Hempel, Ernest Nagel or others, such as covering laws, causal models, or functional explanation).

The paper includes a provocative discussion of the nature of causation, that revolutions in cultural diffusion, such as Fibonacci's simplification of Arabic numerals for Western societies in the 13th century, or, in ensuing centuries, for Western imperialist powers and globalization, or contemporary revolutions in cultural diffusion, such as access to graphical user interfaces in video games and commercial and business computer and electronics applications, increase the cultural capacity for scientific and technological growth, and scientific and technological revolutions; however, from the point of view of causation, they are not necessary and sufficient causes for technological and scientific revolutions like access to higher written languages like Greek, Latin, or Arabic based scripts, or access to Chinese or Japanese based scripts, since in the ancient world, cultural groups that had access or developed Greek, proto-Arabic, Latin, and Chinese scripts, had scientific and technological revolutions before the revolutions of cultural diffusion of Arabic numerals by Fibonacci in the 13th century or graphical user interfaces by Atari, Steve Jobs, Bill Gates or others in the 20th and 21st centuries.

1. Introduction

Concepts, Conceptual Innovation, and Conceptual Revolutions Philosophers sometimes use a concept of "logical space" to describe the nature of logical possibility and also the concepts, conceptual language, or abstract linguistic terms that describe and define logical space itself: atoms, molecules, electromagnetic waves, gravity, natural selection, species, cells, chloroplasts, mitochondria, metabolism, birds, beaks, feathers, talons, adaptation; unicorns, gods, devils, goblins, gargoyles, religious personas and personifications, theological constructs and metaphysics; natural persons, legal persons, and corporate persons, ecclesiastical jurisdictions and secular jurisdictions; Bertrand Russell supported the translation of Ludwig Wittgenstein's *Tractatus Logico-Philosophicus* post WWI, and invited Wittgenstein to Britain: Bertrand Russell, Karl Popper, and Ludwig Wittgenstein use a concept of logical space to describe the space of logical possibility including the conceptual language that may be used to describe the empirical world, the logical relationships of geometry and mathematics, and aesthetic, religious, and creative worlds of flying unicorns, minotaurs and garudas, polytheistic gods and monotheistic gods, and the hundreds of thousands of different portrayals of gods, goddesses, beasts, and demons in religion, art, sculpture, architecture, and design of the West, East, and around the world.

In philosophy, and also from the points of view of religion, science, and art, Wittgenstein, Russell, Karl Popper and others, are sometimes concerned with the questions and problems of the "logical positivists" of early 20th century Austria and continental Europe that philosophical, scientific, and intellectual discourse be limited to questions of logic, mathematics, and empirical science. However, if one applies the standards of, say, Bertrand Russell or Ludwig Wittgenstein, or ancient Greek philosophers, what is logically possible or what is logical space is greater than the empirical description of the world; what is logical space is greater than the description of the world by theoretical physics or empirical science; what is logical space is greater than the description of the world by theoretical chemists, practical chemists, or practicing biologists; what is logical space is greater than the description of the world by theologians and metaphysicians; what is logical space is greater than the description of the world by ecclesiastical law, religious law, secular law, canon law, or common law. Evolutionary biologist Jared Diamond calls Ernst Mayr's contribution to the Neo-Darwinian synthesis of Darwinism and Mendelian genetics a "conceptual revolution," instead of a scientific revolution per se. (Other

figures such as Theodosius Dobzansky and J.B.S. Haldane were arguably also part of this “conceptual revolution” in the biological sciences earlier in the 20th century since they also were important figures contributing to attaching Mendelian genetics to Darwin’s theory of evolution by natural selection). Since Darwin used a “blending” conception of inheritance, or a conception of inheritance, as John Dewey surmises, still partly derived from Aristotle’s conception of “pangenesis,” connecting Darwinist concepts of natural selection and adaptation to Mendelian genetics was viewed as a “conceptual revolution” by Jared Diamond and others. This conceptual revolution laid the basis for predictive models of the differential success of genes across generations of organisms, and shifted the “unit of selection” from the classic Darwinist view of organisms as the unit of selection or the breeding populations of species as the unit of selection to the gene itself.

What are “conceptual revolutions,” why do people talk about them, and why are they important? Conceptual innovation and conceptual revolutions in science are sometimes viewed as important because they may set the stage for future progress in science, including scientific revolutions.

What are examples of conceptual revolutions in science, instead of empirical discoveries per se, new predictive theories, or scientific revolutions in themselves?

Many earlier “conceptual revolutions” in the history of science and the history of ideas and thought are taken for granted: The basic concepts of science like the different forces of nature, or concepts that describe fundamental phenomena in physics, chemistry, and biology, are all “conceptual revolutions” upon which future progress in science are based.

Here are a few examples of conceptual revolutions across the physical sciences, biological sciences, behavioral sciences, and humanities:

- 1) Flemish scientist Jan Baptist van Helmont is credited with inventing the concept of “gas” to describe substances like air (in 1620).
- 2) Michael Faraday invented the concept of “force field” to describe electromagnetic phenomena.
- 3) Herman Minkowski interpreted Einstein’s work as implying the unification of the concepts of space and time, and proposed the four-dimensional conception of “space-time.” This conceptual revolution also was dependent on a
- 4) negative conceptual revolution: astronomers and physicists continued to use a concept of the “aether” through the beginning of the 20th century; the aether was conceived as a substance through which light and other electromagnetic phenomena would move; complex experiments, such as that of Michelson and Morely, attempted to demonstrate the existence of the aether; Michelson and Morely’s experiments were viewed as not successfully demonstrating the existence of an aether; Henri Poincare and Albert Einstein called for discarding the aether as unnecessary for explaining the behavior of light and electromagnetic phenomena: Italian historian of science Enrico Gianetto states that Poincare called for discarding the concept of the aether as early as 1889, and Einstein discarded it in his theory of special relativity in 1905; that is, physicists and astronomers did not discard the Platonic-Aristotelian conception of an aether or the 17th, 18th, and 19th centuries’ conceptions of the aether developed by Newton and others until self-conscious “positivist” scientists, particularly Henri Poincare and Albert Einstein, discarded the conception of the aether as unnecessary for physical explanations; (thus, even though experimental physicists like Michelson and Morely were not able to conclusively demonstrate the existence of the aether, astronomers and physicists did not discard the “fifth element” of the aether until theorists like Einstein and Poincare were able to provide physical explanations without reference to an aether).
- 5) Marshall McLuhan used a concept of “global village” to describe the consequences of instantaneous or near instantaneous electronic communications spanning the globe; McLuhan is also credited with predicting characteristics of the internet partly based on his conception of a “global village” of electronic communications.
- 6) Malthus’ conception of a struggle for existence and checks on population growth: Malthus conceived of a struggle for existence in which there was a potential geometrical increase of offspring over generations that was checked by more limited food or nutrient supplies, or disease pathogens, or warfare in human populations (“warfare, disease, pestilence, and famine”); Thomas Malthus is usually classified as a figure in “political economy” or early social science: Darwin poached Malthus’ conception from early “political economy” or social science to the evolution of biological species: Darwin commented that the theory of evolution by natural selection was the “doctrine of Malthus applied to the animal and vegetable kingdoms.” The “conceptual revolutions” of Poincare in theoretical physics, and Malthus in early social science, were important to setting the stages for the scientific revolutions of Einstein with special relativity and general relativity, and Darwin in the biological sciences.
- 7) In the 18th century Adam Smith and Montesquieu in effect “re-discovered” the Roman conceptions of a “division of labor” in economic productivity and a
- 8) “division of powers” in societal governance. Adam Smith explained and popularized the conception of a “division of labor” of economic productivity, and developed a theory of economic productivity and efficiency in which divisions of labor distributed across different organizational boundaries and national boundaries were more productive and efficient than divisions of labor that did not expose the divisions of labor of business firms to the competition of other business firms nationally or internationally. Adam Smith shocked early “mercantilist” and “protectionist” governments in Europe and the Americas by arguing that national governments should not “protect” or overly subsidize dominant businesses or businesses of the host country or the most prominent ethnic group or ethnic groups; this is because such government “protection” and subsidies reduced the exposure of the protected or subsidized firms to the economic competition that forced the firms to be more efficient and productive in the national or international

marketplaces in which the business firms would compete. Adam Smith's popularization of the conception of the "division of labor" also was important to the biological sciences, especially anatomists and cellular biologists conceiving of and describing the division of labor of different organs, tissues, and cells and cell lines in bodies of organisms.

9) Neapolitan Italian philosopher Gian Battista Vico used a concept of "natural technology" to distinguish the artifices or man-made technologies of human societies from the "natural technologies" or adaptive structures distributed across different species of organisms that emerged in the evolution of different species or organisms. Karl Marx interpreted Charles Darwin's theory of evolution of natural selection as Darwin providing an explanation of the evolution of the "natural technologies" of organisms, that is, of providing an explanation of the productive capacities of organisms in their struggle for survival, existence, and reproduction in relation to their environment. Marx thus treated Darwinian biologists' conception of adaptive structures and adaptive properties of organisms as conceptually equivalent to Gian Battista Vico's conception of "natural technologies." Karl Marx, J.B.S. Haldane, Theodore Roosevelt, Prince Kropotkin, and others, also interpreted Darwin's theory as implying different kinds of socialism.

Physicists and philosophers of science sometimes comment that explanation in the physical sciences and the biological sciences is different in that explanations in biological sciences tend to employ a style of explanation that involves "explanation by concept" of important discoveries, patterns, or findings, while the physical sciences are explicitly predictive and employ general principles or laws to explain discoveries, patterns, and results.

There are biologists and biochemists, however, that do more than "explanation by concept," "covering-law explanations," or "causal explanations."

The major categories of scientific explanation used by philosophers of science are A) "explanation by concept": such as Steve Jay Gould and Niles Eldridge's explanation of non-gradual evolution by

10) "punctuated equilibria"; biologists and biochemists explanation of nutrient consumption, energy production, and waste expulsion by

11) "metabolism"; the absorption and extraction of energy from light by plants, explained by the concept of

12) "photosynthesis"; the capacity of biological characteristics of organisms to shift or change their functions to new tasks and functions, which, in turn may shape biological characteristics in new ways or new directions: this has been called

13) "exaptation" by Gould and Vrba and others; the evolution of feathers is an example: feathers initially functioned to regulate body temperature; however, lines of organisms with feathers, aves or birds, continued to evolve, and evolved in different functional directions i.e., the capacity for flight; regions of the brain evolved for different tasks and functions than language per se; however, regions of the brain that evolved for different tasks and functions in the evolution of primates and the evolution of the Genus Homo evolved the emergent capacities for speech, language, language learning, and symbol manipulation and written language in the evolution of the Genus Homo and Homo Sapiens;

14) the potential capacity for biological systems for self-reference, or "autopoiesis," by Maturana and Varela;

15) explanations and rankings of the hardness of minerals, compounds, and solids by the concept of "hardness," as in diamonds having more "hardness" than glass;

a) Covering law or hypothetico-deductive explanations (following the work of philosophers of science such as Carl Hempel and Karl Popper); it is possible to identify covering law explanations independent of their subject matters, and independent of their empirical validity: thus, Ptolemy's predictive astronomy is an example of covering law explanation (planet Earth centered astronomy); Copernican astronomy and Newtonian astronomy are examples of covering law explanation;

b) Causal explanations; causal explanations may use the former two categories in causal explanations, as in causal explanations in controlled in-put and out-put systems or experimental systems that may also use or make reference to explanation by concept (such as experimental studies of bacteria); causal explanations may use covering law explanations with the causal explanations or as the causal explanations themselves, as in the experimental physics of Galileo, or experiments testing Galilean and Newtonian mechanics, or other physical laws, such as Boyle's Law on the nature of gases; causal explanations may use a single force to explain a phenomenon, phenomena, pattern, or patterns; Causal explanations may use more than one force of nature to explain the phenomenon or phenomena in question or the instrument or technology in question, and may employ explanation by concept, covering law, or both, with the causal explanation or a covering law explanation or explanations with the causal explanation (physicists and engineers such as Jearl Walker and others employ more than four forces of nature and multiple causal factors to explain complex interactions of physical phenomena in "every-day life," and also sometimes complex technologies or complex manufacturing processes). However, scientists sometimes engage in research and explanations that do more than the three previous categories of explanation by concept, covering law explanations, or causal explanations.

c) Additional categories of scientific explanations might include:

d) modeling complexity across different levels of reality by complexity theorists (see, e.g., Waldrop 1987; Gell-Mann 1996);

e) developing models of technologies based on a single physical law, principle, or rule (like the thermometer);

f) developing models of technologies based on the interaction of multiple physical forces, principles, or rules (like Alan Turing or Nicholas Metropolis developing abstract models of computers that became the basis of early computing machines, or other exam-

ples of introducing or developing techniques, principles, or models of technologies for ordering physical phenomena as technologies, like the extension of computer science into artificial intelligence and robotics);

g) developing models of governmental, corporate, and organizational ‘technologies’ that employ multiple principles of political science or the behavioral sciences: these include principles of hierarchy, bureaucracy, and written rules; principles and rules of organizational segregation, jurisdiction, and authority (including the “division of powers”), the delegation of authority, degrees of autonomy and authority given to different kinds of experts and producers, such as scientists, engineers, and professionals as experts, and industrial workers or farmers as producers; additional organizational principles or inter-organizational principles include Adam Smith’s “division of labor” for the explanation of the greater productivity of organizations and economies with divisions of labor and specializations across roles in a division of labor than groups, organizations, or economies lacking a division of labor; Karl Marx’s dialectical materialism for the organization of Communist societies and political parties in the former Soviet Union or China focused on industrial and scientific production; Chinese and East Asian farm-village collectives employing “socialist capitalism”; Henry Ford’s assembly line technique of mass production; Japanese corporations’ organizational principle of “quality circles” for industrial production; in capitalist societies, some principles are legal or legal-financial in nature, like the principle of corporation used for legal corporate “persons,” whether Catholic Churches and their property distinguishable from government ownership, universities and their property distinguishable from government ownership, or business corporations and their property distinguishable from ownership by government or government agencies; the standardization and distribution of risk and compensation in “no-fault” insurance and other types of insurance; the classification and differentiation of different kinds of stock, bonds, and equity in corporate property.

h) simulating and modeling the behavior of natural populations and natural phenomena of different branches and sub-branches of science with artificial populations in computer science; this includes simulations of Darwinism, natural selection, and different kinds and levels of biological phenomena and bio-chemical phenomena; simulations of astronomical phenomena, physical phenomena, and chemical phenomena; simulations of behavioral patterns of the behavioral sciences, including cultural, linguistic, organizational, and inter-organizational and network patterns and behavior; However, it is possible to consider an additional category:

I) modeling “natural technologies” in biochemistry and the biological sciences; biochemists and biologists sometimes provide models of natural technologies or models of adaptive properties, including at the level of protein molecules and organic compounds. This includes models of protein molecules that perform different functions and tasks in cells in organisms, or models of the DNA and RNA that perform functions of storing genetic information for the distribution of information required for the building blocks of cellular protein structures in the genesis of organisms from generation to generation; thus, the modelling of natural technologies or the adaptive properties of organisms involves more information than Linus Pauling-style models of molecules per se; the modeling of natural technologies or adaptive properties by bio-chemists and biologists involves discussions of the functions and tasks of tissues, organs, and, at the molecular level, protein molecules or other molecules, and how tissues, organs, and protein molecules or other molecules might fulfill their functions and tasks in relation to other tissues, organs, cells, and molecules; it is interesting to recognize that modeling natural technologies or adaptive structures or properties of protein molecules that perform functions and tasks in cells, cell lines, and tissues does not require the additional conceptual revolution of Watson and Crick in relation to the DNA (and also RNA); that is, within this category there are at least two sub-categories; that is, Watson and Crick did not use Claude Shannon or others’ quantitative conception of information used in early 20th century physics; instead, Watson and Crick used a conception of information that combined frameworks of biology, post-Mendelian genetics, linguistics, and bio-chemistry, i.e., that a biochemical structure might carry the units of particulate inheritance postulated by Mendel; that a biochemical molecule that carried the genetic information was in the gametes and the chromosomes; that a bio-chemical molecule would carry information for the organization of the proteins and cellular structures required for cellular growth and multicellular complexity; that bio-chemical molecules might code for different proteins analogous to symbols, letters, and words referring to different content and objects; Watson and Crick did not use a conception of information that equated information with entropy, or even the inverse of entropy per se; (in his famous and infamous autobiography and unofficial biography of Francis Crick, James Watson suggested that he and Crick were able to win the race to discover the model of the DNA, instead of Linus Pauling and other chemists and biochemists that thought the genetic information was carried by a protein molecule, partly because they were able to recognize that a molecular structure besides a protein, and simpler than most organic compounds, could perform the function of carrying the genetic information); the decoding of the DNA and the RNA, and the transference of the information of the DNA and the RNA to other media, such as computer storage or music, offers additional ways of storing the DNA and RNA information as digital information; this in effect offered an additional framework for interpreting the nature of the DNA and the genetic material: that the DNA and the genetic material were digital in nature; (however, it has not been possible or it has not been shown that it is possible to take the digitally stored DNA or RNA information as digital information, to code for building blocks of cellular life; instead, information of DNA or RNA from organisms stored as digital information, such as music, would have to be translated back to some kind of DNA, RNA, or other biochemical template to code for the building blocks of cells, cellular differentiation of cell lines, and cellular growth). Thus, in this category, there are two types of modeling natural technologies: there is another level of information content, and another level of explanation, in the explanation of biochemical molecules that carry information for the construction and building blocks of cells, as in DNA or RNA, compared to modeling proteins, fats, or other molecules as natural technologies or adaptive properties that perform different functions and tasks for cells, cell lines, cell growth, cell differentiation, and tissues and organs. Linus Pauling’s framework for modeling complex

molecules is a sometimes unacknowledged scientific revolution that has been used by scientists for multiple discoveries involving the modeling of complex organic and inorganic molecules; however, the scientific models of organic molecules by bio-chemists that are concerned with the functional quality and nature of the molecules as natural technologies or adaptive properties for the cells of organisms carry more information content than only the formal characteristics of the organic molecules as described by chemistry; that is, scientific models of organic molecules also will have informational content related to their functions or contributions to the performance, differentiation, and also growth of cells and cell lines; thus, when biologists and biochemists model organic molecules they many times use a style of explanation that may be called or referred to as the modeling of natural technologies or the modeling of adaptive properties or structures (and thus, to use earlier frameworks, may combine “covering law” explanation and causal explanation with functional explanation). Are conceptual revolutions important in the case of Watson and Crick’s discovery of the double-helical structure of the DNA, an acknowledged scientific revolution? It required nearly a century from Gregor Mendel’s conceptualization and postulation of a particulate nature of genetic inheritance, that might appear and reappear across generations, to the discovery by Watson and Crick of the double-helical structure of the DNA (and the immediate theory of Watson and Crick that the functional significance of the double-helical structure of the DNA was that it was a universal or near universal molecule for carrying instructions for the building blocks of cells of organisms, and, more generally, the genetic inheritance of organisms). From the point of view of the social organization of science and the cultural growth of science in addition to the philosophy of science per se, given that Watson and Crick’s discovery of the double-helical structure of the DNA was a scientific revolution related to the growth of experimental and engineering research programmes concerned with decoding the DNA, related RNA molecules, and the functional relationships by which DNA codes for amino acids, proteins, and the building blocks of cells, cellular growth, and cellular differentiation; thus, the conceptual revolution of Mendel postulating a particulate unit of genetic inheritance instead of blending inheritance, and Mendel’s scientific revolution for predicting regularities in the distribution of genetic units across generations, has led to a larger set of experimental and engineering research programs in the biological sciences and genetics than Darwin’s theory of evolution by natural selection).

i) There are cases of scientific explanation that not only build on earlier scientific discoveries but that create or establish a larger theoretical architecture or set of frameworks that combine or synthesize multiple concepts, principles, and even laws of earlier scientific achievements: The periodic table created by Mendeleev, and qualified by generations of chemists, is an example. The naming and conceptions of every element in the periodic table are themselves mini-conceptual revolutions, and the periodic table consists of multiple frameworks for predicting the characteristics of elements with limited information, and for predicting the characteristics of groups of elements, like the noble gases or the reactive or alkali elements and hydrogen.

Linus Pauling’s framework for modeling complex molecules was not available or apparent to all chemists that had access to the periodic table of elements; earlier in the 20th century, James Watson and Francis Crick reported that only a small number of chemists and bio-chemists in the United States and Europe were able to perform Linus Pauling-style modelling of complex molecules even though all chemists had access to the periodic table itself; like the periodic table, Pauling’s framework for modeling complex molecules builds on multiple discoveries and multiple principles of physics and chemistry related to chemical bonds.

What is the “Underdetermination of Theory” by Data and Empirical Observation?

In science and the philosophy of science there are philosophers and scientists that claim that there is an “underdetermination of theory” by data and empirical observation. This is the idea that “no matter how large the data collection one has, there are always in principle an infinitely many potential explanatory theories covering those data. . . . The data do not nail down a unique theory.” The underdetermination of theory by empirical data or empirical observation thus implies there may be many theories to explain a single empirical pattern (a similar phenomenon is that there are sometimes more than one theory that is used to explain or interpret why a particular technology or manufacturing process works). What does it mean to say that there are an infinite number of theories to explain an empirical pattern or a set of data?

Some philosophers claim, like the quoted passage from the authors of *The Little Book of Logic*, “there are always in principle an infinitely many potential explanatory theories covering those data.” In the philosophy of science this idea is sometimes expressed in terms of mathematics and the graphical representation of data in relation to the number of lines that might be drawn through a set of data points on a graph. In this manner of thinking of the problem, given a conventional definition of a line as a unit that connects at least two points, there are an infinite number of lines that may be drawn through the data points or to approximate the data points: straight lines, and also many different lines within different categories of lines that may be drawn through the data points on a graph, curved, zig zag, parabolic, waves, and also eccentric, “squiggly” lines.

However, it is also possible to think of the problem from the standpoint of the substantive nature of theory in science, and the history of science: There are not an infinite number of theories in science at any point in time or space-time; there are only a few theories related to any particular subject matter or subject matters. In the evolution and growth of science, or any branch of science, there are relatively few concepts instead of millions, billions, or an infinite number of concepts; in the evolution and growth of science or any branch of science there are few substantive theories that compete with each other instead of a large number or an infinite. Thomas

Kuhn, in his famous *Structure of Scientific Revolutions*, claims that there is usually a dominant theory or only a few dominant theories in any particular branch or sub-branch of science. (The number of branches of mathematics, and the different logical spaces of different branches of mathematics and alternative geometries is larger than the logical space of any branch of science concerned with some category or categories of empirical phenomena).

In the history of science there are few theories, not many: In the so-called Western world and also the Muslim world, Ptolemy's predictive theory of astronomy was dominant until Copernicus provided an alternative heliocentric theory of planetary orbits for what contemporary physicists recognize as the solar system; Aristotle's theory of gravity was dominant until Galileo demonstrated that Aristotle's theory of gravity was irrational, logically contradictory, and also empirically false (much to the consternation of medieval Inquisitors and torturers during the counter-Reformation). The ancient Greeks classified the basic elements of matter as air, earth, fire, and water; it was not until the 17th, 18th, and 19th centuries that scientists began to self-consciously distinguish between more elements and properties; Jan Baptist van Helmont is credited with inventing the concept of "gas" to describe substances like air, in 1620; by the 18th century there was a near "conceptual revolution" in the conception and explanation of combustion in terms of the "phlogiston" concept and theory of J.J. Becher and Georg Stahl; this near conceptual revolution by Becher and Stahl was discarded by the end of the 18th century: in 1774, Joseph Priestly discovered that air was not a single substance but a composition of substances, including what he called "dephlogisticated air"; in 1778 Antoine Lavoisier arguably contributed a "conceptual revolution" by naming and conceiving "dephlogisticated air" as an element, oxygen, and discarding the phlogiston theory of combustion which might have explained the combustion of wood, candles, or engines with an ethereal substance, the "phlogiston"; before Mendeleev's scientific revolution of the periodic table of elements (in which characteristics of elements may be predicted based on their position and relation to other positions on the periodic table), there were not an infinite number of competing theories, but only a few other competing theories related to the potential periodicity of elements, such as that of John Newlands, Alexandre-Emile de Chancourtois, or Lothar Meyer.

Aristotle's theory of "pangenesis" was in effect dominant until the 19th century in the Western world since naturalists and biologists like Charles Darwin and Alfred Russel Wallace used a conception of the biological inheritance of organisms derived from Aristotle's conception of "pangenesis" (as John Dewey and other philosophers and historians of science recognize); it was not until the beginning of the 20th century that biologists and geneticists re-discovered Gregor Mendel's work on the postulation of particulate units of genetic inheritance; relatedly, the demonstration of the chromosomal basis of heredity by Walter Sutton and Theodor Boveri gave Mendel's theory a firmer empirical basis; thus, as John Dewey and others have commented, it was not until the beginning of the 20th century that Aristotle's conception and theory of "pangenesis" was discarded for Mendelian genetics and also derivative concepts of Aristotle's theory like Darwin's conception of blending "gemmules" of inheritance.

In the preceding section I discussed what is called a "conceptual revolution" in early 20th century biology, the "neo-Darwinian" synthesis of Mendelianism with Darwinism by which scientists such as Theodosius Dobzhansky, J.B.S. Haldane, and Ernst Mayr sought to interpret Darwinism in terms of Mendelianism, and Mendelianism in terms of Darwinism; these scientists and others, such as R.A. Fisher and Sewall Wright's statistical modeling of populations, sought to show that Darwinism could be tested empirically by measuring the differential success of genes and their alleles across generations of organisms. Why weren't some other figures in early 20th century biology, such as Walter Sutton, part of the neo-Darwinian synthesis? Before the neo-Darwinian synthesis that sought to test Darwin's work in terms of the differential success of genes, many biologists and naturalists in the US and Europe were highly "positivist," and questioned the testability of Darwin's theory of natural selection even if they believed in the evolution of species.

As suggested, conceptual revolutions may be negative, such as Poincaré and Einstein discarding the 19th century conception of "the aether" through which objects in space moved; Max Planck and Albert Einstein's conceptual revolution of the quantum, that light might behave not only as a wave but also as a discrete particles that were energy packets or photons contributed to the scientific revolution recognized as quantum mechanics (experimental physicist Arthur Compton was able to conclusively demonstrate the existence of a quantum nature of light, that light behaved as photon particles in addition to light waves, by colliding electrons and light waves to generate a scattering of particles). Although the spoken English language was originally derived from a spoken Germanic language, Britain was a former Roman colony for centuries, and "Western" languages like English and German have been connected to and are written in Latin based scripts; linguists have demonstrated that over 70% of English words are derived from Latin; in Western languages, in the "high English" of Shakespeare, Byron, Keats, or Shaw, or in the words and concepts used in science, technology, and scholarship, the number of words and word-concepts derived from Latin and Greek is higher than 70%; (the Chinese script plays a similar role in some Asian societies and languages, such as Korea and Japan); in the 18th century Immanuel Kant struggled with the origins of logic and reason, and questioned whether they emerged from experience (like empiricist philosophers) and contact with syntax and language; Kant proposed a "transcendental deduction of the categories of reason" in which categories of logic and reason must be innate or partly innate in the brain instead of merely being learned through experience; thus, contra empiricist and behaviorist ideas of a what psychologist Stephen Pinker calls a "blank slate" of mind in which individuals might learn different ideas and capacities through experience, Kant proposed that the nature of logic and reason required for scientific and mathematical reasoning must be innate or partly innate in the brain; 18th and 19th century psychologists and "phrenologists" in

Europe developed a research program based on qualitative interviews that led to psychologists claiming that there were dozens of intelligences and personality characteristics, possibly over fifty, that would inhere in different regions of the brain; the research program was largely dropped when researchers attempted to prove that different intelligences and personality characteristics were also directly related to shapes and grooves on Europeans skulls; for contemporary psychologists and neuroscientists, the number and range of behaviors that are innate or potentially innate, including the capacity for language learning, musical abilities, and other capacities that are “wired” in mini-organs or “modules” in the brain are larger than what Kant would recognize as the transcendental categories of reason (that inhere in the mind or that co-evolved with some plastic culture, like spoken or written languages).

The success of the idea that the capacity for language learning, music, logic, and other capacities might be partly innate and “wired” in the brain in mini-organs or “modules” in the brain instead of through behaviorist processes of learning or trial-and-error learning is partly dependent on Noam Chomsky’s revolution in linguistics in the 20th century; in 1861 French neuroscientist Paul Broca discovered that there was a “language centre” in the brain: however, behaviorist and empiricist ideas regarding the nature of language learning by trial-and-error or other learning strategies were not discarded until the 1950s and 1960s when theoretical linguist Noam Chomsky was able to convince psychologists, neuroscientists, and linguists in the English and French speaking worlds to give up their intuitive theories of language learning for a theory that implied that the capacity for learning any complex grammar required for language learning was innate in the brain. (French psychologist Jean Piaget, for example, continued to claim that language learning was by some kind of trial and error learning process into the 20th century).

Prominent historian of science, Arthur Koestler, writes of the origins of science in the early scientific revolutions and achievements of ancient astronomers in ancient Mesopotamia, ancient Egypt, and ancient Greece; the build-up of established knowledge and the early conceptual revolutions and scientific revolutions amalgamating disparate word concepts and astronomical observations of ancient Mesopotamia and ancient Egypt set the stage for the cultural diffusion of early astronomy from the ancient Middle East and Egypt to the early science of ancient Greece; Koestler writes that by the 4th and 3rd centuries B.C. the achievements of a few Greek scientists, like Heraklides, Aristarchus, and Archimedes, were spectacular to the point that European science did not reach their level until the 1500s; similar to Koestler’s reactions, Muslims in the Middle East translated and referred to the predictive astronomy of Claudius Ptolemy (of Alexandria in formerly Greek Roman Egypt), that was based on the idea of “mother earth” being the center of the universe instead of a heliocentric theory, as the *Almagest* or “the Greatest Book”; the simplification and introduction of Arabic numerals by Fibonacci was a revolution in cultural diffusion from the Muslim world to the Western, Christian world in the 13th century; the simplification and introduction of Arabic numerals in the Western, Christian world clearly improved societal productivity in science, technology, business, and government; however, from the standpoint of the philosophy of causation, Arabic numerals were not necessary or sufficient cultural or symbolic causes for scientific and technological revolutions in the Christian or Muslim worlds since the Mesopotamian, Egyptian, Greek, and Roman worlds had early scientific and technological revolutions before the simplification and introduction of Arabic numerals; an analogy: the invention of the Graphical User Interface or GUI, usually credited to Xerox’s Office PARC and Steve Jobs and Apple Computer, facilitates greater productivity in science, technology, business, and government, and potentially facilitates more and greater scientific and technological achievements and revolutions; however, the introduction of the graphical user interface or GUI is not a necessary or sufficient cause to scientific and technological revolutions in the contemporary world. (This discussion also treats causation as potentially occurring at multiple and different levels of reality, including at the level of symbolic culture, instead of assuming, as “physicalist” philosophers and scientists believe, that “everything” or all phenomena might be explained, ultimately, by elementary particles or the most elementary constituents of matter).

Another prominent historian of science, George Sarton, comments that the delay in the recognition of important scientific discoveries is due to “prejudices” and “non-experimental thinking”: “the discovery of the sexuality of higher plants by Camerarius in 1694 could have been made two thousand years earlier, if the experimental method had been applied to it . . . It was retarded by non-experimental thinking and by prejudices, and after its publication it was rejected and its general acceptance was delayed for half a century because of the same prejudices. Similar remarks could be offered with regard to almost every fundamental discovery of modern science down to the theory of evolution (1859). Each discovery was delayed by a kind of intellectual inertia, and when it was finally made, its acceptance was delayed by the same inertia, the refusal to experiment (or even to observe) and to abide by the experimental results.”

Sarton is a brilliant historian of science, and recognizes that, in some cases, resistance to discoveries and innovation in science may be the consequence of “prejudices” and more than the refusal “to abide by the experimental results.” Moreover, resistance to advances in science may be the result of resistance to unfamiliar concepts, frameworks, and paradigms, as Thomas Kuhn famously and forcefully argued, and as Sarton, himself, admits: “Think of the ‘Weltanschauung’ or scientific outlook before and after Copernicus, before and after Galileo, before and after Newton, before and after Darwin. Each of those great men made a new gigantic ‘cut’ in our fundamental conceptions.” (Sarton 1952) Resistance to Camerarius’s conceptual revolution and discovery of the sexual nature of plants may have been more than a failure or refusal “to abide by the experimental results.” Instead, resistance to Camerarius’ conceptualization and classification of the sexual nature of plants, and the discovery of components of plants that relate to the classification of the sexual nature of plants, may have been a consequence of unfamiliarity, lack of understanding, or resistance to changing the previous patterns by which the classification of plants were understood.

It is sometimes surprising that there was resistance to Kuhn and Sarton's work on the resistance to new frameworks and paradigms in the evolution and development of science: Resistance to conceptual and theoretical innovation in science sometimes post-dates the empirical discoveries that are later interpreted in terms of the new concepts and theories: Resistance to the idea that there is an innate capacity for learning language post-dates the discovery of a "language centre" in the brain; Paul Broca discovered the "reductionist" basis of a language capacity in humans by discovering a language centre in the brain; however, as suggested, the idea that language learning was an innate capacity was not recognized in the English and French speaking worlds until the theoretical demonstrations by Noam Chomsky in the 1950s and 1960s that the complexity of grammars across languages, and their universal, near universal, or at least highly analogous characteristics for the functioning of spoken languages, implied an innate language capacity that in the brains of all human ethnic and linguistic groups; Chomsky's "revolution" in linguistics is thus the opposite of the traditional theory-reductionism logic in the history of science: in the history of science theoretical constructs usually pre-sage the "reductionism" of empirical research: Mendel's postulation and theory that there were particulate units of genetic inheritance that appeared, disappeared, and re-appeared across generations was ignored until the beginning of the 20th century in Europe and the United States until Sutton in the U.S. and Boveri in Europe were able to demonstrate an empirical and chromosomal basis for heredity; Watson and Crick's model of the double-helical structure of the DNA, that is, the discovery of the units of particulate or genetic inheritance across biological organisms was not achieved until nearly a century after Mendel's postulation of genetic factors he could not directly observe.

Resistance to Darwin and Wallace's original discovery of the theory of evolution by natural selection is a product of more than the refusal "to abide by the experimental results": Darwin and Wallace independently sought to show that there were constant or near constant slight variations across individual organisms, from species to species to species; however, the demonstration of this pattern was not the result of experiment per se but the investigations of naturalists in the field (Darwin in Latin America and Wallace in the Malaysia-Indonesian Archipelago); resistance to Darwin's theory was cultural and religious: religious figures rejected Darwin and Wallace's theory for contradicting or subverting religious doctrine; others rejected or expressed skepticism of Darwin and Wallace's theory in the way that English speakers from Shakespeare to Gladstone rejected the authoritarianism implicit in Machiavelli's political science (i.e., English speakers that were more accustomed to the rights of the Magna Carta and the contention and argument of parliaments and theatrical and Shakespearian dialogue than authoritarianism, dictatorships, or the "strife of the jungle").

Darwin complained that his co-discoverer Wallace did not always agree with the generality of his theory: Wallace supported Darwin's theory; however, Wallace claimed that the theory of evolution by natural selection did not explain the emergence of the human brain and its faculties of learning, reasoning, and logic; this is because the theory of natural selection only explained the adaptation of organisms to the immediate needs and wants of the organism in relation to its environment; by that standard, Wallace concluded that the emergence of a human brain with higher faculties and capacities for learning and scientific reasoning was an extravagance instead of an immediate adaptation to the needs and wants of the environment; by this standard, the capacity of the mind to listen to music, or generate music and sing, was a capacity that was an extravagance instead of an immediate adaptation of the needs and wants of the environment, and the same applies to other "higher" faculties of the mind and brain, like learning, language, and the manipulation and production of symbols. Wallace's criticism suggested that the evolution of the human brain with faculties and capacities for learning, language, and logic were a product of other processes besides Darwinist natural selection per se.

Conclusion

In the preceding section of the paper, I attempted to delineate classifications of different kinds and styles of scientific explanation; however, the list of classifications is not meant to be comprehensive or complete, but to suggest how to conceive of kinds and styles of explanation by scientists that sometimes go beyond the traditional or classic categories of covering law models, causal models, and functional explanation (of Hempel, Nagel, Popper, or others). Moreover, I have attempted to demonstrate that in the evolution, development, and growth of science, the "underdetermination" thesis of some philosophers and scientists (of Quine or others), that there are always a large number or infinite number of theories to fit the data or explain patterns or sets of data, is false.

This also suggests that the logical space of science, including its relationship to engineering, is less than mathematics or more limited than mathematics (that potentially provide more branches of mathematics than there are of empirical science, and also potentially provide a large number or "infinite" number of mathematical interpretations of data). Science is more difficult than mathematics and logic, since scientific statements or propositions can be empirically wrong, since the logical space of science and its branches and sub-branches are less than the larger set of spaces and branches of mathematics, and since statements and principles within different mathematical systems are "analytic" or true by definition. In science, at any point in the development of science and its various branches and sub-branches, there are only a few or small number of concepts and theories in any scientific field or branch that compete with each other to explain the phenomena that scientists seek to investigate and explain.

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Technological Growth as Exponential Growth, Democratic Theory as Cultural Diffusion, & Scientific Growth as Cumulation, Diffusion, and Innovation

Abstract

I seek to evaluate popular claims that science and technology grow exponentially in democratic and non-democratic societies: This includes the capacity for science to grow exponentially and related questions of how to distinguish scientific growth from technological growth, including “Moore’s Law.” This paper seeks to place patterns of societal evolution in relation to each other, including scientific growth, technological growth, and how cultural diffusion and access to symbolic systems and media (access to Japanese or Chinese scripts, or Latin, Greek, or Arabic scripts, or GUIs) contribute to scientific growth and technological growth in democratic and non-democratic societies. I find that technology sometimes grows exponentially, and that science grows cumulatively and is marked by diffusion and innovation.

The paper includes a series of provocative thought experiments that seek to show that established knowledge of physics or other branches of science do not double every 15-20 years, or 20-25 years, or at some other exponential rate of growth. I seek to show that the established knowledge of textbook physics, including the classical mechanics of Galileo and Newton, does not double every 15-20 years, and that, more generally, the established knowledge of different branches of science, including discoveries or sets of ideas that are considered revolutionary in nature, from Mendeleev’s Periodic Table, to Mendel’s Theory of the Particulate Nature of Genetic Inheritance, to Watson and Crick’s discovery of the double-helical structure of the DNA, does not double every 15-20 years.

Keywords: Exponential Growth, Moore’s Law, Technology, Science, Culture, Democratic Societies, Non-Democratic Societies

1. Introduction

It is sometimes claimed by scientists, social scientists, engineers, technologists, media theorists, businesspeople, and also philosophers of science that technology grows exponentially, and that science grows exponentially [1]. Harvard scientist Edward O. Wilson, for example, claims that “scientific knowledge doubles every 15-20 years,” and that science grows exponentially like technology or technological growth [2]. Economist Helena Lastres comments on the “Evolutionary Approach to Technical Change” that the “evolutionary approach” rejects economic theories that consider technology and technological innovation as a “given” in advanced societies with some form of economic capitalism or economic policies for economic growth: “Evolutionary theory rejects the ceteris parabis models which assume that technology is exogenously given . . . (as in traditional economic growth theory) and could be treated as a ‘residual,’ and defines inventions and innovations as, at least partly, endogenous activities within the economy.” Instead, this paper attempts to consider the nature of technological growth and scientific growth in democratic and non-democratic societies, and attempts to place patterns of technological growth and scientific growth in relation to patterns of human social evolution including cultural diffusion and access to particular cultural patterns like writing systems and symbolic systems (such as access to Latin, Greek, or Arabic writing systems, or Japanese or Chinese writing systems). The advancement of science and technology are relevant to the growth of organizations, corporations, and democratic societies and non-democratic societies: In this paper, I seek to evaluate popular claims that technology grows exponentially, that science grows exponentially, and that, since democratic societies usually enjoy more cultural diffusion than non-democratic societies, they have more technological growth and scientific growth. I shall focus on the question of the capacity for science to grow exponentially and the related question of how to distinguish scientific growth from technological growth, including “Moore’s Law” and the claim that there is non-cumulative or revolutionary change in science. Thus, as suggested, this paper seeks to place patterns of human social evolution in relation to each other, including scientific growth, technological growth, cultural growth, and how cultural diffusion and access to particular cultural patterns like writing systems and symbolic systems (such as access to the Latin, Greek, or Arabic scripts, or Japanese or Chinese writing systems) contribute to scientific growth, technological growth, and cultural growth in democratic societies and non-democratic societies.

2. Materials & Methods

Theory: How Different Technologies Have Different Rates of Technological Growth, including discussions of “Moore’s Law” and Tesla Motors:

Scientist Edward Wilson claims that technological growth is exponential, and that scientific growth is exponential as well: “High technology runs at a comparable pace alongside . . . science.” Wilson also claims that exponential growth in science “will continue through most of the 21st century,” though at some point scientific growth will plateau or “level off.” In the journal *Nature*, scientist Alexander Szalay and former Microsoft scientist Jim Gray claim that, “the amount of scientific data is doubling every year,” and that, “as data volumes grow, it is increasingly arduous to extract knowledge [3].” Alexander Szalay and Jim Gray comment that, because of the growth in the amount of data, “scientists must labour to organize . . . and reduce the data . . . producing smaller data sets that eventually lead to the big picture.” It is an interesting question of how to evaluate the nature of technological growth. At

least since William Ogburn's work on the subject earlier in the 20th century, it has been recognized that technology or material culture potentially grows exponentially in the evolution of human societies [4]. From the perspective of William Ogburn and others, the macroscopic perspective of the evolution of human societies in the evolution of the human species, technological growth is exponential or potentially exponential.

However, from a more "fine-grained" perspective, technologists sometimes comment that different technologies grow at faster rates than others [5-6]. G.E. Moore, co-founder of the Intel Corporation, sought to establish what has been called "Moore's Law," that computer processing power doubles every two years. (Moore initially suggested that the processing power of computer chips doubled every 18 months, and revised his estimation to every two years) [7]. In 1977, Robert Noyce, former Chairman of the Board at Intel Corporation, described the success of "Moore's Law": "with circuits containing 218 (262,144) elements available, we have not yet seen any significant departure from Moore's law. Nor are there any signs that the process is slowing down, although a deviation from exponential growth is ultimately inevitable. The technology is still far from the fundamental laws of physics: further miniaturization is less likely to be limited by the laws of physics than by the laws of economics."⁸ There were celebrations of "40 years of Moore's Law in 2005," and celebrations of 50 years of "Moore's Law" in 2015, although the journal IEEE Spectrum originally titled their interview with Gordon E. Moore, "The Man Whose Name Means Progress" by another title, "The Law that's Not a Law."⁹⁻¹⁰

This is presumably because of continued projections that Moore's Law will not continue indefinitely in the computer industry. Gordon E. Moore himself gave an interview in 2010 claiming that "Moore's Law" was "dead," and that computing power would continue to increase (though not at the earlier exponential rate of growth described by "Moore's Law" for 40 to 50 years).¹¹ "Moore's Law" is commonly viewed as a model for the suggestion that science and technology grow exponentially. However, computer scientists T. Lewis and G. Denning comment that, clearly, not all technologies grow exponentially: "Moore's Law. . . is not available for every technology. We might wish for automobiles that travel 1,600 miles on a gallon of gasoline—approximately six doublings (26) better than today's most efficient automobiles."¹² The following generations of automobiles would be expected to get 3,200 miles per gallon, 6,400 miles per gallon, 12,800 mpg, 25,600 mpg, etc.

As Gordon E. Moore stated at a press conference in 2005 celebrating 40 years of "Moore's Law": "If the automobile industry moved this fast, your car would move at a million miles per hour and it would get 50,000 miles per gallon."¹³ Thus, gasoline or diesel fuel vehicles do not demonstrate exponential growth in their horsepower, torque, or fuel efficiency over the longer term: In the event that gasoline or diesel fuel automobiles doubled in their horsepower every generation, the vehicles would travel faster than planes, rockets, European Space Agency spacecraft, National Aeronautics and Space Administration spacecraft, or the spacecraft and satellites of other nation-states or nation-state agglomerations. In the short term, in their early stages, new technologies may grow exponentially, and then plateau or level off in their growth, power, and efficiency.

However, from Ogburn's perspective, over the longer term, new technologies may emerge that replace or provide alternatives to existing technologies, that may give the appearance of exponential growth: The electric vehicles of Tesla Motors, for example, in effect travel more than 1600 miles per gallon; however, in terms of their everyday usability, Tesla Motors cars may travel approximately 200-250 miles before requiring re-charging, and the new generation of Tesla Motors vehicles are supposed to be able to travel 400 miles before requiring re-charging. This is potentially related to Ogburn's idea of the exponential growth of societies over the long term of the evolution of human societies; that is, that there may be exponential growth in one kind of technology or set of technologies, then a plateau or slowing rate of growth, and then the discovery or invention of another technology or set of technologies that may replace the earlier technology or set of technologies and their growth rate.

Before Ogburn, Henry Adams, in *The Education of Henry Adams*, published in 1907 and 1918, proposed a "Law of Acceleration" related to technological growth.¹⁴ He used multiple examples of technological growth from the 19th century, including stupendous growth of locomotive trains and train lines in the United States, Europe, and elsewhere, and also the exponential growth rate in the production and use of coal throughout the world: "society by common accord agreed in measuring its progress by the coal-output. The ratio of increase in the volume of coal-power may serve as dynamometer. The coal-output of the world, speaking roughly, doubled every ten years between 1840 and 1900." Moreover, Adams summarized, the efficiency of coal production increased three to four times over the same time period: "in the form of utilised power, for the ton of coal yielded three or four times as much power in 1900 as in 1840." By Ogburn's more general perspective of the evolution of human societies of Homo Sapiens from about 500,000 years ago to the Neolithic Revolution 10,000 years ago, to the Industrial Revolution of the 18th, 19th, and 20th centuries, to the "Information Age" Post-Industrial Revolutions of the 20th and 21st centuries, the technological growth of earlier technologies or sets of technologies, when they slow in their growth or reach plateaus, are replaced at some point by new inventions or combinations of technologies that set a new pace of exponential technological growth.

In the area of scientific publications, sometimes treated as a measure of scientific productivity, it has been alleged that scientific growth is exponential. However, this may only be the case in the early stages of scientific growth in particular branches of science or sub-branches or sub-fields of science. In 2012, the number of peer-reviewed scholarly journal publications, including science

journals, was 28,100 [15]. If the growth rate of scientific journals was exponential, the number of scientific journals in 2012 might have been in the hundreds of thousands or millions, depending on the start date at which the doubling rate was expected to begin. Instead, as suggested, early exponential growth in scientific publications is a short-term process limited to the early stages of growth of new branches or sub-branches of science, or when a revolutionary advance or invention in an established branch or sub-branch attracts short-term exponential growth before returning to the earlier rate of growth (i.e., returning to the “equilibrium” after the “punctuation”), leveling off to a lower rate of growth compared to the short-term exponential growth, reaching a plateau, or possibly contracting somewhat as a sub-branch of science compared to other branches or sub-branches.

Lewis and Denning discuss Moore’s Law, and how the processing power of computer chips has doubled approximately every two years at least since the 1950s; however, has the efficiency and usability of commercially available computers doubled every two years? Since the development of commercially available personal computers in the 1980s, has the usability and efficiency of personal computers doubled every 2 years, or even with every generation of personal computers?

In this case, the answer is no: Instead, the introduction of Graphical User Interface (GUI) software by Apple and Microsoft for commercial and business computing increased the usability and efficiency more than the doubling of the processing power of computer chips; advances in the software of Graphical User Interfaces, such as Microsoft PowerPoint and Office Applications, and graphical user interface software for Apple iPhones, iPads, and other computers and devices have increased the usability of commercially available computers more than the doubling of the processing power of computer chips. Thus, exponential growth may sometimes be a “mirage,” and other kinds or types of advances in technology or science may be more important or fundamental for efficiency, productivity, usability, or societal, technological, or scientific growth (as in advances in software versus the doubling of computer chip processing power every 2 years, or particular advances or inventions in science or technology versus the sheer growth in the number of scientific articles or scientific journals in a branch or sub-field).

3. Technological Growth as Exponential Growth, & Scientific Growth as Something Different

Edward Wilson is a brilliant scientist, and his book *Letters to a Young Scientist* has numerous forceful statements and advice for young scientists. He states that, “ideas in science emerge when some part of the world is studied for its own sake.” Wilson also evaluates and criticizes theoretical models in the biological sciences: “The annals of theoretical biology are clogged with mathematical models that either can be safely ignored, or, when tested, fail.” Wilson also consistently rails against religious and political authorities that refuse to test ideas publicly, and supports scientists, scientific journals, and scientific institutions that test their ideas and theories against empirical reality. Wilson thus publicly endorses democratic theory that claims that democratic societies enjoy more technological growth and scientific growth than non-democratic societies because they have more cultural diffusion (and that individual freedoms such as freedom of the press, freedom of expression, and freedom of religion are related to democratic societies having more cultural diffusion, and, usually, more ideological diversity and cultural diversity than non-democratic societies). Wilson also encourages scientists to take advantage of the freedom of expression made available by the internet, a degree of freedom of expression he views as consonant with science, scientific values, and scientific progress: “The internet and all other accoutrements of digital technology have rendered communication global and instant . . . all published knowledge in the sciences and the humanities will be available in a few keystrokes . . . science and technology hide . . . no secrets [18].”

How is it possible to evaluate the claim that science grows exponentially like technology and technological growth? There are at least two ways of evaluating the claim made by scientists like Edward O. Wilson and others that, since science is related to technology, science grows exponentially like technology.

That is, it is possible to evaluate this claim quantitatively, and qualitatively and quantitatively:

- Do the number of scientific publications grow exponentially, including over the long-term? As reviewed in the previous sections, social scientists have sought to show that while scientific publications in particular fields or sub-fields may grow exponentially in their early phases, the number of scientific publications does not grow exponentially over the long term;
- Does the established knowledge of physics or other branches of science double every 15-20 years, or 20-25 years, or at some other exponential rate of growth? I seek to show that the established knowledge of textbook physics, including the classical mechanics of Galileo and Newton, does not double every 15-20 years, and that, more generally, the established knowledge of different branches of science, including discoveries or sets of ideas that are considered revolutionary in nature, from Mendeleev’s Periodic Table, to Mendel’s Theory of the Particulate Nature of Genetic Inheritance, to Watson and Crick’s discovery of the double-helical structure of the DNA, does not double every 15-20 years.

4. Thought Experiments on the Nature of Knowledge

A doubling rate of articles qualifying the ideas of Galileo’s discoveries or Mendeleev’s discoveries are not doubling rates in the nature of scientific knowledge; instead, they are doubling rates in scientific publications; General Laws and Principles of Science, like Galileo’s Laws, Mendeleev’s Laws, Hubble’s Law, or Darwin and Wallace’s Principles of Natural Selection do not grow exponentially like, say, coal production in the 19th century or computer processing power described by Moore’s Law. It is possible to

ask, what would it mean if the established knowledge of classical physics, including all of the branches and subfields of classical physics, were to double every 15-20 years? What would textbooks in classical physics and modern physics be like if their knowledge doubled every 15-20 years? Did the knowledge of your physics textbook of this year, including all of the branches and subfields of classical physics and modern physics, double from the physics textbook you had 15-20 years ago? The answer to this question is no.

When scientists such as Harvard professor Edward Wilson or others speak of “exponential growth” in science they may be referring to short term exponential growth in scientific publications; however, this is not exponential growth in scientific knowledge itself.

Thus, there is a simple thought experiment that may distinguish differences in the nature of knowledge: say there is exponential growth in the number of publications on Galileo’s classical mechanics over a period of time, though the publications largely explicate, test, re-establish or hone or qualify Galileo’s classical mechanics.

Does this Imply or Result in?

- exponential growth in the nature of science and scientific knowledge, or only
- exponential growth in the number of publications on a particular subject or set of discoveries and ideas in a branch of science? Say there is exponential growth in the number of publications on Mendeleev’s periodic table:

Does this Imply or Result in?

- exponential growth in the nature of science or scientific knowledge, or
- only imply or result in exponential growth in the number of scientific papers, books, and publications instead of exponential growth in the nature of scientific knowledge in a particular branch of science?

The exponential growth in the number of publications on any scientific discovery or set of ideas does not necessarily imply or result in exponential growth in the substantive nature of science or knowledge, i.e., the intellectual content or substantive nature of knowledge of your physics textbook (including Newton’s Laws, Galileo’s classical mechanics, or the Compton effect), chemistry textbook (including Avogadro’s Law, Mendeleev’s periodic table, or Linus Pauling’s principles of chemical bonds), or biology textbook (including Darwin and Wallace’s law of evolution by natural selection, Mendel’s laws of genetics, Kimura’s neutral theory of evolution, or Watson and Crick’s model of the universal nature of genetic information) does not double every 15-20 years.

Thus, the established knowledge of classical physics, the established knowledge of physics from early modern Europe through the end of the 19th century, does not double every 15-20 years; moreover, the established knowledge of post-classical 20th century physics and contemporary physics does not double every 15-20 years. The established knowledge of physics doubling every 15-20 years is not possible, and the established knowledge of physics of other branches of science growing exponentially or doubling at a fixed rate is not possible: Galileo’s Laws, Newton’s Laws, Mendeleev’s Laws, Darwin and Wallace’s Principles of Natural Selection, or Hubble’s Law do not double every 15-20 years or at other rates of exponential growth, like, say, coal production did in the 19th century through part of the 20th century or computer processing power described by Moore’s Law; consequently, scientific knowledge does not grow exponentially; this is a law of social evolution; scientific knowledge may grow cumulatively, like the gathering of facts and the cumulation of empirical discoveries; by comparison, some technologies may grow exponentially, like periods of the exponential growth of coal production in the 19th century and part of the 20th century, or the exponential growth in computer processing power recognized as “Moore’s Law”: scientific publications in different sub-fields of science may grow exponentially during different periods of time; however, this does not necessarily imply exponential growth in the nature of knowledge, only exponential growth in the number of publications over specific intervals of time.

Economist Laſtres comments that science and technology have a “strong reciprocal interaction,” however, Laſtres, following Christopher Freeman, rejects the argument that since technology is sometimes dependent on discoveries and advances in science, that science grows exponentially like some technological patterns: “science and technology cannot be treated as the same thing.”

5. Results

Tripartite Process in the Growth of Science in Human Social Evolution: since scientific knowledge does not grow exponentially, though technological invention does sometimes grow exponentially, a three-stage process in the growth of scientific knowledge may be identified;

- scientific knowledge does not grow exponentially: scientific knowledge may be relatively static without growth in knowledge, may reduce or collapse during medieval periods or Inquisitions, or scientific knowledge may grow cumulatively by adding facts, testing propositions and ideas, qualifying or extending existing knowledge, and by adding new discoveries though not as an exponential process;
- by comparison, sometimes, technology and technological growth does grow exponentially, such as coal production in the 19th and 20th centuries or exponential growth in computer processing power described by Moore’s Law (elaborated above);

• by comparison, sometimes, scientific discoveries and scientific theories “jump” or “fly” ahead of established knowledge in science or established methods or practices in technology and invention; (i.e., scientific knowledge may develop as a non-cumulative process when there are discoveries or sets of ideas that are revolutionary in nature, though do not involve or imply exponential growth per se: examples include Mendeleev’s periodic table of elements, Edwin Hubble’s discovery that the galaxies are separating from each other at accelerating rates instead of being static in relation to each other, Watson and Crick’s discovery of the double-helical structure of the DNA, or earlier scientific revolutions, such as those of Copernicus, Galileo, or Newton).

This criticism and elaboration of this three-stage or tripartite process also may be relevant to the interaction and intersection of science, ideas, and the business world in the “information age.”¹⁸

Thus, this paper also places claims and ideas on the nature of non-cumulative or the revolutionary nature of change in science in relation to patterns in human social evolution. Like qualitative changes in physical phenomena that are related to quantitative differences in heat and energy, i.e., qualitative changes from solids to liquids to gases, there are qualitative differences in the nature of science, scientific knowledge, scientific growth, and technological growth that are related to their quantitative growth; the nature of exponential or potential exponential growth in technology is not identical or even nearly identical to cultural growth in science (symbolically: technological growth, “TG” is not equal to scientific growth, “SG,” or, “TG incessant $\neq$ or near incessant technological change and growth; from the standpoint of the SG”); moreover, science, as a form of symbolic culture, usually ‘lags’ behind philosophy of science, this is a rule instead of a law: that is, this is a pattern with specific exceptions, i.e., scientific growth, “SG,” is less than “TG,” technological growth, or, “SG discoveries < “jumping” for “flying ahead” of established technology or established TG”; however, there are exceptional cases of scientific theory and scientific methods or practices in technology and invention; that is, there are special cases in the growth of science in which the nature of scientific change is not cumulative, and not exponential over the long term, though “jumps” or “flies” ahead of established knowledge in science and established methods or practices in technology and invention; however, as suggested, revolutionary discoveries like Mendeleev’s Periodic Table or Watson and Crick’s model of the double-helical structure of the DNA and theory that it implied a universal nature of the DNA as genetic information across cellular life, do not imply that scientific growth is identical to the exponential growth of technology; thus, in the history and development of scientific knowledge there are cases and periods of scientific growth that are non-cumulative and “jump” or “fly” ahead of established knowledge and cumulative growth; this is when scientific growth is greater scientific growth is not equal to exponential > growth, “SG $\neq$ EG”; thus, revolutionary and than cumulative growth, or, “SG $\neq$ CG”; however, “revolutionary” and non-cumulative non-cumulative discoveries and advances in science are different than and not equal to exponential patterns of growth in technology and invention (e.g., exponential growth in 19th and 20th century coal production, 19th and 20th century train and freight train growth and productivity, or 20th and 21st century computer processing power as described by Moore’s Law); “revolutionary” and non-cumulative scientific growth in discoveries or new sets of ideas or theories may “jump” or “fly” ahead of existing or established knowledge or established methods in technology or invention, however, these do not sustain exponential growth, i.e., discoveries like Galileo’s laws of classical mechanics are not reproduced at an exponential rate every 15-20 years; discoveries like Mendeleev’s periodic table are not reproduced at an exponential rate every 18 months or 2 years (like Moore’s Law), five years, 10 years, or 15-20 years; discoveries like Watson and Crick’s discovery of the double-helical structure of the DNA are not reproduced at an exponential rate every 2 years, five years, 10 years, or 15-20 years; or, discoveries like Edwin Hubble’s discovery of the accelerating separation of the galaxies in the universe are not reproduced at an exponential rate every 2 years, five years, 10 years, or 15-20 years.

6. Discussion

Democratic Theory as Cultural Diffusion, and its Relationship to Scientific and Technological Growth

Democratic theory is also related to this body of knowledge: democratic theory postulates that democratic societies have more technological growth and inventions than non-democratic societies or different types of authoritarian societies, and that democratic societies have more scientific growth and discoveries than non-democratic societies or different types of authoritarian societies; democratic theory also attempts to explain how and why societies with authoritarian political or military leadership may increase their productivity in invention, science, and technology when they are put into contact with more “democratic” social conditions, like the decentralized and plural political and jurisdictional structure of early modern Europe and Western societies distributed across hundreds or thousands of different political jurisdictions before the French and American political revolutions, or the cultural contact and cultural diffusion languages, technologies, and international markets to authoritarian and isolated Japan in the 19th century, or the cultural contact and cultural diffusion of electronic communications, international markets, and technologies to China with the economic liberalization of one-party state Communist China post-1975; thus, the body of knowledge that is called or referred to as “democratic theory” in popular politics and academia is supported by the conditions of democratic societies supporting the conditions of cultural diffusion, i.e., the accessibility and spread of ideas and inventions, and the accessibility and spread of science, scientific knowledge, discoveries, technology, technological practices, methods, and inventions; democratic laws and practices such as individual freedoms, freedom of expression, freedom of religion, and freedom of the press sustain or are supposed to sustain patterns of cultural diffusion related to the greater spread, accessibility, and growth of ideas and inventions in democratic societies compared to non-democratic societies; thus, in world history, democratic theory seeks to explain why several Catholic societies that originally

led Europe in scientific discovery and technological achievements had different or reduced patterns of scientific and technological growth as a consequence of Inquisitions and counter-reformations that banned books, tortured natural philosophers as religious skeptics, and tortured potential followers of the natural philosophers or early scientists: the Portuguese explorers were the first to circumnavigate the globe, the Spanish and Italian explorers are credited with discovering the Americas, the generation of Italian physicists with Galileo and Torricelli that are credited with inventing modern experimental physics, and the Polish astronomer Copernicus that studied music, law, and science is credited with the first scientific revolution in predictive astronomy that jumped ahead of the “scientific revolution” of Claudius Ptolemy’s of the ancient world; the Inquisitions and counter-reformations of Catholic countries involved torture and attempted to ban the works of prominent natural philosophers and religious philosophers that were either involved in the scientific revolutions of early modern Europe or supported their revolutionary ideas and practices: the works of Galileo were banned, the works of Copernicus were banned; the exploratory and explicatory works Giordano Bruno were banned; the the scientific, mathematical, and philosophical works of Descartes were banned; the works of Erasmus on natural philosophy and secular education were banned; the works of Erasmus on religious education, his translations of the New Testament into Latin, and his commentaries on this translation on the New Testament were banned; and the works of many other figures of science, natural philosophy, and religious philosophy were banned under threat of arbitrary torture and punishments in Catholic countries that previously had led all of Europe in scientific discoveries and technical achievements; several countries completely ignored or repulsed attempts by the Catholic Church to ban or place the works of Galileo, Copernicus, Descartes, and Erasmus and others on the Index of banned books: these included most Protestant countries and also Catholic France that never banned the works of Descartes, Erasmus, Newton, Galileo, or Copernicus; the former Spanish Netherlands converted to Protestantism or mostly to Protestantism and ignored or repulsed attempts to ban the works of natural philosophers and religious philosophers that threatened religious authorities of foreign countries; Belgium, that mixed Protestant and Catholic populations ignored or repulsed attempts to ban the works of prominent natural philosophers and religious philosophers; England and Scotland largely converted to Protestant sects and ignored or repulsed attempts to ban the works of Galileo and Newton, Erasmus and Descartes, Copernicus and Giordano Bruno, and other prominent natural philosophers and religious philosophers that were banned in several nation-states on continental Europe during the Inquisitions and counter-reformations that lasted through the 19th century in many parts of Catholic continental Europe; the early colonies of the United States and the United States post the 1787 Constitution ignored or repulsed attempts by religious and political authorities of continental Europe attempting to ban prominent works by natural philosophers and religious philosophers; democratic theory thus explains the reversal of several patterns related to the relative decline in technical achievements of Catholic countries versus Protestant countries and secular Catholic France: Italy, Portugal, Spain, and Poland briefly led all of Europe in scientific discoveries and technical achievements: as reviewed, there were considerable technical and scientific achievements of Catholic countries, such as Galileo’s experimental physics, Copernicus’ predictive astronomy, the Portuguese explorers circumnavigating the globe, or the Spanish and Italian explorers, credited by George Washington or others, of discovering the Americas; however, the Inquisitions that lasted in Catholic countries through the 19th century (except for secular Catholic France) explain, from the point of view of democratic theory, why industrial revolutions happened more quickly and earlier in France, Great Britain, the Netherlands, Belgium, and the United States in the 18th and early 19th centuries than Italy, Spain, Portugal, or Poland; (German areas are mixed cases since Germany was disaggregated across hundreds of city-states and principalities, and would lose talent to France, Great Britain, the US and other countries before the ‘revolutions’ of 1848 that officially ended inquisitorial and other policies of torture in German city-states and principalities); Inquisitions and counter-reformations reduced the cultural diffusion of ideas and scientific and technical achievements by banning books and torturing subjects; natural philosophers, talent, followers of natural philosophers, and religious dissenters also fled to Great Britain, France, and the US, and, in smaller numbers to the Netherlands and Belgium; as suggested, these countries also enjoyed industrial revolutions before Spain, Portugal, Italy, Germanic states, and Poland; moreover, they enjoyed more scientific achievements and adapted and absorbed more scientific achievements than countries that were affected by Inquisitions and counter-reformations, i.e., when a small number of Italian scientists contributed potentially revolutionary discoveries such as Volta and Galvani on electricity, these discoveries were not initially absorbed by Catholic societies such as Italy, Spain, Portugal, Poland or authoritarian Germanic societies that did not attempt to reduce arbitrary torture and punishments until after the political ‘revolutions’ of 1848 across Europe; instead, the discoveries of Volta and Galvani were utilized and absorbed by rapidly industrializing France, Great Britain, the Netherlands, Belgium, and the United States.

In principle, democratic theory, or aspects of democratic theory related to cultural diffusion, seeks to explain differential patterns of scientific growth in the world history of Europe, the Muslim world and the Ottoman Empire, and the medieval and early modern Chinese Empires; in the medieval period, the Muslim world and China were technologically and scientifically ahead of Europe; during the so-called Middle Ages or medieval period, there was a greater flow of technologies, trade, and ideas across Muslim societies and China than from and across European societies and foreign societies; within the Muslim world, there was greater contact and flow of ideas and translations from scientific and technical achievements of the ancient world, including the ancient Greek world, than from the ancient Greek world to Europe and Western societies; these patterns began to reverse with the revolution in cultural diffusion of Fibonacci simplifying Arabic numerals for use in European universities, trade, science, and invention; by the 16th and 17th centuries, wars and ideology may have played a role in reversing these patterns in Muslim societies and China, as European societies, distributed across thousands of different decentralized jurisdictions, including city-states, principalities, bishoprics, universities, and kingdoms, during the Renaissance and Enlightenment periods, began absorbing more culture, technology, and

inventions from foreign societies, and also from translations from the ancient Greek world, than Muslim societies and early modern China; from the point of view of democratic theory and cultural diffusion theory, the decentralized political and military geography of early modern Europe, including thousands of different political, legal, and military jurisdictions, explains why patterns of cultural growth, scientific growth, and technological growth began to reverse in the late Middle Ages, Renaissance, and Enlightenment in Europe and Western societies compared to the Muslim world and early modern China; (from the point of view of organization theory, or the economic-organizational theories of Karl Marx and Karl Wittfogel, many of the small European political, legal, and military jurisdictions were too small to extract, exploit, and use resources and inventions and technologies for large-scale political, economic, and political uses, compared to, say, the Ottoman Empire or early modern China; however, some of the small political and military jurisdictions of early modern Europe, like the Netherlands or Italian city-states were initially more successful in producing resources and extracting taxes than larger early nation-states, such as France or Britain; moreover, many of the inventions and organizational-legal inventions of small city-states and bishoprics like the Netherlands, the bishopric of Liege, or Italian city-states were absorbed or adapted by larger nation-states, particularly France, Britain, and the US).

7. If Science is Conceived as a Kind of Culture, Does Science Sometimes “Lag Behind” Technological Invention, and Sometimes “Jump” or “Leap” ahead of Technology?

Technology and Science may be classifiable as kinds of culture under the frameworks of cultural anthropologist Alfred Louis Kroeber and social scientist William Ogburn: Ogburn and Kroeber view science as culture, though their theories of scientific and cultural growth have different points of emphasis. By Ogburn’s theory, technology is material culture, scientific instruments and tools are material culture, and the body of scientific knowledge in different branches of science are kinds of symbolic culture: since science is a kind of symbolic culture it is expected, like other cultural patterns, to “lag” behind incessant or near incessant technological growth; however, Kroeber (and the biographers of great scientists) recognize that in science and cultural phenomena more generally, there are sometimes advances in science and culture (including scientific theory and entrepreneurialism) that “jump,” “leap,” or “fly” ahead of the social patterns of their contemporaries, including the technology and technological growth of their contemporaries.

William Ogburn was the first social scientist to claim that cultural growth is exponential or potentially exponential over the generations of human evolution (instead of merely focusing on rates of technological growth over short time spans like the Industrial Revolution): that early simple societies for most of human evolution, from archaic Homo Sapiens approximately 500,000 years ago to 10,000 years ago had relatively small amounts of culture and technology, and slow rates of cultural accretion, until the neolithic revolution of established settlements 10,000 years ago and the emergence of established settlements and writing systems as early as 5,000 years ago; since the neolithic revolution, post-neolithic societies have had much faster rates of cultural and technological growth compared to pre-neolithic societies, as the base of culture, including a larger base of combinations of existing technologies and inventions, have increased. Societies that have participated in the industrial revolution have had much faster rates of technological and cultural growth than pre-industrial societies; thus, Ogburn suggested that material cultural growth or technological growth have been exponential from the earliest simple societies to contemporary post-industrial societies; thus, while Darwin sought to establish the gradual nature of the evolution of biological species, Ogburn (called a “Darwin of the social sciences”) showed that material cultural growth or technological growth is exponential or nearly exponential in the evolution of human societies from archaic Homo Sapiens to most contemporary societies around the world; from a more microscopic or “fine-grained” perspective, the development and success of different patterns in symbolic culture may facilitate or play a role in technological invention and growth (“hardware”), and the diffusion and spread of material culture or technology.

In what languages, mathematical systems, or symbolic systems (“software”) do individuals or groups contribute potential scientific and technological revolutions? For Copernicus, Galileo, and Newton, exposure or fluency in Latin, Greek, Euclidean geometry, and Arabic numerals may have been cultural prerequisites for their scientific revolutions, and they may have been cultural prerequisites for technological advances and revolutions by their contemporaries (as the graphical user interface and contemporary computer software may be prerequisites that facilitate contemporary scientific and technological advances; in the medieval period, Europe and the West were technologically behind the Arab and Muslim worlds, and also China, before Fibonacci’s revolution in cultural diffusion simplifying and spreading Arabic numerals and the decimal system to Europe and the West). From Ogburn’s perspective, the greater political diversity and linguistic diversity of Europe contributed to the greater cultural diffusion of ideas and technologies compared to the early modern Muslim world or China, once Europe had reached a level of development that it could compete with the Muslim world and China. From the standpoint of human evolution, the invention of new technologies that may have exponential rates of growth, like increasing computing power described by “Moore’s Law,” are special cases of Ogburn’s Principle. There are debates in the literature as to whether some sets of technologies, and also societies themselves, may plateau in technological development and growth. However, brief technological plateaus may be overtaken by unexpected inventions and combinations of technologies over the longer term. From the standpoint of human biological evolution, cultural growth is potentially exponential or nearly exponential over the generations of human evolution, although in particular centuries or millennia there may be fits and starts, plateaus, and also acceleration and stupendous leaps and jumps.

Moreover, from the standpoint of Ogburn’s theory, the intellectual content of science is symbolic culture, and the instruments and

technological products of science are material culture; thus, the earlier statements that the established knowledge of classical physics does not double every 15-20 years may be evaluated from the standpoint of Ogburn's theory: the symbolic culture of classical physics, or the intellectual content of classical physics, does not double every 15-20 years since it is impossible for the established knowledge of classical physics or even post-classical physics to double every 15-20 years; from the standpoint of Ogburn's theory, the instruments of science are part of larger patterns of technological growth in the societies of which they are a part, and thus the instruments and technologies of science usually grow faster than the intellectual content or established knowledge of science; there may be incessant technical advances and improvements in instrument design and productivity, like technical advances and improvements in telescopes for astronomy; the philosopher Quine might say that the access to technology and instruments, like powerful telescopes, was relatively constant in many countries around the world; however, the discoveries and theoretical interpretation of Edwin Hubble was not constant across the national or international scientific community, I.e., they were new discoveries and a new theory, Hubble's Law that described and explained the galaxies separating from each other at accelerating rates; when Edwin Hubble made a series of telescopic observations and discovered that the galaxies were separating at accelerating rates, the international scientific community still claimed that the galaxies were static in relation to each other, and some theoretical physicists claimed there was a "fifth force" that held the galaxies in relation to each other.

Alfred Louis Kroeber also studied cultural growth in his *Configurations of Cultural Growth* and other works; however, Louis Kroeber recognized that sometimes high-level innovations in cultural patterns jump, leap, or fly ahead of the established symbolic cultural patterns and technological growth of the generations of which the new or high-level innovations emerge.²¹ It is many times commented that Charles Darwin's theory of evolution and the body of Darwinist theory more generally does not allow 'large mutations' or so-called 'macromutations' across human individuals or individual organisms of other species, since the large mutations across individual organisms are not assimilable by the genetics of breeding populations; however, small or slight heritable variations across human individuals that result in a diversity of behavioral characteristics or branching patterns of behavioral characteristics across human individuals themselves, when expressed in culture and cultural patterns by human individuals and human social groups, like written languages (Latin, English, or other languages) or Arabic numerals, there may result in spectacular expressions of "progress" in behavioral patterns and cultural achievements in science, philosophy, religion, technology, music, and the arts. Prominent examples include the scientific revolution of Claudius Ptolemy, or the scientific revolutions of Copernicus, Galileo, or Newton, or the technological revolutions of Watt, Marconi, Edison, Ford, Bill Gates, or Steve Jobs, or the religious "revolutions" that established the major world religions, of Confucius, Buddha, Christ, or Muhammed. Important cultural achievements, or cultural "progress," or "revolutions," sometimes are not generational: Alfred Louis Kroeber comments that the Chinese language existed for thousands of years before Chinese scholars recognized, when in contact with and translating Buddhist texts from Sanskrit, that the Chinese language had tones; Wittgenstein, Noam Chomsky, and Jorge Luis Borges suggest that ideas about the nature of language remained largely unchanged since the work of St. Augustine; philosopher John Dewey comments that concepts of biological inheritance remained largely derivative of Aristotle's concept of 'pangenesis,' including the work of Darwin and Wallace, until Mendel's conception of particulate units of genetic inheritance; the particulate units of genetic inheritance that Mendel postulated to develop his simple predictive rules on the nature of genetic inheritance were not identified for nearly a century, by Watson and Crick in their model of the double-helical structure of the DNA; early physics retained Aristotle's theory of gravity until Galileo showed Aristotle's conception to be illogical and theory to be empirically wrong.

From Ogburn's perspective, scientific theory, scientific knowledge, and mathematics usually "lag" behind incessant or nearly incessant technological growth; however, sometimes, scientific discoveries or scientific theory jumps, leaps, or flies ahead of established knowledge and even contemporary technology.

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Physicalist Theories as Science and Physicalist Theories as Philosophy Christopher Portosa Stevens

Abstract

Physicists and philosophers sometimes claim that all of the phenomena of the universe, as in “theories of everything,” are or should be explainable in terms of the elementary constituents of matter or elementary particles; I seek to show that physicalist theories that attempt to reduce “higher order” phenomena in chemistry, bio-chemistry, biology, and the neuroscience of mind, brain, and consciousness to explanations involving elementary particles are either unstable or not empirically valid; moreover, I seek to show that there are successful cases of reduction in science, such as in chemistry, bio-chemistry, neuroscience, and evolutionary biology including Darwinism, that do not necessarily involve or imply “physicalism” or the tenets of physicalist theories; I also seek to show that physicalist theories undermine and do not address the empirical and theoretical content of successful discoveries and theories at different levels of reality, and within and across different branches of science.

Keywords: Elementary Particles, Roger Penrose, Reductionism, Neuroscience, Written Languages, Moore’s Law, Graphical User Interfaces

1. Introduction

Physicists and philosophers sometimes claim that all of the phenomena of the universe, as in “theories of everything,” are or should be explainable in terms of the elementary constituents of matter, such as atoms or other elementary or subatomic particles, such as electrons, protons, or neutrons (the “original” subatomic particles), or quarks, gluons, or bosons. Thus, physicists may claim that it is possible to develop theories that explain or reduce all of the forces of physics or all of the phenomena studied by different branches and sub-branches of science in terms of elementary particles. From the point of view of the theory and framework of physicalism, every scientific theory is in principle reducible or explainable in terms of a physicalist theory, that is, a theory that reduces or explains the phenomena in question in terms of elementary particles, from galaxies to stars, from planets to synapses to brains, from metabolism to photosynthesis, from cellular growth and differentiation to genes, from claws, to talons, to hoofs, to hands, or from societies, to languages, culture, and the exponential growth of technology and Moore’s Law. From the point of view of the theory and framework of physicalism, the only exception or exceptions might be theories of elementary particles themselves: these are not reducible further with physicalist theories since they are already the physicalist theories of elementary particles or the elementary constituents of matter.

The paper also includes a provocative discussion on the nature of causation related to mind-brain-culture interactions: that access to higher written languages in world history, like Japanese or Chinese, or Greek, Latin, and Arabic scripts, are kinds of causation related to technological and scientific growth and innovation, and that access to new kinds of symbolic technologies and media, particularly Graphical User Interfaces for video games and commercial, business, and science applications are partly analogous to access to higher written languages as kinds of causation at the level of culture.

2. Neuroscience and Physicalism

Is every layer of the complex evolved human brain explainable in terms of physicalist theories and explanations (cf. 1-4)? There are physicists, philosophers, and neuroscientists that claim that, in principle, the phenomena of the brain, including consciousness itself, are reducible and explainable in terms of elementary particles or elementary constituents of matter. That is, there are neuroscientists, physicists, and philosophers that claim that the brain, the mind, cellular interactions of neurons and synapses, modules of functional specialization distributed across neurons in the brain, correlations of neurons, “coalitions” and “assemblies” of neurons, networks of neurons, neuronal plasticity or brain plasticity, and consciousness itself, may be explained in terms of the behavior of atoms or sub-atomic particles; physicalists claim that these phenomena may be explained in terms of the behavior of elementary particles and forces of physics related to elementary particles that influence or cause events at the cellular level of neurons and synapses, that influence or cause events at the level of unconscious physiology, or that influence or cause events at the level of brain regions, brain modules or mini-organs in the brain, or that influence or cause events at the level of the brain as a complex organ or the mind as a complex phenomenon; (these include the unconscious maintenance of cellular structures and metabolism, unconscious brain patterns including imagery, speech, language, and memories during sleep, the conscious movement of body parts, tissues, and muscles for movement, the conscious and unconscious use of lung and breathing patterns, the conscious use of mind, mouth, tongue, and lips to produce speech or singing, the conscious use of the mind to produce speech, singing, music, imagery, and memories); moreover, since physicalism attempts to explain the behavior of minds, the theory or set of principles of physicalism implies that the elementary constituents of matter or elementary particles cause or explain events at the level of the interaction of minds, and cause or explain events at the level of cultural patterns and symbolic systems with which minds express or excrete thought in the evolution of the Genus Homo and the evolution of the species Homo Sapiens; the theory or principles of physicalism should explain phenomena

resulting from the interaction of minds, like the manipulation of tools, symbols, early technologies, spoken languages, and written languages; Moreover, since minds interact with each other, and interact with each other in different ways, it is thus possible to observe and seek to understand and explain phenomena involving the interaction of minds; these include the cultural patterns through which minds interact, such as speech, language, written languages and patterns, and also sounds, signs, and forms and instruments of and for the transmission of signs and sounds; relatedly, these also include various media that combine different physical instruments, cultural patterns, and spoken and written languages, like musical instruments, flags, banners, billboards, drums, newspapers, magazines, radios, televisions, film, and other media; are all of these phenomena explainable in terms of the theory of physicalism, or specific theories of physicalism that might apply to different interactions and levels of phenomena across these layers of the interaction of minds, spoken languages, written languages, cultural patterns like music, dance, and religion, and large scale phenomena involving societal growth, cultural growth, and technological growth like Moore's Law?

3. Testability and Cause & Effect in Physics, Chemistry, & Biology

From the standpoint of science and natural philosophy, there are at least two related ways of how to evaluate these questions related to the nature of the universe and how to evaluate the larger framework and theory of physicalism, and potential theories of physicalism that might apply or explain specific phenomena involving or related to the nature of the brain, the mind, and the interaction of minds: testability and cause and effect. Is it possible to test the theory of physicalism across all of these levels of mind and the interaction of minds, from different aspects of brain physiology, plasticity, metabolism, conscious and unconscious reflexes, instincts, and trained or honed talents? It is not possible to test the theory of physicalism across these levels of mind.

Is it possible to test the theory of physicalism across phenomena related to the interaction of minds, spoken and written languages, patterns of culture, religion, music, dance, art, or patterns of societal growth and technological growth including Moore's Law? No. There is also the question of cause and effect: Is the explanation of cause and effect always improved or supported by explanations by lower-order phenomena; in the history and development of science, new and powerful explanations of phenomena are not always reduced to lower-order phenomena, or the elementary constituents or particles of matter; examples include Copernicus' explanation of celestial bodies with a new predictive astronomy that is not related to the explanations connected to the elementary particles or constituents of matter; Galileo's explanations of moving bodies and classical mechanics that are not constantly reduced to lower order phenomena or elementary particles or elementary constituents of matter; Newton's Laws and unification of gravity as an explanation of celestial bodies and objects and bodies at or near the surface of the earth do not constantly refer or are reducible to lower-order phenomena or elementary particles or elementary constituents of matter; in other branches of science, Mendel's Laws contributed significant ideas to the development of biology and genetics, including the idea and conception of a particulate unit of genetic inheritance or gene that departed from Aristotelian ideas or Aristotelian derived ideas on the nature of genetic inheritance (philosopher John Dewey comments that Darwin's ideas on 'gemmules' and others from the 19th century continued to use an Aristotelian framework related to blending inheritance before Mendel's conception); Darwin and Wallace's original theory of evolution by natural selection is not reducible to physicalist theories (cf.1, 5-6): the theory explains "higher-order" phenomena, i.e., given constant or near constant slight variations across individual organisms in the natural populations of species, variations in the breeding populations of individual organisms more favorable for adaptive fitness and reproduction are more likely to be conserved and retained by the breeding populations of species (this is also discussed, below); there are cases of 'reduction' in the explanation of phenomena in terms of genes, though these do not necessarily require reference to elementary particles like protons, neutrons, electrons, or possibly quarks or bosons: Sutton and others contributed to the re-discovery of Mendel's work by discovering an empirical basis to genetic inheritance in the discovery of chromosomes; Watson and Crick's discovery of the double-helical structure of the DNA, and their theory that their model of the DNA provided a structure for the universal nature of genetic inheritance across a cellular life, is partly reductionistic in nature; however, it may not be an explanation in terms of the elementary particles or elementary constituents of matter, or even elementary molecules since bio-chemists and chemists were not successful in modeling the genetic information using other simple or complex molecules, like proteins or fatty acids. Thus, particular instances of reduction in science, like Sutton explaining genetic inheritance in terms of the discovery of chromosomes, or Watson and Crick explaining genetic inheritance in terms of the reproducible structure of the double-helical DNA, does not necessarily imply explanations or reductions in terms of atoms, sub-atomic particles, or other elementary particles; as suggested, genes and genetic information were not explained in terms of elementary particles per se; moreover, before Watson and Crick's model of the double-helical DNA, prevailing ideas of the scientific community of chemists and bio-chemists included ideas that the molecular structure of the genetic information was a protein molecule or protein molecules.

Does the physical or philosophical doctrine of physicalism even apply to chemistry? Consider the work for modeling complex molecules using chemical bonds: The Periodic Table of Elements conceived and invented by Mendeleev was available to all chemists, and the Periodic Table was available to all scientists and to all engineers in related fields; however, the frameworks for modeling complex molecules developed by bio-chemists and chemists in the mid-20th century, and borrowed and adapted by Dewey Watson and Francis Crick for modeling the double-helical structure of the DNA, was available to only a small group of chemists and bio-chemists for modeling complex proteins and other molecules; moreover, within this small group of chemists and bio-chemists involved in modeling complex proteins and other complex organic molecules, only Dewey Watson and Francis Crick departed from

the larger community of chemists and bio-chemists that thought that the molecule or molecules that might carry the genetic information were complex protein molecules that performed a multitude of tasks in large, eukaryotic cells.

4. Evaluation of Physicalist Theory, or, Physicalist Theory as Philosophy & as Science

By contrast, there are protagonists of the framework and theory of physicalism, like physicist and neuroscientist Roger Penrose, that make claims such as: “At the root of quantum theory is the wave/particle duality of atoms, molecules and their constituent particles. A quantum system such as an atom or sub-atomic particle which remains isolated from its environment behaves as a ‘wave of possibilities’ and exists in a coherent complex-number valued ‘superposition’ of many possible states . . . quantum gravity effects could plausibly have relevance at the physical scales relevant to brain processes. For quantum gravity is normally viewed as having only absurdly tiny influences at ordinary dimensions. However, we shall show . . . that this is not the case, and the scales determined by basic quantum gravity principles are indeed those that are relevant for conscious brain processes. . . [such as] collective mass of particles in superposition for a time period long enough to reach threshold, and brief enough to be useful in thought processes [7-8].”

These claims by Penrose and others are not testable, and thus there is also the question of whether physicalism or different varieties of physicalism are themselves testable; moreover, there is the related question of whether they are useful for describing or manipulating phenomena at different levels of reality, like engaging in testable experiments or developing or using instruments and technologies that make no use or reference to phenomena at the level of elementary particles or elementary constituents of matter (I also call this a ‘Standard of Technological Growth’ with which to evaluate ‘theories of everything’ or physicalist theories that are attempts to develop scientific theories that do not have clear or direct consequences or applications for technological invention, engineering, or instrument design) [9].

Physicalist theories sometimes overlap with “theories of everything” that attempt to unify theories of gravity with quantum effects at the level of elementary particles: Theoretical physicist Strominger comments that String Theory is a “potential unified theory of nature . . . string theory not only reconciles quantum mechanics and gravity, but can also contain within it electrons, protons, photons, and all the other observed particles and forces, and hence is a viable candidate for a complete unified theory of nature [10,11].” Theoretical physicist Witten compares quantum field theory to String Theory, and suggests that String Theory is more powerful than quantum field theory: “Even though we do not really understand it, quantum gravity is supposed to be some sort of theory in which, at least from a macroscopic point of view, we average, in a quantum mechanical sense, over all possible spacetime geometries. (We do not know to what extent that description is valid microscopically.)”

However, the American Physical Society comments that “theories of everything” like String Theory, though they are potential alternatives to quantum field theory have “not yet made any testable predictions, and some scientists worry that string theorists have strayed too far from physical reality.” Physicalist theories sometimes resemble “theories of everything” in physics in that “theories of everything,” such as String Theory or Quantum Gravity attempt to unify all of the forces of nature in a single grand theory; “theorists of everything” have the underlying belief that it is the direction of science to unify all of the local, regional, or isolated causal factors and concepts of every early branch of physics into a single branch of physics, and, ultimately, into a single theory unifying all of the forces of physics and all of the forces of nature; physicalists have a different though related underlying belief on the nature of the science, that all scientific phenomena of any branch of science, including the mind, brain, and consciousness, are subject to reductionist theories and explanations, and, ultimately subject to reduction to explanations in terms of the elementary constituents of matter or elementary particles. Both underlying beliefs on the nature of science may be wrong.

Moreover, both underlying beliefs on the nature of science may be unnecessary, possibly counter-productive because of their untestable nature, and unrelated to scientific productivity and also technological productivity derivative of scientific discoveries and theories. Moreover, both underlying beliefs on the nature of science may undermine simplicity in science, simplicity related to the success of particular theories and discoveries in specific branches and sub-branches of science, like Mendeleev’s Periodic Table, or Watson and Crick’s model of the double-helical structure of the DNA, or Edwin Hubble’s discovery that the galaxies are separating from each other at accelerating rates, or Darwin and Wallace’s theory of evolution by natural selection, or Ogburn’s Theory of the Accelerating Rate of Technological Evolution, or Moore’s Law. Attempts to reduce and unify all of these discoveries and theories and more to a single theory or a single type of reductionism by elementary particles are unwieldy, ugly, untestable, and wrong.

There are Many Varieties of Physicalism, are They all Wrong?

Philosophers such as Willard V. Quine or Richard Rorty have suggested that physicalist theories are, in principle, right, though unimportant [12,13]. However, I argue that physicalist theories are, in principle, wrong.

5. The Special Case of Darwinism & Physicalism: Darwinist Theories are Sometimes Reductionist, Though not “Physicalist” in Nature

There are neo-Darwinists that claim that the phenomena of the brain are reducible to theories derivative or explainable in terms of Darwinism; these include neural Darwinism, that is, the reduction of the behavior of neurons to Darwinist processes; this is a

peculiar kind of reductionism since Darwinism originally explained higher order phenomena: Darwin and Wallace's original theory of evolution by natural selection is not reducible to physicalist theories per se: the theory explains "higher-order" phenomena, i.e., given constant or near constant slight variations across individual organisms in the natural populations of species, variations in the breeding populations of individual organisms more favorable for adaptive fitness and reproduction are more likely to be conserved and retained by the breeding populations of species.

Darwinist theories attempt to explain phenomena that are not elementary particles or elementary constituents of matter, and thus Darwinist theories and the phenomena that they seek to explain, if they are ever reductionist in any way, are examples of scientific theory that are sometimes reductionist in nature, though not physicalist; Moreover, not all Darwinists agree on the nature of explanatory reductionism; an example is the co-discoverer of Darwinism or the theory of natural selection, Alfred Russel Wallace: Russel Wallace did not support Darwin and others' attempts to extend or apply Darwinism to the faculties of intelligence of the brain or emotions and personality characteristics: Wallace, like Darwin, sought to show that there were constant or near constant slight variations across individual organisms in the natural populations of organic species; however, Wallace claimed that the theory of evolution by natural selection explained the adaptation of organisms to the immediate needs and wants of the environment, i.e., that the theory explained the conservation and retention of characteristics or properties that were immediately useful to the fitness and reproduction of organisms in their survival in the breeding populations of organisms of the natural population of any species;

Thus, for Wallace, the theory of natural selection did not explain the emergence of the human brain and its faculties of learning, reasoning, and logic; Wallace concluded that by the standards of the theory of evolution by natural selection, the emergence of the human brain with higher faculties and capacities for learning, memory, and scientific reasoning was an extravagance instead of an immediate adaptation to the needs and wants of the environment; Wallace's criticism suggested that the evolution of the human brain with faculties and capacities for learning, reasoning, and logic were a product of other processes besides Darwinist natural selection per se.

6. Atari, Steve Jobs, Bill Gates, & Causation: Are Access to Written Languages and Graphical User Interfaces Kinds of Causation, and at What Level of Reality?

The languages of the world are sometimes organized in different ways by their spoken properties, and attempts to trace the history and evolution of their spoken properties are connected to extant written sources and also customs, artifacts, and early religions; linguists identify the Altaic language group as originating in Central Asia, and including contemporary populations in Central Asia, Turkic populations in the Middle East and Europe, and other populations including Koreans and Japanese. Semitic linguistic populations include populations in the Middle East, the Mediterranean, and North Africa, and the thousands of early dialects of Semitic languages largely unified into Arabic, though earlier Semitic languages survived through the 20th century like Kabyle in parts of the Mediterranean and North Africa, and Hebrew in the Eastern Mediterranean and Jewish populations in Europe and Western societies; It is also possible to organize languages by their written properties: Phoenician was an early Semitic written language, before the consolidation and standardization of Arabic over two thousand years later; the early Phoenicians were mercantile, and Phoenician was sometimes a simplified written language for successful traders in the Mediterranean; letters and aspects of the Phoenician written language were adapted and simplified by Greeks in the ancient Mediterranean and thus aspects of Phoenician were incorporated in Greek, and, indirectly, Latin and Cyrillic in the history of written scripts and languages of European societies, Russia, and Western societies; 13th century mathematician Fibonacci adapted and simplified Arabic numerals, a significant feat of cultural diffusion (discussed below); Earlier in world history, written Arabic spread to Turkic populations, Persian populations, and Central and South Asian populations at the height of the Ottoman Empire; the decline of the Ottoman Empire resulted in Turkey adapting the Latin script to its written language, Persians returning to Farsi, and Central Asian Republics employing Cyrillic based scripts, Latin based scripts, and sometimes also Arabic scripts; thus, written Cyrillic scripts and Latin scripts also have spread to the Middle East, Central Asia, and internationally; written Cyrillic, an adaptation of Greek to Russian, Serbian, and other languages, spread to Soviet Republics, including Central Asian Republics; Uzbekistan and Kazakhstan, for example, have used Arabic, Cyrillic, and Latin based scripts, and officially use Latin based scripts; Prominent historian of science Arthur Koestler writes of the origins of science in the the early scientific revolutions and achievements of ancient astronomers in ancient Mesopotamia, ancient Egypt, and ancient Greece; the build-up of established knowledge and the early conceptual revolutions and scientific revolutions amalgamating disparate word concepts and astronomical observations of ancient Mesopotamia, the Middle East, and ancient Egypt set the stage for the cultural diffusion of early astronomy from the ancient Middle East and Egypt to the early science of ancient Greece; over generations, the disparate concepts, forces, and theories of different settlements and countries were amalgamated into the achievements of ancient scientists from Egypt, Mesopotamia, and Phoenicia, and these early achievements were culturally diffused and absorbed into early Greek science that then expanded, centuries later, across different regions of the Mediterranean, Europe, and also the Middle East; Koestler writes that by the 4th and 3rd centuries B.C. the achievements of a few Greek scientists, like Heraklides, Aristarchus, and Archimedes, were spectacular to the point that European science did not reach their level until the 1500s; similar to Koestler's reactions, Muslims in the Middle East translated and referred to the predictive astronomy of Claudius Ptolemy (of Alexandria in formerly Greek Roman Egypt), that was based on the idea of "mother earth" being the center of the universe instead of a heliocentric theory, as the *Almagest* or "the Greatest Book"; the simplification and introduction of Arabic numerals by Fibonacci was a revolution

in cultural diffusion from the Muslim world to the Western, Christian world in the 13th century; the simplification and introduction of Arabic numerals in the Western, Christian world post Fibonacci clearly improved societal productivity in science, technology, business, and government; however, from the standpoint of the philosophy of science of causation (that different branches of science might have their own causes, forces, and phenomena as objects of study and inquiry), Arabic numerals were not sufficient cultural or symbolic causes for scientific and technological revolutions in the Christian or Muslim worlds; the Mesopotamian, Phoenician, Egyptian, Greek, and Roman worlds had early scientific and technological revolutions before the simplification and introduction of Arabic numerals per se; thus, access to early “higher” written languages, like proto-Arabic Semitic languages, Phoenician, and Arabic, or Greek and Latin, were necessary causes for technological and scientific revolutions in these in the ancient world, and the early Muslim and Christian worlds; access to written Chinese was a necessary cause for technological and scientific revolutions in early China; however, access to written Chinese did not result in industrial revolutions, or technological or scientific revolutions in the history and development of other East Asian societies like Japan, the Koreans, Thailand, Vietnam, Malaysia, Indonesia, the Philippines, or other East Asian societies; instead, industrial progress at the level of industrial revolutions of Western societies did not result in Japan until forced cultural contact with Western societies and the introduction and standardization of Arabic numerals and Romaji in Japan, and also access to Western languages like English, French, and Italian; similarly, in the 20th century and especially post WWII, industrial progress at the level of industrial revolutions in Western societies did not result in other East Asian societies like the Koreans, Thailand, Vietnam, Malaysia, and the Philippines having industrial progress at the level of industrial and scientific revolutions of Western societies until the collapse of Western and Japanese Empires earlier in the 20th century and with WWII; in these East Asian and Southeast Asian societies political independence and the enjoyment of national sovereignty and standardized national education and information systems resulted, counter-intuitively, in greater access to Western languages, culture, science, and Arabic numerals. On the nature of causation at the level of GUIs, written languages, and cultural symbols: the invention of Graphical User Interfaces or GUIs, by video game companies like Atari, and also by Apple Computer and Microsoft for commercial, business, and educational applications, facilitates greater productivity in science, technology, business, and government, and potentially facilitates more and greater scientific and technological achievements and revolutions; however, like Fibonacci’s simplification and diffusion of Arabic numerals to Western and other societies, the introduction of the graphical user interface or GUI increases cultural and technological growth though is not a sufficient cause to scientific and technological revolutions in the contemporary world (i.e., as suggested, scientific and technological revolutions do not necessarily require Arabic numerals or GUIs; however, access to GUIs may function like access to higher written languages: access to the higher written languages or GUIs may function as necessary causes for some scientific and technological revolutions); thus, this discussion treats causation as legitimately occurring at multiple and different levels of reality, including at the level of written languages, GUIs, and symbolic culture, instead of assuming, as “physicalist” philosophers and scientists believe, that “everything” or all phenomena might be explained, ultimately, by elementary particles or the most elementary constituents of matter [14-17].

This section also seeks to show that simplicity in science does not necessarily involve undermining, eliminating, or ignoring discoveries or empirical content related to the subject matter or subject matters in question. Physicalist theories and the tenets of physicalism largely ignore the mind-brain-culture interactions discussed in this section, including causal interactions at the level of spoken languages, written languages, and graphical user interfaces. Sometimes powerful theories and discoveries in science are credited with unveiling, releasing, and connecting lines of empirical variation that were unrecognized or unacknowledged before the discovery or theoretical contribution (e.g., Mendeleev’s Periodic Table for chemistry, or Watson and Crick’s discovery of the DNA as the genetic material that identified and recognized the DNA as the genetic material for the cells of all biological life).

Earlier, I discussed that there are at least two ways of evaluating physicalist theories, testability and cause and effect. An additional way of evaluating theories in science is whether the theories undermine, eliminate, or ignore the empirical and theoretical content of discoveries related to the subject matter or subject matters of some branch or branches of science, or address, stimulate, connect, or reveal discoveries or empirical content related to the subject matter or subject matters in question (this is related to testability, though has a different point of emphasis). Perhaps this should be called a theory’s capacity for adherence to some subject matter and related discoveries, and the capacity for relevance to some subject matter and related discoveries in some branch or branches of science and engineering.

Physicalist theories and other ‘theories of everything,’ are so simple that they ignore substantive discoveries and empirical and theoretical content related to the subject matter or subject matters that they putatively address, whether in neuroscience, mind-brain interactions, mind-brain-culture interactions, or, say, physics and bio-chemistry. This was elaborated and discussed in the preceding sections: the sections on neuroscience and the brain (sections 2 & 3) sought to show that the layers of complexity and the distribution of unconscious and conscious functions of the brain are not addressed by physicalist theories of the brain or consciousness; mind-brain-culture interactions (sections 3 & 6) are also not addressed by physicalist theories, such as causal interactions at levels of reality involving spoken languages, music, written languages, print, multi-media, and GRAPHICAL USER INTERFACES or GUIs; I also sought to show that there are successful cases of reduction in different branches of science, and at different levels of reality, such as in physics, chemistry, bio-chemistry, and evolutionary biology including Darwinism, that do not necessarily involve or imply physicalism or physicalist tenets (sections 3, 4, & 5).

Successful theories, discoveries, and explanations in science are sometimes revelatory, that is, they may reveal aspects of reality that are ignored, connect aspects of reality or kinds of variation previously disconnected, or identify and organize aspects of reality or forces of nature that are unacknowledged or previously impossible to visualize: examples include the Copernican revolution in astronomy; the revolutions of Galileo and Newton in classical mechanics identifying and organizing the forces of physics; the scientific revolution by Mendeleev identifying and organizing the elements of chemistry in the Periodic Table; Watson and Crick's discovery of the double-helical structure of the DNA, and theory that the double-helical structure of the DNA provided a universal code for the genetic information for all cellular life (Mendel's and Watson and Crick's discoveries organize research more in the biological sciences than Darwin's theory per se).

These scientific revolutions also organized the subject matters of their branches of science, and the discoveries of their branches of science in new ways; physicalist theories are sometimes so simple that they undermine or even eliminate discoveries and empirical content related to the subject matters and branches of science that they putatively address or attempt to unify. Physicalist theories and the tenets of physicalist theories may respond to scientific and philosophical attempts earlier in the 20th century, and through the 21st century, to unify all of the branches of science in a single framework or single theory (18-23); however, the attempts to do this by physicalist theories and physicalist theorists many times results in ignoring or eliminating discoveries and aspects of reality related to the subjects in question or the branches of science in question.

7. Kierkegaard and Buddha, Francis Bacon, Erasmus, Auguste Comte, & the 'Law of Three Stages'

Francis Bacon and Auguste Comte, and most natural philosophers and scientists, are usually satisfied by two kinds of evaluation, testability and cause and effect; sometimes, they are also satisfied by evaluations related to the generality and simplicity of discoveries and theories (discussed above); humanists of the aesthetic and philosophical stripe, from Renaissance humanists to pre-Darwinian naturalists like Louis Agassiz or Goethe, claim that such reductionistic or overly reductionist explanations like physicalist theories are lacking or missing all kinds of information, like colors, textures, and hues that physicalist theories completely ignore; religious philosophers and writers like Erasmus, Sir Thomas Moore, Erasmus Darwin, Soren Kierkegaard, or the cults of Apollo or Dionysus, or the religious prophets like Muhammad, Christ, or Buddha, may discard physicalist theories for similar rationales and reasoning as humanists; however, these theological and religious philosophers ignore the logic of Comte's Law of Three Stages of explanatory progression from religion and magic to metaphysics, and from metaphysics and theology to positive science, for religious ecstasy, religious and supernatural explanations, singing, music, and explanations of the ecstatic nature instead the natural or scientific.

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Three-Dimensional Venn Diagram as an Explanation of Two Kinds of Generality in Science, Invention, & Engineering

Abstract

This paper describes a Venn Diagram with three dimensions, “Predictability,” “Generality,” and “Technological Growth”: this Venn Diagram is used to explain two kinds of generality in science, invention, and engineering instead of one kind: there is an additional kind of generality related to technological productivity and technological growth, like the technological growth related to the work of Alan Turing, Nicholas Metropolis, or Claude Shannon, in addition to generality related to the generality of predictions of some subject matter, like Ptolemy’s predictive astronomy, or Copernicus’ predictive astronomy, or Galileo’s classical mechanics.

The paper includes a provocative thought experiment on the nature of technology and biotechnology: Vico and Marx likely viewed the vast array of functional and adaptive capacities of plant and animal life as considerably greater than the technologies and inventions of human labor; in the 19th century biological adaptations of organisms, or what Vico and Marx called “natural technologies,” were unquestionably far greater than the technological adaptations of human labor and inventiveness; however, given the nature of technological growth, it may be possible for the vast array of human inventions to eclipse the number and diversity of “inventions” or functional and adaptive properties distributed across plant and animal life.

Keywords: Venn Diagrams, Generality, Predictability, Technological Growth, Adaptation, Exponential Growth

1. Introduction

Prominent philosophers of science Karl Hempel and Karl Popper developed ideal standards for evaluating generality and predictability of scientific theories and scientific discoveries (1-2): By the standards of Karl Hempel’s celebrated “Covering Law” model of scientific explanation, and Karl Popper’s celebrated if sometimes controversial “Hypothetico-Deductivism,” Arthur Eddington, in his famous test of Albert Einstein’s theory of general relativity, showed that Einstein’s theory of gravity and space-time was **more general** than Galileo’s theory of gravity (and its applications in classical mechanics and early experimental physics) and more general than Isaac Newton’s theory of gravity uniting the movement of celestial bodies with explanations of the movement of objects at or near the surface of the earth.

However, from the standpoint of a **Standard of Technological Productivity** or **Standard of Technological Growth**, since Galileo’s theory and framework for gravity, classical mechanics, and the self-conscious manipulation of the forces of physics in experimental physics and invention directly or indirectly generated more inventions, technologies, and feats of engineering (such as in the industrial revolutions of Britain, France, and the United States in the 18th and 19th centuries) than Einstein’s theory, or, similarly, because Newton’s Laws for gravity, classical mechanics, and the self-conscious manipulation of the forces of physics directly or indirectly generated more inventions, technologies, and feats of engineering than Einstein’s theories, Galileo’s work and Isaac Newton’s work are **more general than Einstein’s for technological productivity or technological growth**.

Thus, it is also possible to discern and distinguish different kinds of generality in science, technology, and engineering. This is represented in a Venn Diagram classifying theories and frameworks in science by their capacity for prediction or predictability, their generality or scope, and their relationship to technological growth.

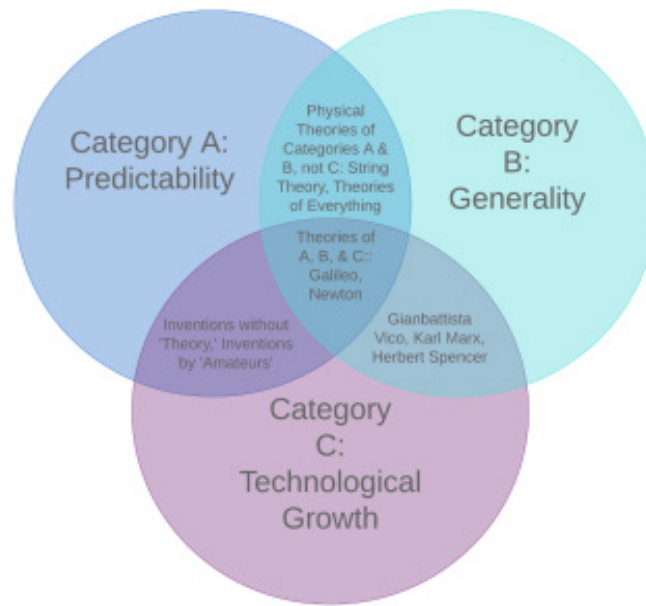


Figure 1: Venn Diagram: Predictability, Generality, Technological Growth

As suggested, Arthur Eddington showed in his test of Einstein's theory of gravity space-time versus Newton's theory of gravity, that Einstein's theory of gravity was more general than Newton's (and, thus, also more general than Galileo's theory of gravity). However, if one were to classify different theories and frameworks in science by their capacity to directly or indirectly generate inventions, technologies, feats of engineering, and industrial and post-industrial revolutions, Galileo's work has had a greater capacity for generating technological growth than Einstein's, and Newton's work has had a greater capacity for generating technological growth than Einstein's; thus, while classic ideal models and theories of science and scientific explanation focus on generality in science in terms of predictability and testability, it is possible to recognize explicitly that there are two kinds of generality in science, technology, invention, and engineering: there is the generality of scientific theories, such as Galileo's, Newton's, or Einstein's, that enjoy the highest levels of generality and predictability; however, though Einstein's theory of gravity space time is highly general, and more general in scope than Galileo's or Newton's theories of gravity, there are different kinds of theories and models that may enjoy more generality than Einstein's general theory of gravity space-time in terms of their capacity or relationship to the direction of invention, industrial revolutions, post-industrial revolutions, and technological growth.

Examples include Alan Turing and Nicholas Metropolis developing abstract models of computing machines for scientists and engineers to build computers, including before the physical components were available to build the computers, and suggesting different physical components that might be functionally interchangeable for the computers; Claude Shannon's development of information theory for computer science and the digitization of sound, knowledge, and information when analog communications was still largely dominant (in 1956, The Soviet Academy of Sciences called Shannon's 'mathematical theory' a theory of technology instead of mathematics per se); additional examples might include Michael Faraday's conception of "force fields," important for advances in physics, technology and engineering related to electromagnetism; Dmitri Mendeleev's Periodic Table, important for inventions and advances in inorganic and organic chemistry, including metals, alloys, semiconductors, pharmaceutical products and medicines; Ben Franklin's theory of the conduction of electricity, tested in his famous kite experiments.

Thus, this Venn Diagram is used to identify and explain two kinds of generality in science, technology, engineering, and invention instead of one kind: that is, there is an additional kind of generality in science related to technological productivity and technological growth, like the technological growth related to the work of Alan Turing, Nicholas Metropolis, or Claude Shannon, in addition to generality related to the generality of predictions of some subject matter, like Ptolemy's predictive astronomy, or Copernicus' predictive astronomy, or Galileo's classical mechanics.

2. Materials & Methods

Theory: Galileo's and Newton's theories fit or include all three categories ("Theories of Categories A, B & C," from Figure 1); however, String Theory and "Theories of Everything" in physics include the first two categories but not all three categories, Predictability, Generality, and Technological Growth. String Theory, while potentially highly general, has been criticized by many physicists, scientists, and philosophers of science for not having any explicitly empirical or testable results: String theory has been described as a "potential unified theory of nature . . . string theory not only reconciles quantum mechanics and gravity, but can also contain within it electrons, protons, photons, and all the other observed particles and forces, and hence is a viable candidate for a complete

unified theory of nature.” (3) However, the American Physical Society comments that, “String theory has not yet made any testable predictions, and some scientists worry that string theorists have strayed too far from physical reality in their obsession with mathematics.” (4) Nobel prize-winning physicist Sheldon Glashow has similarly commented that String Theory has not made “even one teeny-tiny experimental prediction.” Mathematical physicist Peter Woit, formerly a participant in String Theory, has evaluated the oeuvre of String Theory as “not even wrong,” (5) in his book *Not Even Wrong: The Failure of String Theory and the Search for Unity in Physical Law*. (In this, Woit uses Wolfgang Pauli’s famous characterization of theories in physics that are testable and wrong as more valuable than theories that are untestable). Woit argues that String theory is not empirically testable, is “post-empiricist” from the standpoint of empirical science, and argues that String Theory has failed in its attempts to unify the forces of physics or to successfully attach String Theory to particle physics. The Venn diagram in this paper dramatizes another criticism of String Theory and “theories of everything”: there are no important inventions, technologies, feats of engineering, or industrial or post-industrial revolutions that are explicitly derivable or at least related to the Theory of String Theory.

3. Results & Discussion

The Venn diagram has spaces for inventions and innovations that might include Predictability and Technological Growth, though not Scientific Generality per se, as in inventions, manufacturing processes, and industrial products that may occur without explicit use of theoretical science, including inventions and manufacturing processes by so-called “amateurs”; in the history of the industrial revolutions of 18th and 19th century Britain, France, and the United States, inventions, industrial processes, and industrial products were sometimes generated or invented without explicit use of scientific theory: physicists such as Jearl Walker or computer scientists such as John Graham-Cumming have shown that it was not until years later that physicists might attempt to employ physical theories to explain why particular inventions “worked,” or the success of many inventions, manufacturing processes, and industrial products. (6-7) There has been a consensus of contemporary 20th and 21st century physicists and astronomers to simplify the number of forces in the physical sciences to gravity-spacetime, electromagnetism, and the strong and weak forces (thus discarding additional concepts of forces used in earlier Galilean and Newtonian physics, or 18th and 19th century physics related to the Industrial Revolution). In practice, however, engineers, inventors, and technologists use more than the four forces of gravity-spacetime, electromagnetism, and the strong and weak forces when they create, invent, and manipulate technologies in the physical sciences. Moreover, inventors sometimes invent tools, technologies, and manufacturing processes that do not make reference to the established knowledge of physical theory (and that intuitively make use of more than the four forces of physics stipulated by contemporary theoretical physicists): when scientists analyze the nature of inventions that are not explicit applications of physical theory, they sometimes invoke more than the four forces of physics stipulated by contemporary theoretical physicists.

Thus, for example, computer scientist and inventor John Graham-Cumming writes that, “In 1782, William Watts patented a method of making lead shot that involved pouring molten lead through a copper sieve and letting it fall a long distance before being cooled in a pool of water . . . Watts was less concerned with the science than with the result. But if he asked, “How does this work?” the answers would have covered surface tension, intramolecular forces, and terminal velocity.” Graham-Cumming also explains the nature of Watts invention with gravity and upward drag: “How fast is the lead shot going when it hits the water? . . . Gravity is acting on the falling body, but this is balanced by the drag from the air. . . Bodies falling through the air experience an upward force caused by drag, which is proportional to the square of their velocity. The force is defined by the equation $F = -\frac{1}{2} C_p A v^2$.” Other physicists and engineers, such as Jearl Walker, when they analyze and seek to explain why specific technologies work, or the basis of complex interactions of “everyday” physical phenomena, use more than four forces in their explanations. By point of comparison, String Theory is not used by physicists, inventors, or engineers to develop or invent important technologies, inventions, feats of engineering, or generate industrial revolutions or post-industrial revolutions.

4. Another space in the Venn diagram is for theories and frameworks that may demonstrate considerable generality, and inspire or are related to technological growth, though may be lacking in predictability. Are there any examples? What are the examples? Examples may include Giambattista Vico and Karl Marx’s classification scheme and analogies for identifying, categorizing, and distinguishing the vast array of functional and adaptive capacities of plant and animal life as “natural technologies”; Vico and Marx likely viewed the vast array of functional and adaptive capacities of plant and animal life as considerably greater than the technologies and inventions of human societies or “artificial technologies” or artifices; their framework also was a way of inspiring greater innovation and inventiveness in societies as the vast array of “natural technologies” provided analogical models for human generated inventions and technologies.

This section thus includes a thought experiment on the nature of technology and biotechnology: in the 19th century, biological adaptations of organisms, or what Vico and Marx called “natural technologies” were unquestionably far greater than the technological adaptations or artifices or “artificial technologies” of human labor, inventiveness, and societal productiveness; however, given the nature of technological growth, and the recognition that technology grows exponentially (or that at least some technologies grow exponentially) by figures such as G.E. Moore (“Moore’s Law”), or earlier figures that wrote on exponential technological growth, such as Henry Adams and William Ogburn, it may be possible for the vast array of human inventions, manufacturing processes, industrial and post-industrial revolutions to eclipse the number and diversity of “inventions” or functional and adaptive properties and adaptive structures distributed across plant and animal life.

(Admittedly, this would be difficult to measure, i.e., attempting to measure the number and diversity of biological adaptations and adaptive properties and structures across all biological species, and then attempting to compare the number and diversity of functional inventions and tools of human labor and inventiveness; this framework also may assume a disjunct or separation between human generated technology and plant and animal adaptive characteristics as classified by Vico and Marx, and also implied by Darwin's principle of gradualism as applied to the evolution of animal and plant species; it is as if the growth of physical technologies and bio-technologies create the capacity for invading or re-organizing the "natural technologies" of animal and plant species, potentially undermining the classic physical and conceptual divide between the functional capacities of the "natural technologies" of the adaptive properties of plant and animal species, and the functional capacities of human generated or "artificial technologies" that might invade or re-organize the adaptive properties of animal and plant species for ill, or for worse, or for superior organisms, or for increasing the rate of evolution against Darwin's principle of gradualism, or, counter-intuitively, for undermining the rate of evolution and thereby undermining fundamental Darwinistic processes; the separation between human generated technologies and plant and animal adaptive properties or "natural technologies" has been collapsing for several decades with the potential introduction of different techniques for bio-technology and genetic engineering); it is an interesting question what other theories or models might fit in the logical space of the intersection of Generality and Technological Growth without Predictability per se: possibly the systems of Herbert Spencer (social Darwinism) and Auguste Comte (scientific socialism), with their elaborate classification schemes related to considerable scientific and technological advances in Britain and France in the 19th century; Spencer and Comte's schemes also may have stimulated or helped generate technological advances in their societies, and also other European societies and the United States, by organizing knowledge in the sciences and relating it to advances and developments in human social organization; however, sometimes Spencer and Comte attempt predictive models in early political economy and the intersection of physics, biological science, and early social science, though with mixed success (at least some of their work, especially their elaborate classification schemes of scientific knowledge and human social organization fit the logical space of the intersection of the categories of Generality and Technological Growth without explicit Predictability).

Conclusion

The discussion involves four categories at the intersections of the Venn Diagram: "Theories of A, B, & C," i.e., Galileo's and Newton's theories; "Theories of Categories A & B, not C," i.e., String Theory and Theories of Everything; "Inventions without Theory or by 'amateurs,'" i.e., inventions that do not involve the explicit or self-conscious use of general theories or theoretical science, including inventions by amateurs; "Generality and Technological Growth, without Predictability," i.e., theories and frameworks that stimulate and relate to technological growth without explicit predictive models, i.e., the frameworks of Gianbattista Vico, Karl Marx, Auguste Comte, or Herbert Spencer.

(In principle, instead of only focusing on the four categories at the intersections of the Venn Diagram, there are seven categories of the Venn Diagram, including Predictability, Generality, and Technological Growth; however, given the nature of the phenomena in question, science, theory, technology, invention, and engineering, there might be only isolated cases of in early science and technology of theories, discoveries, or inventions that only have predictability without generality or technological growth, or cases of philosophical speculation, metaphysics, and theology, like the intermediate stage in Comte's Law of Three Stages, that might have generality without predictability or technological growth; the cumulation of technological growth is perhaps the most common pattern across societies before the development of general and predictive scientific explanations, such as by the frameworks of Galileo or Newton, that might be used to self-consciously manipulate the forces of nature for invention and engineering).

Thus, this three dimensional Venn Diagram, with its four categories at the intersection of its three dimensions, is useful to identify, discern, and explain two kinds of generality in science, technology, invention, and engineering: that is, while classic ideal models and theories of science and scientific explanation focus on generality in science in terms of predictability and testability, it is possible to explicitly re-organize and re-classify knowledge in science, technology, invention, and engineering to recognize that there are two kinds of generality in science, technology, invention, and engineering: the generality of scientific theories, such as Galileo's, Newton's, or Einstein's, that enjoy the highest levels of generality and predictability, and the generality of theories and models of Galileo's, Newton's, Faraday's, or Franklin's, that may be less general than Einstein's or James Clerk Maxwell's in terms of generality of predictive science, though more general in terms of their relationship to the direction of invention, industrial revolutions, post-industrial revolutions, and technological growth.

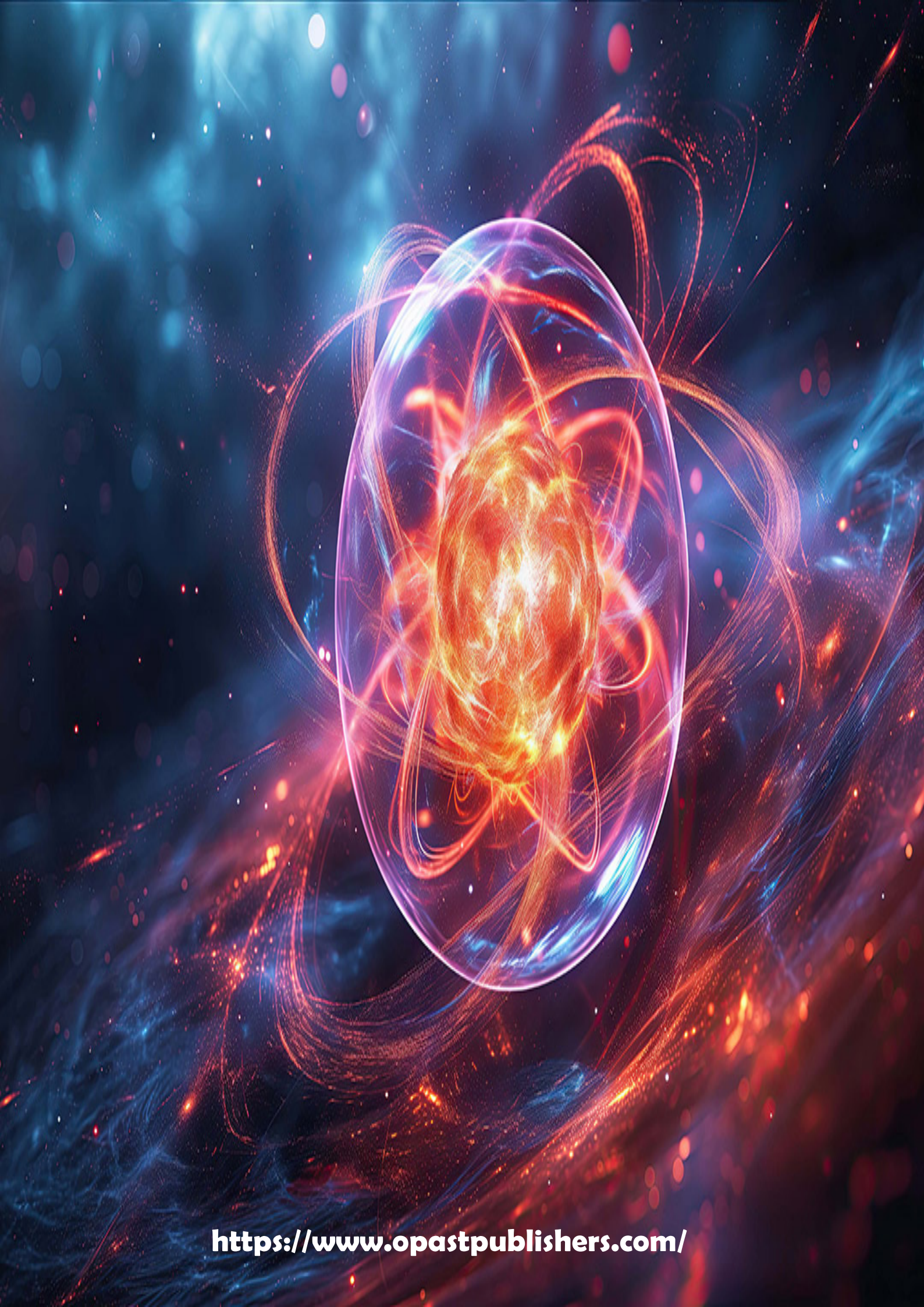
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