Life: If Meaning is Ambiguous, Inequality Appears Inescapable

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Abstract

Here we explore how a fundamental organizational principle can contribute to our understanding of life and its meaning. We start from the observation that the universe is composed of a vast collection of discrete systems, i.e. systems that are composed of distinguishable entities. All discrete systems have two co-existent sets of properties only one of which is dependent on meaning. A time-honored example is the book, a discrete system wherein the meaning of the words permits communication from author to reader whilst simultaneously the relative frequencies of the words fall into a consistent mathematical pattern regardless of the book or the language. We suggest that this mathematical pattern (an emergent property that is independent of both meaning and mechanism) is shared by all discrete systems whether physical or biological in nature. The ideas discussed here are developments of published arguments rooted in information theory and statistical mechanics and we note numerous examples that constitute empirical tests of its predictions. If the theoretical development presented here is correct it has implications for the meaning of life and it also leads to the conclusion that what we perceive as gross inequality is an emergent and essentially inevitable property of life.

1 Keywords

Meaning of Life; Inequality; Discrete System; Power-Law; Conservation of Hartley-Shannon Information; Mechanism

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2 Introduction

Whether or not life has ultimate meaning has been the basis of a recent interesting exchange of ideas in this journal,[1] presented primarily in the context of philosophy and cognitive psychology. Here we ask whether stripping away all meaning and mechanism from discrete systems helps us make better sense of the way that life and the world are organized.

As a preliminary, let us return to a discussion of books and the words within them. It has been known for almost a century[2] that if we consider the words in a book as having no intrinsic meaning but with the sole property of being different (distinguishable) one from another, then if we count the frequencies of each word and rank them in descending order of occurrence, then a very strange phenomenon emerges. Independently of the language of the book, who wrote it or its subject matter, those word frequencies form an uncannily consistent pattern. This pattern manifests itself as the second most frequent word occurring about half as often as the first word, the third most frequent word occurring about a third as often as the first word, the fourth most frequent word occurring about one fourth as often as the first word and so on until we have exhausted all the unique words in the book. This pattern is one example of a frequency distribution known as a *power-law*.

One of the most insidious properties of a power-law is its embodiment of gross inequality; in the example above, the word in the hundredth category will be used just 1% as frequently as the most-used word. We will return to the topic of inequality inherent to a power-law relationship later but for now we will examine more closely the issue of word frequency. Whilst authors around the planet are pounding away on their keyboards on any subject in any language, the relative frequency of the words they use is pre-ordained. The word frequencies will arrange themselves along a power-law as we have just described, even though each book has its own vocabulary and the identical word will appear at a different relative frequency in different books. For

[1] Rivka Weinberg. “Ultimate Meaning: We Don’t Have It, We Can’t Get It, and We Should Be Very, Very Sad”. In: *Journal of Controversial Ideas* 1.1 (2021). ISSN: 2694-5991. DOI: 10.35995/jci01010004. URL: https://journalofcontroversialideas.org/article/1/1/132; Nelson Cowan. “Life Is Pointless—Good Point...and How Do You Feel about That?” In: *Journal of Controversial Ideas* 2.1 (2022). ISSN: 2694-5991. DOI: 10.35995/jci02010013. URL: https://journalofcontroversialideas.org/article/2/1/173; Michael-John Turp, Brylea Hollinshead, and Stephen Rowe. “Don’t Worry, Be Happy: The Gettability of Ultimate Meaning”. In: *Journal of Controversial Ideas* 2.1 (2022). ISSN: 2694-5991. DOI: 10.35995/jci02010012. URL: https://journalofcontroversialideas.org/article/2/1/177.

[2] George K. Zipf. *Psycho-Biology of Languages: an introduction to dynamic philology.* Houghton-Miflin, Boston MA, 1935.

example, *and* is the fourth most frequently used word in the Victorian novel Three Men in a Boat (To Say Nothing of the Dog) by Jerome K. Jerome, but it is the tenth most frequently used word in Tractatus Logico-Philosophicus by Ludwig Wittgenstein. This conformity to a power-law in word frequency appears to be the case for all books ever written in any language and presumably for all books ever to be written. It doesn't even matter how thick the books or indeed documents are, provided they have a reasonable number of words. So how can this be? Do we not have agency in the choice of what we write? In one sense, it appears not.

The power-law in relative word frequency is an example of an *emergent property.* This term is often used to describe phenomena we don't understand terribly well, if at all. However, a recent general theory of discrete systems (Conservation of Hartley-Shannon Information or CoHSI) embeds information theory in a statistical mechanics framework and predicts that all qualifying discrete systems, whether physical or biological, will show the emergent property of one of two novel distributions, both of which are dominated by a power-law.[3] These distributions with a power-law at their heart arise purely probabilistically as the overwhelmingly most likely equilibrium state; the theory explicitly strips the components of any discrete system of their meaning, and the probabilistic outcome is inherently independent of any or all mechanisms. Thus meaning and mechanism, whether understood as in everyday use or in any more fundamental sense have no role in the global, emergent properties of discrete systems. The fundamental implication of this theory is that the emergent properties of essentially every discrete system in the universe – atoms, craters on the moon, organisms, ecosystems and the evolution of life, literature, computer programs, wealth, death, motor car sales, banana production, rugby playing and beer-drinking, which are just a few of the systems that share a power-law distribution,[4] can be understood only if we accept that any concepts of meaning and mechanism are beside the point. This is a falsifiable claim as the predictions of CoHSI theory, particularly its most counter-intuitive predictions, can be tested.

[3] Les Hatton and Gregory Warr. "Strong evidence of an information theoretical conservation principle linking all discrete systems". In: *R.Soc. open sci* 6.191101 (Nov. 2019). URL: http://dx.doi.org/10.1098/rsos.191101; L. Hatton and G.W. Warr. *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe.* Bluespear Publishing, 2022. ISBN: 978-1-908-42204-0.

[4] Hatton and Warr, *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe*; Geoffrey West. *Scale: The Universal Laws of Life, Growth and Death in Organisms, Cities and Companies.* Penguin Random House LLC, New York, NY. ISBN: 9780143110903.

3 The Unreasonable Effectiveness of Mathematics

Although not conceived as a Popperian investigation,[5] the ideas presented here arose from curiosity about reproducibly observable patterns in computer software, which were distributions of program sizes that were always dominated by power-laws, even in software developed using modern software structuring principles such as Object Orientated Development, in which such an outcome is not expected.[6]

We then realized that generations of biologists of a mathematical inclination have observed, essentially everywhere they have looked, a similarly simple power-law relationship that describes the distribution of properties in many biological systems.[7] The examples of biological systems that manifest this particular behavior span vast scales of time and space. At the longest time-scale they include the size of extinction events[8] and the time between initiation and extinction of families of organisms in the fossil record.[9] When we look at the branching of the evolutionary tree the pattern is that of a power-law.[10] At the smallest scale power-laws describe the relative concentrations of proteins and messenger RNAs inside living cells[11] and the relative frequency of short nucleotide sequence motifs in genomes[12] . In populations the frequency and severity of infectious disease outbreaks follows a power-

[5] Karl Popper. *The Logic of Scientific Discovery.* Routledge, 1959, p. 513. ISBN: 1-1344-7002-9.

[6] A. Potanin et al. "Scale-free geometry in OO programs". In: *Comm. ACM.* 48.5 (May 2005), pp. 99–103.

[7] Thomas Gisiger. "Scale invariance in biology: coincidence or footprint of a universal mechanism?" In: *Biol Rev Camb Philos Soc* 76 (2001), pp. 161–209. URL: `https://doi.org/10.1017/S1464793101005607`.

[8] M. E. J. Newman. "Self-organized criticality, evolution and the fossil extinction record". In: *Proceedings of the Royal Society of London. Series B: Biological Sciences* 263.1376 (1996), pp. 1605–1610. DOI: `10.1098/rspb.1996.0235`.

[9] J. John Sepkoski Jr. "Ten Years in the Library: New Data Confirm Paleontological Patterns". In: *Paleobiology* 9.1 (1993), pp. 43–51.

[10] Chi Xue, Zhiru Liu, and Nigel Goldenfeld. "Scale-invariant topology and bursty branching of evolutionary trees emerge from niche construction". In: *Proceedings of the National Academy of Sciences* 117.14 (2020), pp. 7879–7887. ISSN: 0027-8424. URL: `https://www.pnas.org/content/117/14/7879`.

[11] Stanislav Naryzhny et al. "Zipf's law in Proteomics". In: *J. Proteomics Bioinform* 10 (2017), pp. 79–84. DOI: `10.4172/jpb.1000427`; Chikara Furusawa and Kunihiko Kaneko. "Zipf's Law in Gene Expression". In: *Phys. Rev. Lett.* 90 (8 2003), p. 088102. URL: `https://link.aps.org/doi/10.1103/PhysRevLett.90.088102`.

[12] Xiaocong Gan, Dahui Wang, and Zhangang Han. "A growth model that generates an n-tuple Zipf law". In: *Physica A Statistical and Theoretical Physics* 390 (Mar. 2011), pp. 792–800. DOI: `10.1016/j.physa.2010.11.001`.

law.[13] Genetic variants (alleles) in populations show these distributions[14] and in ecology they are frequently observed, as in the species richness/area relationship classically described by MacArthur and Wilson.[15] Many more examples can be found.[16,17] This remarkably frequent occurrence of scale-invariant (power-law) behavior led Gisiger to speculate that this may reflect an underlying universal mechanism.[18]

Power-law behaviors in human society often extend beyond the boundaries that we typically regard as those of biology; they occur in areas intimately associated with creativity, state actors, human organizations and our emergent collective behavior.[19] Well known examples include as discussed above the frequency of word use in texts[20] and the distribution of wealth first reported by Pareto.[21] A startling and disturbing observation that was reported over a century ago and has since been confirmed by rigorous statistical analysis is the scale of casualties in warfare.[22]

These diverse power-law behaviors are suggestive of the "Unreasonable effectiveness of mathematics" in describing the natural world.[23] But what

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[13] Rhodes C.J. and Anderson R.M. "Power laws governing epidemics in isolated populations". In: *Nature* 381 (1996), pp. 600–602; Bernd Blasius. "Power-law distribution in the number of confirmed COVID-19 cases". In: *Chaos* 30 (2020), p. 093123. URL: https://pubmed.ncbi.nlm.nih.gov/33003939.

[14] Noa Slater et al. "Power laws for heavy-tailed distributions: modeling allele and haplotype diversity for the national marrow donor program." In: *PLoS computational biology* 11 (2015), p. 1004204. URL: https://doi.org/10.1371/journal.pcbi.1004204.

[15] R. Macarthur and E.O. Wilson. *The Theory of Island Biogeography.* Princeton University Press, 1967, p. 203.

[16] Hatton and Warr, "Strong evidence of an information theoretical conservation principle linking all discrete systems".

[17] Hatton and Warr, *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe*; West, *Scale: The Universal Laws of Life, Growth and Death in Organisms, Cities and Companies.*

[18] Gisiger, "Scale invariance in biology: coincidence or footprint of a universal mechanism?"

[19] Hatton and Warr, *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe*; West, *Scale: The Universal Laws of Life, Growth and Death in Organisms, Cities and Companies.*

[20] Zipf, *Psycho-Biology of Languages: an introduction to dynamic philology.*

[21] Vilfredo Pareto. *Cours d'économie Politique.* Vol. 1. Librairie de l'Université de Lausanne, 1896, p. 416.

[22] Aaron Clauset. "On the Frequency and Severity of Interstate Wars". In: *Lewis Fry Richardson: His Intellectual Legacy and Influence in the Social Sciences.* Ed. by Nils Petter Gleditsch. Cham: Springer International Publishing, 2020, pp. 113–127. ISBN: 978-3-030-31589-4. DOI: 10.1007/978-3-030-31589-4_10. URL: https://doi.org/10.1007/978-3-030-31589-4_10.

[23] E.P. Wigner. "The Unreasonable Effectiveness of Mathematics in the Natural Sciences". In: *Communications in Pure and Applied Mathematics* 13.1 (1960), pp. 1–14.

can be going on that facilitates this unreasonable effectiveness? We can envisage primarily two explanations. First, we could postulate that the specific circumstances that underlie scale independent phenomena in computer science, literature, wealth, warfare, cellular biochemistry, genome structure, epidemics, ecosystem dynamics and the evolution of life itself can all coincidentally generate precisely the same outcome. However, the invocation of a particular mechanism or set of mechanisms as the generator of identical outcomes in such diverse biological and human cultural systems seems tenuous to say the least; we are unaware of any predictive and testable theory that could achieve this. There is however a second type of possible explanation for such widespread distribution of power-law behavior in living systems. There could indeed be a fundamental natural law that generates such ubiquitous behavior as suggested by Gisiger.[24] This is a suggestion that biologists tend to resist. Indeed, biologists seem to have given up the search for fundamental physical laws that have such a widespread impact on living systems and have reached a consensus that living systems are just too diverse, too rich in detail and too complex to be explicable globally by simple, universal natural laws.

We will argue now that this is too defeatist. It is indeed possible to expose emergent properties of biological systems, but this requires stripping away *all* local mechanism and meaning. This is a radical but by no means unprecedented step, as we will describe. But once this abstraction of biological systems from mechanism and meaning has been achieved it is straight-forward to show that the well-established framework of statistical mechanics predicts the power-law behavior that is seen so broadly in all discrete systems, living or not. Statistical mechanics does not enforce this behavior, it simply shows that it is overwhelmingly likely; there is no associated mechanism.

3.1 Conservation of Hartley-Shannon Information (CoHSI)

The full argument that leads to CoHSI theory, with supporting evidence that it predicts the most likely state of all discrete systems, is laid out in detailed publications[25] but in summary there are only two important steps. First, discrete systems must be visualized in a manner that is universal and devoid of specific context; this can be achieve by defining the total information

DOI: 10.1002/cpa.3160130102.

[24] Gisiger, "Scale invariance in biology: coincidence or footprint of a universal mechanism?"

[25] Les Hatton and Greg Warr. "Protein Structure and Evolution: Are They Constrained Globally by a Principle Derived from Information Theory?" In: *PLOS ONE* 10 (2015), e0125663. DOI: 10.1371/journal.pone.0125663; Hatton and Warr, "Strong evidence of an information theoretical conservation principle linking all discrete systems".

content of any system simply as a function of the number of ways in which the pieces of that system can be arranged. *The critical step is to require only that different pieces can be distinguished one from another, rather than enjoying any particular meaning,* an approach first championed by Ralph Hartley and then Claude Shannon.[26]

Then, given a system for which the total size (i.e. the number of pieces) and total information content are known, the methods of Boltzmann[27] can be used to find the most likely distribution of properties for any possible system *simply from this knowledge of their total size and total information content.* From this simple mechanism- and meaning-free approach, the remarkable result emerged that the overwhelmingly most likely distribution of properties in the given system will be one of two novel possibilities, but both of which have at their heart a power-law.[28] This result is general to all discrete systems of any size or total information content, providing in passing a proof of Zipf's Law.[29]

This may seem to be troublingly counter-intuitive but it simply recognizes that all discrete systems have two *co-existent* sets of properties, those flowing from meaning and mechanism, the standard tools of reductionism in which the life sciences in particular have excelled, but also a new set of properties that flow from freedom from mechanism and from meaning and which are entirely complementary. This latter set would be classed as emergent properties that have not been considered previously.[30]

4 The Near Inevitability of Gross Inequality

The foregoing discussion implies the existence of a novel natural law which rather than being tied to biological systems through meaning, is simply shared with non-biological systems through lack of specific mechanism or meaning. The embedded power-law is a classical example of a distribution

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[26] R.V.L. Hartley. "Transmission of Information". In: *Bell System Tech. Journal* 7 (1928), p. 535; C.E. Shannon. "A mathematical theory of communication". In: *Bell System Tech. Journal* 27 (July 1948), pp. 379–423; C.E. Shannon. "Communication in the Presence of Noise". In: *Proc. I. R. E.* 37 (1949), p. 10.

[27] A. Sommerfeld. *Thermodynamics and Statistical Mechanics.* Academic Press, New York NY, 1956; Mike A. Glazer and Justin S. Wark. *Statistical Mechanics. A survival guide.* OUP, 2001, p. 142. ISBN: 978-0-19-850816-8.

[28] Hatton and Warr, "Strong evidence of an information theoretical conservation principle linking all discrete systems".

[29] Zipf, *Psycho-Biology of Languages: an introduction to dynamic philology.*

[30] Hatton and Warr, "Strong evidence of an information theoretical conservation principle linking all discrete systems".

that always manifests as marked inequality; thus this novel law has been referred to as "The Fundamental Law of Inequality." This Law, through its statistical mechanical heritage, is related to but distinct from the Laws of Thermodynamics, because it does not involve energy, merely configuration. The outcome of its operation is however nearly inevitable.

4.1 Inequalities in Human Society

Wealth is the inequality with which we are most familiar and although great disparities in wealth were first documented as a power-law distribution by Pareto[31] in the Italy of his time, it appears that inequality of wealth has historically been a component of essentially all civilizations for which records survive. Furthermore the distribution of wealth in all these societies appears to follow a power-law.[32] However, although wealth may present the starkest of disparities, many other aspects of our societies show exactly the same features, especially the "long tail" that is an inevitable characteristic of a power-law distribution, giving it its property of gross inequality. The documented examples of these constitute a long list, from beer-drinking and rugby playing to the population of cities, and from motor car purchases and naming babies to polluting the oceans.[33] Here we will select just a few (in addition to wealth) to illustrate how these can pose particular ethical and policy challenges.

If features of our social organizations are categorized such as religion and sexual orientation the evidence is that these most likely also follow a power-law distribution.[34] Thus the long tail of these distributions will inevitably be with us; in the case of religion many minority faiths, sects and cults with few adherents will occupy the long tail. Suppression of minority faiths disturbs the equilibrium state and inevitably over time the system will, purely probabilistically, re-equilibrate and new (or revived) minority faiths will repopulate the tail of the distribution. The same argument holds for minority categories of sexual orientation that lie in the tail of the distribution. The occupancy of these categories is essentially inevitable, and arguments about whether or not they constitute an active choice miss the point. As long

[31]Pareto, *Cours d'économie Politique.*

[32]Hatton and Warr, *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe.*

[33]Hatton and Warr, *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe*; West, *Scale: The Universal Laws of Life, Growth and Death in Organisms, Cities and Companies.*

[34]Hatton and Warr, *Exposing Nature's Bias: the Hidden Clockwork behind Society, Life and the Universe.*

as there are categories in the spectrum of human sexual orientation, then for purely probabilistic (and mechanism-independent) reasons there will be individuals in these categories.

4.2 Can Inequalities be Mitigated?

The influence of CoHSI is not a strait-jacket - for those systems over which we have some measure of influence, the inequality, if we deem it unacceptable, can be mitigated (but not eliminated) by strong and sustained effort. The best evidence that mitigation takes substantial and sustained effort comes from the disparities of wealth in the societies that preceded the communist regimes of China and the USSR and that were in large measure suppressed (but not eliminated) by communist policies. This suppression of wealth disparities by communist regimes involved methods that can politely be described as brutal and in recent decades once they were relaxed wealth inequality rapidly grew again in both China and Russia, reaching quickly the present levels that are comparable to those of the capitalist societies of the West. Most Western societies avoid the more heavy-handed tactics of communist regimes and actively employ policies such as transfer payments to mitigate inequality and improve the financial status of the poorest families. In many Western countries these policies fall far short of effective mitigation, one impediment to their implementation being the moral judgement that the poor are in some way responsible for their lot in life. This is once again beside the point ... occupancy of the categories of the least well-off in society is unfortunately inevitable and independent of particular mechanism.

Certain inequalities, for example those of religion or sexual orientation, are not obvious candidates for mitigation but instead the fact that these inequalities are essentially inevitable and therefore always with us should encourage a greater degree of tolerance.

One of the most troublesome of inequalities is that of casualties in warfare. The power-law nature of these casualties was first noted by Lewis Fry Richardson, a mathematician who worked in a Friend's Ambulance Unit during the First World War. Subsequent analyses with additional data and rigorous statistical methods[35] have confirmed Richardson's observations, a conclusion that is particularly disturbing. The highest burden of casualties in any conflict was suffered in the Second World War, in which as many as 75 million people may have died. Because of the power-law relationship a future major war could threaten a scale of slaughter that substantially exceeds that of the Second World War. The conundrum we face in attempting

[35] Clauset, "On the Frequency and Severity of Interstate Wars".

to reduce the threat of war is that our instinctive approach is to identify the mechanisms that lead to war so that we can manipulate them to our advantage. Unfortunately any system guided by CoHSI is mechanism-indifferent - this greatly complicates any attempt to manipulate the system at the fundamental mechanistic level. In this regard warfare is unlike wealth, where the disparities can be readily reduced if we have the political will.

4.3 Why do we see Distributions that are not Power-Laws?

An obvious question to ask is that if the Fundamental Law of Inequality is operating continuously on discrete systems, why do many distributions appear that are not power-laws, for example the bell-shaped Gaussian (or normal) distribution, the log-normal distribution, the gamma distribution etc.? One possible explanation appears to be that the Fundamental Law predicts the equilibrium state of a system but as noted above it is not a straitjacket. If a qualifying discrete system is in transition, our data are sparse or of poor quality, the distribution may well appear as ambiguous.

We can give an example involving proteins, which are essential components of all living systems and come in all shapes and sizes. All proteins consist of amino acids coupled together into a chain, which can contain as many as 10,000 or more amino acids. There are usually considered to be 20 different amino acids that can be combined in almost unlimited ways to make a protein and each of these 20 amino acids has a different chemical structure and thus each amino acid has a characteristic molecular mass. Over 200 million different proteins are known and are collected in an invaluable database.[36] If the distribution of lengths of the proteins in this database measured simply by the number of amino acids in the chain is analysed, then an unequivocal power-law distribution has been observed as predicted by the Fundamental Law of Inequality.[37] However, each protein has a different sequence and composition of amino acids, and since each amino acid has a distinctive molecular mass, we can also ask about the distribution of molecular masses. When for example we look at all proteins of a particular specified length, let us say 200 amino acids, we might expect to observe a normal distribution of molecular masses and in this we are not disappointed. However,

[36] The UniProt Consortium. "UniProt: the universal protein knowledgebase in 2021". In: *Nucleic Acids Research* 49.D1 (Nov. 2020), pp. D480–D489. ISSN: 0305-1048. DOI: 10.1093/nar/gkaa1100. eprint: https://academic.oup.com/nar/article-pdf/49/D1/D480/35364103/gkaa1100.pdf. URL: https://doi.org/10.1093/nar/gkaa1100.

[37] Hatton and Warr, "Strong evidence of an information theoretical conservation principle linking all discrete systems".

as we expand the window of protein lengths to say 190-210 amino acids, then to 150-250 amino acids and so on, the apparent normal distribution rapidly disappears, and the power-law re-establishes itself.

This result arising from a focused or restricted observation of one part of a much larger power-law distribution is a phenomenon that we suspect may be of wide occurrence, suggesting that many observed distributions (e.g. normal, log-normal, gamma distributions etc.) quite possibly arise from the observation of a selected segment or a fragment of a much larger discrete system. Lyon[38] presents a detailed discussion of why distributions that are apparently normal are on the one hand frequently observed in nature, while on the other hand failing to qualify as normal distributions. We conjecture that scientists are often interested to fit their data to well-described distributions, rather than making predictive models from theory and then testing if the data fit the predictions. This topic certainly warrants further investigation, and in the following section we discuss how the approach of developing predictive models on the basis of theory and then subjecting the model to experimental test can be applied to the ideas about meaning and inequality that we have expressed here.

To summarize these ideas, we argue that only by discarding the concept of intrinsic meaning can the shared global properties of all discrete systems, which include the gross inequality that plagues many aspects of human societies, be understood and appropriate mitigation efforts undertaken.

4.4 Are these Ideas falsifiable?

Falsifiability, the linked concept of reproducibility and indeed even the existence of an objective truth to be discovered[39] are important subjects that have all received a great deal of attention from the scientific and philosophical communities. We mentioned earlier in this article that the ideas presented here did not arise from a consciously Popperian approach to the problem of meaning in the world.[40] Prior to Popper however, experimental evidence was already at the heart of scientific progress throughout the 19th and early 20th centuries. The first reaction to a new result was an immediate attempt to reproduce it independently. In some cases the independence of the observations was already built in; such was the attempt by Sir Arthur Eddington in the 1919 total solar eclipse to falsify Einstein's predictions of distortions

[38] A. Lyon. "Why are Normal Distributions Normal ?" In: *Brit. J. Phil. Sci.* 65 (2014), pp. 621–649. URL: `https://aidanlyon.com/normal_distributions.pdf`.

[39] T.S. Kuhn. *The Structure of Scientific Revolutions.* University of Chicago Press, 1962, p. 264. ISBN: 978-0-22-645811-3.

[40] Popper, *The Logic of Scientific Discovery.*

to the orbit of Mercury to account for General Relativity. Two expeditions were dispatched to acquire two sets of photographic plates independently. Even this was almost insufficient as both sets were lost and the falsification attempt in the end depended on Eddington's on-site analysis on one of the expeditions. This result of course did not constitute proof of General Relativity but confirmed it as a conditional truth. It embodied a consensus in science that has grown slowly over the centuries that continuing failure to falsify a theory on the basis of new evidence and repeated testing gradually builds trust in that theory. A century after Einstein's 1915 paper, we are still launching unsuccessful attempts to falsify the theory.[41]

One of Popper's incisive contributions to science and philosophy was to observe that theories had to be capable of such falsification, leading to uncompromising viewpoints such as that of the 20th century physicist Richard Feynman:

> *"It doesn't matter how beautiful your theory is, it doesn't matter how smart you are. If it doesn't agree with experiment, it's wrong."*

This is the essence of the scientific method and it is what distinguishes science from the ever-shifting sands of human opinion.

The reason we raise the subject here is that there is a growing existential crisis in science.[42] Many results simply are not reproducible and their theories non-falsifiable. The problem is multi-faceted and ubiquitous; it is partly due to the fact that there are often no underlying falsifiable theories, but in addition it is increasingly exacerbated by the growing dependence of investigations on inherently non-reproducible scientific computation[43] and on datasets that are simply enormous and can be analyzed only by computation. Human pressures such as competition for funding, the role of journals, how academics are assessed and remunerated and numerous other factors merely make reproducible science more difficult to achieve. Some disciplines have been singled out by commentators; examples include theory in evolu-

[41] C.W. Chou et al. "Optical Clocks and Relativity". In: *Science* 329 (2010), pp. 1630–1633. URL: `https://www.science.org/doi/abs/10.1126/science.1192720`.

[42] Editorial. "Code share". In: *Nature* 514.536 (2014). DOI: `doi:10.1038/514536a`.

[43] R.D. Peng. "Reproducible Research and Biostatistics". In: *Biostatistics* 10.3 (2009), pp. 405–408; R.D. Peng. "Reproducible Research in Computational Science". In: *Science* 334.6060 (2011), pp. 1226–1227. URL: `doi:10.1126/science.1213847`; Darrell C. Ince, Leslie Hatton, and John Graham-Cumming. "The case for open program code". In: *Nature* 482 (Feb. 2012). doi:10.1038/nature10836, pp. 485–488.

tionary biology,[44] computer science[45] and earth science,[46] but the problem is clearly far more pervasive as evidenced by its choice as the subject of a *Nature* special edition.[47]

These considerations motivate us to be explicit about falsifiability. While CoHSI and the associated Fundamental Law of Inequality have implications for many aspects of human society and human behavior, this is at its heart a physical theory rooted in the methods of statistical physics and thus in the Popperian sense it is falsifiable by experiment.

In this context we can state clearly that CoHSI and the associated Fundamental Law of Inequality are open to refutation by experimental test of their predictions. Of particular importance are predictions that are counter-intuitive and that would not be self-evident without the insights derived from CoHSI theory. The outstanding cooperation of the scientific, sociological and other communities continues to generate many vast, constantly growing and publicly accessible databases that provide opportunities with which to make novel testable predictions based on the Fundamental Law of Inequality. Efforts to date[48] have failed to falsify predictions of this Law, including some of its more counter-intuitive predictions. Even then, we should point out that there is a degree of resilience built in to CoHSI which devolves from its statistical mechanical heritage and the fact that it is not a straitjacket as we intimated earlier. It makes no guarantees but states only what is overwhelmingly likely to happen.

CoHSI and the Fundamental Law of Inequality then exhibit some attractive features. They are ubiquitous in application to both biological and non-biological systems, eminently falsifiable with existing datasets of very

[44] Bertram G. Jr. Murray. "Are ecological and evolutionary theories scientific?" In: *Biol Rev Camb Philos Soc.* 76 (2001), pp. 255–89. URL: `https://doi.org/10.1017/s146479310100567x`.

[45] Walter F. Tichy et al. "Experimental evaluation in computer science: a quantitative study". In: *J. Syst. Softw.* 28 (1 Jan. 1995). 10.1016/0164-1212(94)00111-Y, pp. 9–18. ISSN: 0164-1212. URL: `http://portal.acm.org/citation.cfm?id=209090.209093`.

[46] Anton M. Ziolkowski. "Further Thoughts on Popperian Geophysics–the Example of Deconvolution". In: *Geophysical Prospecting* 30 (1982), p.155–165. URL: `doi:10.1371/journal.pcbi.1003285`.

[47] M. Baker. "1,500 scientists lift the lid on reproducibility". In: *Nature* 533.7604 (May 2016).

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varied provenance, free of any absolute or conditional meaning in symbols and require no assumptions about or knowledge of mechanisms (although they do not dismiss the obvious fact that mechanisms exist). Any competing theories should have at least this set of properties.