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Reconsidering the Foundations of Physics: From Symmetry to Asymmetry as a Guiding Principle

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Abstract: ***This essay examines the role of symmetry and asymmetry across the natural sciences, with particular emphasis on physics. Symmetry has historically guided mathematical formalism and theoretical development, yet its meaning in physics has diverged from its everyday and biological meanings, where it signifies proportion, structure, and observable patterns. Historical developments from geometry and crystallography to modern gauge theories are reviewed, highlighting how the pursuit of symmetry has shaped, though sometimes constrained, conceptual understanding. Contrastingly, asymmetry emerges as a fundamental principle underpinning physical phenomena, the arrow of time, molecular chirality, and the evolution of life. By analysing examples from particle physics, cosmology, and chemistry, the essay argues that embracing asymmetry provides explanatory power where symmetry-based frameworks fall short. The discussion advocates for a conceptual shift in physics: moving beyond the dogma of symmetry to integrate asymmetry as a guiding principle for understanding the dynamic, directional, and structured reality of the universe.***

Keywords: symmetry, asymmetry, symmetry breaking, chirality, invariance

1. Introduction

Conventional physics has long adhered to a one-directional notion of time – in itself already an asymmetry! – which, within the framework of Einstein's theories necessitates complex mathematical constructions. Undoubtedly, the progress made when applying his principles in the quest of understanding nature was enormous. However, the framework of a four-dimensional spacetime hit hard on its conceptual limits, when it came to explaining how the curvature of space could be understood as an underlying principle of a theory of all – the Theory of Everything (ToE) as it is called. When it comes to describing black hole formation there is a clear temporal direction, which Einstein's field equations do not single out. These equations are fully covariant, treating all coordinate systems symmetrically; yet this symmetry fails to capture the inherent temporal direction of gravitational collapse. Also other realms of importance like causality and event realisation remain vague and unexplained when put in the light of General Relativity.

Physicists often resist any renewal of their philosophy, although a philosophically and logically grounded simplification could overcome the complex framework they created. Yet, most of the heavy formalism created in modern physics comes from forcing a one-directional time concept into places where it does not fit. All the minute steps, the advanced algebra, the patched-on tensors, the manipulations necessary to keep their models consistent will not be necessary if one keeps in mind that *moving in Space means moving in Time*. And that Time – ever since renowned philosophers started speculating about it – is intimately interwoven with Space.

A comparative examination of contemporary symmetry considerations *vs* naturally abundant asymmetry will follow, outlining the limitations of the symmetry-based interpretations of nature, and asymmetry as the real motor of our universe.

1) Symmetry as a Guiding Principle

The importance of symmetry for humanity emerged early, as can be seen in architectural remains all over the world. But symmetry existed long before humans constructed Egyptian and Mesoamerican pyramids, Greek and Indian temples, and European churches throughout the Middle Ages: Still today, contemporary buildings mirror symmetric features. However, this kind of *aesthetic* symmetry was mainly for the eye, for beauty – expressing harmony; it differs distinctly from *functional* symmetry. And from there, it was only a small step to imply the concept of proportion, and consequently that of an equality relation. It must be stated that the term symmetry in contemporary physics is no longer used in the classical aesthetic sense – this will be discussed in a later chapter.

In biology, specifically in the development of life, symmetry plays a major role [1]. One can trace its importance back to the earliest organisms, which thrived because of their symmetric shape. Over the course of time, ever more diversified species relied on it as well. However, it would go far beyond the scope of this essay to note all the examples that nature provides in this respect.

Symmetry proved advantageous – if not crucial – in the evolution of species. An early Cambrian animal like *Spriggina* is often presented as an early bilaterian "prototype". Its elongated and segmented body, slightly tapering towards the front, with a distinct head-like region shows clear bilateral symmetry. This is thought to allow for more efficient movements, and confer an advantage in feeding and sensing [2].

One of the earliest known dinosaurs, *Coelophysis*, a true theropod that lived in the mid-Triassic and early-Jurassic periods can be taken as another proof for the importance symmetry played in evolution. It was bipedal, running on its two hind legs while using its forelimbs – three-fingered hands mirroring each side – for grasping or balance. Its overall symmetry likely facilitated balance and efficient locomotion as a fast predator [3].

It is to say that, throughout the biological evolution of species, symmetry continued to be advantageous, and most clearly seen when we consider the development of vertebrates: bilateral symmetry was there to stay because it stabilises locomotion and simplifies paired-organ development [4]. One step toward ever more highly developed bipeds in this respect is doubtlessly *homo erectus*: the bilaterian template is maintained through paired limbs, paired organs, and a single anterior-posterior axis [5]. Aligned with the evolving bodily capacities and capabilities matured the development of the brain and the mind.

Whereas symmetry seems to be essential for the development of life and for the survival of species, the mental capabilities of *homo sapiens* – until now the last step in the evolution of humankind – allowed the species to develop beyond purely functional symmetry. The emerging capabilities of abstraction and symbolism witness this evolution clearly. Also, these capacities enabled humankind over the millennia to foster societies and cultures.

In retrospect, on the basis of the emerging mathematical and scientific advances, the view on symmetry took an astonishing turn in the development of physics in the early modern period, about 1500–1800 CE. Newton introduced symmetry into physics through his geometrically grounded *Principia*, which gave him a rigorous, visual way to argue about motion, forces, orbits, and invariances. Geometry allowed him to formulate mechanics, which reflected stable patterns in nature through rotational and translational invariances, and he implicitly introduced invariance principles in his laws of motion. However, Newton did not use symmetry as an organising concept. Only later physicists recognised the importance of invariances embedded in his laws, which eventually led away from the classical view of symmetry toward modern group-theoretic methods [6].

The next step to formalise symmetry was done by French mathematician Galois. He introduced the idea that symmetry can be captured by a group of transformations acting on a structure. His work proved that the behaviour of equations is governed not by their explicit form but by the symmetries of these transformation groups – something that was not understood by his contemporary peers [7]. However, Galois' work eventually became the conceptual root of treating symmetry as a mathematical object in its own right. But it took until the 1870s – 1880s, when Galois theory became part of mainstream algebra [8].

Later, Lie supplied the algebraic language for viewing transformations systematically. In his foundational work, the full programme of continuous transformation groups is developed [9]. Galois' discrete groups were conceptually extended through the step of treating transformation groups in a continuous setting, a generalisation in spirit rather than a direct continuation of Galois' algebra. These Lie groups form the foundation of symmetry operations in contemporary physics. They provide the necessary means to execute rotations, boosts, gauge transformations, and every continuous invariance that later appears in Noether's theorem and the Standard Model, the current framework describing fundamental particles and their interactions. [10]

The link between geometric symmetry and the symmetry of physical law was further deepened by Poincaré. He analysed how only relational, transformation-invariant quantities carry physical meaning, and how the form of physical laws stays unchanged under specific geometric transformations [11]. Also, he formalised the principle that only relations preserved under these transformations have physical meaning. Poincaré knew the Lorentz transformations and recognised their group properties, reformulated them cleanly, and even stated the invariance of Maxwell's equations under them. In showing that Lorentz transformations arise from requiring the same geometry for all inertial observers, which tied spacetime structure directly to physical law, he also coined the term *Lorentz group*.

Known for their outstanding optical symmetry, crystals served as a natural laboratory. Curie's studies of crystallography reveal how breaking or preserving symmetry determines mechanical, optical, and electrical properties. He also showed how material properties follow – and sometimes break – specific structural symmetries [12]. Furthermore, he was able to show that physical effects depend on symmetry properties of the underlying structure, leading to his Dissymmetry Principle, which states that a physical effect cannot have a dissymmetry absent from its efficient cause. This clarified how material symmetries constrain possible phenomena, preparing the ground for Noether's step of linking symmetries of the laws themselves to conserved quantities.

With Curie's findings Noether – in 1918 – established with two theorems the deeper principle that symmetries of the fundamental laws themselves generate conserved quantities [13]. This work unified earlier strands by showing that continuous symmetries correspond to conservation laws, a principle that later guided the gauge-based framework of the Standard Model. Noether's first theorem states that every continuous symmetry of the action of a physical system with conservative forces has a corresponding conservation law. She showed that the action of a system can be expressed through the integral over time of a Lagrangian function, from which the system's behaviour follows by the principle of least action. The theorem applies to continuous and smooth transformations of the action, not only to spatial symmetries.

The field-theoretic extension in her second theorem states that continuous local symmetries – gauge symmetries – yield conserved currents linked to corresponding identities among the Euler - Lagrange equations. The theorem connects the symmetries of the action functional to differential identities that express the underlying gauge redundancies. Further on, it underpins modern gauge theories, which form the structural basis of today's field-theoretic physics, including the prevailing Standard Model.

The seminal work of Noether laid the foundations of modern algebra and strongly influenced its further development. In fact, without her ground-breaking work, one may doubt whether the rapid advances in GR and quantum physics – among other correlated fields – would have been possible. However, it took several decades before significant advancements were made. By then, the meaning of the word *symmetry* had drastically changed: from optical to functional and mathematical. This shift was based on the rise of invariance principles – not merely the left side of an equation equalling the right, but the deeper idea that laws remain unchanged under specified transformations.

Once again, one of the major motivations driving research was the hope to unify quantum mechanics and gravity within a single framework. To accommodate extra degrees of freedom, the older Kaluza - Klein idea reappeared: additional spatial dimensions compactified into tiny, effectively unobservable scales [14].

This strategy later re-emerged in string theory, which replaces point particles by one-dimensional "strings" whose vibrational modes correspond to particles known from classical physics. In the early 1970s a symmetry-driven program began to gain traction. This incited Pierre Ramond to suggest a deeper link between bosons and fermions [15], and subsequent work – notably Green and Schwarz's anomaly-cancellation result – showed that string constructions could be mathematically consistent, again on the basis of symmetry considerations. Even so, these frameworks and their successors remain highly speculative.

The next step consisted in developing supersymmetry [16]. This framework proposed that every known particle has a yet-undiscovered "superpartner" belonging to the opposite spin class, linked by a fermion–boson exchange symmetry – i.e. each boson paired with a fermion, and vice versa [17]. However, although extensive searches have been conducted, no superpartners have been observed so far. Mathematically, however, supersymmetry delivers an elegant unification of bosonic and fermionic degrees of freedom and offers technical advantages, e.g. naturalness-related arguments, which motivated its widespread adoption.

In summary, these speculative models rely on abstract and increasingly exotic algebraic structures to describe a hypothetical superspace. SUSY-based extensions tend to treat time algebraically, embedded within larger symmetry groups, while leaving untouched the deeper questions about time's directionality, multiplicity or ontology. Despite their internal coherence, supersymmetric time extensions remain only loosely connected to physical intuition and observation, continuing the long-standing tendency of spatial bias in high-dimensional unification efforts [18]. This persists even with the symmetry emphasis that motivated these programmes.

The above historical overview clearly shows that symmetry in physics ultimately refers to invariance of the action, and not to any visual regularity. Noether's theorems cover exclusively continuous symmetries – discrete ones stand outside her framework. Also, certain classical symmetries fail once quantised, because anomalies can break them, showing that symmetry is not guaranteed at all scales. What is more, some approaches in quantum gravity lack a well-defined action, which limits the reach of Noether's method altogether. Broken symmetries, whether spontaneous or explicit, and those emerging only in limiting regimes, are a clear indication that such symmetries are not fundamental. What complicates matters further is that dualities can make seemingly unrelated theories equivalent. Certainly, symmetry may function as a powerful modelling tool, yet it does not automatically reflect the structure of nature itself.

2) Can Asymmetry be a Guiding Principle as well?

We do not really know what happened during the Big Bang. First thing to admit is that we cannot be sure whether it really was a big bang that initiated our universe: and second, our means of evaluating what *could* have occurred at that moment are not sufficient to give a precise account of the happenings. Assuming that there *was* a Big Bang that initiated our universe, two statements can be made on this reasoning. According to the most evolved theories, it came at a time zero, and mass was created – in nearly equal proportions of anti-matter and matter [19]. Why we exist is due to the minuscule amount of matter that was spared annihilation. And again, two things naturally come to mind: if physical laws were fully symmetric, exactly the same amount of matter and anti-matter should have been created, which was not the case – evidently a dissymmetry. And there is the other consideration that our universe evolved from this big event onward, through inflation (one is not sure today whether is continues), from simple matter to the creation of life, and finally to species who wonder about all this. Even strong proponents of symmetry must acknowledge that asymmetry underlies our very existence.

The dissymmetries in the beginning of our universe clearly indicate that asymmetry is a driving force of evolution. But there are many other occasions that reveal asymmetry. Pierre Curie, explaining his "principle of dissymmetry", formulated like this, when analysing symmetry in crystals, magnetism, electricity, and optical activity: « Dans chaque cas, une certaine dissymétrie caractéristique est nécessaire en chaque point du corps. » (In any case, a certain characteristic dissymmetry is necessary in each point of the medium). In context: a physical phenomenon can only appear if the physical conditions include a *specific lack of symmetry*, matching the phenomenon itself. That natural systems display – not only in the case of crystals – significant departures from perfect symmetry must catch the eye. One *must* realise that in nature reigns more asymmetry than symmetry – and that the latter is very often broken …

The success of modern physics has often been tied to mathematical elegance, and understandably so: symmetry, understood as equivalence, yields conservation laws, solvable equations, and unifying patterns. But focussing the theoretical approach on symmetry alone, one important feature seems to have been forgotten: asymmetry.

The success of modern physics has often been tied to mathematical elegance, and understandably so: symmetry considerations led to conservation laws, solvable equations, and unifying patterns. Noether and her predecessors in the field of group theory, as discussed above, provided the tools for physicists to focus their theoretical approaches almost exclusively on symmetry. In the beginning of the 20th century, symmetry played a dominant role in research, such that it became a quasi-dogma for coming generations. Apparent inconsistencies in developed theories were – and still are – brushed away as mere discrepancies which will be eliminated in due course of time.

Entire frameworks – string theory, supersymmetry, loop quantum gravity – hinge on the belief that deeper symmetries are simply hidden from view. But the failure of supersymmetric particles to materialise, the symmetry-breaking mechanisms in the early universe, and the *ad hoc* inflation field are all signs of strain in a system too committed to mathematical elegance. This despite the fact that insurmountable obstacles remain if we strictly adhere to the symmetry principle.

Take CPT symmetry, where C stands for charge conjugation, P for parity transformation, and T for time reversal: it is held up as the last bastion of invariance, even as CP violation is well-documented [20]. These experiments did not simply infer asymmetry – they tracked transitions and their time-reversed counterparts directly, using entangled neutral meson pairs and their decay pathways. In both cases, the probability of forward and reversed transitions differs measurably, demonstrating that time-reversal symmetry is not preserved in weak interactions. This is a concrete directional feature of particles, not merely a subtle quantum effect.

Still, rather than confront the apparent asymmetry directly, and instead of furthering the assumption of a symmetric vacuum or a possible constant, modern theories often preserve symmetry by absorbing the discrepancy into existing frameworks. When confronted with data that appear to defy it – such as the accelerating expansion of the universe – the framework of ΛCDM, the standard model of cosmology, responds not by dismantling the ideal, but by accommodating the deviation as possibly caused by the cosmological constant and Dark Energy [21]. However, Dark Energy is a case in point: its underlying nature remains unknown, yet it is incorporated into the model as a placeholder representing a uniform energy density of empty space. Instead of challenging the foundational assumption of a symmetric vacuum, expressed by the constant Λ, the existing anomaly is effectively normalised within the model – restoring theoretical balance even though the mystery deepens. In seeking formalisms that work, physics has too often settled for frameworks that fit the data but obscure nature.

Strikingly, this ambivalence toward symmetry appears in a completely different field: human perception. In a study performed in 2005, participants rated naturally asymmetrical human faces as more attractive than perfectly symmetrical, computer-generated composites [22]. The authors suggest that inherent asymmetry may signal biological vitality or authenticity, echoing the idea that *too much symmetry* may evoke artificiality rather than perfection. Similarly, Rhodes et al., and Fink et al., found that while moderate facial symmetry tends to enhance perceptions of health and attractiveness, perfect symmetry is not optimal – suggesting that symmetry's value lies not in its absoluteness, but in its subtle deviations [23]. This perceptual sensitivity to asymmetry may be more than a psychological quirk; it could reflect deep cognitive or evolutionary tuning to a world where symmetry signals order – or expressed heretically: stasis.

When we look around, nature shows under the appearance of symmetry overwhelmingly asymmetric traits. Aren't the five-petalled flowers beautifully symmetric? If we take a closer look, we discover, however, that this is not strictly true: there *are* differences, asymmetries; small, but perceptible imperfections. Even human existence is based on the fact that nature is not perfect. Would life as we know it exist if nature were perfectly symmetric? Most probably *not*. – Look at your hands: you can rotate and flip your left hand any way you like, but you'll never make it become your right hand – they are asymmetric.

The same goes for amino acids, the basic building blocks for life on earth. These are molecules which possess something that is called chirality: although their sum formulae are the same, they differ in the spatial distribution of their functional groups – they are asymmetric. This particularity of molecules was already discovered in the mid-19th century [24]. And these molecules are the cornerstones of life as we know it.

It can be safely deduced from the foregoing that deviations in the form of asymmetries also carry information. Consequently, research should not focus further on the former one, trying to find ever-new symmetries, which anyway are mere theoretical constructs – and in most cases not related to observables. In this sense, the aesthetic judgments of human observers may reflect an embodied understanding of symmetry breaking, the same principle by which time becomes directional, and particles acquire mass.

Yet symmetry remains a sacred principle. The real world is asymmetrical: time has direction, entropy has bias, events are irreversible [25]. And yet, theoretical physics often acts as if these facts are annoyances to be smoothed away, rather than truths to be embraced. True insight does not come from symmetry. It comes from understanding why asymmetries exist, how they structure reality, and what they imply about time, causality, and realisation. In this 3S+3T framework, time is not a mirror of space – and never was. It certainly mirrors certain features, but they describe different domains of our universe and perception.

2. Discussion

Undeniably, symmetry played a significant role, especially in the development of life on Earth. However, this symmetry is only approximate, if one reconsiders the apparent mirroring of similar or like features in plants and animals. It surely had a significant influence on their development, but the underlying, crucial element certainly is asymmetry: if there were no chiral molecules, life as we know it could not have arisen.

This appears to be the major issue when the progress in physics is meticulously reviewed. The term symmetry in physics is no longer the same as in common language, where it signifies similarity, perfection and beauty. The original sense of the Greek word *συμμετρία* is about proper proportion between parts, not visual mirror-likeness. Only much later did it gain the everyday meaning of left-right sameness. Nothing of that is reflected in the physical sense of the word, when symmetry is considered as equality, as invariance of a system under a transformation. The significant shift in the meaning is rarely acknowledged, fuelling conceptual confusion in interdisciplinary relationships.

Biologists have a very pertinent way to use the term *symmetry*: it refers to how an organism's body parts are arranged around an axis, and in a wider sense when classifying body plans, describing development, and comparing related species. In chemistry, symmetry considerations are important when it comes to examine molecular symmetry groups for predicting spectra, possible intra- and intermolecular bonding, and its potential inference on a molecule's reactivity. It seems contradictory, but symmetry considerations play an important role in chirality analysis and stereochemistry. Essential in the description of molecules is their placement in point groups, which are a collection of symmetry operations that can be performed on a molecule, resulting in a conformation that looks the same as the original. In mathematics, and in a way similar to chemistry, symmetry is used to classify shapes, tilings, and algebraic structures. It remains an important tool in combinatoric, graph automorphisms, and group theory in the realm of mathematics. Unlike physics, these sciences keep the everyday sense of symmetry intact.

In physics, the term symmetry is used in stark contrast to its use in these sciences. For physicists, apart from changing the original meaning, symmetry simply became a habit of mathematical convenience: an elegant and comfortable way to render theories "beautiful", disregarding whether they actually confer to nature or conform to observables. But symmetry as physicists defined it does not reflect nature.

There are many examples in physics, where established symmetries are broken, some mentioned in previous chapters. But it is to say that practically *every* fundamental symmetry we know is broken in the real world. This is also true for various subjects like the observed CMB large-scale anomalies and anisotropies, in condensed-matter physics, where crystals break continuous translational and rotational symmetry, and superconductors break gauge symmetry. This pattern is systematic, not accidental, and the enumeration of broken symmetries could be continued; but it should be evident by now that the way physicists use symmetry in the way they defined it and made to a dogma is a dead end. This dogmatic over-reliance – in connection with the particular interpretation of the term symmetry – limits understanding, since it inevitably leads to selective attention towards models that preserve elegance over explanatory power. Symmetry explains conservation and structure, but fails where the universe actually moves.

Asymmetry on the other hand offers the missing explanatory power, forcing models to align with observables, directionality, and actual processes. It is the principle that links origins, evolution, irreversibility, life, and temporal behaviour. Without asymmetry, nothing happens: no arrows of time, no universal structure, no stars, no chemistry, no life. Only an asymmetric view on the universe can describe its reality [26]. In the skewed 3S+3T framework, the structure of time and event realisation is determined by directional and functional axes, making symmetry considerations secondary rather than foundational. It strips away much of the ultimately artificial, mathematical machinery in modern physics; its nearly flat, curvature-free structure reveals a cleaner, more transparent picture of the underlying principles. In such a framework, where Time *and* Space have three independent directions, many of these complications disappear naturally. Further, it retains exact conservation laws without needing pseudo-tensors, energy accounting is unambiguous, and gravitational as well as quantum effects can be incorporated directly into true tensors.

If physics is to move forward conceptually – and not merely computationally – it must break with its long-standing fixation on symmetry and re-examine the very questions it should pose about nature.

References

[1] P. Alberch (1985). The evolution of developmental pathways. American Zoologist, 25(1), 15–34.

[2] J. W. Valentine (2004). On the origin of phyla. Chicago & London: University of Chicago Press. ISBN 0-226-84548-6.

[3] L. F. Rinehart, S. G. Lucas, A. B. Heckert, J. A. Spielmann & A. P. Hunt (2009). The palaeobiology of *Coelophysis bauri* (Cope). New Mexico Museum of Natural History and Science Bulletin 45.

[4] K. V. Kardong (2018). Vertebrates: Comparative anatomy, function, evolution (8th ed.). New York: McGraw-Hill Education. ISBN 978-1260092042.

[5] G. P. Rightmire (1990). The evolution of *Homo erectus*: Comparative anatomical studies in an extinct human species. Cambridge University Press.

[6] J. Stillwell (2008). Mathematics and its history. New York: Springer. ISBN 978-0-387-49309-6.

[7] R. Taton (1947). Les relations d'Evariste Galois avec les mathématiciens de son temps. Revue d'histoire des sciences, 1–2, 114–130.

[8] (a) C. Jordan (1870). Traité des substitutions et des équations algébriques. Paris: Gauthier- Villard.
(b) L. Kronecker (1895). Über die Lösung der Gleichungen vom vierten Grade. In *Gesammelte Werke*, Band 3. Berlin: Reimer.
(c) F. Frobenius (1896–1897). Über Gruppencharaktere; Über die Markoffsche Determinante und die Grundlagen der Theorie der Gruppen. In *Gesammelte Abhandlungen*. Springer, 1968.

[9] S. Lie & F. Engel (1888–1893). Theorie der Transformationsgruppen, Vol. I–III. Leipzig: Teubner.

[10] T. Hawkins (2000). Emergence of the theory of Lie groups. Springer.

[11] (a) H. Poincaré (1902). La science et l'hypothèse. Paris: Flammarion.
(b) H. Poincaré (1906). Sur la dynamique de l'électron. Rendiconti del Circolo Matematico di Palermo, 21, 129–176.

[12] P. Curie (1894). Sur la symétrie dans les phénomènes physiques, symétrie d'un champ électrique et d'un champ magnétique. Journal de Physique Théorique et Appliquée, série 3, tome 3, 393–415.

[13] (a) E. Noether (1918). Invariante Variationsprobleme. Nachrichten der Gesellschaft der Wissenschaften zu Göttingen, Mathematisch-Physikalische Klasse, 235–257.
(b) E. Noether (1971). Invariant variation problems. Transport Theory and Statistical Physics, 1(3), 186–207. arXiv:physics/0503066. doi:10.1080/00411457108231446
(c) W. J. Thompson (1994). Angular momentum: An illustrated guide to rotational symmetries for physical systems, Vol. 1. Wiley. ISBN 0-471-55264-X.

[14] T. Kaluza (1921). Zum Unitätsproblem der Physik. Sitzungsber. K. Preuss. Akad. Wiss., 966–972. O. Klein (1926). Quantum theory and five-dimensional theory of relativity. Z. Phys., 37, 895–906. doi:10.1007/BF01397481.

[15] P. Ramond (1971). Dual theory for free fermions. Phys. Rev. D, 3, 2415. doi:10.1103/PhysRevD.3.2415.
[16] (a) M. B. Green & J. H. Schwarz (1984). Anomaly cancellations in supersymmetric D = 10 gauge theory and superstring theory. Physics Letters B, 149, 117–122. doi:10.1016/0370-2693(84)91565-X
(b) J. Wess & B. Zumino (1974). Supergauge transformations in four dimensions. Nucl. Phys. B, 70, 39–50. doi:10.1016/0550-3213(74)90355-1.
[17] H. P. Nilles (1984). Supersymmetry, supergravity and particle physics. Physics Reports, 110(1–2), 1–162.
[18] L. Smolin (2006). The trouble with physics. Penguin.
[19] A. Riotto & M. Trodden (1999). Recent progress in baryogenesis. Annual Review of Nuclear and Particle Science, 49, 35–75.
[20] (a) S. Wu, E. Ambler, R. W. Hayward, D. D. Hoppes & R. P. Hudson (1957). Experimental test of parity conservation in beta decay. Phys. Rev., 105, 1413–1415. doi:10.1103/PhysRev.105.1413
(b) A. Angelopoulos et al. (CPLEAR Collaboration) (1998). First direct observation of time-reversal non-invariance in the neutral kaon system. Phys. Lett. B, 444, 43–51. doi:10.1016/S0370-2693(98)01395-4
(c) J. P. Lees et al. (BABAR Collaboration) (2012). Observation of time-reversal violation in the B meson system. Phys. Rev. Lett., 109, 211801. doi:10.1103/PhysRevLett.109.211801.
[21] (a) P. J. E. Peebles & B. Ratra (2003). Reviews of Modern Physics, 75(2), 559–606.
(b) S. Dodelson & F. Schmidt (2020). Modern cosmology (2nd ed.). Academic Press / Elsevier. ISBN 978-0-12-815948-4.
[22] D. W. Zaidel & J. A. Cohen (2005). The face, beauty, and symmetry: Perceiving asymmetry in beautiful faces. Int. J. Neurosci., 115, 1165–1173. doi:10.1080/00207450590914464.
[23] (a) G. Rhodes, A. Sumich & G. Byatt (1999). Are average facial configurations attractive only because of their symmetry? Psychol. Sci., 10, 52–58.
(b) B. Fink, N. Neave, J. T. Manning & K. Grammer (2006). Facial symmetry and judgments of attractiveness, health and personality. Pers. Individ. Differ., 41, 491– 499. doi:10.1016/j.paid.2006.01.017.
[24] L. Pasteur (1848). Recherches sur les relations qui peuvent exister entre la forme cristalline, la composition chimique et le sens de la polarisation rotatoire. Comptes Rendus de l'Académie des Sciences, 26, 535–538.
[25] (a) H. Price (1996). Time's arrow and Archimedes' point. Oxford University Press.
(b) I. Prigogine (1997). The end of certainty: Time, chaos, and the new laws of nature. Free Press.
[26] (a) G. Muchow (2025). Time, a three-directional dimension I. ASRJETS, 101(1), 179– 190.
(b) G. Muchow (2025). Three directions of time: Temporal geometry beyond scalars. International Journal of Science and Research (IJSR), 14(4). DOI 10.21275/SR25416164512.