ISSN: 2977-4047

Journal of Life Sciences Research and Reviews

SCIENTIFIC Research and Community

Research Article

Open Access

How a Cosmology of a Nonlocally Unified, Meaningfully in-formed, Holographically Manifested and Purposefully Evolving Universe Engenders Planetary Systems as Gravitational Environments for the Emergence of Biological and Biomechanical Complexity

Jude Currivan

Co-founder WholeWorld-View, 17 Withy Bed, Bushton, Wiltshire, SN4 7QD, UK

ABSTRACT

The emergent cosmology of a nonlocally unified, meaningfully in-formed, holographically manifested and purposefully evolving Universe, treats gravity as an emergent consequence of the in-formational and holographic nature of space-time and describes it as the consequence of the informational content, or intropy, associated with positions in space-time of massive bodies. In doing so, the evolutionary impulse inherently embodied in the Universe's finite lifecycle engenders solar systems and planetary homes for the eventual evolution and complexity of biological organisms. Showing that planetary gravitational fields are required to enable cellular differentiation and subsequent development of a range of biomechanical strategies for building complex morphology, describes how such complex organisms such as human beings could eventually develop.

***Corresponding author**

Jude Currivan, Co-founder WholeWorld-View, 17 Withy Bed, Bushton, Wiltshire, SN4 7QD, UK.

Received: October 21, 2024; **Accepted:** November 08, 2024; **Published:** November 15, 2024

Keywords: Cosmology, Evolution, Information, Intropy, Biology, Gravitation, Biomechanics

Introduction

While commonly viewed as a fourth universal force, gravity is becoming better understood in being considering as a consequence of how energy-matter and space-time informationally interact.

Treating gravity as an emergent consequence of an informational and holographic structure of spacetime appears to offer a more literal interpretation of general relativity and might account for why physicists have been as yet unable to detect gravitons, gravity's hypothesized force-carrier particle. While a work in progress, such an approach may also be able to explain why gravity is so much weaker than the three fundamental forces.

This viewpoint, that both gravity and inertial acceleration in general, may be consequences of the informationally entropic nature of space-time, goes back to the early work on black-hole informational entropy in the 1970s. In 1995, Ted Jacobson was then able to show mathematically that combining entropic considerations with the equivalence of gravity and acceleration leads to Einstein's gravitational equations [1].

From 2010 and following a series of modifications, Erik Verlinde has described gravity as an emergent phenomenon as the consequence of the informational entropy associated with the positions in space-time of massive bodies and in 2012 Tower Wang unified a number of such modified approaches showing them, while constraining certain aspects, to be consistent with Einstein's gravity [2,3].

From a different perspective, a number of apparently diverse theories of quantum gravity are also converging on a view that at the Planck scale all quantized energy-matter fields and particles seem to behave as though space is one-dimensional and when combined with time form a two- dimensional holographic space-time.

Reducing dimensions first developed through this approach when, in 2005, Renate Loll and colleagues ran computer simulations to test their idea of causal dynamic triangulation (CDT), which describes how particles move apart from each other. At the Planck scale the simulations showed that particles behave as though moving in such a two-dimensional space-time [4].

Other quantum gravity theories such as loop quantum gravity (LQG) and so-named Horava gravity proposed by Petr Horava in 2009 also result in particles moving as though in a two-dimensional space-time [5]. String theory too at high Planck-scale temperatures behaves entropically as though space-time has two dimensions.

They all seem to be pointing in the same direction: to the holographically manifested nature of space-time, and gravity as an emergent entropic phenomenon.

While also early days, attempts at restating other fundamental forces as being entropically based are also gathering pace. In 2010, Peter Freund extended Verlinde's hypothesis of entropic gravity to a proposal that all energy-matter force fields can be described entropically [6]. And in 2011, Zhe Chang, Ming-Hua Li, and Xin Li obtained an apparently good fit with observational data to suggest a possible unification of dark matter and dark energy within a modified entropic force model [7].

Underpinned by the now settled science of a nonlocally unified Universe, as recognised by the award of the 2022 Nobel Prize for Physics, expanding the three Laws of Thermodynamics to three Laws of Information, or Infodynamics also enables the energy-matter and space-time appearance of our Universe to be redefined in terms of complementary expressions of information and frames its finite and universal lifecycle. In doing so, the 2nd Law concept of entropy as the energetic microstates of a system is expanded to the intropy, or informational content of a system – both described by the same Boltzmann formula.

Materials and Methods

The 1st Law of Infodynamics algorithmically enables our Universe to exist through its conservation of quantized energy-matter and the 2nd Law of Infodynamics enables our Universe to evolve through its increasing space-time intropic flow, with the 3rd Law of Infodynamics then showing how reducing universal temperature (as space expands) correlates with increasing intropy over time [8].

Foundationally, though, such a framework is only able to account for meaningful in-formation, literally in-forming the emergence of quantized energy-matter and in-tropic space-time, and thus that cosmic mind and consciousness are primary to and all-pervasive throughout their universal expression; thereby showing how our Universe meaningfully exists and purposefully evolves; from its initial simplicity to emergent complexity and individuated self-awareness.

As described in detail and with supporting evidence at all scales of existence and across numerous fields of research, the cosmology of a nonlocally unified, meaningfully in-formed, holographically manifested and purposefully evolving Universe, in-tropically engenders the eventual emergence of solar systems and planets that then offer gravitational environments for further evolutionary complexity and specifically with regard to biological organisms [9-11].

The evolutionary journey of our Universe from its first moment, around 13.8 Ga and its initial simplicity almost completely comprising elemental hydrogen and helium, led to generations of stars and their nucleosynthesis of heavier elements, black holes, both stellar and super massive, and galaxies. As a precursor to the birth of planetary systems including our own, after some nine billion years of evolution, end-of-life stellar explosions, stellar mergers and high-energy cosmic ray cascades, had seeded the formation of interstellar clouds, containing vast amounts of both atomic and molecular hydrogen (after which they are commonly named), multi-elemental dust, non-crystalline grains of water ice and gases including polycyclic aromatic hydrocarbons or PAHs [12].

While low-gravity, with higher densities than the ambient interstellar medium, internal temperatures warmer and bathed by low-level ultraviolet (UV) light, such clouds and their elementary nutrients are essential planetary birthing clouds, enabling the in-formational synthesis of a varied range of complex organic molecules including the vital precursors of amino acids and nitriles, forerunners of RNA and simulations also supporting the potential further development of the nucleobases of RNA and DNA there too [13-16].

Coherent magnetic fields flowing through the clouds also support the burgeoning evolutionary potential by aligning the dust grains, which then spin with their longer axes perpendicular to the fields and accordingly diffuse and polarize incoming UV light from nearby stars. In reducing the intensity of the light that would otherwise destroy any possibility of complex molecules forming, instead, the low level of irradiation of the dust-ice grains energetically triggers the formation of carbon-to-carbon and carbon-to-nitrogen bonds, which are foundational for the emergent creation of organic molecules.

The diffused UV light, however, remains sufficiently powerful to partially ionize the atomic hydrogen present, thus freeing its electrons from their proton nuclei. Its coherent polarization also imposes a specific direction of spin, clockwise or counterclockwise, on the electrically charged electrons. By doing so, it instils in all later organic molecules an inherent right- or left-handedness, or chirality, imbuing each type with an overwhelming preference for one or the other and optimally imprinting its fundamental organic material for future in-formational flows in numerous biological processes.

Increasingly spectroscopic evidence from the clouds is showing a commonality of organic harbingers for subsequent evolution on future planetary homes and essentially unchanged ever since. These include the structures for RNA and DNA molecules with the latter estimated as being a ‘one in a million’ best choice for biological complexity and the optimal number of amino acids for biological protein assemblies [17, 18].

The final factor ensuring ideal conditions for the subsequent birth of planetary systems is the combined frequency and explosive power of supernovae. Interstellar molecular clouds form at the intersections of their shock waves and subsequent waves trigger the gravitational collapse of sections of the clouds into protoplanetary nebulae. If supernovae were more frequent and/or more powerful, the clouds would be too turbulent to support such emergence; if less frequent and/or less powerful, the clouds would disperse before planetary systems could form.

Some 4.6 Ga, in the depths of such a gestating cloud, shock waves from a nearby supernova did indeed likely trigger a gravitational collapse, leading to the birth of our planetary home, Gaia, and our Solar System [19]. As the gravitational collapse of its birthing cloud continued, the infalling material of Gaia’s incipient Solar System began to spin. In doing so, it formed a protoplanetary disk, or proplyd, around our young Sun; not chaotically but as a series of harmonically ordered orbits that would eventually coalesce to form its planetary family along with numerous satellites, asteroids, and comets.

As evidenced by the inability to differentiate biological cells in low or zero gravity conditions the milieu of interstellar molecular clouds, while in-formationally gestating the harbingers of organic life, are unable to take them beyond this threshold. For this, the birth of planetary systems is essential [20, 21].

The dynamics of such protoplanetary disks and the magnetic fields that pervade them, though, are themselves key for enabling planetary systems, including our own to evolve. Magnetic fields interacting with electrically charged ionized gas and dust grains have the characteristic of being able to efficiently transfer moving gas inward to feed the growth of central protostars. This also involves a reverse process of outward transfer of angular momentum from protostars to their disks, slowing the axial spin of the former and so stabilizing their development while differentiating orbital spin rates within the material that comprise latter developing planets, into harmonically relational periodicity that support future orbital stabilities and thus setting the stage for the next great leap in universal evolution.

For planetary systems, however, to then nurture biological emergence, a series of interdependent conditions are seemingly vital. Detailed examinations of our own Solar System and increasingly the exo-planets of other systems are progressively revealing both the ongoing challenges of doing so and also the incredible means by which it seems, 'life will find a way'.

While ongoing discoveries render a work-in-progress perspective, the following appear to be key factors in considering whether a planet (or planetary moon) may harbour the potential for ongoing biological complexity.

To do so, a planetary/lunar body needs to be relatively stable and on an ongoing basis in both its structure and orbital dynamics, and crucially a dissipative open system; able to utilize external and internal energy sources to provide the structural and metabolic features and needs inherent to biological lifeforms and release the unused remaining energy to space. Primarily such energy is provided by the heat/light from a parent star (hence the well-known view of a planetary habitable zone), but can also be derived for example from gravitationally driven tidal forces or internally from geospheric radioactive decay as long as neither of these are too disruptive

Two Vital Attributes of Planetary Bodies (or moons) as In-formational and Emergent Dissipative Systems are then:
Temperature differentials maintained between them and outer space are in-tropic measures of their ongoing ability to sustain biological life and their evolutionary potential.

The entire in-formational sentience of a planet (or moon), its gaiasphere comprising the totality of its geosphere, hydrosphere, atmosphere and biosphere, form the interdependent and wholistic entity of its emergence [10].

Due to the physics of gravity and angular momentum, planets (and larger moons) are generally spherical and spin on their axes. Their likely primordial processes of accretion also support their gravitational fields to be both relatively homogenous and stable. In addition, and unless subsequently compromised for example by large-scale impacts, the longer such stability is maintained, the greater the opportunity for ongoing emergence.

Their inherent gravitational gradients also provide precise in-formational guidance and especially a consistent up-down locational context enabling the structures and processes of biological organisms to evolve; in-tropically developing both across three-dimensional space and through time [22, 23, 24].

One intriguing aspect of many moons, however, is that they are in a 1:1 orbital resonance with their planets and thus, as is the case for our own Moon, with one face to their planet at all times. While for our planetary home offering many benefits, it may be a severely limiting factor for the possibilities for complex biology to evolve in such lunar environments.

Indeed, given the interdependent fine-tuning and intricacy of further emergence, beyond simple organisms (themselves complex!), further contributory factors, as embodied by Gaia, are likely to be requisite to nurture and harbour the level of sophistication that has evolved here over four billion years [10].

The following mentions some that especially pertain to Gaia's ambient gravitational field and consequential in-formational and in-tropic aspects that have then enabled complex biological emergence:
Orbiting in a 'habitable zone' optimising incoming light/heat from our Sun and supporting a biologically hospitable surface temperature.

Orbital dynamics that include so-named Milankovitch cycles of ellipticity, precessional planetary spin and tilt, interweaving over a chronological tempo of some 112,000 years, engender varied environmental niches and change and thereby drive biological emergence [25].

As a 'rocky' planet, embodying a medium scale gravitational field and surface solidity and environmental niches for an abundant variety of biological expression.

A strong planetary magnetic field enabling UV and solar wind protection.
As a water planet, embodying a consistent profusion of surface liquid water; vital for all biological organisms.
Gaia's interdependent *gaiasphere* comprises all ninety-four natural elements and crucially a surface availability of the sixty or so that are utilised in biological organisms.
Lunar tidal forces that optimise churning of nutrients throughout Gaia's hydrosphere.
Thin crustal rocks enabling tectonic plates and subduction processes which allied to periodic volcanic activity drive atmospheric carbon-oxygen cycles, that themselves help to drive evolutionary processes.

These gravitationally related attributes together with electro-magnetic fields, biochemical relationships and unique characteristics of water combine to in-formationally guide biological structures and processes through space and time and based also on the dynamic read-write template of an organism's genome.

Planetary gravitational fields and gradients are also vitally important for the biomechanics of organic structures and the strength, flexibility and resilience required to empower the emergence of complexity. Examined now are two examples, actin and collagen, of foundational proteins, the building blocks of organic forms, showing how such biomechanical attributes are gravitationally and in-tropically underpinned.

Emergence in the Cambrian era (starting c539 Ma) and beyond of multicelled animals, while building on the fundamentals of Gaia's 'right first time' organic foundations, required additional and novel levels of holarchic organization.

These would include ongoing in-formational specialization of internal functional forms and processes, full-body coherence, and body-wide networks of dynamic signalling.

To implement such advances, animals adaptively utilised increasingly complex in-tropic guidance using properties of gravitational space-time locating and gradients, electro-magnetic fields, biochemical electric charges and gradients, and the extraordinary characteristics of water. Fundamentally underpinned by intrinsic biomechanical forces and additional emergence of specialised biomolecules, proteins, and organic materials, such wholistic cooperation enabled coherence and behavioural capabilities in increasingly complex animals.

Some of the highly versatile molecules involved, such as actin, actually evolved much earlier but has been used ever since and with minimal if any modifications to enable ever more multifaceted processes.

Tracing its origins to the prokaryotic cells of bacteria and archaea, actin is found in the gel-like cytoplasm of all eukaryotic cells. As a family group of spherically shaped proteins that also form microfilaments, it has important and varied roles. Its genetic sequence is so well optimized for its organic multifunctionality that it is able to carry out more interactions than any other protein. While essentially unchanged in the billion years that separate the emergence of the yeast Arabidopsis and its embodiment in human beings, across different organic groups, Gaia's evolutionary impulse has in-formationally selected for diversified actin filaments to expand and optimize their functional variety [26].

Its early and ongoing evolutionary uses include interacting with cell membranes to facilitate cell mobility, division, and signalling, and later helping the contraction in specialized muscle cells. Foundationally, it forms a major component of cellular cytoskeletons; the protein scaffolding it makes up, together with microtubules and what are called intermediate filaments, enable cells and organisms to quickly and appropriately remodel themselves in response to their outer environments and their own internal needs.

The in-formational characteristics of actin are extremely important in enabling its multifunctionality. Its biomechanical strength and organizational flexibility are also essential for cellular and larger body morphology.

Cytoskeletal structures and processes, too, need to be highly and rapidly responsive, while remaining coherent. Cells do this by effectively existing in critical states, far from equilibrium, and through continuous in-tropic flow and energy dissipation, facilitated by actin.

In addition to their other benefits, semiflexible and multipurpose actin filaments clustering, especially near cell membranes, are ideal for intra- and inter-cellular and transient in-formation flows that determine cell shape and migration. They complement the rigid microtubules that guide the transport of intracellular organelles and lipid-encased molecules, known as vesicles, and the intermediate filaments also help provide the cell's structural properties. Further supported by various types of what are called accessory proteins, the entire cytoskeletal structure is a complex and dynamic system.

Involvement of quantum coherence and tunnelling in biological processes such as enzyme activities is increasingly being perceived. There is also growing evidence of quantum effects possibly playing a significant role in cytoskeletons. For example, actin cooperates with a family of thickly filamented molecular motors, proteins known as myosins. In a great variety of ways, together they enable biochemical forces and movement from transporting organelles within cells to muscle contractions. In the presence of actin, myosin, with its associated enzyme ATPase, catalyses and converts chemical ATP energy, the powerhouse of the cell, to release mechanical energy that drives motion.

The extremely efficient actin-activated process extracts heat, thereby condensing into a macroscopic state of quantum coherence and so guiding and driving a biochemical sliding movement [27].

Actin also acts in conjunction with other protein groups, enabling organisms to evolve greater complexity through in-formational coordination of inter-cellular signalling and so ensuring biofield and morphological coherence [28]. To do that, specialized electrical signalling cells, or neurons, and their networks of nervous systems also evolved to greatly enhance the sensory capabilities of animals. Fossilized evidence for body-wide nervous systems suggests the earliest evolved between 550 Ma and 525 Ma.

Neurons, though, are not the only cell types able to be used for sensing their surroundings, with, for example, sponges employing other specialised cells to detect stimuli. However, neurons dramatically developed those capabilities further, and, it seems, in response to the emergence of predator-prey relationships in the early Cambrian era and the first appearance of aggressive and defensive hard body features and for which gravitational biomechanics are key.

While the earliest predators and their prey could have detected each other before nervous systems evolved, increasingly their interactions would have driven its emergence in improving their relative reaction times and faster movements to eat or avoid being eaten. The innate stress involved likely triggered its evolutionary development, offsetting the energetic and in-tropic investment required with additional survival benefits. Indeed, in bilaterian animals, nervous systems are extremely well conserved, and genetic evidence points to their being evolved only once and before the divergence of protostomes and deuterostomes. Ever since, using conserved genes, expressing them in conserved bodily forms, and transferring many genes across disparate functions and lineages has in-formationally guided the increasing complexity of animals to the present day [29].

Such predator-prey relationships have provided an inherent competitive tension in the innately collaborative and ongoing evolutionary impulse of the gaiasphere. In living animals, nervous systems have culminated in responses acting on a millisecond scale and likely the biophysical limit for body-wide detection and response signalling.

Also, intrinsically co-evolving with nervous systems, increasing sensory capabilities gave rise, for example, to the emergence of eyes around 525 Ma. By around 510 Ma, a group of arthropods called Radiodonta had developed the largest and most complex eyes of the Cambrian era. Anomalocaris, the apex predator of the Cambrian, was the largest of their number. While their body forms facilitated their predatory lifestyles, it was their eyes that were the likely main cause of their success, with size and complexity rarely matched since. With one fossil revealing an eye formed of 28,000 lenses, they helped find prey and evade other predators in differing light conditions and especially the dim light of the deeper waters where the Radiodonta hunted [30].

Further allied with actins and with the increasing need for in-formational signalling for such sensory complexity, another family of proteins known as catenins, acting as molecular sensors, bind with actin filaments. In doing so they integrate signal pathways at cell-cell junctions with cytoskeletal dynamics and ensure in-formational multicellularand whole-body coherence [31].

Within a cell, biomechanical and biochemical signalling then relies on yet another group of proteins known as small GTPases. As "molecular switches" they alternate between an active state where they are bound to an energy-containing biomolecule known as guanidine triphosphate (GTP) and an inactive or standby state where they're bound to an alternative form, guanidine diphosphate (GDP). Cells are inherently dynamic and responding to in-formational signals switches their states and so chooses what biomechanical response to set in motion. While the forces are tiny, about a billionth of the weight of a paperclip, they have fundamental impacts; for example, when in-formationally guided by so-named Hox genes, they regulate progressive cell development in animal embryos across space and through time [32].

The evolution of multicellular animals, though, required even greater and additional biomechanical attributes to enable cells to join together to embody a coherent body shape. The development of an extracellular matrix (ECM), comprising water, proteins, sugars, and carbohydrates, and the emergence of a group of fibrous proteins called collagens and their co-creative enzyme collagenase provided such a biomechanical and dynamic glue. Likely involving the in-formational intricacy of reticulate assembly with still another group of proteins called integrins that act as adhesion points, spanning cells' membranes and linking the ECM with the cells' internal cytoskeleton, the combination proved so extremely effective that it has been a fundamental and widely used feature of animal bodies ever since.

Collagen is incredibly resilient and viable amounts have been extracted from fossilized dinosaur bones. In conjunction with its effector enzyme collagenase, it also possesses remarkable properties of strength and nonlinear rigidity combined with rapid responsiveness. Its protein filaments twist together in triple strands, which then further bond into thicker fibres, threading through the entirety of an animal's ECM and holding all its cells and its entire body together. In complex animals, it is also present in the tendons that anchor muscles to bones and in ligaments that connect bone to bone. Its nonlinear rigidity enables it to be in-formationally fit for multiple purposes. In differing conditions, it can trigger significant reorganization of a cell's cytoskeleton, in turn biomechanically influencing cellular proliferation, movement, maturation, and tissue shape. Its responsiveness depends on collagenase, whose efficiency as an enzyme is so powerful that it radically speeds up, for example, an animal's fight or flight threat response from what would have taken up to 68 million years to mere milliseconds [33].

Providing the foundational medium for both the ECM and the cytoplasm of all cells, both prokaryotic and eukaryotic, is water. Present primarily in the liquid cytosol of the cell's cytoplasm, it is used not as a watery aqueous solution, but as a viscous gel; the difference embodying huge implications for cellular structure, functionality, and biomechanics.

The cellular cytosol gel is a dynamic matrix of water and proteins to which electrically charged ions adhere. Enabling partitioning of such ions within cells, it helps control, together with receptor proteins and their enzymes, the cell's electrical potentials. It does so through two-way transfers of such ions across cellular membranes. Unlike a watery solution, cytosol's viscosity also allows for membrane damage to be mitigated by retaining the cell's integrity, balance of semipermeable ion and protein transfers, and functionality for a while, enabling time for the damaged cell to be replaced. A further benefit is that unlike an aqueous solution whose water would freeze not much below 0 degrees Celsius, creating destructive ice crystals that would rip cells to shreds, the gel of cell cytosol freezes at much lower temperatures.

Indeed, when cellular cytosol's properties are evaluated in this light and in conjunction with the cell's semipermeable membrane, composed of some 50 percent to 80 percent receptor proteins whose different conformations are able to in-formationally partition and control the flows of ions, the current paradigmatic requirement for numerous further, separate, and multiple ion channels and pumps is removed [34].

Conclusion

The emergent and evidence-based cosmology of a nonlocally unified, meaningfully in-formed, holographically manifested and purposefully evolving Universe, is revealing how from its beginning some 13.8 Ga its inherently interdependent nature embodied an evolutionary impulse in-formationally and in-tropically guiding its emergent progress from its primordial simplicity of hydrogen and helium, to the complexity of planetary systems and biological organisms After more than nine billion years, its evolutionary progression led to interstellar molecular hydrogen clouds able to gestate the subsequent emergence of such systems and the organic harbingers of biological life. For further evolutionary complexity, though, the gravitational fields of such planetary homes are a pre-requisite for cell differentiation and the biomechanic structures and processes required for the strength, flexibility and resilience of the bodily morphology and coherence of complex organisms.

References

1. Jacobson T (1995) Thermodynamics of Spacetime: The Einstein Equation of State. Physical Review Letters 75: 1260-1263.
2. Verlinde EP (2011) On the Origin of Gravity and the Laws of Newton. Journal of High Energy Physics https://arxiv.org/abs/1001.0785.
3. Wang T (2012) Modified Entropic Gravity Revisited. High Energy Physics Theory https://arxiv.org/abs/1211.5722.
4. Loll R (2005) What You Always Wanted to Know about CDT, but Did Not Have Time to Read about in Our Papers, mp4 seminar http://pirsa.org/14040086.
5. Hořava P (2009) Quantum Gravity at a Lifshitz Point. Physical Review 79: 8.
6. Freund PGO (2010) Emergent Gauge Fields. High Energy Physics http://arxiv.org/abs/1008.4147 .
7. Chang Z, Li MH and Li X (2011) Unification of Dark Matter and Dark Energy in a Modified Entropic Force Model Commun. Theoretical Physics 56: 184-192.
8. Currivan J, A New IN-SCIght of IN-formational SCIence https://www.wholeworld-view.org/a-new-inscight-of-informational-science.
9. Currivan J (2017) The Cosmic Hologram: In-formation at the Center of Creation (inner Traditions https://www.innertraditions.com/books/the-cosmic-hologram.
10. Currivan J (2022) The Story of Gaia: The Big Breath and the Evolutionary Journey of our Conscious Planet (Inner Traditions, 2022).
11. Currivan J (2023) How an emergent cosmology of a nonlocally unified, meaningfully in-formed and holographically manifested Universe can underpin and frame the biological embodiment of quantum entanglement. Progress in Biophysics and Molecular Biology 185: 33-36.
12. McGuire BA, Burkhardt AM, Kalenskii S (2018) Detection of the aromatic molecule benzonitrile (c-C6H5CN) in the

interstellar medium. Science 359: 202-205.
13. Max-Planck-Institut für extraterrestrische Physik (2020) New Organic Molecule Discovered in an Interstellar Cloud. Spaceref, press release.
14. Kyodo News, 2022. Kyodo News. https://english.kyodonews.net/news/2022/06/9a7dbced6c3a-amino-acids-found-in-asteroid-samples-collected-by-hayabusa2-probe.html.
15. https://www.frontiersin.org/journals/astronomy-and-space sciences/articles/10.3389/fspas.2022.876870/full.
16. Oba Y, Takano Y, Naraoka H (2019) Nucleobase Synthesis in Interstellar Ices. Nature Communications 10.
17. DNA one in a million and right first time. Ref Freeland SJ and Hurst LD (1998) The Genetic Code Is One in a Million. Journal of Molecular Evolution 47: 238-248.
18. Amino acids optimal Doig AJ (2016) Frozen, But No Accident—Why the 20 Standard Amino Acids Were Selected. FEBS Journal 284: 1296-1305.
19. Banerjee P, Qian YZ, Heger A (2016) "Evidence from Stable Isotopes and 10Be for Solar System Formation Triggered by a Low-Mass Supernova," Nature Communications 7.
20. Purevdorj-Gage B, Sheehan KB, Hyman LE (2006) Effects of low-shear modeled microgravity on cell function, gene expression, and phenotype in Saccharomyces
21. cerevisiae. Appl. Environ. Microbiol 72: 4569-4575.https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4235978/#:~:text=In%20both%20studie2C%20microgravity%20significantly,on%20the%20STS%2D131%20mission.
22. Anand Narayanan S (2023) Gravity's effect on biology. Frontiers in Physiology 14: 1199175.
23. Thorne S (2021) Modeling the role of gravitation in metabolic processes. Communicative & Integrative Biology 14: 115-135.
24. Hariom SK, Ravi A (2021) Animal physiology across the gravity continuum. Acta Astronautica 178: 522-535.
25. Spiegel DS, Raymond SN, Dressing CD (2010) Generalized Milankovitch Cycles and Long-Term Climate Habitability. The Astrophysical 2.
26. Gunning PW, Ghoshdastider U, Whitaker S (2015) "The Evolution of Compositionally and Functionally Distinct Actin Filaments," Journal of Cell Science 128: 2009-2019.
27. K Matsuno (1999) Cell Motility as an Entangled Quantum Coherence. Biological Systems 51: 15-19.
28. Carpenter CL (2000) Actin Cytoskeleton and Cell Signaling. Critical Care Medicine 28.
29. Monk T and Paulin MG (2014) Predation and the Origin of Neurones. Brain, Behavior and Evolution 84: 246-261.
30. Paterson JR, Edgecombe GD and García-Bellido DC (2020) Disparate Compound Eyes of Cambrian Radiodonts Reveal Their Developmental Growth Mode and Diverse Visual Ecology. Science Advances 6: eabc6721.
31. Perez-Moreno M, Fuchs E (2006) Catenins: Keeping Cells from Getting Their Signals Crossed. Developmental Cell 11: 601-612.
32. Eisenstein M (2017) A Measure of Molecular Muscle. Nature 544: 255-257.
33. Schweitzer MH, Suo Z, Avci R (2007) Analyses of Soft Tissue from Tyrannosaurus rex Suggest the Presence of Protein. Science 316: 277-280.
34. Pollack GH (2001) Cells, Gels and the Engines of Life: A New, Unifying Approach to Cell Function.