Evolution in Real Time

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Abstract

Time is the primary independent variable for evolutionary and paleo-biologists, and a real,absolute and unidirectional arrow of time, is supported by the geological and fossil record. On the other hand, based on kinematic analyses, where a material body is considered as a mathematical point that experiences no friction as it moves through space and time, mathematical physicists conclude that times' arrow is relative and local.

By taking into consideration the Doppler effect expanded to the second order, I show that friction caused by the photons through which any particle moves is inevitable. The optomechanical friction results in an increase of entropy, consistent with an absolute and unidirectional arrow of time. By taking into consideration the optomechanical friction, I contend that the Second Law of Thermodynamics is a primary law of nature and I offer an alternative to the relativity of the magnitude and direction of time posited by Special Relativity and statistical mechanics, respectively.

If "Nothing makes sense in biology except in the light of evolution," then nothing in biology makes sense unless the arrow of time is real. By presenting the strong case for the arrow of time marshalled by the biologists and geologists, and by pointing out neglected physical phenomena such as the optomechanical friction and the mechanical angular momentum of the photon, I show that as biologists we can confidently base our theories and experiments on the assumption that time's arrow is absolute and unidirectional. This conclusion is consistent with biological, geological and physical observations.

Keywords: Arrow of time, Darwin, Dobzhansky, evolution, Huxley, Kelvin.

"Throughout the latter part of the last century a controversy, as to the possible age of the earth as a planet fitted for habitation, existed between two schools, represented by the physicists on the one side and the biologists on the other. Some of the arguments advanced by the former make strange reading at the present time."

--Frederick Soddy [1]

INTRODUCTION: PRIMARY AND SECONDARY LAWS OF NATURE

According to Gómez-Gómez and Hochberg [2], the search for original and creative answers to the difficult questions of life using the scientific method require multidisciplinary and transdisciplinary approaches. This is particularly important when such approaches lead to ontological clashes, particularly over something as fundamental as the nature of time.

For nearly a century, the papers published on organismal evolution, development and physiology have been based on the postulate that the arrow of time is absolute and unidirectional [3-40]. But, is the postulate that the arrow of time is absolute and unidirectional defensible? As a practicing biologist studying the movement of ions, molecules, organelles, and cells through time, I accept the absolute and unidirectional arrow of time as a truth even though the mathematical physicists, consistent with statistical mechanics and the Theories of Special and General Relativity, have declared time to be an illusion [41-45]. According to Brian Greene [46], "*the laws of physics that have been articulated from Newton through Maxwell and Einstein, and up until today, show a complete symmetry between past and future. Nowhere in any of these laws do we find a stipulation that they apply one way in time but not in the other. Nowhere is there any distinction between how the laws look or behave when applied in either direction in time. The laws treat what we call past and future on a completely equal footing. Even though*

experience reveals over and over again that there is an arrow of how events unfold in time, this arrow seems not to be found in the fundamental laws of physics."

Greene's conclusion depends on what is considered to be fundamental. According to Arthur Eddington [47], "*Some things never happen in the physical world because they are impossible; others because they are too improbable. The laws which forbid the first are the primary laws; the laws which forbid the second are the secondary laws."*The mathematical physicists claim that the Second Law of Thermodynamics, which is first order with respect to time, is not fundamental because the direction of time is merely probabilistic, while the laws of physics that are quadratic with respect to time are fundamental because they show no preference for the direction of time. I contend that in every situation in which the Second Law of Thermodynamics has been tested, it has proven to be absolute. That is, no processes forbidden by the Second Law of Thermodynamics, ever occur.

The fact that some biologists are willing to settle for a compromise position between the absolute reality and the illusion of the arrow of time is captured in a comment by an associate editor of a journal that rejected this paper, "*I'm worried that the author is addressing a non-problem. Even if time's arrow is not real, there still may be local time asymmetries – in the same way as organisms constitute local violations of the law of increasing entropy*." Why do biologists settle for an inconsistent and disunified definition of time, when, it is the primary independent variable used by biologists, and, for centuries, biologists and geologists have marshalled such strong evidence for the absolute and unidirectional arrow of time? I think that the reason biologists defer to mathematical physicists when it comes to the nature of time is based on Auguste Comte's [48] view of the hierarchy of the sciences.

THE POSITIVE PHILOSOPHY OF AUGUST COMTE

Either knowingly or unknowingly, most academics are influenced by the positive philosophy of Comte when we consider what is fundamental and what is derived. In describing the development of human intelligence, Comte stated that each branch of knowledge passes successively through three stages. The first stage, called the Theological stage, supposes that all natural phenomena such as life itself, lightning, volcanoes and the falling of rocks are caused by supernatural agents such as gods and spirits. The second stage, which according to Comte is just a modification of the first, is known as the Metaphysical stage. In the Metaphysical stage, the gods and spirits of the Theological stage are replaced by abstract forces, such as the electrical and gravitational forces, which explain the relationship between cause and effect. In the third and final stage, known as the Scientific stage, the forces that drove out the gods and spirits were themselves exorcized to give way to the laws of nature that describe without explaining the phenomena of interest. While the ultimate aim of the Scientific stage is to represent all phenomena as individual facets of a single general law, Comte thought that the attainment of this goal was unlikely due to the narrowness of our resources and the complexity of the universe. Sir Arthur Eddington [47] and Sir James Jeans [49] swept away much of the complexity by emphasizing that mathematics was more real than matter itself and that thegeneral laws of nature will consequently be mathematical formulae. Jeans [49] wrote that "*God made the mathematics and man made the rest.*" He expanded on the purity and clarity of mathematics: "*the history of theoretical physics is a record of the clothing of mathematical formulae which were right, or very nearly right, with physical interpretations which were often very badly wrong.*" The mathematical physicists may have swept the complexity under the rug, but hiding the complexity does not eliminate it and the human need to understand it. The "*shut up and calculate*" approach

advocated by David Mermin [50] and Max Tegmark [51] is too restrictive. Theodosius Dobzhansky [52], and more recently, T. Colin Campbell [53] have argued eloquently about the limits of reductionism.

Comte suggested that in attaining a scientific theory, each branch of knowledge passes through the same three stages albeit at different rates. The branches of knowledge, such as mathematics and physics, which are based on facts that appear to be general, simple and independent of other branches of knowledge progress the fastest, while the branches of knowledge, such as biology and sociology, which are based on facts that appear to be particular, complex and dependent on other branches of knowledge progress the slowest. Comte saw the exactness of the sciences to be inversely proportional to their complexities and arranged the sciences in a hierarchical order: mathematics, astronomy, physics, chemistry (and its derivative geology), biology (and its derivatives botany and zoology), and sociology (Figure 1). The former on the list were (1) historically older than, (2) logically simpler than (3) more widely applicable than, and (4) independent of the latter sciences on the list.

Comte claims that no branch of knowledge can be effectively pursued without a competent knowledge of the branches that precede it in the hierarchy. I claim that the time is ripe to question the unidirectional nature of Comte's list. Specifically, we must question whether the assumptions used to reduce the complexity of the more exact sciences have outlived their usefulness and have resulted in supercomplexities, analogous to epicycles upon epicycles, which are no longer useful for either the exact sciences or the sciences that depend upon them. If mathematical physics, with its search for a Theory of Everything with a mathematical structure "*existing outside of space and time*" [54], is more fundamental than biology and geology, are geologists and biologists to accept that time is not really a fundamental independent variable

upon which to base our observations and make our theories? If mathematical physics is more fundamental than biology, are we to accept the orthodox interpretation of quantum mechanics [55] that states that a cat can be dead and alive at the same time [56, 57]? If mathematical physics is more fundamental than biology, are we to believe that two identical twins can have different ages depending on their relative velocities [58]? If mathematical physics is more fundamental than biology, are we to believe that there is no such thing as a gravitational force and that in reality, a plant senses the curvature of spacetime in order for the roots to grow down and the shoots to grow up? If we must accept that the Newtonian theory of the gravitational force be merely the limiting case and a first approximation to the Theory General Relativity, which is the fundamental theory that describes everything from weak gravitational fields to strong gravitational fields, then we must conclude that a horseshoe crab rights itself, a giant sequoia grows skyward, and sediments accumulated to form the coal measures as a consequence of the curvature of spacetime. I am not willing to go that far.

Comte points out that in the primitive state of human knowledge, there are no regular divisions and each individual cultivates knowledge in all areas. As human knowledge advances, divisions between the branches of knowledge develop and each individual cultivates knowledge in only one branch. Comte argues that the divisions that have allowed individuals to specialize in a single subject have allowed the great advance of science. While pointing out the merits of specialization, he reminds us not to be blind to the "*eminent disadvantages which arise from the limitation of minds to a particular study*." As a remedy, Comte proposes a new class of scientists who will ascertain the mutual connections between the various branches of knowledge and find the smallest number of general principles that transcend the artificial divisions between them. Again, the time is ripe to act on this proposition.

Comte explains that each branch of knowledge can be presented using the historical method, or the dogmatic method, or a combination of the two. The historical method presents the knowledge and how it was obtained in the order in which it was actually obtained while the dogmatic method presents the knowledge in the most logical way. According to Comte, the dogmatic method supersedes the historical method. I claim that an overreliance on the dogmatic method hinders questioning the assumptions upon which specialized knowledge is based and such a questioning is essential when the assumptions concerning what is fundamental in different branches of knowledge are at odds. Here I will discuss specifically assumptions concerning the nature of time. In constructing a theory of time, the mathematical physicists may not have given sufficient weight to data from a wide range of experiments and observations performed by scientists in many other branches of science. Therefore, the theories proffered by the mathematical physicists may not be fundamental and generalizable, and it is actually possible that the theory of time made by geologists and biologists may be more simple, general and applicable to all the branches of knowledge in the hierarchy of science than that of the mathematical physicists.

Dobzhansky [59] felt that "*seen in the light of evolution, biology is, perhaps, intellectually the most satisfying and inspiring science.*" He went on to say, "*Without that light it becomes a pile of sundry facts some of them interesting or curious but making no meaningful picture as a whole*." In a talk aimed at refuting the trend towards the complete reduction of biology to the more exact sciences, Dobzhansky [52]said that "*if the living world has not arisen from common ancestors by means of an evolutionary process, then the fundamental unity of living things is a hoax and their diversity is a joke. The unity is understandable as a consequence of common descent and of universal necessities imposed by common materials. The diversity is intelligible as the outcome of adaptation of life to different environments."*

The processes that lead to unity within diversity occur in diverse spaces—real space and take time—real time. If Dobzhansky's [52] dictum that "*Nothing makes sense in biology except in the light of evolution*" be true, then nothing in biology makes sense unless the arrow of time is absolute and unidirectional. Indeed, I would go as far as to say that nothing in life makes sense unless time is real and unidirectional [60].

EVOLUTION AND THE AGE OF THE EARTH

Charles Darwin's theory of evolution over time, driven by natural selection, is one of the cornerstones of biological thought, and depends on the arrow of time being absolute and unidirectional and on the age of the Earth. Before the eighteenth century, the best estimates of the age of the Earth came from the theologians, including Bishop Ussher [61] and John Lightfoot [62], who traced back "the begets" in the Bible and posited that the earth was approximately 6000 years old. Studies that concluded that the earth must be older than 6000 years began with those of Nicolaus Steno [63] and William Smith [64]. Based in part upon the supposition that nature makes nothing in vain, Steno, along with Robert Hooke [65] and John Ray [66], realized that fossils might be the remains of living organisms that lived long ago. Steno further recognized that there was a connection between the strata and the fossils endemic to them, and if the rock strata were formed from sedimenting particles, the particles would form horizontal layers with the lower layers forming before the upper layers. Smith [64], a mineral surveyor in Britain, noticed that the fossil-containing strata in coal pits and along the coal canal were arranged in a consistent pattern that could be found in canals, quarries and road cuttings

throughout Britain. Smith hypothesized that if two layers of rock at widely differing locations contained similar fossils, then it was very plausible that similar layers of the earth were of the same age. Smith [64] wrote "*As the section of a Tree shows its increase by annual rings of growth, so the Strata seem to show the earth's lamellar increase.*" According to George Cuvier [67], "*The importance of investigating the relations of extraneous fossils with the strata in which they are contained, is quite obvious. It is to them alone that we owe the commencement even of a Theory of the Earth; as, but for them, we could never have even suspected that there had existed any successive epochs in the formation of our earth.*"By taking into consideration the height and area of a formation and the amount of sediment carried off from that formation and then reversing the calculation, Smith's nephew, John Phillips [68] estimated that the time needed to form that formation and by extension the age of the earth was at least 95,904,000 years.

When James Hutton observed similar stratification of the land that he farmed, he wondered about the processes that caused the stratification [69]. Hutton [70] surmised that the topology of the earth was determined by both fire and water and that the strata resulted from the soil being washed into the sea where the sediment was then consolidated as a result of the evaporation of water and eventually pressed into bedrock by pressure and heat. Subsequently, the bedrock was forced to the surface by the retreat of the oceans or by the raising up of land by expansion forces within the earth. Over time, the rocks were worn down to soil and the cycle continued. If the earth was formed by the same slow processes of sedimentation and erosion that occur today but are barely noticeable in the nearly century-long lifetime of a human, the earth must be much older than the several thousand years calculated through biblical study. According to Hutton [71], "*the course of nature, cannot be limited by time.*" After looking at the cliffs of

Siccar Point with James Hutton, John Playfair [72]wrote, "*the mind seemed to grow giddy by looking so far into the abyss of time.*"

In the three volumes and many editions of *Principles of Geology*, Charles Lyell [73] popularized the idea that the distinguishing features of the surface of the earth were not due to short-term catastrophic causes as suggested by Cuvier [67], but rather could be ascribed to the operation of the same slow and tranquil causes observable at the present. As a consequence, the earth must be vastly older than the age derived from biblical scholarship. In his first volume, Lyell [73] wrote, "*The imagination was first fatigued and overpowered by endeavouring to conceive the immensity of time required for the annihilation of whole continents by so insensible a process*." In the second volume of *Principles of Geology*, Lyell [73] presented Geoffrey St. Hilaire's and Jean-Baptiste Lamarck's geological evidence of variations in fossil morphology and agricultural evidence for domesticating animals and cultivating plants for the transmutation of species. While Lyell [73] did not accept Lamarck'sconclusions in terms of specific variations, Lyell realized that our conception for the apparent stability of species might be an artifact of the short lifetime of humans relative to the age of the earth, writing "*if once there appears ground of reasonable doubt, in regard to the constancy of species, the amount of transformation which they are capable of undergoing, may seem to resolve itself into a mere question of the quantity of time assigned to the past duration of animate existence.*" In his book, *The Antiquity of Man*, Lyell [74] took the possibility of long time periods seriously. Understanding the difficulty of making conclusions based on epically-long time periods, Cuvier [67] wrote "*Would it not also be glorious for man to burst the limits of time, and, by a few observations, to ascertain the history of this world, and the series of events which preceded the birth of the human race*?"

While on the H. M. S. Beagle, Charles Darwin, following the advice of his mentor John Henslow, read the first volume of Lyell's *Principles of Geology*. Darwin was impressed with Lyell's ability to turn a seemingly random rock formation into something intelligible by considering the stratification and nature of the rocks and fossils within them and relating them to other formations to understand the history of the earth. Lyell'sconcept of time and gradualism influenced Darwin in his thinking of the origin of species. In the first edition of *The Origin of Species*, Darwin [75] estimated that if the wave action of the sea eroded a 500 foot high chalk cliff at a rate of one inch per century, then the denudation of a chalk deposit in England known as the Weald would have taken 306,662,400 years. This would be an underestimate if the cliff escaped the action of the sea for any length of time. Consequently, Darwin concluded that the earth was very old indeed and wrote "*What an infinite number of generations, which the mind cannot grasp, must have succeeded each other in the long roll of years!*" Such an ancient earth could provide the stage for the gradual origin of species by natural selection. Intimidated by William Thomson's calculations that lead to an estimation of a younger earth, Darwin revised his assumptions in the second edition [75] and completely removed his estimate of the minimal age of the Weald from the third [75] and later editions of the *Origin of Species* after having "*been convinced of its inaccuracy in several respects by an excellent article in the 'Saturday Review,' Dec. 24, 1859."* Even so, Hugh Miller [76-78], despite his belief in divine creation, garnered and accepted the geological and fossil evidence that the earth was very old.

William Thomson [79], who would later become Lord Kelvin, questioned the assumptions Darwin used to estimate the minimum age of the Weald and thus the habitable earth based on his own thermodynamic reasoning where he estimated that it is "*most probable that the sun has not illuminated the earth for 100,000,000 years*." It also weighed on Thomson's [80]

mind for eighteen years that the principles of thermodynamics, a field that he helped found, were overlooked by the geologists who favored uniformitarianism and opposed the catastrophic theories. The terms Uniformitarians and its opposite Catastrophists were coined by William Whewell [81] in a review of the second volume of Lyell's *Principles of Geology* to define the two sects of geologists. Uniformitarians saw a world that was shaped in the past by slow and gradual processes such as erosion and uplift that can be observed in the present. Catastrophists saw a world that obtained its topography through convulsive changes such as flooding (Neptunism), volcanoes (Vulcanism) and/or heating (Plutoism) that were more powerful in the past than in the present. While both sides conceded that time and force were required to shape the surface of the earth and thus the two theories were not mutually exclusive [68,82, 83] taking catastrophism to the extreme required infinite force while taking uniformitarianism to the extreme required infinite time—tantamount to perpetual motion [84].

Given the observation that temperature increases with depth as one descends in a cave or a mine, Thomson [85] realized that heat must move, according to Fourier's mathematical theory of heat, from the core to the surface of the earth by conduction. Moreover, since the surface of the earth does not become hotter from year to year, then there must also be a secular loss of heat from the whole earth. To deny this one way flow of heat, which is consistent with his enunciation of the Second Law of Thermodynamics, would be the same as believing "*that a clock constructed with a self-winding movement may fulfill the expectations of its ingenious inventor by going for ever.*" By estimating the current rate of heat flow and the current temperature of the core, Thomson could determine the length of time that heat had been flowing and consequently, the age of the earth. Given his analysis, Thomson concluded that "*it is quite*

certain that the solar system cannot have gone on even as at present, for a few hundred thousand or a few million years."

Thomson [85] concluded that age of the earth was less than the time needed to explain the slow and gradual origin of species by natural selection. Given that Thomson was one of the most, if not the most, prominent physicists of his day and that physics was considered to be a more exact science than either geology or biology, most scientists deferred to Thomson's authority [86]. Mark Twain [87], satirized the situation: "*Some of the great scientists, carefully ciphering the evidences furnished by geology, have arrived at the conviction that our world is prodigiously old, and they may be right but Lord Kelvin is not of their opinion. He takes the cautious, conservative view, in order to be on the safe side, and feels sure it is not so old as they think. As Lord Kelvin is the highest authority in science now living, I think we must yield to him and accept his views.***"** However, the courageous T. H. Huxley began to question the simplicity of the assumptions that went into Thomson's calculations and also questioned the hierarchy of science that led to the appearance of authority. According to Huxley [82], "*I do not presume to throw the slightest doubt upon the accuracy of any of the calculations made by such distinguished mathematicians….On the contrary, it is necessary to my argument to assume that they are all correct. But I desire to point out that this seems to be one of the many cases in which the admitted accuracy of mathematical process is allowed to throw a wholly inadmissible appearance of authority over the results obtained by them. Mathematics may be compared to a mill of exquisite workmanship, which grinds you stuff of any degree of fineness; but, nevertheless, what you get out depends upon what you put in; and as the grandest mill in the world will not extract wheat-flour from peascods, so pages of formulæ will not get a definite result out of loose data.*" Although there is no doubt and has never been doubt about the value of

mathematics and physics for the less exact sciences [88-90], Osmond Fisher [91,92], Archibald Geike [93, 94]and others [95, 96] later expressed similar views concerning the *simplistic* assumptions used by mathematical physicists.

Kelvin [84] reconsidered his assumptions although the rethinking caused him to lower his estimate of the age of the earth to 20 million years. Thomson [83] never conceded that the earth was old enough to allow for Darwin's view of the origin of species by natural selection and offered his own natural hypothesis, "*we must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about through space. If at the present instant no life existed upon this Earth, one such stone falling upon it might, by what we blindly call natural causes, lead to its becoming covered with vegetation.*" This idea of panspermia was later take up by Svante Arrhenius [97], Francis Crick [98] and Fred Hoyle and Chandra Wickramasinghe [99]. Overly simplistic assumptions lead to overly- complex, complicated and convoluted theories.

With the discovery of radioactivity [100] as a source of heating in the earth's core and a putative source of solar energy for the production of light by the sun, it became clear that Thomson's assumptions of the limits of the thermodynamic system on earth and in the sun were overly simplistic and that the calculated ages of the earth and sun could be extended greatly. In fact, radioactivity allowed the accurate determination of the age of the earth to be approximately 4.5 billion years old [101] and since then, the fundamental nature of time has been further developed by the geologists to help us understand the planet we live on [102-105]. The fact that the earth is very old is consistent with Charles Darwin's original thinking before he was intimidated by what was then current physical theory.

TIME AND THE NEGLECTED PROPERTIES OF LIGHT

When science is healthy, scientists are skeptical [106-108]. Just as there was room for T. H. Huxley to doubt Lord Kelvin's theory of the age of the earth, there is room to question the relativity of time given by Albert Einstein's Theories of Relativity [109]. L. T. More [110], wrote "*The chief incentive to the development of relativity is the desire to express all natural phenomena by a set of simple equations; and he* [Magie] *is right when he objects to making the demand for simplicity the chief purpose of a scientific theory. It is better to keep science in homely contact with our sensations at the expense of unity than to build a universe on a simplified scheme of abstract equations. And in the last analysis, a solution of our problems must be intelligible to the man of general intelligence as well as to the trained specialist. From the contradictory statements of the specialists themselves he might also include them in the class which finds the Principle of Relativity of dubious clarity.*"

By taking into consideration the Doppler effect expanded to the second order [111], which is a fundamental and ubiquitous property that can be observed whenever a source of energy, whether a developmental signal within a zebrafish embryo [112], a swimming duck, a fire engine, or a quasar, is moving relative to an observer, I have been able to craft an intelligible and testable theory of motion through absolute space and time by showing that at any temperature greater than absolute zero, light produces an optomechanical counterforce on a moving particle that has charge and/or a magnetic moment, and consequently, light itself, and not the relativity of time posited by the Theory of Special Relativity, prevents charged particles from moving faster than the speed of light [113]. The optomechanical counterforce produces a friction that is fundamentally inherent in the phenomena and cannot be considered accidental.

The Doppler effect was first conceived by Christian Doppler [114] when he guessed that if light were a wave, then the blue and red colors of binary stars might be caused, respectively, by their movement towards or away from an observer. Doppler also proposed that relative motion would not only cause a change in the color of light waves but also a change in the pitch of sound waves. Following the introduction of the newly-invented, rapidly-moving steam locomotive, C. H. D. Buijs Ballot [115] tested Doppler's theory acoustically by placing musicians on a railroad train that traveled 40 mph past musically trained observers. The stationary observers found that notes were perceived to be a half-note sharper when the train approached and a half-note flatter when the train receded. John Scott Russell [116] also noticed that when he was on a train moving at 50 to 60 mph, the pitch of the whistle of a stationary train was higher when the train moved towards it and lower when the train moved away.

Following the demonstration of the acoustic Doppler effect, William Huggins [117, 118], Vesto Slipher [119] and Edwin Hubble [120]observed the Doppler shift in the optical spectrum of the heavenly bodies and assuming that the chemicals that emitted the light had the same properties in the heavenly bodies as they had on earth, they used the Doppler shift to determine the radial velocities of the heavenly bodies.

Johannes Stark [121] realized that the Doppler effect would also apply to rapidly moving terrestrial light sources such as the positively-charged ions that made up the canal rays. Indeed, the positions of the spectral lines emitted from the atomic ions moving towards him were shifted towards the violet end of the spectrum and the positions of the spectral lines emitted from the atomic ions moving away from him were shifted towards the red end of the spectrum. Stark used the Doppler shift to determine the velocity of the positively-charged atoms.

By taking the unidirectional nature of light propagation into consideration Stark [122] defined the linear momentum (p) of a photon to be related to its energy (E) by the following formula:

$$p = \frac{E}{c} \quad (1)$$

that states that the linear momentum of a photon is equal to the ratio of its total energy to the speed of light (c). Since the energy (E) of a photon is given by:

$$E = \frac{hc}{\lambda} \quad (2)$$

where h is Planck's constant, the linear momentum of a photon is given by the following equation:

$$p = \frac{h}{\lambda} \quad (3)$$

that states that the linear momentum of a photon is inversely proportional to its wavelength.

Scattering X-rays from (using wave terminology) or colliding X-rays with (using particle terminology) an electron causes the electron to recoil. Arthur Compton [123] showed that the interaction of X-rays with an electron results in the exchange of linear momentum between the two and that the decrease in linear momentum of the scattered photon can be calculated from the observed wavelength shift consistent with the predicted Doppler red shift.

The Doppler effect experienced by aphoton can also be used to describe and explain why particles with a charge and/or a magnetic moment cannot go faster than the speed of light. To characterize the Doppler-shifted photons that will collide with or scatter from the moving particle, we have to begin with Planck's blackbody radiation law.

Max Planck [124] discovered the universal function that related the spectral distribution of light emitted by a blackbody to its temperature. According to the blackbody radiation law, the greater the temperature of a space, the greater the number of photons in that space and the shorter

their average wavelength is. This means that at any temperature greater than absolute zero, there will be photons in any space through which a particle moves. Given the relationship between linear momentum and wavelength, the greater the temperature, the shorter the average wavelength and the greater the average linear momentum of the photons in the space.

The photons in the space randomly collide with the particle moving through the sea of photons. However, the linear momentum exchange in the collisions is not symmetrical because the photons that collide with the front of the moving particle will be blue shifted as a result of the Doppler effect and the photons that collide with the back of the moving particle will be red shifted as a result of the Doppler effect. Since the photons that hit the front of the moving particle are blue shifted and the photons that hit the back are red shifted, as a consequence of the inverse relationship between the linear momentum of a photon and its wavelength, the light itself through which the particle moves produces an optomechanical counterforce directed antiparallel to the accelerating force. The greater the velocity of the particle moving through the Doppler-shifted photons the greater the difference in the linear momentum between the photons that collide with the front and push the particle backwards and the photons that collide with the back and push the particle forwards. As the particle approaches the speed of light, the optomechanical counterforce produced by the light exactly balances the accelerating force. At this point, the net force becomes zero and the particle ceases to accelerate. Consequently, light itself prevents charged particles from exceeding the speed of light [113].When one assumes that space is not empty but contains a temperature-dependent distribution of photons, then one has the degrees of freedom necessary to assign the limiting speed of light to the interaction between a particle and the Doppler-shifted photons instead of the properties of spacetime. Indeed, while he was working on the quantum nature of radiation, Einstein [125, 126] realized that the momentum of radiation

would exert a "*radiation friction*" on a moving body, but was too engaged in the General Theory of Relativity to re-interpret the electrodynamics of moving bodies in terms of dynamics.

The counterforce provided by light introduces friction due to the Doppler effect and irreversibility because the Dopplerized photons are radiated away from any and all moving particles at the speed of light and cannot be returned to the particle by reversing the accelerating force [127]. The Dopplerized photons are the carrier of entropy. The inescapable, ubiquitous and irreversible degradation of energy that results from the optomechanical counterforce provided by light ensures that the Second Law of Thermodynamics is a primary Law of Nature [127]. This solves Ludwig Boltzmann's dilemma of why natural systems evolve in time when it seemed to him that fundamental processes were all reversible. Reversibility would only exist at absolute zero where there are no photons in the space. While absolute zero is unattainable, near absolute zero, processes are nearly reversible as evidenced by superfluidity and superconductivity.

Ludwig Boltzmann was fascinated by Charles Darwin's evolutionary theory and tried to understand the evolution of atomic systems in terms of the time-reversible laws of Newtonian mechanics. Boltzmann's statistical approach to Newtonian mechanics postulated that a transition from one configuration to any other configurationis equally probable. The fact that a mechanical system is far more likely to evolve in time from a lower entropy state, characterized by one configuration to a higher entropy state, characterized by many configurations, is solely a result of chance and statistics. Consequently, Boltzmann claimed [128] that contrary to observation, there is nothing in theory to prevent the same mechanical system from evolving backwards from a higher entropy state, characteristic of the typical final or future condition to a lower entropy state, characteristic of the initial condition, and "*the two directions of time are indistinguishable in the universe, just as there is no up or down in space.*" As a result, Boltzmann considered the

Second Law of Thermodynamics, which is asymmetrical with respect to time, to be merely a secondary law of nature that is only statistically true, and not a primary law that is fundamentally true. Because Boltzmann neglected to incorporate into his theory the inherent friction that results from the optomechanical Doppler force, he was unable to see how all processes could be fundamentally irreversible in theory and practice. Consequently, he concluded that time, like space, is not fundamentally unidirectional. By incorporating the optomechanical Dopper force, the Second Law of Thermodynamics becomes a primary law based on the arrow of time being absolute and unidirectional.

The world was dramatically awaked to the idea of the relativity of space and time when in 1919, Arthur Eddington observed the deflection of starlight during an eclipse of the sun [129, 130]. The results confirmed Einstein's prediction based on the assumption that space and time were interdependent, relative, and warped by the mass of the sun. The event was recorded in *The New York Times* [131] in the autumn of that year. The *New York Times* reported that "*if those English scientists are right in feeling that the theory is strongly supported we may be forced to conclude after all that our world is in just a topsy-turvy condition, and that we must learn the theory of relativity to understand it*." They also reported that "*As all common folk are suavely informed by the President of the Royal Society that Dr. Einstein's deductions from the behavior of light observed during an eclipse cannot be put in language comprehensible to them, they are under no obligation to worry their heads, already tired by contemplation of so many other hard problems….*" This point of view was a real turnabout from the outlook of Liberty Hyde Bailey [132] who promoted the people's understanding of science and the scientific spirit as a way to promote democracy. It seemed that the common folk would never again be able to understand the world unless they joined the 12 wise men who could understand the Theory of General

Relativity. Here I will describe and explain the observed gravitational deflection of starlight—the *experimentum crucis* in favor of the General Theory of Relativity, in terms of the radial extension of a photon thus making it unnecessary to discard the geologists' and biologists' assumption of the fundamental unidirectional nature of time.

In the paper describing the research for which he explicitly got the Nobel Prize, Albert Einstein [133] wrote "*It seems to me that the observation associated with black body radiation, fluorescence, the photoelectric effect, and other related phenomena associated with the emission or transformation of light are more readily understood if one assumes that the energy of light is discontinuously distributed in space. In accordance with the assumption to be considered here, the energy of a light ray spreading out from a point is not continuously distributed over an increasing space, but consists of a finite number of energy quanta which are localized at points in space, which move without dividing, and which can only be produced and absorbed as complete units.*" But what if the photons deflected by the sun were not mathematical points traveling through a warped interdependent and relative spacetime, but photons that had radial extension traveling through absolute and independent space and time? Would the deflection of starlight be the same as Eddington observed?

By assuming that the gravity was not a Newtonian force that influenced massive objects directly but that gravity influenced the movement of mathematical point-like objects indirectly by warping an interdependent spacetime, through which they moved, Einstein [134, 135] predicted that starlight would be bent by the sun twice as much as was predicted by Johann von Soldner using the Newtonian interpretation that gravity is a force that interacts with a translating but nonrotating light corpuscle [136].

World War I prevented the planned test between the Newtonian and Einsteinian models. Almost immediately after the armistice, Eddington turned his telescope towards the heavens and measured the deflection of sunlight by comparing the positions of stars near the sun made visible during the day as a result of a solar eclipse with the positions of the same field of stars at night. The measured deflection of starlight was exactly what Albert Einstein had predicted based on the assumption that space and time are interdependent, relative and warped by the sun. Decreeing the results, the geneticist, John Burdon Sanderson Haldane[137] wrote *"I do not doubt that he* [Einstein] *will be believed. A prophet who can give signs in the heavens is always believed….Einstein has told us that space, time, and matter are shadows of the fifth dimension, and the heavens have declared their glory."*

If one makes the assumption, contrary to Einstein's, that a real photon is not a mathematical point, but has radial extension in space [88, 138], then one has the degrees of freedom to assign the observed deflection of starlight to the properties of the photon instead of the properties of spacetime.

The fact that all photons have angular momentum is really *a priori* evidence that real photons have radial extension in space and that the mathematical point-like model of photons is an oversimplification. The mechanical spin angular momentum (L) for each and every photon is given by the following equation:

$$L = \frac{h}{2\pi} = \hbar \qquad (4)$$

where ħ is known as h-bar. Interestingly, the mechanical spin angular momentum is unique in terms of conserved quantities in that its value is independent of the wavelength, and consequently, it is the only conserved property shared by all photons. The assumption that mechanical angular momentum is conserved in the interaction between light and matter is the

basis of the selection rules that describe and explain the absorption and emission spectra of chemicals.

Long before the introduction of the uncertainty principle, Planck's constant was interpreted by John Nicholson [139] as a "*natural unit of angular momentum*." Nicolson realized that the characteristic absorption and emission spectra of atoms would be intelligible if "*the angular momentum of an atom can only rise or fall by discrete amounts when electrons leave or return.*" Nicholson's idea of quantized angular momentum was applied to Ernest Rutherford's planetary model of the atom by Niels Bohr [140] who concluded: "*In any molecular system consisting of positive nuclei and electrons in which the nuclei are at rest relative to each other and the electrons move in circular orbits, the angular momentum of every electron round the centre of its orbit will in the permanent state of the system be equal to h/2π, where h is Planck's constant*."

Arnold Sommerfeld [141] not only realized the importance of angular momentum but demanded that it be conserved in any interaction between light and matter: "*…in the process of emission…, we demanded…the conservation of energy. The energy that is made available by the atom should be entirely accounted for in the energy of radiation v, which is, according to the quantum theory of the oscillator, equal to hv. With the same right, we now demand the conservation of momentum and of moment of momentum: if in a change of configuration of the atom, its momentum or moment of momentum alters, then these quantities are to be reproduced entirely and unweakened in the momentum and moment of momentum of the radiation.*"

In Einstein's mathematical point-like photon, the angular momentum and spin are quantum numbers without any mechanical analog such as rotational kinetic energy or an explanation of what is spinning since a mathematical point cannot spin [142]. I am assuming that

the mathematical point-like model of the photon with its numerical quantum definitions of angular momentum and spin has outlived its usefulness and is now too simplistic. If a real photon has radial extension, we can calculate the radius (r) of the photon to get an idea of what is spinning [88, 138, 143].

I have used Bohr's Correspondence Principle which sets a classical quantity equal to a quantum quantity to determine the radius of a photon with the observed quantized angular momentum ($\hbar$) and spin (± 1). Classically, the mechanical angular momentum of a particle is equal to $mvr\Gamma$, where m is the mass of body, v is its angular velocity, r is its radius, and Γ is a dimensionless geometric factor between 0 and 1 that equals unity for a point mass at the end of a mass-less string of radius r. For simplicity, let $\Gamma = 1$, which will give the minimum radius of the photon.

I applied Rudolf Clausius' [144] equipartition theory, which he originally introduced to explain the specific heat of diatomic gases, to the photon by assuming that the total energy of the photon is equally partitioned between the translational energy and the rotational energy. The mass of the photon is attained by giving the quantized linear momentum the corresponding classical quantity:

$$p = \frac{E}{c} = \frac{h}{\lambda} = mc \qquad (5)$$

where m is the mass of the photon and c is the speed of light. The validity of the correspondence comes from the fact that rearrangement of the above equation yields the following well-known equation:

$$E = mc^2 \qquad (6),$$

which states that the mass of the photon, which can be transferred in an interaction, is related to its total energy by the speed of light squared. The mass of the photon is a wavelength-dependent quantity and is given by:

$$m = \frac{h}{\lambda c} \tag{7}.$$

By setting $L = \frac{h}{2\pi} = mvr$, and letting $m = \frac{h}{\lambda c} = \frac{h\nu}{c^2}$, and $v = 2\pi\nu r$, where v is the angular velocity and ν is the frequency of the photon, we get:

$$\frac{h}{2\pi} = \frac{h\nu}{c^2} 2\pi\nu r^2 \tag{8}.$$

After cancelling and rearranging, we get:

$$r^2 = \frac{c^2}{(2\pi)^2\nu^2} \tag{9}.$$

Since $\frac{c^2}{\nu^2} = \lambda^2$ is the dispersion relation for light waves, we get:

$$r^2 = \frac{\lambda^2}{(2\pi)^2} \tag{10}.$$

And after taking the square root of both sides, we get:

$$r = \frac{\lambda}{2\pi} \tag{11}.$$

That is, the radius of the photon is equal to the wavelength of light divided by 2π. This means that the circumference ($2\pi r$) of a cylindrical photon is equal to its wavelength and its diameter ($2r$) is equal to approximately one-third of its wavelength.

The equation given above, which is based on the strong assumptions that the photon has energy, linear momentum and angular momentum and the arbitrary assumption concerning the geometry of the photon, describes the radial extension of a photon with a given wavelength. When the wavelength of a photon approaches zero, so does its radial extension and the photon

approaches the size of a mathematical point. When the wavelength of a photon approaches infinity, so does its radial extension and the photon approaches an infinite plane wave.

If the photon has angular momentum and radial extension, then it must have rotational motion, which means rotational energy. If the total energy of a photon were equipartitioned between the translational energy and the rotational energy, then the photon would have one-half of the expected translational energy. If a photon had infinite translational energy, it would not be deflected by the sun. If a photon had zero translational energy, it would fall into the sun. If a photon had one-half the expected translational energy because one-half of its total energy is partitioned into rotational energy, it would bend twice as much in a gravitational field and exhibit a double deflection—consistent with observation.

That is, a model of a photon with radial extension traveling through independent and absolute space and time gives the same prediction as Albert Einstein's General Theory of Relativity which assumes that mathematical point-like photons travel through an interdependent and relative spacetime that has been warped by the sun.

Einstein [145] believed in theories of principle based on the fewest possible assumptions over constructive theories based on the greatest possible number of empirical observations. Perhaps he used too few assumptions. Had Einstein included the known angular momentum of light in his assumptions, the observed deflection of starlight would be understandable in terms of Newtonian gravity acting through independent and absolute space and time without the need to invoke the relativity of space and time posited by Einstein's General Theory of Relativity [146]. Again, the relativity of space and time resulted from the disregard of a known aspect of light.

In his book, entitled, *Physics & Philosophy*, Sir James Jeans [49] wrote "*A detailed investigation of the sources of our ideas have shown that there is only one type of model or picture which could be intelligible to our restricted minds, namely one*

*in mechanical terms. Yet a review of recent physics has shown that all attempts at mechanical models or pictures have failed and must fail. For a mechanical model or picture must represent things as happening in space and time, while it has recently become clear that the ultimate processes of nature neither occur in, nor admit of representation in, space and time. Thus an understanding of the ultimate processes of nature is for ever beyond our reach; we shall never be able—even in imagination—to open the case of our watch and see how the wheels go round. The true object of scientific study can never be the realities of nature, but only our own observations of nature."*By adopting the biologists' and geologists' view of time, we can have a mechanical explanation that is intelligible to all.

HIERARCHICAL OR EGALITARIAN STRUCTURE OF SCIENCE

So this is my plea for a less hierarchical and more egalitarian structure of science (Figure 2) much like that that existed in the Lunar Society that included polymaths, "*Birmingham philosophers*" and "*fellow schemers*" such as Erasmus Darwin, James Watt, Matthew Boulton, James Keir [147], Thomas Day, Samuel Galton, Augustus Johnson, Jonathan Stokes, John Whitehurst [148], Richard Lovell Edgeworth, William Small, William Murdoch, William Withering, Josiah Wedgwood and Joseph Priestley [149, 150]. An egalitarian structure that appreciates diversity has no need to marginalize or ignore those who question the authority of the mathematical physicists, and to label them as contrarians or crackpots [151, 152]. I hope that I have given sufficient reason to show that the conflict between the mathematical physicists' view of time and the geologists' and the biologists' view of time is only apparent and can be

reconciled by reinstating neglected physical phenomena, including the Doppler effect expanded to second order and the mechanical angular momentum of light, into fundamental physical theories. I have argued, like Huxley, Fisher and Geikie before me, that the mathematical physicists' theory of time is based on kinematic assumptions that are too restrictive and simplistic. If this is not the case, then time is not fundamental, and the mathematical physicists' theory of the symmetry of time must be applied to evolution. If the mathematical physicists' view of time is correct, we must heed Eddington's [153] advice: "*time does not exist in the physical universe and is a wholly subjective impression...we must be careful not to treat the usual past-to-future presentation of the history of the physical universe as truer or more significant that a future-to-past presentation. In particular we must drop the theory of evolution, or at least set alongside it a theory of anti-evolution as equally true and equally significant.*

I say to [a professional scientist]*: 'You are a teacher and leader whose duty it is to inculcate a true and balanced outlook. But you teach, or without protest allow your colleagues to teach, a one-sided doctrine of evolution…. Why do you suppress all reference to the sequence from future to past, which according to you is an equally significant sequence to follow? Why do you not tell us the story of anti-evolution? Show us how from the diverse species existing to-day Nature anti-evolved clumsier forms, more and more unfitted to survive…. Narrate the whole story of anti-progress from future to past, and depict the activity of Nature as a force which takes this great work or architecture around us and—makes a hash of it."*

Following the discovery of radioactivity, Frederick Soddy [1] described the hullabaloo that occurred between the physicists and biologists with regards to the age of the earth in the quote that can be found at the beginning of this paper. By presenting the strong case for the absolute and unidirectional arrow of time marshalled by the biologists and geologists, and

pointing out the physical phenomena such as the optomechanical friction produced by the Doppler effect expanded to second order and the mechanical angular momentum of the photon that have been neglected by the mathematical physicists, I show that as biologists we can confidently base our theories and experiments on the assumption that the arrow of time is absolute and unidirectional. I imagine that, in the future, the idea that time is an illusion will also make strange reading, to the scientist and layperson alike, in the light of evolution.

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Figure Legends

Figure 1. Comte's Hierarchy of the Sciences. According to Comte, the exactness of the science is inversely proportional to its complexity. He arranged the sciences in a hierarchical order: mathematics, astronomy, physics, chemistry (and its derivative geology), biology (and its derivatives botany and zoology), and sociology, where the former on the list were (1) historically older than, (2) logically simpler than (3) more widely applicable than, and (4) independent of the latter sciences on the list. According to Comte, no branch of knowledge can be effectively pursued without a competent knowledge of the branches that precede it in the hierarchy.

Figure 2. Proposed relationship among the sciences that were enumerated by Comte. This arrangement allows for a better understanding of each science that comes from egalitarian respect. For example, the sociologists of science are important to the understanding of the assumptions used in physics.

Figure 1.

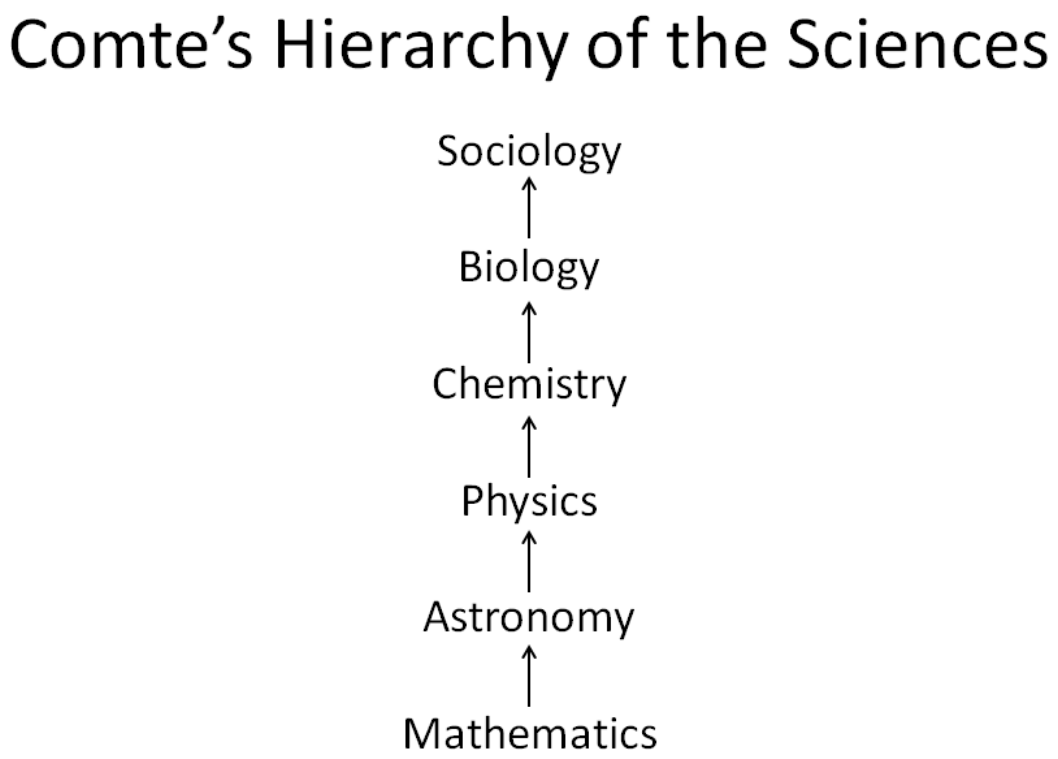

Figure 2.